1.0 EXECUTIVE SUMMARY

The Bonne Femme Watershed covers 93 square miles in southern Boone County, Missouri. Although the watershed is actually two separate surface watersheds (Bonne Femme and Little Bonne Femme), they are interconnected by the Devil's Icebox Cave Branch. Most of the time, all of the flow in the upper portion of Bonne Femme Creek flows through the cave, which then flows into the Little Bonne Femme, thereby completing the inter-watershed transfer of water. The watershed has several notable features, including former prairie, Ozark karst, and wooded floodplain, all shaped through geological processes relating to prehistoric oceans and glaciers. About 250 million years ago, a shallow ocean covered most of the Midwest, leaving behind extensive limestone. More recently (about one million years ago), glaciers progressed from Canada to southern Boone County. The glaciers sculpted the land and deposited till material during retreat. Prairies, savannas, and wooded streams developed in the eastern portion of the watershed over thick wind-borne soil, or loess. Karst and floodplains developed in the central, western, and southern portions of the watershed.

During the early 1800s, European settlers cleared many forests and prairies in the northern, eastern, and southern portions of the watershed for farming and livestock pasture. More recent development in Columbia and Ashland resulted in the conversion of open agricultural fields into areas dominated by houses, streets, and buildings. Land use changes described above resulted in degraded stream conditions, including channel instability and non-point source pollution. Because surface water infiltrates into many of the cave systems, it has a direct impact on the water quality and ecological condition of these distinctive karst resources.

To address these issues, concerned citizens, governmental agencies, and Boone County developed a partnership that resulted in a four-year grant titled *Land Use Planning and Water Quality Restoration in Bonne Femme Creek Watershed*, from the Environmental Protection Agency through the Missouri Department of Natural Resources. Boone County retained Applied Ecological Services, Inc. (AES) to develop the Bonne Femme Subwatershed Sensitivity Analysis as part of this grant.

Goals and Objectives

The mission of the Bonne Femme Watershed Project is to *Use watershed planning as a tool to prevent further water resources degradation in order to maintain long-term quality within the Bonne Femme Watershed.* The objectives of the project are to:

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

The scope of services for the Subwatershed Sensitivity Analysis emphasized the creation of a GIS database to be used primarily for communicating information to stakeholders, as well as for development of a watershed sensitivity analysis to be used as part of an overall watershed-based land management plan.

Analysis Approach

Existing Data were gathered, synthesized and summarized as appropriate for the watershed work. New data layers were created as necessary. Existing and new data layers were synthesized into a GIS Database.

AES completed a **Watershed Vulnerability Assessment** that included three main components:

1. AES completed a **Stream Sensitivity Analysis** based on existing and projected impervious cover, natural resource criteria, and some field verification of natural resource data.
2. AES completed a **Stream Carrying Capacity Model** based on existing and predicted flows relative to the measured cross sectional area of receiving streams.
3. AES completed a **Landscape Function Model** in an attempt to capture landscape functions not adequately represented in the Stream Sensitivity Analysis or Stream Carrying Capacity Analysis.

Using results generated from Watershed Vulnerability Assessment, AES developed a **Best Management Practices (BMP) Model** to classify the entire watershed into regions that should receive similar BMP treatments. AES then provided **Policy Recommendations** on how proposed BMPs could be incorporated into regulations.

Work described above is summarized in this **Final Report**. Instruction on how to work with the interactive models AES developed will occur during a **Technical Assistance** phase of the work that has yet to be completed.

Discussion

Watershed professionals use a variety of resources and methods to assess the health and future condition of a watershed. Topographic, geologic, soils, and meteorological data provide the basis upon which all analyses are performed. Land use and land cover are the dependent variables that change over time, and ultimately affect watershed health.

Most watershed-based models measure the rate, volume and quality of stormwater runoff as it relates to flooding. Other investigators, upon observing the correlation between impervious cover and degraded stream biota, have focused on diagnosing the health of a watershed based on the percent impervious cover. Biologists focus on the stream biota as an indicator of watershed health.

Each of these approaches has its own strengths and weaknesses. None of these approaches, in and of themselves, provide a comprehensive assessment of the overall health, vulnerability and restoration potential of a watershed.

In this study, a variety of techniques were used to obtain a deeper, more comprehensive assessment of the watershed. The ultimate goal is to develop methods by which watershed health can be preserved, protected, or restored. "Watershed health" includes biodiversity and habitat in uplands and lowlands.

Watershed Characteristic Assessment

Although base information indicates that there are two main surface drainages in the Bonne Femme Watershed that drain from east to west, these are modified because all of the flow under normal conditions in the upper Bonne Femme Creek crosses the watershed divide to the Devil's Icebox Cave Branch, which feeds into Little Bonne Femme Creek . Gans Creek, Clear Creek and Little Bonne Femme drain the northern portion of the watershed. Turkey, Bass, Smith, Bonne Femme and Fox Hollow branches drain the southern part of the watershed.

Low permeability prairie soils dominate in the upper reaches of the watershed to the east, which is primarily in agricultural land uses. More permeable woodland soils dominate the lower reaches of the watershed, which include wooded areas in steep, rugged terrain and agricultural uses along the floodplains.

Most development within the watershed has occurred at the north end of the watershed along the fringes of Columbia, and to the south along the edge of Ashland.

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 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 consist 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 material is actively being transported into these conduits, this could be impacting these sensitive systems. Cave ecosystems are particularly vulnerable to sedimentation.

Stream Sensitivity Model

The Stream Sensitivity Model uses existing and projected impervious surfaces data, 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 often beyond repair. These watershed classifications can be improved or reduced based on the implementation of BMPs.

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. The implementation of BMPs can improve a given subwatershed rank per the sensitivity model.

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. Landscape functions considered include: biodiversity, habitat, water quality, flood protection and ground water recharge. 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 and poor land management practices are prevalent. Floodplain functioning along the lower reaches of the watershed that have been converted from bottomland forest to agricultural land without proper BMPs also rated poorly. Highest quality functioning exists in the remnant woodlands along steep and rugged terrain.

Watershed Trends and Implications of the Models

1. The conversion of native prairie to agricultural uses where BMPs are not employed in the upper reaches of the watershed 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 have also led to stream degradation in the lowest reaches of the watershed.
2. The conversion of floodplain bottomland forest to agricultural uses without proper BMPs in the lower reaches of the watershed has also led to increased runoff and decreased soil stability. Most of the streams in the lower reaches are entrenched and unstable due to shear forces imparted on embankments by stream flow. This results in disconnection between the stream and adjacent floodplain. 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 degradation.
4. Karst topography plays a major role in hydrology of the watershed. The two largest caves are mapped and their recharge areas are mostly delineated. The scientific community understands karst decently, although 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.
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 Icebox 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, if approached, will occur 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.

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.

In this section, a suite of BMPs is matched to landscape characteristics within the watershed. The efficacy of listed BMPs in treating watershed stressors is also summarized.

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 (see Figure 9.1-A BMP Zones).

Headwater Pasture

General Assessment and Description – The Upper Pasture zones consist of the upper reaches of North and South Gans Creek, Upper Bonne Femme, Turkey Creek and Bass Creek. Most of this region is east of Route 63, where the topography gently rolls. Most of the land has been cleared for pasture and row crops, though estate-sized (five to 10 acres) lots are becoming increasingly prevalent. Soils range from somewhat poorly drained to drained hydric soils. Wetlands were not observed within this zone, other than narrow bands of wetland vegetation around constructed ponds.

Soil texture within the stream channels and side slopes ranges from highly erosive sand to sandy silt. Nearly all of the channels exhibit some degree of down-cutting. It appears that down-cutting and side slope erosion are most severe and active at locations where the woody riparian buffer has been replaced with pasture grass and grazed. The most stable reaches occur in areas where cattle are excluded and the woody riparian buffer remains.

Reaches transitioning from intensive grazing to estate lots are moving toward a more stable equilibrium. While transitional reaches remain down-cut – as they are likely to remain since that is where the culvert inverts are set at road crossings – active erosion of the bottom and side slopes appears to be slowing down and may eventually stop with the implementation of BMPs.

Most of the groundwater recharge areas for Devil's Ice Box and Hunter's caves occur within this Headwater Pasture zone. Thus, implementation of BMPs is very important to protecting these caves.

BMPs recommended within this zone should be strictly implemented and enforced within the recharge zones and adjacent buffer areas.

Wooded/Karst Slope

General Assessment and Description – The Wooded/Karst Slope zones occur primarily in the central and southeastern portions of the project area, including the Middle, Lower, and South Branches of Bonne Femme Creek, as well as the most downstream portions of Turkey and Bass Creeks. The topography is steep (greater than 30% slopes) and rugged at higher elevations and relatively flat within the floodplains below (floodplain habitat is discussed below under Bottomland/River Valley Floodplain). Most of the cover consists of oak hickory woodland, though some of the timber has been cleared for pasture, estate lots, and farmsteads. Upland soils are very well drained, thin, and vulnerable to erosion. Where localized gullies do occur, it appears as if the thin surficial soils are easily eroded, but severe gullying is often arrested once the gully reaches the underlying bedrock or cobble. The steepest slopes in the project area occur within this zone. This zone contains karst features usually manifested in the landscape as losing streams and wooded sinkholes. This region is the most sensitive in the watershed in terms of biodiversity and water quality.

Urban/Developed

General Assessment and Description – The Urban/Developed zones occur within the Clear Creek, Gans Creek, Bass Creek and upper reaches of the Lower Little Bonne Femme subwatersheds. Most of the existing and projected development has occurred or will occur within this region, which is at the south edge of the City of Columbia and near Ashland. The topography ranges from relatively steep to gently rolling. Cover consists of residential and commercial development particularly at the north end of this region, with pasture and timber within the steepest areas of the region. Historically, plant communities within this region would have been similar to plant communities within the Wooded/Karst Slope zones.

Some of the most severely eroded soils in the project area occur within the Urban/Developed zones. Erosion is exacerbated by heavy development pressure from

Columbia to the north and Ashland to the south. Development is increasingly spreading into the Transitional Fringe zone described below.

In general, there were few BMPs, such as detention ponds, observed in this region. However, there were at least two new subdivisions observed that use BMPs with good results. The Bearfield Meadows subdivision has wet-bottomed detention ponds and wetland pretreatment bays to detain and treat runoff prior to discharge into the creek. The receiving creek was in good condition, which we attribute to the use of BMPs in this subdivision.

The Highlands subdivision provides the best examples of BMPs observed within the project area. These BMPs included extensive use of detention ponds, grass swales with check dams, outlet protection to disperse concentrated flows, infiltration ponds, and siltation basins. Silt fences around active construction were used throughout the project, but maintenance—and presumably monitoring and enforcement—seemed to be lacking. Receiving streams were in much better condition than expected, which was also attributed to the use of listed BMPs. It should be noted that many of the observed BMPs were installed by the City of Columbia in the Forum Boulevard right-of-way below the subdivision.

Stream channel characteristics were similar to the Wooded/Karst Slope zones. Stream channel bottoms consisted primarily of cobble less than eight inches in diameter and gravel. Channel side slopes are variable but generally include cobble, silt and sands. Down-cutting appeared to be less of an issue than the lateral migration of the stream around woody debris obstructions and large cobble bars. Debris jams were common and likely play a significant role in side slope erosion.

Bottomland/River Valley Floodplain

General Assessment and Description – The Bottomland/River Valley Floodplain zones occur primarily within the Lower Little Bonne Femme, Missouri River, and Lower Bonne Femme subwatersheds. The topography is generally flat. Land uses and cover consist primarily of row crops and pasture in the bottomlands, with a few farmsteads in the hills. Historically, most of this region would have consisted of bottomland, open woodlands.

Waterways within this area have been extensively ditched and channelized. Creek erosion and entrenchment is severe, particularly in the flat bottomlands where row crops and pastures leave very little riparian buffer.

Most of the creeks within the bottomlands were severely entrenched and actively eroding. Soils on the side slopes and creek bottoms are silty. The lowest reaches of creeks within this area are influenced by water level fluctuations in the Missouri River.

Transitional Fringe

General Assessment and Description – The Transitional Fringe zone consists of undeveloped land with slopes less than 30% and non-hydric soils outside of the floodplain. This land is transitional in the landscape – situated between Wooded/Karst Slope, Urban/Developed, and Headwater Pasture – and at many locations, it is land likely to transition into a more intensive use. The topography is moderately rolling. Land cover includes pasture, row crop, and woodland.

Most of the area within this zone occurs in the upper reaches of subwatersheds where there are opportunities to detain and retain water conveyed to the channels below. Where waterways traverse this zone, the general condition of creeks resembles most closely the neighboring Wooded/Karst Slope zone or Headwater Pasture zone.

Recommended BMPs – BMPs recommended for this zone include the same suite of BMPs listed for previously discussed zones, with customization as appropriate to respond to existing or proposed land uses.

Policy Considerations and 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, including:

   a. Limiting stormwater discharges from developments to rates, volumes, and frequencies that prevent future flooding, limit erosion, and protect stream channel 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 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 that the Watershed's local governments adopt the following "Technical Policy Guideline for Stormwater Management" in all developments:

a. Require that any post-development release rates do not exceed the one-year predevelopment release rates for all storms with a frequency of greater than 10 years. Also require that 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 minimum 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 conservation 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 topsoil 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 Watershed. 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 previously 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 training and provide sufficient funding for the Watershed's local governments so that staff are better able to assess the aforementioned measures.

Conclusion

The Bonne Femme Watershed contains a plethora of important and rare natural resources including remnant woodlands, prairies, floodplain habitat, and unique karst features such as sinkholes and losing streams. Historical land use changes in conjunction with more recent development pressure have resulted in degradation of water and other natural resources.

AES was retained by the Bonne Femme Watershed Project to develop a Bonne Femme subwatershed analysis. AES assessed the existing conditions of the watershed, and developed analysis and models useful in assessing future conditions of the watershed.

The results of these models led to the development of five BMP zones that would benefit from a suite of recommended BMPs. The analysis also makes several policy recommendations appropriate for local governments within the watershed.

This Subwatershed Analysis provides the watershed planning group with tools to support decisions that will impact the Bonne Femme watershed. Existing stream degradation and opportunities for restoration are documented. Predicted degradation and opportunities for restoration based on future conditions are reported. Ultimately, the long-term health of the watershed is entirely in the hands of local communities. It is hoped that this report contributes to their ability to help protect and preserve the watershed's valuable resources.