Introduced by Hindman Council Bill No. PR 260-07

A POLICY RESOLUTION

adopting the Bonne Femme Watershed Plan.

WHEREAS, in 2001 the Boone County Commission sponsored a non-point source pollution grant to acquire funds for protection of the Bonne Femme Watershed through education, federal-local cost share funding of projects and development of a watershed plan; and

WHEREAS, the combined efforts of a stakeholder group, a policy committee and a technical committee has produced a plan dated February, 2007 with an Addendum dated June 1, 2007; and

WHEREAS, the Boone County Planning and Zoning Commission and the City of Columbia Planning and Zoning Commission, after separate public hearings, unanimously recommend approval of the Bonne Femme Watershed Plan.

NOW, THEREFORE, BE IT RESOLVED BY THE CITY COUNCIL OF THE CITY OF COLUMBIA, MISSOURI, AS FOLLOWS:

SECTION 1. The City Council hereby adopts the Bonne Femme Watershed Plan, dated February, 2007, a copy of which is attached hereto and marked "Exhibit A."

ADOPTED this 19th day of November, 2007.

ATTEST:

City Clerk

Mayor and Presiding Officer

APPROVED AS TO FORM:

City Counselor

Agenda Item No. PR 260-07

Source:

Timothy Teddy

Fiscal Impact

YES

NO

Other Info.

NEED TO COORDINATE PLAN INTERPRETATION AND IMPLEMENTATION WITH COUNTY! FUNDING FOR PROPOSED ENFORCEMENT AND INCENTIVES SHOULD ALSO BE SHARED.

TO: City Council

FROM: City Manager and Staff

DATE: September 24, 2007

RE: Bonne Femme Watershed Plan (case 07-60)

EXECUTIVE SUMMARY:

Staff has prepared for Council's consideration a policy resolution that would recognize the recently-completed Bonne Femme Watershed Plan as a city policy in the watershed area. The plan is a product of a three-year process of planning, public education, and technical assistance undertaken pursuant to a Boone County-sponsored "section 319" grant.

DISCUSSION:

Boone County sponsored a grant under Section 319 of the Clean Water Act, which creates opportunities for technical assistance to reduce and prevent non-point source water pollution, to prepare a plan for the Bonne Femme Watershed. The watershed drains a 93-square mile area to the Missouri River. The City of Columbia, Boone County government, and the City of Ashland have land use jurisdiction in the watershed; the Village of Pierpont is also located within the area.

The east portion of the watershed is part of the glaciated "Two Mile Prairie" area and is characterized by relatively flatter topography, head waters of streams, and former prairie soils; the mid-section is an area of *karst* topography with rock outcroppings, woodlands, caves, sinkholes, and "losing" streams (streams that lose a proportion of their discharge to underground channels); and the west section is a woodland/floodplain area characterized by deep wind-blown or flood-deposited soils, eroded bluffs, and flat flood plain areas.

There has been development activity in the watershed area. The plan documents 1,110 new dwelling units in the watershed during the period 2000-2005. The City of Columbia has four of its five future land use categories represented in the corridor: Neighborhoods, Employment, Commercial, and Open Space/Greenbelts.

The plan recommendations are summarized in a goal-strategy-recommendations table in the executive summary and chapter 6.

The Boone County and City of Columbia planning and zoning commissions have recommended approval and the City of Ashland has approved the plan. The Boone County Commission has had work session discussions on the plan but has not approved it to date. The City Planning and Zoning Commission conducted its hearing on September 20, 2007, and voted 7-0, two absent, to recommend approval of the plan. One person addressed the commission and remarked on the importance of the watershed sensitivity analysis that had been performed in the watershed by a consultant [Applied Ecological Services sub-watershed study dated August 2005].

Assuming city and county approvals, the next steps will include a County-led "implementation *charrette*" among the interested parties to coordinate the implementation phase of the plan. Effectiveness in watershed planning requires consistency across jurisdictional boundaries.

SUGGESTED COUNCIL ACTION:

Staff recommends approval of the plan by resolution. The plan, policy resolution, staff reports, and meeting minutes are attached.

MEMORANDUM

TO: **Planning and Zoning Commission**
Jeff Barrow, Chairman
FROM: **Timothy Teddy, AICP, Planning and Development Director**
DATE: **September 13, 2007**
RE: **STAFF REPORT Bonne Femme Watershed Plan**

The Planning and Zoning Commission is scheduled to review the proposed Bonne Femme Watershed Plan at a public hearing on September 20, 2007. The City Council has directed the Commission to review the plan, conduct a hearing, and make recommendations to the City Council.

The plan is a special area and special topic plan. The Bonne Femme Watershed Project mission statement is to "*Use watershed planning as a tool to prevent further degradation and to maintain the long-term quality of water resources.*" The plan consists of sections on stakeholder group issues; the scientific findings that are the basis of the plan; land use vision; goal-setting and analysis of obstacles to their achievement; and recommendations The policy implications of the plan are in the goals, strategies and recommendations, which have been organized in a quick-reference table in the executive summary. Some incidental progress has been made toward implementation of several of the recommendations. The City of Columbia, for example, has passed a stream buffer ordinance and a new storm water management ordinance (amendments to Chapter 12A of the City Code) and its companion storm water management design manual.

The Bonne Femme watershed is a 93 square mile area. Major streams which drain the watershed include Gans Creek, Clear Creek, Little Bonne Femme Creek, Bonne Femme Creek, Turkey Creek, Bass Creek, Smith Branch, Fox Hollow Branch and various tributary streams. The City of Columbia has jurisdiction over a minority of the area presently – Boone's Pointe, The Cascades, and The Highlands subdivisions as well as areas south of South Hampton and old Nifong Boulevard, the Bristol Lake development, and most of the University of Missouri South Farm are in the watershed - but we would anticipate continued annexation activity in the future within the plan area. The City of Ashland also has jurisdiction over part of the southern portion of the watershed. To date, the Boone County Planning and Zoning Commission have recommended approval of the plan (without modifications) and it is pending review by the County Commission. The City of Ashland has approved the plan.

Watershed planning is a well-established approach. Watersheds are logical planning boundaries because of the hydraulic connection of all areas within them and many other shared characteristics such as geology (sensitive *karst* topography is prevalent in the Bonne Femme), soil associations, and wildlife habitat. In environmental management, it is counter-productive to balkanize watersheds with conflicting planning and management practices. A multi-jurisdictional watershed plan is more effective because it offers some uniformity of practice.

Recommendation:

The Planning staff recommends approval of the plan. We recommend that the City adopt a policy resolution recognizing the plan as city policy in the Bonne Femme Watershed area. The only caveat is that to be effective, the plan must be adopted by all jurisdictions within the watershed on more or less equal terms, and implementation must be coordinated with Boone County government and the City of Ashland. Appropriate language could be written into the policy resolution to reference the importance of coordination.

A staff report to the Boone County Planning and Zoning Commission is attached. The plan has been previously distributed to the City of Columbia Planning and Zoning Commission [*note: staff will provide copies to any commissioners who need a copy of the plan*]. The plan and other information about the Bonne Femme Watershed Project may be viewed at www.cavewatershed.org.

Bonne Femme Watershed Plan
Staff Report for Public Hearing
June 21, 2007

The Bonne Femme Watershed Plan was developed as a component of the Bonne Femme Watershed Project. The project officially began in 2003 as a four-year grant funded project. Funding for the project was provided by the United States Environmental Protection Agency through the Missouri Department of Natural Resources. Local government along with other project partners provided matching funds.

Development of the plan began with the creation of a Stakeholder Committee. The Committee was appointed by the Bonne Femme Policy Committee which included elected and appointed local government officials and a representative from the University of Missouri Columbia. The composition of the Stakeholder Committee was diverse and intended to represent three major constituencies: business and land development, landowner and environmental. A diverse committee was key to developing a plan that reflected the social and political context of the community.

The Stakeholders were given control of the content of the plan. Project staff and the project Steering Committee provided information and meeting facilitation. The Stakeholder Committee held their first meeting on June 21, 2004 and continued to meet on a monthly basis until June 11, 2007 the date of their final meeting.

The plan was published in March of 2007. Public meetings were held April 10 at Rockbridge Elementary School, April 18th in the Ashland City Hall and April 23rd at Little Bonne Femme Baptist Church. A postcard providing notice of the meetings was sent to each property owner within the watershed. In addition flyers were posted at locations around the watershed and there were several news stories printed in local newspapers. The purpose of the meetings was to educate the public regarding the content of the plan and to advertise a public comment period. Written comments were accepted and have been published as an addendum to the plan along with responses by the Stakeholders.

The plan includes a set of policy recommendations for local governments to consider in addressing issues that will arise as urbanization of the watershed occurs. It also provides details regarding the manner in which the policy recommendations were developed by the Stakeholders along with background and scientific information about the watershed.

3,928 property owners were sent notification of tonight's public hearing. Staff recommends approval of the plan due to the intensive public process that was used for it's development.

Bonne Femme Watershed Plan Addendum

1 June, 2007

Public Comments on the Bonne Femme Watershed Plan

On behalf of the Stakeholders, Bonne Femme Watershed Project staff worked hard to gather public comment on the Plan:

- Three public meetings were held at different locations around the watershed. These meetings featured an educational presentation about the plan, and made public comment forms available
- Each watershed landowner was mailed two notices about the plan and public meetings/ open house
- Public notices about the public meetings were published in two local newspapers
- An email was sent to Stakeholders inviting them to encourage people to submit public comments, and offering to give a presentation on the plan to their respective groups
- Fliers describing the public comment gathering process were displayed at various commercial locations throughout the watershed
- Many local groups were offered a presentation on the plan, with six groups requesting and receiving the presentation
- There was a press release and subsequent coverage in local newspapers about gathering public comments on the Plan

The Stakeholders thank people for taking the time to read the Plan and submit their comments. The Stakeholders have not verified any statements from the commenters.

The comments are listed, verbatim, in the order they were received. Only comments submitted in writing are listed, as per all official communication about the public comment gathering process.

1. Name: Carl Freiling

1) The use of TDRs could be linked with LIDs. i.e. the required # or amount of TDR "units" could be reduced based on commitments to LIDs (& BMPs)
2) Could property tax mitigation be used as an incentive for agricultural use commitment to BMPs and LIDs (like Farm Forestry Programs).

Stakeholder response to Mr. Freiling's comments:

The Stakeholders recommend that policy makers consider Mr. Freiling's comments during plan implementation.

2. Name: John Ikerd

Obviously, a lot of hard work and careful thought went to development of the Bonne Femme Watershed Plan. I don't want my comments to be construed as derogatory of the thoughts and efforts that went into preparing the plan. However, I was disappointed that the plan did not even seem to suggest the necessity for a comprehensive "land use plan" for the watershed. The current plan provides the logical and rational means to implement such a plan. However, without a "land use plan," the current plan is likely to be of little value in protecting the ecological integrity of the Bonne Femme watershed.

Terry Frueh, in the initial meeting introducing the plan to the public, indicated that the task force, in developing the plan, did not feel they were competent to address the land use plan process. However, they certainly could have drafted an initial land use plan as a point of departure for broader community involvement in the land use planning process – which is an inherent necessity in developing any land use plan. Land use planning is not a process to be carried out by so called experts, but rather by those most likely to be affected by the planning process. They should rely on science-based information and expert opinions to guide their deliberation but not rely on experts to make the necessary decisions in developing the plan.

Watershed planning ultimately is about looking at the watershed as a whole to determine the best use of land in varied and diverse parts of the watershed. Lacking a comprehensive land use plan, the current plan is little more than a set of best management practices that have no particular connection to this particular watershed. There is no sense of using an understanding of the watershed as a whole to determine the appropriate use of its individual parts.

For example, I think there is adequate science-based information and expert opinion to support limiting the intensity of development of the Bonne Femme watershed. The science suggests allowing no more than 15% of impervious surfaces for the watershed as a whole. Thus, intensive development of some parts of the watershed, such as those along HWY 63, must be offset by less intensive development elsewhere in the watershed to limit the average to 15% for the entire watershed. Maximum use of so-called best management practices would then have to be used in the intensively developed areas whereas less restrictive and costly practices would be appropriate and adequate in less intensively developed areas. Developers of the areas planned for more intensive, and thus more profitable, development could be required to pay for the purchase of development rights and conservation easements from landowners in those areas planned for less intensive development. Such a plan would allow the watershed to be developed to the maximum extent consistent with its ecological capacity, while allowing all landowners in the watershed to receive an equitable share of the economic value of development.

Stakeholder response to Mr. Ikerd's comments:

The Stakeholders were not charged with creating a detailed land use map. They felt this process is more applicable to the implementation stage. Their work lays a partial foundation for creating such a map.

The Stakeholders decided it would be better to use performance-based goals instead of impervious cover (IC) limits. Such goals are intended to achieve the same stream-protection as IC limits, but allow more flexibility about how the protections are achieved.

3. Name: Agnes & Bill Crowley, Co-Administrators, Crowleys Cove Farm, LLC

On page iv of the Foreward of the BFWP it states: *"The committee's balance ensured that the plan would represent the values of the community as a whole and not be skewed toward any particular special interest.*" and page 1 of the Executive Summary stated: "*...the balanced nature of the committee improved the likelihood it would be unbiased.*" After speaking to several past and present committee members I am not convinced that your committee and its conclusions and recommendations achieved that balance. For example, in Appendix B there is no reference to or definition of "Property Rights." And, in Appendix C there are no references to the broad and deeply pertinent topic of property rights. Therefore, in an effort to rectify what I consider to be a major oversight of your effort, I offer the following as my public comment to be appended to the addendum to the plan.

Property Rights Bibliography

CONSTITUTION OF THE STATE OF MISSOURI

Sec. 26. That private property shall not be taken or damaged for public use without just compensation. Such compensation shall be ascertained by a jury or board of commissioners of not less than three freeholders, in such manner as may be provided by law; and until the same shall be paid to the owner, or into court for the owner, the property shall not be disturbed or the proprietary rights of the owner therein divested. The fee of land taken for railroad purposes without the consent of the owner thereof shall remain in such owner subject to the use for which it is taken. Governor Matt Blunt; Thursday, Jan. 26, 2006

"We must ensure that eminent domain abuses in Missouri are forever ended." "Property ownership is among our most basic rights as a people. It is government's role to protect those rights."

United States Representative Kenny Hulshof, Nov 22,2005

Private Property verses the use of Eminent Domain by Kenny Hulshof, Columbia Business Times Review, November 22, 2005

"This is a dangerous precedent that could serve to erode the property rights of private citizens. That is why I supported passage in the U.S. House of H.R. 4128, the Private Property Rights Protection Act."

University of Missouri Center for Economic Education; www.missouri.edu/~cee/Grades/ceehs42.html

"One duty of government in a market economy stands head and shoulders above all others: the protection of property rights, without which the incentive to produce (as well as the means to produce) does not exist."

University of Missouri Extension

Your Rights Under Condemnation in Missouri

Stephen F. Matthews and Timothy W. Triplett; Department of Agricultural Economics

http://extension.missouri.edu/explore/agguides/agecon/g00500.htm

Missouri First; www.mofirst.org/essays/property-rights.html

Any social compact that permits the stronger, more powerful to forcefully take the property of the weaker members of society will eventually allow similar takings of "property" of a more personal nature, like life and liberty.

Private Property Rights Under Fire in Missouri

http://www.pacificlegal.org/?mvcTask=topic&id=1&PHPSESSID=b2e94084951c7419e3daefae8e5cac7e; http://www.cato.org/pub_display.php?pub_id=7974 "But Missouri has managed to make things worse. A state law allows nonprofit organizations to take private land for their own private uses — without paying the owners a dime. And on Feb. 7 the Missouri Court of Appeals refused even to consider whether the law is constitutional."

Wetlands Property Rights

What About Takings?

The Issue: When does a government action affecting private property amount to a "taking," and what are the takings implications of wetland regulation?

The Fifth Amendment to the Constitution of the United States of America

"No person shall...be deprived of...property without due process of law, nor shall private property be taken for public use, without just compensation."

Legal Background

The concept of takings comes from the Fifth Amendment (see box above), which prohibits the taking of private property by the government for a public use without payment of just compensation. This fact sheet briefly explores the issue of takings as it relates to wetlands regulation. The Supreme Court and lower courts have established a body of law used to determine when government actions affecting use of private property amount to a "taking" of the property by the government. When private property is "taken" by the government, the property owner must be fairly compensated. Initially, the courts recognized takings claims based on government actions that resulted in a physical seizure or occupation of private property. The courts subsequently ruled that, in certain limited circumstances, government regulation affecting private property also may amount to a taking. In reviewing these "regulatory" takings cases, the courts generally apply a balancing test; they examine the character of the government's action and its effect on the property's economic value. Government actions for the purpose of protecting public health and safety, including many types of actions for environmental protection, generally will not constitute takings. The courts also look at the extent to which the government's action interferes with the reasonable, investment-backed expectations of the property owner.

In Lucas v. South Carolina Coastal Council (1992), the U.S. Supreme Court ruled that a State regulation that deprives a property owner of all economically beneficial use of that property can be a taking. The court further clarified, however, that a regulation is not a taking if it is consistent with "restrictions that background principles of the State's law of property and nuisance already placed upon ownership." As an example of "background principles," the court referred to the right of government to prevent flooding of others' property.

Dolan v. City of Tigard (1994), a more recent Supreme Court takings case, involved a requirement by the City of Tigard in Oregon that, to prevent flooding and traffic congestion, a business owner seeking to expand substantially onto property adjacent to a floodplain create a public greenway and bike path from private land. The Supreme Court ruled that the City's requirement would be a taking if the City did not show that there was a "reasonable relationship" between the creation of the greenway and bike path and the impact of the development. As compared to the facts in Dolan, the Clean Water Act Section 404 program generally does not require property owners to provide public access across or along their property.

Current Status

The presence of wetlands does not mean that a property owner cannot undertake any activity on the property. In fact, wetlands regulation under Section 404 does not necessarily even result in restricting the use of a site. Many activities are either not regulated at all, explicitly exempted from regulation, or authorized under general permits.

Moreover, in situations where individual permits are required, the Federal agencies can work with permit applicants to design projects that meet the requirements of the law and protect the environment and public safety, while accomplishing the legitimate individual objectives and protecting the property rights of the applicant. Overall, more than 95% of all projects receive Section 404 authorization.

http://www.epa.gov/owow/wetlands/facts/fact18.html

Property Rights and Wetlands

The government's attempt to regulate the use of private land is a major issue facing small business. Regulations continue to undermine the rights of individuals to lawfully use their property and effectively conduct business. Government agencies such as the EPA, the Department of the Interior and the Army Corps of Engineers issue regulations that are devastating to small business. For instance, the Corps of Engineers is trying to extend to extend its jurisdiction of navigable waters under the Clean Water Act to non-navigable waters, which includes private land that contains wetlands. By sweeping more private land under its jurisdiction, the Corps forces property owners to go through a series of expensive regulatory hoops in order to develop their property.

The NFIB Legal Foundation is working to guarantee that small-business owners retain the right to use and develop their land, and that government agencies assess the impact of their regulations on private property.

* Glass v. Goeckel -- Protecting Small Business in Beach-Ownership Dispute

* Deaton v. U.S. -- Fighting Army Corps' Encroachment on Private-Property Rights

* U.S. v. Rapanos -- Fighting Expanded Criminalization of Private Land Use of Wetlands

* U.S. v. Newdunn -- Fighting Civil Penalties Assessed in Wetlands Case

* Norwood v. Gamble, et al. – Legal Foundation Joins Eminent Domain Struggle

* Rapanos v. U.S.--Fighting Expanded Federal Regulation of Private Land Use of Wetlands - Victory!

* Blue v. City of Los Angeles--Eminent Domain Strikes another Small Business

http://www.nfib.com/page/propertyRightsCases.html

How 'Wetlands' Bureaucrats Crush Private-property Rights

On Aug. 18, 2004, 68-year-old Michigan resident John Rapanos is scheduled to be sentenced for the third time by Federal District Court Judge Lawrence P. Zatkoff.

Following the conviction of Mr. Rapanos for violating the federal Clean Water Act by filling wetlands on his 175-acre parcel without a federal permit, Judge Zatkoff set aside the conviction because of deficiencies in the prosecution's presentation. The federal appellate court reversed Judge Zatkoff's action and ordered him to sentence Rapanos.

At the sentencing hearing – which followed the sentencing of an illegal immigrant for drug trafficking – the judge signaled his disgust at the Justice Department's prosecution of Rapanos with this bench comment:

"So here we have a person who comes to the United States and commits crimes of selling dope and the government asks me to put him in prison for 10 months. And then we have an American citizen who buys land, pays for it with his own money, and he moves some sand from one end to the other and the government wants me to give him 63 months in prison. Now if that isn't our system gone crazy, I don't know what is. And I am not going to do it."

At Rapanos' second sentencing, Judge Zatkoff sentenced him to 200 hours of community service, three years probation, and a $185,000 fine, each of which Rapanos fulfilled. Still not satisfied that Judge Zatkoff had not imposed prison time, the appellate court, at the Justice Department's urging, ordered Judge Zatkoff to imprison Rapanos for a minimum of 10 months.

Assuming this happens on Aug. 18, and if that isn't enough, the government is asking for civil damages against Rapanos in the shocking amount of $10 million in fines, forfeiture of 81 acres of his land, and $3 million in "mitigation fees" – all on top of the earlier ordered fine of $185,000 which Rapanos already paid.

What is really going on here? Is John Rapanos one of the country's leading outlaws? What explains the U.S. government's seemingly insatiable zest for retribution against a productive, taxpaying citizen with no prior criminal record?

http://www.pacificlegal.org/?mvcTask=opinion&id=384&PHPSESSID=bbae4cda81419737d3df3ff091ae6910

Stakeholder response to Mr. & Mrs. Crowley's comments:

The Stakeholders discussed property rights frequently. A national expert on property rights, Dale Whitman, informed the Stakeholders on general parameters of property rights and takings. From the information from this expert, the Stakeholders do not believe their recommendations would be considered takings.

The concept of respect for individual property rights was discussed frequently by the stakeholders. The right to control the use of one's property was balanced against the duty to do no harm to the property of others. Government should not have the ability to arbitrarily dictate what a property owner does with his/her land. But that on the other hand, there should be sufficient regulations and restrictions in place that one property owner cannot ruin or damage another's property or property value by what he does on his land. One of the overarching recommendations, that applies to all goals within the plan, is that "Measures implemented to protect water quality should not unfairly burden individuals." (Bonne Femme Watershed Plan, Section 6.b2).

4. Name: Tom O'Connor

The plan does not address the important concept of a regional wastewater treatment plant—an issue that is key to the future of the region and a target of much attention, money, and study in recent years.

This entire region, not just recharge and karst areas, should be afforded protections comparable to State Parks and Conservation Areas.

I disagree with the goal of "policies which boost jobs, retail, tax base, and local economics" and the associated recommendations to "reduce fees and other expenses paid by developers of commercial property." These are not conducive to environmental protection.

Stakeholder response to Mr. O'Connor's comments:

The Stakeholders consider the proper handling of sewage as vital to the watershed. They did not significantly discuss proper sewage treatment since it is a fundamental expectation of development, as are the other utility services. Wastewater, which is considered point source pollution, was not the focus of the Plan, in part because the funds that supported the Stakeholders' work came from a Nonpoint Source Pollution grant.

Concerning protections comparable to state parks, the Stakeholders recognize that development will occur, and therefore wanted to have an appropriate and reasonable level of protection for the streams.

The Stakeholders felt it was important to take social and economic aspects into consideration, along with the environmental aspects, when drawing up this Plan.

Executive Summary

The Bonne Femme Watershed Plan is the product of over two and one-half years of work from a group of Stakeholders (see Appendix D for committee membership). The Bonne Femme Policy Committee chose to have a broad and balanced representation on the Stakeholder Committee in order to produce a plan that reflects its representation: broad and balanced. The wide variety of Stakeholders' perspectives ensured that many points of view were considered in the process, and the balanced nature of the committee improved the likelihood it would be unbiased. Local governments will be more likely to adopt the plan if it has support from a wide and balanced range of interests. Although the plan's focus is on protecting and preserving water quality, the Stakeholders wanted to make sure this was accomplished while maintaining economic vitality, and respecting community values.

It should be noted that although the Stakeholders did receive guidance and feedback from the Bonne Femme Steering and Policy Committees, they had the final say on the plan's content. This ensured it was truly a product of citizen involvement, and not one controlled by politicians or by technical staff.

The plan is designed to focus local governments on protecting stream health in the Bonne Femme watershed as it urbanizes (see Figure ES.1, page 3). It provides policy recommendations that, if adopted, will achieve specific goals that enhance the Bonne Femme watershed.

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

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

Chapter 3 discusses scientific information considered by the 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 they developed it. The vision statement is detailed, along with the elements that formed its basis.

Executive Summary

> **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 each obstacle 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.

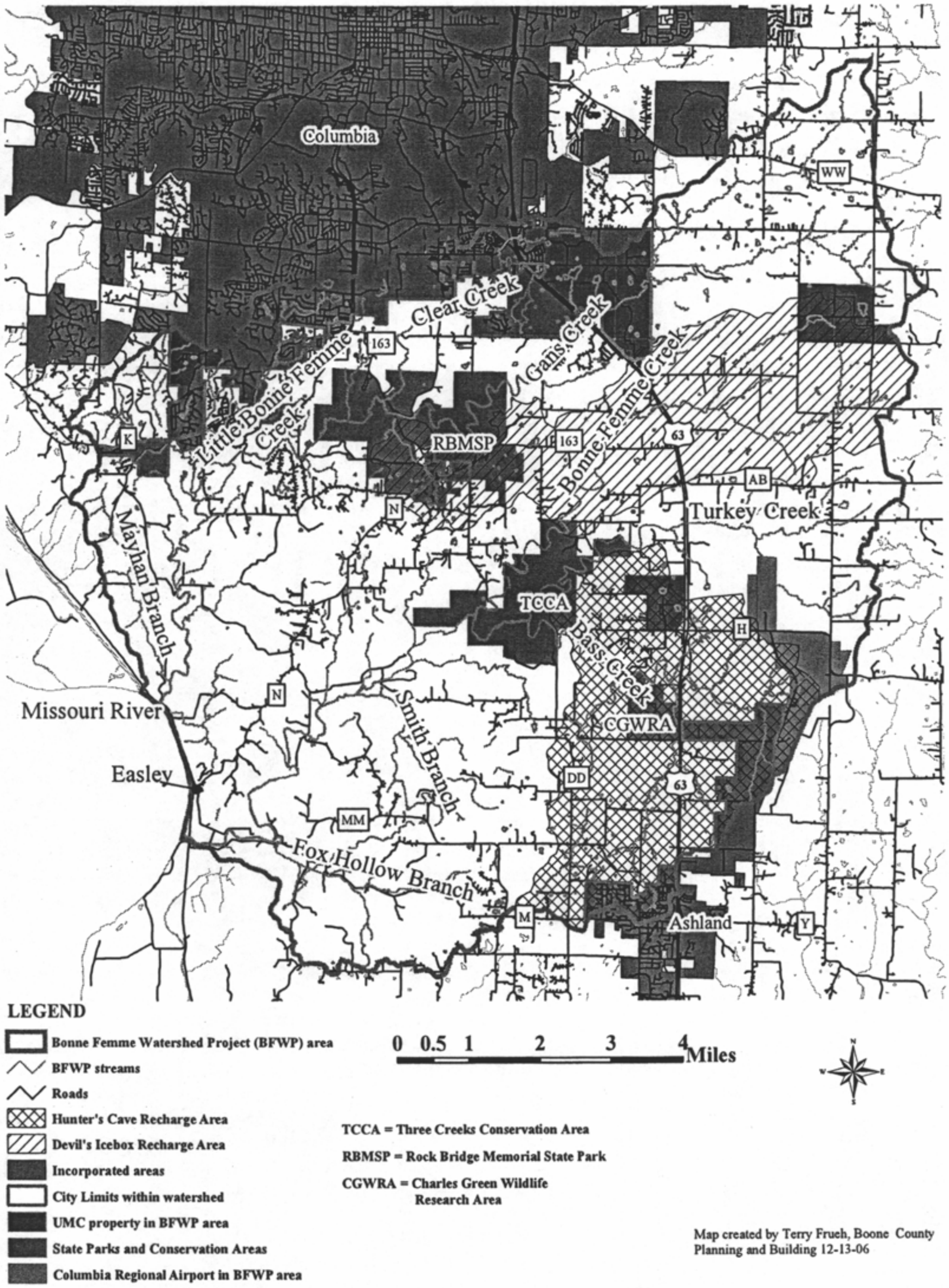

Figure ES.1 Map of the Bonne Femme Watershed Project Area.

Recommendations

Note: these recommendations are not prioritized.

Recommendations that apply to all goals:

1) It is important to have a follow-up program to assess the effectiveness of plan implementation. This follow-up program includes three aspects:

- **Enforcement/inspection** will assure that new ordinances are being followed.
- **Maintenance** of new stormwater and sewer infrastructure will be necessary for proper functioning.
- **Plan evaluation** is key to understanding whether the plan is being followed as intended, and how effective the various measures are. This may include actual stream monitoring, as well as analyzing implementation of the recommendations. Stream monitors must use generally accepted, quantifiable measures of water quality obtained at regular intervals on an ongoing schedule, and the data must be collected by certified entities/persons.

2) Equity: Measures implemented to protect water quality should not unfairly burden individuals. Every effort should be made to create incentive-based programs.

Goal	Strategies	Recommendations
Ensure that structures are not built in places that will flood	Update 100 year flood-plain maps and regulations	Political subdivisions should consider complete hydrologic modeling to determine where the 100-year floodplain would be under full build-out conditions, and locate it more accurately on floodplain maps. This modeling should be limited to developing areas to keep costs down. Allow no construction of structures for occupancy in the re-delineated 100-year floodplain.
	Zoning – Streamside buffer ordinance	Adopt a stream buffer ordinance that limits construction within its boundaries
	Design manual	Do not permit new development to increase peak flows downstream so that flooding is not exacerbated.
	Purchase structures that flood now	City or County may offer to purchase a structure, at prevailing market rate, to correct a flooding problem in an existing neighborhood, if the cost of correcting the problem exceeds the value of the structure.

Executive Summary

Goal	Strategies	Recommendations
Conserve recharge & karst areas with special protections	Design manual/ Performance based goals	The *level of service* (following Columbia's proposed storm-water manual and ordinance) will be more restrictive (e.g. by one or two points on the level of service scale) in karst and re-charge areas than in other areas. Local governments will adopt similar, compatible stormwater ordinances and design manuals.
	Zoning	Zoning ordinances will establish specific criteria for develop-ment in karst recharge areas. These should include defining levels of stormwater quantity and quality, and limiting new sanitary sewers to *no discharge systems*.
	Land purchase	Local governments may purchase land from willing sellers in karst recharge areas, but other options for protecting water qual-ity should be explored first. Create management plans for this purchased land with a primary goal to protect water quality. (Government takings or eminent domain should not be used for acquiring land for this purpose)
	TDRs & conservation easements	Transfer of development rights (TDR) should be established county-wide, with sensitive areas (such as karst recharge areas and steep slopes) being primary sending areas. This program should enable the cities and the county to have *joint program reciprocity*. TDR and conservation easements should be eco-nomically and logistically feasible options for use by landown-ers and developers.
	Tax relief	Create incentives to encourage conservation in karst recharge areas.
	Zoning and Subdivision regulations; Design manual	Consider a plan to provide special protections to karst and re-charge areas.
	Further scientific study and monitoring	More scientific analysis should be done to delineate further karst recharge and other environmentally sensitive areas, and more definitively identify sources of contamination.

Goal	Strategies	Recommendations
Ensure that changes in land use do not increase downstream flooding or channel in-stability, or decrease water quality	Design manual	The *level of service* (following Columbia's proposed stormwater ordinance and manual) for stormwater runoff flow characteristics post-development shall be no less than pre-development. Similarly, stormwater quality should have the same or better characteristics for post-development as it had pre-development. Local governments should adopt similar, compatible stormwater ordinances and design manuals.
	Encourage *low impact development (LID)*	Local governments should establish additional zoning and subdivision regulations that allow LID as a *matter of right* (i.e., approval will be expedited). This avoids the problems associated with the planned development process and encourages LID.
	Education	Make new stormwater manuals and ordinances widely available and familiar to the public through a public outreach and education effort.
	Develop funding mechanisms	New sources of funding should be pursued to assist landowners in implementing stream-protection *best management practices (BMPs)*. Compile a list of available sources of funding and provide to landowners and developers.
	Financing of storm water program	Secure sustainable, adequate funding for stormwater programs.

Goal	Strategies	Recommendations
Encourage low impact developments as a way to maintain or improve water quality	Education	Implement a comprehensive educational program for the general public, landowners, and developers to encourage LID.
	Design manual	Revise local governments' development regulations to promote environmentally sensitive design and maintenance.
		The level of service (following Columbia's proposed stormwater manual and ordinance) will be more restrictive (e.g. by one or two points on the level of service scale) in susceptible subwatersheds (following maps 6.0E, 7.3E and 8.2B of the Subwatershed Sensitivity Analysis) than in less susceptible subwatersheds . Local governments will adopt similar, compatible stormwater ordinances and design manuals.
	Tax relief, funding, Economic development	Create economic incentives to encourage developers to implement LID.

Executive Summary

Goal	Strategies	Recommendations
In order to maintain quality of life, encourage parks, healthy streams, LID, and municipal services.	Land purchase, Develop funding mechanisms, Economic incentives	Provide mechanisms and/or incentives to set aside land in non-LID developments for land to be set aside for parks or green space, especially in conjunction with a stream buffer. Encourage these features in other new, as well as preexisting, neighborhoods.

Goal	Strategies	Recommendations
Maintain the economic viability of the community while protecting clean streams	Education	Include information on protecting clean streams in development information distributed by the city and county (through web, forms, brochures). Develop a map that shows protected areas and include this in all literature related to development.
	Design manual	Local governments should adopt similar, compatible stormwater ordinances and design manuals that have stream protection information and requirements.
	Zoning	Address zoning where protection is necessary.

Goal	Strategies	Recommendations
Enhance healthy streams in parks	Education	Make stream protection a central part of park management. Establish park definitions to include stream protection goals. BMPs should be used on property owned by local governments.

Goal	Strategies	Recommendations
Maintain clean water without unnecessarily restricting property rights	Design manual	Give detailed design information to developers and engineers to assist them in controlling runoff quality and quantity from development.
	Zoning	Use voluntary zoning changes to direct density, and therefore higher runoff, to the most appropriate areas.
	Subdivision and zoning regulations	Revise local governments' ordinances and design manuals to enable reductions in impervious surface by allowing flexibility in street width, sidewalks, etc.
	Education	Expand public education newsletters and mail them more frequently.
	Develop funding mechanisms	Secure sustainable public funding for the operation and maintenance of BMPs, especially those initially funded by government agencies.
	TDRs and conservation Easements	Encourage landowners to use various economic incentives (e.g. conservation easements and TDR).

Goal	Strategies	Recommendations
Have policies which boost jobs, retail, tax base, and local economics	Zoning	Locate retail, by appropriate zoning, to areas that will allow the most efficient use of infrastructure and the least hazard of stream pollution.
	Economic incentives	Consider reduction in fees and other expenses paid by developers of commercial property, in preference to the creation of additional special transportation districts. For locally-owned businesses, give economic incentives to help implement LID. Use tax incentives for owners of LID-style commercial/retail structures.
	Zoning	Exempt agricultural land from restrictions and stream buffers to maintain and enhance maximum economic opportunity for farmers and related agricultural activities, as well as to keep land in agricultural use.

Executive Summary

Goal	Strategies	Recommendations
The impacts of upstream urbanization should be mitigated to prevent increased costs to agricultural and other downstream property owners.	Performance based goals/ Design manual	1) Determine baseline conditions for the establishment of monitoring programs. These conditions should include stream water quality, amount of stormwater discharge, *stream cross-sections.* 2) Publicly monitor at specified time periods at specific locations to determine effectiveness of currently implemented plan.
	Develop funding mechanisms	Ensure that local governments provide adequate funding for their stormwater programs via a stormwater utility fee.
	TDR & conservation easements	Use land purchase, TDRs, conservation easements, etc. where applicable to encourage conservation in appropriate areas.

Goal	Strategies	Recommendations
Ensure that BMPs do not unreasonably affect housing affordability.	Education	Publicize information on cost-effective BMPs.
	Zoning	Amend zoning regulations to allow for increased density in exchange for improved stormwater quality and quantity management.

Goal	Strategies	Recommendations
Ensure that certain areas receive special protections while maintaining the economics of urbanization.	Zoning	Zoning regulations will reflect the sensitivity of the watershed/ subwatershed. This will allow for economic growth while protecting sensitive subwatersheds.
	Design manual	Revise local governments' stormwater design manuals with specific design criteria for sensitive subwatersheds.

EXCERPTS
PLANNING AND ZONING COMMISSION MEETING
September 20, 2007

07-60 The Little Bonne Femme Watershed Plan.

MR. CADY: May we have a staff report, please?

MR. TEDDY: I'll give the staff report, and before I do, I just wanted to acknowledge one of my colleagues in the audience, Mr. Bill Florea has come over from Boone County Planning and Building Department, and he's been involved with the Boone Femme Watershed project, so I'll probably encourage you to direct any tough questions to him rather than me. But I'll make the presentation and what I've got on screen is actually a slide show that the Commission has seen, but for the record and for the public in the audience, let me go through this.

Staff report was given by Mr. Tim Teddy of the Planning and Development Department. Staff recommends approval of the plan. They recommend that the City adopt a policy resolution recognizing the plan as City policy in the Bonne Femme Watershed area. The only caveat is that to be effective, the plan must be adopted by all jurisdictions within the watershed on more or less equal terms, and implementation must be coordinated with Boone County government and the City of Ashland. Appropriate language could be written into the policy resolution to reference the importance of coordination.

MR. CADY: Thank you, Mr. Teddy. Are there any questions of staff or Mr. Florea to address the plan? I think many of you -- I attended the first meeting back -- I think it was March 17th, and then I attended the one at the end of August before Mr. Frueh left to go out west. So, I think it's a very good plan. My initial comment in it is, since I've been on the Commission, we have been asking and asking for urban planning, and I think this is one tool that will help us get towards that because we've got to realize that Columbia grows out and not in, so we're going to always be annexing in the future more land within this watershed. Even though we're a small portion of it now, who knows what it will be in the future. So, like I say, I think it's a well put together plan, and I think it's a good starting place. That's my general observation of it. Ms. Curby?

MS. CURBY: I, too, attended both of those meetings and am very impressed by the plan. And my question is how we should frame our recommendation. If we just want to recommend that the City adopt the resolution and state it as a policy, or do we also need to add to that that they set up a way to cooperate with the other entities? Can we recommend that, or do we even need to?

MR. TEDDY: Yeah. As I mentioned, going through the plan again, I think it's pretty clear in the text of the plan that the principals of this plan recognize that it's absolutely essential to have that coordination. We gave it a little extra emphasis in our report just because we know that watershed management doesn't work unless there is some common rules and programs and that kind of thing. But if you want, you could put a condition on it that would be put into the policy resolution, or you could just simply say that the Commission recommends that the Council adopt the plan by an appropriate policy resolution.

MR. CADY: Mr. Rice?

MR. RICE: Yeah. I would just like the minutes to show that adopting this plan is only a first step, and that I would want to encourage Council to do everything they can to start adopting -- assuming that we vote to approve this plan. I'm getting ahead of myself -- to encourage Council to begin implementing the recommendations as soon as possible because if none of the recommendations are implemented, then this plan doesn't mean anything.

MR. CADY: Okay. Further discussion? Ms. Curby?

MS. CURBY: I move that we recommend that the City adopt a policy resolution recognizing the plan as the City policy in the Bonne Femme Watershed area.

MS. DOKKEN: Is this a public hearing?

MR. TEDDY: Public comment, please.

MR. CADY: Oh, excuse me. I'm sorry. Like I say, I'm new at this. Sorry about that. I'm new at this.

PUBLIC HEARING OPENED

MR. CADY: Anyone wishing to speak on this, please come forward. I apologize.

MS. DOKKEN: My name is Dee Dokken; I live at 804 Again in Columbia. Yes, and I urge you to adopt this, and recommend that the Council adopt it. It's a good first step. It goes with the assumption that you can develop this area and still protect the watershed, which is a big assumption. And I think the evaluation part is very, very important, as well as the maintenance and the enforcement part. We're going to have to make sure that this is actually working. Focusing on education incentives is going to actually protect the watershed. But this is a good first step. I would like to direct people -- they asked a consultant to do a subwatershed sensitivity analysis, which is Appendix G, and I just don't want people to miss that because it was scientifically based, trying to use the latest technology. And I think they go a little further, maybe, than the plan does, and that maybe, eventually, people should look at that, and especially if the plan doesn't seem to be protecting the watershed. And one thing that they recommended that the plan doesn't recommend is establishing a countywide environmental stewardship and storm-water real estate transaction surcharge fee. That means every time land changed hands, a certain amount of money would go into a fund. They recommended a transaction fee of .05 percent to .2 percent of all real estate transactions in the county to -- would establish the fund. The fund could be managed for interest generation as a professionally managed fund, and could be used to leverage other funds, landowner participation and land protection, stewardship, restoration, and repair. And they also say to establish a core natural area protection plan for the most important parts of the watershed, initiate or work with a local land trust to work with private landowners to protect the core natural areas. The land trust could be partially funded with the environmental stewardship and storm-water real estate transaction surcharge fee. So, I just want to just bring that to people's attention because it's kind of hidden way in the back.

MR. CADY: I think we have a question. Mr. Wheeler?

MR. WHEELER: You said "they" recommended. Is that the scientific -- the study in Appendix G or the committee?

MS. DOKKEN: Well, okay. Yeah. It was the AES or whatever that stands for -- Applied Ecological Services. They were hired by the steering committee, I guess.

MR. WHEELER: Okay.

MS. DOKKEN: And a lot of times, the City seems to get these studies, consultants, and then maybe ignore some of what they're telling us, and sometimes they know what they're talking about.

MR. TEDDY: If I may, there at least one cross-reference to several of the maps in the subwatershed sensitivity analysis. That's the Applied Ecological Services study. Is that the name of the consultant that did that in 2005? And those are maps that show subwatersheds that are "susceptible." In other words, it shows different degrees of risk, or I don't know if I'd use the term "impairment," but --

MR. FLOREA: Potential for impairment.

MR. TEDDY: Potential impairment in different zones or subwatersheds within the Boone Femme. And we have a copy of that study and those maps, and we could incorporate those in this plan document.

MS. DOKKEN: And the plan does mention sometimes giving extra protections to -- (inaudible.)

MR. CADY: Any more questions? Thank you. Ms. Peters? She might have a question. Excuse me, Dee.

MS. PETERS: I noticed that there is some educational outlets that were going to be pursued, but I didn't notice anything in the public school systems, possibly through the science departments. Is there any plan for that?

MS. DOKKEN: I didn't notice anything, but --

MR. CADY: Maybe Mr. Florea. I don't want to put Bill on the spot, but Mr. Florea --

MS. PETERS: Well, I don't really know who should get the question, but --

MR. FLOREA: This project is, as Mr. Teddy said, coming to an end, so there is no ongoing educational component of it. Although Columbia, Boone County, and the University of Missouri-Columbia jointly participated in an educational outreach through our storm-water programs, and those people are actively trying to engage the school system and trying to reach the school kids on general storm-water issues.

MS. PETERS: Thank you.

MR. CADY: Is there anybody else out there that I have ignored? Sorry about that.

PUBLIC HEARING CLOSED

MR. CADY: Kind of backwards. We've already got a motion, so --

MR. WHEELER: Who seconded the motion?

MS. ANTHONY: Second.

MR. WHEELER: Ms. Anthony?

MR. CADY: Yeah. It's been moved and seconded to recommend approval. Any further discussion? Roll call, please.

MR. WHEELER: A motion has been made and seconded to recommend that the City adopt a policy resolution recognizing the Bonne Femme plan as a City policy in the Bonne Femme Watershed area.

Roll Call Vote (Voting "yes" is to recommend approval.) Voting Yes: Mr. Cady, Ms. Curby, Ms. Peters, Mr. Rice, Mr. Wheeler, Ms. Anthony. *Motion carries 6-0*

Exhibit A

Bonne Femme Watershed Plan

Bonne Femme Stakeholder Committee
February, 2007

Edited by W. Terry Frueh, Watershed Conservationist
Boone County Planning and Building Department

Columbia, Missouri

On the cover:
Harvesting photo courtesy of Tim Reinbott, University of Missouri-Columbia
Stream monitoring photo courtesy of Jane Ann Travlos
Home photo courtesy of Rob Wolverton

Bonne Femme Watershed Plan
Completed by the Bonne Femme Stakeholder Committee
February, 2007

Bonne Femme Watershed Project
www.CaveWatershed.org

U.S. Environmental Protection Agency Region 7, through the Missouri Department of Natural Resources, has provided partial funding for this project under Section 319 of the Clean Water Act.

The Bonne Femme Watershed Stakeholder Committee would like to dedicate this publication to honor the memory of committee member Donna Dodge.

Donna Dodge was an active, articulate and dedicated member of this committee. Her enthusiasm for the project, her passionate defense of her positions and her educator's background made her a valuable and respected member of our diverse group. Even as she debated a contentious point, her respect for each member's opinion and her positive attitude made us value her words even when we did not agree with her position. She was a friend to all of us and her wisdom, humor and smiles helped us work together.

Donna passed away on Thursday, July 13, 2006. Memories of her beautiful spirit stayed with us as we continued on with our work. She would have been thrilled to see the culmination of this project.

As we move on to the next level in this venture, help us honor Donna's memory by working together to preserve and protect the watershed.

Table of Contents

Foreword iv

Executive Summary 1
Recommendations 4

Chapter 1. Introduction 11
1.a Introduction to the Project 11
1.b Stakeholder–led Planning Methodology 16
1.c. Watershed Characteristics 18
1.d. Economics 32
1.e. Plan Overview 34

Chapter 2. Stakeholder Issues 35
2.a. List of Stakeholder Issues 35
2.b. Stakeholder Issues - Consolidated Grouping 39

Chapter 3. Science in the Watershed 44
3.a Karst Hydrogeology and Soils of the Bonne Femme Watershed 44
3.b Cave Life 51
3.c Stream Ecology and Use of EPT Insects as Indicators of Water Quality 56
3.d Water Quality Monitoring, 2001-2006 60
3.e Bonne Femme Dye Traces 63
3.f Subwatershed Sensitivity Analysis, a Planning Tool 65

Chapter 4. Watershed Land Use Vision 69
4.a Land Use Vision Purpose 69
4.b Land Use Vision Methodology 69
4.c Vision Statement for the Bonne Femme Watershed 69

Chapter 5. From Vision to Reality 71
5.a Transforming Vision Elements into Achievable Goals 71
5.b Obstacles to Achieving Goals 75

Chapter 6. Watershed Plan Recommendations 78
6.a Process for Determining Recommendations 78
6.b Recommendations 78
6.c Plan Approval 85
6.d Plan Continuity 85

Appendix A. Clarification of Issues....86
A1. Clarification of Stakeholder Issues....86
A2. Clarification of Policy Committee Issues....94
A3. Clarification of Steering Committee Issues....97

Appendix B. Glossary....99

Appendix C. References....105

Appendix D. Bonne Femme Watershed Committee Membership....114

Appendix E. Valuation of Ecological Services....116

Appendix F. Stakeholder Decision-Making....117

Appendix G. Science....118
G.1 EPT report....118
G.2 Devil's Icebox Cave Branch Biomonitoring....124
G.3 Water Quality Monitoring, 2001-2006....127
G.4 Bonne Femme Dye Traces....141
G.5 Subwatershed Sensitivity Analysis, a Planning Tool....147

List of Figures

Figure ES.1 Map of the Bonne Femme Watershed Project Area....3
Figure 1.1 Bonne Femme Watershed Project Area....13
Figure 1.2 Stonefly nymph....16
Figure 1.3 Soil associations....19
Figure 1.4 Prairie burn....20
Figure 1.5 How karst systems work....22
Figure 1.6 View from inside Hunter's Cave....23
Figure 1.7 Pink Planarian....24
Figure 1.8 Harvesting....29
Figure 1.9 House under construction....30
Figure 3.1 Location of Bonne Femme watershed, subwatersheds, and karst recharge areas...45
Figure 3.2 Land use/land cover for the Bonne Femme watershed....46
Figure 3.3 Generalized geologic stratigraphy for the Bonne Femme watershed....48
Figure 3.4 Soil associations....49
Figure 3.5 Life cycle....51

Figure 3.6 The Pink Planarian....52
Figure 3.7 Amphipods and habitat....53
Figure 3.8 The semi-aquatic mink....56
Figure 3.9 Aquatic-terrestrial life connections....57
Figure 3.10 Gans Creek....58
Figure 3.11 Bonne Femme watershed monitoring sites....61
Figure 3.12 Devil's Icebox recharge area....64
Figure G.1 Bonne Femme watershed monitoring sites....127
Figure G.2 Percentage of quarters in which state and federal water quality standards for whole body contact were exceeded....135
Figure G.3 Detection frequency of specific waterborne pathogens in Bonne Femme watershed....136
Figure G.4 Devil's Icebox recharge area....143
Figure G.5 Dye trace locations....145

List of Tables

Table 1.1 Columbia and Boone County census figures and census forecast....31
Table 1.2 New dwelling units in Bonne Femme Watershed and entire Boone County....31
Table 1.3 Rough population estimates for Bonne Femme (BF) and Boone County (BC), based on new dwelling units....31
Table 1.4 Columbia and Boone County Population and dwelling unit growth projections for 2030....32
Table 1.5 Projected dwelling unit growth in Bonne Femme Watershed for 2030....32
Table 5.1 Achievable Goals - Obstacles matrix....77
Table E.1 Ecological valuation of watershed following the methodology of Costanza *et al.* (1997)....116
Table E.2 Ecological valuation of the watershed following the methodology of IDC (1993)....116
Table G.1 X, Y coordinates for the upper and lower ends of the sample reaches....119
Table G.2. Presence/absence of EPT taxa at the eight sites, spring 2006 collections....123
Table G.3 P3 results of Pink Planarian monitoring....126
Table G.4 Devil's Icebox Cave biological sampling....126
Table G.5 General stream water properties by site....128
Table G.6 Average nutrient concentrations by site....130
Table G.7 Average herbicide concentrations by site....132
Table G.8 Average fecal coliform and *E. Coli* concentrations by site....133
Table G.9 Average fecal coliform and *E. Coli* concentrations by quarter of the year....138
Table G.10 BMP Summary Implementation and Benefit Table....151

Foreword

This watershed plan represents years of planning and hard work by local citizens and governments, as well as state and federal researchers and land managers. In 2001, the directors of the Missouri Departments of Natural Resources and Conservation urged a group of interested local, state and federal employees to form a task force. They were asked to consider specific actions that could be taken to protect the water quality in streams of Southern Boone County with particular interest in public lands and endangered species. The primary recommendation of the task force was to pursue a Nonpoint Source Pollution grant (EPA 319 Program) to acquire funds for the protection of streams in the Bonne Femme watershed through:

- Education
- Disbursal of cost-share funds
- Development of a watershed plan that makes policy recommendations.

By the end of 2001, a proposal had been prepared. The Boone County Commission agreed to sponsor the grant. The proposal was funded, and the project began in Spring 2003. A key aspect of the proposal was the formation of three separate entities: Steering, Policy, and Stakeholder Committees (see Appendix D for a list of each committee's members).

The Steering Committee was composed of members from local, state and federal agencies. Several members were involved in the initial task force that helped to establish the Bonne Femme Watershed Project (BFWP). The primary functions of the Steering Committee included project administration, providing technical assistance to the Stakeholder and Policy Committees, and facilitation of Stakeholder meetings. Other important tasks of the Steering Committee included disbursing cost-share funds, and public outreach and education activities. These activities included annual open houses, newsletters, organization of workshops on low impact development, and two debates on water quality and development issues.

The Steering Committee understood that for a watershed plan to be assured of broad citizen support, it must be developed by the community. Thus, the committee turned the responsibility for developing the plan over to a citizen's group, the Stakeholder Committee. The Stakeholder Committee represented a broad and balanced set of the community's interests. While each individual committee member brought a variety of experience and values to the committee, an attempt was made to have six people representing each of these general interest categories: development, landowner, environmental. The Stakeholders' diversity ensured many perspectives were considered in the planning process. The committee's balance ensured that the plan would represent the values of the community as a whole, and not be skewed toward any particular special interest. The diversity and balance of the Stakeholder committee increased the likelihood that the plan would gain acceptance in the physical, social and economic context of our community. It is important to highlight that the Stakeholders were responsible for the content of the plan, although the Steering and Policy Committees provided feedback during its development.

The Steering Committee understood that for a plan's recommendations to be enacted, there must be political support. Thus, the committee requested that a group of political decision-makers form the Policy Committee to be involved with the plan. This committee's members represented various local agencies that influence how development occurs. Their initial task was to choose the participants on the Stakeholder Committee, because they knew a broad network of community leaders representing diverse interests. Over the course of the project, the Policy Committee observed the Stakeholders' planning efforts, and offered feedback on strengthening the plan's recommendations. Policy Committee participation will be crucial for the eventual adoption of the plan, since their agencies will be responsible for implementing it. Moreover, individual members will be advocates to their respective agencies, as they move through the adoption process. Representatives on the Policy Committee were chosen by the respective agencies.

The primary goal of the plan is to maintain the health of streams within the Bonne Femme watershed, as it urbanizes. The plan attempts to achieve this goal through the recommendation of specific stream protection policies for local government implementation. In addition, this plan can serve to educate the public about the Bonne Femme watershed.

We want to express our gratitude for all the dedication and thoughtfulness of the Stakeholders. They spent about two and a half years, meeting on a monthly basis, forging a consensus on the plan. The Stakeholders did an excellent job crafting a balanced plan that will further the goals of protecting water quality and maintaining economic vitality for the watershed. We believe that local governments should adopt and implement the policies recommended in this plan.

Sincerely,

The Bonne Femme Watershed Project Steering Committee:

Georganne Bowman, Missouri Department of Natural Resources
Roxie Campbell, Rock Bridge Memorial State Park
Bill Florea, Boone County Planning and Building Inspection
Terry Frueh, Boone County Planning and Building Inspection
Robert Lerch, USDA-Agricultural Research Service
Scott Schulte, Rock Bridge Memorial State Park (retired)
Scott Voney, Missouri Department of Conservation

NOTE ON THE TEXT

Words that are defined in the glossary (Appendix B) appear in *this font.*

Executive Summary

The Bonne Femme Watershed Plan is the product of over two and one-half years of work from a group of Stakeholders (see Appendix D for committee membership). The Bonne Femme Policy Committee chose to have a broad and balanced representation on the Stakeholder Committee in order to produce a plan that reflects its representation: broad and balanced. The wide variety of Stakeholders' perspectives ensured that many points of view were considered in the process, and the balanced nature of the committee improved the likelihood it would be unbiased. Local governments will be more likely to adopt the plan if it has support from a wide and balanced range of interests. Although the plan's focus is on protecting and preserving water quality, the Stakeholders wanted to make sure this was accomplished while maintaining economic vitality, and respecting community values.

It should be noted that although the Stakeholders did receive guidance and feedback from the Bonne Femme Steering and Policy Committees, they had the final say on the plan's content. This ensured it was truly a product of citizen involvement, and not one controlled by politicians or by technical staff.

The plan is designed to focus local governments on protecting stream health in the Bonne Femme watershed as it urbanizes (see Figure ES.1, page 3). It provides policy recommendations that, if adopted, will achieve specific goals that enhance the Bonne Femme watershed.

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

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

Chapter 3 discusses scientific information considered by the 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 they developed it. The vision statement is detailed, along with the elements that formed its basis.

Executive Summary

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 each obstacle 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.

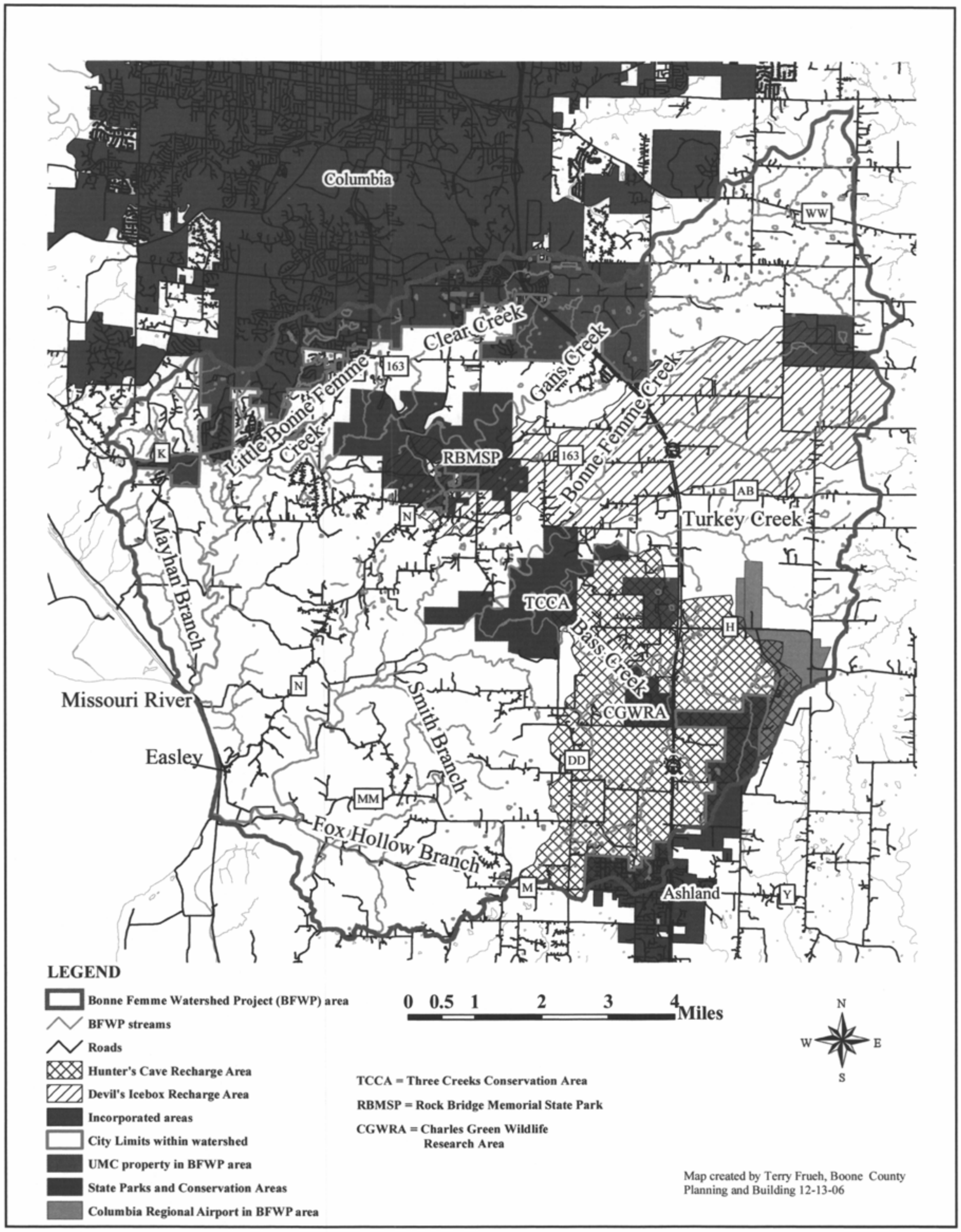

Figure ES.1 Map of the Bonne Femme Watershed Project Area.

Recommendations

Note: these recommendations are not prioritized.

Recommendations that apply to all goals:

1) It is important to have a follow-up program to assess the effectiveness of plan implementation. This follow-up program includes three aspects:

- **Enforcement/inspection** will assure that new ordinances are being followed.
- **Maintenance** of new stormwater and sewer infrastructure will be necessary for proper functioning.
- **Plan evaluation** is key to understanding whether the plan is being followed as intended, and how effective the various measures are. This may include actual stream monitoring, as well as analyzing implementation of the recommendations. Stream monitors must use generally accepted, quantifiable measures of water quality obtained at regular intervals on an ongoing schedule, and the data must be collected by certified entities/persons.

2) Equity: Measures implemented to protect water quality should not unfairly burden individuals. Every effort should be made to create incentive-based programs.

Goal	Strategies	Recommendations
Ensure that structures are not built in places that will flood	Update 100 year flood-plain maps and regulations	Political subdivisions should consider complete hydrologic modeling to determine where the 100-year floodplain would be under full build-out conditions, and locate it more accurately on floodplain maps. This modeling should be limited to developing areas to keep costs down. Allow no construction of structures for occupancy in the re-delineated 100-year floodplain.
	Zoning – Streamside buffer ordinance	Adopt a stream buffer ordinance that limits construction within its boundaries
	Design manual	Do not permit new development to increase peak flows downstream so that flooding is not exacerbated.
	Purchase structures that flood now	City or County may offer to purchase a structure, at prevailing market rate, to correct a flooding problem in an existing neighborhood, if the cost of correcting the problem exceeds the value of the structure.

Executive Summary

Goal	Strategies	Recommendations
Conserve recharge & karst areas with special protections	Design manual/ Performance based goals	The *level of service* (following Columbia's proposed stormwater manual and ordinance) will be more restrictive (e.g. by one or two points on the level of service scale) in karst and recharge areas than in other areas. Local governments will adopt similar, compatible stormwater ordinances and design manuals.
	Zoning	Zoning ordinances will establish specific criteria for development in karst recharge areas. These should include defining levels of stormwater quantity and quality, and limiting new sanitary sewers to *no discharge systems*.
	Land purchase	Local governments may purchase land from willing sellers in karst recharge areas, but other options for protecting water quality should be explored first. Create management plans for this purchased land with a primary goal to protect water quality. (Government takings or eminent domain should not be used for acquiring land for this purpose)
	TDRs & conservation easements	Transfer of development rights (TDR) should be established county-wide, with sensitive areas (such as karst recharge areas and steep slopes) being primary sending areas. This program should enable the cities and the county to have *joint program reciprocity*. TDR and conservation easements should be economically and logistically feasible options for use by landowners and developers.
	Tax relief	Create incentives to encourage conservation in karst recharge areas.
	Zoning and Subdivision regulations; Design manual	Consider a plan to provide special protections to karst and recharge areas.
	Further scientific study and monitoring	More scientific analysis should be done to delineate further karst recharge and other environmentally sensitive areas, and more definitively identify sources of contamination.

Goal	Strategies	Recommendations
Ensure that changes in land use do not increase downstream flooding or channel in-stability, or decrease water quality	Design manual	The ***level of service*** (following Columbia's proposed stormwater ordinance and manual) for stormwater runoff flow characteristics post-development shall be no less than pre-development. Similarly, stormwater quality should have the same or better characteristics for post-development as it had pre-development. Local governments should adopt similar, compatible stormwater ordinances and design manuals.
	Encourage *low impact development (LID)*	Local governments should establish additional zoning and subdivision regulations that allow LID as a *matter of right* (i.e., approval will be expedited). This avoids the problems associated with the planned development process and encourages LID.
	Education	Make new stormwater manuals and ordinances widely available and familiar to the public through a public outreach and education effort.
	Develop funding mechanisms	New sources of funding should be pursued to assist landowners in implementing stream-protection *best management practices (BMPs)*. Compile a list of available sources of funding and provide to landowners and developers.
	Financing of storm water program	Secure sustainable, adequate funding for stormwater programs.

Goal	Strategies	Recommendations
Encourage low impact developments as a way to maintain or improve water quality	Education	Implement a comprehensive educational program for the general public, landowners, and developers to encourage LID.
	Design manual	Revise local governments' development regulations to promote environmentally sensitive design and maintenance.
		The level of service (following Columbia's proposed stormwater manual and ordinance) will be more restrictive (e.g. by one or two points on the level of service scale) in susceptible subwatersheds (following maps 6.0E, 7.3E and 8.2B of the Subwatershed Sensitivity Analysis) than in less susceptible subwatersheds . Local governments will adopt similar, compatible stormwater ordinances and design manuals.
	Tax relief, funding, Economic development	Create economic incentives to encourage developers to implement LID.

Executive Summary

Goal	Strategies	Recommendations
In order to maintain quality of life, encourage parks, healthy streams, LID, and municipal services.	Land purchase, Develop funding mechanisms, Economic incentives	Provide mechanisms and/or incentives to set aside land in non-LID developments for land to be set aside for parks or green space, especially in conjunction with a stream buffer. Encourage these features in other new, as well as preexisting, neighborhoods.

Goal	Strategies	Recommendations
Maintain the economic viability of the community while protecting clean streams	Education	Include information on protecting clean streams in development information distributed by the city and county (through web, forms, brochures). Develop a map that shows protected areas and include this in all literature related to development.
	Design manual	Local governments should adopt similar, compatible stormwater ordinances and design manuals that have stream protection information and requirements.
	Zoning	Address zoning where protection is necessary.

Goal	Strategies	Recommendations
Enhance healthy streams in parks	Education	Make stream protection a central part of park management. Establish park definitions to include stream protection goals. BMPs should be used on property owned by local governments.

Goal	Strategies	Recommendations
Maintain clean water without unnecessarily restricting property rights	Design manual	Give detailed design information to developers and engineers to assist them in controlling runoff quality and quantity from development.
	Zoning	Use voluntary zoning changes to direct density, and therefore higher runoff, to the most appropriate areas.
	Subdivision and zoning regulations	Revise local governments' ordinances and design manuals to enable reductions in impervious surface by allowing flexibility in street width, sidewalks, etc.
	Education	Expand public education newsletters and mail them more frequently.
	Develop funding mechanisms	Secure sustainable public funding for the operation and maintenance of BMPs, especially those initially funded by government agencies.
	TDRs and conservation Easements	Encourage landowners to use various economic incentives (e.g. conservation easements and TDR).

Goal	Strategies	Recommendations
Have policies which boost jobs, retail, tax base, and local economics	Zoning	Locate retail, by appropriate zoning, to areas that will allow the most efficient use of infrastructure and the least hazard of stream pollution.
	Economic incentives	Consider reduction in fees and other expenses paid by developers of commercial property, in preference to the creation of additional special transportation districts. For locally-owned businesses, give economic incentives to help implement LID. Use tax incentives for owners of LID-style commercial/retail structures.
	Zoning	Exempt agricultural land from restrictions and stream buffers to maintain and enhance maximum economic opportunity for farmers and related agricultural activities, as well as to keep land in agricultural use.

Executive Summary

Goal	Strategies	Recommendations
The impacts of up-stream urbanization should be mitigated to prevent increased costs to agricultural and other downstream property owners.	Performance based goals/ Design manual	1) Determine baseline conditions for the establishment of monitoring programs. These conditions should include stream water quality, amount of stormwater discharge, *stream cross-sections.* 2) Publicly monitor at specified time periods at specific locations to determine effectiveness of currently implemented plan.
	Develop funding mechanisms	Ensure that local governments provide adequate funding for their stormwater programs via a stormwater utility fee.
	TDR & conservation easements	Use land purchase, TDRs, conservation easements, etc. where applicable to encourage conservation in appropriate areas.

Goal	Strategies	Recommendations
Ensure that BMPs do not unreasonably affect housing affordability.	Education	Publicize information on cost-effective BMPs.
	Zoning	Amend zoning regulations to allow for increased density in exchange for improved stormwater quality and quantity management.

Goal	Strategies	Recommendations
Ensure that certain areas receive special protections while maintaining the economics of urbanization.	Zoning	Zoning regulations will reflect the sensitivity of the watershed/ subwatershed. This will allow for economic growth while protecting sensitive subwatersheds.
	Design manual	Revise local governments' stormwater design manuals with specific design criteria for sensitive subwatersheds.

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 *non-point 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.

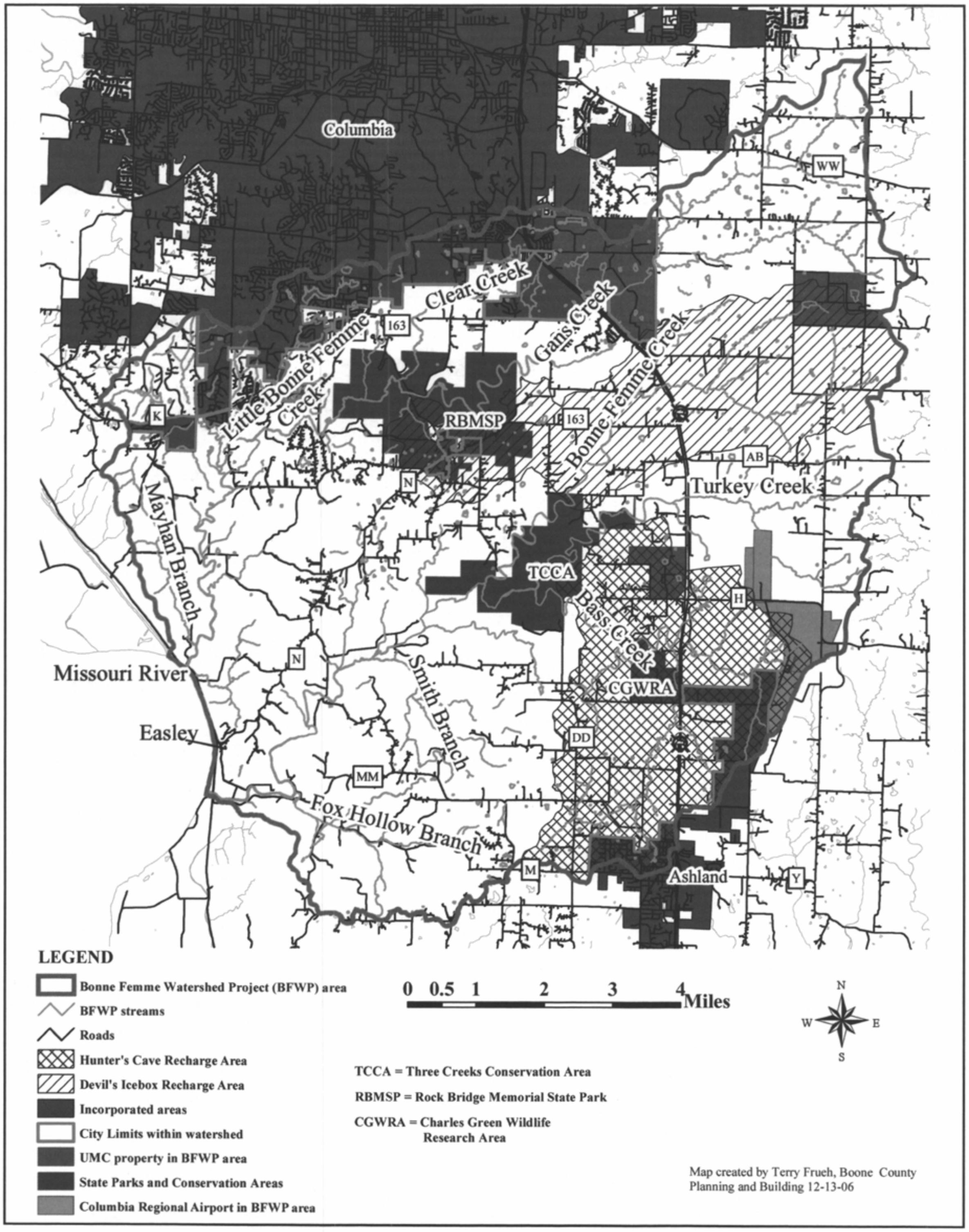

Figure 1.1 Bonne Femme Watershed Project Area

Chapter 1

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.

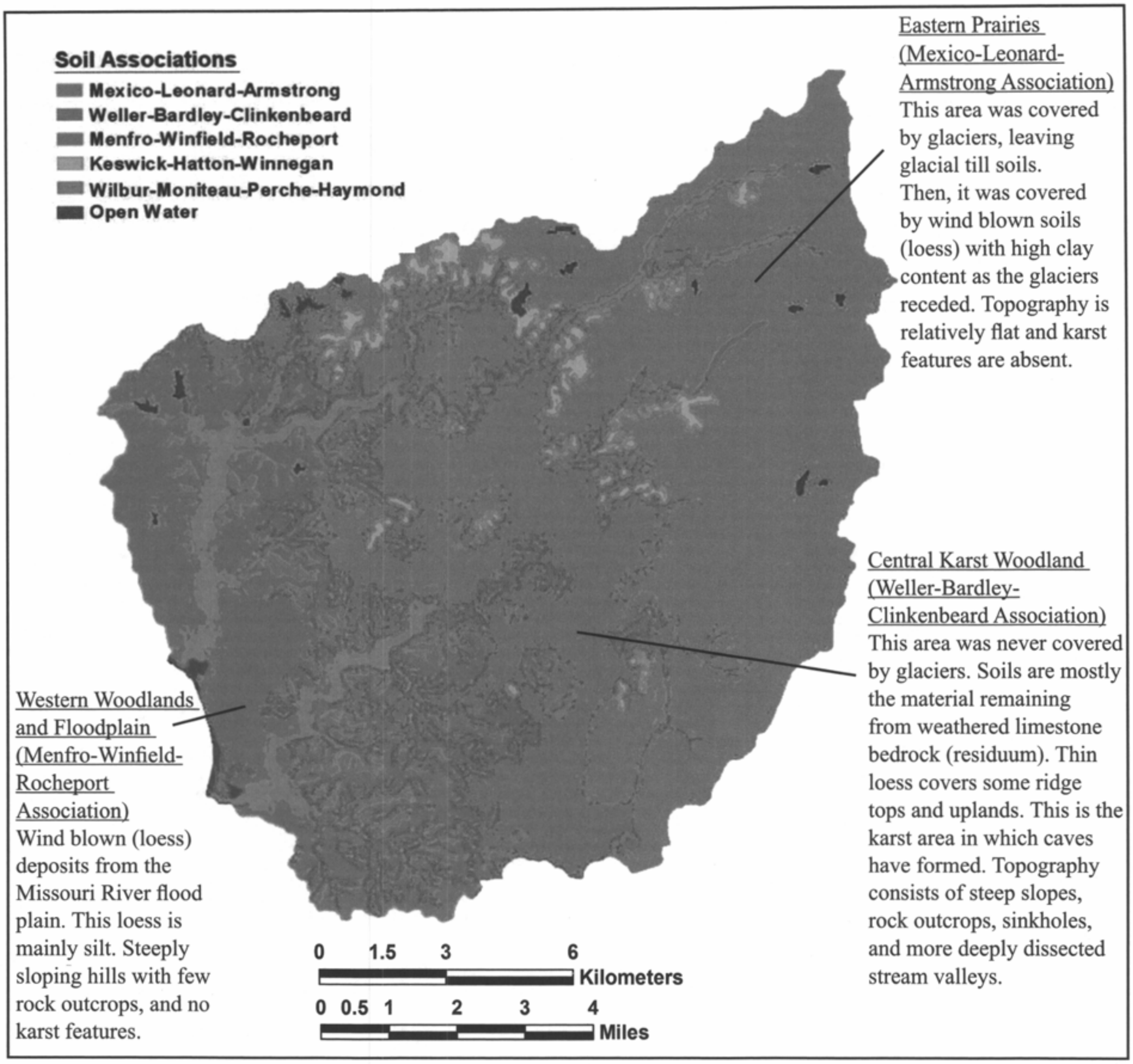

Figure 1.3 Soil Associations

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.

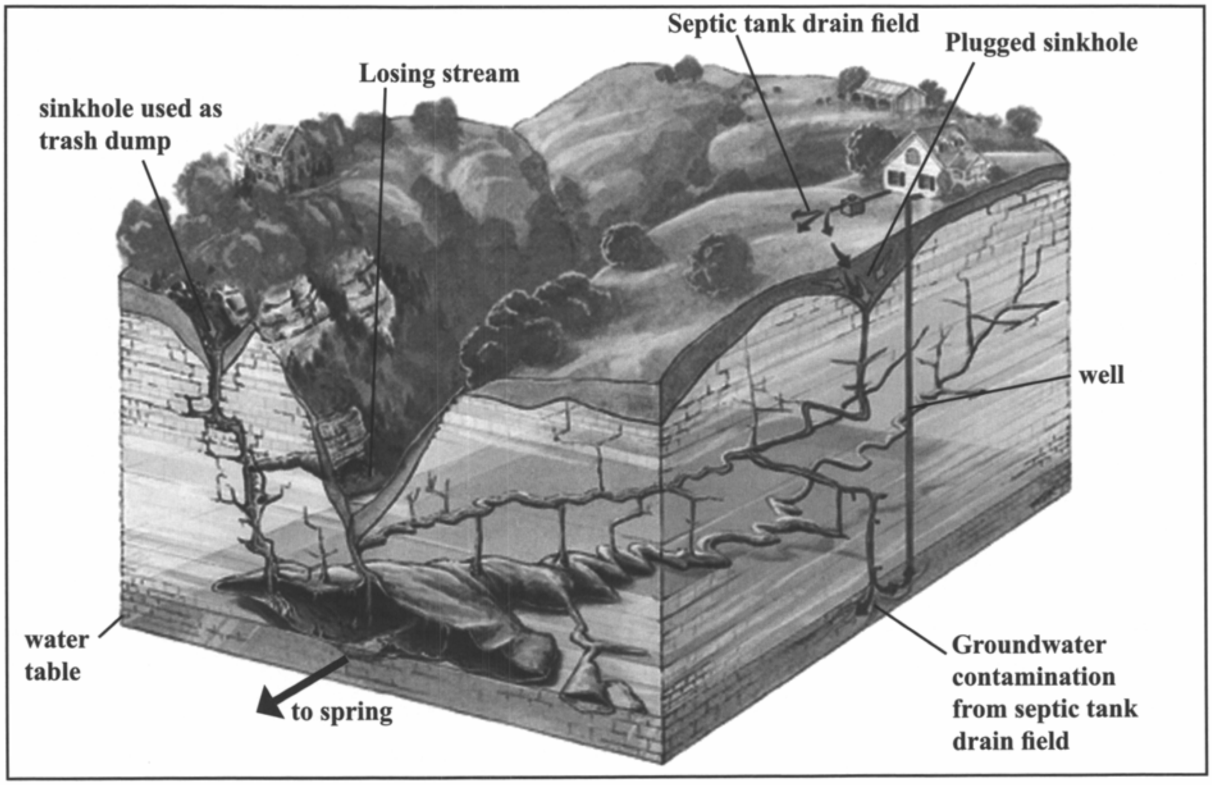

Figure 1.5 How Karst systems work

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.

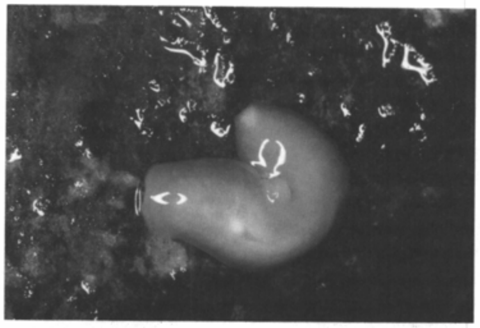

Figure 1.7 Pink Planarian

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° F to 57° F, and ranging from -20° to 110° 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.

Chapter 1

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.

Chapter 1

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 permit-holder 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.

Chapter 2. Stakeholder Issues

This chapter lists the issues identified by the Stakeholders (see below, 2.a List of Stakeholder Issues). In addition to this list, this chapter includes a consolidated grouping of issues (see below, 2.b Stakeholder Issues-Consolidated Grouping). Appendix A has a further explanation of each of the issues for clarification. Appendix A also lists the issues identified by the Project's Policy and Steering Committees. For more information on each committee, see Chapter 1.

2.a. List of Stakeholder Issues

The Stakeholder Committee gave a balanced, diverse perspective representing community input to the planning process. This breadth of representation on the committee was essential to making a successful plan the entire community can support. They are also important for making sure the plan gets implemented by garnering community support and speaking at public hearings. See Appendix D for its membership.

Each Stakeholder was asked to think about their issues in the watershed before the second meeting. Each individual was given three minutes to speak, and all members present participated. Stakeholders spent several months adding to the list, rewording issues, and discussing how they wanted the list organized. In order to most efficiently utilize the Stakeholders' time, they were aided by project staff acting as first writer and secretary. Stakeholders had final say over content. They approved the list of issues on January 10, 2005.

Since the Stakeholders represent the greater Boone County community, this list of their issues places the watershed in its societal context. The list also forms the foundation of the Stakeholders' work (by showing what needs to be considered in the planning process).

Property Rights

1. Property rights: people want to have the choice to do what they want to with their property.

2. Property rights: what one property owner chooses to do on his/her property should not adversely affect another person's use of his/her respective property.

3. A significant portion of the watershed is public land, and therefore a larger group of people have an interest in that property.

4. Affected parties need notice of what is going on (i.e. notice of public meetings) in order to assure good public participation.

5. Landowners need to defend themselves from groups that try to restrict them.

6. There is a need to integrate the future use of the watershed in such a manner as to allow for reasonable development while not infringing upon property owners' rights.

Streams/Conservation

7. Devil's Icebox Cave Branch is getting muddier.

8. There is higher and more frequent flooding than used to occur for a given amount of rain, bringing in garbage and moving sand bars; this also causes aquatic habitat destruction and subsequent lower low flows.

9. Urbanization can cause water quality degradation in streams.

10. Endangered species could become eliminated from the watershed.

11. The Outstanding State Resource Waters (Bass, Turkey, Bonne Femme, Gans Creeks, and Devil's Icebox Cave Branch) demand special protection.

12. Potential exists for a toxic spill that could negatively impact a stream.

13. Small acreage landowners need to address the issue of erosion from overgrazed horse pastures (sometimes to the extreme of being bare).

14. Erosion in road right of ways is a serious problem that needs to be addressed on both public and private land.

15. Many *best management practices (BMPs)* have been installed on crop and pasture land in the watershed, but there is always a need for additional BMPs as needs arise.

16. It is important to protect the unique biological diversity (plant and animal) in the watershed.

17. Much of this watershed is particularly environmentally sensitive because of the high number of karst structures (sinkholes, caves, springs, and losing streams) present; this makes the watershed very vulnerable to increased levels of contaminants and stormwater runoff.

18. It is important to have plentiful drinking water that is of good quality, therefore it needs to be protected.

Standards and Ordinances

19. It is important to have standards not based on impervious cover, but on Best Management Practices (BMPs); there is science indicating impervious cover can be mitigated.

20. Impervious surfaces can degrade streams and there is no clear science indicating they can be fully mitigated; therefore, in order to protect streams, impervious cover needs to be addressed in any standards.

21. Boone County, and the Cities of Columbia and Ashland, need to develop good stormwater management plans and ordinances in order to set good standards for the future development of this watershed; the standards should be meaningful (and not arbitrary), and be designed so that going into a project everyone knows what the rules are.

22. Water quality should be protected without putting a strict ban on development.

23. Some flexibility of recommendations and standards is needed.

24. We need to develop a watershed-based plan that makes use of the best scientific data, as well as the best watershed plans from other communities, that will provide the best chance to protect the Greater Bonne Femme Watershed.

25. Much of the stream can be protected with a buffering situation. Other portions of the stream would not likely be sufficiently protected with any amount of buffering.

26. County zoning encourages development.

27. Development should be given incentives to occur in areas with adequate infrastructure and discouraged in less suitable areas.

28. Development should be encouraged in less environmentally sensitive areas and discouraged in more environmentally sensitive areas.

29. Erosion problems and stormwater need to be addressed in existing developed areas.

30. Guidelines for installing and maintaining BMPs need to be established. Soil and Water Conservation District, Natural Resources Conservation Service, Missouri Department of Conservation and Missouri Department of Natural Resources already have existing specifications for many practices.

Chapter 2

Health

31. It is important never to see a sign posted warning people to stay out of a stream because of the quality of the water.

32. Failing onsite sewage systems contaminate streams with fecal material (which is a human health hazard).

Science

33. Science is inexact.

34. There is a need to track sources of contaminants (i.e. microbial source tracking) in order to base long term plans on good information and not guesses.

35. Good mapping of sinkholes is needed.

36. Facts and data should lead process, not biased opinion.

37. It is important to base decisions on studies that have been reviewed by a board of peers.

Education

38. There is a need to educate the public about why better practices are important to conserve resources, and about the differences between loess and karst.

39. Recreational use and enjoyment of public lands (Rock Bridge and Three Creeks) is at stake.

40. Educational opportunities concerning stream ecology could be lost, affecting over 2,000 students each year who visit Rock Bridge Memorial State Park.

41. It is important to educate people about the issues and rights of landowners within the watershed.

Agriculture

42. Maintaining agricultural productivity is important.

43. Agriculture-related soil erosion causes problems.

44. Excess agricultural chemicals and nutrients are emitted to streams, thereby polluting them.

45. Livestock have open access to streams, which accelerates streambank erosion and increases fecal bacterial concentrations in the streams.

46. There is a need for a farmland preservation program since many people value open land and green space.

47. Farms that use good agricultural practices are a benefit to the watershed.

2.b. Stakeholder Issues - Consolidated Grouping

A Stakeholder devised this grouping in order to help him better see the bigger picture of how the issues were related and how to work with them. The Stakeholder Committee decided to adopt the regrouping for inclusion in the plan. This section organizes the above issues into three sections:

- Property Rights
- Ecological/Public Interests
- How to Achieve Balance

Many of the concerns listed by members overlap ecological interests and the rights of the landowners within the project watershed; thus, many of the issues are cited under more than one of the three sections. Note that, to maintain consistency between lists, the issues listed below have the same numbers as in the preceding section.

Property Rights

People who own property expect and have the legal right to do what they want to with their property within the local ordinances, and as long as their actions do not degrade the value or infringe on their neighbors' property uses. As long as uses do not violate the law (federal, state and county), how property owners use their land is something they consider to be their business, and they do not feel that anyone else should have the right to tell them what to do. The numbered issues that are relevant are: 1, 2, 3, 4, 5, 6, 8, 9, 13, 14, 15, 22, 24, 25, 29, 32, 44, 45.

1. Property rights: people want to have the choice to do what they want to with their property.

But, 2. Property rights: what one property owner chooses to do on their property should not adversely affect another person's use of their respective property.

For example, 32. Failing onsite sewage systems contaminate streams with fecal material (which is a human health hazard).

3. A significant portion of the watershed is public land, and therefore a larger group of people have an interest in that property.

4. Affected parties need notice of what is going on (i.e. notice of public meetings) in order to assure good public participation.

And 5. Landowners need to defend themselves from groups that try to restrict them.

6. There is a need to integrate the future use of the watershed in such a manner as to allow for reasonable development while not infringing upon property owners' rights.

24. We need to develop a watershed-based plan that makes use of the best scientific data, as well as the best watershed plans from other communities, that will provide the best chance to protect the Greater Bonne Femme Watershed.

22. Water quality should be protected without putting a strict ban on development.

9. Urbanization can cause water quality degradation in streams.

8. There is higher and more frequent flooding than used to occur for a given amount of rain, bringing in garbage and moving sand bars; this also causes aquatic habitat destruction and subsequent lower low flows.

25. Much of the stream can be protected with a buffering situation. Other portions of the stream would not likely be sufficiently protected with any amount of buffering.

29. Erosion problems and stormwater need to be addressed in existing developed areas.

13. Small acreage landowners need to address the issue of erosion from overgrazed horse pastures (sometimes to the extreme of being bare).

45. Livestock have open access to streams, which accelerates streambank erosion and increases fecal bacterial concentrations in the streams.

44. Excess agricultural chemicals and nutrients are emitted to streams, thereby polluting them.

14. Erosion in road right of ways is a serious problem that needs to be addressed on both public and private land.

15. Many *BMPs* have been installed on crop and pasture land in the watershed but there are still some areas that will always need work to maintain acceptable erosion control practices.

Ecological/Public Interests

We have a number of outstanding streams in our watershed that are home to rare or endangered species and offer unmatched beauty and recreational opportunities. Many of the things we do, whether it is careless/over-development or environmentally-unfriendly agricultural practices, degrade the quality of these resources. It is critical for us all to take the necessary measures to protect these resources for future generations. Individual property owners may very well have to accept restrictions they don't like, in order to serve the greater good of the community. Relevant numbers are: 7, 8, 9, 10, 11, 12, 16, 17, 18, 20, 22, 28, 29, 31, 32, 39, 40, 43, 44, 45, 47.

11. The Outstanding State Resource Waters (Bass, Turkey, Bonne Femme, Gans Creeks, and Devil's Icebox Cave Branch) demand special protection.

17. Much of this watershed is particularly environmentally sensitive because of the high number of karst structures (sinkholes, caves, springs, and losing streams) that it has; this makes the watershed very vulnerable to increased levels of contaminants and stormwater runoff.

16. It is important to protect the unique biological diversity (plant and animal) in the watershed.

7. Devil's Icebox Cave Branch is getting muddier.

10. Endangered species could become eliminated from within the watershed.

39. Recreational use and enjoyment of public lands (Rock Bridge and Three Creeks) is at stake.

40. Educational opportunities concerning stream ecology could be lost affecting over 2,000 students each year who visit Rock Bridge Memorial State Park.

31. It is important never to see a sign posted warning people to stay out of a stream because of the quality of the water.

18. It is important to have plentiful drinking water that is of good quality, therefore it needs to be protected.

32. Failing onsite sewage systems contaminate streams with fecal material (which is a human health hazard).

43. Agriculture-related soil erosion causes problems.

44. Excess agricultural chemicals and nutrients are emitted to streams, thereby polluting them.

45. Livestock have open access to streams, which accelerates streambank erosion and increases fecal bacterial concentrations in the streams.

12. Potential exists for a toxic spill that could negatively impact a stream.

8. There is higher and more frequent flooding than used to occur for a given amount of rain, bringing in garbage and moving sand bars; this also causes aquatic habitat destruction and subsequent lower low flows.

9. Urbanization can cause water quality degradation in streams.

20. Impervious surfaces can degrade streams and there is no clear science indicating they can be fully mitigated; therefore, in order to protect streams, impervious cover needs to be addressed in any standards.

29. Erosion problems and stormwater need to be addressed in existing developed areas.

47. Farms that use good agricultural practices are a benefit to the watershed.

22. Water quality should be protected without putting a strict ban on development.

28. Development should be encouraged in less environmentally sensitive areas and discouraged in more environmentally sensitive areas.

How to Achieve Balance

This section organizes the issues that address how to solve some of the issues brought up in groupings of Property Rights and Ecological/Public Interest (see above). We should be able to come up with a balanced approach in our community plans and our zoning regulations by developing an educational program, backed by ordinances (founded on science, facts and community values) that protect natural resources, promote economic growth, and preserve rights of property owners. The issues are: 4, 5, 6, 15, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 32, 33, 34, 35, 36, 37, 38, 41, 42, 46.

6. There is a need to integrate the future use of the watershed in such a manner as to allow for reasonable development while not infringing upon property owners' rights.

5. Landowners need to defend themselves from groups that try to restrict them.

4. Affected parties need notice of what is going on (i.e. notice of public meetings) in order to assure good public participation.

21. Boone County, and the Cities of Columbia and Ashland, need to develop good stormwater management plans and ordinances, in order to set good standards for the future development of this watershed; the standards should be meaningful (and not arbitrary), and be designed so that going into a project everyone knows what the rules are.

23. Some flexibility of recommendations and standards is needed.

24. We need to develop a watershed-based plan that makes use of the best scientific data, as well as the best watershed plans from other communities, that will provide the best chance to protect the Greater Bonne Femme Watershed.

22. Water quality should be protected without putting a strict ban on development.

26. County zoning encourages development.

27. Development should be given incentives to occur in areas with adequate infrastructure and discouraged in less suitable areas.

28. Development should be encouraged in less environmentally sensitive areas and discouraged in more environmentally sensitive areas.

46. There is a need for a farmland preservation program since many people value open land and green space.

20. Impervious surfaces can degrade streams and there is no clear science indicating they can be fully mitigated; therefore, in order to protect streams, impervious cover needs to be addressed in any standards.

29. Erosion problems and stormwater need to be addressed in existing developed areas.

19. It is important to have standards not based on impervious cover, but on Best Management Practices (BMPs); there is science indicating impervious cover can be mitigated.

30. Guidelines for installing and maintaining *BMPs* need to be established. *SWCD, NRCS, MDC, MDNR* already have existing specifications for many practices.

15. Many BMPs have been installed on crop and pasture land in the watershed but there are still some areas that will always need work to maintain acceptable erosion control practices.

25. Much of the stream can be protected with a buffering situation. Other portions of the stream would not likely be sufficiently protected with any amount of buffering.

42. Maintaining agricultural productivity is important.

36. Facts and data should lead process, not biased opinion.

37. It is important not to base decisions on studies that have not had some type of review by a board of peers.

34. There is a need to track sources of contaminants (i.e. microbial source tracking) in order to base long terms plans on good information and not guesses.

32. Failing onsite sewage systems contaminate streams with fecal material (which is a human health hazard).

38. There is a need to educate about why better practices are important to conserve resources, and about the differences between loess and karst.

41. It is important to educate people about the issues and rights of landowners within the watershed.

35. Good mapping of sinkholes is needed.

33. Science is inexact.

Chapter 3. Science in the Watershed

This chapter discusses various scientific analyses that were used in the planning process. Several studies were carried out in conjunction with the Bonne Femme Watershed Project, while others discussed in this chapter were completed independently. It was important for the Stakeholders to understand various aspects concerning stream health and function, combined with how they might change in the future. These studies helped provide an understanding of the scientific necessity for, and impact of, their planning decisions. Various studies were given to the Stakeholders via reports and presentations. Project-related studies were carried out to give the Stakeholders scientific information that helped inform their planning process. Also, initial studies recorded baseline conditions for the watershed's streams. Each study is briefly summarized.

Details of these studies are provided in Appendix G.

3.a Karst Hydrogeology and Soils of the Bonne Femme Watershed

General Watershed Information

As shown in Figure 3.1, page 46, the Bonne Femme watershed is located in southern Boone County, Missouri between the cities of Columbia and Ashland (Figure 3.1, left). The watershed encompasses 93.3 square miles and consists of nine subwatersheds (Figure 3.1, upper part). For convenience, these are combined into three major subwatersheds (Figure 3.1, left): Little Bonne Femme Creek; Bonne Femme Creek; and the combination of Turkey and Bass Creeks. The upper map in Figure 3.1 shows the surface-drained subwatersheds (i.e., those subwatersheds in which most of the water stays at or near the land surface). The lower map in Figure 3.1 shows the two karst recharge areas (i.e., subwatersheds which contribute water to the two major cave systems; see the discussion below). The term karst refers to soluble bedrock (limestone and dolomite) terrain that has *sinkholes*, caves, *losing streams* and springs. A karst recharge area is the surface land area that drains to a cave system.

A mixture of land uses occurs within the Bonne Femme watershed, with agricultural activities the predominant land use, encompassing 61.5% of the watershed area (Figure 3.2, page 47). Row crop production is mainly in the eastern (higher elevation) portions of the watershed, and along flood plains in the western (lower elevation) portions of the watershed. Pasture and range lands are more widely scattered, but generally concentrated in the central and eastern portions of the watershed. Forested areas make up nearly one-third of the watershed, mainly within the central and western parts of the watershed. These forested areas also encompass most of the publicly-owned lands, including Rock Bridge Memorial State Park and Three Creeks Conservation Area. Urban areas are beginning to encroach on the watershed as the cities of Columbia and Ashland continue to grow.

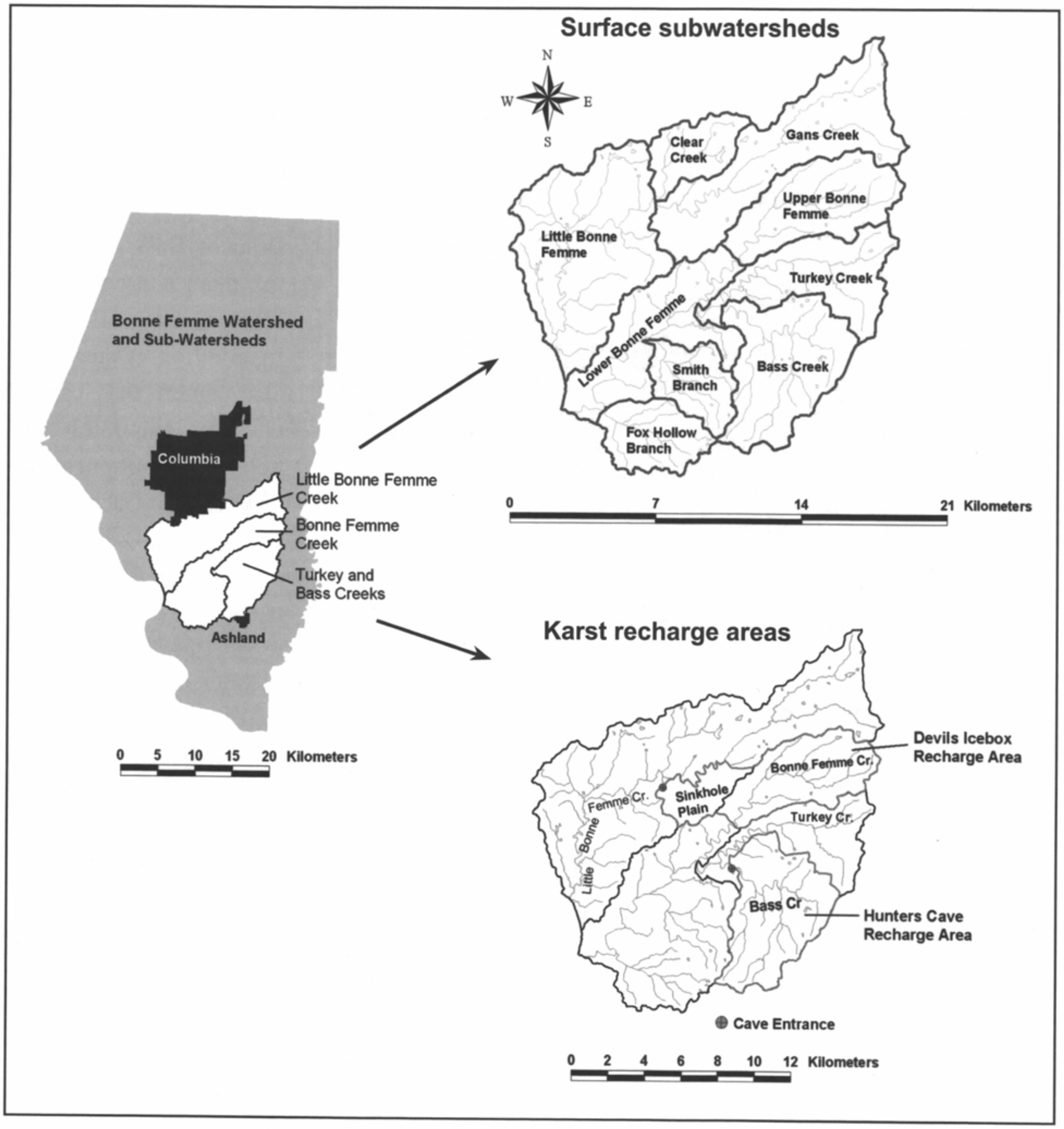

Figure 3.1 Location of Bonne Femme watershed, subwatersheds, and karst recharge areas.

Karst Recharge Areas and Implications for Water Quality

The two *karst* recharge areas that supply water to the Devil's Icebox and Hunters Cave Branches are of similar size (Devil's Icebox, 13.1 square miles and Hunters Cave, 12.9 square miles); their combined areas account for approximately 28% of the entire watershed (Lerch *et al.*, 2005). In both areas, recharge to the cave streams occurs along sinking or losing surface stream channels, in which water infiltrates through porous streambed sediments or through

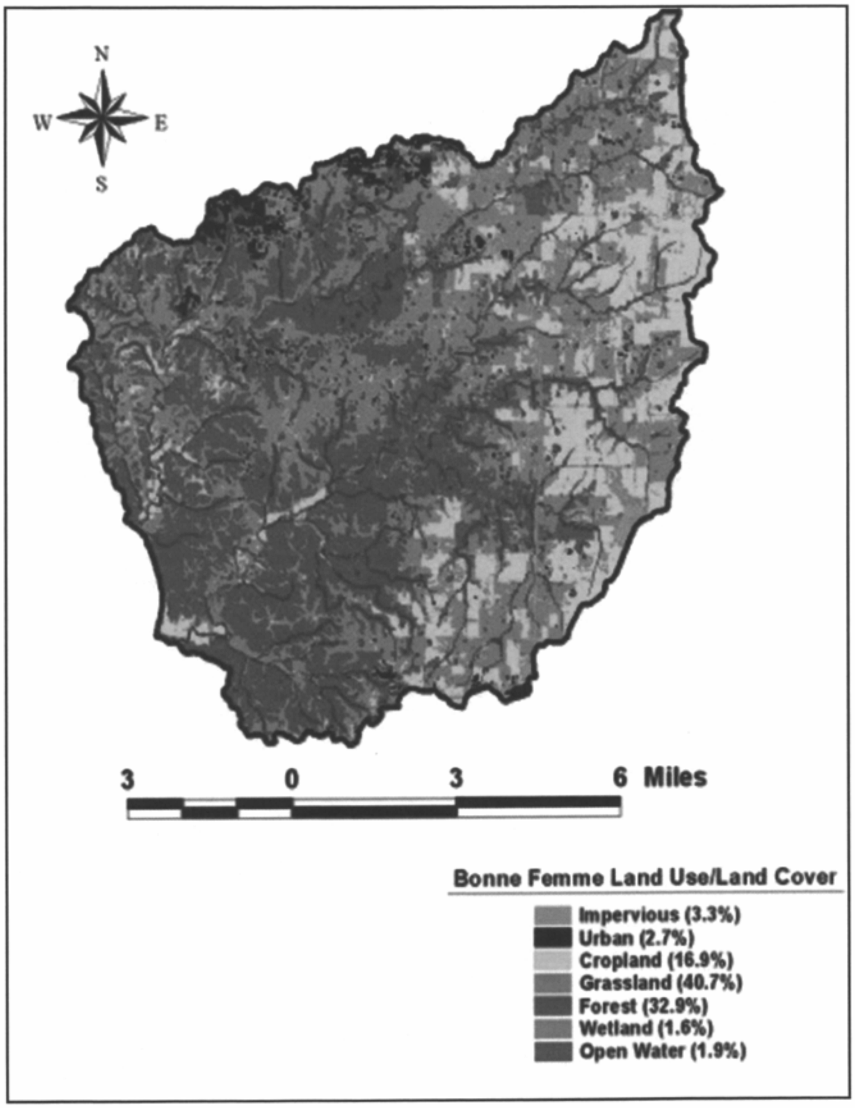

Figure 3.2 Land use/land cover for the Bonne Femme watershed.

Data were obtained from 30-m resolution LANDSAT data collected from 2000-2004.

cracks in the bedrock. Upper Bonne Femme Creek is the *losing stream* that supplies most of the water to the Devil's Icebox Cave Branch; Bass Creek is the main source to the Hunters Cave Branch. In addition, water can also enter the caves through sinkholes (a hole at the bottom of a depression). Each sinkhole drains a small land area and therefore contributes less water volume to the cave than the losing streams. Many *sinkholes* in the Pierpont area drain into the Devil's Icebox Cave Branch, so a considerable volume of water can enter the cave in this manner. However, the sinkhole drainage area is smaller than the upper regions of the Bonne Femme Creek drainage area, so the latter is the major contributor. Of particular interest is the underground transfer of water between two surface subwatersheds. For example, in the Devil's Icebox Cave Branch recharge area, water from upper Boone Femme Creek loses water to the Devil's Icebox Cave Branch, which eventually discharges to the Little Bonne Femme Creek.

Management Challenges

Overall, karst recharge areas are very vulnerable to groundwater contamination, because surface water rapidly enters the cave system with little or no opportunity for reducing contaminants by surface soils. In the Bonne Femme watershed, sources of pollution that are a potential threat to karst groundwater quality include unmitigated urban development, improper application of chemicals and nutrients, malfunctioning private septic systems, and animal waste. These pollution sources can impact karst aquifers through the introduction of numerous contaminants, such as oil, gasoline, antifreeze, pesticides, fertilizers, sediment, and fecal coliform bacteria (Ruhe *et al.*, 1980; Boyer and Pasquarell, 1999; Mahler *et al.*, 1999; Lerch *et al.*, 2001).

A growing threat to karst groundwater in the Bonne Femme watershed is the increasing area of land surface that is impervious to water as a result of urbanization. In developments without proper handling of stormwater and removal of pollutants, *impervious surfaces* such as roads, building rooftops, sidewalks, driveways, and parking lots, will negatively impact stream hydrology, biology, and channel shape. In surface stream watersheds, impervious surfaces increase speed and amount of storm water runoff, which in turn degrades aquatic habitat and biological health of streams, increases stream bank erosion, and decreases base flow discharge (Burges *et al.*, 1998; Booth *et al.*, 2002). These hydrologic impacts have also been shown to occur in karst recharge areas (Betson, 1977; Ruhe *et al.*, 1980). Karst systems further complicate the impact of unmitigated impervious surfaces because stormwater runoff can transfer from one watershed to another through underground channels. This situation exists where water transfers from the upper reaches of Bonne Femme Creek to the Devil's Icebox Cave Branch, and hence to the Little Bonne Femme Creek. The increased runoff caused by impervious surfaces will most profoundly impact The Devil's Icebox Cave Branch, but localized increases in impervious surface could negatively impact the water quality and quantity of the Hunters Caves Branch as well.

Geology, Soils, and Land-Use

The geology and the soils of the Bonne Femme watershed are rather atypical for karst watersheds in Missouri (Figure 3.3, page 48). The difference is due to the fact that the watershed lies at the edge of glacial activity that occurred in the last two million years. The layers of bedrock within the watershed were formed during the Mississippian Age, 310-345 million years ago. The lower layers of bedrock form a unit called the Chouteau Group, which is rarely exposed at the Earth's surface. This layer is composed of limestone, dolomite, and silty dolomite with a total thickness of approximately 100 feet, but it is not conducive to cave development because of its insoluble nature (Unklesbay, 1952). The Chouteau Group serves as the base of the cave stream in the Devil's Icebox Cave. Overlying the Chouteau Group is the Burlington Limestone, a crinoid-rich limestone with abundant chert and a total thickness of approximately 160 feet (Wicks, 1997). Caves within the watershed were formed within the Burlington Limestone layers, which are exposed throughout the central portions of the watershed.

The eastern portions of the watershed are covered by clay-rich Pleistocene age glacial and loess (i.e. wind blown) deposits (Figures 3.4, page 49). These poorly drained, fertile soils

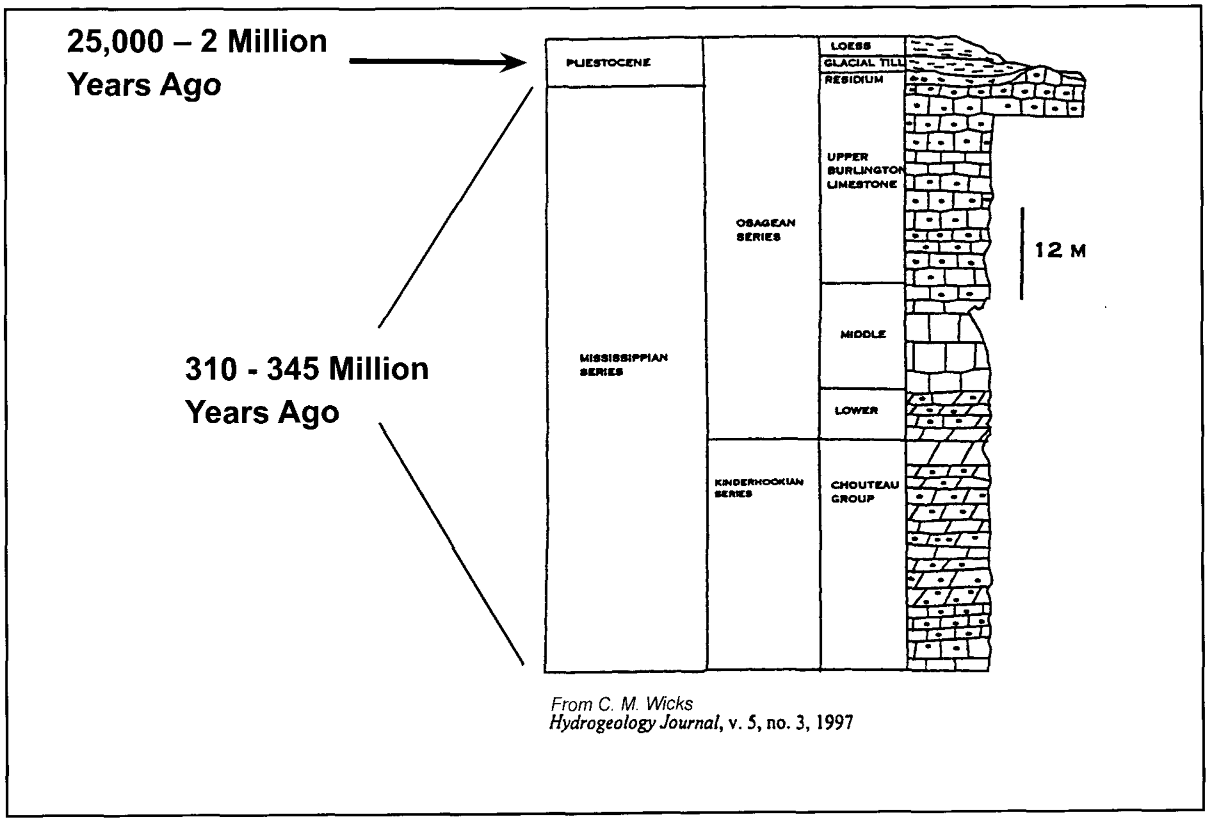

Figure 3.3 Generalized geologic stratigraphy for the Bonne Femme watershed.

are generally in the Mexico-Leonard-Armstrong soil associations (USDA-NRCS, 2001) (Figure 3.4), and they also support the most intensive row crop production within the watershed (Figure 3.2). This area was covered by glaciers, leaving *glacial till* soils. Then, as the glaciers receded, it was covered by *loess* with high clay content, leaving deep soil deposits. Topography is relatively flat and karst features are absent.

Central portions of the watershed are characterized by *residual soils* (i.e. weathered from bedrock) of the Weller-Bardley-Clinkenbeard association (USDA-NRCS, 2001). This area was never covered by glaciers. Soils are mostly the material remaining from weathered limestone bedrock (residuum), and the soils tend to be rocky and shallow. Thin loess covers some ridge tops and uplands. This central region is the karst area, with features such as sinkholes, caves (including Devil's Icebox and Hunters Caves), and springs. Topography is characterized by steep slopes, rock outcrops, and deeply dissected stream valleys. These soils support some pasture and range land, but forested areas are the most common land cover in this area of the watershed.

The western portion of the watershed is covered by *loess* (wind blown) and *fluvial* (water deposited) soils of the Menfro-Winfield-Rocheport and Keswick-Hatton-Winnegan soil associations. The deep loess deposits were derived from the Missouri River floodplain, and

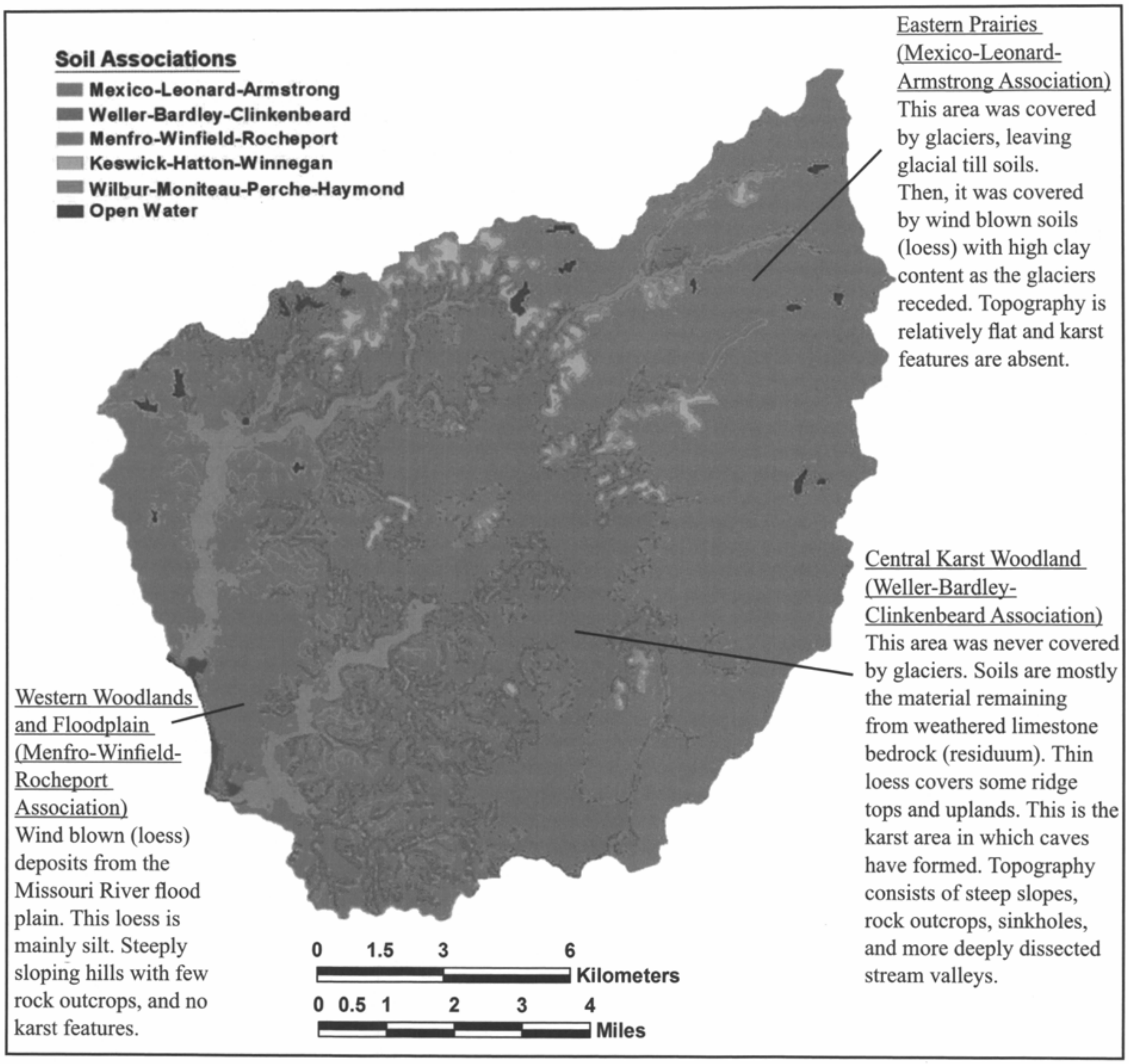

Figure 3.4 Soil Associations

they are mainly silt rather than the clay-rich loess in the eastern part of the watershed. The topography consists of steeply sloping hills with few rock outcrops and no karst features.

Soils perform some essential functions with respect to mitigation of contaminants. These functions can be divided into three categories: 1) hydrologic, 2) retention, and 3) degradation. First, soils impact watershed hydrology based on the rate that water moves into the soil (*infiltration*) and the soils' water holding capacity. In general, thicker soils will have greater water holding capacity than thinner soils; therefore, the soils in the eastern and western portions of the watershed will hold more water than those in the central area of the watershed. The karst area of the watershed not only has thin soils, but also has sinkholes in which water flow has little interaction with the soil before draining to groundwater or one of the cave streams in the watershed. In contrast, soils in the eastern portion of the watershed have high clay content, which significantly slows the rate of water infiltration, which leads to more runoff.

The second key function of soils is their ability to retain contaminants. Soils contain clays and organic matter that can chemically bind some contaminants, such as metals and pesticides, while other contaminants, such as nitrate (NO_3^-), will travel downward with percolating water and will not be retained by the soil. Although the soils in the eastern portion of the watershed have high clay contents, their ability to retain contaminants is limited by their high runoff potential. However, management factors, such as incorporating fertilizers and pesticides for crop production, do greatly improve retention of these contaminants by enhancing their interaction with soil. Soils in the central portion of the watershed are typically so thin that, regardless of their clay or organic matter content, their ability to retain contaminants is very limited. The silt loess soils in the western portion of the watershed have the best overall characteristics for retaining contaminants, but steep slopes that promote runoff may limit contaminant retention in some settings. Also, the relatively shallow water table and higher infiltration rates of these silt loess soils likely creates a high risk for leaching of poorly retained contaminants, such as nitrate, to groundwater.

The third important function of soils is their ability to biologically or chemically degrade contaminants, resulting in the formation of less- or non-toxic byproducts. Often, this function will be related to the organic matter, clay content and hydrologic characteristics of soils, since these properties determine how conducive the soil is to microbial growth and activity, and how chemically reactive the soils may be. The thin soils within the central portion of the watershed certainly have less ability than soils in the eastern and western portions of the watershed with respect to this function. Compared to the thicker clay and silt loess soils, thin soils with low organic matter will not support sufficient microbial populations to achieve significant contaminant degradation. However, short- and long-term land uses also affect the ability of a soil to degrade contaminants. For instance, the persistence of the herbicide atrazine often is related to the cropping history of the soil. Soils with even a short-term history of corn production, in which atrazine was used for weed control will degrade atrazine many times faster than areas that have never received the herbicide. Also, certain forage grasses, such as tall fescue, orchardgrass, and eastern gamagrass have the ability to stimulate microbial populations near the soil surface, resulting in enhanced degradation of some herbicides, and in reductions in nutrient leaching to ground water. Thus, the degradation potential of any soil is a complex function of soil properties and their associated plant communities.

Contributor: Robert N. Lerch, Soil Scientist, USDA-ARS.

Figure 3.5 Life Cycle
Federally endangered gray bats (left) that inhabit caves of Boone County, spend summer nights catching thousands of flying insects that in younger stages of life were aquatic. Living in streams of the watershed are mayfly nymphs (middle), one of the *EPT* insects that are sensitive to water quality. After metamorphosis, mayfly nymphs become adult flying insects (right) that are preyed upon by bats.

3.b Cave Life

Missouri is sometimes called "The Cave State" because caves are so abundant throughout Southern Missouri and the Missouri and Mississippi River border areas. The Missouri Speleological Survey has recorded locations of about 6,300 caves. Many people find caves to be fun places to explore, places to see beautiful *stalactites* of calcite, and to challenge one's fear of the dark and unknown. Adding to the mysterious surroundings are mysterious animals. Bats, with their unique insect-catching abilities of flight and *echolocation*, sleep through the winter while hanging from cave ceilings in the mild year-round temperatures. Other creatures are unlike anything seen above ground. They lack color and eyes, and manage to live quite well in an environment with no light or plants.

Many of these mysterious creatures remain undiscovered, because scientists haven't yet visited their cave — only about 1,000 (about 15%) of Missouri's caves have been inventoried for cave life. Undiscovered because some of the animals are tiny. Undiscovered in the sense that while some have been found, they haven't yet been taxonomically described and named. Undiscovered in that while some have been described and named, we understand very little about how they live and interact with other animals.

The pink planarian (Figure 3.6) existed in obscurity underground for thousands of years, before its discovery by scientists in 1956 (Hyman, 1956). Fifty years later, only a little research has been conducted (and still much is unknown about how the pink planarian lives or about the ways it could benefit humans). Other species of planarians were useful in the 1960s in memory research (Jacobson *et al.*, 1966). Planarians are one of the simplest of animals that have brains and nervous systems. The pink planarian is a flatworm approximately one inch long and approximately one-quarter inch wide. They are white or translucent, sometimes with a pink tinge. Both male and female sexual organs exist within each individual. A cocoon of eggs is produced (Kenk, 1975). In a laboratory, pink planarians ate amphipods. One of the mysteries

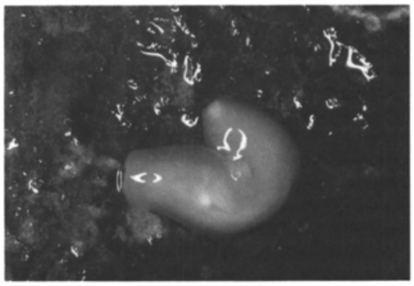

Figure 3.6 The Pink Planarian.
Not only is the pink planarian cave adapted, it is also endemic, depending entirely upon Devil's Icebox Cave for it's habitat. It has not been found to exist anywhere else.

that remains is how pink planarians manage to catch *amphipods* in the wild. Amphipods are fast swimmers and pink planarians have no eyesight (and it's dark anyway). Another mystery is whether animals such as crayfish and salamanders prey upon pink planarians.

Notably, the pink planarian is rare. This species has been found to exist in no other cave besides Devil's Icebox Cave. This means the pink planarian is "*endemic*," being restricted to this one habitat. Endemic can refer to areas of various size, but with cave animals, usually refers to one cave. The entire population of pink planarians exists in one cave stream, making it vulnerable to extinction should Devil's Icebox Cave Branch become polluted. One would hope that if the main cave stream became polluted, that some individuals in the underground tributaries to the main stream would survive to repopulate, but to date, none have been found in the cave tributaries (Sutton, 2004).

The pink planarian is adapted to the nutrient inputs received from hundreds of sinkholes and has obviously survived agricultural practices of early Boone County that included hog lots and soil erosion. However, it's not known what effect modern chemicals, pesticides, oils, etc. may have on the pink planarian — another mystery. A 1981 ammonia pipeline break killed thousands of cavefishes, cave crayfishes, and grotto salamanders in Meramec Spring Cave, Missouri. Nonetheless, the more common types of cave pollution are less dramatic and occur over a long time period, including siltation and the input of extra nutrients.

Siltation occurs when fine silt or dirt is washed in and is deposited in between and on top of rocks on the bottom of the cave stream. A low amount is natural, but high amounts can be very harmful. If not managed well, large amounts of silt can be washed in from construction sites and other lands that lack vegetation. Pink planarians and other cave animals move through spaces under and between rocks, so if those spaces are filled, they lose habitat. In Mammoth Cave, Kentucky, siltation in the lower level pools resulted in the elimination of a previously common cave-restricted *isopod* and its predator crayfish (Lewis, 1980; Poulson, 1996). In Missouri, siltation from land clearing probably caused the severe decline of the Tumbling Creek cavesnail (Elliott *et al.*, 2005).

Caves naturally have very little food available for animals. Species adapted to caves can live in these conditions but most animals can not. Because caves are naturally poor in food supply, it is a threat when extra nutrients from fertilizers, manure, etc. are carried in from the land. Too much food supply can cause a population explosion of species of *amphipods* and *isopods* that live both above and below ground. Increased competition for space disrupts the cave ecology, and harms species that live only in caves. The result is a replacement of

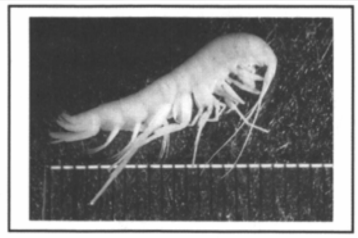

Figure 3.7 Amphipods and habitat

The amphipod on the left (*Crangonyx forbesi*) lives both above and below ground, while the amphipod on the right (*Bactrurus brachycaudus*) is restricted to underground habitats. Photos taken by William R. Elliott, courtesy of the Missouri Department of Conservation.

the cave-restricted species with species that also exist on the land. For instance, in Mammoth Cave, Kentucky, a rotting staircase in one area caused an amphipod to dominate and replace the previous resident — a cave-restricted isopod (Lewis, 1987; Poulson, 1996). A severe case of sewage pollution in Hidden River Cave, Kentucky caused the disappearance of cavefish and cave crayfish (EPA, 1981; Lewis, 1989; Quinlan, 1977).

It is no mystery that each animal needs a habitat. Some animals are more restricted in what can serve as habitat for them. Cave-restricted species (also called troglobites) live their entire lives inside caves and cannot survive outside of caves. Other species (called troglophiles) can live both in caves and above ground. For example, a salamander that normally lives in leaf litter above ground can find its way into a cave and survive there as well. If a temporary toxic pollution event occurs in a cave, a *troglophile* species would lose only a small percentage of its population and could repopulate the cave when conditions improve. However, the entire population of a cave-restricted species could be eliminated from the cave with no nearby individuals available to repopulate. The only way both categories of animals can continue to exist is if cave habitats are managed primarily for the sake of cave-restricted species. The natural world is healthier when a greater number of native species (*biodiversity*) are present because each is unique and plays a role within its ecosystem. Protecting biodiversity is a goal among biologists. In part, biologists are admitting that much remains a mystery. Since we don't understand all of the intricacies of relationships among animals in an ecosystem it's prudent, as Aldo Leopold advised, to "keep all of the parts," just in case we learn that something is more important than previously realized. It's hard to get research dollars devoted to obscure little cave animals, so many are not researched. They may hold the secrets that will unlock mysteries that can benefit people, someday… if we keep all of the parts.

Missouri has 83 cave-restricted species, 68 described and 15 not yet described, (Elliott, 2007). *Troglobites* found in Missouri caves include white and blind cavefishes, the grotto Salamander, millipedes, crustaceans (crayfishes, isopods and amphipods) and planarians. Sometimes an animal is not only restricted to cave habitats, but also restricted to a single cave (*endemic*). Such is the case with the pink planarian, and with a new species of isopod that was collected by Mick Sutton in 2003. Both live in the stream inside Devil's Icebox Cave.

Because it is endemic, the pink planarian is listed as a *species of conservation concern* by the Missouri Conservation Department in categories defined as "critically imperiled" in Missouri (S1) and "globally imperiled" (G2G3) (MDC, 2006). A difficult process is involved in becoming classified as "*endangered*" by the U.S. Fish and Wildlife Service - something not yet attempted for the pink planarian.

The number of endemic and cave-restricted species recorded for a particular cave affects how the cave ranks among others in biodiversity[1]. In addition to being the seventh longest cave in Missouri with 6.25 miles of passages, Devil's Icebox Cave is ranked second in biodiversity among Missouri's 6,300 caves. The cave that is number one in Missouri is also the highest in cave biodiversity among caves west of the Mississippi River - Tumbling Creek Cave in Taney County. Missouri ranks about seventh in the United States in troglobite biodiversity. Overall, Devil's Icebox Cave would rank highly among known western US caves, while many Eastern US caves would still have higher *biodiversity* (Elliott, 2007).

The biological records for Devil's Icebox Cave include about 200 observations and collections. These records have been entered into the Missouri Cave Life Database, a project of the Missouri Department of Conservation and its partners. Devil's Icebox Cave now has about 80 species, 9 of which are cave-restricted. About 23 species are not completely identified, but this is not unusual for a large cave with a rich fauna. The cave-restricted species include a spider, an amphipod, the Tingupa cave millipede and the Missus cave springtail. Their identity is about all we know about them.

Much research has been conducted with bats. U.S. Navy sonar systems are not as sophisticated as those of bats (Simmons, 1998). Bats are able to differentiate between sounds that are only 2 to 3 millionths of a second apart, and between objects separated by only the width of a human hair (Simmons, 1998). Research for medical benefits has focused on hibernation and reproduction. Sperm is stored alive inside the female bat's body all winter prior to fertilization (Schwartz, 1981). Bats of the genus Myotis (includes gray and Indiana bats) caught 500 to 1000 mosquitoes in one hour in a laboratory study (Griffin, 1960). Each female corn earworm moth lays about 250 eggs that become caterpillars and damage our corn crops, but bats eat these moths and disrupt their reproductive behavior (Gillam, 2002).

Devil's Icebox Cave is important as habitat for both gray and Indiana bats, which are federally-listed endangered species. Female gray bats establish a nursery colony each year in Devil's Icebox Cave from April through August. The colony currently numbers about 13,000. One mystery that remains is how the bats, who fly here in the spring from caves about 325 miles away, find the small cave entrance. Scientists are trying to determine why Indiana bat numbers continue to drop drastically, while gray bat numbers have been steadily increasing. A few hundred Indiana bats are hibernating inside Devil's Icebox Cave, despite the fact that the temperature there is warmer than what scientists thought they prefer.

1. This scoring system was developed by William R. Elliott, Missouri Department of Conservation Cave Biologist as a means of evaluating and communicating the relative biological importance of Missouri caves (Elliott, 2000a, 2007; Elliott and Ashley, 2005.)

Hundreds, if not thousands, of other bats hibernate in the 55 degree F temperatures of Devil's Icebox Cave, including the little brown, big brown, long-eared and Eastern pipistrelle species. In addition, a variety of land animals use caves occasionally to escape from predators, drought, heat and cold. These include pickerel frogs, which congregate in the water passage of Devil's Icebox Cave, sometimes in the hundreds.

Why does Devil's Icebox Cave have such a high *biodiversity* level? The answer has to do with its location within the natural divisions of Missouri, and with its watershed. Most Missouri caves are located south of the Missouri River and were not affected by glaciers. Some glaciers covered northern Missouri and stopped their southern push in the general area of what is now central Boone County. These glaciers deposited deep soils. Their melting washed silt into the Missouri River valley. That silt was picked up by winds and deposited over much of Boone County. It is theorized that the deep mud deposits inside Devil's Icebox Cave may have washed in when the glaciers melted (Weaver, 1980). Definitely, water that flows through the Devil's Icebox Cave now carries with it nutrients from the deep soils of the upper Bonne Femme Creek. In addition, leaves, sticks and other debris enter the cave through the many sinkholes of the Pierpont Karst. These inputs provide more nutrients for cave life than what is typically observed in caves of Southern Missouri. These nutrient levels are still much lower than those of surface streams, and much lower than what could easily occur if poor land management occurs in the cave's watershed. To generalize, Northern Missouri doesn't have caves and Southern Missouri's caves are lower in nutrient inputs, making caves of Boone County rather unique. The caves of Boone County do not contain the cave-restricted species of fishes and crayfishes found in Southern Missouri, but contain cave life not found in Southern Missouri caves.

Large caves of Boone County, other than Devil's Icebox Cave, include Hunter's Cave (located within Three Creeks Conservation Area, within the Bonne Femme watershed) and Rocheport (Boone) Cave (not in the Bonne Femme watershed). These have few cave-restricted animal species and no *endemic* species, so their biodiversity scores are low. The watersheds that feed water through most of the length of Hunter's Cave and through Rocheport Cave are small in size. Some water diverts from Bass Creek to flow through a short lower section of Hunter's Cave, but the land drained by Bass Creek has soils that are not as rich and deep as those of the upper Bonne Femme Creek (which feeds Devil's Icebox Cave Branch). Hunter's Cave has 33 animal species, four of which are cave-restricted. It is a minor roosting site for male gray bats during the summer months. For some maybe not-so-mysterious reason, they don't hang out with the females at the nursery site in Devil's Icebox Cave! Probably more species will be found in Hunter's Cave, but it is smaller than Devil's Icebox Cave, has fewer microhabitats and less flowing water. Consequently, it will likely not have as much biodiversity as Devil's Icebox Cave. Rocheport Cave is a relatively short cave that floods violently. Although Rocheport Cave has 32 animal species, it has no cave-restricted species. It does, however, provide an important roosting area for Indiana and gray bats because of the height and shape of cave passages and their temperatures (Elliott, 2007).

Devil's Icebox Cave and some of its life are unique. The rich soils of the cave's watershed and numerous sinkholes input more nutrients than what most caves receive and thus support a rich diversity of life. Devil's Icebox Cave is ranked second in biodiversity among Missouri's 6,300 caves. Slowly, as funds are available, scientists are revealing more about the mysterious life that resides only in caves. Since many mysteries remain, some of which may benefit people in the future, it is an important goal to protect these cave-restricted animals. The endemic, cave-restricted pink planarian lives in the stream that flows through Devil's Icebox Cave. It and other aquatic cave animals are very vulnerable to chemicals, dirt and extra nutrients that could easily wash in from the watershed.

Contributors: William R. Elliott, Cave Biologist, Missouri Department of Conservation, Resource Science Division; Roxie Campbell, Interpretive Resource Specialist, Missouri Department of Natural Resources at Rock Bridge Memorial State Park.

Figure 3.8 The semi-aquatic mink.
It obtains about half of his diet from aquatic animals such as frogs, fish and crayfish. Streams also provide wildlife with a source of drinking water. Trees and other tall plants near a stream allow wildlife to approach the stream with some amount of cover from detection by predators. These riparian corridors also serve as travel routes for wildlife that need a large habitat.

3.c Stream Ecology and Use of EPT Insects as Indicators of Water Quality

The streams of the Bonne Femme Watershed possess a diversity of animal life that is typical of this region, transitional as it is between the prairies to the north and the Ozarks to the south. Some of the streams have flowing water at all times (perennial streams), while others flow intermittently and may have only isolated pools at other times.

The community of *invertebrates* visible to the naked eye is a diverse mix, dominated by mayflies, stoneflies, caddisflies, dragonflies, beetles, true flies, crustaceans and snails. Estimates of the total richness of these streams, in terms of the numbers of different species identified in stream riffles, range from 18 in Clear Creek to 27 in Turkey Creek. The fish communities of the Bonne Femme watershed and nearby streams generally range from 11 to 17 species, represented by shiners, minnows, suckers, redhorse, sunfish, bass, darters and

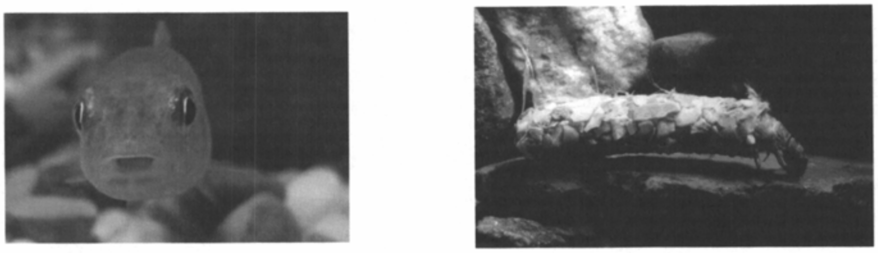

Figure 3.9 Aquatic-terrestrial life connections.
Some fish species (left) need a habitat of rocky substrate free of sediment. This caddisfly larva (right) lives among the spaces between rocks. If mud fills the spaces, certain caddisflies are harmed. This caddisfly larva covered his case with sand.

stonerollers. No federally listed threatened or endangered fish species are known to exist now in these waters. The Topeka shiner, listed as federally endangered, was historically found in the watershed, but not since 1997.

Stable aquatic communities, both plants and animals, have evolved over time in harmony with their environment. Biologists refer to a stream in this condition as having "biological integrity." This term implies the capability of maintaining a balanced natural community with good diversity and resilience to minor changes (Karr and Dudley, 1981). In other words, such a stream system can withstand an assault and recover.

Stream communities are influenced by at least five interrelated factors: 1. energy source (green plants that engage in photosynthesis); 2. water quality (level of pollutants or temperature extremes); 3. habitat quality (e.g. *substrate*, appropriate water depth for certain species, etc.); 4. varying characteristics of water flow, such as volume and speed (known as "flow regime" of the stream); and 5. interactions of species within the food web. Changes in any one of these factors can so change a stream environment that the plants and animals cannot adapt. The result will be a reduction in the number of species present, the elimination of species, and an overall decrease in biodiversity in the stream environment.

Unmitigated urban and agricultural runoff are of greatest concern to the health of the streams in the Bonne Femme watershed. Examples are stream bank erosion and collapse associated with uncontrolled runoff from impervious surfaces, poor livestock management, surface soil erosion, and high levels of fecal coliform bacteria, nutrients and herbicides (Lerch, 2006). Increased urban runoff and poor land management practices in upland areas of a watershed usually have two immediate effects: an increase in the speed and volume of flowing water, and an increase in the sediment it carries. Clearing of vegetation and compacting of the soil in *riparian areas* (i.e. in direct proximity to a stream) further increase the delivery of sediment to the stream, and decrease the resistance of the stream banks and streambed to erosion (Jacobson *et. al.*, 2001). Besides affecting water quality, increased runoff of water and fine sediment can cause significant changes in the *flow regime*, as well as the energy sources in the stream,

Figure 3.10 Gans Creek.
In 2006, nearly 200 photographs were taken as one aspect of a project to document the physical condition of streams within Rock Bridge Memorial State Park. This was taken on May 4, 2006 at Gans Creek Station 31, looking upstream.

Stream Team Monitoring and Rock Bridge Project

Stream Teams are composed of concerned citizens who conduct litter pickups, monitor water quality, conduct bank stabilization, and become stewards for their adopted stream. The Volunteer Water Quality Monitoring Program is an activity of the Stream Team Program that teaches volunteers to monitor stream water quality on their adopted sections of streams. Eight Stream Teams have entered data on sections of eight streams within the Bonne Femme watershed. The Stream Team Program, managed jointly by the Missouri Department of Conservation and Missouri Department of Natural Resources, provides training, testing equipment and data management. Four levels of training are available. Level 2 training/monitoring indicates that the trained volunteer has attended 3 workshops (32 hours) and passed a quality assurance test of their monitoring procedures and equipment. While Stream Team data is not expected to be as exact as that of professionals and laboratories, it does indicate conditions in the watershed. When problems have been detected, professional data have consistently confirmed Stream Team findings. Stream Team monitoring includes conducting a visual survey; chemical testing for dissolved oxygen, Ph, temperature, conductivity and nitrates; measuring water depth and velocity; and collecting and identifying *macroinvertebrates*. (For online information, see www.mostreamteam.org.)

In the spring of 2006, a project was conducted to document the physical condition of streams within Rock Bridge Memorial State Park (RBMSP). UMC Intern Austin DeVoe conducted the study under the direction of Park Naturalist Roxie Campbell. Protocols were established and followed that enable the study to be duplicated in the future. Where applicable, Stream Team protocols were used. GPS coordinates were recorded for stations that were established every 100 to 200 meters on Devil's Icebox Spring Branch, Clear and Gans Creeks. Four photos were taken at each station (see Figure 3.10, above). Other data collected included stream channel width and depth, water width and depth, water velocity and embeddedness. The data are available at www.CaveWatershed.org.

its suitability as habitat for living creatures, and the interactions among those living creatures within the stream. Thereby, aquatic life suffers further harm.

An increase in fine sediment in stream riffles and pools may result in the alteration or elimination of preferred habitats for some stream species because of changes in the stability or composition of the streambed or stream bank (*substrate*). Other possible effects include interference with the respiratory function or nesting behavior of the stream organisms, or interference with their feeding activities by reducing the concentration or value of food (Lemly, 1982; Graham, 1990). Increased penetration of light into a stream by removal of streamside vegetation can result in higher water temperatures and quantity of plants and bacteria that live on rocks in the stream, known as *periphyton biomass*.

Unmitigated urban runoff is widely believed to adversely affect aquatic communities in adjacent streams by increasing pollution and modifying stream channels. Impervious surfaces, without adequate stormwater treatment, that cover 8% to 15% of a watershed are known to negatively affect stream health by funneling pollutants and excessive quantities of water into streams from streets, parking lots, driveways, roofs, patios and sidewalks (Schueler, 1994; Center for Watershed Protection, 2003). While pollutants have a direct effect on living organisms, increased peak flows and total volumes of water are believed to have indirect, yet more deleterious, effects through stream bank erosion, streambed sedimentation, and disruption of pool and *riffle* sequence (Center for Watershed Protection, 2003). In a study of land use relationship to fish health in Wisconsin streams, the health of fish communities was negatively related to the amount of upstream urban development as well as the amount of agricultural land (Wang *et.al.*, 1997). The health of fish populations was positively related to the amount of upstream forest in the watershed (Ibid).

Maintaining a good streamside or *riparian* vegetative buffer, consisting of a mixture of grasses, bushes and trees, is essential to the protection of the stream. The riparian buffer reduces stream bank collapse and its attendant excess sediment load delivered to the stream, mediates stream water temperatures, and provides a variety of organic food sources to maintain a productive stream environment (Hubbard and Lowrance, 1994). A vegetative buffer of twice the width of the stream on each side is usually considered sufficient (Rabeni, personal communication, 2006).

In an effort to determine baseline conditions within the streams of the Bonne Femme Watershed, a biological monitoring program was started in the Spring of 2006. Invertebrate species visible to the naked eye, rather than microscopic species, were used as biological measures of water quality. These "*macroinvertebrates*" were studied following guidelines established by the MDNR, to determine how many "taxa," or groups of distinct but related organisms, are present in each of three "Orders," or larger categories of generally pollution-sensitive creatures. These larger categories are the mayflies (Ephemeroptera), stoneflies (Plecoptera) and caddisflies (Trichoptera). The measure used is called "EPT richness." This measurement is useful because of the expectation that impairment of water quality will result in a decrease in numbers of pollution-sensitive macroinvertebrate species. EPT richness has been shown to detect most of the potential problems that may affect the Bonne Femme Watershed, including organic pollution, acidity and metals, fine sediment and insecticides. Collections made in the spring of 2006 indicated that all the sampled streams were at least "partially biologically supporting" of macroinvertebrate species, based on EPT richness scores provided by MDNR for this area (Doisy, 2006; full report is located in Appendix G).

Contributors: Charles Rabeni, Leader, and Kathy Doisy, Research Biologist, Missouri Cooperative Fish and Wildlife Research Unit, Department of Fisheries and Wildlife Sciences, University of Missouri, Columbia.

Devil's Icebox Cave Branch Biomonitoring

While looking for EPT insects is widely used to monitor the health of surface streams and is sometimes used to monitor streams fed by spring water, the best biomonitoring approach for evaluating the health of Devil's Icebox Cave Branch is to enter the cave, identify and count the cave animals that live in the cave stream. A scientific protocol (set of procedures) was developed in 2004 that standardized the methods so that one year's data can be compared to the data of other years (Sutton, 2004). Certain marked sections of cave stream are searched for pink planarians (that often cling to the bottom of rocks) and other aquatic animals such as isopods and amphipods. This biomonitoring tells us three things: 1) whether the water quality is good enough to continue to support the pink planarians; 2) whether pink planarian numbers are trending upward or downward (important since all of the world's pink planarians depend upon this one cave stream for survival); and 3) whether there is an increase in surface species that compete with cave species (this occurs when nutrient levels are increased beyond normal cave levels). Research is lacking on how sensitive pink planarians are to water quality, but if their numbers drop, some aspect of their aquatic habitat has changed for the worse. Current numbers appear to be modest. The three survey plots of preferred habitat have yielded an average of 27 pink planarians during fall counts and an average of 12 during Spring counts.

Refer to Appendix G for more information.

Contributors: Roxie Campbell, Interpretive Resource Specialist, Missouri Department of Natural Resources at Rock Bridge Memorial State Park; Priscilla Stotts, Environmental Specialist who works with stream monitoring, Missouri Department of Natural Resources; Tim Rielly, Biologist, Missouri Department of Conservation; Doug Novenger, Stream Ecologist, Missouri Department of Conservation.

3.d Water Quality Monitoring, 2001-2006

Water quality monitoring in the Bonne Femme watershed has been ongoing since 1999, when studies were initiated at Hunters and Devil's Icebox Spring Branches (Lerch *et al.*, 2001; Lerch *et al.*, 2005). In 2001, the monitoring was expanded to include six surface subwatersheds in addition to the two caves, and with the initiation of the Bonne Femme Watershed Project in 2003, an additional two surface sites were added, the total number of monitoring

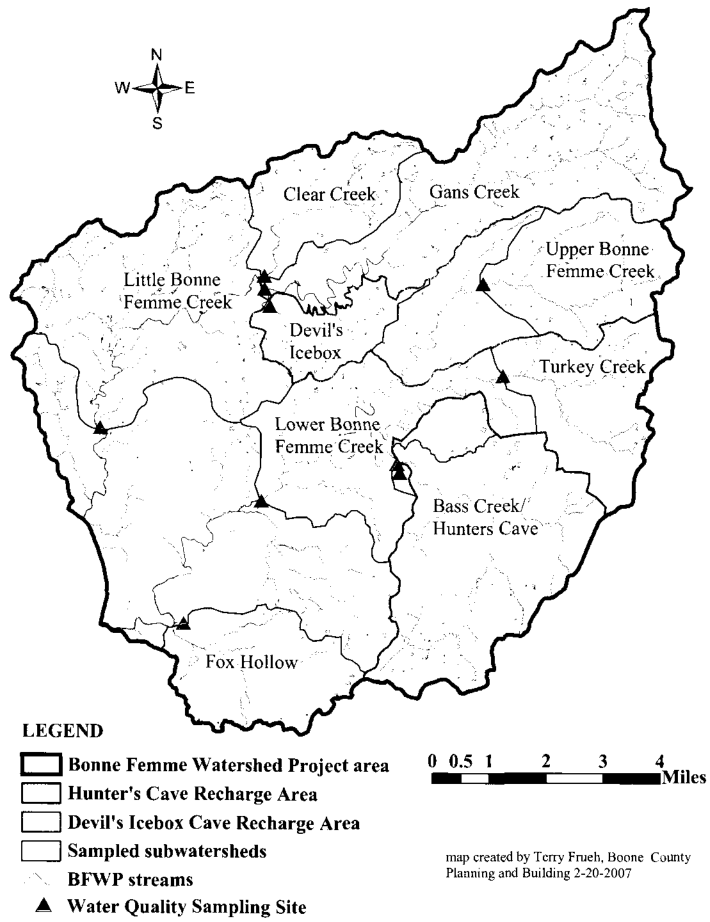

Figure 3.11 Bonne Femme watershed monitoring sites.

sites increasing to ten (Figure 3.11). The current monitoring program includes eight surface subwatersheds (Clear Creek, Gans Creek, Upper Bonne Femme Creek (at US 63), Turkey Creek, Bass Creek, Lower Bonne Femme Creek (at Nashville Church Rd.), Little Bonne Femme Creek, and Fox Hollow) and the two karst recharge areas (Devil's Icebox and Hunters cave branches). This monitoring scheme covers about 80% of the entire watershed. Samples were collected at all sites once per quarter, since fourth quarter 2003. General stream water properties analyzed were turbidity, pH, dissolved oxygen, specific conductivity, and temperature. Nutrient analyses included total nitrogen and phosphorus, and dissolved nitrate (NO_3^-), ammonium (NH_4^+), and orthophosphate (PO_4^{3-}). Herbicides were analyzed only for the second quarter samples. The following herbicides were measured: atrazine, deethylatrazine (*metabolite*), deisopropylatrazine (metabolite), metolachlor, acetochlor, alachlor, and metribuzin. Sampling for fecal bacteria was conducted for four weeks each quarter, with samples collected at weekly intervals. Bacterial analyses included fecal *coliforms* (FC), generic *E. Coli* (EC), and qualitative analyses for specific pathogenic bacteria – *E. Coli* O157:H7, *Salmonella*, and *Shigella*. FC analyses have been conducted at eight of ten sites since 2001; EC analyses have been conducted since fourth quarter 2004; and pathogen specific analyses have been conducted since fourth quarter 2005. If there was no stream flow, samples were not collected from stagnant pools. All laboratory methods and the sampling scheme were detailed in the Quality Assurance Project Plan (Lerch, 2004).

Chapter 3

Water Quality Monitoring Conclusions

The following general conclusions can be reached from the monitoring study:

- General stream water properties indicate no acute contamination, with all five properties measured falling within typical ranges for carbonate bedrock streams, and dissolved oxygen levels above the State minimum standard of 5 mg/L;
- Nutrient levels were similar to or less than streams in other agricultural watersheds of northern Missouri. There was no evidence of acute contamination at any site;
- The combination of dissolved oxygen, turbidity, nutrient levels, and field observations indicated that all sites have some level of nuisance algal growth and presumed loss of macroinvertebrate diversity, but *eutrophication* (the process by which a body of water becomes over-enriched in dissolved nutrients from fertilizers or sewage, thereby encouraging the growth and decomposition of oxygen-depleting plant life and resulting in harm to other organisms) conditions have not occurred at any site;
- At least one herbicide or metabolite was detected in every sample at all sites, but typically at low levels. Atrazine and its metabolites had the highest average concentrations at all sites;
- Fecal bacterial contamination was widespread with significant differences observed across sites and over seasons. Concentrations of fecal bacteria were highest in spring and summer;
- Whole body contact standards for fecal bacteria were commonly exceeded. Seven of 10 sites exceeded the State fecal coliform standard 40% of the time. Eight of 10 sites exceeded the Federal *E. Coli* standard 50% of the time;
- Frequency of detection of specific pathogens was in the following order: *E. Coli* O157:H7 > *Salmonella* > *Shigella*. The pattern of *E. Coli* O157:H7 detections indicated that cattle were the probable source;
- Of the general stream water properties measured, concentrations of fecal bacteria were significantly correlated only to turbidity and stream discharge (based only on the two cave sites);
- Land cover classes did not significantly correlate to the concentrations of fecal bacteria;
- Multiple sources apparently were the cause of fecal contamination in most subwatersheds while site specific sources of fecal bacteria appear to be responsible for the high levels observed at Devil's Icebox Spring Branch (most likely from septic systems) and Fox Hollow (most likely from nearby cattle herds).

Note that some of these conclusions may require further studies to confirm them. For more detailed information about the water quality sampling, see Appendix G.

Contributor: Robert N. Lerch, Soil Scientist, USDA-ARS

3.e Bonne Femme Dye Traces

Groundwater recharge in karst systems is highly vulnerable to pollution since there is little to no filtering of surface water as it enters subterranean conduits. *Nonpoint source (NPS)* pollutants are transported to streams dissolved in water and bound to sediments suspended in surface runoff. This pollution poses a special threat to karst systems, in part because it is spread throughout a watershed and therefore is harder to control, and in part because aquatic life in karst systems tend to be especially vulnerable to pollution. Thus, it is important to know the recharge area (the land area that contributes water to a cave) of a cave branch in order to determine the sources of water and their associated land uses. This delineation of the *recharge area* of a cave system provides the basic information required to protect organisms living in its water. Dye tracing is a method frequently used to determine hydrogeological flow characteristics of an area, and it is the primary tool available for delineating recharge areas.

Two dye trace experiments were performed by the Bonne Femme Watershed Project. The first dye trace, carried out during winter 2003-2004, confirmed that the reach of Bonne Femme Creek downstream of Highway 163 *loses* water to the Devil's Icebox Cave Branch. This approximately one-mile long reach was previously determined to be losing continuously along the reach (St. Ivany, 1988), and thus is presumed to lose flow to Devil's Icebox Cave Branch down to the point where elevation precludes transmission of water to the cave (estimated to be 700 feet above sea level). The results of this dye trace allowed us to add approximately 2.0 square miles to the previously known Devil's Icebox Cave Branch recharge area. The second dye trace, carried out in the summer of 2004, indicated that Gans Creek does not lose any water out of the stream channel during low flow to any springs, although further study is needed to confirm these results. However, it is important to note that St. Ivany (1988) found that Gans did lose a portion of its water during normal flows to a spring located in the Gans Creek floodplain, but Gans Creek did not lose water to the Devil's Icebox Cave Branch under low and normal flow conditions.

The drainage area that contributes to the losing section of Bonne Femme Creek confirmed in this trace is approximately 2.0 square miles (Figure 3.12, area C). Two recharge areas, the Pierpont Sinkhole Plain (Fig. 3.12, area A) and the upper Bonne Femme Creek subwatershed (Fig. 3.12, area B), were confirmed to be losing to Devil's Icebox Cave Branch in previous studies (King and Hargrove, 1973; St. Ivany, 1988). These have areas of 3.6 square miles and 7.5 square miles, respectively. The total identified recharge area for Devil's Icebox Cave Branch is approximately 13.1 square miles. It contains portions of the recently-formed village of Pierpont, unincorporated parts of Boone County, University of Missouri's Bradford Research Farm, Rock Bridge Memorial State Park and Three Creeks Conservation Area.

For more detailed information on the dye traces, see Appendix G.

Contributor: W. Terry Frueh, Watershed Conservationist, Bonne Femme Watershed Project.

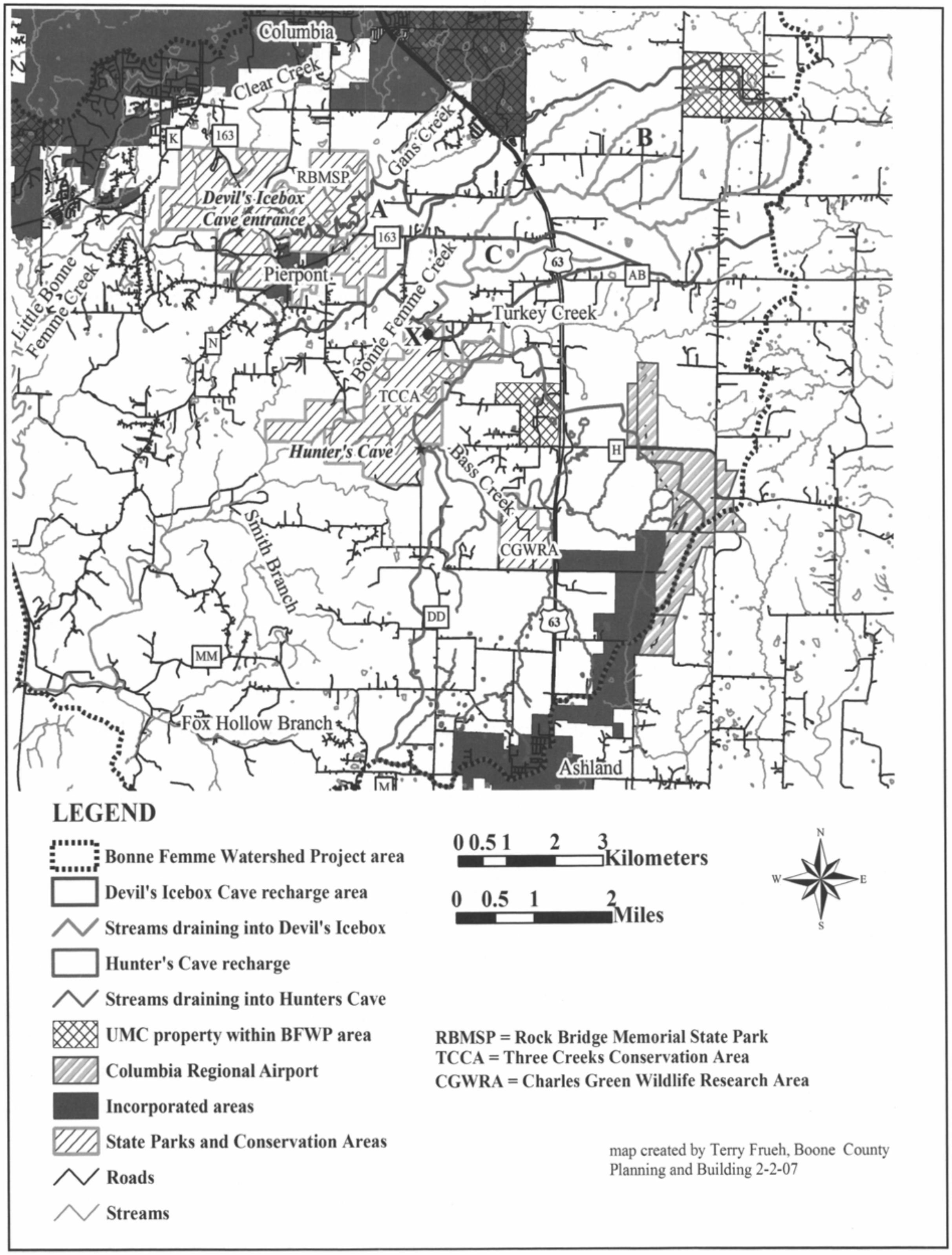

Figure 3.12 Devil's Icebox Recharge area.

3.f Subwatershed Sensitivity Analysis, a Planning Tool

The Steering Committee wanted to have an independent, scientifically-based decision-support tool created to help the Stakeholders in their planning effort. It was decided to hire a consultant with experience doing hydrologic analysis, who could use the latest technologies to create GIS data layers, and who could create an interactive model for forecasting future stream conditions.

A group of technical experts, formed by the Steering Committee, wrote a Request for Proposals (RFP) to complete a Subwatershed Sensitivity Analysis of the Bonne Femme Watershed that would serve as a decision-support tool for the Stakeholder Committee. Writing the RFP was challenging because the group had never seen an analysis completed at a similar scale and depth of study that combined hydrological modeling and a natural resource assessment. Therefore, they could not precisely state how the goals of the RFP were to be met. Thus, the RFP requested a creative approach to analyzing the streams within the watershed. Three consultants responded to the RFP, of which Applied Ecological Services (AES) was selected. Following is a brief description of the Subwatershed Sensitivity Analysis AES completed.

In this analysis, a variety of techniques were used to obtain a more comprehensive assessment of the watershed. Three different models were used to assess stream conditions.

The report lists the following conclusions from the models:

1. In the upper reaches of the watershed, the conversion of native prairie to agricultural uses without appropriate BMPs in place has resulted in increased stormwater runoff and decreased soil stability. As a result, streams in the upper reaches are downcut and eroding. Increased flows in the upper reaches also have led to stream degradation in the lowest reaches of the watershed.

2. In the lower reaches of the watershed, the conversion of floodplain bottomland forest to agricultural uses without appropriate BMPs in place has also led to increased runoff and decreased soil stability. Most of the streams in the lower reaches are entrenched, shear, unstable and disconnected from the floodplain during channel forming (one to two year storm events) storm events. These conditions become exacerbated as flows continue to increase with projected development.

3. Most of the groundwater recharge to Devils Ice Box and Hunters Cave occurs in the upper reaches of the watershed. Streams within the recharge zones occur on highly erosive loess and sandy soils, making the recharge zones highly vulnerable to erosion, streambank degradation, reduced water quality, and sedimentation impacts to sensitive cave systems.

4. Karst topography plays a major role in hydrology of the watershed. The two largest caves are mapped and their recharge areas are fairly well delineated. While the scientific community understands how karst topography affects hydrology, generally more education is needed for the lay public, especially since they have the greatest influence on how land is managed.

5. Channel instability issues appear to be migrating upstream, especially in the Northern Little Bonne Femme subwatershed. This is a common and expected phenomenon in downcutting streams as the stream seeks a flatter, more stable grade.

6. Subwatersheds most vulnerable to degradation based on the impervious cover and field indicators are clustered around Columbia and Ashland. Upper Bonne Femme and subwatersheds downstream from Upper Bonne Femme are the next most vulnerable group of subwatersheds. Most of the recharge for Devils Ice Box occurs in Upper Bonne Femme, a "moderately" vulnerable subwatershed. Most of the recharge for Hunters Cave occurs in the Bass Creek subwatershed, which is ranked as "vulnerable."

7. All subwatersheds are considered restorable, though the greatest restoration challenges will occur, in order of difficulty, in the North Branch Little Bonne Femme, Clear Creek and Bass Creek subwatersheds.

8. When assessed collectively, the three models indicate that there are regions within the watershed that should be prioritized for protection and remediation, namely the urbanizing regions around Columbia and Ashland, and the agricultural headwater region in the eastern portion of the watershed.

The Subwatershed Sensitivity Analysis report makes a series of recommendations. Their inclusion here is for informational purposes only and does not necessarily reflect the opinion of the Stakeholder Committee. Following are the main points of the Subwatershed Sensitivity Analysis report policy recommendations.

It is recommended that Boone County and the cities of Ashland, Columbia, and Pierpont (hereafter, the Watershed's local governments) take the following actions to improve stormwater and groundwater management for protection of water resources and restoration of degraded areas. At a minimum, Boone County and its municipalities could adopt the latest version of

American Public Works Association (APWA) Section 5600 stormwater design criteria and BMP Manual (APWA, 2003). These manuals were written specifically for the Kansas City metro region, and therefore would be easy to adapt to conditions in Boone County. Other recommendations build on these documents, including public education, incentive programs, and water resource protection and restoration recommendations.

1. Adopt APWA 5600 Storm Drainage Systems and Facilities stormwater design criteria.
APWA 5600 specifies application and design criteria for stormwater management, conveyance, detention, and natural stream protection. In particular, APWA 5600 includes guidance that will address problems noted in Boone County.

2. Adopt the APWA Manual of Best Management Practices for Stormwater Quality (BMP Manual).
The BMP Manual would provide the Watershed's local governments with the tools to prevent future flooding and protect water quality, including a flexible framework for developers to estimate potential water quality impacts and increased runoff from development plans. The BMP Manual would also design a comprehensive stormwater management system that includes site design and dispersed, structural and non-structural best management practices (BMPs) for residential, commercial, and industrial developments. The "Level of Service Method" can be used to maintain or reduce predevelopment runoff volumes and pollutant loads.

3. Adopt Additional Stormwater Management and Development Policies
APWA Section 5600 criteria may not be sufficient in all circumstances to stabilize stream channels and manage water quality, rates, and volumes entering streams and other water bodies.

AES recommends the Watershed's local governments adopt additional guidelines for stormwater management in all developments.

4. Public Education and Incentives
Public education and incentive programs could build support for new policies and help landowners and developers meet their obligations under the policies.

AES recommends pursuing additional education efforts and incentive programs.

5. Habitat and Biodiversity Preservation
   Finally, many of the measures described above would preserve or restore scarce habitat as well as protect streams.

AES recommends that the Watershed's local governments take additional measures that would further enhance habitat protection and biodiversity in the County.

For more detailed information about the Subwatershed Sensitivity Analysis report, please see Appendix G.

Contributor: W. Terry Frueh, Watershed Conservationist, Bonne Femme Watershed Project.

Chapter 4. Watershed Land Use Vision

4.a Land Use Vision Purpose

By coming together to work on a vision for the Bonne Femme Watershed, the Stakeholders laid out the ideal for how the watershed should look in 2030. The vision acted as a central guiding statement of where the Stakeholders want to go in their planning.

4.b Land Use Vision Methodology

The Stakeholders' "visioning" occurred at their October 10th, 2005 meeting. They split into three groups, each having its own table and flip chart. The tables were separated to ensure discussion at one table would not influence discussion at another table. A professional community development specialist, John Tharp, led the Stakeholders through the visioning process. It was stressed that it is very important for people to create an ideal situation. Since the group's effort will only rise to the level of the members' expectations, it was stressed that they should aim high in order to create an excellent plan.

Each group had thirty minutes to make a list of what lessons can be learned from the watershed's history. Next, each group spent thirty minutes discussing what is occurring in the watershed that needs immediate attention. Finally, each group spent 30 minutes listing all of the elements of their vision for how it should look in the year 2030 (see the lists below). After every thirty minute session, each group reported their list to the larger committee.

The entire committee agreed to the basic elements for the vision statement, but there was insufficient time in that meeting to finish the statement. The group concurred that a subcommittee could draft a statement. The subcommittee narrowed the elements to five basic components: quality of life, economics, water resources, a mixture of land uses, and agriculture. The subcommittee drafted a vision statement for the entire committee to work from at their next meeting. At their December 2005 meeting, the Stakeholders discussed the visioning work and agreed to the following vision statement. The vision statement passed with one member in dissent.

4.c Vision Statement for the Bonne Femme Watershed

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 4

<u>Following are the elements each group listed for their vision for the watershed</u>

<u>Group 1.</u> (George Montgomery, Glen Ehrhardt, Steve Cheavens, Amelia Cottle, Robin Crane)
In the year 2030, the Bonne Femme Watershed will be a …

- Blend of developed and undeveloped areas with special protection for certain areas (i.e. recharge areas)
- Will contain viable (profitable) agricultural operations
- More new style livable communities (residential/commercial/office)
- All of this will be done with minimal change and degradation of the watershed

<u>Group 2.</u> (Ben Londeree, Carol Van Gorp, Stephanie Smith, Carolyn Terry)

- Mixed Use (farming, urban, public land) with tolerance, respect, considerateness
- Quality of life
- Creek stability—gradual changes
- Safe level of pollutants—chemicals and bacteria (clean water)
- Minimal silt in creeks
- "no" flooding of structures

<u>Group 3.</u> (Steve Sapp, Donna Dodge, Dave Bennett, Jane Travlos)

- We won't recognize it
- Still enjoyable to live in
- Parks are similar
- Clean water
- Fire, police protection
- Wildlife control
- Good roads
- Economics
- Agriculture
- Tax base
- Jobs, retail
- BALANCE

<u>The entire Stakeholder Committee:</u>

- Clean, safe water
- Mixed land use (housing, farming, commercial, recreation)
- Viable economic base
- Creek stability (maintain water resources)

Chapter 5. From Vision to Reality

The purpose of this chapter is to describe how the Stakeholders transformed their vision into achievable goals by breaking down the various vision elements. In Chapter 4, the Stakeholders developed their vision for what the watershed should look like in the year 2030. In order to reach the vision, the Stakeholders transformed its elements into achievable goals. They completed this transformation by working through the vision elements.

The first step of the transformation involved placing the vision elements into complementary and conflicting groupings. Some elements of the vision are highly compatible and even reinforce one another, creating synergy in their implementation. These are termed *complementary vision elements.* Other elements of the vision are in direct conflict with one another in the context of the current social, economic and environmental setting. These conflicts therefore need to be resolved. These are referred to as *conflicting vision elements.* The achievable goals were created by reformulating each listing within the groupings into a policy statement.

Next, the Stakeholders completed an exercise to make the achievable goals more usable. The Stakeholders brainstormed potential obstacles to achieving the goals. These obstacles help to understand how difficult each goal will be to achieve. In addition, identifying the obstacles helps to achieve the goals by indicating what needs to be addressed when making recommendations (see Chapter 6) for reaching each goal. Finally, to clarify the connection between the goals and obstacles, the Stakeholders completed a matrix rating the strength of each obstacle for each goal.

5.a Transforming Vision Elements into Achievable Goals

Stakeholders formed two groups to outline which vision elements they thought were complementary and which were conflicting. The raw lists of the complementary and conflicting vision elements are included in Chapter 4 to help the reader understand the basis for the following narrative.

Complementary Vision Elements

Two vision elements are considered complementary if, in the process of achieving one vision element, it would be easy or helpful to achieve its complementary vision element. This narrative clarifies how the vision elements are complementary. In addition, it consolidates the two groups' lists to enhance their comprehensibility, and paves the way for stating achievable goals. These goals are included in the following narrative.

1. Undeveloped land and viable agriculture are considered complementary. Any goals that encourage agriculture would necessarily encourage undeveloped land, since agriculture needs

the undeveloped land in order to farm, and any goals that encourage undeveloped land could encourage agriculture thereby garner greater support.

Achievable Goal: Encourage undeveloped land and viable agriculture as complementary goals.

2. A strong local economy is complementary with the vision elements of jobs, retail business and tax base. Having a good supply of well-paying jobs helps to boost the local economy, since the employees will spend money within the community. In addition, having a healthy retail sector provides jobs and boosts the economy, especially since that sector brings dollars into the community (Columbia being is a regional center for commerce). Plentiful jobs, a healthy economy, and a strong retail sector all support the tax base at the local, state and federal levels.

Achievable Goal: Have policies which boost jobs, retail business, tax base, and local economics.

3. The vision element "quality of life" was listed as complementary with numerous vision elements: parks, healthy streams, *low-impact development (LID)*, and municipal services. Quality of life, or what makes people's lives enjoyable, is very subjective and community-specific. Many people in Boone County find that the parks (both city and state) in the area add enjoyment to their lives, and make this a more attractive place to live. Many people also appreciate the streams in the Bonne Femme Watershed, whether for fishing, wading, paddling, or simply for their aesthetics. LID enhances the quality of life by giving people a greater connection to the environment, by helping to protect it, and by providing greater opportunity for interactions among neighbors. People appreciate all the benefits they derive from municipal services (e.g. police and fire protection, garbage collection, etc.).

Achievable Goal: In order to maintain quality of life, encourage parks, healthy streams, LID, and municipal services.

4. Good roads, municipal services, and retail business are complementary vision elements. A well-designed road network helps people get to and from retail locations safely and efficiently. The roads also convey the delivery of municipal services, such as fire and police protection, and ambulance service. Retail business helps to sustain the tax base that supports the municipal services and good roads.

Achievable Goal: Encourage good roads, municipal services, and retail business as complementary goals.

5. *Low-impact development (LID)* and healthy streams are complementary vision elements. LID manages the quality and quantity of urban stormwater runoff so that stream health is maintained. This is accomplished by treating runoff as close to its source as possible through the use of BMPs such as rain gardens, *bioretention*, etc.

Achievable Goal: Encourage LID as a way to maintain or improve water quality.

6. Special protection for certain areas is complementary with recharge areas (areas where water flows from the surface to cave systems), parks, karst, undeveloped areas and clean water (healthy streams). The purpose of special protections for certain areas is to protect the streams, karst and recharge areas. One way of providing special protections would be to encourage undeveloped areas. Another way of providing these protections would be through acquiring park land, either for existing or new parks.

Achievable Goal: Conserve recharge areas and karst, parks, undeveloped areas, and clean water through special protections for certain areas.

7. Parks and healthy streams are complementary elements. Parks generally have less stormwater runoff than urban areas, since they tend to have lower amounts of impervious surface. In addition, aquatic pollutants such as excess pesticides and nutrients usually are not a problem originating from parks. Both of these characteristics help to maintain stream health. Healthy streams are a popular component of parks that enhance their enjoyment. They are also essential to natural parks' ecological functioning and educational value.

Achievable Goal: Enhance healthy streams via parks.

Conflicting Vision Elements

Two vision elements are considered conflicting if, using current practices and policies, they would be detrimental to each other. The following narrative adds clarification about how the vision elements are conflicting. In addition, it consolidates the two subgroups' lists to enhance their understanding and help the Stakeholders formulate achievable goals. These goals were derived from restating the conflicting vision elements so that a policy statement is created that resolves their current conflict. The following narrative includes these goals, which were developed from the list of resolved conflicting vision elements.

8. The vision elements characteristic of urbanization (roads, retail business, and conventional development) and healthy streams are conflicting. The stormwater that runs off of unmitigated urbanized areas is usually of poor quality and large in volume. Both of these characteristics degrade stream health. Polluted water kills or decreases the vitality of stream organisms. The increase in runoff erodes channels, thereby degrading habitat of aquatic organisms.

Achievable Goal: Maintain the economic viability of the community while protecting clean streams.

9. Urbanization can also conflict with preventing flooding of structures. Unmitigated urbanization increases the volume of runoff for a given storm, thereby increasing the height of floodwaters. Thus, structures that have rarely or never flooded are more likely to experience future

flooding or increased frequency of flooding. Furthermore, urbanization often increases the desire to locate structures in or near the floodplain, thereby potentially increasing the number of structures prone to flooding.

Achievable Goal: Ensure that structures are not built in places that will flood.

Achievable Goal: Ensure that changes in land use do not: increase downstream flooding, decrease water quality, or increase channel instability.

10. The cost of implementing stream-protecting *best management practices (BMPs)* and of properly treating sewage conflicts with adequate funding sources. Many new or improved BMPs might cost more than BMPs that are currently required. Likewise, many older sewer systems (both individual and community systems) do not adequately treat their effluent and therefore need to be updated or replaced. A conflict arises when there is a lack of external funds from local, state, or federal governments to pay for the BMPs and sewers. Thus, the costs are usually more directly covered by property owners.

Achievable goal: Ensure that BMPs do not unreasonably affect housing affordability.

11. Urbanization and viable agriculture are two conflicting vision elements. An area that urbanizes inherently cannot be farmed. This is because the land where the agricultural activities would have taken place is physically not available. In addition, zoning usually restricts significant agricultural activities in urban settings. Furthermore, there are often cultural conflicts between farmers and suburban residents.

Achievable goal: Regulations should be proportional to water quality impact of land use

Achievable goal: The impacts of upstream urbanization should be mitigated to prevent increased costs to agriculture and other downstream property owners.

12. Property rights and clean water conflict. People who want to have the right to use their land as they see fit can find their projects slowed down or impeded by restrictions that protect streams.

Achievable goal: Maintain clean water without unreasonably restricting property rights.

13. Urbanization and special protection for certain areas are conflicting elements. Special protections can hamper development by restricting where it can occur or adding regulations that curtail how it happens. As an area develops, there are fewer locations that can have special protections since they may already have structures in place. This is further complicated by the fact that retroactive restrictions that could protect developed, special areas are very difficult to enact.

Achievable goal: Ensure that certain areas receive special protections while maintaining the economics of urbanization.

5.b Obstacles to Achieving Goals

Stakeholders brainstormed a list of obstacles to achieving each of the goals. The process of listing the obstacles, then indicating which ones apply to which goals, has several purposes. These obstacles help to refine the process of addressing the achievable goals by indicating which ones may have too many and/or insurmountable obstacles to be worth trying to achieve. The obstacles are also useful in developing the recommendations in Chapter 6 by indicating the barriers that need to be overcome in order to reach a goal.

Obstacle Clarification

Each obstacle in the matrix represents something that can stand in the way of achieving a goal. The obstacles are clarified below so that everyone understands what they mean.

Social Acceptability: How well the greater community will accept or support a particular regulation. **Professional Acceptability** is similar but more focused, referring to those segments of the community whose livelihood could be impacted.

Affordability/cost: Many of the strategies to reach the goals could include options that have a cost associated with them, which could affect the affordability of new developments, or the cost of maintaining present development.

Lack of local technical experts: As many of the techniques for designing and evaluating stormwater BMPs that protect stream health are new, it will take time for local engineers (both private and public sector) to become well-versed in the techniques.

Resistance to change: Often, many people do not want to change their habits and customs.

Politics: Politicians in local governments may not want to change their ordinances for a variety of reasons (fiscal, pressure from special-interest groups, etc.).

Inadequate Monitoring: There has been insufficient monitoring (biological, chemical, and physical) of streams to characterize their current state. Thus, the success of any measures that are taken to protect water quality could not be properly assessed.

Zoning/existing regulations: In some instances, existing zoning or other regulations may encourage or allow development in a way that harms streams. These could be difficult to change for political, societal or economic reasons.

Lack of public understanding: For the general public to support any changes in policies or ordinances, the public must understand why these changes are necessary. If this comprehension is missing, initiating such changes would be more difficult.

Lack of enforcement: For a regulation to be effective, it needs to be properly enforced. To do this, there must be the political will to enforce it, and the necessary funding to make staff available to enforce it.

Lack of design manual: Currently, local governments have no design manual that guides design professionals on how to protect streams and other property.

Preserve property values: Regulations could decrease property values if they restrict too severely what may be done on private property.

Obstacles Matrix

The result of the Stakeholders' work with the obstacles is the matrix below. The left-hand column of the matrix contains the achievable goals the Stakeholders developed. The top row of the matrix lists obstacles to achieving the goals. Each goal has each obstacle scored, indicating the "strength" (2 = high, 1 = medium, or 0 = low) of each obstacle for each goal to which it applies. This "strength" refers to how much of an impediment the obstacle is to the achievement of the stated goal. The sum of the obstacles' strengths for each goal and each obstacle is also included. Columns A and B refer to the assessments by the two groups (A and B) of the Stakeholders as they discussed the obstacle matrix separately.

Table 5.1 Achievable Goals - Obstacles matrix.

ACHIEVABLE GOALS / OBSTACLES	Social acceptability		Professional Acceptability		Affordability/ cost		Local technical expertise		Resistance to change		Politics-multi-jurisdictional		Inadequate monitoring		Zoning/existing regulations		Lack of public understanding		Lack of enforcement		Lack of design manual		Preserve property values		Totals	
Resolved Conflicting Elements:	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Maintain economic viability of community while protecting clean streams	0	1	0	1	2	0	0	0	1	2	1	2	1	1	2	2	1	2	0	1	1	2	2	2	11	16
Ensure structures are not built in places that will flood	0	0	0	0	2	1	0	0	1	2	0	2	0	1	0	1	0	2	0	1	0	0	1	0	4	10
Ensure that changes in land use do not: increase downstream flooding, decrease water quality, and increase channel instability	0	1	1	1	2	2	1	1	1	2	2	2	1	1	2	2	2	2	1	0	2	2	2	2	17	18
Ensure that BMPs do not unreasonably affect housing affordability	0	0	0	0	2	0	1	1	1	2	0	2	1	1	1	1	2	2	1	0	2	1	2	0	13	10
Government has a responsibility to correct problems from older stormwater systems and the cost of doing this needs to be addressed	0	0	0	0	2	1	1	0	1	2	1	2	0	1	1	0	1	2	1	0	1	0	0	1	9	9
Regulations should be proportional to water quality impact of land use	0	0	1	0	2	1	1	0	1	2	1	2	1	1	2	2	2	2	1	0	2	2	2	1	16	13
Impacts of upstream urbanization should be mitigated to prevent increased costs to agriculture and other downstream property owners	0	1	0	2	2	2	0	1	1	2	2	2	1	1	2	2	1	2	1	0	2	2	2	2	14	19
Maintain clean water without unreasonably restricting property rights	0	2	0	1	2	1	1	0	1	2	1	2	1	1	2	1	1	2	1	0	2	1	2	1	14	14
Ensure that certain areas receive special protections while maintaining the economics of urbanization	2	1	2	2	2	2	1	0	2	2	2	2	1	1	2	1	2	2	1	0	1	0	2	2	20	15
Complementary Vision Elements:																										
Encourage undeveloped land and viable agriculture as complementary goals	0	1	0	1	0	1	0	0	0	2	1	2	0	1	0	1	1	2	0	0	0	0	0	0	2	11
Have policies which boost jobs, retail, tax base, and local economics	1	1	0	0	1	1	0	0	1	2	2	2	0	1	1	0	2	2	0	0	0	0	0	1	8	10
In order to maintain quality of life, encourage parks, healthy streams, LID, and municipal services	2	1	2	2	2	2	0	1	2	2	1	2	0	1	2	1	1	2	0	0	1	1	2	0	15	15
Encourage good roads, municipal services, and retail as complementary goals	0	0	0	0	2	2	0	0	1	2	2	2	0	1	1	0	1	2	0	0	0	0	0	1	7	10
Encourage LID as a way to maintain or improve water quality	2	0	1	2	1	1	1	2	2	2	1	2	1	1	2	1	2	2	0	1	2	2	1	1	16	17
Conserve recharge areas and karst, parks, undeveloped areas, and clean water through special protections for certain areas	2	1	2	2	2	2	1	1	2	2	2	2	1	1	2	2	2	2	0	0	2	1	2	1	20	17
Enhance healthy streams via parks																										
Totals	9	10	9	14	26	19	8	7	18	30	19	30	9	15	22	17	21	30	7	3	18	14	20	15		

Chapter 6. Watershed Plan Recommendations

6.a Process for Determining Recommendations

The Stakeholders took several steps in determining their recommendations for reaching each achievable goal. They began by brainstorming strategies to achieve these goals. These strategies are general ideas for approaches that could be used. They realized that strategies tended to apply to more than one goal. Next, they matched each strategy with the applicable achievable goals. Then, the Stakeholders wrote policy recommendations that clarified how the strategy could be used to achieve each goal. Finally, as a group, they reviewed each recommendation to assure that its intent was clear and well stated, and that it helped to achieve its respective goal. The Stakeholders formally approved the recommendations at their January 29th, 2007 meeting.

It should be noted that the recommendations are somewhat general. The Stakeholders decided it was important to make the overall message of each recommendation well-stated for policy makers. However, they wanted to leave flexibility for the different governing agencies regarding the specifics of implementation. The Stakeholders also thought that they did not have the technical expertise, nor time to add sufficient detail on how each recommendation should be implemented.

6.b Recommendations

Note: these recommendations are not prioritized.

Recommendations that apply to all goals:

1) It is important to have a follow-up program to assess the effectiveness of plan implementation. This follow-up program includes three aspects:

- **Enforcement/inspection** will assure that new ordinances are being followed.
- **Maintenance** of new stormwater and sewer infrastructure will be necessary for proper functioning.
- **Plan evaluation** is key to understanding whether the plan is being followed as intended, and how effective the various measures are. This may include actual stream monitoring, as well as analyzing implementation of the recommendations. Stream monitors must use generally accepted, quantifiable measures of water quality obtained at regular intervals on an ongoing schedule, and the data must be collected by certified entities/persons.

2) Equity: Measures implemented to protect water quality should not unfairly burden individuals. Every effort should be made to create incentive-based programs.

Goal	Strategies	Recommendations
Ensure that structures are not built in places that will flood	Update 100 year flood-plain maps and regulations	Political subdivisions should consider complete hydrologic modeling to determine where the 100-year floodplain would be under full build-out conditions, and locate it more accurately on floodplain maps. This modeling should be limited to developing areas to keep costs down. Allow no construction of structures for occupancy in the re-delineated 100-year floodplain.
	Zoning – Streamside buffer ordinance	Adopt a stream buffer ordinance that limits construction within its boundaries
	Design manual	Do not permit new development to increase peak flows downstream so that flooding is not exacerbated.
	Purchase structures that flood now	City or County may offer to purchase a structure, at prevailing market rate, to correct a flooding problem in an existing neighborhood, if the cost of correcting the problem exceeds the value of the structure.

Goal	Strategies	Recommendations
Conserve recharge & karst areas with special protections	Design manual/ Performance based goals	The *level of service* (following Columbia's proposed stormwater manual and ordinance) will be more restrictive (e.g. by one or two points on the level of service scale) in karst and recharge areas than in other areas. Local governments will adopt similar, compatible stormwater ordinances and design manuals.
	Zoning	Zoning ordinances will establish specific criteria for development in karst recharge areas. These should include defining levels of stormwater quantity and quality, and limiting new sanitary sewers to *no discharge systems*.
	Land purchase	Local governments may purchase land from willing sellers in karst recharge areas, but other options for protecting water quality should be explored first. Create management plans for this purchased land with a primary goal to protect water quality. (Government takings or eminent domain should not be used for acquiring land for this purpose)
	TDRs & conservation easements	Transfer of development rights (TDR) should be established county-wide, with sensitive areas (such as karst recharge areas and steep slopes) being primary sending areas. This program should enable the cities and the county to have *joint program reciprocity*. TDR and conservation easements should be economically and logistically feasible options for use by landowners and developers.
	Tax relief	Create incentives to encourage conservation in karst recharge areas.
	Zoning and Subdivision regulations; Design manual	Consider a plan to provide special protections to karst and recharge areas.
	Further scientific study and monitoring	More scientific analysis should be done to delineate further karst recharge and other environmentally sensitive areas, and more definitively identify sources of contamination.

Goal	Strategies	Recommendations
Ensure that changes in land use do not increase downstream flooding or channel instability, or decrease water quality	Design manual	The ***level of service*** (following Columbia's proposed stormwater ordinance and manual) for stormwater runoff flow characteristics post-development shall be no less than pre-development. Similarly, stormwater quality should have the same or better characteristics for post-development as it had pre-development. Local governments should adopt similar, compatible stormwater ordinances and design manuals.
	Encourage *low impact development (LID)*	Local governments should establish additional zoning and subdivision regulations that allow LID as a *matter of right* (i.e., approval will be expedited). This avoids the problems associated with the planned development process and encourages LID.
	Education	Make new stormwater manuals and ordinances widely available and familiar to the public through a public outreach and education effort.
	Develop funding mechanisms	New sources of funding should be pursued to assist landowners in implementing stream-protection *best management practices (BMPs)*. Compile a list of available sources of funding and provide to landowners and developers.
	Financing of storm water program	Secure sustainable, adequate funding for stormwater programs.

Goal	Strategies	Recommendations
Encourage low impact developments as a way to maintain or improve water quality	Education	Implement a comprehensive educational program for the general public, landowners, and developers to encourage LID.
	Design manual	Revise local governments' development regulations to promote environmentally sensitive design and maintenance.
		The level of service (following Columbia's proposed stormwater manual and ordinance) will be more restrictive (e.g. by one or two points on the level of service scale) in susceptible subwatersheds (following maps 6.0E, 7.3E and 8.2B of the Subwatershed Sensitivity Analysis) than in less susceptible subwatersheds . Local governments will adopt similar, compatible stormwater ordinances and design manuals.
	Tax relief, funding, Economic development	Create economic incentives to encourage developers to implement LID.

Chapter 6

Goal	Strategies	Recommendations
In order to maintain quality of life, encourage parks, healthy streams, LID, and municipal services.	Land purchase, Develop funding mechanisms, Economic incentives	Provide mechanisms and/or incentives to set aside land in non-LID developments for land to be set aside for parks or green space, especially in conjunction with a stream buffer. Encourage these features in other new, as well as preexisting, neighborhoods.

Goal	Strategies	Recommendations
Maintain the economic viability of the community while protecting clean streams	Education	Include information on protecting clean streams in development information distributed by the city and county (through web, forms, brochures). Develop a map that shows protected areas and include this in all literature related to development.
	Design manual	Local governments should adopt similar, compatible stormwater ordinances and design manuals that have stream protection information and requirements.
	Zoning	Address zoning where protection is necessary.

Goal	Strategies	Recommendations
Enhance healthy streams in parks	Education	Make stream protection a central part of park management. Establish park definitions to include stream protection goals. BMPs should be used on property owned by local governments.

Goal	Strategies	Recommendations
Maintain clean water without unnecessarily restricting property rights	Design manual	Give detailed design information to developers and engineers to assist them in controlling runoff quality and quantity from development.
	Zoning	Use voluntary zoning changes to direct density, and therefore higher runoff, to the most appropriate areas.
	Subdivision and zoning regulations	Revise local governments' ordinances and design manuals to enable reductions in impervious surface by allowing flexibility in street width, sidewalks, etc.
	Education	Expand public education newsletters and mail them more frequently.
	Develop funding mechanisms	Secure sustainable public funding for the operation and maintenance of BMPs, especially those initially funded by government agencies.
	TDRs and conservation Easements	Encourage landowners to use various economic incentives (e.g. conservation easements and TDR).

Goal	Strategies	Recommendations
Have policies which boost jobs, retail, tax base, and local economics	Zoning	Locate retail, by appropriate zoning, to areas that will allow the most efficient use of infrastructure and the least hazard of stream pollution.
	Economic incentives	Consider reduction in fees and other expenses paid by developers of commercial property, in preference to the creation of additional special transportation districts. For locally-owned businesses, give economic incentives to help implement LID. Use tax incentives for owners of LID-style commercial/retail structures.
	Zoning	Exempt agricultural land from restrictions and stream buffers to maintain and enhance maximum economic opportunity for farmers and related agricultural activities, as well as to keep land in agricultural use.

Goal	Strategies	Recommendations
The impacts of upstream urbanization should be mitigated to prevent increased costs to agricultural and other downstream property owners.	Performance based goals/ Design manual	1) Determine baseline conditions for the establishment of monitoring programs. These conditions should include stream water quality, amount of stormwater discharge, *stream cross-sections.* 2) Publicly monitor at specified time periods at specific locations to determine effectiveness of currently implemented plan.
	Develop funding mechanisms	Ensure that local governments provide adequate funding for their stormwater programs via a stormwater utility fee.
	TDR & conservation easements	Use land purchase, TDRs, conservation easements, etc. where applicable to encourage conservation in appropriate areas.

Goal	Strategies	Recommendations
Ensure that BMPs do not unreasonably affect housing affordability.	Education	Publicize information on cost-effective BMPs.
	Zoning	Amend zoning regulations to allow for increased density in exchange for improved stormwater quality and quantity management.

Goal	Strategies	Recommendations
Ensure that certain areas receive special protections while maintaining the economics of urbanization.	Zoning	Zoning regulations will reflect the sensitivity of the watershed/ subwatershed. This will allow for economic growth while protecting sensitive subwatersheds.
	Design manual	Revise local governments' stormwater design manuals with specific design criteria for sensitive subwatersheds.

6.c Plan Approval

The Stakeholders agreed that they play an important role when various agencies undertake the plan approval process. The Stakeholders are an important resource in order to clarify any uncertainties in relation to the plan. Their support will also be crucial to the plan's approval, since the Stakeholders represent various important perspectives from the community. They can play important roles, both in work sessions and in public hearings related to the plan.

After the plan is published, three public meetings will address the plan. These meetings, run by the Bonne Femme Watershed Project, will provide the public an opportunity to learn more about the plan. The thirty days between plan publication and the meetings will give the public time to read the plan, and prepare comments. The Stakeholders will have a follow-up meeting to respond to the public's comments. Both the public comments and the Stakeholders' responses will be published as a plan addendum.

Upon publication of the plan and its related addendum, members of the Bonne Femme Policy Committee (see Appendix D) should initiate the approval process with their respective agencies.

6.d Plan Continuity

Although county support for the Stakeholders will end with the conclusion of the Bonne Femme Watershed Project, Stakeholders may choose to function as an autonomous group. In order to keep the plan alive, Stakeholders felt that it was important that the plan's progress be evaluated over the next decade. They decided they would ask local governments for annual reports on the plan's implementation. These reports would help to hold local governments accountable for the plan's implementation. In addition, the reports will document local governmental support for the plan, aid the public in tracking the implementation of the plan, and provide for ongoing public input. Upon evaluation of the reports, the Stakeholders and the public may suggest how the plan could be more effectively implemented.

Appendix A. Clarification of Issues

The purpose of this appendix is to clarify the issues stated in Chapter 2. Since each issue statement is one or two phrases, there is potential they could be misinterpreted. Therefore, we felt it was important that more information be available for those readers who wish to know more detail or are unclear about what an issue statement means. For ease of reading, the order of issues listed here is identical to that of chapter 2.

For reference, the Policy and Steering Committees' issues were included. This inclusion helps one see how their issues relate to those of the Stakeholder Committee.

A1. Clarification of Stakeholder Issues

Property Rights

1. Property rights: people want to have the choice to do what they want to with their property.

People that own property expect that over the life of ownership of the property, laws become no more restrictive over the use of the property than they currently are. They want to have the choice of how they use it, and they expect that the choice comes along with holding title to the property; these rights are commonly referred to as property rights.

2. Property rights: what one property owner chooses to do on their property should not adversely affect another person's use of their respective property.

A closely related topic to #1 above, people do not want the enjoyment, value or use of their property to be degraded by what other people do on their property. The most notable example of this in watershed work occurs when someone along a stream is affected by what somebody did upstream; for example, if upstream urbanization causes higher peak flows and more frequent flooding, a downstream person may have property damage and/or devaluation and increased costs to repair or protect infrastructure.

3. A portion of the watershed is public land, and therefore a larger group of people have an interest in that property.

There are several large tracts of public land in the watershed. As they are essentially owned and used by a large number of people (the public), any adverse impacts to those properties affects many more people than would similar impacts on privately held property.

4. Affected parties need notice of what is going on (i.e. notice of public meetings) in order to assure good public participation.

Since governmental decisions could affect landowners, the latter have the right to know what is going on and to participate in the process of making these decisions.

5. Landowners need to defend themselves from groups that try to restrict them.

Some landowners feel they have to protect their property rights (see above, #1), and feel these rights are being threatened or infringed upon by various groups and/or governmental agencies.

6. There is a need to integrate the future use of the watershed in such a manner as to allow for reasonable development while not infringing upon property owners' rights.

Streams/Conservation

7. Devil's Icebox Cave Branch getting muddier

Someone has observed that the water flowing from the Devil's Icebox Cave Branch is getting muddy (suspended sediment) after storms. They noticed that during the previous 30 years, this had never happened before. The suspended sediment can negatively affect aquatic life by destroying its habitat and clogging their oxygen exchange mechanisms.

8. There is higher and more frequent flooding than used to occur for a given amount of rain, bringing in garbage and moving sand bars; this also causes aquatic habitat destruction and subsequent lower low flows.

Some people have noticed that for a given amount of rain, the flood peaks (volume and height of water in a creek) have increased, as well as their frequency of occurrence has increased. This flooding has brought in garbage to the persons' property, and has changed the stream bed by moving sand bars.

Higher peaks and more frequent floods can drastically alter the stream-channel: cross-section area can increase by 2 to 10 times, pool-riffle structure can collapse, stream bed can lower or raise (depending on where it is in the stream), banks can collapse, and spaces between rocks can fill in with sediment. These stream channel alterations can decrease aquatic habitat and cause infrastructure damage. Since more of the water runs off, less infiltrates the ground, thereby decreasing the low flows between flood events; this lower flow leaves less habitat for aquatic organisms.

9. Urbanization can cause water quality degradation in streams.

There is a wide range of pollutants that enter streams both during and after construction. These pollutants include fecal bacteria, excess nutrients, pesticides, oil and grease, sediment, and heavy metals. They can enter the streams in a variety of ways, including: being transported as part of stormwater runoff; sewer malfunctioning (leaks, back flows, etc.); and being poured directly into the storm drainage system.

10. Endangered species could become eliminated from within the watershed.

There are several endangered species, some of which live in the water (Pink Planaria, Topeka Shiner), and some who eat many insects whose life-cycle is intertwined with the streams (Indiana and Gray Bats). If water quality decreases, and habitat is degraded, these species could be extirpated from the watershed.

11. The Outstanding State Resource Waters (Bass, Turkey, Bonne Femme, Gans Creeks, and Devil's Icebox Cave Branch) demand special protection.

The Outstanding State Resource Waters (Bass, Turkey, Bonne Femme, Gans Creeks, and Devil's Icebox Cave Branch) demand special protection. The parts of the subwatersheds that contribute to these waters (primarily, the area east of Rock Bridge M.S.P. and Three Creeks C.A.) are almost half of the entire 93 square mile project watershed.

12. Potential exists for a toxic spill that could negatively impact a stream.

The potential exists for a spill of toxic material which could severely devastate a stream. This could occur by a truck carrying toxic material having an accident. Also the Williams pipeline (which transports gasoline) could rupture, due to an earthquake, flooding (?), sabotage, or other mechanism. There should be a clear mechanism in place to protect the streams should an accident occur.

13. Small acreage landowners need to address the issue of erosion from overgrazed horse pastures (sometimes to the extreme of being bare).

Some horse pastures are severely overgrazed, especially when the horses are confined to small areas. These overgrazed areas can expose the soil to erosion, which can end up in streams causing problems for aquatic habitat. It is also a loss of the precious soil resource from the farm.

14. Erosion in road right of ways is a serious problem that needs to be addressed on both public and private land.

Many roads have ditches on one or both sides of them to convey stormwater runoff. Many times these ditches are not stable or do not have stable outlets. Many times this causes erosion from overland flow as water leaves these road ditches. Head cuts also migrate from some of the eroded ditches into fields, pastures or lawns as these ditches are eroding because of road culverts being lowered or ditches not being stable.

15. Many BMPs have been installed on crop and pasture land in the watershed, but there is always a need for additional BMPs as needs arise.

As new practices and techniques become available, many producers will be adding additional practices to there management. Some of the older BMPs are nearing the end of their useful life and producers will be updating these practices with newer and more improved methods.

16. It is important to protect the unique biological diversity (plant and animal) in the watershed.

The watershed has one of the highest levels of biological diversity of any watershed found in Northern Missouri. Part of what makes it unique is the high number of rare and endangered plants and animals that it has. This is due, in part, to the high diversity of habitats that the watershed still has (streams, springs, caves, sinkholes, bottomland forests, bluffs, glades, upland forests, old fields, and others). There are about 50 different species of plant and animals which live in the watershed which are officially listed by the State of Missouri as rare and endangered, five of which are listed by the Federal Government as threatened or endangered. Most of these rare and endangered species depend on the watershed's streams and caves for their survival. Therefore any negative impacts to the area's streams and caves will also have a negative impact on these unique species.

17. Much of this watershed is particularly environmentally sensitive because of the high number of karst structures (sinkholes, caves, springs, and losing streams) that it has; this makes the watershed very vulnerable to increased levels of contaminants and stormwater runoff.

In addition to the Devil's Icebox Cave, there are many other caves (over 20 in the Three Creeks Conservation Area), springs, sinkholes (Pierpont Sinkhole area), and losing streams (streams that lose more than 30% of their surface water to the groundwater and caves) in the watershed. The karst systems are very vulnerable to pollution due to their interconnection with surface water.

18. It is important to have plentiful drinking water that is of good quality, therefore it needs to be protected.

Drinking water (both private and public systems) in the watershed comes primarily from groundwater sources. The groundwater is replenished by precipitation filtering through the soil. Therefore, what happens on the surface affects both the quantity and quality of water that recharges the aquifer.

Standards and Ordinances

19. It is important to have standards not based on impervious cover, but on Best Management Practices (BMPs); there is science indicating impervious cover can be mitigated.

If impervious cover is limited, it would decrease the amount of construction in the area, thereby decreasing economic opportunities for those people involved with the construction process. In addition, housing opportunities and economic activity that would occur in the buildings is decreased.

20. Impervious surfaces can degrade streams and there is no clear science indicating they can be fully mitigated; therefore, in order to protect streams, impervious cover needs to be addressed in any standards.

With an increase in unmitigated impervious surfaces, there is an associated change in hydrology and water quality (see above, #27, 28).

21. Boone County, and the Cities of Columbia and Ashland, need to develop good stormwater management plans and ordinances in order to set good standards for the future development of this watershed; the standards should be meaningful (and not arbitrary), and designed so that going into a project everyone knows what the rules are.

In order to properly protect streams, good stormwater plans need to be implemented that have good, clear standards. In some instances, standards are implemented which are arbitrary and do not really protect streams. Standards that are enacted to protect the streams need to be effective at performing the purpose for which they were originally created. When someone wants to develop their property, they would like to know what the rules and standards are before they start. This is important so that they know how much it will cost to meet these standards.

22. Water quality should be protected without putting a strict ban on development.

It is important to protect streams. It is also important to allow development to occur since our population is growing. A good balance needs to be found to allow for both of these interests.

23. Some flexibility of recommendations and standards is needed.

Rigid standards may actually impede solving the very problems they were designed to address. For example, saying that a development must have curb, gutter, and storm drains in order to decrease flooding can increase flooding downstream; if a developer is allowed the flexibility to use alternative techniques (i.e. Low-Impact Development), they could take care of both localized and downstream flooding.

24. We need to develop a watershed-based plan that makes use of the best scientific data, as well as the best watershed plans from other communities, that will provide the best chance to protect the Greater Bonne Femme Watershed.

In order to preserve the quality of water resources, thinking ahead is required (a.k.a. planning). With a formalized plan that is backed by the community, implemented and adopted by the various governmental and private groups, there is greater likelihood streams will be adequately protected.

25. Much of the stream can be protected with a buffering situation. Other portions of the stream would not likely be sufficiently protected with any amount of buffering

26. County zoning encourages development

27. Development should be given incentives to occur in areas with adequate infrastructure and discouraged in less suitable areas.

Infrastructure (roads, water, sewer, etc.) is very expensive to build and maintain, with the cost usually carried by taxpayers. Therefore, in order to serve the community most cost-effectively, development should be encouraged in areas with adequate infrastructure.

28. Development should be encouraged in less environmentally sensitive areas and discouraged in more environmentally sensitive areas.

As development occurs, it should be done in a way that protects environmentally sensitive areas. One way to do this is by having policies and measures that encourage it to happen in areas that are less environmentally sensitive. This helps relieve some of the pressure to develop in the more environmentally sensitive areas. These policies and measures should have counterparts that discourage development in more environmentally sensitive areas.

29. Erosion problems and stormwater need to be addressed in existing developed areas.

Most development that has occurred in the watershed has not adequately addressed the problems caused by stormwater. These need to be fixed in addition to preventing future developments' erosion and stormwater problems.

30. Guidelines for installing and maintaining BMPs need to be established. SWCD, NRCS, MDC, MDNR already have existing specifications for many practices.

Best management practices (BMPs) can be used to protect streams. As standards are written to use them, there needs to be clear guidelines to follow to meet the standards. Many agencies (i.e. SWCD, NRCS, MDC, MDNR, etc.) have some guidelines already in place that could be used.

Health

31. It is important never to see a sign posted warning people to stay out of a stream because of the quality of the water.

People enter streams for various recreational purposes (fishing, wading, etc.). Therefore, they do not want to be prohibited from entering the streams because of health threats.

32. Failing onsite sewage systems contaminate streams with fecal material (which is a human health hazard).

Onsite sewage systems contaminating streams with fecal material (a human health hazard), coming from poorly maintained or improperly built systems and illicit discharges. This becomes an area of concern since there are many people who like to recreate in the streams, especially in the caves, which are particularly susceptible to contamination because of their source water coming essentially unfiltered from the surface.

Science

33. Science is inexact.

The body of scientific knowledge concerning various issues related to streams is inexact and constantly being expanded upon. As such, planning needs to be flexible enough to allow for changes as the science behind decisions evolves.

34. There is a need to track sources of contaminants (i.e. microbial source tracking) in order to base long terms plans on good information and not guesses.

When making decisions about how to solve a pollution problem, it is important to know the source of the contaminant. Without this knowledge, decision makers would not have sufficient credibility if their proposals are not based on sound information. In addition, the problem might not be solved without the proper information.

35. Good mapping of sinkholes is needed.

Sinkholes are direct conduits for pollution to enter groundwater, especially that which feeds in to cave streams and springs. In order to prevent this pollution, it is necessary to have a good map indicating precisely where they are.

36. Facts and data should lead process, not biased opinion.

It is important that data and facts are driving the planning process. Otherwise, it could be biased opinion directing decision making, at which point proposed solutions might not adequately address the problems.

37. It is important not to base decisions on studies that have not had some type of review by a board of peers.

Closely related to #21, it is important that the data and/or methodology for collecting the data have had some type of peer review. The peer review process is our best mechanism to insure that information is valid and of high quality, so that the decisions are based on high quality information.

Education

38. There is a need to educate about why better practices are important to conserve resources, and about the differences between loess and karst.

People can help conserve resources by the types of choices they make. In order for them to make better-informed choices, there needs to be sufficient education as to what types of choices they can make. One example of this concerns homeowners with different landscape features, such as those dominated by karst and loess. In these instances, there are big differences in the outcomes of different types of choices they make (i.e. how they treat their wastewater)

39. Recreational use and enjoyment of public lands (Rock Bridge and Three Creeks) is at stake.

Stream degradation could cause a loss of aesthetics / psychological enjoyment, pose health hazards for those who wade in streams and wash out trails and bridges (funding for repairs is not guaranteed and is delayed by at least one year for bridges).

40. Educational opportunities concerning stream ecology could be lost affecting over 2,000 students each year who visit Rock Bridge Memorial State Park.

During these school-sponsored outings, students have the opportunity to interact with streams (wading, using nets, seeing and identifying stream animals).

41. It is important to educate people about the issues and rights of land owners within the watershed.

There are many educational opportunities concerning agriculture, industry and family. There is more than just streams and aquatic life in the watershed. Other issues are important to many residents that live there. In order to balance the stream-related educational opportunities, other education is needed to be available. These could cover topics such as private property rights, farming, business, history/genealogy and family tradition.

Agriculture

42. Maintaining agricultural productivity is important.

It is important to maintain agricultural productivity on agricultural land in order to provide food for people and maintain the source of income from the land.

43. Agriculture-related soil erosion causes problems.

Depending on the type of agricultural practice and how it is done, there can be significant amounts of soil erosion. This causes problems from degrading the soil resource upon which the farming activities are based. In addition, the sediment causes problems for aquatic life in the streams.

44. Excess agricultural chemicals and nutrients are emitted to streams, thereby polluting them.

Pesticides and nutrients are commonly used to enhance agricultural production. When used or stored improperly, they can enter into streams, causing water pollution.

45. Livestock have open access to streams, which accelerates streambank erosion and increases fecal bacterial concentrations in the streams.

Farmers often allow their livestock to get to streams. These animals can significantly increase erosion of the streambank by trampling vegetation and working the soil loose. They can also increase fecal bacterial levels in the stream, posing a human health hazard.

46. There is a need for a farmland preservation program since many people value open land and green space.

Many people value open space, green space, and farms. There should be some type of program in place to encourage or keep those properties in a similar land use.

47. Farms that use good agricultural practices are a benefit to the watershed.

Agricultural practices tend to have less impact on a watershed than urbanization. Farms that use good agricultural practices are a benefit to the watershed, and may lessen the impact of urbanization. We need to promote good agricultural practices, through education and demonstrations. We also need to encourage the survival of the small family farms in Boone County. With the continued population growth of the County, small family farms may be endangered.

A2. Clarification of Policy Committee Issues

The Policy Committee plays several key functions throughout the life of the project. They promote the Project and act as liaisons with their agencies about what is happening with the Project. Since the watershed lies in many different jurisdictions, their interagency coordination is important to ensure their efforts are synergistic and not counterproductive. They also provide input on the watershed plan and related policy and ordinances. Finally, they are key to implementing the governmental part of the plan since they are on the governing bodies that will be adopting the plan's recommendations.

The Policy Committee represents the following entities: Boone County Commission, Boone County Planning and Zoning Commission, Boone County Regional Sewer District, Boone County Water District #9, City of Ashland, City of Columbia Council, City of Columbia Planning and Zoning Commission, Consolidated Public Water Supply District #1, and University of Missouri-Columbia.

P1. What policies should the county and other governments follow for this specific watershed vs. the entire county, or should there be different rules for different watersheds?

Some people question how fair it is to treat one area differently or as more important than others, with the underlying question being "Doesn't every place have something beautiful and unique about it?" Others feel that is it okay to treat some places as being special and unique, similar to our national parks (see below, P9).

P2. It is necessary to expedite real collaborative planning and growth area management on urban fringes.

Currently, the decisions of where growth and development occur are largely in reaction to a proposal by a specific landowner or developer. They take a proposal to Columbia, Ashland, or Boone County, depending on the political and geographical situation. These local governments in turn go through their approval process. The approval or denial decisions are not always in the best interest of the community or local streams. Furthermore, these decisions are often not determined within a greater planning framework. The greater planning framework needs to be established jointly by the County and each of the Cities since they need to be working together to have a cohesive picture that works effectively.

P3. State regulations don't allow us to do what needs to be done in terms of joint planning.

As a corollary to issue #2, state statues hamper joint planning between different local governments (although they do not restrict informal collaborative work).

P4. There is a need to see what other areas have implemented planning tailored for karst areas.

Karst areas (those typified by caves, springs, sinkholes and losing streams) are unique natural features that require special measures to protect them. In order to avoid re-inventing the wheel, we should see what other areas have implemented good planning techniques designed specifically for karst.

P5. It is important to address the issues not on an entire watershed basis, but smaller area (i.e. subwatershed).

Appendix A

The entire Bonne Femme Watershed is a large area (~93 mi.^{2}). Since there is significant variation within the larger area, it is important to have smaller areas for comparison and prioritization of the resources (*editor's note: this was accomplished by studying the subwatersheds during the Subwatershed Sensitivity Analysis).*

P6. Sewage treatment will be challenged to meet the requirements of new state/federal regulations.

New state and federal regulations concerning sewage treatment come into effect at different times. Some of these regulations may add considerably to the cost of treating wastewater. New and existing sewage treatment facilities will likely have difficulty covering the added cost.

P7. It will be difficult to draw lines about which areas will require protection and which do not.

Some people believe it is unfair to have different policies and regulations for one area compared with other areas since that implies one place is more important than another.

P8. There's nothing wrong with people in Boone County saying we want to protect an area (similar to the nation's parks).

Contrasting with the previous issue, some people believe it is acceptable and even laudable to protect environmentally sensitive areas. As a nation and a state, we have decided to do this selective protection through our National Park Service, Missouri's State Parks and Conservation Areas, and other similar measures.

P9. It is necessary to figure out policies that create fairness for people that are in sensitive/less developable areas.

Policies or ordinances may be passed in sensitive areas to protect streams. These could limit the economic development potential for some parcels of land if measures are not enacted to create a fair situation for those property owners.

P10. We do not want to make it so hard to develop that people leave the county to develop.

Some people are concerned that if there are too many regulations in place, people will take their money and economic development potential out of the county.

P11. Utilities would like to know what areas are going to develop so that they can put their infrastructure in order to get a good return on the investment.

Installing infrastructure is a costly endeavor for a utility. They want to place it to maximize the return on the investment, which is accomplished when development occurs in the area serviced by the new infrastructure.

P12. Landowners should be protected from legal actions arising from the policies and practices encouraged in the plan.

Practices and policies in the plan will encourage or require landowners to follow certain guidelines. A landowner's adherence to the guidelines should not open them up to being sued when they would not have been liable had they not followed the guidelines.

P13. It is important not to infringe upon landowners' rights.

Landowners expect to have certain rights that come with owning property, namely that they get to choose to treat the property as they see fit (within the applicable federal, state, and local laws). As regulation increases, they feel that their right to do what they want to on the property has been infringed upon. Similarly, people don't want the use or value of their property diminished by what other people do on their respective property.

P14. Agriculture-related business should not be hampered to the point that they can no longer run their business profitably.

Ordinances and policies that are enacted to protect streams have the potential to increase costs for landowners. This could be difficult for some farmers since they do not have large incomes, especially if some of the costs were proportional to the size of their property.

P15. The plan should not conflict with practices and policies of other agencies (i.e. FSA, USDA, MDNR, BCSWCD, etc.).

Various governmental agencies have their respective interests and points of view. As such, they sometimes propose practices and policies that conflict with those of another agency. It would be a good idea if the policies and practices recommended in the plan did not conflict with those of another agency.

A3. Clarification of Steering Committee Issues

The Steering Committee is the group of people overseeing the entire workings of the project and its staff, including administering the grant. They help coordinate the other two committees' work and provide technical assistance to them. They have representatives from Boone County Planning and Building Inspection, Missouri Department of Natural Resources (319 program and Rock Bridge Memorial State Park), Missouri Department of Conservation, and USDA-Agricultural Research Service.

Appendix A

Note: Since the Steering Committee's issues were the same as some of the Stakeholders' issues, the numbering of this list is the same as that of the Stakeholders' list in order to make it easier to cross-reference between the two lists.

8. There is higher and more frequent flooding than used to occur for a given amount of rain, bringing in garbage and moving sand bars; this also causes aquatic habitat destruction and subsequent lower low flows.

Some people have noticed that for a given amount of rain, the flood peaks (volume and height of water in a creek) have increased, as well as their frequency of occurrence has increased. This flooding has brought in garbage to the persons' property, and has changed the stream bed by moving sand bars.

Higher peaks and more frequent floods can drastically alter the stream-channel: cross-section area can increase by 2 to 10 times, pool-riffle structure can collapse, stream bed can lower or raise (depending on where it is in the stream), banks can collapse, and spaces between rocks can fill in with sediment. These stream channel alterations can decrease aquatic habitat and cause infrastructure damage. Since more of the water runs off, less infiltrates the ground, thereby decreasing the low flows between flood events; this lower flow leaves less habitat for aquatic organisms.

9. Urbanization can cause water quality degradation in streams.

There is a wide range of pollutants that enter streams both during and after construction. These pollutants include fecal bacteria, excess nutrients, pesticides, oil and grease, sediment, and heavy metals. They can enter the streams in a variety of ways, including: being transported as part of stormwater runoff; sewer malfunctioning (leaks, back flows, etc.); and being poured directly into the storm drainage system.

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There are several endangered species, some of which live in the water (Pink Planaria, Topeka Shiner), and some who eat many insects whose life-cycle is intertwined with the streams (Indiana and Gray Bats). If water quality decreases, and habitat is degraded, these species could be extirpated from the watershed.

11. The Outstanding State Resource Waters (Bass, Turkey, Bonne Femme, Gans Creeks, and Devil's Icebox Cave Branch) demand special protection.

The Outstanding State Resource Waters (Bass, Turkey, Bonne Femme, Gans Creeks, and Devil's Icebox Cave Branch) demand special protection. The parts of the subwatersheds that contribute to these waters (primarily, the area east of Rock Bridge M.S.P. and Three Creeks C.A.) are almost half of the entire 93 square mile project watershed.

Appendix B. Glossary

Adsorb To accumulate gases, liquids, or solutes on the surface of a solid or liquid.

Amphipod Any of several *crustaceans* with one set of feet for jumping or walking and another set for swimming.

Aquifer Groundwater-bearing geologic formations that yield water in usable quantities.

Benthic Relating to or characteristic of the bottom of a sea, lake, or deep river, or the animals and plants that live there.

Best management practice (BMP) A practice used to reduce impacts from a particular land use.

Biodiversity The range of organisms living in an ecological community or system.

Biomonitoring (aquatic) The gathering of biological data in both the laboratory and the field for the purposes of making an assessment, or determining whether regulatory standards and criteria are being met in aquatic ecosystems.

Bioretention The use of a vegetated depression located on a site that is designed to collect, store and infiltrate *stormwater* runoff.

BMP *see* Best Management Practice.

Coliform Rod-shaped bacteria that are normally found in the colons of humans and animals.

Crustacean Arthropods, including shrimp, crabs, crayfish and lobsters, that usually live in the water and breathe through gills; they have a hard outer shell and jointed appendages and bodies.

Depauperate Lacking or depleted in the variety of plant or animal species.

DI Devil's Icebox Cave Branch.

Dye trace A method of determining where water flows (typically, underground) by injecting dye into flowing water and recording where it appears.

Appendix B

Echolocation A means of locating an object based on an emitted sound and the reflection back from it, used naturally by some animals (e.g. bats).

Endangered species A species that is in danger of extinction and whose survival is unlikely if the causal factors of its decline continue (U.S. Fish and Wildlife Service official designation).

Ecosystem A localized group of interdependent organisms together with the environment that they inhabit and upon which they depend.

Endemic species Species found in only one location.

Ephemeroptera One of the insect *orders*, made up of the mayflies, characterized by membranous wings, nonfunctional mouthparts, two or three abdominal appendages, and incomplete metamorphosis.

EPT Refers to three orders of insects, *Ephemeroptera, Plecoptera, Trichoptera*; often, these orders are used as a *metric* for stream health.

Eutrophication The process by which a body of water becomes rich in dissolved nutrients from fertilizers or sewage, thereby encouraging the growth and decomposition of oxygen-depleting plant life and resulting in harm to other organisms.

Flow regime The quantity, frequency and seasonal nature of water flows.

Fluvial Produced by, or found in, a river or stream.

GIS (Geographic Information Systems) A computer system designed to allow users to collect, manage and analyze large volumes of spatially referenced information and associated data.

Glacial till Unsorted geological material deposited directly by glaciers.

Globally imperiled/vulnerable Imperiled globally because of rarity or because of some factor(s) making it very vulnerable to extinction throughout its range.

GPS (Global Positioning System) A system of satellites and receiving devices used to compute positions on the Earth.

Grab sample A sample of water taken by placing a jar in a stream, used for analyzing its chemical and physical properties.

HC Hunters Cave.

Hydrology The study of water occurrence, distribution, movement and balances in ecosystems; the seasonal patterns of a river's flow.

Joint program reciprocity This occurs when two programs from different political jurisdictions have a reciprocal agreement such that they have similar ordinances across the political boundaries.

Impervious Surfaces Surfaces which do not allow water to *infiltrate* into the ground.

Infiltrate To penetrate the interstices of a tissue or substance.

Invertebrate An animal that does not have a backbone.

Isopod A small invertebrate animal with a flattened body and seven pairs of legs.

Karst An area possessing surface topography resulting from the underground solution of subsurface limestone or dolomite. Karst includes features such as *sinkholes, losing streams*, caves, and springs.

Land use plan A written, comprehensive document that includes goals and strategies for future development or preservation of land.

LID *see* Low impact development.

Limestone A sedimentary rock consisting mainly of calcium carbonate, often composed of the organic remains of sea animals such as crinoids, corals, etc. It dissolves relatively easily, allowing the formation of *karst* features such as caves, *sinkholes, losing streams*, and springs.

Loess A type of soil composed of silt and clay sized materials that were transported and deposited by wind.

Losing stream A stream whose water seeps into the groundwater; its flow decreases as one moves downstream.

Appendix B

Low impact development (LID) A development strategy designed to mimic a site's predevelopment hydrology by using techniques that infiltrate, filter, store, evaporate, and detain *stormwate*r runoff close to its source.

Macroinvertebrate An invertebrate animal large enough to be seen with the naked eye.

Matter of right A part of an ordinance automatically allowing a certain action to occur if certain, specified conditions are met.

Mesic Refers to sites characterized by intermediate moisture conditions neither decidedly wet nor decidedly dry.

Metabolite A by-product of metabolism.

Metric A system of measurement.

MDC Missouri Department of Conservation.

MDNR Missouri Department of Natural Resources.

Neotropical migrant bird Songbirds that spend the summers in the US and Canada, and winters in tropical regions to the south.

No discharge area Area requiring wastewater disposal systems that do not discharge water to surface or subsurface waters of the State.

Nonpoint source pollution (NPS) Pollution originating from runoff from diffuse areas (land surface or atmosphere) having no well-defined source.

NPS *see* Nonpoint source pollution.

NRCS Natural Resources Conservation Service (part of U.S. Department of Agriculture)

Order A *taxonomic* classification made up of related families of organisms.

Outstanding state resource waters High-quality waters that may require exceptionally stringent water quality management (official State of Missouri designation).

Partners in flight A group of public and private organizations working together to conserve bird populations in the western hemisphere.

Pathogen A living organism that can cause disease, such as a bacterium or a virus.

Periphyton biomass The mass of living organisms (plants and animals) that live in water attached to rocks and other submerged objects.

Photolysis The irreversible decomposition of a chemical compound as a result of the absorption of electromagnetic radiation, especially visible light.

Planarian A small, soft-bodied, free-living flatworm (Phylum Platyhelminthes) with bilateral symmetry and a primitive brain.

Plecoptera One of the insect *orders*, made up of the stoneflies, characterized by membranous wings, chewing mouthparts, two short abdominal appendages, and incomplete metamorphosis.

Recharge area The area that feeds water into an aquifer.

Recording stream gage Instrument that measures and records the elevation of a stream's water surface. These data are used to calculate the flow of water.

Residual Soils Soil that develops directly from weathering of the rock below.

Resdiuum *see* residual soils.

Riffle An area of rough water caused by submerged rocks or a sandbar.

Riparian Situated or taking place along or near the bank of a river or stream.

Siltation The deposition of finely divided soil and rock particles upon the bottom of stream and river beds and reservoirs.

Sinkhole A bowl-shaped depressions in the ground formed when cracked *limestone* below it collapses. Surface water flows into a sinkhole to join an underground drainage system.

Species of conservation concern Species that the Missouri Department of Conservation is concerned about due to population declines or apparent vulnerability.

Appendix B

Specific conductivity A measure of the ability of a substance (e.g. water) to conduct an electrical current. It is related to the type and concentration of ions in solution and can be used for approximating the dissolved-solids content of the water.

Stalactite An icicle-shaped formation in a cave that has gradually built up as a deposit of calcium carbonate precipitated out of groundwater that has seeped through the cave's roof.

Stalagmite A conical formation in a cave that has gradually built up as a deposit of calcium carbonate precipitated out of groundwater that has seeped through the cave's roof and dripped onto the top of the formation.

Stormwater Water that accumulates on land as a result of storms. Often, it refers to runoff from urban sources.

Substrate The mineral and/or organic material that forms the bed of the stream.

Subwatershed sensitivity analysis (SWSA) For the purpose of this plan, SWSA refers to an assessment of the subwatersheds within the Bonne Femme watershed (for more information, see Chapter 3 and Appendix G).

SWCD Soil and Water Conservation District

Taxon A group to which organisms are assigned according to the principles of *taxonomy*, including species, genus, family, order, class, and phylum.

Taxonomy The science of classifying plants, animals, and microorganisms into increasingly broader categories based on shared features.

Trichoptera One of the insect *orders*, made up of the caddisflies, characterized by hairy, moth-like wings, long hairlike antennae, nonfunctional mouthparts, and complete metamorphosis.

Troglobite An animal that lives its entire life within a cave and is specifically adapted to life in total darkness.

Troglophile An animal that can live inside or outside a cave.

USGS United States Geological Survey, part of the Interior Department.

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Appendix D. Bonne Femme Watershed Committee Membership

Policy Committee:

Consolidated Public Water Supply District #1	Gary Woody, Superintendent
Boone County Water District #9	Roger Ballew, District Manager
Boone County Regional Sewer District	Debbie Schnedler, Board Member
Ashland	Mike Asmus, Mayor
Columbia City Council	Barbara Hoppe, Ward 6 (replaced Bob Hutton, Ward 3)
City of Columbia Planning and Zoning Commission	Jerry Wade, Chair
University of Missouri-Columbia	Peter Ashbrook, Director, Environmental Health and Safety
Boone County Commission	Karen Miller, District I (Southern) Commissioner
Boone County Planning and Zoning Commission	Larry Oetting, Three Creeks Township Representative

Note: There may be interests for each person that are not listed.

Stakeholder Committee:	**Interest**
Dave Bedan	member Audubon Society, Mo. Parks Assn., recreator
Dave Bennett	engineer
Steve Cheavens	landowner, farmer lower Bonne Femme Subwatershed
Randal Clark	resident Gans Creek Subwatershed, watershed partnership, recreator
Amelia Cottle	PTSA, Voluntary Action Center, Friends of Rock Bridge, recreator
Robin Crane	landowner, farmer Gans Creek Subwatershed
Bill Crockett	engineer (resigned from committee)
Donne Dodge	farmer, educator (deceased before the end of the Stakeholder Plan)
Glen Ehrhardt	lawyer, Columbia Chamber Commerce
David Grant	landowner, farmer (resigned from committee)

Larry Henneke	educator (resigned from committee)
Ben Londeree	recreator
MaryLou Mayse	landowner, farmer (resigned from committee)
Chuck Miller	educator, farmer (resigned from committee)
Joe Miller	banker (resigned from committee)
George Montgomery	resident, recreator, engineer, farmer Little Bonne Femme Subwatershed
Annie Pope	Homebuilders Association of Columbia
Steve Sapp	landowner, farmer Devil's Icebox recharge area
Stephanie Smith	landowner, farmer Turkey Creek Subwatershed, Boone Co. Soil and Water Conservation District
Steve Sowers	banker
Don Stamper	Central Missouri Development Council (resigned from committee)
Carolyn Terry	landowner, Gans Creek Subwatershed
Jane Ann Travlos	recreator, Girl Scout Day Camp Director at Rock Bridge Memorial State Park
Carol Van Gorp	Columbia Board of REALTORS®
Rob Wolverton	Central Missouri Development Council

Steering Committee:

U. S. Deparment of Agriculture-Agricultural Research Service	Bob Lerch, Soil Scientist
Boone County	Bill Florea, Senior Planner
Boone County	Terry Frueh, Urban Watershed Conservationist
Missouri Department of Natural Resources	Georganne Bowman, Environmental Specialist (replaced John Johnson and John Knudsen, Environmental Specialists)
Rock Bridge Memorial State Park	Roxie Campbell, Naturalist
Rock Bridge Memorial State Park	Scott Schulte, Superintendent (retired)
Missouri Department of Conservation	Scott Voney, Fisheries Biologist

Appendix E. Valuation of Ecological Services

Following are the calculations for determining the values reported in chapter 1.d Economics for the value of ecological services for the watershed.

Table E.1 Ecological valuation of watershed following the methodology of Costanza *et al.* (1997).

Note that the land use/land cover data are the most current (1991).

Land Use/Land Cover	acres	value ($/acre)	total value ($)
urban impervious	520.8	0	0
urban vegetated	80.9	0	0
crops	10783.1	37.25	401637
pasture	27247.0	93.93	2559237
pasture (warm season)	7.8	93.93	732
cedar/deciduous forest/ woodland	6239.6	122.27	762894
deciduous woodland	1565.1	122.27	191357
deciduous forest	12872.7	122.27	1573913
bottomland hardwood	90.4	122.27	11050
marsh/wet herbaceous	13.1	7927.13	104073
open water	318.0	3440.49	1094073
Totals	59,738.5		6,698,965

Table E.2 Ecological valuation of the watershed following the methodology of IDC, 1993.

(from Valuing Ecosystem Services: Toward Better Environmental Decision-Making, p. 170)

	total acres	value ($)/acre	total value ($)
floodplain	3,423.9	8,177	27,996,983

Appendix F. Stakeholder Decision-Making

This appendix clarifies how the Stakeholder Committee operated during their planning process. The Stakeholders approved of these rules at their December 13, 2004 meeting.

1. **Officers:** Ben Londeree and Glen Ehrhardt were selected to co-chair the meetings. The committee decided to have co-chairs in order to maintain balance of leadership, and to ensure there would be continuity in running the meetings should one of the co-chairs be unable to attend.

2. **How meetings will be run:** A co-chair ran the meetings. Terry Frueh (Bonne Femme Watershed Project Staff) acted as secretary for the meetings. Meeting agendas were jointly drafted by Mr. Frueh and the co-chairs. Agenda items for a meeting could be suggested by anyone on the committee, either at the end of the previous meeting or two weeks prior to the meeting. The co-chairs considered these suggestions for inclusion on the agenda. Terry sent out the agenda to Stakeholders one week prior to the meeting.

3. **Decision-Making:** For policy decisions, a super-majority of three-fourths of members present at a meeting was required for passage of the vote, with a quorum required for voting defined as 10 people. These decisions had two readings at consecutive meetings, with a vote at the second meeting. Minority reports discussing the viewpoints of those who differ with a decision were allowed.

Ground Rules: The committee decided that common courtesy was sufficient.

Appendix G. Science

G.1 EPT report

Benthic Macroinvertebrate Collections and Identifications within 8 Streams of the Bonne Femme Watershed.
A Final Report to the Boone County Watershed Coordinator
April 26, 2006
Prepared by Kathy E. Doisy

Introduction

The Bonne Femme Watershed Project is a 4-year, EPA-funded initiative sponsored by Boone County, Missouri. Partners in the project include the Boone County Commission, City of Columbia, City of Ashland, Missouri Department of Conservation, Missouri Department of Natural Resources, Boone County Soil and Water Conservation District, University of Missouri, USDA-Agricultural Research Service, Chouteau Grotto, and the Friends of Rock Bridge.

The main objective of this project is to maintain long-term water quality within the Bonne Femme watershed using watershed planning as a tool to manage growth and prevent further watershed degradation. This report addresses a small portion of the project goals in relation to the monitoring of streams within the watershed with the use of biological criteria.

The 1972 Amendments to the Federal Water Pollution Control Act and the Clean Water Act of 1987 changed the concept of water quality management in the United States. Management efforts shifted from simply determining what goes into a particular water body, to a more integrated approach that addresses the needs of the aquatic community. This new goal of "ecological integrity" refers to a system that has the capability of supporting and maintaining a balanced, integrated and adaptive community that has good diversity and resiliency. In other words, it is a system that can withstand an assault and recover. This requires more than just good water quality. Research by Judy et al. (1984) and others (Karr et al., 1985) has shown that halting the chemical degradation of water doesn't assure the restoration of its ecological or biological integrity. Changes in the energy source, habitat structure or flow regime can also profoundly affect the aquatic communities (Karr et al., 1986).

This change in focus has also resulted in a change in monitoring technology. Classical water quality monitoring was done using physical and/or chemical parameters. This was problematic because these data only provide information about the conditions that exist at the time of sampling. Most current monitoring programs have added a third component known as "biological monitoring" or "*biomonitoring*." This is the systematic use of biological responses (called "*metrics*") to evaluate changes in the environment. Biological impairment of the benthic community may be indicated by the absence of generally pollution-sensitive macroinvertebrate *taxa*, dominance by any particular taxon combined with low overall taxon richness, or appreciable shifts in community composition relative to the reference condition (Plafkin et al., 1989). These data can provide an indication of the cumulative effects of conditions changing over time.

For this study, the biological data presented herein will serve as a baseline data set to help researchers assess how stream health of the Bonne Femme watershed has changed over time, and help evaluate the effectiveness of the watershed planning and cost-share program.

Site locations

The *GPS* locations of the 8 sites that are the focus of this study are reported in Table G.1. Macroinvertebrate samples were taken according to MDNR protocol starting at the lower end of the reach and moving upstream to prevent disturbance of the habitats to be sampled. Site 1 indicates the first or lower end of the reach (Table G.1). It should be noted that Rock Bridge Creek [*a.k.a. Devil's Icebox Spring Branch –editor*], was included in these collections despite the expectation that its macroinvertebrate community would not be comparable to the other sites. The flow of this site comes up to the surface just a few feet upstream of the collection site from an underground cave. Localities with this type of "karst" topography are areas where the surface and groundwater are integrally connected. Unlike groundwater that is filtered through dense soil layers, groundwater in karst systems often moves rapidly through underground channels that fail to provide the effective natural filtration and absorption that characterizes other systems. As a result, these waters often contain contaminants and pollutants not found in groundwater. For these reasons this site was included in the collections due to its value as a sentinel site of possible perturbations in that area.

Table G.1 X, Y coordinates for the upper and lower ends of the sample reaches. The X, Y numbers are in the following projection: feet with X= east, Y = north in reference to the fixed point NAD 1983 State Plane Missouri Central FIPS 2402 Feet.

Location	Site 1 X	Site 1 Y	Site 6 X	Site 6 Y
Bass Creek	1701103.43375	1092750.87158	1701853.96909	1092273.08773
Bonne Femme at 63 highway	1709216.18352	1107780.41314	1709668.54104	1108180.25056
Bonne Femme at Nashville Church	1689737.01449	1088629.47664	1690268.43553	1089049.75344
Clear Creek	1689772.42773	1108887.20800	1690132.94993	1109087.20387
Fox Hollow	1681833.83088	1077074.31629	1681832.91073	1076844.38539
Gans Creek	1690451.56558	1107722.12855	1691230.81796	1107527.09812
Rock Bridge Creek	1689788.13216	1106103.73720	--	--
Turkey Creek	1700157.08049	1092885.08328	1700149.22058	1093341.86078

Appendix G

Methods

The coarse flow habitats of 8 reaches of streams of interest within the Bonne Femme watershed were sampled according to MDNR protocol (Semi-Quantitative Macroinvertebrate Stream Bioassessment, June 20, 2003) from 28 March to 13 April, 2006. Modifications to the MDNR laboratory sorting protocol (MDNR-WQMS-209) were submitted to the MDNR project manager and approved prior to collections (see below, section G.1.a). All identifications were made to the lowest possible level. Species identifications are reported for two genera, *Perlesta* and *Rhyacophila*, which are only reported to the genus level according to MDNR protocol. This information was included since it may prove of value in future investigations. However for this report, those sites with more than one species of these genera are restricted to a count of one to compare with the detection coefficients developed by the Missouri Department of Resources Environmental Services Program.

As indicated in section G.1.a, biomonitoring for this project has been limited to surveillance of the *EPT* [*Ephemeroptera* (mayflies), *Plecoptera* (stoneflies), *Trichoptera* (caddisflies)] *taxa*, three orders of (generally) pollution-intolerant *benthic* insects. Although a multi-metric approach is used by the MDNR (Biological Criteria for Wadeable/Perennial Streams of Missouri, February 2002), the EPT richness metric has been reported in multiple studies to be a highly sensitive indicator of a variety of stream perturbations (Barbour *et al.*, 1992; Wallace *et al.*, 1996; Rabeni *et al.*, 1997). The EPT richness metric measures the species richness (number of taxa) of the aforementioned orders, providing a consistent, quantifiable biometric of stream health.

Results and Discussion

MDNR has published baseline or "reference" biocriteria for each of the ecological drainage units (EDU) within the state for either spring or fall collections (Missouri Biocriteria Wadeable/Perennial stream 25th Percentile and Bisection Values, 10 January 2006). The intended uses of these biological criteria as stated by MDNR include: the establishment of regional attainment goals within Missouri that are relevant to aquatic communities and protect the resource, establishing a scientific benchmark or baseline for monitoring the effectiveness of best management practices and restoration efforts, and to allow a baseline for evaluating the status of waterways and any changes over time. These baseline data, to which other streams may be compared, were developed by MDNR from multiple samplings of streams within each EDU. Reference conditions are represented by values that fall above the 25th percentile for the EPT richness metric. For details on the methodology see the Biological Criteria for Wadeable/Perennial Streams of Missouri, February 2002.

The current EPT richness metric reference data for warm water streams within the Ozark/Moreau/Loutre drainages sampled between 15 March and 15 April are 13 for the 25th percentile and 6 for the bisection value. Since this study is based on a single metric out of the four metrics suggested by the MDNR, these results can not be considered the final statement regarding stream conditions. In addition, it should be noted that the values presented by MDNR are based on riffle and pool habitat, in contrast to the use here of riffle habitat alone[1]. Despite this, examination of the single metric may allow for tentative conclusions about stream conditions. Streams with metric values higher than the 25th percentile may be considered fully biologically supporting, values equal to or less than the 25th percentile and greater than or equal to the bisection are partially biologically supporting, while values below the bisection indicate streams that should be considered non-biologically supporting.

Results of the sampling are reported in Table G.2. For the 7 streams (excluding Rock Bridge Creek) the EPT richness metric ranged from 6 – 11 taxa. None of the sampled sites appear to be in reference (fully biologically supporting) condition, although all of them are equal to or above the bisection value for this area. The site with the highest EPT richness was Bass Creek, while the site with the lowest was the Bonne Femme at Highway 63. All the sites, excluding Rock Bridge, had at least one species of each order. Although the exact sampling locations are unknown, a previous study (early May 2001) of coarse flow habitat of some of these streams by the Community Storm Water Project found higher EPT richness values for Turkey (13) and Gans (11) creeks. There was no difference in EPT richness for Bass Creek, while the 2001 collections in Clear Creek found one less species.

Although abundance data were not part of this study, it should be noted that both Clear Creek and Gans Creek had exceptionally low numbers of specimens as compared to the other sites despite comparable collecting methods. Reductions in abundance may indicate chronic impact(s).

Another aspect of these data is the sensitivity of the collected taxa. Certain species from these collections are considered more sensitive to pollutants than others. These taxa include all the stoneflies, and the caddisflies *Chimarra*, *Polycentropus*, and *Rhyacophila*. In this regard, Turkey Creek scores the highest or best with 7 of these more sensitive taxa, followed by Bass Creek and Bonne Femme (at Nashville Church) with 6, and Fox Hollow with 5.

The collections from Rock Bridge Creek had only one relatively tolerant caddisfly, *Cheumatopsyche*. Since there are no previously reported collections from this location no assessment of conditions can be made at this time.

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1. Inclusion of EPT taxa from pool habitat may increase the total EPT richness by 1-2 taxa.

Appendix G

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G.1.a

Modifications to the Missouri Department of Natural Resources Semi-Quantitative Macroinvertebrate Stream Bioassessment (SOP#8) of the QUALITY ASSURANCE PROJECT PLAN FOR WATER QUALITY MONITORING IN BONNE FEMME WATERSHED

Prepared by Kathy E. Doisy for the Boone County Watershed Conservationist, Terry Frueh.

The following change will be made to the MDNR Semi-Quantitative Macroinvertebrate Stream Bioassessment (June 20, 2003) under section 3.0 Laboratory Processing of Samples:

The protocol for this project has been limited to riffle samples of 8 streams within the Bonne Femme watershed. In addition, metric calculations will be limited to EPT richness. Due to monetary constraints and the lack of interest in metrics related to abundance, field collected samples will not be sub-sampled as indicated in the MDNR protocol. Instead the complete sample will be returned to the laboratory, drained of the preservative (75% ethyl alcohol), rinsed in distilled water, and placed in a white enamel pan where the macroinvertebrates will be separated from debris and sediment using a sugar floatation procedure described by

Table G.2. Presence/absence of EPT taxa at the eight sites, spring 2006 collections.
Presence is indicated by a "1". An asterisk also indicates presence but these were not included in the taxa count since MDNR does not identify to the species level for the indicated genera.

		Bass	Bonne Femme	Bonne Femme	Clear	Fox	Gans	Rock Bridge	Turkey
		Creek	at 63 Highway	at Nashville Church	Creek	Hollow	Creek	Creek	Creek
	TAXA IDENTIFIED	3/29/06	4/4/05	4/5/06	4/3/06	4/5/06	3/28/06	4/13/05	3/29/06
	Number of mayfly taxa	3	2	3	4	3	4	0	3
	Number of plecoptera taxa	3	2	4	1	3	1	0	4
	Number of trichoptera taxa	5	2	3	4	3	3	1	3
	EPT richness	11	6	10	9	9	8	1	10
codes									
from	Ephemeroptera								
MDNR	Baetidae								
1040	Acerpenna				1		1		
	Heptageniidae								
1240	Stenacron interpunc-tatum	1		1	1	1	1		1
1263	Stenonema femoratum	1	1	1	1	1	1		1
	Caenidae								
1444	Caenis latipennis	1	1	1	1	1	1		1
	Plecoptera								
	Nemouridae								
3200	Amphinemura			1		1			1
	Perlidae								
3590	Perlesta cintipes			*					
3590	Perlesta fusca	1	1	1	1	1	1		1
3621	Perlinella drymo								1
	Perlodidae								
3690	Isoperla mohri	1		1		1			1
3438	Chloroperlidae		1						
3460	Haploperla brevis	1		1					
	Trichoptera								
	Hydropsychidae								
5130	Cheumatopsyche	1	1	1	1	1	1	1	
5160	Hydropsyche	1							
	Polycentropidae								
5090	Polycentropus	1			1	1	1		1
	Philopotamidae								
5030	Chimarra	1		1	1				1
	Rhyacophilidae								
5240	Rhyacophila fenestra	1	1	1	1	1	1		1
5240	Rhyacophila lobifera	*	*				*		*

Anderson (1959). Each sample will be repeatedly hydrated with distilled water and re-floated until no new specimens of Ephemeroptera, Plecoptera, or Trichoptera are recovered during a 5-min inspection under an illuminated magnifying ring. This method ought to closely replicate the large and rare search method used by MDNR allowing the comparison of these EPT richness results with those all ready in place by MDNR.

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G.2 Devil's Icebox Cave Branch Biomonitoring

Biomonitoring is the process of measuring the presence and numbers of living organisms in an environment. This approach, applied to stream life, speaks volumes about the health of the stream. These living organisms function as indicator species, like the proverbial canary in the coal mine. For surface streams, measuring bottom dwelling or "benthic" organisms like the EPT invertebrates described above serves well, since these macroinvertebrates are known to be sensitive to water pollution. It is still very important to test the water itself to monitor its quality. However, biomonitoring does something that water quality monitoring cannot do. The effect of factors not tested for and the combined effect of multiple factors can be demonstrated by the indicator species that must live under these conditions. Biomonitoring also reflects conditions over time, whereas water samples are taken at one point in time. This section explores why EPT monitoring is problematic for springs and cave streams and describes the biomonitoring program being used for Devil's Icebox Cave Branch.

In a report titled "Benthic Macroinvertebrate Collections and Identifications within Eight Streams of the Bonne Femme Watershed", Doisy (2006) points out that Rock Bridge Creek (the water of Devil's Icebox Cave Branch 100 ft. downstream from where it exits the cave) was sampled not for the purpose of comparing its EPT richness score to that of surface streams, but for the purpose of comparing its current data with future data. Doisy and Rabeni (2005) report that "Spring communities typically are represented by fewer species and have less diversity than downstream areas as a result of an environment with relatively constant temperature regimes, mineralization (high dissolved solids), low dissolved oxygen, absence of plankton as a food source, and *depauperate* (impoverished) habitats." Therefore it was expected that the EPT sampling of Rock Bridge Creek would have a low EPT richness score. One of the listed factors (low dissolved oxygen) was not however present in this case. Unlike many springs, Devil's Icebox Cave Stream Branch flows in contact with air in about 3.5 miles of passageways, making its dissolved oxygen levels of 9 to 12 milligrams per liter (Lerch, 2005), comparable to those of surface streams.

One would suppose that we could compare one Missouri spring to another. Rock Bridge Creek's EPT richness score was lower than that of the eight springs monitored for the Ozark National Scenic Riverways. However, Doisy and Rabeni (2005) found that EPT richness scores for those eight springs had an unexpectedly wide range, from 4 to 15. When investigating the possible causes of the variability, they evaluated water depth and velocity, electrical conductivity (affected by dissolved mineral content), acidity or pH, minimum and maximum volume of water discharge, size of the rock substrate and percentage of plant cover within the spring brook. The discharge volume or size of the spring appeared to be the prevailing influence on the invertebrate community. The report concludes, "These data indicate that the spring communities are too different to use one set of biomonitoring standards for all." The authors recommend that a customized biomonitoring protocol be developed for each spring (Doisy and Rabeni, 2005).

A customized *EPT* protocol may have been a viable option for Rock Bridge Creek had its EPT richness been greater. But given that only one relatively pollution-tolerant EPT species was found, that species' future presence or absence would not tell us much about the health of the cave stream.

Many springs flow from water-filled passages, making monitoring outside of the spring the only feasible option. Devil's Icebox Spring differs from the usual model however, since we have the option to enter and conduct biomonitoring inside the cave. This provides us with the opportunity to monitor cave invertebrates directly. We know little about the sensitivity of cave invertebrates other than the EPT insects to water quality, so that monitoring those other organisms may not be so indicative of stream health as monitoring EPT insects. However, since one cave invertebrate, the pink planarian, is a "species of conservation concern", a reduction in its numbers would be cause for alarm. The pink planarian is aquatic, making it likely that a reduction in its population is due to changes in water quality or quantity. Therefore, one important biological indicator species for Devil's Icebox Cave Branch is the pink planarian. It is listed as a *species of conservation concern* by the State of Missouri, considered not only locally but globally imperiled because it is endemic to Devil's Icebox Cave Branch, not known to live anywhere else.

A customized biomonitoring plan for Devil's Icebox Cave Branch should therefore include monitoring the numbers of pink planarians as well as the organisms that associate with them. Documented cases (EPA, 1981, Lewis 1987, 1989, Poulson, 1996, Quinlan, 1977) indicate that an increase in invertebrates that can live either on the land or in caves (*troglophiles*) is associated with a decline or elimination of cave-restricted species (*troglobites*) due to competition within the habitat. Therefore, an increase in the numbers of invertebrates that are troglophile species is a danger signal for troglobites. Both types of organisms are monitored in the Devil's Icebox Cave. This ongoing project at Rock Bridge Memorial Park is known as the Pink Planarian Project, or P3. Michael Sutton of the Cave Research Foundation developed the protocol for the P3 Project during a study he conducted in 2002-2004.

While observation records have been kept for many years, the P3 scientific protocol has been followed for only two years. Because it is not possible to search the entire cave stream to determine a total population number for the pink planarian, three survey "plots" of preferred habitat were selected to follow population trends.

Numbers of pink planarians observed have varied with the season of the year. Fall numbers have averaged 27, while spring numbers have averaged 12. To date, no pink planarians have been found in tributary streams. Sutton stated, "The apparent absence of planarians from the tributary streams is of serious conservation concern, since if the main stream population suffers a catastrophe, there may not be sub-populations available to repopulate the habitat (2004)."

Below is a snapshot of the P3, showing the organisms found during the September 13, 2002 survey of a survey plot named The Shark (for a flowstone):

Table G.3 P3 results of Pink Planarian monitoring.

Date	# in 3 survey plots
9-10-04	21
4-30-05	13
9-11-05	35
5-7-06	11
9-28-06	24

Table G.4 Devil's Icebox Cave biological sampling.
Cave animals found at "The Shark" survey plot on September 13, 2002 inside Devil's Icebox Cave.

Scientific Name	Common Name	Type	Number
Macrocotyla glandulosa	Pink planarian	Troglobite	10
Caecidotea brevicauda	Isopod	Troglophile	409
Crangonyx forbesi	Amphipod	Troglophile	43
Bactrurus brachycaudus	Amphipod	Troglobite	2
Physa sp.	Snail	Troglophile	38
Effort			96 min.

In summary, the Pink Planarian Project (P3) begun in 2002 provides a sound, customized biomonitoring protocol for Devil's Icebox Cave Branch. Twice a year, survey plots inside the cave are monitored for the pink planarian and other invertebrates that share this dark aquatic ecosystem. P3 provides data on a species of conservation concern, and at the same time provides some indication of water quality.

G.3 Water Quality Monitoring, 2001-2006

Water quality monitoring in the Bonne Femme watershed has been ongoing since 1999, when studies were initiated at Hunters and Devil's Icebox Spring Branches (Lerch *et al.*, 2001; Lerch *et al.*, 2005). In 2001, the monitoring was expanded to include six surface sub-watersheds in addition to the two caves, and with the initiation of the Bonne Femme 319 project in 2003, an additional two surface sites were added bringing the total number of monitoring sites to ten (Figure G.1). The current monitoring program includes eight surface sub-watersheds (Clear Creek., Gans Creek., Upper Bonne Femme (at US 63), Turkey Creek., Bass Creek., Lower Bonne Femme (at Nashville Church Rd.), Little Bonne Femme Creek., and Fox Hollow) and the two karst recharge areas (Devil's Icebox and Hunters spring branches). This monitoring scheme covers about 80% of the entire watershed. Samples were collected once per quarter, since 4th quarter 2003, for nutrients, turbidity, pH, dissolved oxygen, *specific conductivity*, and temperature at all sites. Sampling for fecal bacteria was conducted for 4 weeks each quarter, with samples collected at weekly intervals. Bacterial analyses included fecal coliforms (FC), generic E. Coli (EC), and qualitative analyses for specific *pathogenic* bacteria – E. Coli O157:H7, Salmonella, and Shigella. FC analyses have been conducted at eight of ten sites since 2001; EC analyses have been conducted since 4th quarter 2004; and pathogen specific analyses have been conducted since 4th quarter 2005. If there was no stream flow, samples were not collected from stagnant pools. All laboratory methods and the sampling scheme were detailed in the Quality Assurance Project Plan (Lerch, 2004).

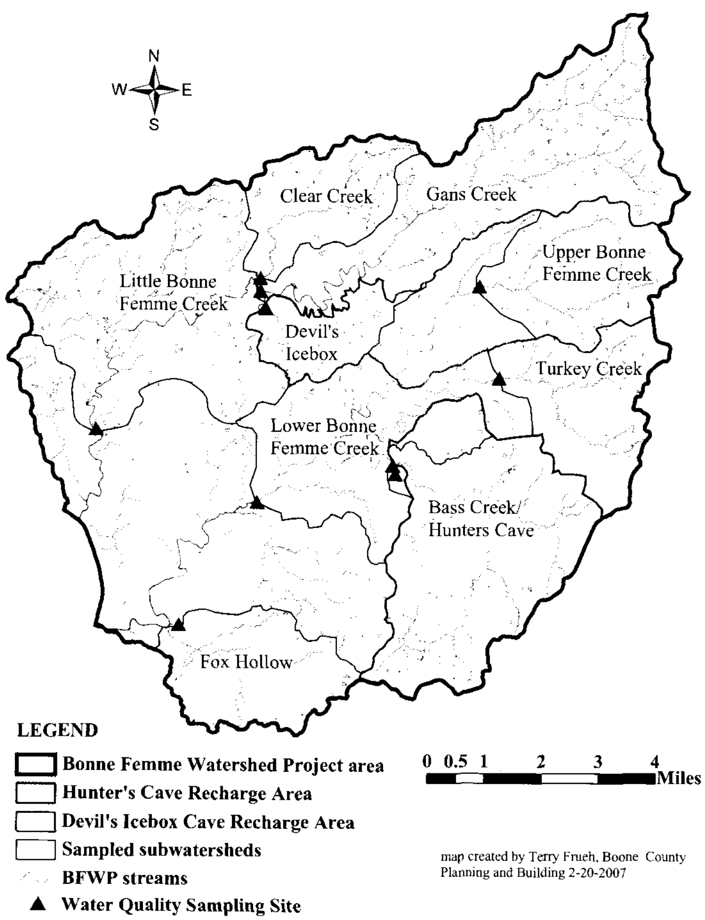

Figure G.1 Bonne Femme watershed monitoring sites.

Appendix G

General Stream Water Properties

The general water quality properties included temperature, *specific conductivity* (how many ions are in solution), dissolved oxygen, pH, and turbidity. These parameters were measured once each quarter and coincided with the collection of samples for nutrients, herbicides (2nd quarter only), and one of the weekly *pathogen* samples within a quarter. The dissolved oxygen data are expressed as absolute concentration (mg/L) and relative concentration (% saturation). Percent saturation is the measured dissolved oxygen as a percentage of the oxygen solubility in water for a given water temperature.

The general parameters were typically not statistically different over sites when the data were averaged over all ten quarters (Table G.5). Only pH was statistically different, with the Upper Bonne Femme Creek site having significantly lower pH than all but two sites. The Upper Bonne Femme Creek sub-watershed has the highest intensity of row crops (67% of the sub-watershed), and the lower pH may reflect the impact of NH_4-based fertilizer usage. Overall, the slightly alkaline pH and moderately high *specific conductivity* reflected the influence of the limestone bedrock on the water chemistry. Limestone bedrock will create slightly alkaline conditions as the limestone is dissolved by the groundwater which recharges the streams. The soluble nature of limestone, compared to most other bedrock, results in fairly high dissolved

Table G.5 General stream water properties by site.

Site	Temperature	pH	Specific Conductance	Dissolved Oxygen	Dissolved Oxygen	Turbidity
	°C*		µS/cm	mg/L	% Saturation	NTU***
Clear Creek.	13.1	7.88	525	11.84	111.2	3.6
Gans Creek.	11.7	7.76	397	11.57	105.2	17.5
Devils Icebox	11.6	7.53	424	11.05	101.7	22.9
Upper Bonne Femme	13.6	7.22	478	9.79	95.7	28.3
Turkey Creek.	13.8	7.49	586	12.04	117.1	22.7
Hunters Cave	11.5	7.73	409	11.37	103.7	11.9
Bass Creek.	13.7	7.80	455	14.39	140.3	12.6
Lower Bonne Femme	12.8	7.47	408	11.39	108.6	12.1
Little Bonne Femme	12.6	7.63	446	11.06	99.4	19.4
Fox Hollow	14.6	7.60	520	10.92	107.0	3.3
Average across sites	12.9	7.61	465	11.54	109.0	15.4
LSD**	NS	0.28	NS	NS	NS	NS

* °C= Celsius. Fahrenheit = (9/5 °C) + 32

**LSD = least significant difference. This value is the minimum difference between sites to be considered statistically different. NS = not significantly different across sites. Data are averaged over 10 quarters (3rd quarter 2004 – 4th quarter 2006).

***NTU = Nephelometric Turbidity Units.

ion levels in the water, and this is reflected in the specific conductivity data. In addition, Upper Bonne Femme Creek and Turkey Creek occasionally had very high specific conductance (>700 μS/cm) due to the use of salt on US 63 in the winter months. Eight of ten sites had average dissolved oxygen levels that were at or near 100% saturation. The lowest observed dissolved oxygen levels occurred in the third quarter of each year when the stream water temperature was highest. The lowest dissolved oxygen level observed was 5.11 mg/L (62.6% saturation); therefore, no site was under the state standard level of 5.0 mg/L. The much >100% saturation levels observed at Turkey and Bass Creeks reflected the persistent nuisance algal growth conditions at these sites. Turbidity measures the clarity of the water, and thus, both suspended sediment and algae can contribute to lower clarity and higher turbidity. Highest turbidity was observed under runoff conditions when the suspended sediment content of the water is high. Turbidity levels were occasionally elevated under low flow conditions, suggesting that algal growth was negatively impacting water clarity, especially in the 2nd and 3rd quarters of the year.

Dissolved oxygen and turbidity levels showed that eutrophication was not a problem in these streams, but nuisance algal growth was a common condition (see additional discussion in the Nutrient section). Eutrophication is a condition marked by excessive algal growth which occurs because of high nitrogen and phosphorus concentrations in the streams. The algal bloom phase begins as water temperature rises in the spring, and dissolved oxygen levels may greatly exceed 100% saturation because algae are photosynthetic organisms and photosynthesis generates oxygen. The algal bloom phase is then followed by death and decay of the algae during the late summer to early fall, resulting in very low dissolved oxygen levels that are harmful to fish and other aquatic life. Although the 3rd quarter dissolved oxygen data were the lowest of any quarter, this was mainly an effect of water temperature rather than algal decay.

Nutrients

Five separate nutrient analyses were conducted: total Nitrogen (TN); total Phosphorous (TP); dissolved nitrate-N (NO_3-N); dissolved ammonium-N (NH_4-N); and dissolved orthophosphate-P (PO_4-P). Average nutrient concentrations by site are summarized in Table G.6. Statistical analyses (analysis of variance) were conducted to determine if significant differences in average concentration existed between sites.

In general, nutrient concentrations in the Bonne Femme sub-watersheds were similar to or lower than other agricultural watersheds in northern Missouri (Blanchard and Lerch, 2000; Goolsby *et al.*, 1999). This is partially due to the lower row crop intensity of the Bonne Femme watershed compared to most northern Missouri watersheds. In addition, soils in the most intensively cropped sub-watersheds (Upper Bonne Femme Creek, Turkey Creek, Bass Creek, and Gans Creek) are predominantly claypan soils of the Mexico-Leonard Association, and these soils, although runoff prone, tend to have lower nutrient concentrations than the more well-drained soils of north-central and especially northwestern Missouri. Perhaps a better way to put these data into perspective, however, is to compare nutrient concentrations of the Bonne

Femme sub-watersheds to the recommended nutrient criteria established by the U.S. Environmental Protection Agency (EPA) (USEPA, 2000). EPA established these nutrient criteria to maintain aquatic invertebrate diversity and to prevent nuisance algal growth and *eutrophication* (excessive algal growth leading to low dissolved oxygen conditions). Based on the nitrogen criteria, all sub-watersheds suffer some degree of impairment, and this is consistent with field observations and the *EPT* (stream bug) data. The criteria for TP and PO_4-P would suggest that some streams are eutrophic, but this has not been observed as indicated above by the dissolved oxygen data. Instead, nuisance algal growth conditions and some loss of invertebrate diversity appear to be the predominant conditions throughout the watershed.

Significant differences were observed only for TN and NO_3-N across sites. For both TN and NO_3-N, the Devil's Icebox Spring Branch had the highest concentrations while Clear Creek had the lowest concentrations. TN concentrations in the Devil's Icebox Spring Branch were significantly higher than all sites except Bass Creek, and they were, on average, more than twice the concentration of six of the sites. For NO_3-N, the Devil's Icebox Spring Branch had significantly greater concentrations than six of the other nine sites. Averaged across sites,

Table G.6 Average nutrient concentrations by site*.

Site	Total N	NO_3-N	NH_4-N	Total P	PO_4-P
	----------	----------	mg/L	----------	----------
Clear Creek.	0.33	0.14	0.028	0.068	0.053
Gans Creek.	0.68	0.23	0.046	0.163	0.059
Devils Icebox	2.11	1.71	0.032	0.159	0.102
Upper Bonne Femme Creek.	1.26	1.03	0.079	0.205	0.094
Turkey Creek.	1.24	0.97	0.048	0.155	0.076
Hunters Cave	0.65	0.24	0.019	0.102	0.039
Bass Creek.	1.48	1.09	0.033	0.092	0.055
Lower Bonne Femme Creek.	0.61	0.45	0.039	0.104	0.049
Little Bonne Femme Creek.	0.87	0.46	0.049	0.091	0.034
Fox Hollow	0.58	0.27	0.044	0.087	0.049
Average across sites	0.98	0.66	0.042	0.123	0.061
LSD**	0.72	0.75	NS	NS	NS
EPA Nutrient Criteria***	0.28-1.50	0.03-1.0^		0.01-0.09	0.003-0.06

*Average of all samples from 4th quarter 2003 to 3rd quarter 2006 (no. of samples = 11-13).
**LSD = least significant difference. This value is the minimum difference between sites to be considered statistically different. NS = not significantly different across sites.
***Lower end of the concentration range may cause decreased invertebrate diversity and nuisance algal growth while higher concentrations cause eutrophication.
^Combination of NO_3-N and NH_4-N.

NO_3-N accounted for about 67% of the TN, but those sites with the highest NO_3-N concentrations had >70% of their TN as NO_3-N, suggesting that nitrogen sources such as fertilizers, on-site sewers, and animal manures were impacting these sites. Comparisons of water quality between the two cave streams and their primary losing streams showed opposite trends for TN and NO_3-N. For the Devil's Icebox Spring Branch, the concentrations of TN and NO_3-N were much higher than its primary source of water, which is the Upper Bonne Femme Creek. The Pierpont sinkhole plain is the only land area that lies between the Upper Bonne Femme Creek and the resurgence of the Devil's Icebox spring, leading to the conclusion that the increased TN and NO_3-N were derived from the sinkhole plain. Land uses within the sinkhole plain are mainly pasture land and some residential development. Since pastures generally receive little or no fertilizer inputs, the likely sources of nitrogen were cattle and on-site sewers. The primary source of water for Hunters Cave is Bass Creek. Here the comparison between the cave stream and its water source showed the TN and NO_3-N concentrations were significantly lower in the cave stream compared to its surface water source. Apparently, the other sources of water to Hunters Cave (two tributaries of Turkey Creek) had lower TN and NO_3-N concentrations which diluted the more contaminated Bass Creek water.

Although TP and PO_4-P concentrations were not significantly different across sites, there was a considerable range in the data. TP concentrations varied from a low of 0.068 mg/L at Clear Creek to a high of 0.205 mg/L at Upper Bonne Femme Creek. PO_4-P concentrations varied from a low of 0.034 mg/L at Little Bonne Femme Creek to a high of 0.102 mg/L at the Devil's Icebox Spring Branch. Three of the fours sites with the highest TN concentrations also had the some of the highest TP concentrations, but there was generally not a good correlation between TN and TP concentrations or between NO_3-N and PO_4-P concentrations. For instance, Gans Creek had low TN concentrations, but it had the second highest TP concentration. Bass Creek had the second highest NO_3-N concentration, but it was in the lower half of the sites for its PO_4-P concentration.

Herbicides

One or more herbicides were detected at every site for the four sets of samples collected in the 2nd quarter of the year (Table G.7). There were no statistical differences in average herbicide levels across sites for any of the herbicides measured, indicating widespread transport of these chemicals from agricultural production, but it also reflected the generally low levels of the herbicides detected. Herbicide levels in row crop watersheds typically peak during the 2nd quarter of the year since this is when most of the herbicides are applied in the Midwest (Blanchard and Lerch, 2000; Lerch and Blanchard, 2003). However, average concentrations by site were lower than concentrations measured in streams of northern Missouri and southern Iowa (Lerch and Blanchard, 2003). Overall, atrazine and its *metabolites* were detected at higher levels compared to the acetanilide herbicides (i.e., metolachlor, alachlor, and acetochlor), reflecting the common usage of atrazine and its high propensity to be transported by surface runoff. Concentrations of atrazine, DEA, DIA, metolachlor, and acetochlor generally were related to the amount of row crops in each sub-watershed. For example Upper Bonne Femme and Turkey Creeks have the highest proportion of land area in row crops among the ten sites, and they also had the overall highest herbicide levels. Metribuzin and alachlor usage were apparently very low as these two herbicides were generally not detected. Low usage of these compounds also reflects state wide trends. It should be noted that the sampling scheme used in this study was too infrequent to adequately characterize herbicide concentrations. Peak herbicide concentrations were most likely much higher than those reflected in this report. However, previous research at Hunters Cave and Devil's Icebox Spring Branch showed that herbicide transport was not the primary water quality problem in the Bonne Femme watershed (Lerch *et al.,* 2001).

Table G.7 Average herbicide concentrations by site*.

Site	Atrazine	DEA**	DIA**	Metribuzin	Metolachlor	Acetochlor	Alachlor
	μg/L***						
Clear Creek.	0.050	0.032	<0.010	0.011	0.004	<0.006	<0.005
Gans Creek.	0.770	0.314	0.129	<0.010	0.033	0.107	<0.005
Devils Icebox Spring	1.81	1.23	0.551	<0.010	0.177	0.225	<0.005
Upper Bonne Femme	4.23	1.94	0.824	<0.010	0.476	0.360	<0.005
Turkey Creek.	2.07	1.38	0.663	<0.010	0.221	0.468	<0.005
Hunters Cave	0.536	0.242	0.054	0.010	0.003	<0.006	<0.005
Bass Creek.	1.92	0.591	0.203	<0.010	0.004	0.094	0.183
Lower Bonne Femme	1.53	0.732	0.313	<0.010	0.082	0.250	0.121
Little Bonne Femme	1.60	0.641	0.304	<0.010	0.133	0.135	0.005
Fox Hollow	0.359	0.127	0.043	<0.010	0.051	0.076	<0.005
Average across sites	1.49	0.723	0.308	<0.010	0.118	0.172	0.031

*Average of samples collected in the 2nd quarter of 2004, 2005, and 2006 (no. of samples = 3 or 4).
**Atrazine metabolites. DEA = deethylatrazine; DIA = deisopropylatrazine.
***μg/L = parts per billion.

Fecal Bacteria

Two indicator groups of water-borne *pathogens* were monitored in the streams, fecal *coliform* and *E. Coli.* Both groups are considered indicator organisms associated with improper waste management. Fecal coliforms represent a broad array of bacterial species present in mammal feces while *E. Coli* is a single bacterial species that is also present in mammal feces. *E. Coli* is also a subset of the fecal coliforms, thus *E. Coli* levels for a given sample will be less than the fecal coliform concentrations. These indicator bacteria generally do not survive long in soils or water; thus, there consistent detection in water over time indicates one or more sources of continual input. Neither of these groups represents direct measurement of disease-causing (i.e., pathogenic) organisms, but pathogens are likely to be present when the levels of these indicator bacteria in water are high. The reason for monitoring both indicator groups was related to the differences in State and Federal water quality standards. In Missouri, the water quality standard for swimming or other whole body contact is 200 colony forming units (cfu)/100 mL of water based on fecal *coliform* concentrations while the Federal standard is 126 cfu/100 mL based on *E. Coli* concentrations. Note that the whole body contact standards are distinctly different from the maximum contaminant levels allowed in finished drinking water. The U.S. EPA maximum contaminant level for drinking water for either fecal coliform or *E. Coli* is zero cfu/100 mL, which is routinely achieved with disinfection techniques used by drinking water treatment plants.

Over the course of this study, fecal coliform and *E. Coli* data ranged from <10 cfu/100 mL to >5000 cfu/100 mL at all sites. Because of the wide range in the data, statistical analyses were performed on the $\log_{10}$ transformed data. The log-transformed data varies over a narrower range than the raw data and this allows for better discrimination in the statistical analyses. Average log transformed fecal coliform and *E. Coli* data by site are given in Table G.8. Fecal coliform data ranged from 1.72 $\log_{10}$(cfu/100 mL) at Clear Creek to 2.49 $\log_{10}$(cfu/100 mL) at Fox Hollow. The two sites with the highest fecal coliform concentrations, Turkey Creek and Fox Hollow, had statistically greater concentrations than the five sites with the lowest concen-

Table G.8 Average fecal coliform and *E. Coli* concentrations by site.

Site	Fecal Coliform	*E. Coli*
	--------$\log_{10}$(cfu/100 mL)*-----------	
Clear Creek.	1.72	1.54
Gans Creek.	2.07	1.91
Devils Icebox Spring Br.	2.30	2.06
Upper Bonne Femme Creek.	2.17	1.95
Turkey Creek.	2.46	2.38
Hunters Cave	1.93	1.73
Bass Creek.	2.00	1.84
Lower Bonne Femme Creek.	1.97	1.86
Little Bonne Femme Creek.	2.14	1.94
Fox Hollow	2.49	2.26
Average across sites	2.13	1.95
LSD**	0.35	0.35

*Statistical analysis was performed on log transformed data.

**LSD = least significant difference. This value is the minimum difference between sites to be considered statistically different.

trations (Clear Creek., Gans Creek., Bass Creek., Hunters Cave, and Lower Bonne Femme Creek.). Based on statistical differences among sites, the average fecal coliform concentrations fell into three categories: high – Fox Hollow, Turkey Creek., and Devil's Icebox Spring Branch; medium – Upper Bonne Femme Creek., Little Bonne Femme Creek., and Gans Creek; and low – Bass Creek., Lower Bonne Femme Creek., Hunters Cave, and Clear Creek. Average fecal coliform concentrations of the high category sites were equal to or greater than the whole body contact standard (2.30 $\log_{10}$(cfu/100 mL) = 200 cfu/100 mL).

Average *E. Coli* data varied from a low of 1.54 $\log_{10}$(cfu/100 mL) at Clear Creek to a high of 2.38 at $\log_{10}$(cfu/100 mL) at Turkey Creek. On average, *E. Coli* concentrations were about 9% lower than fecal coliform concentrations. The two sites with the highest average *E. Coli* concentrations, Turkey Creek and Fox Hollow, had significantly greater concentrations than every site except the Devil's Icebox Spring Branch (Table G.8). Average *E. Coli* concentrations at the two highest sites also exceeded the Federal whole body contact standard (2.1 $\log_{10}$(cfu/100 mL) = 126 cfu/100 mL). Categorizing the sites based on statistical differences between sites resulted in the following: high – Turkey Creek and Fox Hollow; medium – Devil's Icebox Spring Branch, Upper Bonne Femme Creek, Little Bonne Femme Creek, and Gans Creek; low – Lower Bonne Femme Creek, Bass Creek, Hunters Cave, and Clear Creek. Thus, both sets of indicator bacteria resulted in very similar categories based on statistical differences across sites. The three sub-watersheds with the highest levels of bacterial contamination (Turkey Creek., Fox Hollow, and Devil's Icebox Spring Branch) have consistently greater inputs of fecal bacteria compared to the other sites. Although these data do not indicate the source of the fecal bacteria, there are three likely sources in the Bonne Femme watershed – on-site sewers, livestock, and wildlife.

The U.S. EPA recommends that five approximately equally spaced samples be collected over 30 days when monitoring for compliance with the fecal bacterial whole body contact standards.

Since our scheme was very similar to the recommended scheme (four samples collected at weekly intervals over 28 days), the data were used to assess compliance of the Bonne Femme watershed streams with the State and Federal water quality standards. Another requirement for comparing data against the whole body contact standards is that the geometric mean of a sample set is computed and compared against the standard rather than the arithmetic mean. The geometric mean is computed as $(x_1 X x_2 X x_3 \ldots X x_n)^{1/n}$, where x_1 equals the bacterial concentration of the 1st sample in a set, with up to n samples collected. For our sampling scheme, n equals 4. The geometric mean for data covering a wide range will be less skewed than an arithmetic mean, and therefore, very high or very low bacterial concentrations will not have an undue impact on the geometric mean. This method was used to compute the fecal coliform and *E. Coli* geometric means for each quarterly sample set for the Bonne Femme watershed streams. The data were then grouped by site and the percentage of quarters exceeding the whole body contact standards were graphed (Figure G.2). All sites exceeded the State and Federal standards at least 10% of the time and the three sites with the highest bacterial contamination exceeded both standards >60% of the time. Even Clear Creek., which receives much of its base flow from groundwater pumped from the USGS Environmental Research Center Laboratory, exceeded the standards in a few quarters. Overall, the results showed that the fecal coliform standard (200 cfu/100 mL) used by the State of Missouri was exceeded in 40% of the quarters at seven of the ten sites. However, the Federal standard was shown to be more stringent. The Federal whole body contact standard for *E. Coli* (126 cfu/100 mL) was exceeded in 50% of the quarters at eight of ten sites.

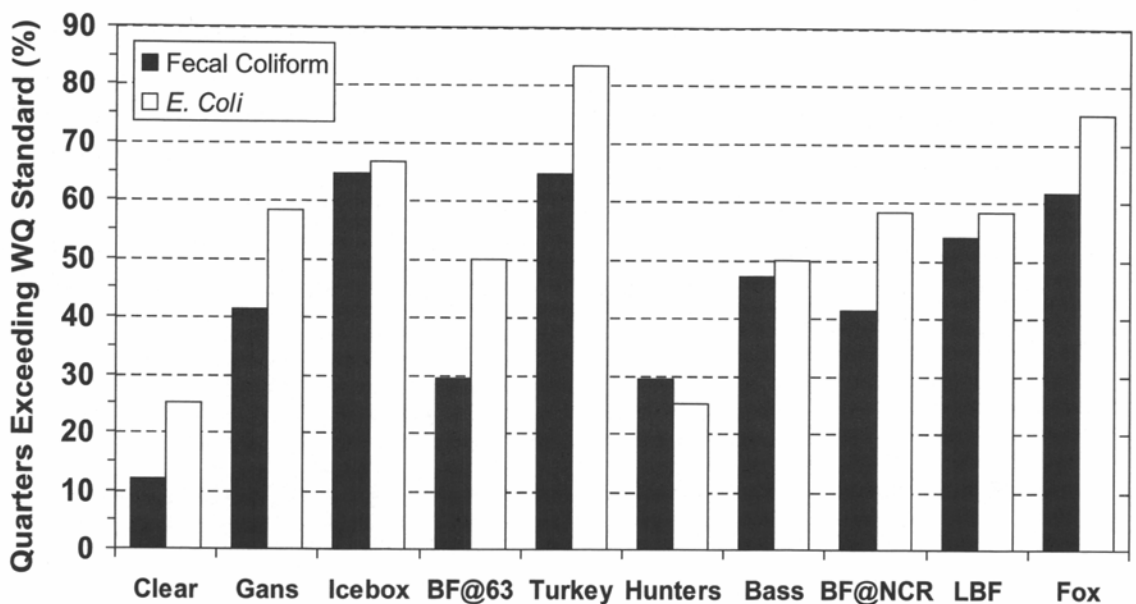

Figure G.2 Percentage of quarters in which state and federal water quality standards for whole body contact were exceeded.

Data are based on computation of geometric mean of 4 samples/quarter and compared against state and federal water quality standards. Federal Whole Body Contact Standard = 126 cfu/100 mL based on *E. Coli*. Missouri Whole Body Contact Standard = 200 cfu/100 mL based on Fecal Coliforms. Fecal coliform data were based on 17 quarters (1st Q 2001 to 3rd Q 2006); *E. Coli* data were based on 12 quarters (4th Q 2003 to 3rd Q 2006).

<u>**Specific Water-Borne Pathogens**</u>

Beginning with the 3rd quarter of 2005, additional analyses were conducted by the USDA-Agricultural Research Service for the detection of three specific water-borne pathogens: *E. Coli* O157:H7, *Salmonella*, and *Shigella*. The methods used were based on DNA extraction from water samples collected at each site, followed by addition of a DNA primer that binds to one or more specific gene sequences that are indicative of a particular organism.

Appendix G

In the case of *E. Coli* O157:H7, three separate genes were required for positive identification (Fratamico *et al.*, 1995) whereas a single gene was used to identify *Salmonella* (Aabo *et al.*, 1993) and *Shigella* (Hartman *et al.*, 1990). These methods are qualitative, meaning that they are limited to indicating the presence or absence of the pathogens. These three organisms are known human pathogens capable of causing food-borne gastrointestinal illnesses, but they are also associated with feces and therefore may contaminant streams and lakes, causing disease through oral contact or ingestion of contaminated water (Wikipedia, 2006). *Salmonella* and *Shigella* are genus classifications that can be further categorized into several species, with each species having multiple serotypes (or strains). *E. Coli* O157:H7 is one of hundreds of serotypes of the species *E. Coli*, and it is a common food contaminant associated with the guts of grain-fed cattle. The Centers for Disease Control and Prevention (http://www.cdc.gov/ncidod/dpd/healthywater /factsheets/ ecoli.htm) states that, "*E. Coli* O157:H7 is most commonly found on a small number of cattle farms where the bacteria can live in the intestines of healthy cattle." In addition, *E. Coli* O157:H7 has also been detected in the guts of swine and deer, which may also serve as carriers for the disease. Like fecal coliforms and generic *E. Coli*, these disease causing bacteria can enter surface waters through sewage overflows, polluted storm water runoff, and polluted agricultural runoff.

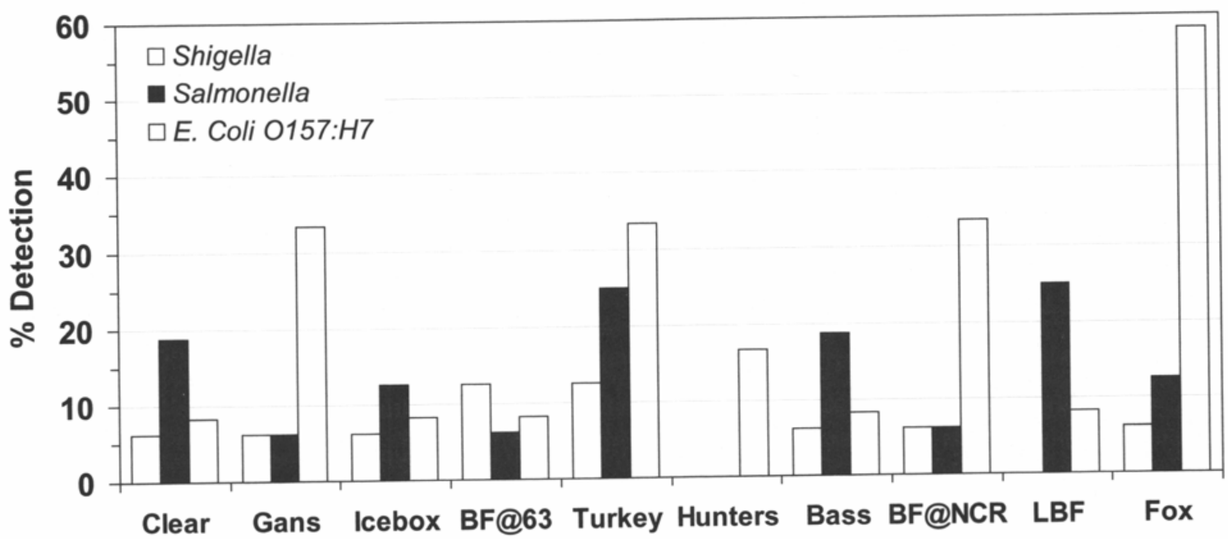

Figure G.3 Detection frequency of specific waterborne pathogens in Bonne Femme watershed.

Data for *Salmonella* and *Shigella* are based on 16 samples per site (3rd quarter 2005 to 2nd quarter 2006); data for *E. Coli* O157:H7 are based on 12 samples per site (4th quarter 2005 to 2nd quarter 2006).

Each of the three pathogens was detected at most of the ten sites monitored (Figure G.3), and at least one pathogen was detected at every site. *Shigella* was detected at eight of ten sites, but generally at lower frequency than *Salmonella* or *E. Coli* O157:H7. *Salmonella* was the most commonly detected pathogen at four of the ten sites, with 33% of the samples collected from Turkey and Little Bonne Femme Creeks testing positive for *Salmonella*. *E. Coli* O157:H7 was the most commonly detected of the pathogens, with at least one detection at every site. Five of the ten sites had multiple detections of *E. Coli* O157:H7. Three sites (Gans Creek, Turkey Creek, and Lower Bonne Femme Creek) had *E. Coli* O157:H7 detected in 33% of their samples, and Fox Hollow had *E. Colii* O157:H7 detected in 58% of it's samples. These data do not definitively indicate source, but they do point to cattle as a probable source of *E. Coli* O157:H7 at those sites with frequent detections. Of the common carriers of *E. Coli* O157:H7 (cattle, swine, and deer), swine can be eliminated as there are no sizable swine operations within the Bonne Femme watershed. Deer are likely responsible for the widespread nature of the detections, explaining the presence of *E. Coli* O157:H7 at sites with otherwise low fecal contamination, such as Clear Creek and Hunters Cave (Table G.8). Although data on specific numbers of cattle by sub-watershed cannot be reliably compiled, there are major cattle operations in the four watersheds with the highest detection frequency of *E. Coli* O157:H7. Furthermore, the Fox Hollow sampling site is immediately downstream from a large cattle grazing operation (see additional discussion below).

Fecal Bacteria Contamination in Relation to Season, Land Cover, and Stream Properties

The data collected from the monitoring of the Bonne Femme watershed streams showed that fecal bacterial contamination of streams varied significantly across sites and over time. In an effort to explain these differences, several factors were considered to explain the observed variation, including season, land cover (Figure 3.2, p. 47), and general stream water properties (based on data from Table G.5). Statistical analyses were performed to determine if these factors were related to fecal bacterial contamination.

Statistical analysis of fecal bacterial contamination over time (i.e. quarters of the year) showed significant differences based on the season in which the sample was collected (Table G.9). For both fecal coliforms and *E. Coli*, the 2nd and 3rd quarters of the year had significantly greater levels of fecal bacteria than the 1st and 4th quarters of the year. Given that the input sources (human, cattle, wildlife) do not vary considerably with the season of the year in this watershed, the data indicates that fecal bacterial contamination of the streams was strongly weather related. In the 1st and 4th quarters of the year, colder air and soil temperatures likely resulted in faster die-off of fecal bacteria released to the environment, and therefore, there were fewer bacteria available for transport during fall and winter compared to spring and summer. Additionally, precipitation events in spring and summer are more frequent and more likely to generate runoff than in fall and winter. Thus, the 2nd and 3rd quarters apparently had greater populations of fecal bacteria surviving in the soil environment combined with a greater probability of runoff events capable of transporting fecal bacteria to the streams.

Table G.9 Average fecal coliform and *E. Coli* concentrations by quarter of the year.

Quarter	Fecal Coliform	*E. Coli*
	log10(cfu/100 mL)	
1st	1.53	1.24
2nd	2.50	2.28
3rd	2.47	2.34
4th	1.95	1.86
LSD	0.22	0.21

Of the stream water properties measured (temperature, pH, *specific conductivity*, dissolved oxygen, and turbidity, Table G.5), there were no significant correlations of these parameters to fecal coliform or *E. Coli* concentrations in the streams. However, a much larger data set exists at the two cave sites for the stream water properties and fecal coliform concentrations, with data collected as far back as 1999 and at much greater frequency than was conducted for this project (Lerch *et al*, 2001). Of the general stream water properties measured at the two caves, only turbidity was shown to significantly correlate to the fecal coliform concentrations. At Hunters Cave, 72% of the variation in fecal coliform concentrations could be explained by the turbidity levels of the water. The correlation between turbidity and fecal coliform concentrations at the Devil's Icebox Spring Branch was much lower, but still significant, because high bacterial concentrations were observed even when turbidity was low. Other researchers have reported a significant relationship between fecal bacterial concentrations and turbidity (Rasmussen and Ziegler, 2003) in surface streams, and it is probable that with a more intensive monitoring regime such a relationship also exists for the surface streams in the Bonne Femme watershed. The only other physical parameter that significantly correlated to fecal bacterial concentrations was stream discharge, but this data only exists at the two cave sites. Although both fecal coliform and *E. Coli* concentrations significantly correlated to stream discharge at the caves, *E. Coli* showed a much stronger correlation to discharge than fecal coliforms. The correlations of fecal bacterial concentrations to turbidity and stream discharge indicated that fecal bacterial concentrations, in general, will be greatest for runoff events with high turbidity. These events have enough energy to induce soil erosion, resulting in transport of sediment-bound fecal bacteria to the streams.

None of the major land cover classes (impervious, urban, row crops, grasslands, or forest, Figure 3.2, p. 46) was significantly correlated to either fecal coliform or *E. Coli* concentrations (Table G.8) in the streams. This result suggests multiple sources or fairly uniformly distributed non-point sources of fecal bacteria exist across the sub-watersheds. Given the wide variation in land cover and human population across sub-watersheds (Figure 3.2, p. 46), multiple but different sources apparently exist. Multiple sources seemed to be the cause of contamination in most sub-watersheds (e.g., Turkey Creek, Little Bonne Femme Creek, Upper Bonne Femme Creek, and Gans Creek) while site specific sources of fecal bacteria appear to be responsible for the high levels observed at two sites (Devil's Icebox Spring Branch and Fox Hollow).

The site specific sources in the Devil's Icebox Spring Branch appear to be from private residences within the Pierpont sinkhole plain where on-site sewers discharge to the cave via transport through the sinkholes. Evidence for this is two-fold: 1) the consistently higher levels of fecal bacteria in the Devil's Icebox Spring Branch compared to Upper Bonne Femme Creek, the main source of water to the Devil's Icebox Spring Branch; and 2) frequently observed high concentrations under low-flow conditions. Regarding the first point, the increase in fecal bacterial concentrations between Upper Bonne Femme Creek and the Devil's Icebox Spring Branch (Table G.8) indicates that additional sources are entering the cave between the losing stream reach in Upper Bonne Femme Creek and the cave stream resurgence. The only land area between these points is the sinkhole plain. Moreover, the distance between the losing reach of Upper Bonne Femme Creek and the Devil's Icebox Spring Branch resurgence is at least four miles, and it would be expected that some die-off of the fecal bacteria or dilution from other tributaries to the cave stream would occur along this lengthy flow path if there were no other bacterial inputs. For example, comparison of fecal bacterial concentrations in Hunters Cave to Bass Creek, the main water source to Hunters Cave, showed that the levels in Hunters Cave were consistently lower than Bass Creek (Table G.8). Thus, dilution or die-off occurred along the sub-surface flow path, yet this flow path is much shorter than that of the Devil's Icebox Spring Branch. With regards to the second point, under low flow conditions the Devil's Icebox Spring Branch had 18 of 41 samples with fecal coliform concentrations >200 cfu/ 100 mL compared to only 10 of 39 samples >200 cfu/100 mL at Upper Bonne Femme Creek. For the *E. Coli* data, Devil's Icebox Spring Branch had 21 of 41 samples with concentrations > 126 cfu/100 mL while Upper Bonne Femme Creek had only 9 of 40 samples >126 cfu/100 mL. Since high bacterial inputs were apparent under low flow conditions, this precludes surface runoff from livestock grazing lands or wildlife as the source, and thus, implicates on-site sewers as the probable source of this additional input to the cave. As discussed above, similar trends for TN and NO_3-N were also observed between Upper Bonne Femme Creek and the Devil's Icebox Spring Branch, providing further evidence that on-site sewers in the sinkhole plain have contributed to water quality degradation in the Devil's Icebox Cave Branch.

The other monitoring site with site-specific causes of contamination is Fox Hollow. The monitoring site is immediately downstream of a sizable cattle operation. The cattle have unrestricted stream access (and were frequently observed in the stream) and manure is stored in the open within 100 feet of the stream. In addition, the pasture land adjacent to the stream is overgrazed and there are no riparian management practices employed to stabilize the stream banks or to mitigate fecal bacterial transport. Not coincidentally, this site had the highest fecal coliform levels, 2nd highest *E. Coli* levels, and the highest occurrence of *E. Coli* O157:H7 of the sites monitored.

Significant fecal bacterial contamination occurred at several sites for which no site specific sources of bacteria were apparent, and therefore, multiple sources appeared to be the cause of contamination. This was the case for Turkey Creek, Upper Bonne Femme Creek, Little Bonne Femme Creek, and Gans Creek. For example, Turkey Creek had the highest fecal coliform, *E. Coli*, and occurrence of specific pathogens as any site except for Fox Hollow. Turkey Creek has a very low human population, but 43% of this sub-watershed's area is grasslands with several sizable cattle operations. As was the case in Fox Hollow, many of the grassland areas are overgrazed, cattle have unrestricted access to the streams, and there is little or no riparian management, especially in the upper portions of the sub-watershed. Apparently, multiple cattle operations were the cause of contamination in Turkey Creek. Sub-watersheds with substantial human populations and considerable agricultural land uses, such as Little Bonne Femme Creek and Gans Creek, likely have a combination of human sewage and cattle inputs as the sources of fecal contamination. Sites with the lowest contamination, such as Clear Creek and Hunters Cave, may largely represent background inputs from wildlife with only limited contributions from cattle or on-site sewers.

Conclusions

The following general conclusions can be reached from the monitoring study:

- General stream water properties indicate no acute contamination, with all five properties measured falling within typical ranges for carbonate bedrock streams, and dissolved oxygen levels above the State minimum standard of 5 mg/L;
- Nutrient levels were similar to or less than streams in other agricultural watersheds of northern Missouri. There was no evidence of acute contamination at any site;
- The combination of dissolved oxygen, turbidity, nutrient levels, and field observations indicated that all sites have some level of nuisance algal growth and presumed loss of macroinvertebrate diversity, but eutrophication conditions have not occurred at any site;
- At least one herbicide or *metabolite* was detected in every sample at all sites, but typically at low levels. Atrazine and its metabolites had the highest average concentrations at all sites;
- Fecal bacterial contamination was widespread with significant differences observed across sites and over seasons. Concentrations of fecal bacteria were highest in spring and summer;
- Whole body contact standards for fecal bacteria were commonly exceeded. Seven of ten sites exceeded the State fecal coliform standard 40% of the time. Eight of ten sites exceeded the Federal *E. Coli* standard 50% of the time;
- Frequency of detection of specific pathogens was in the following order: *E. Coli* O157:H7 > *Salmonella*> *Shigella*. The pattern of *E. Coli* O157:H7 detections indicated that cattle were the probable source;

• Of the general stream water properties measured, concentrations of fecal bacteria were significantly correlated only to turbidity and stream discharge (based only on the two cave sites);
• Land cover classes did not significantly correlate to the concentrations of fecal bacteria;
• Multiple sources apparently were the cause of contamination in most sub-watersheds while site specific sources of fecal bacteria appear to be responsible for the high levels observed at the Devil's Icebox Spring Branch (most likely from on-site sewage) and Fox Hollow (most likely from cattle).

G.4 Bonne Femme Dye Traces

Introduction

The following information is summarized from "Bonne Femme Watershed Project Dye Trace Final Report" (Frueh and Lerch, 2006).

Groundwater recharge in karst systems is highly vulnerable to pollution since there is little-to-no filtering of surface water as it enters subterranean conduits. Nonpoint source (NPS) pollutants are transported to streams and sinkholes dissolved in water and bound to sediments suspended in surface runoff. This pollution poses a special threat to karst systems, in part because it is spread throughout a watershed and therefore is harder to control, and in part because aquatic life in karst systems tend to be especially vulnerable to pollution. Thus, it is important to know the recharge area (the land area that contributes water to a cave) of a cave stream in order to determine the sources of water and their associated land uses. This delineation of the recharge area of a cave system provides the basic information required to protect organisms living in its water. Dye tracing is a method frequently used to determine hydrogeological flow characteristics of an area, and it is the primary tool available for delineating recharge areas.

Two dye trace experiments were performed by the Bonne Femme Watershed Project. The first dye trace, carried out during winter 2003-2004, confirmed that the reach of Bonne Femme Creek downstream of Highway 163 loses water to the Devil's Icebox Cave Branch. This approximately one-mile-long reach was previously determined to be losing continuously along the reach (St. Ivany, 1988), and thus is presumed to lose flow to Devil's Icebox Cave Branch down to the point where elevation precludes transmission of water to the cave (estimated to be 700 feet above sea level). The results of this dye trace allowed us to add approximately 2.0 square miles (5.2 square kilometers) to the known Devil's Icebox recharge area (Frueh and Lerch, 2006). The second dye trace, carried out in the summer of 2004, indicated that Gans Creek does not lose any water out of the stream channel to any springs during low flow conditions, although further study is needed to confirm these results. However, it is important to note that St. Ivany (1988) found that Gans did lose a portion of its water during normal flows to a spring located in the Gans Creek floodplain, but Gans Creek did not lose water to the Devil's Icebox Cave Branch under low and normal flow conditions.

Appendix G

Previous Karst Studies

Devil's Icebox Cave Branch

Previous studies established that surface water flows from both the upper Bonne Femme Creek and the Pierpont Sinkhole Plain to the Devil's Icebox Cave Branch (DI). Work completed in the 1980s showed that the reach of Bonne Femme Creek between Highways 63 and 163 loses water that flows to DI (St. Ivany, 1988). The water is lost via a swallow hole (a sinkhole located in the stream bed) and other cracks in the bedrock of the stream channel within this reach. The 'lost' water flows through sub-surface conduits to DI. The initial recharge area delineation for DI was based on these studies in combination with surface water drainage patterns and topography, giving an estimated recharge area of 11.1 square miles (26.4 square kilometers).

St. Ivany postulated that the reach of Bonne Femme Creek downstream of Highway 163 loses to DI because flow continued to decrease in the reach proceeding downstream from the Highway 163 bridge (St. Ivany, 1988). Its flow decreased enough to meet the standard for classifying it as a losing stream according to Missouri Department of Natural Resources rules. The drainage area of this section that could flow to DI, excluding the area upstream from the bridge, is approximately 2.0 square miles (5.2 square kilometers) in size. However, St. Ivany did not perform the dye tracing studies to confirm that this flows to DI.

Clear and Gans Creeks were confirmed to be gaining streams (and therefore are not losing to DI nor other cave systems) (St. Ivany, 1988). A gaining stream's flow increases when moving downstream due to small tributaries contributing flow, and shallow groundwater being added from the channel banks and channel bottom. St. Ivany did note that Gans Creek seemed to lose some water in one reach, but he showed that this lost water remains in the main stream valley. The lost water flows down through the upper unit of the Burlington Limestone, then flows laterally when it reaches the middle unit of the Burlington Limestone to re-surface further downstream in both Gans Creek and a spring (located in the Gans Creek floodplain) that flows into Gans Creek.

Hunter's Cave

Although Hunters Cave (HC) is not directly related to the dye traces described here, brief discussion of its study is warranted because it is in the Bonne Femme watershed, and it is in close proximity to the traces. Lerch et al. (2005) used dye tracing to delineate the HC recharge area. They found that most of its recharge comes from Bass Creek. This creek loses water to Hunters Cave several hundred yards upstream from its entrance, with its water entering the cave at Angel Spring. In addition, two tributaries to Turkey Creek on its south side were confirmed to lose to HC, although the main channel of Turkey does not. These two tributaries lose at a geologic fault along which HC is formed. The contributing recharge area for HC is approximately 12.9 square miles (33.4 square kilometers) and includes portions of the City of Ashland and the Columbia Regional Airport (Figure G.4).

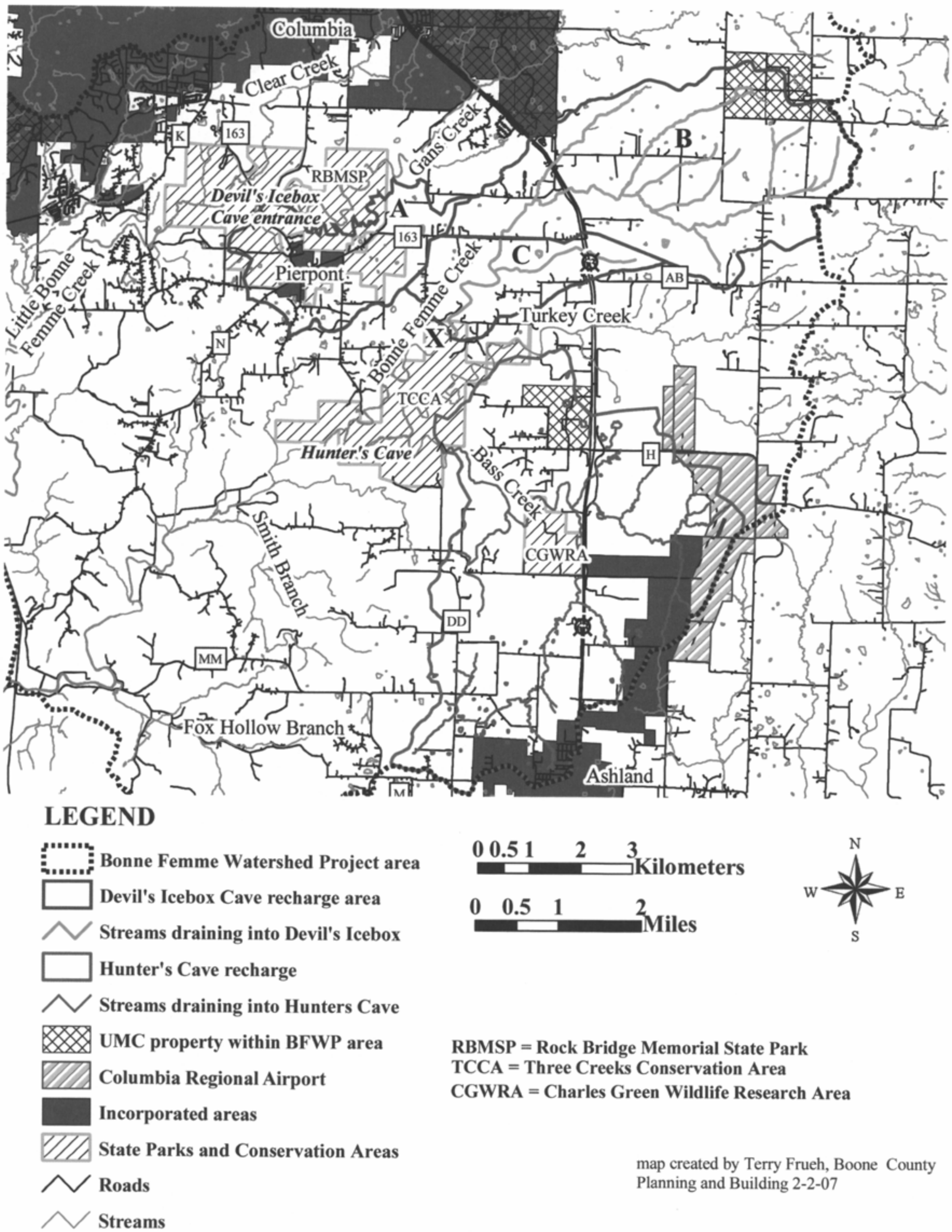

Figure G.4 Devil's Icebox Recharge area.

Appendix G

Methodology

Both of the Bonne Femme Watershed Project dye traces used standard dye tracing techniques, involving the introduction of fluorescent dyes into stream channels and their subsequent *adsorption* from the water by activated carbon samplers (Aley, 1999). These samplers adsorb dye continuously while they are in place, thereby giving a total amount of dye collected integrated over time. In order to avoid the potential for cross-contamination between the two traces, two distinct dyes were used (fluorescein dye in the Bonne Femme Creek trace, and rhodamine WT dye in the Gans Creek trace). The Bonne Femme Creek and Gans Creek trace samplers were placed at 3 and 5 locations, respectively. The specific location for dye injections and locations of activated carbon samplers are given in Figure G.5. It is important to place samplers at all locations where they could potentially catch dye. They were placed downstream from all dye introduction points, and at lower elevations. In addition, they were placed in other locations that could potentially have a hydrogeological connection (i.e. in adjacent basins in order to assess the possibility of inter-basin transfer, and springs within the same subwatershed). The dye was released into the middle of flowing water to ensure it mixed in well with the flowing portion of the stream. In addition, the person who released the dye ensured that no dye splashed on them in order to avoid the possibility of inadvertently contaminating samplers.

Carbon samplers were in place for 3-7 days prior to each injection in order to determine if there was already dye present in the system before releasing the dye into the stream. These background measurements are important in order to determine that any samplers that detected dye were not contaminated by pre-existing dye in the system. Samplers were typically collected and replaced at weekly intervals for up to 2 months following dye introduction. For example, the first sampler, labeled 3 DAI (Days After Injection) was left in place from the day of injection until 3 DAI, and the second sampler, labeled 7 DAI, was in place for the period 4-7 DAI. For more details, see Frueh and Lerch (2006).

Results and Discussion

Bonne Femme Creek dye injection

In Bonne Femme Creek, the largest volume of fluorescein dye appeared in the sampler collected 3 DAI, with a much smaller volume of dye found in the sampler collected at 17 DAI, and virtually no dye at 30 DAI. These results are expected since one would assume that under high flow conditions at least some water would stay in the main channel into which it was introduced. The results also indicate the dye is flushed through the channel relatively quickly. For DI, the sampler collected at 3 DAI had a similar volume of dye as that of the Bonne Femme Creek collected the same day. However, the DI samplers collected at 7 and 17 DAI also had large volumes of dye collected (approximately 1/5 of that from 3 DAI), in contrast to that of Bonne Femme Creek for the same DAI, which had only a barely perceptible amount of dye collected. These elevated volumes of dye indicate that the water moves through DI quickly

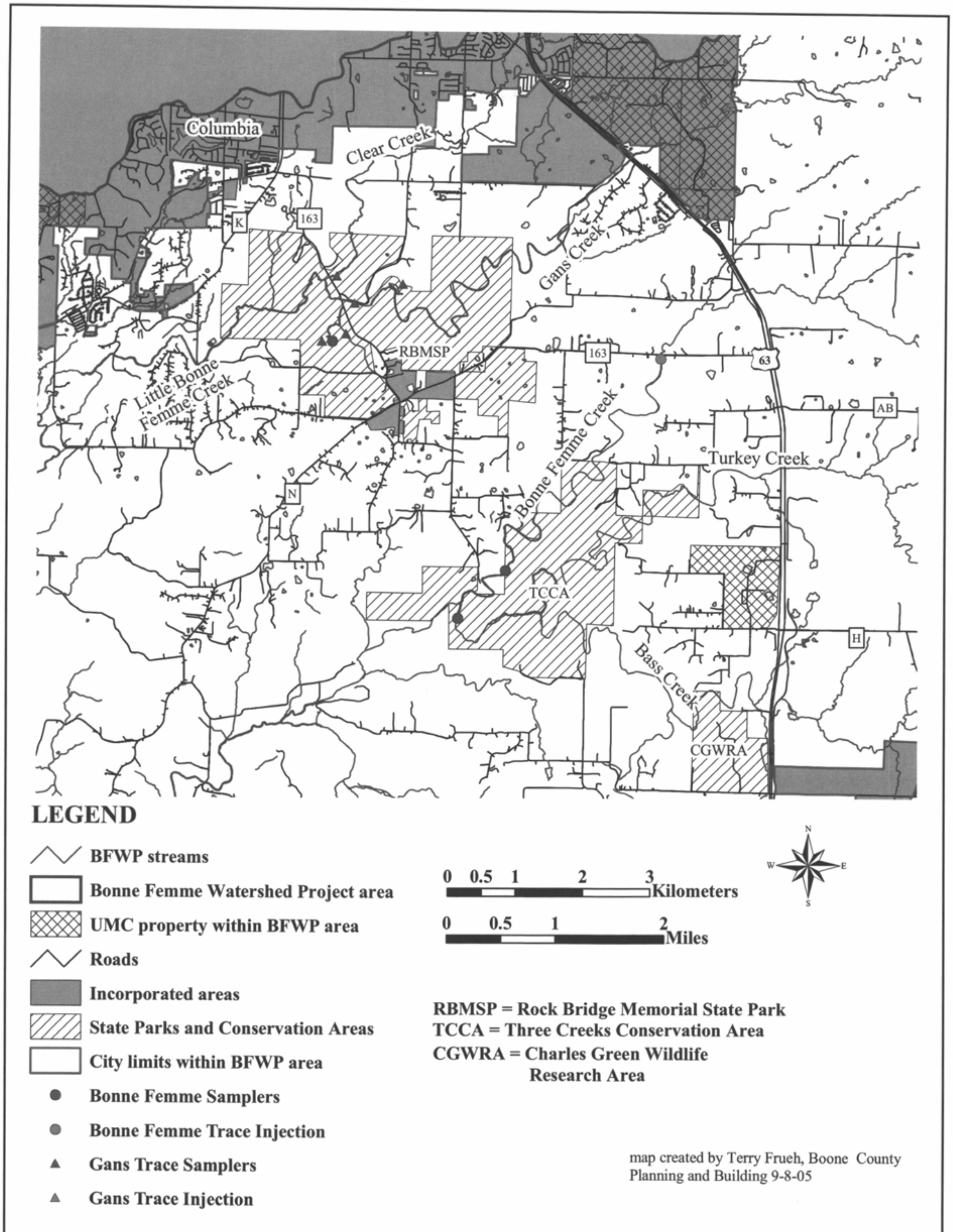

Figure G.5 Dye Trace Locations

(as evidenced by the high volume at 3 DAI), but some of it is also moves through slowly (as evidenced by the moderate volumes at 7 and 17 DAI). Turkey Creek samplers detected no dye. None of the samplers detected the dye used for the other trace, rhodamine WT.

The reach of Bonne Femme Creek downstream from Highway 163 is verified to lose to DI, thereby confirming what St. Ivany (1988) hypothesized was occurring within this reach. The trace also indicates that this reach of Bonne Femme Creek loses no water to Turkey Creek.

The drainage area that contributes to the losing section of Bonne Femme Creek confirmed in this trace is approximately 2.0 square miles (5.2 square kilometers) (Figure G.4, area C). The two recharge areas; the Pierpont Sinkhole Plain (Fig. G.4, area A), and the upper Bonne Femme Creek subwatershed (Fig. G.4, area B); that were found to be losing in previous studies (King and Hargrove, 1973; St. Ivany, 1988) have areas of 3.6 square miles (9.3 square kilometers) and 7.5 square miles (19.4 square kilometers), respectively. Therefore the total identified DI recharge area is approximately 13.1 square miles (34.0 square kilometers). This recharge area contains portions of the recently-formed village of Pierpont, unincorporated Boone County, University of Missouri's Bradford Research Farm, Rock Bridge Memorial State Park and Three Creeks Conservation Area.

Gans Creek dye injection

The only detection of dye for this trace was a small volume of rhodamine WT dye that occurred in Gans Creek, which occurred for the sampler picked up at 30 DAI; all of the other samplers had no detection of either dye. The fact that the only detect was for the period 14-30 DAI indicates water moved slowly through the system. Its low volume means there was very little dye in the water column. As dye was not found in any other locations (and therefore no dye was lost from the system), the weak detect suggests the dye was broken down by *photolysis*; this hypothesis is further supported by the long travel time, thereby allowing ample time for breakdown from sunlight to occur. Also, at this time of year, the days are long and the sun is at a high angle in the sky, giving more time and energy for this breakdown to occur.

The lack of any dye detection at Gans Creek Spring runs counter to St. Ivany's work (1988), although the results for this trace from Frueh and Lerch need further confirmation (2006). St. Ivany (1988) found that dye was detected at this spring 3 weeks after injection, indicating a slow movement through the gravel in the alluvial plain, and possibly through a minor fracture in the bedrock. His hypothesis was further supported by his observation that the spring stopped flowing when Gans Creek stopped flowing during summer months. He also found that under low and normal flows, water did not leave the Gans Creek Valley to enter the Devil's Icebox Cave Branch or other watersheds. Upon analyzing the geology, surface water flow measurements, and dye traces, St. Ivany concludes Gans Creek's water stays within its valley. The lack of dye detection in Gans Creek Spring for this dye trace could be due to the low flow conditions causing sunlight-induced breakdown of dye. In addition, it is possible that flow in the creek was not high enough to allow water with dissolved dye to enter karst conduits that flow to Gans Creek Spring.

G.5 Subwatershed Sensitivity Analysis, a Planning Tool

The Steering Committee wanted to have an independent, scientifically-based decision-support tool created to help the Stakeholders in their planning effort. It was decided to hire a consultant who had experience doing hydrologic analysis, who could use the latest technologies to create *GIS* data layers, and who could create an interactive model for forecasting future stream conditions.

Formed by the Steering Committee, a group of technical experts wrote a Request for Proposals (RFP) to complete a Subwatershed Sensitivity Analysis of the Bonne Femme Watershed that would serve as a decision-support tool for the Stakeholder Committee. Writing the RFP was challenging because the group had never seen an analysis completed at a similar scale and depth of study that combined hydrological modeling and a natural resource assessment. Therefore, they could not precisely state how the goals of the RFP were to be met. Thus, the RFP requested a creative approach to analyzing the streams within the watershed. Three consultants responded to the RFP, of which Applied Ecological Services (AES) was selected since they had the response that best fit the Project's needs. Following is a brief description of the Subwatershed Sensitivity Analysis they completed.

In this analysis, a variety of techniques were used to obtain a more comprehensive assessment of the watershed. Three different models were used to assess stream conditions.

The following is excerpted from the Subwatershed Sensitivity Analysis:

> Stream Carrying Capacity Model
>
> The Stream Carrying Capacity Model uses soil permeability, topography and land use to assess existing stormwater runoff and predict future stormwater runoff. In the model, future runoff is based on projected changes in permeability as a result of predicted land use changes. This model indicates that existing runoff in the upper reaches of the watershed has already resulted in the degradation of streams in lower reaches. This concurs with field observations. The model also indicates that stream channels are stable ("acceptable") in the Upper Bonne Femme, Turkey Creek, Turkey/Bass Confluence and Bass Creek subwatersheds. However, observations in the field indicated that these "acceptable" subwatersheds are relatively unstable in the upper reaches due primarily to poor land management practices and loess or sandy soils, and relatively stable in the lower reaches where the creek bed and bank consists of large rock and cobble. The instability in the upper reaches is a concern most notably for the karst recharge areas that comprise most of the Upper

Bonne Femme and Bass Creek subwatersheds. If sediment or other material is actively being transported into these conduits, this could be detrimental to sensitive cave *ecosystems*.

Stream Sensitivity Model

The Stream Sensitivity Model uses existing and projected impervious surfaces as modified by field criteria to measure the vulnerability of streams to degradation. This analysis is based on observations that watersheds with less than 10% impervious cover remain healthy; watersheds with 10-25% impervious cover are "impacted" and somewhat degraded; and watersheds with more than 25% impervious cover are highly degraded and difficult to restore.

This model indicates that subwatersheds around Columbia and Ashland are currently "impacted." This trend is expected to continue during projected build out conditions with downstream subwatersheds degrading further. Subwatersheds contiguous to Columbia and Ashland are restorable with the implementation of new and remedial BMPs discussed in a subsequent section.

Landscape Function Model

This model uses ecological communities as defined by National Land Cover Data (NLCD) as a surrogate for how well the landscape functions. This model indicates that landscape function is most degraded around Columbia and Ashland due to development pressure and within the upper reaches of the watershed where the native prairie has been converted to agricultural land uses where poor management practices are employed. Floodplains along the lower reaches of the watershed that have been converted from bottomland forest to agricultural land with poor management practices also are rated poorly. Highest quality landscape functions exist in the remnant woodlands along steep and rugged terrain.

Watershed Trends and Implications of the Models

1. In the upper reaches of the watershed, the conversion of native prairie to agricultural uses without appropriate BMPs in place has resulted in increased stormwater runoff and decreased soil stability. As a result, streams in the upper reaches are downcut and eroding. Increased flows in the upper reaches also have led to stream degradation in the lowest reaches of the watershed.

2. In the lower reaches of the watershed, the conversion of floodplain bottomland forest to agricultural uses without appropriate BMPs in place has also led to increased runoff and decreased soil stability. Most of the streams

in the lower reaches are entrenched, shear, unstable and disconnected from the floodplain during channel forming (one to two year storm events) storm events. These conditions become exacerbated as flows continue to increase with projected development.

3. Most of the groundwater recharge to Devil's Ice Box and Hunters Cave occurs in the upper reaches of the watershed. Streams within the recharge zones occur on highly erosive loess and sandy soils, making the recharge zones highly vulnerable to erosion, streambank degradation, reduced water quality, and sedimentation impacts to sensitive cave systems.

4. Karst topography plays a major role in hydrology of the watershed. The two largest caves are mapped and their recharge areas are fairly well delineated. While the scientific community understands how karst topography affects hydrology, generally more education is needed for the lay public, especially since they have the greatest influence on how land is managed.

5. Channel instability issues appear to be migrating upstream, especially in the Northern Little Bonne Femme subwatershed. This is a common and expected phenomenon in downcutting streams as the stream seeks a flatter, more stable grade.

6. Subwatersheds most vulnerable to degradation based on the impervious cover and field indicators are clustered around Columbia and Ashland. Upper Bonne Femme and subwatersheds downstream from Upper Bonne Femme are the next most vulnerable group of subwatersheds. Most of the recharge for Devil's Ice Box occurs in Upper Bonne Femme, a "moderately" vulnerable subwatershed. Most of the recharge for Hunters Cave occurs in the Bass Creek subwatershed, which is ranked as "vulnerable."

7. All subwatersheds are considered restorable, though the greatest restoration challenges will occur, in order of difficulty, in the North Branch Little Bonne Femme, Clear Creek and Bass Creek subwatersheds.

8. When assessed collectively, the three models indicate that there are regions within the watershed that should be prioritized for protection and remediation, namely the urbanizing regions around Columbia and Ashland, and the agricultural headwater region in the eastern portion of the watershed.

Appendix G

Best Management Practices (BMPs)

Best Management Practices (BMPs) are watershed restoration and management techniques that, if implemented, can improve water quality, reduce runoff and flooding, and protect or restore natural resources. BMPs can include preventative measures to reduce the likelihood of new problems occurring, remedial measures that attempt to solve an existing problem, and maintenance measures that can be either preventative or remedial, depending on the circumstances.

The selection of a BMP or suite of BMPs should be based on the efficacy of each specific BMP to achieve the desired result in a given landscape. The suite of BMPs used in a row crop setting, for example, would be different from the suite of BMPs used in a new urban development, though there would certainly be some overlap.

BMP Zones

Five discrete zones were identified within the watershed that would benefit from a specialized suite of BMPs: Headwater Pasture, Wooded/Karst Slope, Bottomland/River Valley Floodplain, Transitional Fringe, and Urban Developed. Zones were categorized using a combination of GIS data layers and attributes.

See Table G.10 for the BMPs they recommend in different zones.

The Subwatershed Sensitivity Analysis report makes a series of recommendations. Their inclusion here is for informational purposes only and do not necessarily reflect the opinion of the Stakeholder Committee. Following are the Subwatershed Sensitivity Analysis report policy recommendations.

It is recommended that Boone County and the cities of Ashland, Columbia, and Pierpont (hereafter, the Watershed's local governments) take the following actions to improve stormwater and groundwater management for protection of natural resources and restoration of degraded areas. At a minimum, Boone County and its municipalities could adopt the latest version of American Public Works Association (APWA) Section 5600 stormwater design criteria and BMP Manual (APWA 2003). These manuals were written specifically for the Kansas City metro region, and therefore would be easy to adapt to conditions in Boone County. Other recommendations build on these documents, including public education, incentive programs, and water resource protection and restoration recommendations.

Table G.10 BMP Summary Implementation and Benefit Table

Recommended Best Management Practice	Recommended Implementation Zone within the Watershed	Attributes Protected or Enhanced				
		Water Quality	Biodiversity	Groundwater Recharge/Infiltration	Flood Protection	Wildlife Habitat
Exclusion of livestock from riparian corridors.	Headwater Pasture, Wooded/ Karst Slope, Bottomland/ River Valley Floodplain	X		X	X	
Restoration of riparian buffers along channels.	All zones.	X	X	X	X	X
Culvert resizing and/or reshaping.	Headwater Pasture, Wooded/ Karst Slope, Bottomland/ River Valley Floodplain				X	
Restore drained wetlands.	Headwater Pasture, Wooded/ Karst Slope, Bottomland/ River Valley Floodplain	X	X	X	X	X
Convert intensively used open space to natural plant communities.	All zones	X	X	X	X	X
Repair rills and gullies caused by concentrated discharges of water fromhomes, farmsteads, and pastures. Provide for dispersion of future discharges.	Headwater Pasture, Wooded/ karst Slope	X			X	
Complete more extensive mapping of areas tributary to karst features including sinkholes and losing streams. Restore these ares where appropriate and to the greatest extent practical	Wooded/Karst Slope	X		X		X
Minimize soil loss in steep areas during road repair and construction, residential and commercial development, and within ares used for agricultural purposes.	Headwater Pasture, Wooded/ Karst slope, Urban/Developed	X				
Remove farm fences obstructing channels.	Headwater Pasture, Wooded/ Karst Slope				X	
Buffer and/or expand protected lands and listed species habitat.	Wooded/Karst Slope		X			X
Localized land planning should occur to protect areas most vulnerable to erosion and sedimentation	Urban/Developed	X				
Implement the use of decreased road widths, detention ponds, silt fences, minimization of mass grading, and/or inlet protection during construction.	Urban/Developed	X		X	X	
Retrofit existing ponds and lakes to detain more water by restricting the outlet, increasing the elevation of the berm/dam, or both	Urban/Developed	X		X	X	
A channel restoration and maintenance plan should be developed to prioritize creeks for restoration and for regular removal of debris jams.	All Zones.	X	X		X	X

Excerpted from the Subwatershed Sensitivity Analysis.

Appendix G

1. Adopt APWA 5600 Storm Drainage Systems and Facilities stormwater design criteria.

APWA 5600 specifies application and design criteria for stormwater management, conveyance, detention, and natural stream protection. In particular, APWA 5600 includes guidance that will address problems noted in Boone County, including:

a. Limiting stormwater discharges from developments to rates, volumes, and frequencies that prevent future flooding, limit erosion, and protect stream stability.

b. Providing stream assessment guidance to quantify stream stability and potential impacts.

c. Requiring developers to maintain stable stream channels and banks by designing stormwater outlets that will not destabilize stream channels and banks and by maintaining predevelopment discharge rate, energy, and flowlines. In addition, APWA 5600 provides guidance for designing non-erosive indirect discharges into stream buffers. The Watershed's local governments should specify that this is the preferred practice.

d. Recommending a systematic riparian buffer program with buffers planted with appropriate native vegetation that vary from 40 to 120 feet, from the ordinary high water mark on both sides of the stream, depending on the size of the contributing drainage area.

e. Requiring that bridge utilities cross at locations and in a manner that preserves stream meander geometry and cross-sectional areas.

f. Minimizing changes to existing channel and floodplain cross-sections and conveyance capacity.

g. Maintaining channel roughness and energy dissipation (and habitat) with preserved or established native vegetation.

h. Maintaining sediment transport capacity necessary for channel equilibrium.

i. Specifying low-impact grade controls, flowing water energy management, and bioengineering to maintain channel plan and profile, and to protect and restore stream stability when infrastructure has or will otherwise impact stream stability.

j. Allowing and encouraging low-impact design, such as conservation subdivisions and other "smart growth" practices, to minimize runoff as an alternative to detention basins.

2. Adopt the APWA Manual of Best Management Practices for Stormwater Quality (BMP Manual)

The BMP Manual would provide the Watershed's local governments with the tools to prevent future flooding and protect water quality, including a flexible framework for developers to estimate potential water quality impacts and increased runoff from development plans. The BMP Manual would also design a comprehensive stormwater management system that includes site design and dispersed, structural and non-structural best management practices (BMPs) for residential, commercial, and industrial developments. The "Level of Service Method" can be used to maintain or reduce predevelopment runoff volumes and pollutant loads by:

a. Encouraging and specifying preservation of upland and bottomland vegetation and infiltration capacity, through the use of riparian buffers and other practices.

b. Minimizing impervious surfaces and encouraging rainfall infiltration through the preservation or restoration of native vegetation and soil profiles.

c. Providing incentives to disconnect impervious surfaces in stormwater conveyance systems.

d. Infiltrating stormwater runoff at the source through engineered BMPs, which maintain groundwater hydrology and are highly effective pollutant filters.

e. Filtering runoff that cannot be infiltrated through dispersed filtration BMPs.

f. Presenting multiple wet detention options, including wet ponds, wetlands, and extended detention wetlands.

g. Providing detailed design guidance for structural and non-structural BMPs including standard specifications and details for common BMPs, and detailed planting and vegetation management guidance.

h. Specifying native vegetation for all BMPs to enhance pollutant removal through filtration and evapotranspiration.

i. Specifying holding times for further pollutant settling and evaporative water losses.

3. Adopt Additional Stormwater Management and Development Policies

APWA Section 5600 criteria may not be sufficient in all circumstances to stabilize stream channels and manage water quality, rates, and volumes entering streams and other water bodies. AES recommends the Watershed's local governments adopt the following "Technical Policy Guideline for Stormwater Management" in all developments:

a. Require any post-development release rates do not exceed the ne-year predevelopment release rates for all storms with a frequency of greater than 10 years. And, rare events such as the 100-year storm should be released at no greater than the 10-year predevelopment release rates.

b. Enact a stream setback ordinance to codify the comprehensive buffer system recommended in APWA 5600. Design the setback zones in accordance with APWA 5600 and the BMP Manual but increase the maximum setback to 150 feet from the ordinary high water mark.

c. Add a Conservation Development classification to the zoning ordinance that specifies Conservation Development planning principles, and encourage alternative stormwater management systems by requiring developments to provide a higher "Level of Service" than the recommendation in the BMP Manual.

d. Develop a stream restoration and maintenance program including floodplain restoration, stream buffers, and restoration practices, to reduce down cutting and to stabilize streambanks throughout the County. Restoration and maintenance practices could be adopted from APWA 5600, the BMP Manual, and other sources.

e. Enact a new zoning classification to preserve upland environments and other off-channel locations with the potential for stormwater detention. Protect hydric soil units (historic wetlands) and naturally occurring depressional storage areas from development and specify natural stormwater management facilities as permitted uses. Natural detention systems should be designed in accordance with the BMP Manual and linked to natural drainage ways or the man-made conveyance system as specified in APWA 5600 and the BMP Manual.

f. Develop cooperative agreements for municipalities within the County to effectively manage stormwater that flows in to or out of shared watersheds within the framework of a single watershed plan, using the criteria in recommendations 1, 2, and 3a for stormwater management and natural resource protection and restoration.

4. Public Education and Incentives

Public education and incentive programs could build support for new policies and help landowners and developers meet their obligations under the policies.

AES recommends the following education efforts and incentive programs:

a. Use an annual "developers' forum" or other methods to educate landowners and developers about:

- comprehensive buffer systems or ordinances and their own buffer requirements;
- watershed-sensitive development strategies and how they can protect the area's valuable land and water resources; and
- alternative stormwater management designs in the BMP Manual and other references that may eliminate the need for stormwater sewers and other costly infrastructure.

b. Promote awareness of natural resources and critical resource issues in the watershed through public education, volunteer stewardship activities in public parks, and through collaboration and partnership with local landowners, conservation groups, agencies, local colleges, and other stakeholders.

c. Establish a County-wide environmental stewardship and stormwater real estate transaction surcharge fee to generate an Environmental Stewardship Fund. This fund should be used, along with other revenue sources (e.g. capital investment funds, taxes, etc) to create private-public partnerships with landowners to help restore, protect, and repair natural resources areas (streams, woodlands, wetlands, etc). AES recommends a transaction fee of 0.05 percent to 0.2 percent of all real estate transactions in the County to establish this fund. The fund could be managed for "interest generation", as a professionally managed fund, and could be used to leverage other funds, land owner participation in land protection, stewardship, restoration and repair.

d. Consider creating other incentives, including stormwater credits for developments that exceed stormwater management requirements.

e. Provide incentives for private landowners to designate conservation, riparian corridor and drainage easements, and other land protection tools. One option is a density credit system that would reward Conservation Developments by allowing developers to transfer density to other more appropriate developments. The Watershed's local governments could also reduce impact fees for developments that employ BMPs and alternative stormwater management practices.

f. Provide training for financing of development to give the confidence that conservation developments are a good investment.

g. Provide training and planning on how to do conservation design, alternative stormwater management, and natural channel restoration for engineers.

5. Habitat and Biodiversity Preservation

Finally, many of the measures described above would preserve or restore scarce habitat as well as protect streams. AES recommends that the Watershed's local governments take the following additional measures that would further enhance habitat protection and biodiversity in the County:

a. Specify that development applications include a conservation plan that protects sensitive habitats and lands and provides land management and ecological restoration recommendations.

b. Require a Natural Resource Inventory with every development application, as commonly required in many municipalities throughout the U.S.

c. At minimum, require proof of wetland delineations where required by U.S. Army Corps of Engineers, and require identification and mapping of drained hydric soils, moderate to highly permeability top and subsoil areas (>10-4 cm-sec or .5 gallons/square foot/hour), and depressional areas that may be valuable stormwater management sites. Set the threshold for identification of these soils and depressional areas as being any site that provides greater than 0.1 acre-foot of storage.

d. Require applicants to delineate forests, prairies, steep slopes (12 percent grade or more), and erosive soils; e.g. loess and silty and sandy loams.

e. Require applicants to submit map overlays that may be combined with other environmental layers such as archeological and cultural resource mapping, water table depth (in locations with high water tables), drainage features, and hydrology.

f. Wildlife habitat delineation may be optional as well.

g. Establish a "Core Natural Area Protection Plan" for the County. Map "Core Natural Areas" that would be the highest priority areas for protection. Include all drainage areas, forested blocks, prairies, wetlands, restorable wetlands, and other key natural communities.

h. Initiate or work with a local land trust to work with private landowners to protect Core Natural Areas on their land and to help landowners realize tax benefits for protecting their lands. The land trust could be partially funded with the environmental stewardship and stormwater real estate transaction surcharge fee described.

i. Design and implement demonstration projects to show functioning stream buffers and riparian corridors, Conservation Developments, alternative stormwater management practices, and ecological restoration programs.

Provide cost and performance data on these projects for use by others in the watershed and in the region.

j. Design proper and adequate training and funding for the Watershed's local governments so that staff are better able to assess the aforementioned measures.