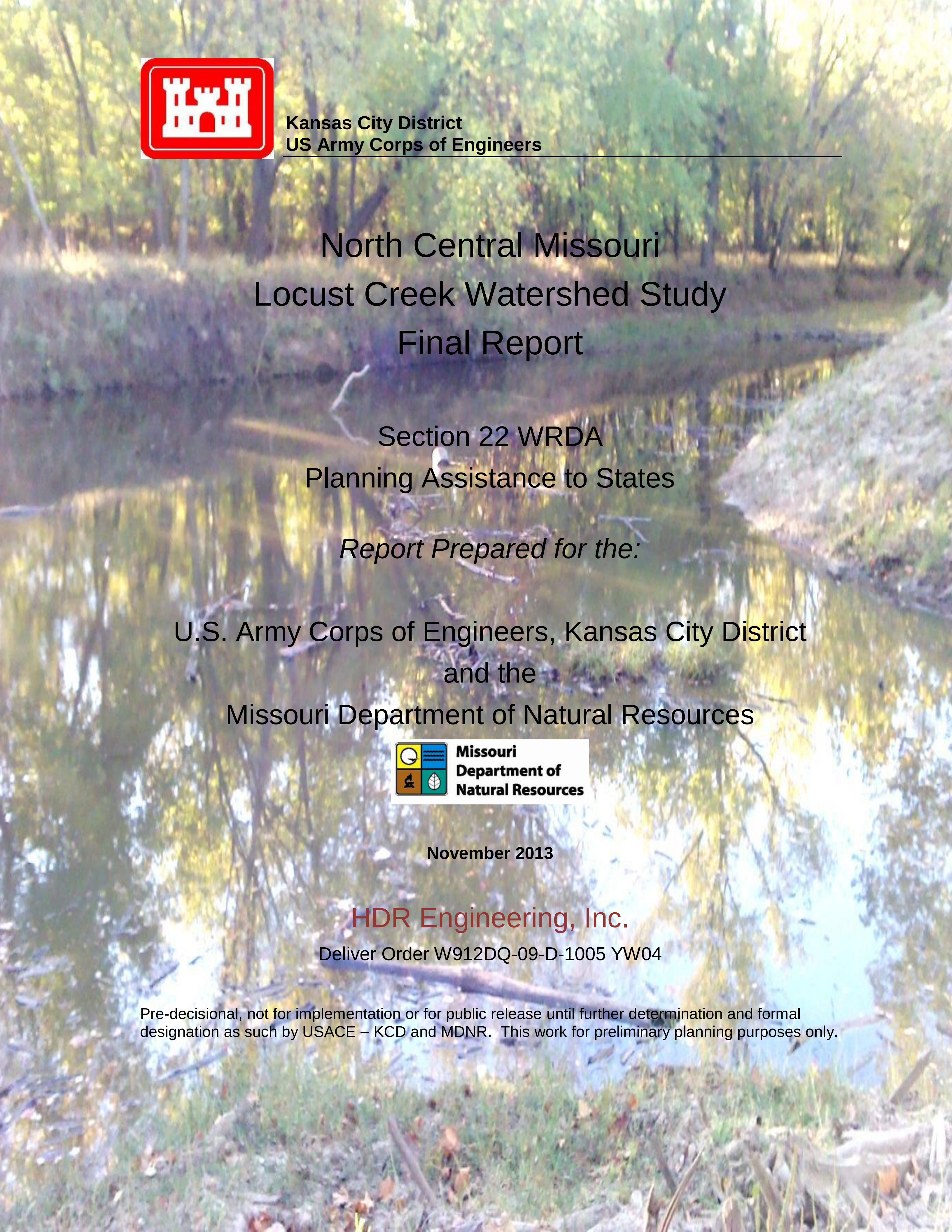


Kansas City District
US Army Corps of Engineers

North Central Missouri Locust Creek Watershed Study Final Report

Section 22 WRDA
Planning Assistance to States

Report Prepared for the:

U.S. Army Corps of Engineers, Kansas City District
and the
Missouri Department of Natural Resources

Missouri Department of Natural Resources

November 2013

HDR Engineering, Inc.

Deliver Order W912DQ-09-D-1005 YW04

Pre-decisional, not for implementation or for public release until further determination and formal designation as such by USACE – KCD and MDNR. This work for preliminary planning purposes only.

Executive Summary

The Locust Creek Watershed Study is follow-on work to a previous study that addressed a channel avulsion headcut migration and related flooding, logs and ice jams, and channel/floodplain aggradation issues on Locust Creek in Pershing State Park in north-central Missouri. Locust Creek and its adjacent floodplain through Pershing State Park, and lower Locust Creek in general, appear to be aggrading sediments, particularly sands; causing decreased channel capacity and increased flooding frequency, log and ice jams, floodplain channel avulsion development, and wetland and other natural resource damages in Pershing State Park. A large avulsion between Locust Creek and Higgins Ditch in Pershing State Park now captures most of Locust Creek's storm event flows and the avulsion was recently stabilized with rock grade controls and bank stabilization. It's likely that much of Locust Creek's sediment load now transports down Higgins Ditch, which may slow or stave off complete aggradation of the Locust Creek channel through PSP over time. In addition to Locust channel aggradation, the Lower Grand River channel is heavily levee fortified and reported to be aggrading. It has documented increases in flooding frequency and discharge from smaller events. The Lower Grand River is heavily channelized; levee confined, and contains several floodway pinch points that may be contributing to flooding and sediment transport on lower Locust Creek.

An assessment of existing conditions was completed in the Locust Creek Watershed. This included reviewing previous reports and studies, as well as conducting some preliminary desktop analysis of stream bank erosion, channelization, levees, riparian buffer, and land use. Bank erosion, channelization and levees are extensive in certain areas throughout the watershed, particularly lower Locust Creek. A Relative Potential Loading analysis for sediments was conducted throughout the Locust Creek Watershed to describe how and where sediment is generated (and mobilized) on the landscape and transferred to channel reaches. The analysis examined the relationship between watershed land cover, its effects on cattle movement within riparian areas, stream buffer density and stream channel capacity to either move or store sediment. This Relative Potential Loadings analysis helped identify potential sediment Critical Source Areas, preliminary Best Management Practices, and potential non-contributing sediment source areas. In addition, a Sensitive Stream analysis was conducted to determine potential sediment source/transport streams versus sensitive (or response) streams that are likely aggrading in the watershed. Problems in the Locust Creek Watershed and potential contributing problems in the Lower Grand River are best summarized as follows:

- Land use, particularly cattle overuse of woodlands and/or riparian buffer in the summer for shade, are likely contributing excessive sediments, through gully erosion, to receiving waters and transporting sediments downstream causing aggradation.
- Channel morphology on Locust Creek and tributaries above Pershing State Park are still adjusting from past channelization and levee confinement. Channel bank and bed erosion resulting from high flow events help re-adjust channel morphology, but likely contributes to aggradation as negative side effect.
- Levee confinements on Locust Creek and tributaries have reduced floodplain function as the ability to diminish energy during high flow events is lost. In addition, lost water and sediment storage capacity functions have resulted.
- Loss of floodwater drainage conveyance capacity from the Hwy 36 fill embankment across the Locust Creek floodplain.
- Potential backwater flooding and sediment transport issues from the adjacent Lower Grand River watershed that drains Locust Creek and its potential effects on Locust Creek flooding and channel bed aggradation.

Ten preliminary goals were established for the Locust Creek Watershed and Lower Grand River. Then, a complete suite of Watershed Actions and Practices were evaluated for feasibility and achievement of goals and then further refined. These Watershed Actions and Practices included Soil and Water Best Management Practices, Floodplain Restoration, Stream Restoration, Floodway Drainage Improvements on the Lower Grand River at Hwy 139/BNSF embankments, Lower Grand River Floodway and Levee System Modifications, On-Going Natural Resource Management, Agency Partnerships and Programs, Public Awareness and Education, and Organizational Structure Establishment. Current restoration projects were also reviewed.

Five action alternatives were developed. The Locust Creek Watershed Alternative focuses on implementing several Best Management Practices to include off-channel cattle management (shade), adding riparian buffer, and improving existing woodland/shrubland, with priority preference to implement Best Management Practices in pasture/hayland and/or cropland sediment Critical Source Areas. In addition to Best Management Practices, this alternative also emphasizes addressing problematic eroding channel bank hot spots, head cutting, stream channelization, and levee confinement issues. It is recommended that these issues should first be focused on the levee confined reach of lower Locust Creek above Pershing State. Then efforts should move upstream further on Locust Creek and into West Locust Creek. The Pershing State Park Alternative is intended to help preserve and restore remaining high value wetland resources at PSP by more effectively managing high flow events and sediment distribution. This alternative focuses on stream restoration/drainage and habitat improvements in the northern section of Pershing State Park around the Hwy 36 corridor. The Lower Grand River Hwy 139/BNSF Floodway Drainage Improvements Alternative and the Lower Grand River Floodway and Levee System Modifications Alternative consider addresses flooding and potential sediment transport issues through major floodway pinch points in the Lower Grand River floodway with modifications to various transportation and water resource infrastructure. The Systemwide Combined Alternative (the Recommended Alternative) is essentially a program level effort that combines the four previous action alternatives into a systemwide approach of major projects to better manage soil and water resources in the Locust Creek Watershed and portions of the Lower Grand River.

Major data analysis gaps were identified in this preliminary planning study. Strategic prioritization of the Systemwide Combined Alternative work activities and implementation were addressed. Planning level cost estimates were made. Major projects of the Systemwide Combined Alternative were matched with potential funding sources. An implementation strategy was developed that matches prioritized work activities and implementation with funding sources. The local sponsor (or other watershed based organization) should consider using cost-share dollars for studies and evaluation initially if available to further analyze watershed issues, while concurrently evaluating in more detail the establishment of an in-lieu fee or mitigation banking program for sites in the Locust Creek Watershed (including Pershing State Park) and/or Lower Grand River.

Table of Contents

List of Tables

List of Figures

Appendices

List of Commonly Use Acronyms and Abbreviations

139/BNSFFDIA - Hwy 139/BNSF Railway Floodway Drainage Improvements.
BMP - Best Management Practices
Corps - U.S. Army Corps of Engineers
CSA - Critical Source Area
ELC - East Locust Creek
EPA - Environmental Protection Agency
EQIP - Environmental Quality Incentives Program
EWPP - Emergency Watershed Protection Program
FGCA - Fountain Grove Conservation Area
GOE - Garden of Eden Levee
GOELD - Garden of Eden Levee District
GRA - Great River Associates
GRP - Grassland Reserve Program
HB - Hickory Branch Creek
HD - Higgins Ditch
HRU - Hydrologic Response Unit
HUC - Hydrologic Unit Code
ILF - In-lieu Fee
LC - Locust Creek
LCDD - Locust Creek Drainage District
LCW - Locust Creek Watershed
LCWA - Locust Creek Watershed Alternative
LCWS - Locust Creek Watershed Study
LGCOA - Lower Grand Conservation Opportunity Area
LGR - Lower Grand River
LGRFLSMA - Lower Grand River Floodway and Levee System Modifications Alternative
LLC - Lower Locust Creek
MB - Mitigation Banks
MC - Muddy Creek
MDC - Missouri Department of Conservation
MDNR - Missouri Department of Natural Resources
NCMRWC - North Central Missouri Regional Water Commission
NRHP - National Register of Historic Places
NRI - National Park Service Nationwide River Inventory
OC - Overflow Channel
PSP - Pershing State Park
PSPA - Pershing State Park Alternative
RPL - Relative Potential Loading
SCA - Systemwide Combined Alternative
SS - Stream Sensitivity
SWCD - Soil and Water Conservation Districts
USGS - U.S. Geological Survey
WAP - Watershed Actions and Practices
WCLC - Watkins Creek - Locust Creek
WLC - West Locust Creek
WPFPP - Watershed Protection and Flood Prevention Program
WRP - Wetland Reserve Program

1.0 Introduction

1.1 Study Location and Area

The Locust Creek Watershed (LCW) originates in extreme south-central Iowa in Wayne County, with most of the watershed located in north central Missouri (Figure 1). The LCW is contained within the larger Lower Grand River (LGR) HUC-8 watershed boundary (Figure 1). In Missouri, the LCW is located in Putnam, Sullivan, Linn, and Chariton Counties. Local communities in the LCW include Milan, Brookfield, Laclede and Linneus.

1.2 Study Background and Issues Overview

The Locust Creek Watershed Study (LCWS) is, in part, follow-on work arising from a 2011 study by Great River Associates (GRA) entitled *Geomorphic Engineering Assessment – Pershing State Park* developed by GRA under contract to Missouri Department of Natural Resources (MDNR). That study considered a watershed stability alternative, which was not ultimately the recommended alternative plan, but was considered support for the recommended plan. GRA's primary focus of the study was determining causal factors and potential solutions for a major floodplain channel avulsion head cut migration issue threatening Locust Creek (LC) in Pershing State Park (PSP). The study addressed potential degradation consequences of a head cut migration, as well as related flooding and floodplain issues in PSP. Specifically, it provided engineering and geomorphologic analysis of related channel and floodplain aggradation and floodplain avulsion head cut migration. While avulsion stabilization measures recommended in the study and now constructed in PSP (completed summer 2012) have mitigated immediate risks, there is still some chance that existing minor avulsions could expand or new avulsions to form, and head cut up LC and tributaries. The GRA study estimated the potential resultant soil loss effects of a major head cut up LC from erosion to be between 650,000 and 1,570,000 tons/year of sediment, with the dominant sediment source as bank erosion at 78-90%. There is increasing collective concern by landowners, elected officials and government agencies to address not only localized problems at PSP, but to address broader issues on watershed basis. The following sections below (1.2.1 through 1.2.5) provide detailed background and issues overview.

1.2.1 Log Jams on Lower Locust Creek Public Lands

For nearly 20 years, Missouri Department of Natural Resources (MDNR) staff have encountered and removed multiple log jams in the Lower LC (LLC) channel running through PSP upstream and downstream of U.S. Hwy 36 (Hwy 36). Winter ice jams are also a problem in PSP. Figure 2 is a photo of a typical log jam in LC and Figure 3 shows mapped PSP log jam locations and extents. The U.S. Geological Survey (USGS) reported that since the Great Flood of 1993 and succeeding floods, LC has been repeatedly choked with log jams in or near PSP (USGS, 1997). Files (2012) reported that as result of the Great Flood of 1993, much upstream bank erosion and tree loss occurred and began to accumulate in the LC stream meanders inside PSP. The earliest detailed log jam information available for review was a log jam in 1999 in PSP that was reported to have been over 6,000 feet long. U.S. Army Corps of Engineers (USACE) Regulatory Branch memos indicate Section 404 permits were issued prior to 1999 for log jams in PSP just south of Hwy 36. In addition to MDNR issues at PSP, Missouri Department of Conservation (MDC) staff at nearby Fountain Grove Conservation Area (FGCA) dealt with a log jam and sediment aggradation problem in LC and Hickory Branch (HB). Between MDNR and MDC, over one dozen Clean Water Act Section 404 permits for log jam/sediment removal have been issued.

Figure 1: Locust Creek Watershed Study Area

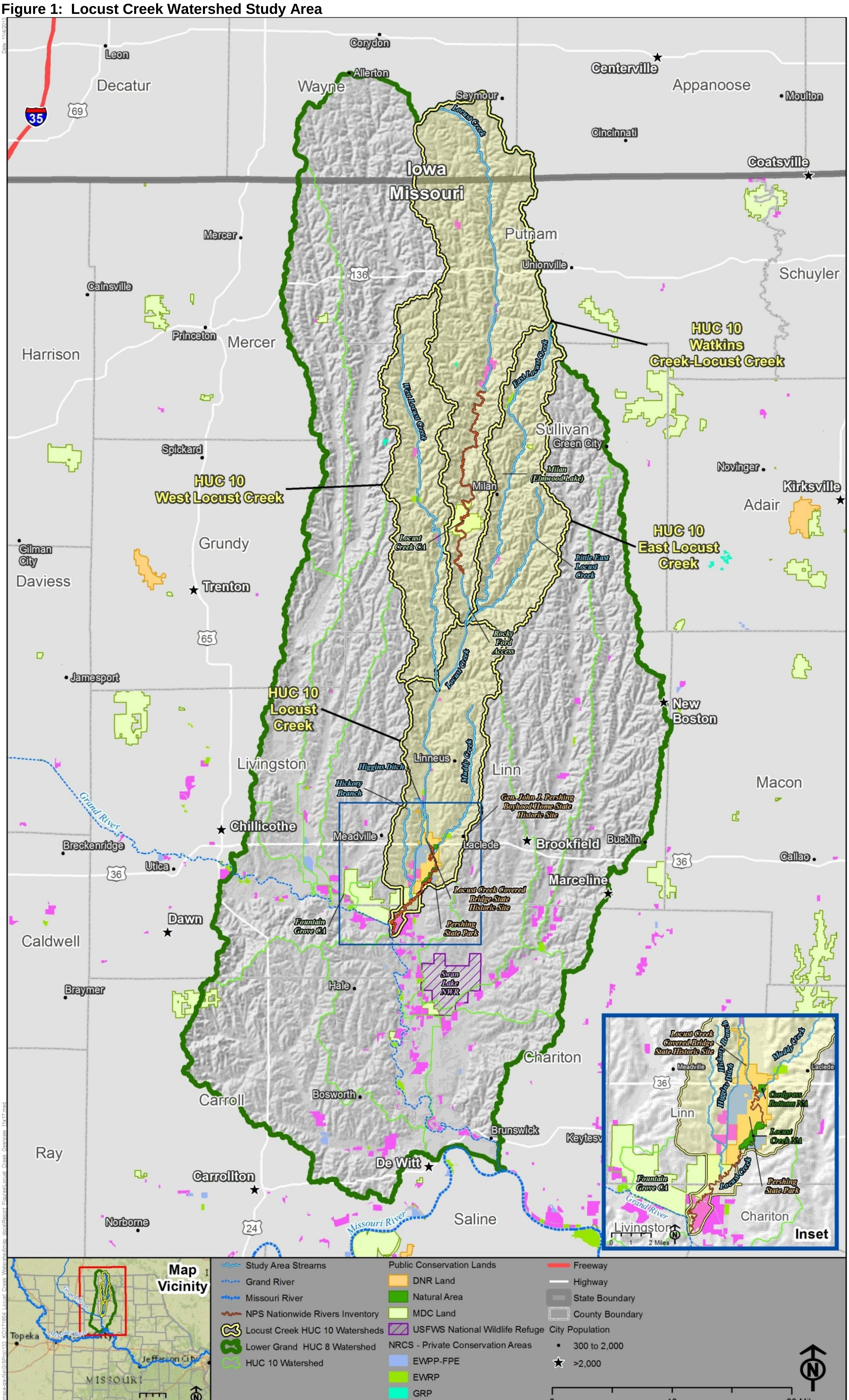
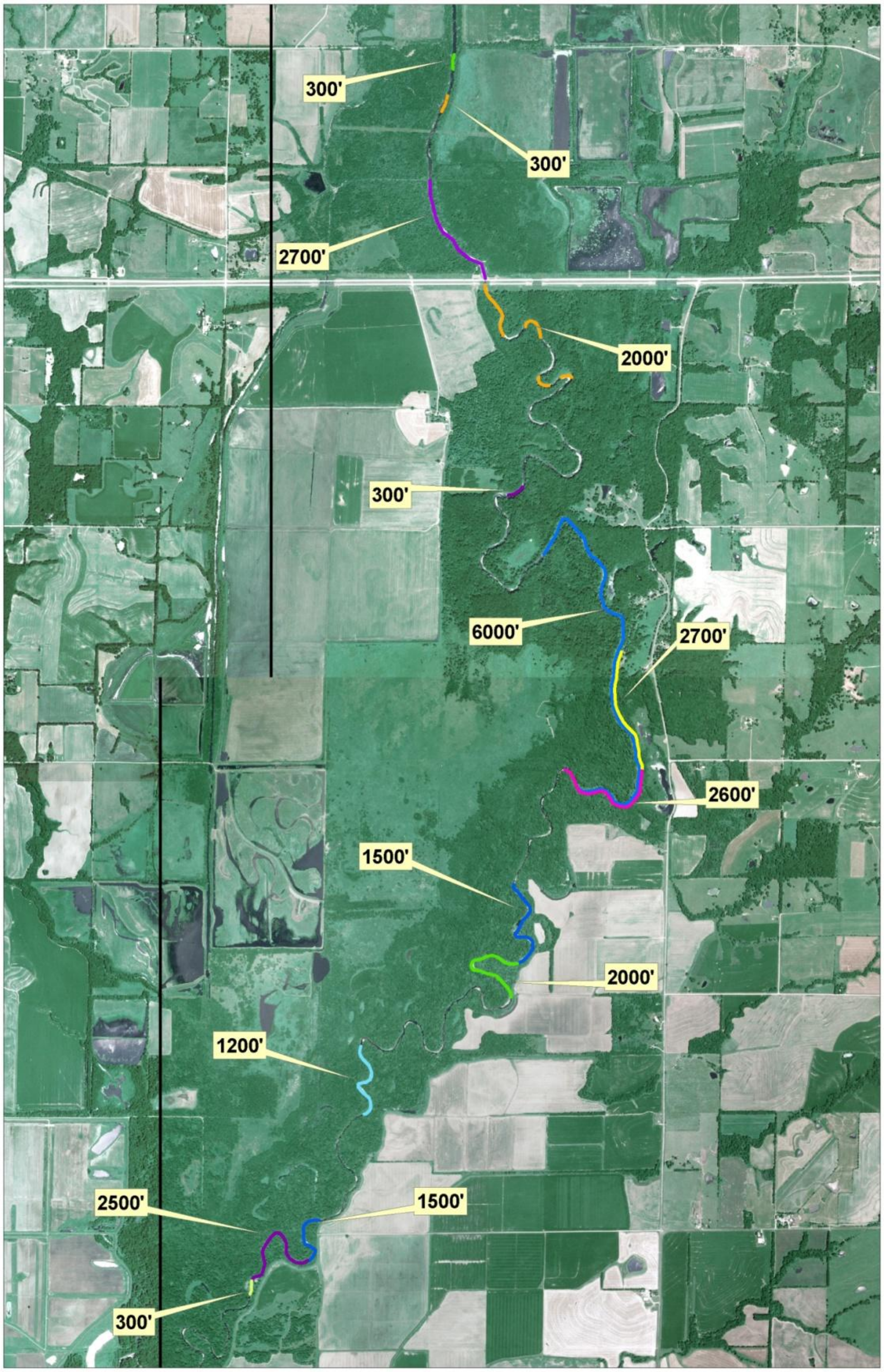


Figure 2: Typical Log Jam in LC

Photo provided by U.S. Army Corps of Engineers, Kansas City District.

Figure 3: Log Jam Locations and Extent Inside Pershing State Park



Graphic provided by U.S. Army Corps of Engineers, Kansas City District.

1.2.2 PSP Locust Creek Channel/Floodplain Aggradation and Flooding Issues

A resultant effect of log jams in PSP and vicinity is the aggradation (sedimentation) of coarse and fine bed materials in the LC channel bed and other nearby drainages. Evidence of this can be seen by increasing channel bed elevations anywhere from about 2 to 4.5 feet since 1974 (GRA 2011) as shown in Figure 4. Bed elevations in LC, Higgins Ditch (HD), the Overflow Channel (OC), and Muddy Creek (MC) along Hwy 36 have all generally increased. GRA (2011) did a theoretical sediment transfer model analysis in LC for 2,000 feet above and below Hwy 36 and assumed sand to be the largest sediment particle to transfer. They estimated that near bankfull or larger flow events were likely needed to transfer fine and medium sand particles, while coarse sand particles had the potential to not be transferred through the study reach. Therefore, GRA concluded bed aggradation of coarse sediments would be the likely consequence, with reduced in-channel water flow capacity and sediment transfer capabilities due to aggraded conditions. This makes it more likely that aggraded sediment can't be scoured and transported effectively downstream in a balanced sediment transport system that neither aggrades nor degrades a stream channel. GRA indicated in their 2011 study that as sediment is continually aggrading and transporting more slowly in LC, channel capacity is lost. Water from both larger less frequent flood events and more frequent smaller flood events creates risk for re-distributing flood flows into avulsion hazards. GRA also speculated that levees along the channelized reach of LC confine the transport of excess sediment and woody debris, thus limiting the ability of flood water's to deposit in adjacent floodplain areas.

Figure 4: Channel Elevation Morphology at Highway 36

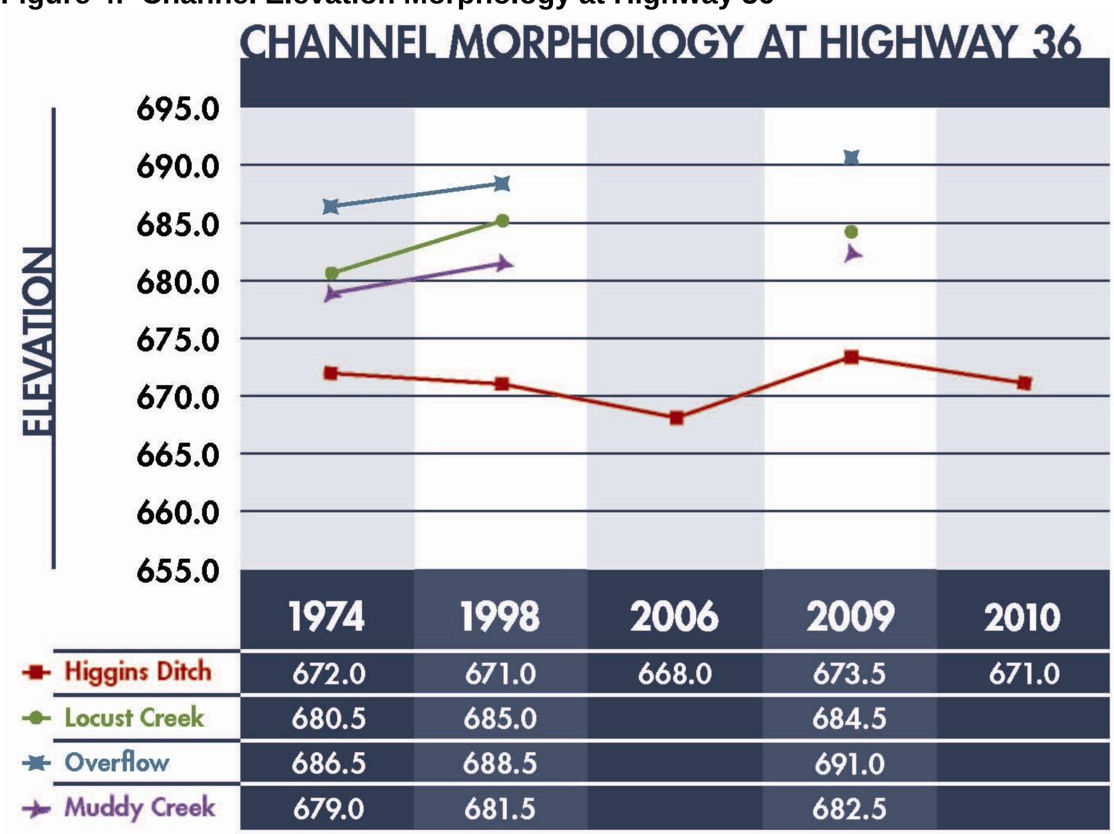


Figure taken from "Geomorphic Engineering Assessment – Pershing State Park" prepared by Great River Associates.

In addition to channel aggradation, floodplain aggradation is occurring along LC as documented by GRA (2011) and shown in Figure 5, a LiDAR topographic survey of the LC valley around

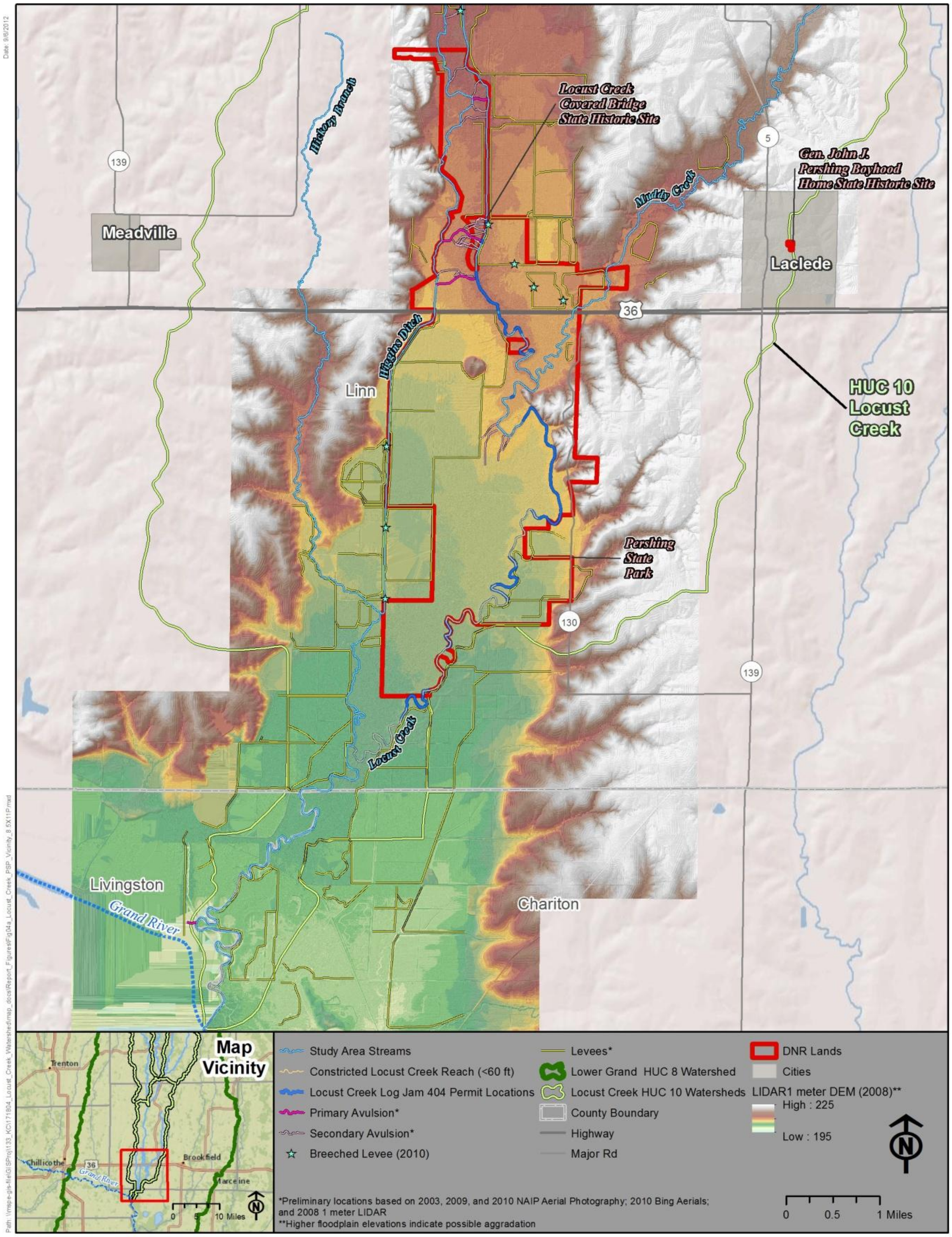
PSP and U.S. Hwy 36. In Figure 5, the floodplain elevation immediately adjacent to LC is higher than floodplain elevations further away from LC, particularly north of Hwy 36. Within PSP, significant water resource impacts (i.e. loss of flow and wetland filling), vegetation damages, and vegetation community changes have occurred as a result of aggradation. The reach of LC draining through PSP is noted for being the last intact and undisturbed high quality stream, with very high quality and diverse riparian and floodplain wetland vegetation communities, in northern Missouri. This reach of LC remains un-channelized and meanders extensively across the floodplain. Many acres of high quality native mature forested, scrub-shrub, emergent and wet-mesic prairie wetlands and riparian area communities, particularly in the northern end of PSP, have become covered and filled in with several feet of sediment. There is significant mortality of bottomland hardwood trees which may be the result of sediment deposition and/or prolonged floodwater inundation. State park officials and Dr. Joe Ely (University of Central Missouri – Warrensburg) have indicated qualitative observations of plant species diversity declining in wet prairie meadows over about the last decade (Fobes, 2012). Tom Woodward (PSP Superintendent) reported at a July 2012 Grand River Conservation Opportunity Area (GRCOA) Watershed Seminar that flooding through PSP has become increasingly worse and more persistent due to channel bed aggradation, such that smaller rainfall events (~ 1 yr. storm), can cause significant overbanking and flooding along LC (Fobes, 2012a). Channel flow capacity in LC has been greatly reduced.

GRA (2011) documented increased LC flooding and floodplain flow over the past 12 years, as several documented repetitive and large natural flood events occurred in the LCW. These events have likely contributed to the de-stabilization of the channelized and partially levee-confined reach of the LC channel upstream of PSP resulting in widespread channel bank erosion, abrupt channel migration, and downstream sediment transfer. An initial online aerial photography review of this 20 plus mile long reach confirms excessive bank erosion, bank sloughing, and inner bend channel sediment deposition. There have been seven 10-year flood events and three 50-year flood events on LC since 2000 (GRA, 2011) based on U.S. Geological Survey LC gage (#06901500). GRA (2011) reported a comparison of the previous approximately 50 year LC gage record in which only three 50-year and seven 10-year events occurred. These larger and more frequently occurring events probably contributed to excessive bank erosion, sediment deposition, and log jams. Flood conveyance restrictions caused by the Hwy 36 fill embankment are a concern. Several drainage conveyance structures under Hwy 36 have lost capacity or are non-functioning due to several feet of channel and floodplain sediment aggradation. The Hwy 36 fill embankment probably compounds aggrading conditions by acting as a significant barrier to effectively pass flood water and excess sediment. This barrier is somewhat offset now by five recent levee breaches near Hwy 36 and east of LC (Figure 10).

1.2.3 Grand River Related Drainage and Flooding Issues on Locust Creek

In addition to flooding increase concerns at PSP, MDNR and MDC staff has reported concerns of increased Grand River backwater flooding at its confluence with LC and Yellow Creek. Some have indicated this could be contributing to the LC channel bed aggradation. MDNR staff member Tom Woodward reported the channel width of LC near the confluence of the Grand River is about 35 feet wide, or half the width of the channel a few miles upstream inside PSP where it's 65-70 feet wide (Fobes, 2012b). This may indicate channel and floodplain aggradation are occurring from Grand River backwater issues. Heitmeyer (2011) provided

Figure 5: Floodplain Aggradation and Channel Avulsions - Pershing State Park Vicinity



compelling evidence and documentation of increased flooding on the LGR below LC and above Yellow Creek confluence with the Grand River in the vicinity of Sumner, Missouri.

1.2.4 Locust Creek Floodplain Channel Avulsions in PSP

In addition to log and ice jams, MDNR staff have observed within the last five to seven years the development of one large and several minor erosive floodplain avulsion channels (Figure 5) into HD (a man-made drainage ditch) located just west of LC and north of Hwy 36). It appears that increasing aggraded floodplain surfaces created slope gradients from higher elevation areas near the LC channel to lower elevation areas further west near HD (GRA, 2011). These increasing slope conditions, combined with lost floodplain storage capacity, are ripe conditions for surface soil erosion and avulsive channel formation during high flow events that can abruptly or eventually lead to recapturing low and high flows. In the LC valley in and around PSP, floodplain aggradation (Figures 5 and 6) is occurring. Large and small avulsions have resulted small and large channels in the floodplain (see Appendix A for detailed locations). Typically avulsions are an indicator of an increase in concentrated floodplain flows (GRA, 2011). Log jams, and channel and floodplain aggradation collectively appear to cause decreased LC flow capacity, and have effectively re-distributed most of it and its flow distribution through the main channel avulsion into HD. LC is now a multiple channel system. Figure 7 is a snap shot showing changes in flow capacity conditions between 1997 and 2010. LC went from carrying about 3000 cfs in 1997 to 235 cfs in 2010. The main avulsion now carries the majority of high flow events. Figure 8 shows the flow distributions from 2000 and 2010. Higgins Ditch is scouring and widening as a result of significant flow increases as confirmed on aerial photography from Hwy 36 going downstream.

1.2.5 Avulsion Strategies

In order to prevent the complete loss of LC flow from avulsion and a catastrophic head cut migration up LC, MDNR installed three rock riffle three grade control structures on the largest main avulsion channel in the floodplain connecting LC to HD in 2007 (Figure 9). In addition, in 2009 five levee notches (breaches) were constructed east of the main avulsion to provide additional flood water relief, sediment storage, and drainage to Muddy Creek. As of July 2012, MDNR completed improvements and repairs to the main avulsions original three grade controls; as well as constructed additional grade controls, rock sills, and longitudinal fill stone toe protection on the main avulsion, smaller avulsions, and within HD (Figure 10) designed by GRA. GRA (2011) stated that should a head cut develop, the structural barriers in place should stop channel bed erosion, migration and grade changes that could lead to a potentially catastrophic migration of a head cut up through LC. A head cut migration up LC would likely cause catastrophic soil, land and tree loss from bed and bank erosion, infrastructure damages (e.g. bridges and utility lines), worsening channel and floodplain aggradation, stream and wetland losses and other natural resource impacts from sediment deposition, and ground water table lowering.

1.3 Purpose and Scope of Report

Based on the background provided in Section 1.2, the purpose and scope of the LCWS is to provide watershed planning for purposes of identifying watershed problems and restoration opportunities. For restoration opportunities the study evaluates various conceptual restoration actions and alternatives; implementation strategies; and planning level cost estimates.

Figure 6: Hwy 36 Corridor Floodplain Topography Indicating Aggradation (PSP Area)

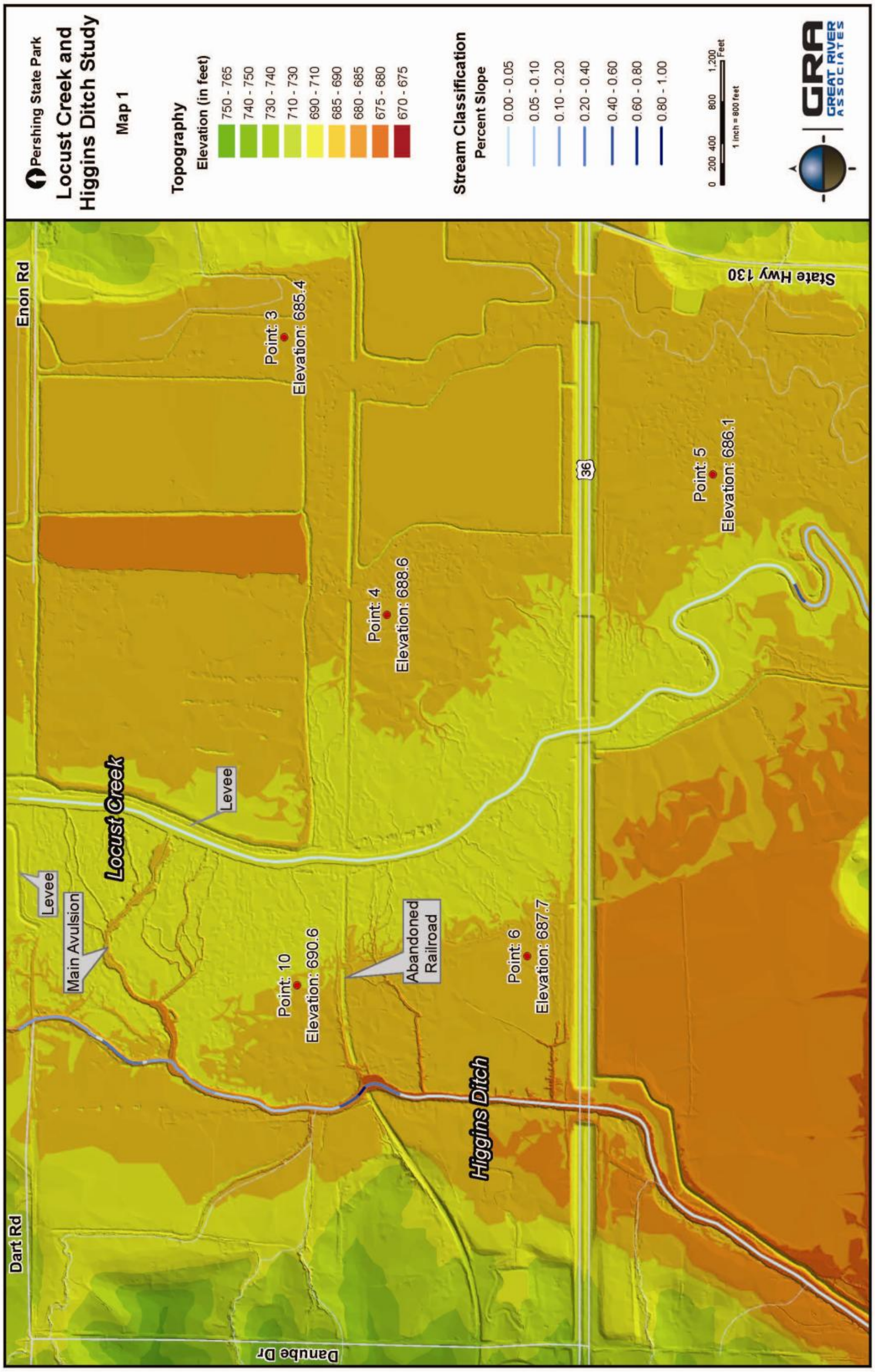


Figure taken from "Geomorphic Engineering Assessment – Pershing State Park" prepared by Great River Associates.

Figure 7: Locust Creek Flow Capacity Before and After Avulsion (ca. 2007) by Year

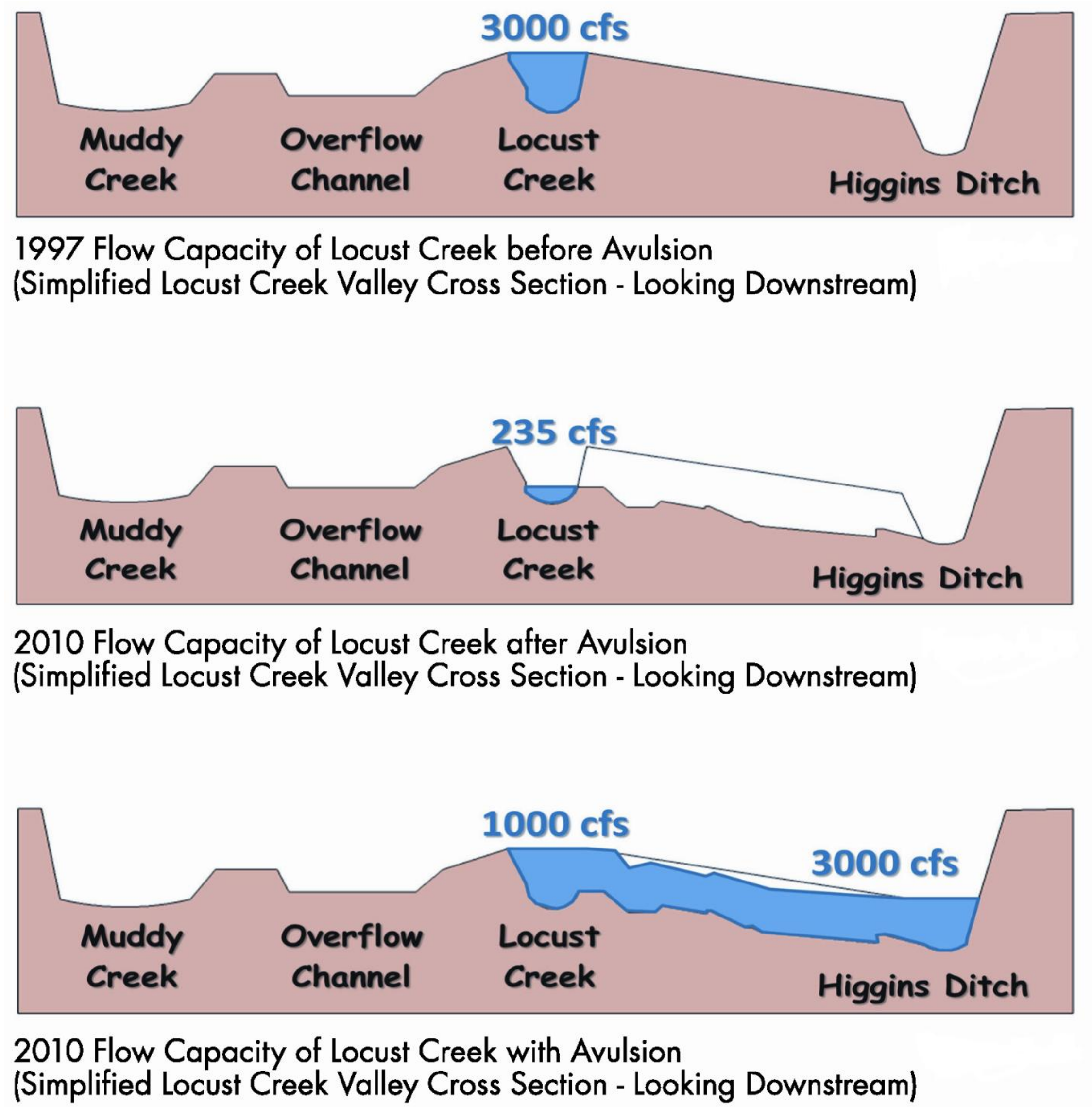


Figure taken from "Geomorphic Engineering Assessment – Pershing State Park" prepared by Great River Associates.

Figure 8: 2-Year Event Flow Distribution in the Locust Creek Valley

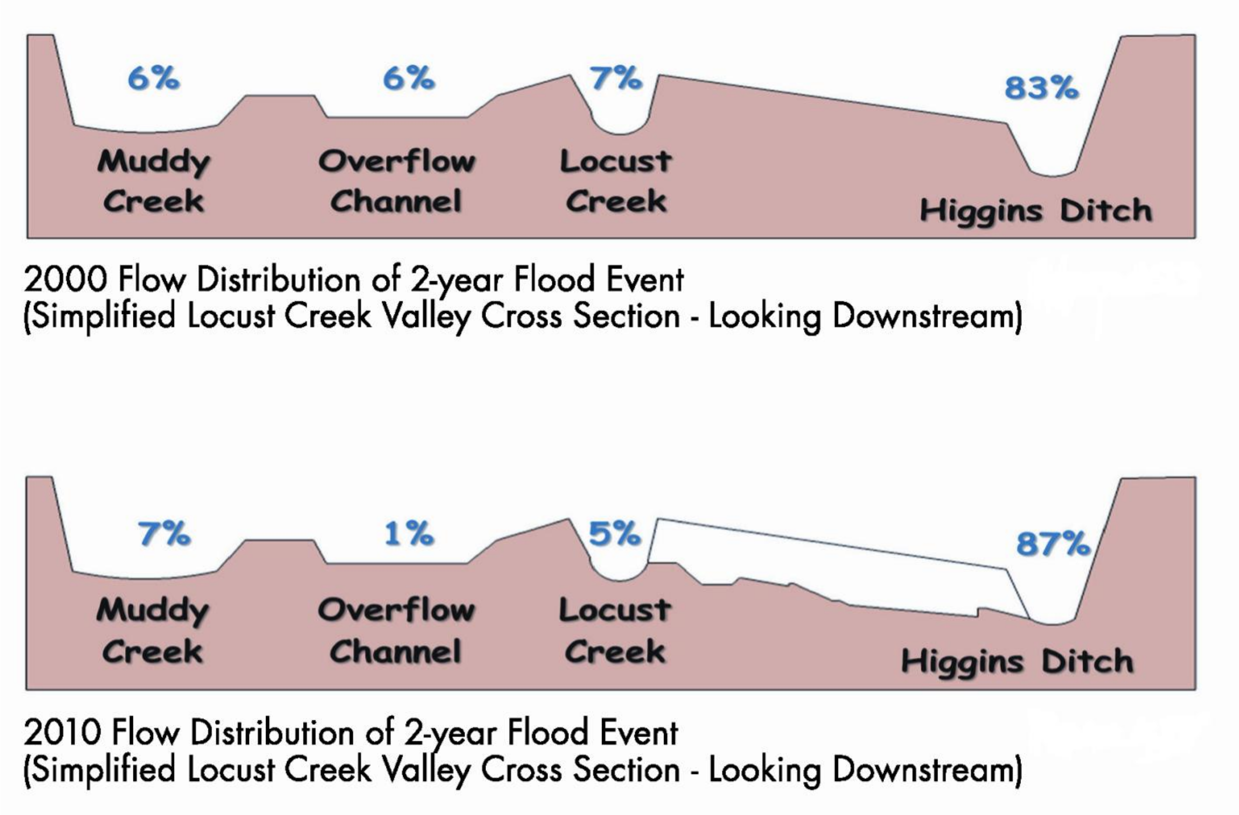


Figure taken from "Geomorphic Engineering Assessment – Pershing State Park" prepared by Great River Associates

Figure 9: 2007 Phase 1 Avulsion Measures - Grade Controls & Levee Notches

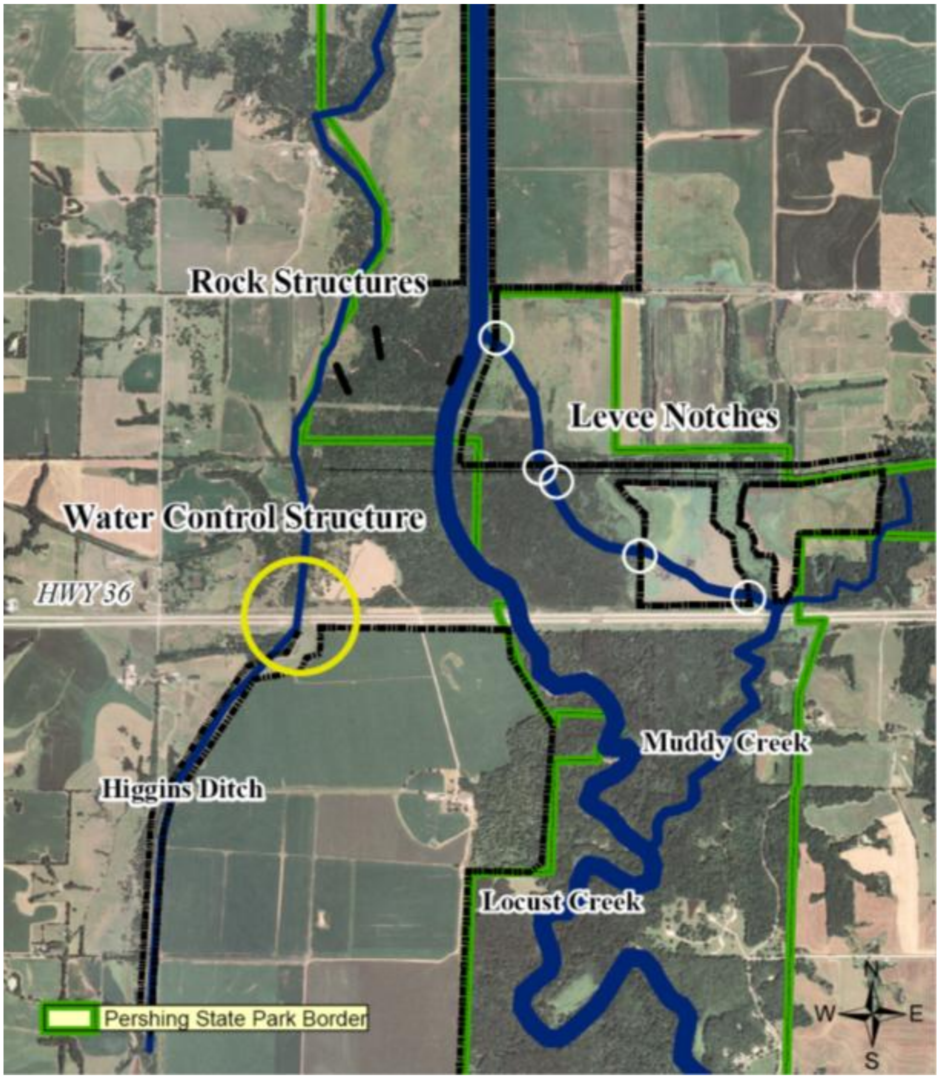
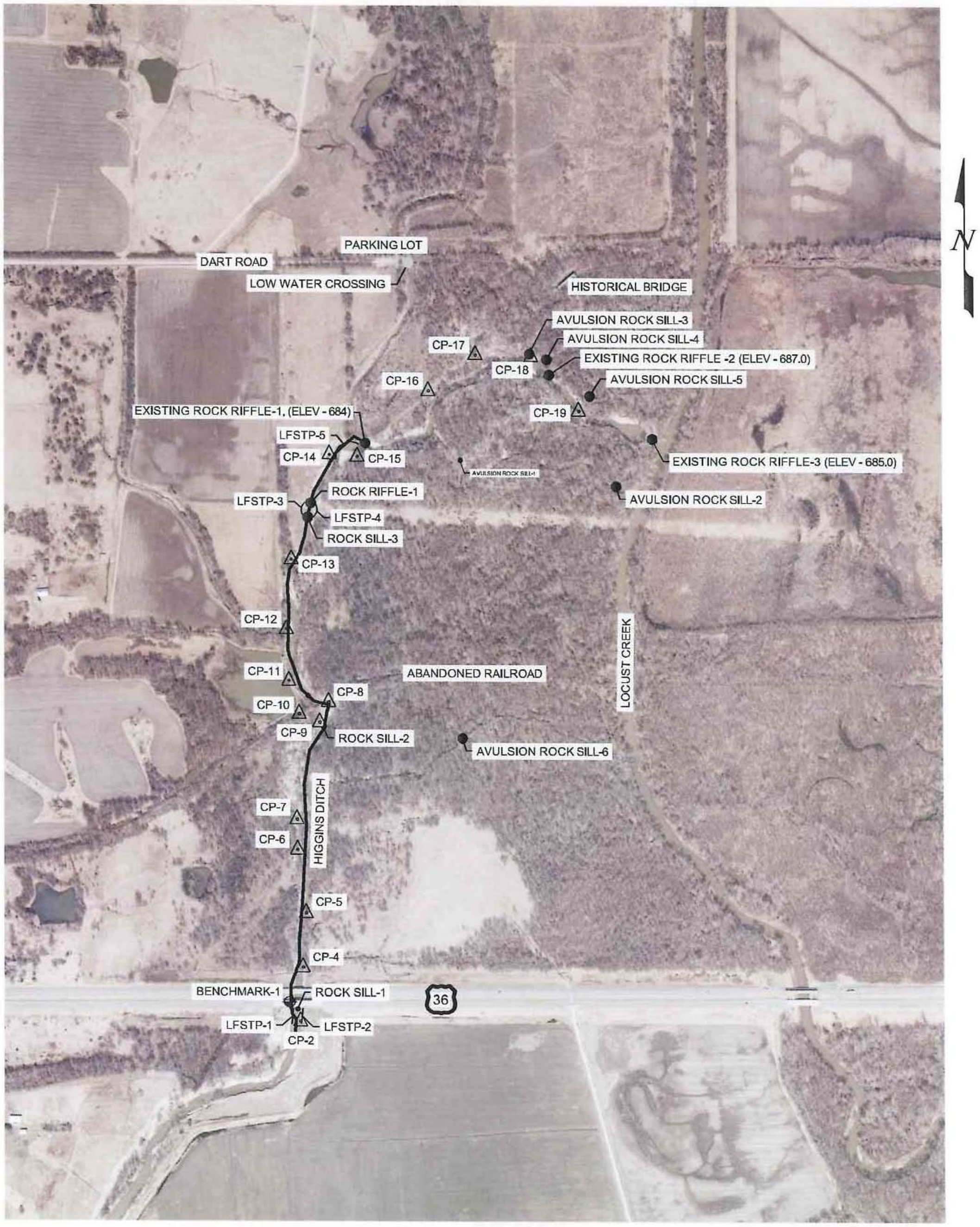


Figure taken from MDNR presentation prepared by Tom Woodward.

Figure 10: 2012 Phase 2 Avulsion Measures - Grade Control and Bank Protection



GRA
GREAT RIVER ASSOCIATES
1598 IMPERIAL CENTER, SUITE 2010
WEST PLAINS, MO 65775
PHONE: (417) 886-7171 FAX: (417) 886-7591
www.greatriv.com

Missouri Department of Natural Resources

Figure taken from "Geomorphic Engineering Assessment – Pershing State Park" prepared by Great River Associates

1.3.1 History of Watershed Development

Historical accounts summarized by MDC's Greg Pitchford (Pitchford, 2012) on the Grand River basin, which includes the LCW, indicates much of the watershed consisted extensively of upland and wetland prairie, with timbered ridge tops and stream valleys. Extensive settlement of the Grand River region started after 1830. Most of the LCW has been developed to support primarily agricultural land uses such as cropland, grassland, and some forest, with very limited urban development. According to the *Locust Creek Basin Management Plan* (MDC, 1994), much stream channelization has occurred within the LCW. MDC reported that the mainstem of LC was originally about 123 miles long, but by 1979 only 51 miles remained un-channelized. The remaining 72 miles were either eliminated (~ 23 miles) or channelized (~ 49 miles). The following is a partial synopsis of LC's history and development as prepared by MDNR staff Dan Files (Files, 2012).

> *Like most streams in Missouri, the meandering 123 mile long LC played an important role in the settlement of the state. The 1882 History of Linn County (pg. 152) mentions the "LC Country, a hunter's paradise of prairie, woods and wetlands." In 1878, the Woodland Mill, built on the bank of LC near the crossing of the Chillicothe / Brunswick Trail, provided a place for transforming wheat and corn into flour and meal for the local farmers. The mill and dam was an attractive recreation spot. It provided a place to trade goods and swap stories with others while waiting for the grain to be processed. General John J. Pershing, in his youth, often visited the millpond and hunted along the stream in what is now Pershing State Park. In the 1912 History of Linn County, a different view is taken toward LC. On page 249, there is mentioned an effort to drain approximately 25,000 acres and raise the value of land from $30/$60 dollars an acre to $150/$200 dollars an acre. The landscape, considered a paradise 30 years previously, was now a hindrance to agriculture.*
>
> *The LC Drainage District was formed shortly thereafter and a tax was levied on landowners to allow for construction of the new channel. The project, started in 1922, took 18 months at a cost of $325,000 to ditch 23 miles of stream and create a new LC. By 1979, LC had 72 miles of channelized stream. The LC Drainage District still taxes he landowners along the stream but is regulated by the Corps of Engineers in the type of work allowed in the channel.*

Historical newspaper articles published in the *Laclede Blade* newspaper in 1935 and June 1942 were made available by Dan Files with MDNR. The 1935 (Laclede, 1935) article mentions the completed construction of the LC Drainage Ditch beginning in Sullivan County and extending south to Laclede, Missouri. The article also states the following:

> …."*the farmers on the lower end were unable to complete the ditch and therefore the drainage project is jeopardized. The article further goes on to mention the completed LC Dr*ainage Ditch was "*filling up rapidly, growing shallow and wide, causing bridges to be inadequate and the water is spread over the bottoms*.
>
> *The original width of the ditch was near thirty feet. It is now in places two hundred feet. It is for this reason there is general cause for alarm. Before the ditch was dug, it was estimated that the distance from the point of origin to Grand River, following the old bed of the Creek, was approximately three hundred miles, while an air line distance is but seventy miles.*
>
> *The unfinished portion of the ditch, from a point west of Laclede to Grand River, is about nine miles, while the regular course of the old channel is approximately forty miles. Such a condition retards the flow and results in back-up and overflow.*

> *The plan as outlined by Captain Walsh of the War Department, is to do this much needed improvement under the relief program. A drainage district will have to be organized to meet government requirements".*

The 1942 article (Laclede, 1942) discusses a meeting held in Laclede that was hosted by L.F. Moore, director of Pershing Park Association, and attended by landowners, elected officials, government and industry officials, to discuss further plans and progress to control flooding on LC southwest of Laclede, MO. The article indicated the war department (presumably the USACE), was in process of preparing a report on "…*a survey for flood control of Grand River and its tributaries.*" There was apparently strong interest at the meeting amongst all parties, including friends and supporters of PSP, to get immediate assistance from the federal government to provide flood control. The article indicated the war department wrote a letter to the local park association indicating it would be economically justifiable to provide flood control extending the LC Drainage Ditch from "….*the existing ditch near the C.B. & Q. railroad bridge and the mouth of the creek"*.

Files (2012a) also provided written email correspondence regarding the history of HD, a drainage ditch west of LC. Mr. Files indicated that he'd personally seen a drawing or print in the past indicating a "*Department of the Army*" or "*COE Proposed Drainage Route"* that would be extended south of Hwy 36, bending to the southwest, and then continuing straight south. Mr. Files indicated no drainage district was ever formed, nor was the drainage completed to connect with LC, but it now connects to HB, a tributary to LC. Mr. Files further indicated that reports from local people with knowledge of past landowners, including locals with knowledge of Higgins (for which the ditch is named) and a past landowner, had "*tied into the railroad drainage above Hwy 36 and continued it south based on the government proposal*". Locals also told Mr. Files that HD was constructed "*with a team of horses and slip or dirt scope*". In summary, HD appears to have been a relatively small drainage channel project constructed by the locals. The complete channelization of LC from near the now abandoned C.B. & Q. railroad going south was never accomplished and had no federal government funding support.

For the last four decades, multiple local project sponsors with support from the U.S. Department of Agriculture - Natural Resources Conservation Service (NRCS) have been in process of planning and constructing small and large reservoir projects for purposes of flood control, water supply, and recreation in response to long-term chronic water supply shortages. According to an NRCS fact sheet (NRCS, 2006), 72 small watershed reservoirs have been built in the East LC sub-watershed (Figure 11). Currently, the NRCS is working closely with the North Central Missouri Regional Water Commission (NCMRWC) under Public Law-566 to permit, design and construction a large 2,235 acre permanent pool reservoir (Figure 11) on the East Fork of LC 4.5 miles north of Milan, Missouri (NRCS, 2006). The reservoir when complete would collect runoff from a 32.8 square mile area draining approximately 21,000 acres and providing 45,000 acre-feet of rural water supply storage, 8,800 acre-feet of floodwater storage, with 58,800 acre-feet of total storage and 2,512 acres of flood pool area. Sediment storage in the reservoir would also occur.

While no other detailed watershed development information was available for this LCWS, it's apparent from reviewing recent aerial photography that there are many other stream channelization projects, drainage ditches, and levees constructed throughout the watershed, particularly on, along or near the main tributaries to LC, the West Fork of LC, the East Fork of LC, and Muddy Creek. In addition, roads, culverts, and bridges that cross streams, wetlands and floodplains have been constructed to convey or separate water from this infrastructure. Land use changes are readily apparent. Many acres of uplands and floodplains have been altered by clearing and/or drainage. Wetlands, prairie and forests have put into row crop production or converted to pasture. Anecdotal reports from MDNR staff that have driven throughout the LCW indicate marginal land clearing of wooded buffer strips to increase grazing and/or row crop production area has increased over the last decade.

1.3.2 Previous Reports, Studies or Data Sources

The following previous reports, studies, or data were used to develop this report.

- Great Rivers Associates, 2011. *Geomorphic Engineering Assessment Pershing State Park*.
- Natural Resources Conservation Service, 2006. *East Locust Creek Watershed Project, Sullivan County, Missouri*.
- Missouri Department of Natural Resources, 2005. *East Locust Creek Watershed Plan Revision*.
- U.S. Army Corps of Engineers, Regulatory Branch, 2010 - 2011. *Various white paper reviews of Section 404/401 regulatory actions on log jams, including permit history and timelines*.
- Missouri Department of Conservation, 1994. *LC Basin Management Plan*.
- Missouri Department of Natural Resources, 2012. *Our Missouri Watershed Initiative – Watershed Advisory Committee Meeting Presentation*.
- Missouri Department of Natural Resources, 2012. *Our Missouri Watershed Initiative – Lower Grand River Watershed Fact Sheet.*
- Heitmeyer, M.E., T.A. Nigh, D.C. Mengel, P.E. Blanchard, F.A. Nelson, 2011. *An evaluation of ecosystem restoration and management options for floodplains in the Lower Grand River Region, Missouri.*

Figure 11: East Locust Creek Watershed Development Plans from NRCS

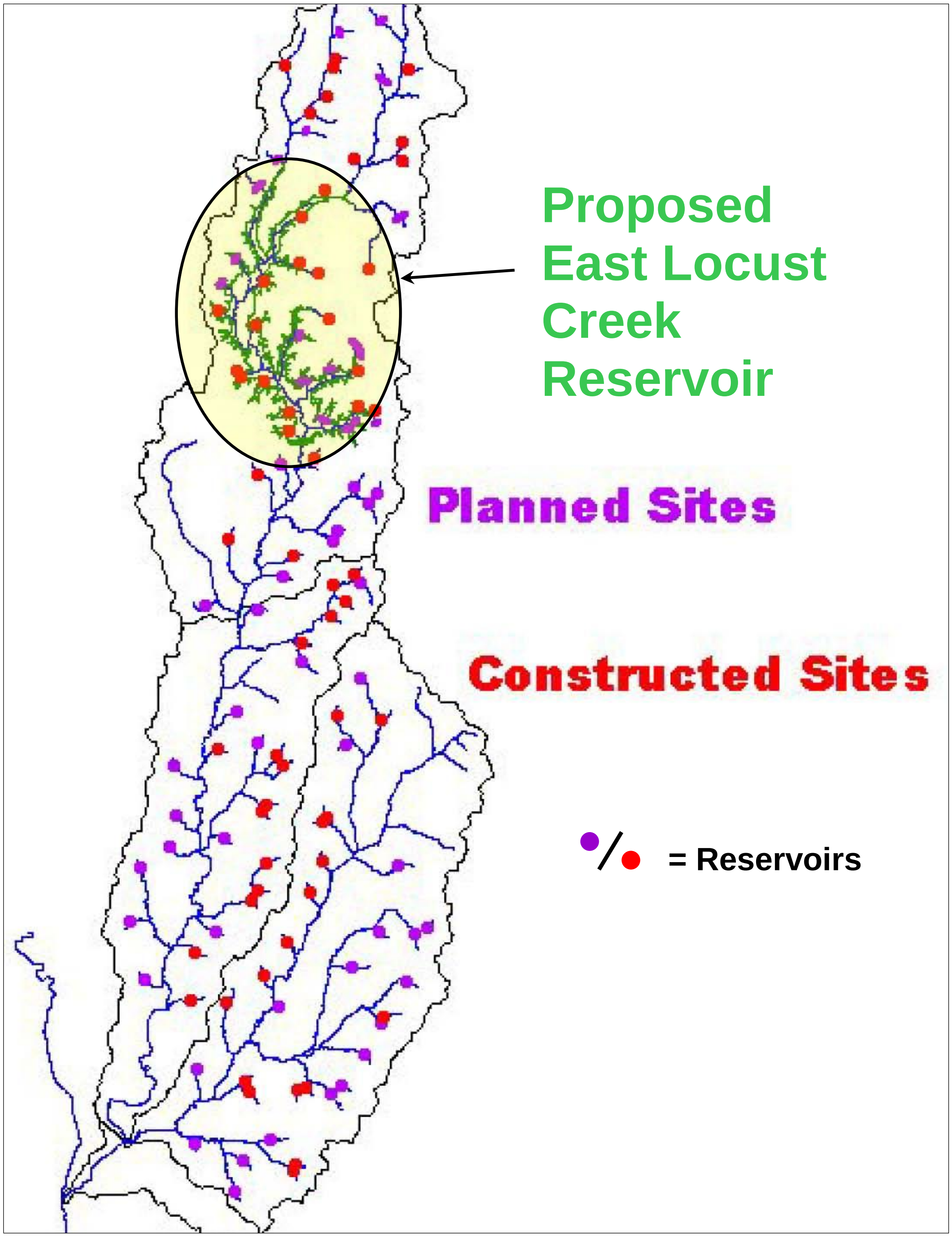


Figure taken from "East Locust Creek Watershed Plan Revision – June 2005 Powerpoint Presentation." Prepared by Lauren Cartwright, MDNR Economist.

1.3.3 Watershed Symptoms and Problems

A brief assessment follows which provides current watershed symptoms and identifies potential problems as described in previous reports, studies, and data sources; or from initial agency input and discussion.

<u>Watershed Symptoms</u>

- Channel bed and floodplain aggradation of sediments in LLC valley
- Log jams (and ice jams) in LC primarily in PSP
- Floodplain avulsions to HD
- HD has widened and deepened as a result of avulsions
- Loss of channel flow capacity in LC primarily in PSP from bed aggradation
- Partial or complete loss of channel flow capacity in three Hwy 36 drainage structures
- Increases in flooding along LC and the Grand River confluence
- Landowner flooding complaints upstream of PSP
- Increases in flooding and sedimentation on PSP boardwalks
- Dying and/or loss of hardwood forests, marsh wetlands, and wet prairie in PSP
- Suspected loss of species diversity in wet meadow prairie in PSP

<u>Watershed Problems</u>

- Land use changes in the watershed may be contributing excessive sediments to receiving waters and transporting sediments downstream.
- Channel morphology on LC and tributaries above PSP may still be adjusting from past channelization and levee confinement. Channel bank and bed erosion resulting from high flow events help re-adjust channel morphology, but, channel sedimentation results as negative side effect.
- Levee confinements on LC and tributaries have reduced floodplain function as the ability to diminish energy during high flow events is lost. In addition, lost water and sediment storage capacity functions result.
- Lose of floodwater drainage conveyance capacity from the Hwy 36 fill embankment across the LC floodplain.
- Potential backwater flooding and sediment transport issues from the adjacent LGR watershed that drains LC and its potential effects on LC flooding and channel bed aggradation.

1.4 Study Authority

The LCWS is being conducted as part of the Section 22 Program – Planning Assistance to States (PAS) Continuing Authority Program authorized under Water Resources Development Act of 1974 (Section 22, Public Law 93-251, as amended, 42 U.S.C. 1962d-16). Section 22 PAS program objective is to "*cooperate with any State in the preparation of comprehensive plans for the development, utilization and conservation of water and related land resources of drainage basins located within the boundaries of such State*". The Section 22 PAS program has commonly been used for broad comprehensive watershed assessment and water related planning topics by local sponsors. Typically PAS is not used for design and construction of "green and grey" water resource infrastructure. The local sponsor for this study is MDNR with technical support from MDC.

2.0 Existing and Future Conditions

2.1 Existing Conditions Analysis

The following subsection overviews available information on existing conditions of various watershed related resources in the LCW. The study area for the LCWS is located in north central Missouri with a small land area in south central Iowa. The study area is primarily rural in nature with small cities located throughout.

2.1.1 Physiography/Geology/Soils

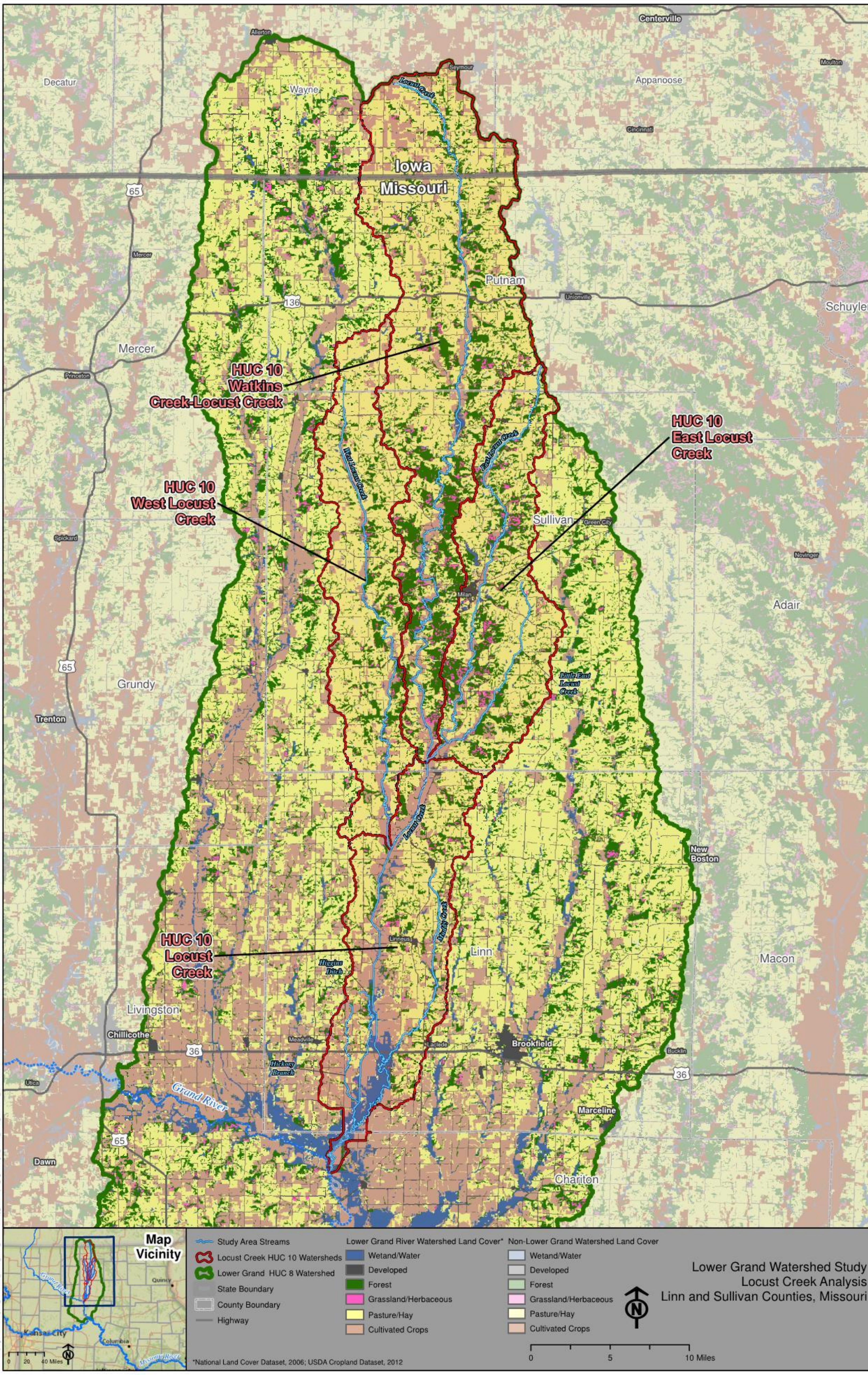
The MDC summarized the following physiographic, geology, and soils information in their 1994 *LC Basin Management Plan* (MDC, 1994). In addition the Linn and Sullivan County Soil Surveys (NRCS, 1990 and NRCS, 1995) was reviewed and used. The LCW is in the Dissected Till Plains physiographic region that is a mix of hills and plains made of glacial till deposits on Pennsylvanian sedimentary rock, with loess deposits common over glacial till in uplands. Till material is primarily clay, sands and silts with some rock and gravel. Till varies in depth greatly. In uplands it can be 70 to 110 feet thick typically or more than 200 feet thick in buried stream bodies. The top soils developed in loess and glacial till deposits 4-8 feet deep with transitional slopes containing both prairie and forest derived soils. Historically prairie grasses favoring more upland areas were dominant in the region, which lead to the development of deep organic rich soils favorable to row cropping. Moderate to severely slopes upland soils are generally considered moderate to highly erodible. Drainage is almost exclusively from north to south, going from steeper uplands to increasingly wider and flatter uplands and stream valleys in the southern part of the watershed.

2.1.2 Land Use

According to MDC (1994) the dominant land covers types in the LCW at that time (ca. 1994) were pasture and cropland. The LCW north of Linn County was approximately 27% cropland, 47% grassland, 24% forested, and 2% urban or other uses. MDC (1994) provided land usage comparisons in the LCW between uplands versus bottomlands. On uplands, 21% was cropland, 53% grassland, 25% forested and 1% other. Bottomland usage was highly cultivated at 69%, 6% grasslands, 24% forest, and 1% other uses. MDC further reported approximately 5% of bottomlands were artificially drained with ditches, tiles, dikes, and pumps.

More recent GIS land cover data from 2001 in the LCW was available and compared to MDC (1994) data. Data indicates the dominant land cover type in the LCW was pasture/hay at 55.7%, a slight increase. Forest cover dropped to 19.4%. Cultivated crops decreased to 14.1%. The 2001 data indicated developed land cover was at 4.1%, water/wetland at 3.8%, grassland/herbaceous at 2.0%, scrub/shrub at 0.9%, and barren at 0.04 %. The 2006 National Land Cover Dataset (NLCD) and 2012 USDA National Agricultural Statistics Service (USDA-NASS) CropScape agricultural land usage data (USDA, 2013) was available and used for creating Figure 12 and analyzing land use changes from 2001. These data indicate the following major land covers in the LCW: pasture/hayland/grassland decreased slightly to 54.7%, forest cover increased slightly to 22.4%, and cropland increased slightly to 15.5%. From the same USDA-NASS dataset, trends in specific agricultural land covers were analyzed from 2006 through 2012. Land converted to corn and soybean acres increased by 17,451 acres. Fallow/Idle Cropland decreased significantly during this time from 29,773 to 63 acres, or effectively about 7.2% of land cover to near 0%. USDA-NASS pasture/hayland cover significantly increased between 2006 and 2008 at 136,613 and 254,484 acres respectively,

Figure 12: Land Use in the Locust Creek Watershed



and then has steadily declined to 189,263 acres in 2012.

Anecdotal reports (Fobes, 2012d) from MDNR's Steve McIntosh, who was present at a professional talk where USDA data was cited, indicated an 18.8% statewide drop in USDA-NRCS Conservation Reserve Program (CRP) contract acres between 2007 and 2012, which likely indicates significant conversions back to row crops. Conversion of pasture to row crops is reported to be increasing and the recent land cover data from the LCW cited above supports this trend. Mr. McIntosh also reported statewide increases in corn and soybean production of 9.2% between 2007 and 2012 and again there is a increasing trend in soybean and corn production acres in the LCW of about 4.2%. If the LCW is indicative of statewide trends, these data suggest increasing conversion of marginal land areas (e.g. CRP, pasture, riparian forest, etc.) to row crops which increase erosion and sediment runoff.

MDC (1994) stated that much of LLC has levees along its length because of high frequency flooding and intensive row-crop farming, while very few levees exist along the streams of the basin north of the Sullivan/Linn County line where there is much less bottomland acreage and row-crop farming. Pitchford (2012) indicated much of the levee building that occurred in the larger LGR watershed containing the LCW were private initiatives in the 1970's and 1980's in response to increasing crop prices and availability of heavy construction equipment. Pitchford cited a USACE 1989 reference indicating construction of private levees were uncoordinated and to different levels of flood protection, which is consistent with anecdotal discussion with DNR staff.

2.1.3 Water Resources

The following subsection overviews the existing conditions of various surface water related watershed resources in the LCW.

2.1.3.1 Watershed Area

The LCW consists of four Hydrologic Unit Code (HUC) 12 sub-watershed basins, which are West Locust Creek (WLC), Watkins Creek-Locust Creek (WCLC), East Locust Creek (ELC), and LC. The LCW is a HUC 10 sub-watershed basin and located within the larger LGR HUC 8 watershed basin (Figure 1). Locust Creek enters the Grand River about 3.5 northwest of Sumner, Missouri (Figure 1). The LCW drainage area is approximately 647.3 square miles or about 414,270 acres.

2.1.3.2 Streams

There are three main named streams in the LCW and include WLC, LC and ELC (Figure 1). There are about eight smaller names tributaries (MDC, 1994) as well many other small un-named tributaries, including MC which drains to LC in the northern end of PSP (Figure 1).

2.1.3.3 Stream Order

According to MDC (1994), of the 100 tributaries third order or greater to LC, 75 are third order streams, 20 are fourth order, four are fifth order, and one is sixth order. LC is a seventh order stream where it drains to the Grand River northwest of Sumner, MO.

2.1.3.4 Channel Bed Gradient

The MDC (1994) estimated channel bed gradient for various reaches of LC, ELC, and WLC throughout the watershed. On LC's lowest 31 miles of 7th order stream, Channel bed gradient was 0.04 percent slope. On reaches of LC further upstream, gradients increased and those increases ranged from 0.050 to 0.132 percent slope. A more recent estimate of channel bed gradient in PSP by GRA (2011) around the Hwy 36 corridor indicated a predominant gradient range from 0.000 to 0.049, with select reaches south of Hwy 36 steeping with bed gradient's ranging from 0.050 – 0.099 and 0.100 – 0.199. MDC estimated channel bed gradient for reaches of south portion of West LC and East LC with gradients increasing moving upstream and ranging from 0.058 to 0.193 percent slope.

2.1.3.5 Stream Habitat

The most recent stream habitat evaluations performed includes work done by MDC (MDC, 1994) in the 1980's throughout the LCW and more focused recent work by MDNR in WLC from 2007 to 2008 for purposes of evaluating whether water quality impairments exist and causes. Although dated, the MDC habitat evaluation will be discussed below as it's more relevant to the scope of study.

The mainstem of LC is reported to have been about 123 miles in length prior to channelization. Only 51 miles were reported to remain un-channelized, while 23 miles are reported to have been eliminated and 49 miles channelized. Most of its channelization was reported by MDC to have occurred north and south of Sullivan County, with emphasis on extensive channelization in Linn County reported to have started around 1918. MDC provided an analysis of total number of miles and percent of stream length channelized and un-channelized for stream reaches that are third to seventh order in the LCW as shown in Table 1 below. MDC reported sixth order reaches in LCW are much more channelized (71% of length), versus third order reaches (11% of length). On the seventh order stream, approximately 44% of stream miles are channelized.

Table 1: Channelization Analysis by Stream Order (3rd – 7th) in LCW

Reach order	Stream miles	Channelized miles (%)	Unchannelized miles (%)
7	31.1	13.6(44)	17.5(56)
6	17.1	12.2(71)	4.9(29)
5	76.3	21.0(28)	55.3(72)
4	116.0	43.9(38)	72.1(62)
3	168.3	18.5(11)	149.8(89)
Total	408.8	109.2(27)	299.6(73)

Table taken from "LC Basin Management Plan - 1994" prepared by Missouri Department of Conservation.

MDC provided an analysis of percent stream length channelized for major names streams of the LCW that are fourth order or larger as shown in Table 2, which are believed to still be pretty accurate based on most channelization reported to have occurred as late as the 1960's. Channelization varies considerably for the major streams of LCW. Locust Creek is 48% channelized (by miles). The south reach of West LC and north reach of West LC were 37% 52% channelized, respectively. Other named tributaries were less than 28% channelized. A more recent GIS visualization analysis of channelization in LCW is shown in Figure 13.

Two largely unchannelized reaches of LC exist within the LCW, both of which are on the National Park Service's Nationwide River Inventory (NRI) list (NPS, 2012) for having one or more outstanding remarkable values (Figure 1). The upstream reach is noted for having a

…."*unique riffle-pool arrangement; one of the last unchannelized, undisturbed landform features in northern Missouri exhibiting oxbow lakes; meanders; unimpeded flooding typical of natural prairie stream; one of the best examples of aquatic community type in the region; and diverse fish types including the unique stone cat.*" The downstream reach is characterized as it ….."*represents the last remnant landform types in northern Missouri of an active meandering river system and associated oxbow sloughs, swamps, and rich flood plain forests; one of last*

Table 2: Channelization Analysis by Major Stream Name (≥ 4th Order) in LCW

Stream name	Stream order	Stream miles	Channelized miles (%)	Unchannelized miles (%)
L.C.	7	96.0	46.0(48)	50.0(52)
W.L.C.(S.)	6	42.3	15.6(37)	26.7(63)
Muddy Creek	5	16.6	3.5(21)	13.1(79)
Unnamed 31	5	8.0	0.5(6)	7.5(94)
E.L.C.	5	32.9	9.1(28)	23.8(72)
L.E.L.C.	5	10.6	2.1(20)	8.5(80)
W.L.C.(N.)	4	18.4	9.5(52)	8.9(48)

Table taken from "LC Basin Management Plan - 1994" prepared by Missouri Department of Conservation.

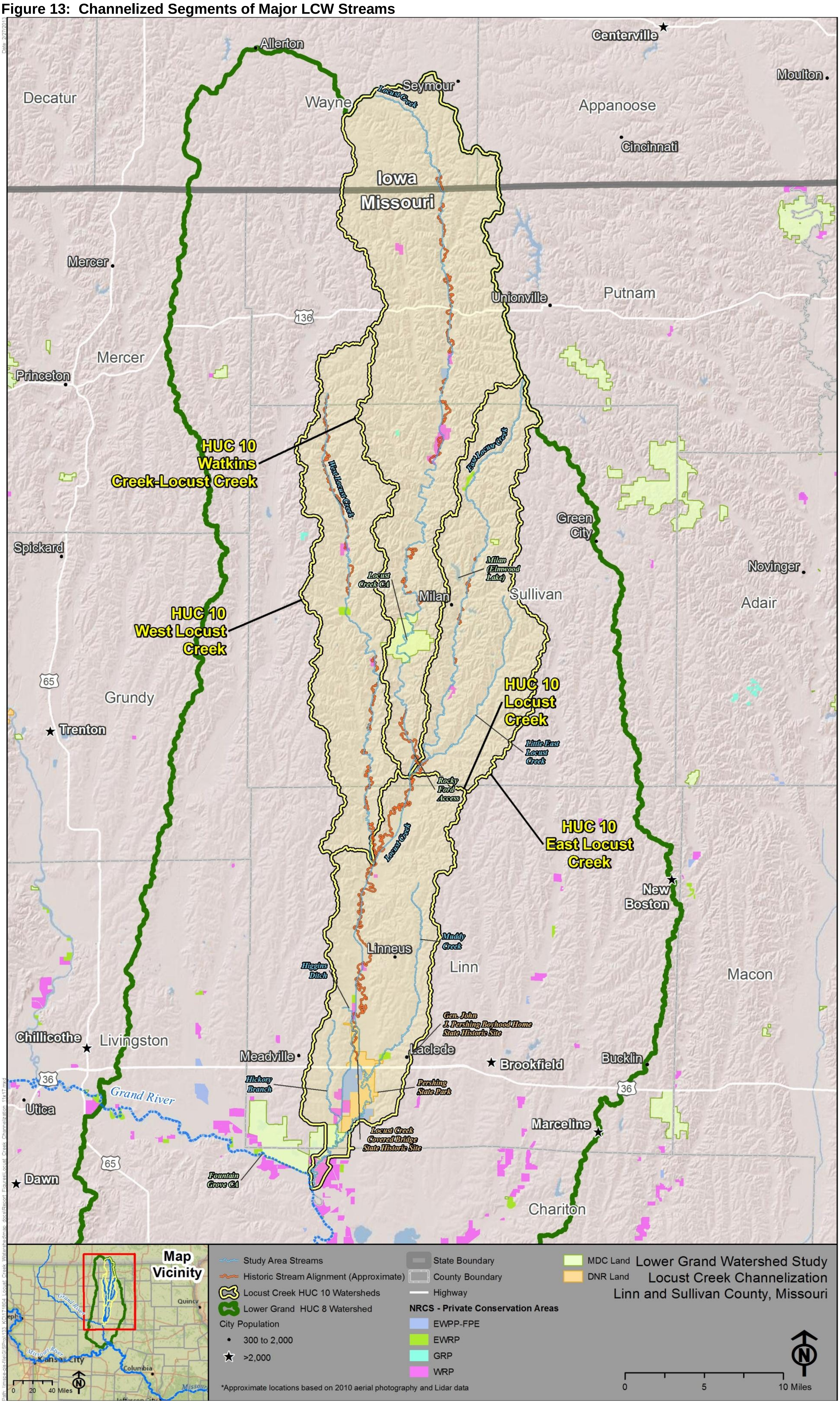
unchannelized, undisturbed landform features in northern Missouri; high recreation potential, especially in and near Pershing State Park; historic covered bridge; one of best examples of aquatic community types in region." MDC (1994) commented on the habitat of downstream NRI reach of LC indicating the reach was aggrading, but has well established wooded corridors, abundant in-stream cover, and unique fish species, including trout-perch collected from PSP in 1988. MDC further stated the reach has frequent annual flooding causing conflict between upstream landowners and MDNR PSP staff. Some landowners desired that MDNR channelize LC through PSP to help alleviate upstream flooding.

Fisheries habitat improvements were constructed on MDC's LC CA near Milan, MO starting in 1987 and included tree revetments; gradient control structures; root wads; willow cuttings, stakes and post plantings; riparian tree plantings; and gully erosion control structures. There was intent by MDC to assess post-construction improvements; however, no information was available on assessments conducted.

A watershed wide stream habitat quality assessment was conducted by MDC between 1983 and 1984 at 31 randomly selected sites. General results indicated low to moderate stream quality due to poor watershed practices that result in bank erosion and channel sedimentation. LC overall scored the highest with fair conditions for riffle-pool complexes, substrate and snag cover, while tributaries had low average habitat ratings due to streambank erosion and lack of woody riparian vegetation.

In 1988, MDC conducted additional stream habitat survey work at 17 sites of channelized and un-channelized reaches to look at fisheries habitat conditions and wooded riparian width conditions. Results for fisheries habitat indicated streambank condition varied from fair to good,

Figure 13: Channelized Segments of Major LCW Streams



with some sites showing signs of moderate erosion or sloughing. In-stream cover generally was lacking. Average maximum pool depth was less than three feet for all sites (thought it was a drought year), while pool depth average was slightly deeper at two feet for un-channelized reaches, versus 1.6 feet on channelized reaches. MDC indicated excessive sand bed loads, presumably from unstable channel banks and adjacent agricultural lands, have filled many pools leaving little substrate for fish spawning. Lack of woody debris was cited as a major factor that limiting fish communities, as it provides many necessary fish habitat requirements. Bed substrate composition throughout the sites was reported as almost entirely sand/silt. Only four sites had riffles which were 75% embedded. Results for wooded riparian width conditions indicated 92% of all streams in the watershed lacked less than 100 feet wide or wider riparian buffer and due in large part to incompatibility with row cropping and grazing activities. Furthermore, MDC reported wooded riparian corridor width tended to increase with stream order and state-owned public lands with larger wooded riparian corridors, as well as woodlands between stream channels and levees on private lands, may have influenced higher width scores reported. Relatively recent fish and mussel surveys was conducted in LC in PSP by MDC (Winston et al., 1998) in an upper channelized (impacted) reach, an intermediate (moderately impacted) middle reach, and an un-channelized (non-impacted) lower reach. This study concluded fish species richness was greatest in the lowest (least impacted habitat) reach and declined in the intermediate and upper (more impacted) channelized reaches of PSP. Mussel density was greatest in the lower un-channelized reach of LC, and decreased drastically in the channelized reach. Mussel species richness declined in the intermediate and channelized reaches.

2.1.3.6 Hydrology

There are two active USGS gaging stations in the LCW (USGS, 2012). One is located on LC near Linneus, Missouri (Gage 06901500) and the other on Little East LC near Browning, Missouri (Gage 06901250). No gages (or long-term flow data) are available in the near vicinity of PSP. Average annual precipitation in the LCW is 36 inches with May and June as typical peak rainfall months. Annual mean discharge cited for the gage on LC near Browning for the period of 1928 – 1972 was 325 cfs, while 7-day Q10 low flow was 1.2 cfs for the period 1929-1965. More recent estimates of annual mean discharge for the period 1930 – 2011 are 348 cfs. MDNR that indicates permanent flow exists in East and West LCs and LC proper in reaches fifth order or larger. Low flows were cited by MDC (1994) as a likely problem based on slope index values calculated as compared to slope index values of other streams in the region.

Currently LC from the main channel avulsion going downstream will only carry approximately 235 cfs before flow capacity is split and diverted between LC, the main floodplain avulsion, other floodplain avulsions, and the levee breach on the east side of Locust. In 1997, prior to the floodplain avulsions, USGS estimated the flow capacity of LC was about 3,000 cfs. A 2011 flow model analysis (GRA, 2011) indicated for a simulated bankfull flow of 4,000 running through LC and the main channel avulsion, LC only had the channel capacity of 1,000 cfs, while the main avulsion carried a bankfull discharge of 3,000 cfs to HD. Therefore, even the smallest storm events (< 1 yr.) will typically divert a majority of LC's flow through the main channel avulsion. MDC (1994) cited data from USDA published in 1982 indicated just a few miles upstream of PSP in the channelized reach of LC, the two-year recurrence interval produces discharges four-times (~9,200 cfs) the bankfull capacity of 2,330 cfs. In some wet years, MDC personal indicated flooding has happened as often as 13 times. Flows are reported to be very flashy on LC (MDC, 1994) from more recent statements made by PSP staff. Locust Creek is considered to have a "flashy" stream flow based on being classified as "Perennial Runoff Flashy Stream" under the Hydroecological Integrity Assessment Process (HIAP) (Kennan et al. 2009). An index used in the HIAP is the base flow index (BFI), which is the ratio of base flow volume to total flow volume. The BFI value calculated for LC is about 0.15, which means that by volume, about 85% of the total flow in these streams occurs during runoff events.

2.1.3.7 Dam Influences

Currently there are no major dams constructed on major tributaries in the watershed. However, 72 small NRCS funded watershed reservoirs have been built in the ELC sub-watershed (Figure 11) for purposes of flood reduction (NRCS, 2006). Currently, the NRCS is working closely with the North Central Missouri Regional Water Commission (NCMRWC) under Public Law-566 to permit, design and construction a large 2,235 acre permanent pool reservoir (Figure 11) on ELC 4.5 miles north of Milan, Missouri (NRCS, 2006). The Upper Locust Creek Watershed Project was approved by the NRCS in 1987 and included large scale land treatments, five large impoundments, and 347 small floodwater detention grade stabilization projects. No information was available to ascertain whether this project was ever constructed. Based on quick aerial photograph review, there are small dams known to have been constructed within other sub-watershed units of the LCW, but no information was available on them. They may be largely privately constructed without federal or state support. In 1991, the LC Riparian Project was approved with funding in place. It was cooperative effort between NRCS, MDC and the Environmental Protection Agency (EPA) to improve water quality and fish and wildlife habitat through riparian protection and restoration on 28 miles of LC in Sullivan County. At the time of plan approval, there was little landowner interest and no information was available to ascertain the current status of this project.

2.1.4 Water Quality and Use

The following subsection overviews the existing conditions of various water quality and use considerations in the LCW.

2.1.4.1 Non-impaired Uses

Based on the EPA approved 2010 Missouri 303(d) List of Impaired Waters, the East Fork of LC is non-impaired for protection of aquatic life and livestock and wildlife watering. LC is non-impaired for protection of aquatic life, public drinking water supply and livestock and wildlife watering. No information was available for the West Fork of LC.

2.1.4.2 Impaired Uses

Based on the EPA approved 2010 Missouri 303(d) List of Impaired Waters (MDNR, 2010), the ELC is impaired for protection of aquatic life and whole body contact recreation from bacteria and low dissolved oxygen (DO) in various reaches. LC is impaired for whole body and secondary contact recreation from bacteria. A Total Maximum Daily Load (TMDL) is currently proposed on both ELC, and 36 miles of LC in Putnam and Sullivan Counties. TMDL completion for bacteria on ELC is scheduled for 2013 and for low dissolved oxygen in 2016. TMDL completion on LC is scheduled for 2013 completion.

In 2010, EPA established a TMDL for 17 miles of the West Fork of LC in Sullivan County for unknown pollutant sources (MDNR, 2010). The TMDL was calculated using total suspends solids (TSS), total nitrogen (TN), and total phosphorus (TP). Specific reasons cited for listing include the presence of dense filamentous algae or duckweed, rocks darkened by manganese, pollution tolerant invertebrate species, anoxic sediments, reduced biodiversity and high specific conductance. Potential nonpoint sources that are contributing to the impairment in the West Fork LC include runoff from agricultural areas, runoff from urban areas, onsite wastewater treatment systems, and various sources associated with riparian habitat conditions. Nutrients within the sub-watershed may be attributed to fertilizer or manure application to the agricultural lands being utilized for pasture, hay, or crop production. Of particular concern are lands near the riparian buffer areas that are subject to livestock grazing or watering and fertilizer applications. The animal wastes from manure applications, for both confined and unconfined feeding sites are considered a major potential source of nutrient loading going into West Fork LC.

2.1.4.3 Point-source Pollution

Point-source permit data provided by MDNR (2012) in a briefing document indicates there are discharge sources throughout the LCW. The most prominent sources appear to several hog confined animal feeding operations (CAFO), several municipal wastewater treatment plants and public water supply facilities, concrete and limestone quarry facilities, and a few other miscellaneous permitted facilities.

2.1.4.4 Non-point Source Pollution

MDNR (2010) indicated potential nonpoint sources contributing to the impairment in WLC and the upper LCW in general include runoff from agricultural areas, runoff from urban areas, onsite wastewater treatment systems, and various sources associated with riparian habitat conditions. Nutrients within the upper watershed may be attributed to fertilizer or manure application to the agricultural lands being utilized for pasture, hay, or crop production. Of particular concern are lands near the riparian buffer areas that are subject to livestock grazing, shade use or watering, and fertilizer applications. Numerous peer reviewed studies were summarized by Ohio State University (OSU, 2013) that indicates the many negative effects of livestock grazing on riparian areas that include negative impacts to riparian and stream bank vegetation, increased stream sedimentation, increased stream water temperature, increased stream bank instability and changes in morphology, and increased nutrient loadings. The animal wastes from manure applications, for both confined and unconfined feeding sites, are considered a major potential source of nutrient loading. MDNR (2012) in a briefing document indicated the lower LCW, where row cropping is much more prominent than CAFO's and pastured livestock, that row cropping too close streams is a major contributor to stream sediment loading and debris and declining water quality. Limited or lack or riparian buffer along with bank instability and erosion are the primary sediment sources.

2.1.4.5 Stream Chemical Quality/Fish Contamination & Kills

Currently MDNR takes periodic grab water samples at various locations in the major streams of the LCW and reports the raw data on their website (MDNR, 2013). The data available varies significantly by stream in terms of period of record available, analyses performed, flow type, etc. Sufficient data was available on ELC and LC to report ranges typical stream chemistry variables. On LC, DO ranged from 6 – 14.9 mg/L, TN was 0.47 – 7.9 mg/L, TP was 0.031 – 1.3 mg/L, TSS was 7 – 3,420 mg/L, and water temperature (WT) was -0.1 – 34.9 °C. On ELC DO ranged from 4.8 – 16.9 mg/L, TN was 0.36 – 92.7 mg/L, TP was 0.04 – 30.9 mg/L, TSS was 5 – 295 mg/L, and water temperature (WT) was 0.1 – 28.7 °C.

MDC conducted contamination analysis for LC in 1990 and found no Food and Drug

Administration actions limits were exceeded for channel catfish and carp, but chlordane and dieldrin were present above detection limits. MDC (2013) provided 2009 fish tissue analysis information from LC at two sample locations for catfish and carp. In these samples, Chlordane DDT, Deptachl, PCBs, Lead, Cadmium, and Mercury were detected, but below limits for establishing a fish consumption advisory. No fish consumption advisories exist currently in the LCW.

MDC (1994) reported that while localized stream chemistry water quality problems do exist, no chronic fish kills were known. No fish kills were recorded during the summer drought of 1988. MDC speculated low dissolved oxygen and flows exist in intermittent streams in permanent pools in the watershed during late summer. MDC fish kill and pollution record investigation reports (MDC, 2013a) were obtained for major streams in the LCW. Four total fish kills were reported going back to 1964 with causes varying such as wastewater treatment plant effluent (high algae), industrial wastes, land application of hog manure lagoon effluent, and unknown. The last reported fish kill was in 2001. Fish kills were reported in WLC, ELC, and LC and were generally small in nature. Several of the reports reviewed contained no reported fish kills, but had reported water pollution investigations.

2.1.5 Aquatic Life

The following subsections summarize available information on fisheries, mussels and macroinvertebrate aquatic life in the LCW as discussed in MDC's (1994) *Locust Creek Basin Management Plan.*

2.1.5.1 Fisheries

As of the mid-1970's, 45 species of fish from 11 families had a distribution range that included the LCW (Pflieger, 1975) and dominated by cyprinid's (true minnow and carp family). MDC (1994) reported thirty-seven (37) species having been collected in LCW (Table 3) from 1988 and prior. Of these, a total of 33 out 37 species were collected in 1988 and there was a trend in much more abundant poor water quality tolerant and omnivorous fish species as a result of fish habitat degradation (MDC, 1994). Declines in macroinvertebrate food sources were cited as the cause for increased omnivorous (more opportunistic) fish species. No threatened and endangered fish species were reported to have been found in the LCW; however, two poor water quality intolerant fish species, the stonecat and trout-perch, have previously been collected. MDC still currently ranks the trout-perch in the Grand River basin as critically imperiled and the brassy minnow as vulnerable. MDC cites a study from 1984 that indicated 3.5 to 5% of all fish species from the LGR watershed have been extirpated or reduced in abundance since the early 20th century presumably from increased turbidity and sediment deposition. Channelization in the LCW was cited as being a consistent negative impact on the fish community. MDC's (1994) study indicated a deep pool created by a low water crossing at Rocky Ford Access had a diverse 26 species collected, versus an average of 13.6 species for channelized sites on fourth to sixth order streams in the watershed. This showed the importance of water depth on species diversity. MDC (1994) reported overall much greater species diversity in un-channelized sections of streams in the LCW.

Table 3: Fish Species Collected with a Distribution Range that Includes LCW

Common Name	Scientific Name	Status
Shortnose Gar	*Lepisosteus platostomus*	2,3
Longnose Gar	*Lepisosteus osseus*	2,3
Gizzard Shad	*Dorosoma cepedianum*	3
Goldeye	*Hiodon alosoides*	1,3
Mooneye	*Hiodon tergisus*	2
Northern Pike	*Esox lucius*	
Carp	*Cyprinus carpio*	2,3
Goldfish	*Carassius auratus*	
Golden Shiner	*Notemigonus crysoleucas*	1,3
Creek Chub	*Semotilus atromaculatus*	1,2,3
Silver Chub	*Macrhybopsis storeriana*	1
Speckled Chub	*Macrhybopsis aestivalis*	
Suckermouth Minnow	*Phenacobius mirabilis*	1,2,3
Emerald Shiner	*Notropis atherinoides*	
Redfin Shiner	*Lythrurus umbratilis*	3
Bigmouth Shiner	*Notropis dorsalis*	1,2,3
Red Shiner	*Cyprinella lutrensis*	1,2,3
Sand Shiner	*Notropis stramineus*	1,2,3
Western Silvery Minnow	*Hybognathus argyritis*	
Plains Minnow	*Hybognathus placitus*	1
Bluntnose Minnow	*Pimephales notatus*	1,2,3
Fathead Minnow	*Pimephales promelas*	1,3
Central Stoneroller	*Campostoma anomalum*	2,3
Bigmouth Buffalo	*Ictiobus cyprinellus*	3
Black Buffalo	*Ictiobus niger*	
Smallmouth Buffalo	*Ictiobus bubalus*	3
River Carpsucker	*Carpiodes carpio*	1,2,3
Quillback	*Carpiodes cyprinus*	1,3
White Sucker	*Catostomus commersoni*	1,3
Shorthead Redhorse	*Moxostoma macrolepidotum*	3
Black Bullhead	*Ameiurus melas*	1,2,3
Yellow Bullhead	*Ameiurus natalis*	2,3
Channel Catfish	*Ictalurus punctatus*	1,2,3
Stonecat	*Noturus flavus*	2
Flathead Catfish	*Pylodictis olivaris*	1,2,3
Trout-perch	*Percopsis omiscomaycus*	1,3
Largemouth Bass	*Micropterus salmoides*	1,2,3
Green Sunfish	*Lepomis cyanellus*	1,2,3
Orangespotted Sunfish	*Lepomis humilis*	1,2,3
Bluegill	*Lepomis macrochirus*	2,3
White Crappie	*Pomoxis annularis*	2,3
Black Crappie	*Pomoxis nigromaculatus*	
Walleye	*Stizostedion vitreum*	
Johnny Darter	*Etheostoma nigrum*	3
Freshwater Drum	*Aplodinotus grunniens*	2,3

Table taken from "LC Basin Management Plan - 1994" prepared by Missouri Department of Conservation. (1 = before 1945, 2 = 1945 – 1988, 3 = 1988). Species without status noted have never been collected in the LCW, but have a known distribution range that includes at least part of the LCW.

More recent fisheries surveys within the LCW was by Winston et al. (1998) who conducted aquatic faunal surveys, including fisheries, at four river mile sampling locations in PSP. A total of 30 species were collected at the four sampling locations. The most species diverse sampling site in PSP on LC was at the lowest site at river mile 8.0 at 22 species. At further upstream river miles 14.5, 16, and 21.5, diversity declined slightly at each site at 21, 19, and 18 species respectively. Voukon et al. (2003) evaluated the diversity of fish species assemblages along the transitions from channelized to un-channelized reaches of seven streams throughout northern Missouri, including sampling LC in Sullivan County. Among other study outcomes, this study determined maximum species richness was typically 3-5 kilometers downstream from the end of stream channelization, indicating the effects of channelization extend into un-channelized reaches of streams. MDC has been collecting fisheries, water quality, and physical habitat data at 20 sites in the LCW since 2002 according to Culler (2013) and some macroinvertebrate data is periodically collected. Fisheries and macroinvertebrate Indices of Biological Integrity (IBI) have been calculated from these sample sites and are available for future use.

2.1.5.2 Macroinvertebrates

Macroinvertebrate work was conducted by the Missouri Cooperative Fish and Wildlife Research Unit for MDC sometime between 1988 and 1993 in select central Missouri streams. Results from sampling done at Locust Creek Conservation Area (LCCA), which is a MDC public land area, indicated a greater biomass of macroinvertebrates in relatively rare snag and riffle habitats. The study concluded increasing these habitat types would improve macroinvertebrate productively in LC. In 2007 and 2008, macroinvertebrate work was completed on the WLC for purposes of further evaluating the current 303(d) impaired waters listing on a 34-mile segment (MDNR, 2008) in Linn and Sullivan Counties. In general, the Class P (perennial) segments on WLC's four sample sites received full biologically sustainable designation for macroinvertebrate communities, while the Class C (intermittent) segment had only one partially biologically sustainable designation sample site in 2007 and all four were designated partially biologically sustainable in 2008. In 2009 and 2010, additional macroinvertebrate was conducted in WLC in Putnam County (MDNR, 2010a). In 2010, a TMDL was approved for a 17-mile segment in Sullivan County, while other reaches remain under observation.

2.1.5.3 Mussels

According to MDC's (1994) *LC Basin Management Plan*, no mussel surveys have been conducted for LCW. Little to no data exists for mussel populations. MDC cited work from 1984 indicating 19 species of freshwater mussels have historically been recorded in the Grand River Basin, eleven of which are species found in the Grindstone Creek sub-basin. LC was surveyed for flat floaters in 1998 and collected at two locations. Flat floaters are state listed as rare. A mussel survey was conducted by Jane Cotton with MDC (MDC, 2012) in PSP and FGCA in 2012 in LC, the lower 1.5 miles of HB, and one mile of the LGR above LC in 2012 and 12 species were collected. MDC (2012) also reported various unpublished mussel surveys were conducted in LC between 1997 and 2009 including work by Winston et al (1998). Species founding during the 2012 and previous surveys included white heelsplitter, yellow sandshell, fragile papershell, pink papershell, and mapleleaf. Creeper, giant floater, flat floater, paper pondshell, and pondmussel were previously observed but were not seen during the 2012 survey. Threehorn wartyback, pink heelsplitter, lilliput, fawnsfoot, pimpleback, pistol grip, and peaclam were observed for the first time during the 2012 survey.

2.1.6 Wildlife

Although no concise review of wildlife species was available for the entire LCW, information on wildlife commonly found at local public wildlife refuges, conservation areas, and parks was available. Information for wildlife found at Swan Lake National Wildlife Refuge (SLNWR) operated by U.S. Fish and Wildlife Service (USFWS) was located (USFWS, 2012). A total of 241 species of birds have been recorded. Common mammal species at Swan Lake include white-tailed deer, fox squirrels, raccoon, coyote, beaver, muskrat, opossum, and cottontail rabbits. Only white tailed deer are hunted on the refuge. River otters are present, but are not often seen. Otter were reintroduced onto the refuge in 1982 by MDC, and the success of the experiment led to a state-wide reintroduction program. Frog and toad species known to occur include western chorus frog, southern leopard frog, gray tree frog, and northern spring peeper. Audubon Society information for birds recorded at nearby FGCA operated by MDC was located. A total of 208 birds species have been recorded at FGCA (ASM, 2012) which represents approximately 1/2 of all bird species recorded in the state of Missouri. A total of 204 species of birds have been recorded either in or migrating through PSP (ASM, 2012 and MDNR, 2012a). In general, wildlife species and abundance are believed to be relatively well supported with the large numbers of acres of public and private lands dedicated to wildlife and related other natural resource service functions.

2.1.7 Rare, Threatened and Endangered Species

A review of the USFWS and MDC county lists of threatened and endangered species that occur in LCW counties was conducted and summarized in Table 4 below. This includes Chariton, Linn, Sullivan, and Putnam Counties. Of particular note, the massasauga rattlesnake, formerly a federally listed species and still extremely rare and listed as state endangered, is found on of the bottomland wet prairie of PSP as an important ecological attribute of the large and complex wetlands system.

Table 4: Threatened and Endangered Species Occurring in LCW Counties

Species	Listing	Threatened Status	Endangered Status	Species or Communities of Conservation Concern State Rank
Least Tern	Federal, State		X	
Indiana Bat	Federal, State		X	S1
Topeka Shiner	Federal, State		X	
Mead’s Milkweed	Federal	X		
Western Massasauga Rattlesnake	State		X	
Plains Spotted Skunk	State		X	
Northern Harrier	State		X	
Peregrine Falcon	State		X	
Snowy Egret	State		X	

American Bittern	State		X	
Auriculate False Foxglove	State			S3
Silver-haired Bat	State			S3
Trout Perch	State			S1
Dwarf Chinquapin Oak	State			S3
Cerulean Warbler	State			S2/S3
Meadow-Sweet	State			S1
American Badger	State			SU
Tall Agrimony	State			SU
Regal Fritillary	State			S3
Flat Floater	State			S2
Carex vesicaria var. monile	State			S2
Bald Eagle	State			S3
Ostrich Fern	State			S2
Grizzly Grasshopper	State			S2
Least Weasel	State			S3
Northern Rein Orchid	State			S2
Dry-mesis Loess/Glacial Till Prairie	State			S1
Central Plains Special Communities (Oxbows and Sloughs)	State			S?
Central Plains Warmwater (Small River)	State			S?
Riverfront Forest	State			S4
Wet Bottomland Prairie	State			S1
Wet Mesic Bottomland Forest	State			S2

S1 – critically imperiled, S2 – imperiled, S3 – vulnerable, S4 – apparently secure, S5 – secure, SU – status unrankable, S? – unranked.

2.1.8 Public Conservation Areas

Public conservation areas are considered those land and water areas that are accessible to the public, owned and/or managed by a public government agency, and provide natural and/or cultural conservation resources benefits and services. Currently the main public areas in the LCW are managed by the federal Department of the Interior – USFWS, and state agencies MDC and MDNR. The major public conservation areas are shown on Figure 1 and include Swan Lake National Wildlife Refuge (SLNWR), LCCA, FGCA, Rocky Ford Access, Milan (Elmwood Lake), Locust Creek Covered Bridge State Historic Site, General John J. Pershing Boyhood Home State Park, and PSP.

Relative to the study location and issues is PSP, which is 5,257 acres in size and primarily preserved and managed for its vast complex of wetlands. The primary mission of PSP, according to MDNR (2012b) is…."*the preservation, restoration and interpretation of a remnant North Missouri landscape. The components include an active meandering stream, sloughs, marshes, wet prairies, bottomland forests, upland forests, savanna, upland prairies, and associated plant and animal species. Consideration is also given to cultural and recreational aspects associated with the natural landscape."*

2.1.9 Other Conservation Areas

Private conservation areas are considered those land and water areas that are generally not accessible to the public and are privately owned, but have received funding with contractual requirements and restrictions from a public government agency for purposes of conserving natural and/or cultural resources benefits or services. The primary private conservation areas within the LCW are all NRCS administered programs and include the Emergency Watershed Protection Program – Floodplain Easements, Emergency Wetland Reserve Program, Grassland Reserve Program, and Wetland Reserve Program (WRP). Some NRCS program land locations are shown on Figure 1, which primarily shows WRP easement areas.

2.1.10 Recreation

Abundant outdoor recreational opportunities exist in the LCW due largely to the rural nature of the watershed and the concentration and amount of public and private conservation areas in the lower LCW. Opportunities include birding, camping, fishing, hiking, hunting and boating. Waterfowl hunting on public and private areas is an extremely popular due in large part to those opportunities that are provided at Fountain Grove CA and on private NRCS Wetland Reserve Program locations. Aquatic recreation in LC itself is generally limited to some fishing (especially for catfish), and where floatable water exists in the middle and LLC, and small boats and canoes can be launched from public lands. The MDC (1994) established habitat, recreational, and biological goals and objectives for the LCW to provide better fisheries, more public access, and better promotion of recreation.

2.1.11 Cultural Resources

The most well-known cultural resource features in the LCW include the LC Covered Bridge State Historic Site and General John J. Pershing Boyhood Home State Park, both of which are on the National Register of Historic Places (NRHP). Several other NRHP sites are located in or near the city of Milan. There are several cultural resources features within PSP including the Woodland Mill and the Iron Bridge over LC. A red wooden barn located on the newly acquired Zell Tract (an NRCS EWPP-FPE), located on the west side of PSP just south of Hwy 36, is known for its historical significance. It is a "kit barn" purchased from the World's Fair held in St.

Louis in 1904. The barn was reported to have been dissembled at the fair, shipped, and re-assembled at its current location on a hill over-looking the Zell Tract in the LC floodplain.

2.1.12 Soil, Water and Wildlife Conservation Projects and Plans

Various soil and water conservation projects and plans have been undertaken in the LCW primarily as federal assistance from USDA to private landowners through various programs. While USDA soil, water and wildlife programs vary in scope and funding, the following programs are being implemented in the LCW and have direct impact to soil, water and wildlife related resources found in the LCW. USDA programs and enrolled participating acres (where available) in the LCW include the CRP, Environmental Quality Incentives Program (EQIP), Emergency Watershed Protection Program – Floodplain Easements (EWPP – FPE), Grassland Reserve Program (GRP), Wildlife Habitat Incentives Program (WHIP), Wetland Reserve Program (WRP), Conservation Stewardship Program (CSP), Watershed Protection and Flood Prevention Program (WPFPP – commonly referred to as PL- 566), and the recently enacted Mississippi River Basin Healthy Watersheds Initiative (MRBI), which is essentially targeted NRCS EQIP funding for supporting a healthier Gulf of Mexico in the Mississippi River Basin. The MRBI is targeting the LGR and several other crucial watersheds in Missouri for water quality improvements.

2.2 Problems

The following subsection reviews apparent problems within the LCW and the LGR in more detail. This review will focus on broad (watershed wide), and where possible localized problems.

2.2.1 Problems in the Locust Creek Watershed

Based on the preliminary assessment of watershed symptoms and problems identified section 1.3.3, and readily available data, some preliminary analysis of stream bank erosion, channelization, levees, riparian buffer, and land use, was performed to support identification of certain problems. Some problems such as head cutting, Hwy 36 drainage structure constrictions, and potential LGR drainage and flooding issues were unable to be analyzed in any detail for this study due to lack of data. A detailed stream bank erosion locational “hot spot” analysis was performed on the four major named LCW streams using aerial photography (Figure 14). Hot spots identified on these four LCW stream need to be verified for active erosion. Hot spot analysis was done primarily because several studies cited by EPA (2012) indicate streambank erosion typically contribute a large proportion of annual sediment yields in streams. EPA (2012) references cited anywhere from 49 to 90% of annual sediment yields come from stream bank erosion alone. In one study on the East Fork of the San Juan River in Colorado, just three miles of an altered reach generated 49% of the annual sediment yield. No sediment sourcing or annual sediment yield estimates have been done within the LCW, but warrant investigation. This hot spot analysis on LCW streams suggested that stream bank erosion was more widespread than originally thought. It also suggested that stream bank erosion tended to be more concentrated in some areas, more uniformly distributed in other areas, and lacking in other areas of the watershed. In general, stream bank erosion tended to be much less in all evaluated channels from approximately Milan, Missouri northward; however, this may be due to the limitations of interpreting aerial photography on the smaller stream channels in the northern part of the watershed. Stream bank erosion was readily evident, widespread and rather uniformly distributed along the channelized reach of LC and main tributaries south of Browning, MO. Bank erosion was also very evident on all stream reaches between approximately Milan and Browning, Missouri. From this hot spot analysis, a more detailed bank erosion extent analysis was conducted as shown on Appendix A map books for all four major streams in the LCW. These map books were prepared with both LiDAR digital topographic information and aerial photography. In some instances no LiDAR data was available, particularly for most of the West LC valley and most of Putnam County. In LLC, the channelized reach above PSP is eroding significantly and in the process of re-establishing a more stable channel geometry plan form (re-meandering); therefore, significant bank erosion occurs and stream sediment supply exceeds the sediment transport capacity of the LC channel. Other channelized and un-channelized reaches of LC and named tributaries show strong evidence of significant bank erosion and sediment deposition (Appendix A). Table 5 shows a rough estimate in the LCW of the linear feet of bank erosion and number hot spots detected, in each of the four sub-watershed units. The total linear footage of 177,571 equates to approximately 33.6 miles.

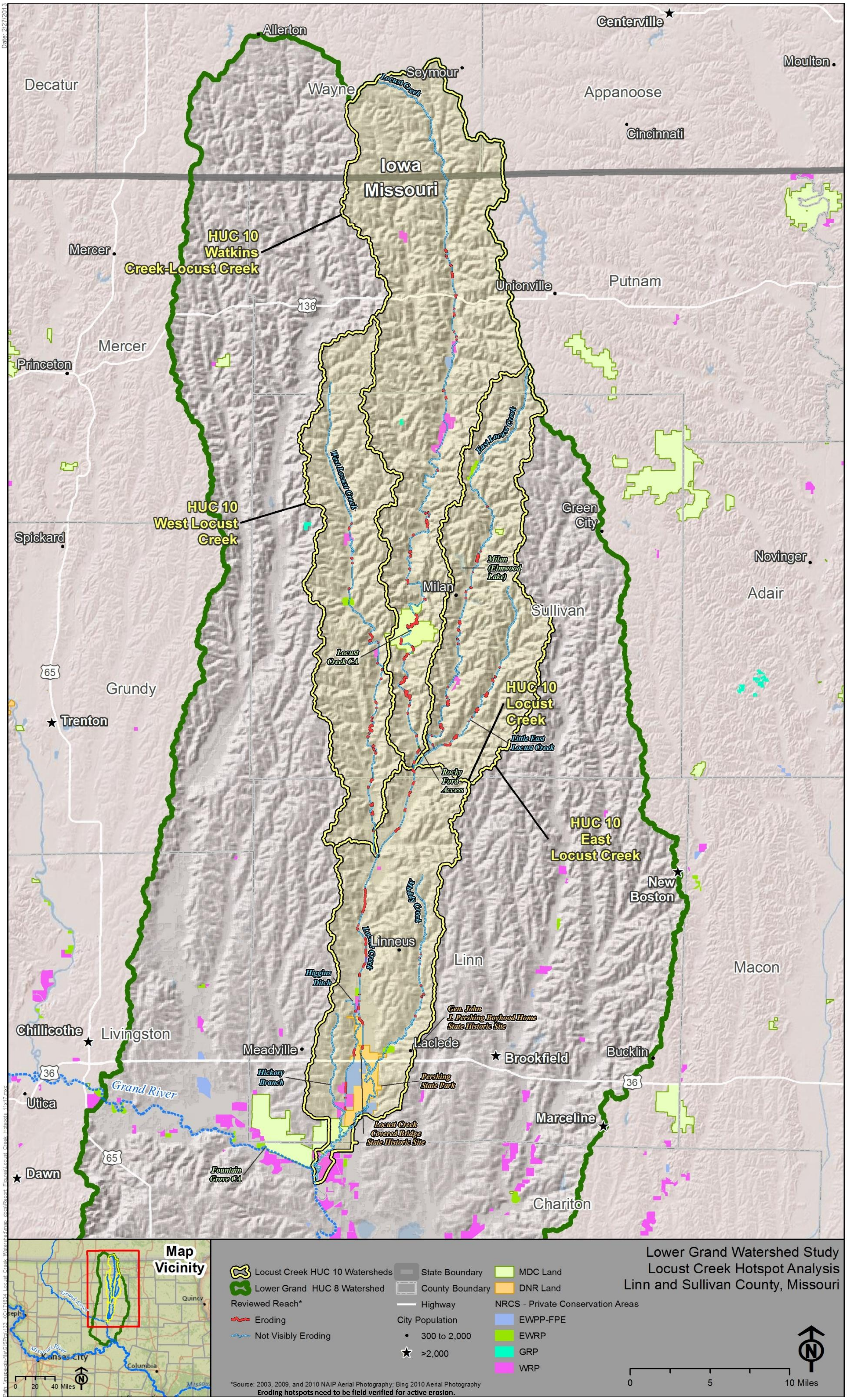
Table 5: Hotspot Analysis Summary

LCW Sub-Watershed	Eroding Hotspots (linear ft.)	Eroding Hotspots Count
East Locust Creek	37,360	28
Locust Creek	47,429	31
Watkins Creek-Locust Creek	64,116	37
West Locust Creek	28,665	27
Total	**177,570**	**123**

Channelization in the watershed is extensive, especially in WLC and LC. Figure 13 and Appendix A mapbooks show the existing channelized sections within the four main named stream systems as contrasted to their respective probable historic channel alignments. Probable historic channel alignments were determined from aerial photography evidence of old channels such as field scars, curve linear forested wetland depressions, and LIDAR digital elevations.

Another significant watershed wide and common problem reported by Greg Pitchford (MDC, 2012a) is significant head cutting as illustrated in the photos on Figure 15. These photos illustrate massive losses of stream channel bed material and upland soils downstream from a knick point elevation change. Pitchford (MDC, 2012a) reported head cut migrations up to roadway culverts as a common feature in the LCW. Unless stabilized, or stopped by a natural channel hard bed feature (e.g. a rock shelf) or man-made infrastructure, erosion will continue and become unconsolidated channel sediment bed material and slowly transport downstream, exacerbating channel bed aggradation and flooding conditions. It's likely that past channelization of streams in the LCW resulted in steeper channel bed slopes and head cuts that could still be actively migrating higher into smaller watershed streams. Land use practices are also probably significant contributors to head cut formation. It's uncertain as to how much head cutting contributes to annual sediment loadings, but warrants further investigation.

Figure 14: Streambank Erosion Hotspot Analysis in the Locust Creek Watershed



Mapbooks in Appendix A also indicate levee locations (where quality data was available). In general, levees are much more prevalent in the lower LCW HUC 10 sub-watershed, especially along LC above PSP.

Previous wooded riparian corridor buffer width by MDC (1994) in the LCW indicated average riparian buffer width to be 40 – 59 feet, with 92% of the sample sites having buffer width less than 100 feet wide. Typically most stream and riparian buffer experts recommend 100 feet minimum width of riparian buffer along stream as a rule of thumb to help maintain stable stream

Figure 15: Representative Headcuts in the Locust Creek Watershed

Active Headcut: Note waterfall effect over the knick point above the head cut channel, abrupt channel bed elevation changes, and downstream bank failure below the knick point. Photo taken on main avulsion between LC and HD.

Inactive Headcut: Headcut in upland area has migrated to a county road culvert and has temporarily stopped or is inactive, as demonstrated by lack of a defined eroded channel on the opposite side of the road. Photo from 220th Road, Putnam, County.

banks, provide habitat, and buffer local runoff. An analysis of riparian buffer conditions was attempted to update MDC's estimates, but not completed, because the watershed level GIS mapping scale used in Appendix A is too large to do a detailed analysis of widths. A smaller scale, more localized sampling analysis that replicates MDC's study would be necessary to accurately determine changes in average riparian buffer widths over time. In lieu of an updated riparian buffer width analysis, a simplified analysis evaluating the total linear feet of existing riparian buffer to the total length of all streams in the watershed was conducted using 2011 aerial photography data. This was estimated to be 6,060,771 linear feet or 59% of all streams contain a wooded riparian buffer, which means nearly 41% of all streams have no wooded riparian buffer.

Pasture/hayland is by far the largest land usage (by percent acreage) in the watershed at approximately 55.7% of total land area and livestock production is a significant agricultural business in the LCW. Livestock typically have un-controlled access to streams of all sizes with and without wooded riparian buffers through the LCW. Streams with mature wooded riparian buffer next to pastures are used for shade in the summer. Independent studies referenced in Appendix B have shown that stream channel reaches with sparse or no off-channel shade produced as much as 5.5 times more sediment than those stream channel reaches with similar amounts of riparian shade, but with effective off-channel shade opportunities. In reaches with sparse off-channel shade, cattle spent 10% of their time in off-channel shade, while in those reaches with more effective off-channel shade options; cattle spent 22% of the day away from riparian areas. The results suggest that provision of off-channel shade can significantly reduce riparian compaction and erosion. Furthermore, references cited in Appendix B have found uncontrolled channel access by cattle paired with dysfunctional (non-sediment-filtering) riparian systems are more likely to generate and allow transport of sediment to fluvial channels. As such, it's very common that riparian buffers and stream banks are heavily trampled and likely susceptible to rill and gully erosion that worsens over time. Due to the previously mentioned factors, it's likely that erosion-forming livestock behaviors probably are a significant contributing factor to channel and floodplain sediment aggradation in the LCW.

A preliminary sediment loading analysis was conducted (Appendix B) to describe how and where sediment is generated (mobilized) on the landscape and transferred to channel reaches. The analysis examined the relationship between watershed land cover, its effects on cattle movement within riparian areas, stream buffer density and stream channel capacity to either move or store sediment. The overlaying of these parameters produced unique hydrologic response unit (HRU) areas that identified an estimated annual Relative Potential Loading (RPL) of sediments for each HRU. Figure 16 is an overview map showing RPL's in the HRU's of the LCW with RPL's shown on a color coded, relative scale of very low to high. Each color code represents an estimated range of sediment load in pounds per year. Note this analysis is relative, it doesn't indicate what actual sediment loadings in pounds/year are occurring in any given HRU. It is important to keep in mind that the classifications merely suggest *relative loading potential* of HRUs with respect to each other. In general, the moderate to very high RPL HRU's take up much less land area on the LCW landscape than RPL HRU's with very low to low loadings. This analysis suggests that moderate to high RPL HRU's are much more likely to contribute higher sediment loadings to streams. Existing and proposed NRCS impoundments and reservoirs (see Figure 11), and other existing small impoundments, were digitized in GIS and were factored into the analysis as fully functioning catchments for sediments and thus were considered non-contributing areas to downstream reaches. More detailed HUC-12 sub-watershed unit RPL analysis mapping is also provided in Appendix B for the 16 HUC-12 units in the LCW. This mapping may be useful for future field verification of the analysis performed and for targeting potential Best Management Practices (BMP) sediment controls.

In addition to the RPL analysis, a Stream Sensitivity (SS) characterization analysis was completed for all stream reaches in the LCW (Appendix B). This SS characterization determined likely potential sediment source reaches versus sensitive (or response) reaches (Figure 17). Source reaches are those that are likely subject to channel scour and sediment transport, while sensitive reaches readily respond to upstream sediment and hydraulic inputs given their relatively low gradient slope. In other words, upstream watershed and channel alteration departures from "natural" characteristics that formed these sensitive reaches will elicit a response, a shift, in their stream typology (i.e., their geomorphology, bedform, habitat, water chemistry and biological community structures). In the LCW, sensitive reaches likely respond by sediment loads falling out of suspension from slope and flow changes with aggradation potentially resulting. In Figure 17, source and sensitive reaches are overlaid on the RPL's mapping to understand the relationship between the watershed and stream network to determine the most critical sediment loading and source reach areas. Reaches in LLC known to be severely aggrading were predicted as sensitive reaches through this analysis. This suggests the SS characterization method's promise as a diagnostic tool in watershed management for future work.

When HRU's with moderate to very high RPLs contain source reaches, a Critical Source Area (CSA) is defined. CSAs are expected to readily mobilize sediment to source channels with high sediment transport capacity. This in turn is expected to exacerbate downstream aggradation in sensitive/response reaches. These CSAs are identified and discussed later in Section 5.2 for field investigation for placement of BMPs that would provide the highest return on investment to conserve soils and reduce channel sedimentation and aggradation downstream of CSAs.

Cultivated land use, which is generally susceptible to soil erosion, is 14.1% of total land area in the LCW based on current (2003) land uses (see Section 2.1.2). Anecdotal reports from MDNR and MDC indicate clearing of timber on marginal croplands to expand row crop production has increased over the past approximate 10 years and this clearing is probably introducing additional sediment into streams and contributing to more gullies being formed.

The Hwy 36 fill embankment across the LC floodplain is a tremendous barrier to flood flow passage. There are currently only four drainage structures under Hwy 36 that currently drain over 400,000 acres of the LCW. The channels of three of these structures are known to be impacted by varying depths of aggradation, which constricts drainage conveyance.

Furthermore, the main LC channel through PSP is likely aggraded its entire length thus conveyance is restricted. The severe floodplain sediment aggradation shown on Figures 5 and 6 just north of Hwy 36 is indicative of the major drainage constrictions caused by the highway embankment.

Figure 16: Relative Potential Sediment Loadings Analysis Overview Map

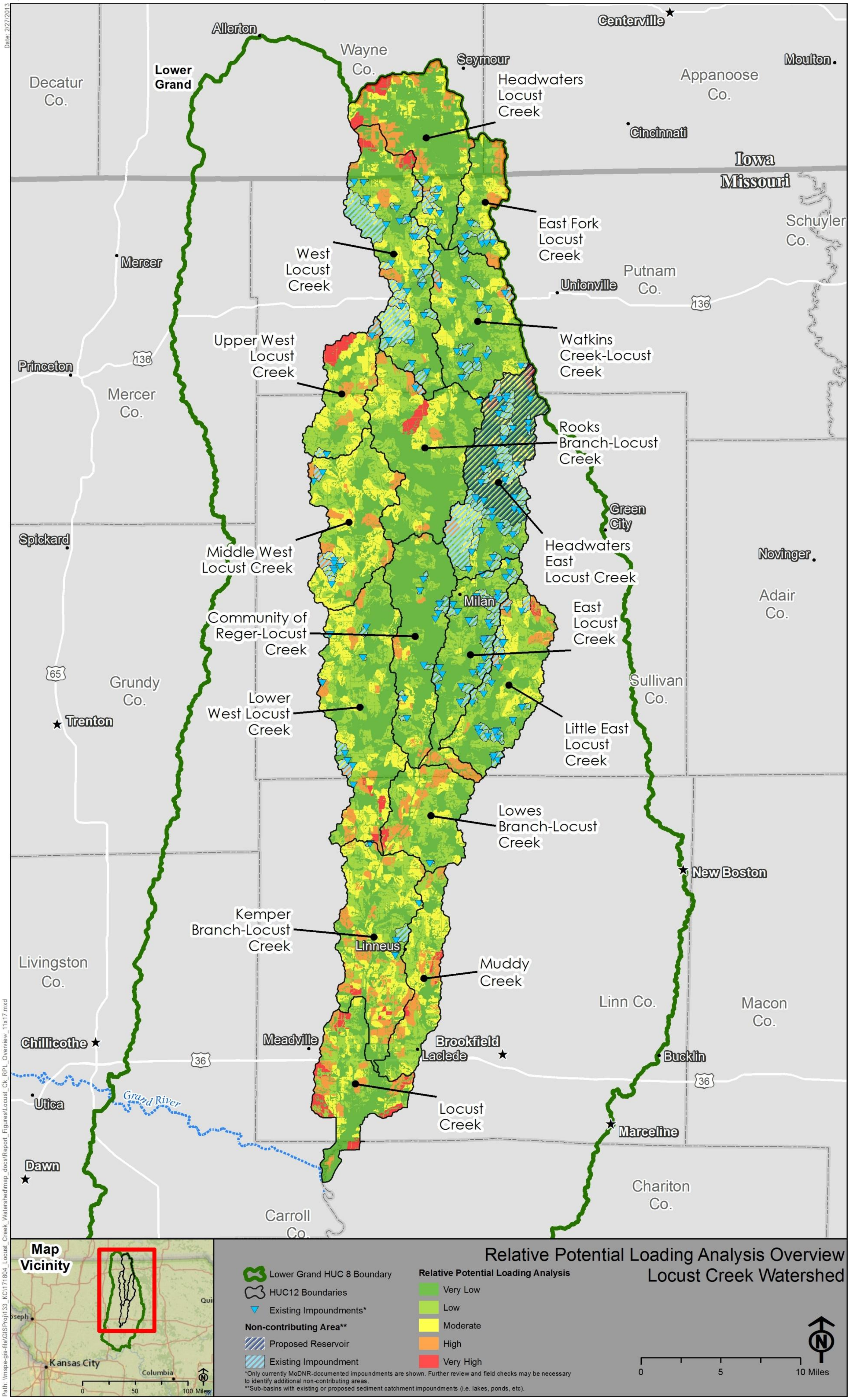
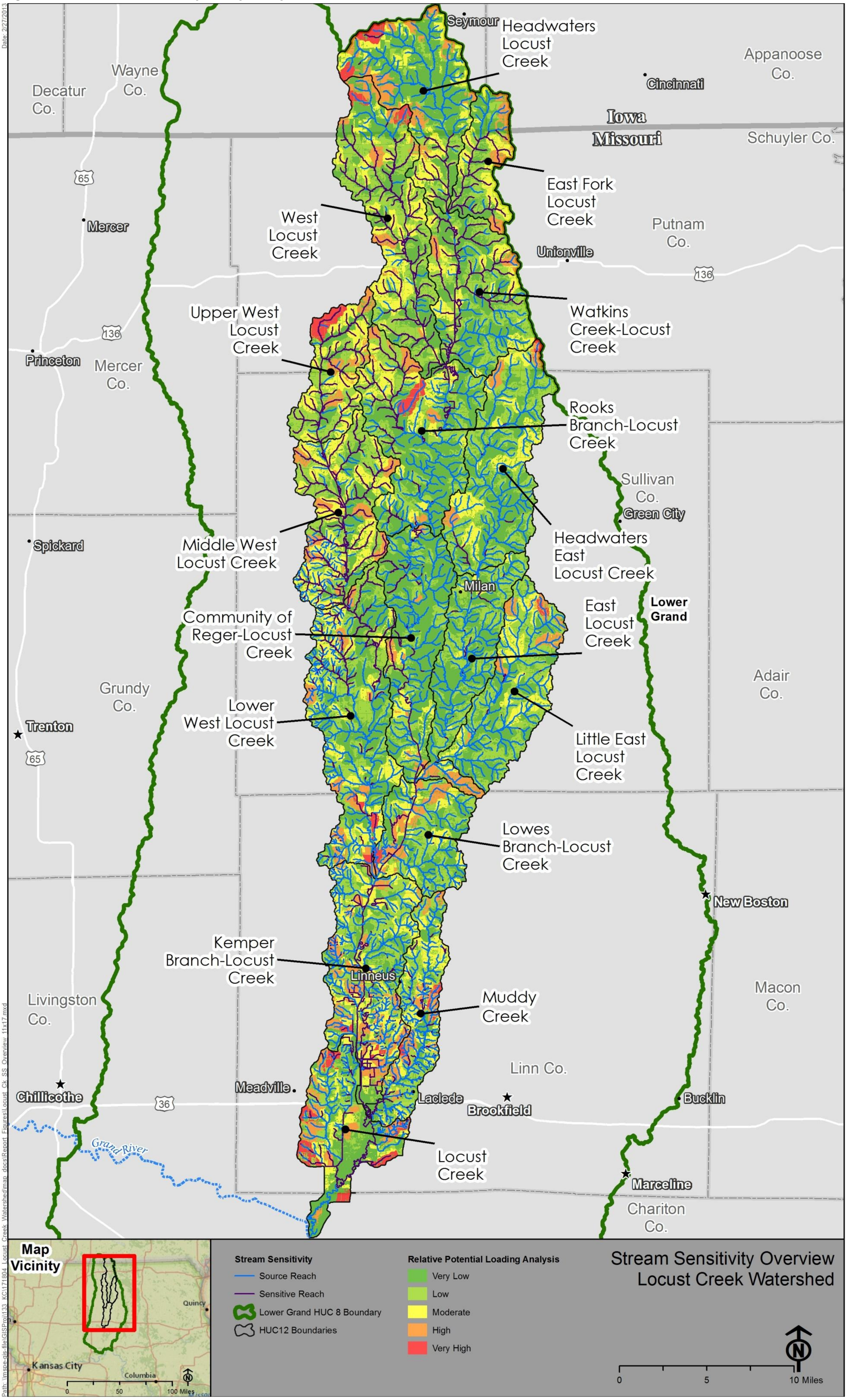


Figure 17: Stream Sensitivity Analysis by Reach



2.2.2 Other Potential Problems – LGR Drainage and Sediment Transport Concerns

Heitmeyer (2011) provided a very comprehensive assessment of the LGR ecosystem, including the historic pre-settlement condition with fully functioning ecological processes and conditions, changes to historic processes and conditions, and general and specific recommendations for management and restoration. This study used a hydro-geomorphic approach that focused on geomorphology, soils, topography, hydrology, land use, and flora and faunal communities. The study well documented changes in land use and drainage modifications in the LGR, including extensive channelization, levee construction, and transportation infrastructure. One telling piece of information in the study was an analysis of changes in discharge on the Grand River from two 40-year periods, 1939 - 1969 and 1970 - 2009, based on data from the Sumner USGS gage on the Grand River. Heitmeyer determined that discharges on the Grand River had increased significantly in the latter period at this gage, most likely due to un-coordinated channelization and levee construction throughout the LGR watershed. His study also determined there was a significant increase in the number of high frequency discharges of 0.25 to 2 year recurrent interval events from 1970 to 2009. Pitchford (2012) indicated the Grand River bed elevation at Sumner, Missouri has risen six feet over the last 40 years, indicating likely aggradation and lost channel capacity and increased flooding, while further up stream at Gallatin, Missouri the Grand River has lower two feet over the same time period (likely degrading). Heitmeyer (2011) stated that the narrowing of floodplains by levees, including the significant Garden of Eden Levee (GOE) floodway pinch point construction at the confluence with Yellow Creek (Figure 18), have caused relatively rapid rises in flood flows and inundated extensive areas of the southern part of the Middle LGR floodplain, including SLNWR and lower Yellow Creek. This levee has an established history of failure, including 1928 and 1930 (Heitmeyer, 2011) and in 2007 (USACE, 2008). Other breaches may have occurred, but no documentation was available for review. Several natural resource professionals from MDC and MDNR suspect this floodway constriction is a major issue. The GOE levee is located along lower Yellow Creek (south side) and on the east bank of the Grand River near Sumner, Missouri. Another potential concern expressed is the floodway constrictions created by the paralleling Hwy 139 and BNSF Railway bridges and fill embankments across the Grand River floodplain (Figure 18) approximately one mile southwest of Sumner, Missouri. The bridges may be old and undersized to effectively transport sediment in the flat sloped Grand River. The fill embankments probably constrict drainage conveyance. MDNR staff report backwater effects from the LGR do prolong flooding in LLC and PSP which contributes to tree mortality and wet prairie decline in PSP and deposits sediments in PSP wetlands.

Figure 18: Lower Grand River Garden of Eden Levee and Pinchpoint

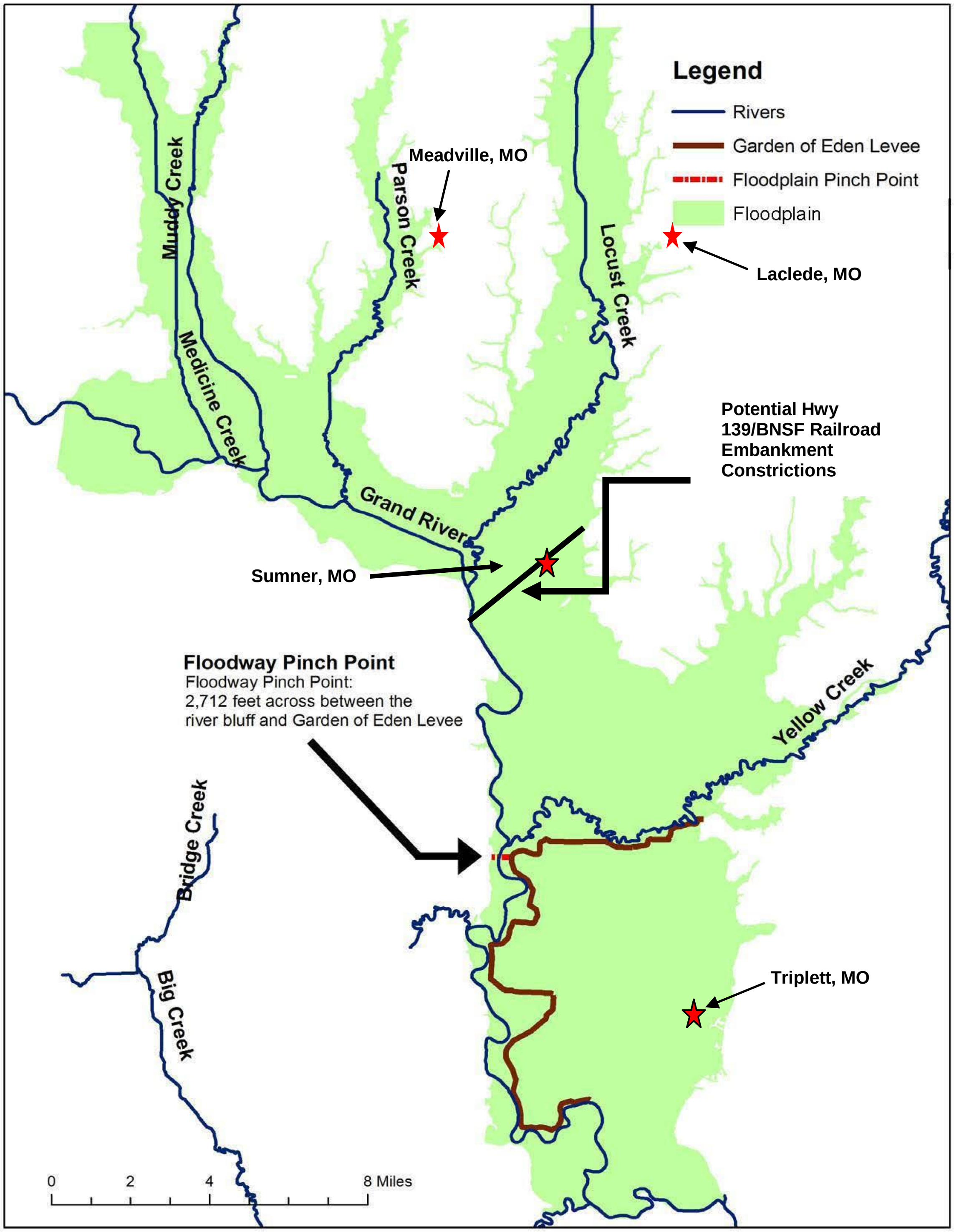


Figure base courtesy of Greenbrier Wetland Services Report 11-01

The Hwy 139/BNSF Railway fill embankment and GOE floodway pinch point are considered two significant drainage concerns that are likely contributing to excessive backwater effects, flooding and potential sediment aggradation in the LGR and in LLC from reduced capacity discharge and related sediment transport capabilities. The Hwy 139/BNSF Railway bridges may be major constrictions affecting sediment transport through LC due to close proximity. There are also other levees that may be constricting flows along the LGR as shown in Figure 19.

Figure 19: Other Lower Grand River Levees

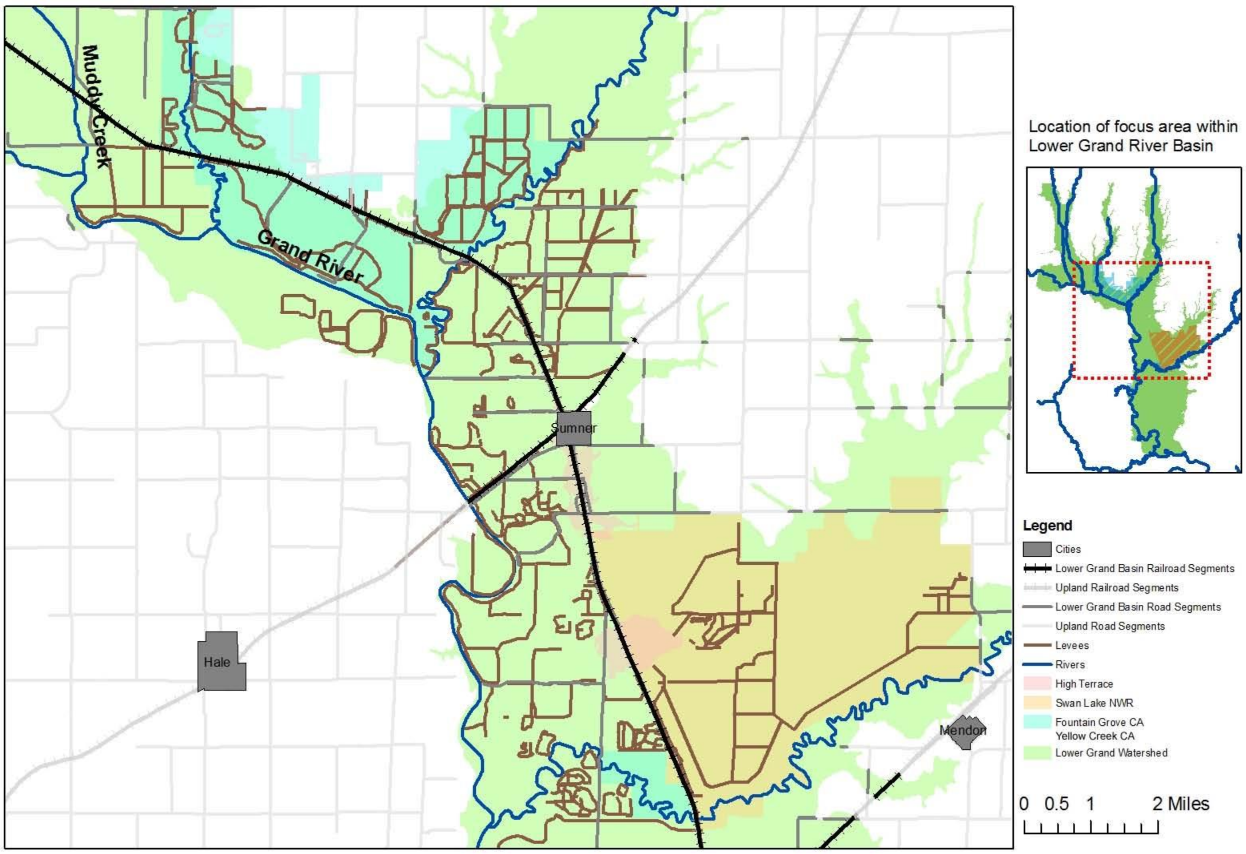


Figure courtesy of Greenbrier Wetland Services Report 11-01

2.2.3 Problems Summary

The root problems in the LCW, in LLC, and within the adjacent LGR, which are or may be causing excess sedimentation and related channel and floodplain aggradation problems, could be best geographically sorted and summarized as follows:

- LCW – Gully, rill and sheet erosion from grazing, land clearing, and crop production
- LLC - Stream bank erosion and head cutting from channelization and levees
- LLC – Lost floodplain functions from levees during high flow events, including energy dissipation, and lost water and sediment storage capacity
- LLC - Loss of floodwater drainage conveyance from the Hwy 36 fill embankment
- LGR – Backwater flooding, drainage constrictions, and loss of sediment transport capabilities from Hwy 139/BNSF Railway fill embankments
- LGR - Backwater flooding and drainage constrictions at the GOE Levee

2.3 Future Conditions

Without taking action in the LCW, lower LC, and the LGR, watershed problems will continue. Symptoms such as log and ice jams, channel sediment aggradation, floodplain avulsions, drainage conveyance concerns, and excessive flooding will continue. Hardwood forests, marsh wetlands, wet prairie and overall vegetation species diversity in PSP may continue to perish or degrade, albeit perhaps more slowly with the diversion of excess water through the multi-channeled stabilized avulsion to HD.

2.4 Planning Constraints

Many planning constraints are acknowledged for this study. The watershed symptoms and problems, existing conditions, and goals (Section 3.0 below), are all based on a collectively large set of data from various sources. In most cases, individual data sources were very general or limited to site specific analysis from previous studies, professional observations and opinions, and on some initial high level GIS analysis using available data. Attempts were made to obtain the most recent existing conditions data; however, there are data gaps and some of the existing conditions data cited in this report are dated. Therefore, caution should be exercised in using the information provided in this report. No field or modeling analysis has been done for this study to verify and quantify the various problems identified. The LiDAR data and aerial photography used in this study was a very helpful substitute for field data to verify many of the existing conditions and “big picture” problems located outside stream channels, but were not useful in understanding “in-channel” stream conditions (elevations, cross-sections, etc.). LiDAR technology, while extremely useful for determining surface contours, cannot penetrate water surfaces effectively. No detailed watershed wide modeling or in-channel hydraulics and hydrology modeling has been performed. No detailed stream geomorphologic analysis has been done. Much intuition and logic and best professional judgment were used to formulate the information provided in this study. Conceptual system based approaches were applied to limited information, and relied on multiple professional opinions and knowledge of watershed and stream problems in general. Watershed actions and practices and watershed alternatives (see sections 4.0 and 5.0) discussed further below are largely planning and conceptual in nature.

3.0 Goals

The following are preliminary goals that were developed from LCW and LGR problems and symptoms with input from the local sponsor. As with all goals, they can be distinguished from each other in that goals typically are not measureable and are more general in nature. As the study moves forward, specific measurable objectives should be developed for each goal to measure progress. Goals shown as follows are loosely arranged based on broad geographic focus areas that should be addressed.

Watershed Wide (WW), Lower LC (LLC), and Lower Grand River (LGR) Goals

1. WW – Reduce Sheet, Rill, and Gully Erosion Runoff from Agricultural Land Uses

2. WW/LLC – Reduce Stream Bank Erosion and Bed Head Cutting

3. LLC – Restore Floodplain Functions

4. LLC/PSP – Restore LC Channel Conveyance and Reduce Flooding

5. PSP – Restore Floodwater Drainage Capacity/Sediment Transport Through Hwy 36

6. PSP – Reduce Log and Ice Jams

7. PSP – Reduce or Prevent Further Loss of Forests, Marshes and Wet Prairie and prevent further decline in overall vegetation species diversity in PSP.

8. PSP – Recover and maintain water flow, aquatic diversity, and natural meandering character of LLC in PSP, especially in Locust Creek Natural Area.

9. PSP - Restore or Enhance Forests, Marshes and Wet Prairie

10. LLC/LGR - Restore Sediment Transport/Floodway Capacity at Constrictions

4.0 Watershed Actions and Practices

4.1 Introduction

Opportunities exist in the LCW, lower LC, and on the LGR, to address on-going symptoms, problems and goals. The purpose of this section is to develop and describe watershed actions and practices (WAP) opportunities that may help address these. Watershed actions are broad in nature, but provide distinctive restoration functions. Watershed practices are specific structural or non-structural measures to achieve the functions of a watershed action. A charette session was conducted by HDR Engineering staff on May 5th, 2012 to discuss watershed problems, data needs and practices. From this meeting, a working list of a wide range of potential watershed actions and practices was developed, then later revised and reorganized into meaningful categories. Watershed practices were grouped under respective broader watershed actions. The initial WAPs were then discussed at a local sponsor meeting with MDNR and other agencies in October 2012 and during the meeting additional watershed actions were discussed and later developed. The broad restoration actions from these meetings are:

- Watershed BMPs
- Floodplain Restoration
- Stream Restoration
- Grand River Levee Modifications
- On-going Natural Resource Management
- Agency Partnerships
- Public Education and Awareness
- Organizational Structure Establishment

4.2 Watershed Actions and Practices Review

WAPs are individually described below. Each watershed action is first discussed in very general terms of descriptive function(s), technical and financial feasibility, and private landowner perceptions. Then, watershed practices that address the watershed action are described below the watershed action. Comments on practice function(s), feasibility, and private landowner perceptions are provided as needed. Where possible, an example graphic depiction, typical drawing, or photo is provided to illustrate the watershed practice. In general, many WAPs can be cost-shared with various state and federal government programs.

4.2.1 Soil and Water Best Management Practices Action

This restoration action consists of applying a whole range of soil and water BMPs throughout the watershed primarily targeting upland agricultural areas (cropland, pasture, etc.), and some floodplains/stream sites. This action functions to manage and conserve soil and water resources. Expected results of the watershed soil and water BMP action are reduced soil erosion and land degradation, reduced sedimentation, water quality improvements in receiving waters, and fish and wildlife habitat improvements. Soil and water BMPs described below were primarily derived from MDNR's Soil and Water Conservation Program Cost Share Practices List (MDNR, 2013a), with a few practices taken from the USDA-NRCS Mississippi River Basin Healthy Watersheds Initiative (MRBI) Environmental Quality Incentives Program (EQIP) approved and funded list (NRCS, 2012). Soil and water BMP practices are numerous and described below.

4.2.1.1 Sheet and Rill/Gully Erosion BMPs

BMPs for sheet and rill/gully erosion consist of a wide range of state and federally approved and cost-share funded practices to help reduce or stop land degradation. These practices are all technically feasible and use of each practice described below depends on landowner needs, site specific conditions, approval for use in a given county, and funding availability. Costs can vary greatly.

- **Permanent Vegetative Cover Establishment**

Establish a permanent vegetative cover to stabilize soil on land that is experiencing significant erosion.

- **Permanent Vegetative Cover Improvement**

Improve plant health and diversity by introducing legumes into established grass communities to protect soil on land that is experiencing significant erosion.

- **Terrace System**

Reduce the erosive force of water by placing terraced embankments to slow water runoff and increase water absorption on crop land that is experiencing significant erosion.

- **Terrace System with Tile**

Reduce erosion with the placement of embankments on slopes to reduce the slope length and use underground piping to more quickly remove erosive water to a stable outlet from tracts that have experienced significant erosion.

- **Windbreak/Shelterbelt Establishment**

Reduce the impacts of wind erosion and improve irrigation efficiency in cropland by establishing trees and shrubs at the edges of crop fields minimizing the impact of wind.

- **No-Till System (Residue & Tillage Management)**

This practice is an incentive payment to encourage farmers to use conservation no-till to reduce erosion on land that is experiencing significant erosion.

- **Permanent Vegetative Cover — Critical Area**

Establish a permanent vegetative cover on small critical areas such as gullies and steep banks to reduce erosion and protect water quality.

- **Permanent Vegetative Cover — Critical Area: Confined Animal Feed Lot**

Establish a permanent vegetative cover on small critical areas associated with animal confinement feeding areas.

- **Water Impoundment Reservoir**

Control erosion and protect water quality by constructing ponds to catch sediment and prevent it from leaving fields on land that is experiencing significant active erosion.

- **Sediment Retention Water Control Structure**

Temporarily retain water to control the release of runoff water and settle out the soil particles and nutrients. This practice is applicable to areas on farms where runoff of substantial amounts of sediment or runoff containing pesticides or fertilizers constitutes a significant pollution hazard.

- **Grade Stabilization**

Earthen dam and associated water control structures constructed to manage water flow gradients and resultant erosion.

- **Grassed (Sod) Waterway**

Prevent or reduce existing erosion and pollution of water or land from agricultural nonpoint sources by using sod-forming grasses to protect soil within waterways to efficiently transport rainfall.

- **Diversion**

Control erosion and reduce or prevent pollution of land, water or air from agricultural nonpoint sources by directing rainwater to less sloping areas of the landscape and allowing it to dissipate or run off at a lower velocity, which encourages infiltration into the soil.

- **Contour Buffer Strips**

Reduce erosion and water pollution by establishing strips of permanent vegetative cover between crops, around hill slopes, and alternated downhill slopes.

- **Contour Strip Cropping**

Reduce erosion and water pollution by implementing crop and vegetation rotations through systematic arrangements of equal-width strips across fields.

- **Cover Crops**

A crop of legumes, winter killed species, grasses and/or certified cereal grains, when planted for purposes of benefiting soil and/or other crops, but is not intended for harvest for feed or sale. Benefits of covers crops include soil quality improvements, erosion control, fertility improvements, suppressing weeds, and insect control.

- **Conservation Crop Rotation**

A small grain crop that is rotationally planted with forage grass or legume crops planted for purposes of managing soil fertility, soil tilth, organic matter, pest management, moisture efficiency, improving crop yields, and wildlife habitat.

4.2.1.2 Grazing Management BMPs

Grazing management BMPs consist of a wide range of state and federally approved and cost-share funded practices to help manage and conserve vegetative cover, soils, and water resources on or near pastures. These practices are all technically feasible and use of each practice described below depends on landowner needs, site specific conditions, approval for use in a given county, and funding availability. Costs for practices vary widely.

- **Permanent Vegetative Cover Enhancement**

Improve the vegetative cover on pastures by introducing legumes into the grass base using no-till technology. Improving the plant community health protects the soil by reducing erosion and preventing water pollution.

- **Grazing System Water Development**

Develop water sources (ponds, springs or wells) for livestock watering that are generally strategically located to help efficiently manage grazing resources (water and grasses).

- **Grazing System Water Distribution**

Develop water distribution, including pipeline and watering tanks/troughs, for grazing areas. By providing water distribution to individual grazing areas, livestock can more effectively utilize the resource. A planned grazing system includes water availability in each grazing area.

- **Grazing System Fence**

A planned rotational grazing system allows time for vegetation to rest and recover before being grazed again. Fencing is used to allow livestock access to a small area to be grazed.

- **Grazing System Lime**

Manage the pH of soil for optimum fertility. This is an important factor in how effectively plants can take in soil nutrients. Lime is the most cost effective method to manage soil pH.

- **Grazing System Seed**

Interseed legumes in an established grass pasture grazing system to improve plant health and diversity and protect soil from erosion.

- **Prescribed Grazing**

The paddock system is used as a means to manage the number of days of livestock grazing per paddock cell for purposes of improving soil health, through reduced soil compaction, and increased plant growth, through reduced plant recovery time after stressed from grazing.

- **Heavy Use Protection**

Gravel and/or concrete in heavy use portions of grazing areas to manage soil erosion.

4.2.1.3 Irrigation Management BMPs

Irrigation management BMPs consist of a wide range of state and federally approved and cost-share funded practices to help manage and efficiently use water resources and provide water quality benefits. These practices are all technically feasible and use of each practice described below depends on landowner needs, site specific conditions, approval for use in a given county, and funding availability. Costs are variable by practice type.

- **Irrigation Water Conveyance**

Install underground piping to create a closed system of water transport to prevent water loss from irrigations systems.

- **Irrigation System, Sprinkler**

Upgrade sprinklers and nozzles on existing pivot irrigation systems to increase system efficiency.

- **Irrigation System, Surface and Subsurface**

Efficiently convey irrigation water from a source to the point of application without causing erosion, water loss or reduction in water quality. This practice allows for more efficient use of irrigation water through improved application methods.

- **Irrigation System, Tailwater Recovery**

Collect and reuse irrigated run-off water to protect surface water and conserve agricultural pesticides and fertilizer.

- **Drainage Water Management**

Install underground piping to drain excess water away from planting areas and control release of water for optimal environmental benefits.

- **Structure for Water Control**

Reduce chemical and nutrient loading to downstream surface water by properly retaining irrigation water on agricultural fields.

4.2.1.4 Animal Waste Management BMPs

Animal waste management BMPs consist of a wide range of state and federally approved and cost-share funded practices to help manage and efficiently use animal wastes for plant nutrients and provide soil and water quality benefits. These practices are all technically feasible and use of each practice described below depends on landowner needs, site specific conditions, approval for use in a given county, and funding availability. Costs are variable by practice type.

- **Beef Waste Management**

Collect, control and manage agricultural waste, manure and litter from beef production operations to protect water and air quality and provide plant nutrients on agricultural land.

- **Dairy Waste Management**

Collect, control and manage agricultural waste, manure and litter from dairy production operations to protect water and air quality and provide plant nutrients on agricultural land.

- **Poultry Waste Management**

Collect, control and manage poultry litter from poultry production operations to protect water and air quality and provide plant nutrients on agricultural land.

- **Swine Waste Management**

Collect, control and manage agricultural waste from swine production operations to protect water and air quality and provide plant nutrients on agricultural land.

- **Incinerator**

Safely dispose of livestock and poultry carcasses to reduce pollution of water and soil resources.

- **Composting Facility**

Build a composting facility to utilize natural decomposition to break down animal waste to be used to improve soil fertility and crop production.

4.2.1.5 Nutrient and Pest Management BMPs

Nutrient and pest management BMPs consist of state and federally approved and cost-share funded practices to help improve crop production while managing nutrient, herbicide and pesticide runoff. These practices are all technically feasible and use of each practice described below depends on landowner needs, site specific conditions, approval for use in a given county, and funding availability. Costs are variable by practice type.

- **Nutrient Management**

There are economic and environmental benefits to following an approved nutrient management plan to improve soil fertility and crop production. Planning is based on soil or plant nutrient testing to ensure adequate fertility without excess nutrient runoff.

- **Pest Management**

There are economic and environmental benefits of following an approved pest management program to reduce pressure from pest species and to improve crop yields or forage production with proper pesticide application. Planning is based on field scouting for weeds and insects.

4.2.1.6 Sensitive Area BMPs

Sensitive area BMPs consist of a wide range of state and federally approved and cost-share funded practices to help protect sensitive areas from nutrient, herbicide, pesticide, and soil erosion runoff. These practices are all technically feasible and use of each practice described below depends on landowner needs, site specific conditions, approval for use in a given county, and funding availability. Costs are variable by practice type.

- **Windbreak/Shelterbelt Establishment**

Reduce the impacts of wind erosion and improve irrigation efficiency in cropland by establishing trees and shrubs at the edges of crop fields minimizing the impact of wind.

- **Field Border**

Establish permanent grass buffers along the edges of crop fields to trap pesticide and fertilizer runoff. This practice reduces soil loss and improves water quality by preventing excess sediment and nutrients from entering streams.

- **Filter Strip**

Establish permanent grass filter strips below crop, hay and grazing land; and to prevent sediments, chemicals or nutrients from entering sensitive areas or water bodies.

- **Riparian Forest Buffer**

Protect soil and shallow groundwater from contamination by sediments, chemicals, nutrients, pesticides or organic matter and protect stream banks from erosion by planting woody species along the stream course and protecting the buffer area from trampling and grazing.

- **Stream Protection (Access Control)**

Exclude livestock from stream corridors to allow re-vegetation with grasses and trees on the streambank. This also provides a filter to trap sediments, chemicals and nutrients.

- **Streambank Stabilization**

Large stones or anchored cedar trees are used as mechanical protection of highly eroded stream banks to provide a stable area to establish grasses or other vegetation to protect the soil and water resource from erosion losses and contamination.

- **Spring Development**

Protect groundwater resources from contamination with collection points that provide dependable, safe water sources in a desired location for livestock watering.

- **Well Decommissioning**

Abandoned wells present a direct connection to the groundwater aquifer as well as a safety hazard. Wells that are properly treated, filled and sealed eliminate the safety hazard and protect the groundwater resource from possible pollution.

- **Sinkhole Treatment**

Protect groundwater springs from pollutants by improving drainage of surface water and protecting those groundwater inlets by establishing buffer and exclusion areas to trap sediments, chemicals and organic matter.

- **Sinkhole Improvement**

Karst areas are particularly susceptible to groundwater contamination from many sources. This practice is aimed at reducing the potential of pollution from nonpoint sources to protect groundwater. It includes protected drains to allow infiltration of water into the subsurface.

- **Buffer Sinkhole Improvement**

Establish grass filters in the areas adjacent to sinkholes to reduce the potential of sediments, chemicals, pesticides or organic matter entering the underground karst system.

4.2.1.7 Woodland Erosion BMPs

Woodland erosion BMPs consist of a wide range of state and federally approved and cost-share funded practices to help conserve woodlands, woodland soils, and minimize harvesting impacts. These practices are all technically feasible and use of each practice described below depends on landowner needs, site specific conditions, approved or not for use in a county, and funding availability. Costs are variable by practice type.

- **Forest Plantation**

Protect the soil and encourage the conversion of marginal soils to less intensive use by planting trees and shrubs and excluding livestock.

- **Woodland Protection through Livestock Exclusion (Access Control)**

Reduce erosion in existing woodlands by installing fence to exclude livestock.

- **Use Exclusion (Access Control)**

Install fence around existing woodlands and sensitive areas to reduce erosion.

- **Timber Harvest Plan**

This practice provides financial assistance for the proper design and construction of logging roads and stream crossings for timber harvest operations.

- **Restoration of Logging Roads, Stream Crossings, and Landings**

Correct and control gully erosion resulting from improperly constructed logging roads, skid trails, stream crossings, and landings following timber harvest.

4.2.2 Floodplain Restoration Action

This restoration action consists of restoring floodplain functions, either partially or fully, to conditions prior to construction of a levee, by capturing flood waters. Results of floodplain restoration are incremental reduced peak flows and related damages, improve habitats, water quality and groundwater recharge. Floodplain restoration is technically feasible, and assuming protected land behind a levee is available (fee title, easement, etc.) for flooding, and no adjacent levee protected land would be impacted by flooding, is generally a very effective, but sometimes costly, practice. A major public concern could be flooding of adjacent property and concern level could range widely from full support to opposition. Floodplain restoration practices are as follows:

4.2.2.1 Levee Breach

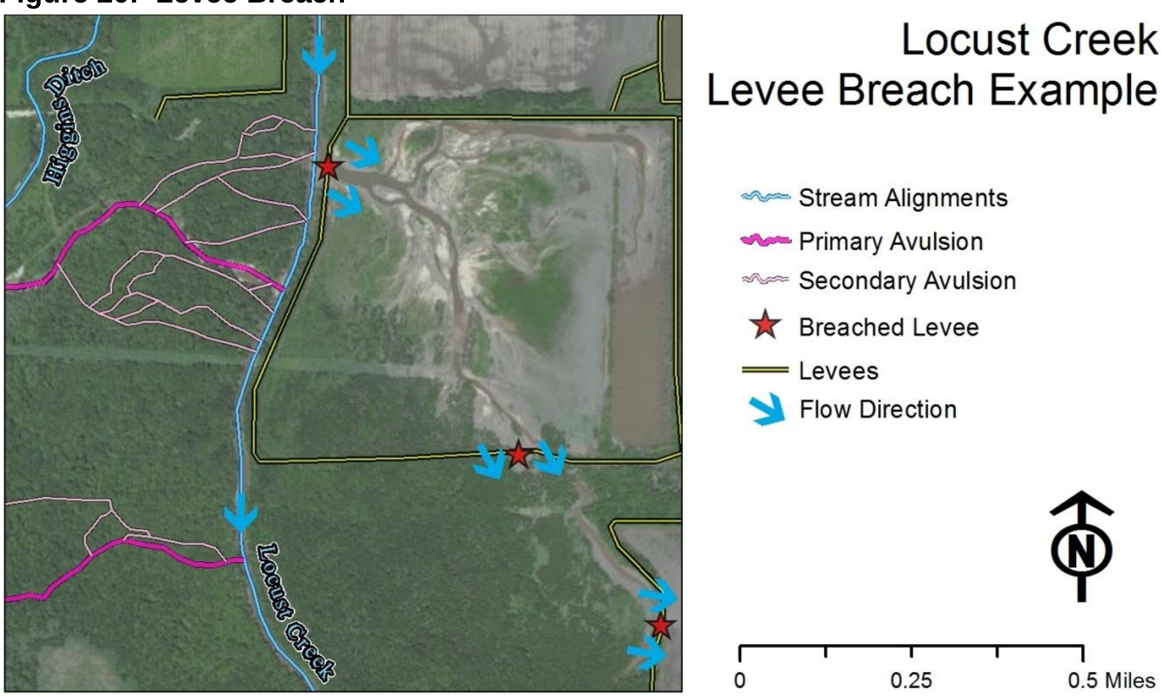
This floodplain restoration practice consists of removing small section(s) of levee (a breach) adjacent to a stream or river to allow floodwater inundation, sediment deposition, potential reduced peak flows and related damages, woody debris deposition, and wetland development. Water quality and groundwater recharge benefits may also result. Figure 20 depicts a real example of several levee breaches completed in 2009 inside PSP along LC east of the main channel avulsion. This practice is technically easy, relatively inexpensive, but potentially controversial with adjacent landowners.

channel avulsion. This practice is technically easy, relatively inexpensive, but potentially controversial with adjacent landowners.

4.2.2.2 Levee Removal or Relocation

This floodplain restoration practice consists of removing or relocating large sections of levee adjacent to a stream to allow floodwater inundation, sediment deposition, potential reduced peak flood and flow and related damages, wetland development, water quality and groundwater recharge. Levee removal means removing a levee without concern for adjacent property flooding impacts due to existing levees in place or no flooding concerns. Levee relocation means removing and relocating a levee in the same vicinity to continue providing flood protection to adjacent property that otherwise wouldn't be protected. Assuming protected land behind a levee is available (fee title, easement, etc.) for flooding, and no adjacent land would be impacted by flooding from removal or relocation, this practice is generally technically feasible, but financially costly. Local concerns would be expected to range from acceptance to opposition. Local adjacent property owner flooding concerns would have to be adequately addressed. Figure 22 depicts an example levee removal completed in 2012 inside PSP along HD and the West Zell Tract. This is a relatively expensive practice.

Figure 20: Levee Breach



4.2.2.3 Drainage Improvements

This floodplain restoration practice consists of making drainage improvements through roadway infrastructure for purposes of managing high flow events, backwater effects, and sediment transport. This could include replacing undersized or aging bridges and culverts, cleaning out sediment from drainage structures, or better managing sediment transport and floodplain flows with larger or additional drainage structures. For the lower LCW, drainage improvements could consist of excavating aggraded sediments that have accumulated in or near the LC Bridge opening or the LC OC that drains under Hwy 36 (Figure 21). This practice could consist of adding additional drainage structures under the Hwy 36 fill embankment as shown hypothetically in Figure 21. This practice could also potentially incorporate stream channel creation/restoration by adding overflow channel(s) from LC north of Hwy 36 through the OC structure and reconnect to LC south of Hwy 36 in PSP. This would be a costly, but highly effective practice.

Figure 21: LC Drainage Improvements

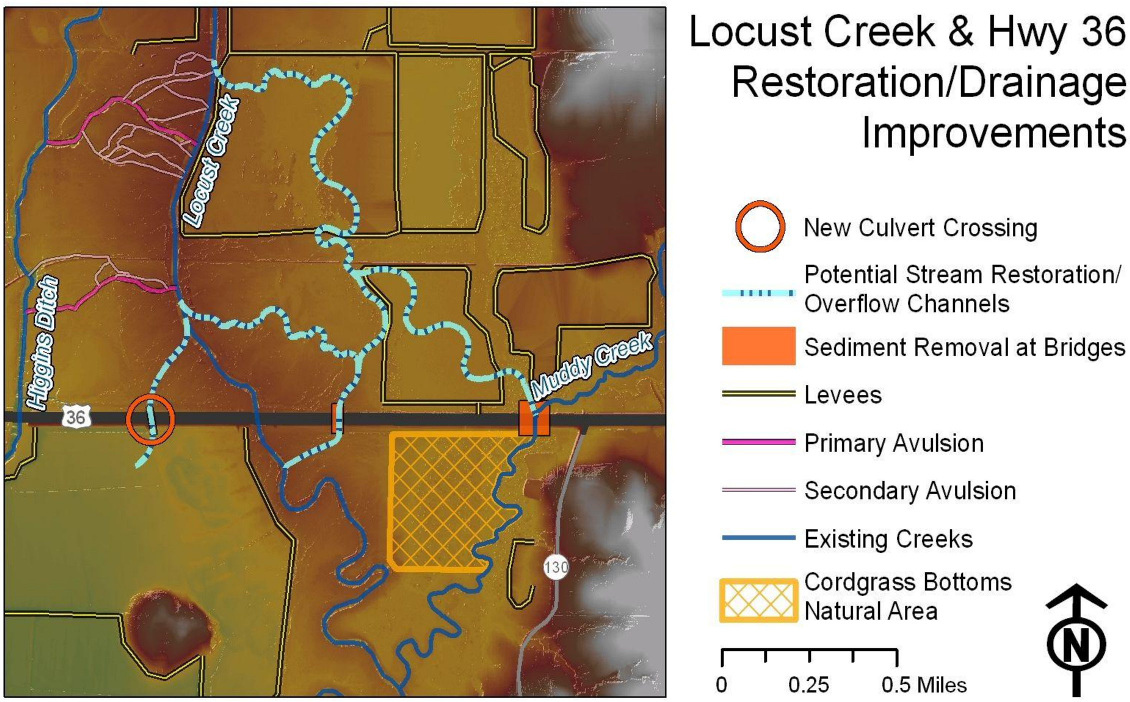


Figure 22: Pershing State Park – Zell Tract West Wetland Restoration Plans

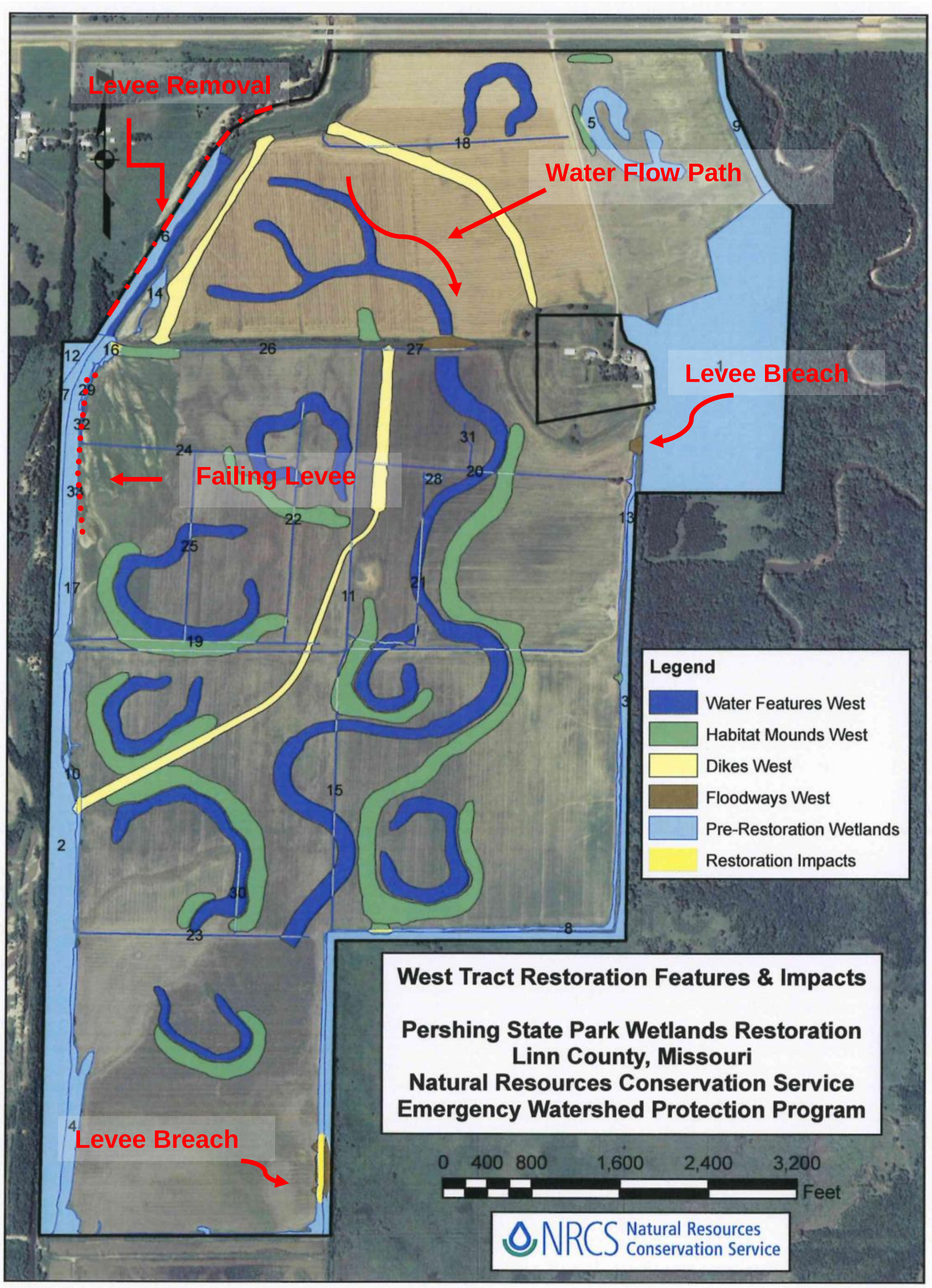


Figure taken from NRCS geopatial analysisof Zell Tract wetlands restoration (NRCS, ca. 2011)

4.2.2.4 Sediment and Woody Debris Catchment

This floodplain restoration practice consists of capturing and controlling distribution of sediment and woody debris from floodwaters in the floodplain. Capturing sediment and woody debris can be accomplished in floodplains where levees don't exist or have been breached or removed. Controlling sediment and woody debris distribution is important in maximizing capture through controlled movement of floodwater. The area east of the existing levee breach on LC north of Hwy 36 (see Figure 20) functions currently as a sediment and woody debris catchment in PSP, as well as the newly constructed West Zell Tract in PSP (Figure 22). NRCS designers purposely intended for the northern portion of the West Zell Tract to accumulate sediment and woody debris overflows from HD that would otherwise migrate down the un-channelized reach of LC in PSP. Construction costs for this practice are negligible, but some long-term recurring maintenance costs may occur for woody debris removal or sediment management.

4.2.2.5 Wetland Restoration or Enhancement

This floodplain restoration practice consists of restoring or enhancing existing wetlands. Restoration involves rehabilitating or re-establishing one or more key wetland characteristics (i.e. soils, hydrology or vegetation) of a degraded or former wetland resource. Conversely, wetland enhancement involves altering or improving a particular feature in an existing degraded or minimally functioning wetland. Figure 22 (West Zell Tract at PSP) is an example wetland restoration project.

4.2.3 Stream Restoration

This restoration practice consists of creating or restoring stream functions, either partially or fully, on degraded or channelized streams. Functional results of stream restoration are reduced or eliminated bank and bed erosion, improved stream habitat, and water quality improvements. Stream restoration practices are technically feasible, and assuming land is available, are generally very effective. Costs can vary widely on individual practices. A major concern could be increased flooding of adjacent property and concern levels could range widely from full support to opposition. Stream restoration practices are discussed below.

4.2.3.1 Channel Grade Control

This restoration practice consists of preventing the progression of stream bed erosion (head cutting) with channel grade control structures such as an engineered rock riffle (aka Newbury Riffle or Structure). This practice also helps reduce channel bank erosion, gully erosion, the loss of farmland soils, and helps prevent damages and loss to bridges, culverts and pipeline crossings. Channel grade control is fairly cost effective because it tends to be small in size and localized in use, and is generally acceptable to landowners, local government agencies, and the public. An example engineered rock riffle grade control is shown in Figures 23 and 24.

Figure 23: Channel Grade Control – Engineered Rock Riffle Plan and Profile

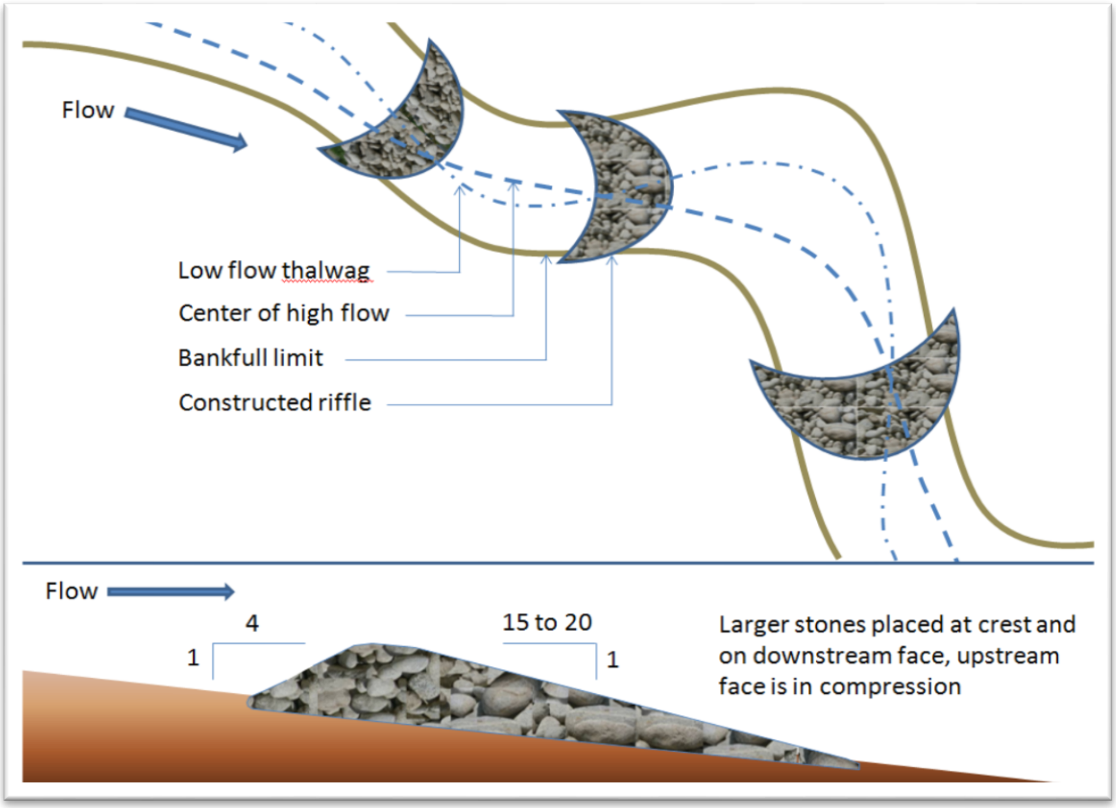


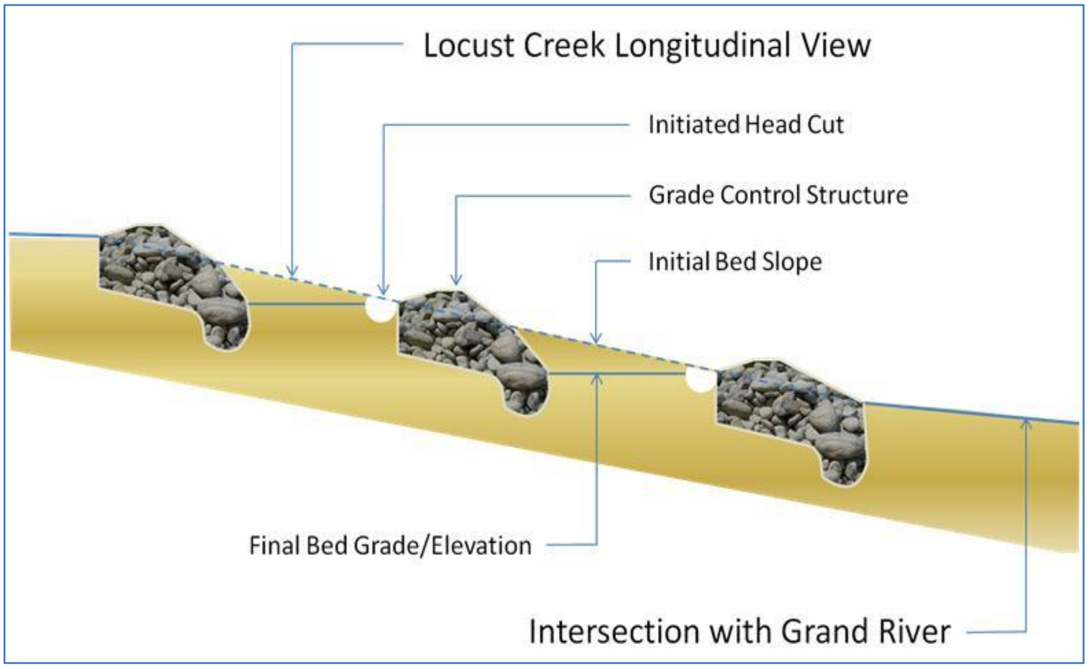
Figure 24: Channel Grade Control – Engineered Rock Riffle

Flow is right to left.

4.2.3.2 Controlled Headcut – Channel Grade Control

This restoration practice, while conceptual and largely an untested restoration practice, consists of constructing regularly spaced engineered rock riffle grade controls at key elevations in stream, then constructing small excavations behind each grade control to initiate a controlled eroding channel bed headcut (Figure 25). The desired effect is to scour an aggraded channel bed back to a more natural flow capacity and a more functional, and less frequent, overbank flooding regime. Sediment transport continuity would need to be maintained for this concept to work. Grade controls would act to permanently maintain a stable channel bed profile that would only scour to desired elevations. This conceptual practice could potentially be done on LLC from the Grand River confluence up through PSP to restore capacity. Extensive modeling would be required to determine whether this practice is feasible. It's likely that this practice would have to be done in conjunction with modifications to portions of the LGR system GOE levee as described further below in Section 4.2.12. Modifying this levee in the LGR should help improve flood water conveyance and could help increase sediment transport capabilities of aggraded coarse sediments (i.e. sands); prevalent in both LC and the LGR channel system.

Figure 25: Controlled Headcut – Channel Grade Control

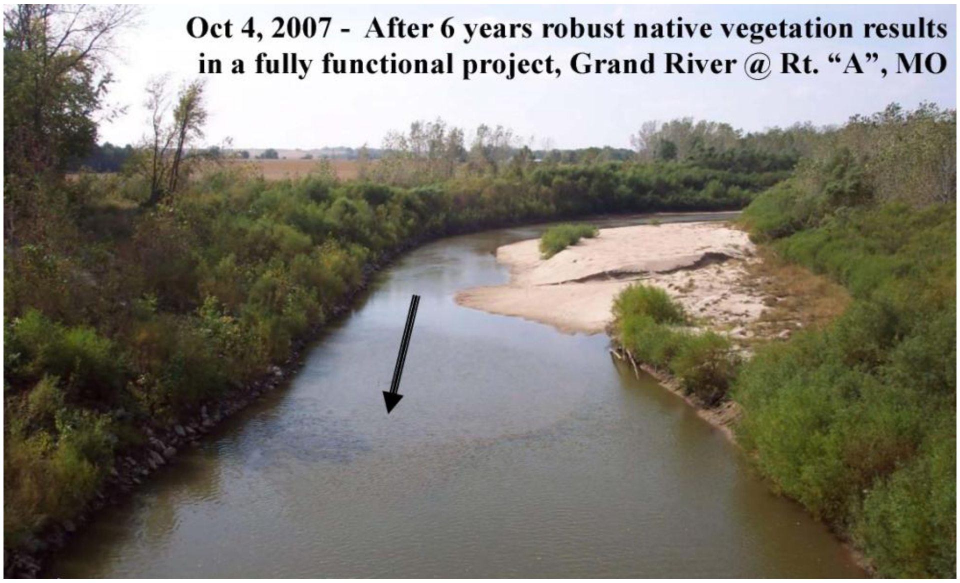


4.2.3.3 Bank Stabilization –Stone Toe Protection

This restoration practice consists of protecting or restoring eroding stream banks with rock riprap features along the toe of the bank with stone toe protection features. Two well established stone toe protection measures are Longitudinal Peak Stone Toe Protection (LPSTP) and Longitudinal Fill Stone Toe Protection (LFSTP). These measures also help stop channel bank erosion, the loss of soils, and can help prevent damages and losses to bridges, culverts and pipeline crossings. This practice is fairly cost effective, especially if combined with bioengineered features to minimize rock costs, and is generally acceptable to landowners, local government agencies, and the public. An example LFSTP constructed on the Grand River in Gentry County is shown in Figures 26 and 27.

Figure 26: LFSTP Bank Stabilization

Figure 27: LFSTP Bank Stabilization Recovery



Photos courtesy HNTB Corporation and USACE ERDC Vicksburg. Project located in Gentry County, Missouri.

4.2.3.4 Bank Stabilization - Re-directive Bank Protection

This restoration practice consists of re-directing flows on unstable eroding stream banks with rock riprap features along the bank. A well-established re-directive measure is the rock vane(s). This practice helps re-direct high energy flows to stop channel bank erosion, the loss of soils, and can help prevent damages and losses to bridges, culverts and pipeline crossings. Re-directive bank protection is fairly cost effective, especially if combined with bioengineered features to minimize rock placement, and is generally acceptable to landowners, local government agencies, and the public. An example rock vane is shown in Figure 28.

Figure 28: Re-directive Bank Protection – Rock Vanes

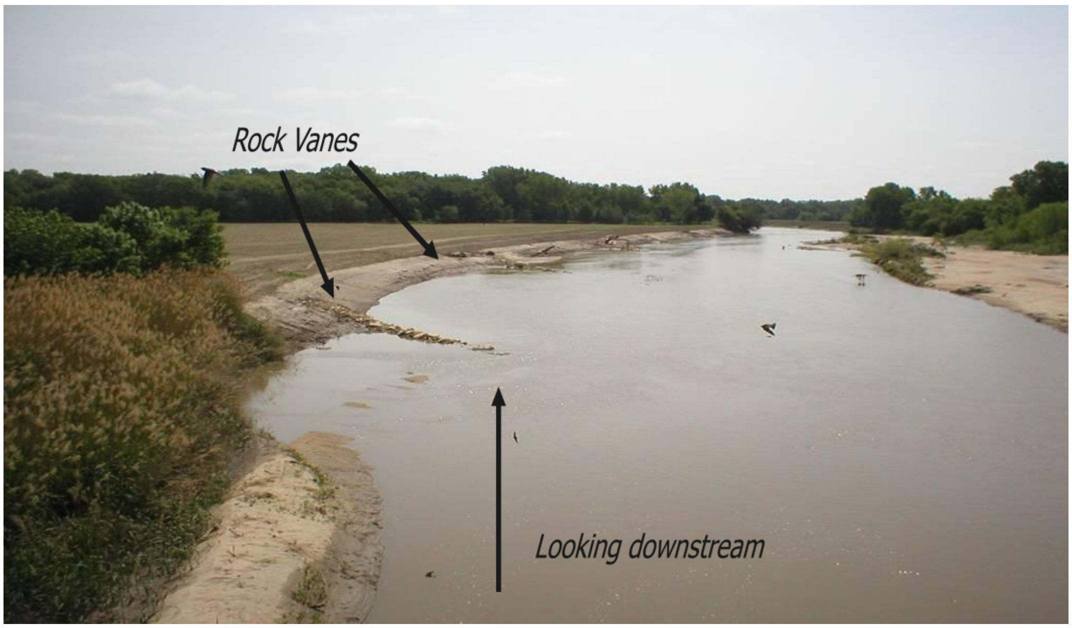
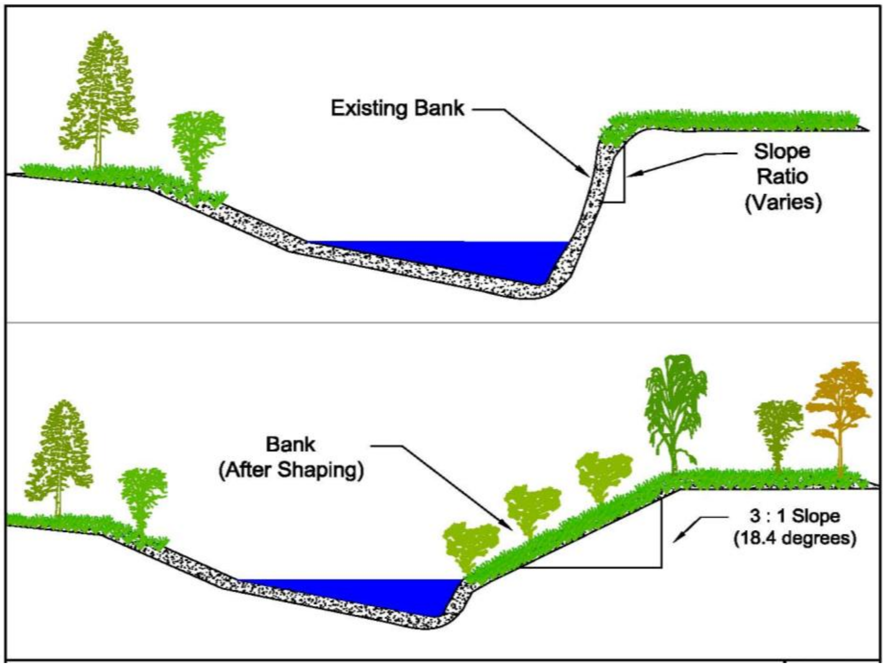


Photo courtesy of Phil Balch, Cottonwood River, Kansas

4.2.3.5 Bank Stabilization – Bioengineered Protection

This restoration practice consists of protecting or restoring eroding stream banks with bank reconstruction that includes biological plant materials, natural and/or synthetic blanketing, or rock riprap features on the toe and slope of stream banks. Many types and combinations of bioengineered bank protection exist. This practice also helps stop channel bank erosion, the loss of soils, and loss of native riparian habitats. Bioengineered bank stabilization costs can vary. This practice is generally acceptable to landowners, local government agencies, and the public provided sufficient education occurs. A conceptual and constructed example of a bioengineered project is shown in Figures 29 and 30.

Figure 29: Bioengineered Bank Stabilization



Concept figure courtesy of Gulf South Research Corporation and USACE Kansas City District

Figure 30: Completed Bioengineered Bank Stabilization

Photo courtesy of David Derrick, USACE ERDC Vicksburg

4.2.3.6 Riparian Buffer Restoration and Enhancement

This restoration practice consists of restoring or enhancing grassland, shrub and/or wooded riparian buffer found along stream banks with native plant materials. This practice helps stop channel bank erosion, the loss of soils, and restores native riparian habitats. Riparian buffer costs can vary substantially. The acceptance of this varies significantly. Some landowners do not support this practice as it takes cropland out of production. An example riparian buffer restoration project is shown in Figure 31.

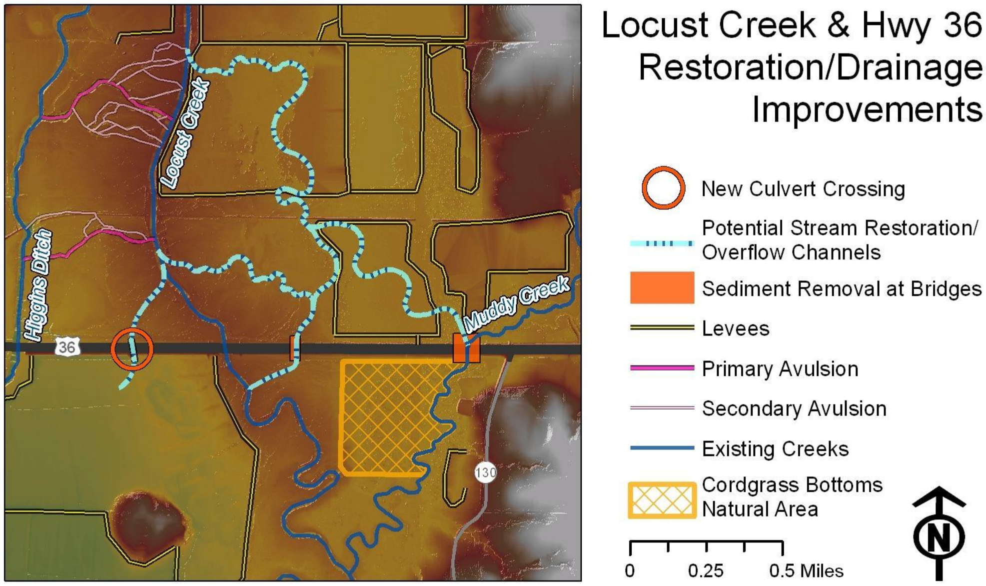
Figure 31: Riparian Buffer Restoration

Photo courtesy of David Derrick, USACE ERDC Vicksburg

4.2.3.7 Stream Channel Re-alignment

This restoration practice consists of creating or restoring a natural stream alignment on channelized reaches of stream channels back into a more sinuous plan form. Bank reconstruction and bioengineering is often associated with channel re-alignment. This practice helps stop channel bank erosion, the loss of soils, encourages natural flooding regimes, and native riparian communities. Stream channel re-alignment is generally very expensive compared to other stream restoration practices. This practice is generally not acceptable to most private landowners. Potential stream channel re-alignment projects in PSP are shown on Figure 32.

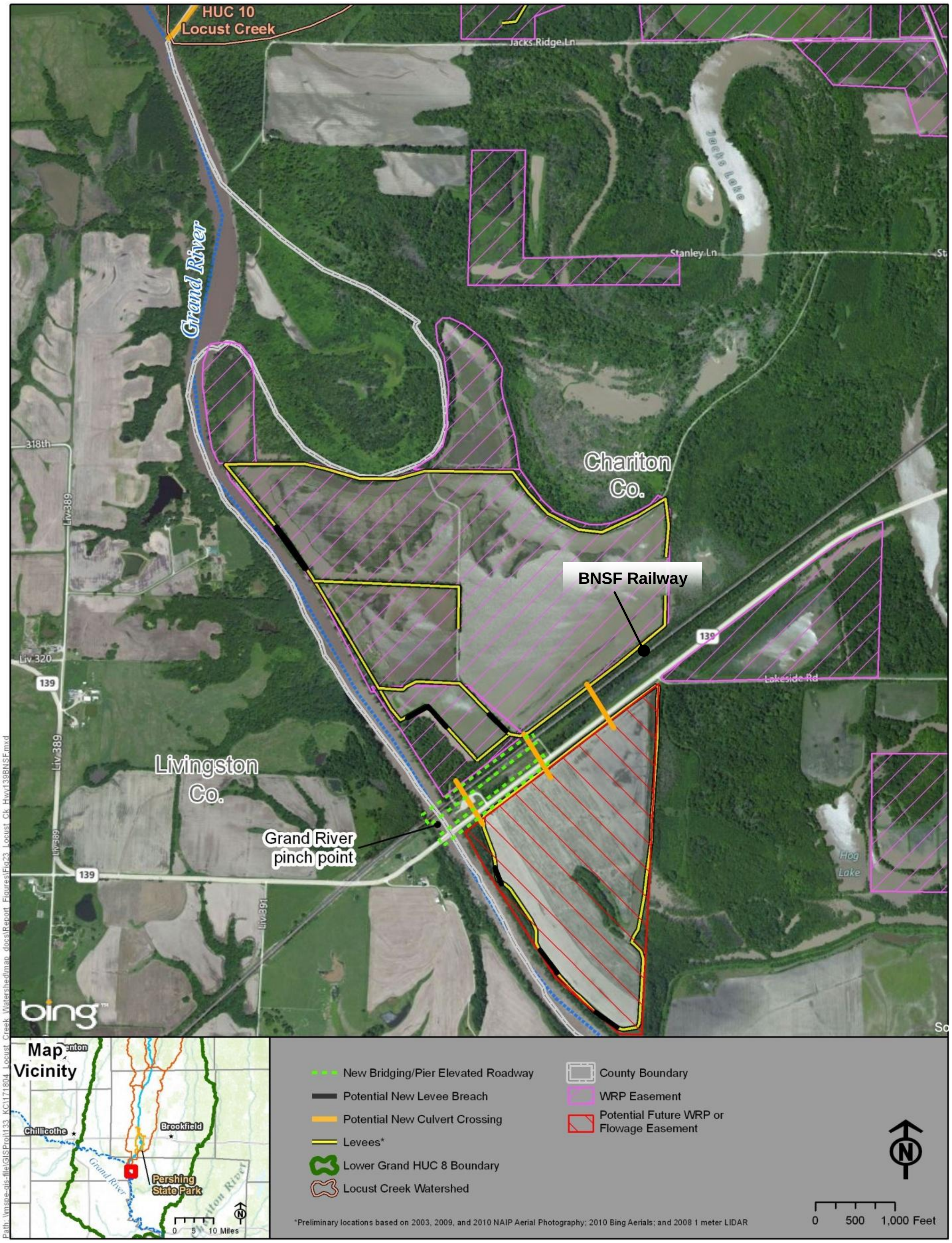
Figure 32: Potential Stream Channel Re-alignments – Pershing State Park



4.2.4 LGR Hwy 139/BNSF Railway Floodway Drainage Improvements

This restoration action consists of improving floodway sediment transport and drainage capacity through the bridge openings and fill embankments of Hwy 139 and the BNSF Railway running across and constricting the Grand River floodway west of Sumner, Missouri. This constricting location is one of several pinch points on the LGR floodway that could be constricting flood drainage and sediment transport on the LGR and LLC, and causing upstream channel bed aggradation. New bridge structures and/or the addition of pier elevated road and track structures would potentially be highly effective in increasing sediment transport. Levee modifications and flowage easements may also be necessary on adjacent properties for this action as shown in Figure 33 to help convey floodwater. Private lands would be needed for a flowage easement. This action, though outside the LCW, but within the Lower Grand watershed containing LC, is considered a potentially highly important restorative action. This action would require further detailed hydrology & hydraulics analysis to determine whether it could create meaningful benefits to LC and the LGR. Currently there is a WRP easement on the north side of these transportation corridors, which is reported by MDNR to capture floodwater primarily from LC flooding. This WRP easement appears to be providing substantial floodway benefits. Consideration for other floodway improvements should be investigated to see if additional modifications would be necessary. If constricting bridges exist, then focus should be first placed on remedying restoring sediment transport in the LGR channel. This action would likely be technically feasible, but extremely expensive, but could produce high system wide benefits. This practice would be difficult to gain acceptance from MoDOT, BNSF Railway, adjacent private landowners, and local taxing and governing jurisdictions.

Figure 33: Hwy 139/BNSF Railroad Floodway Drainage Improvements



4.2.5 LGR Floodway and Levee System Modifications

This restoration action consists of modifying targeted levees in the LGR watershed that may be constricting flood drainage causing backwater effects on LC (and other tributaries). This action, though outside the LCW, but within the Lower Grand watershed containing the LCW, is considered a potentially important restorative action. This action considers breaching or relocating levees along the Grand River with emphasis on the GOE as managed by the GOE Levee District (GOELD). A past attempt was made by several natural resource agencies to relocated a portion of the upper GOE Levee and acquire a WRP easement right on about 1,700 acres of protected farmland below Yellow Creek, but was unsuccessful due to concerns expressed by the GOELD over lost tax revenues. These 1,700 acres represent about 49% of the total land area protected by the GOE Levee, which is significant. Functional results of breaching or relocating the GOE Levee or other levees could be reduced peak flood and flow and related damages in the Grand River and tributaries including LC, improved aquatic habitats, water quality improvements, and groundwater recharge. It's speculative as to whether this action could increase sediment transport in the LGR and LC. This action would require further detailed hydrology & hydraulics and sediment transport analysis to determine whether it could create meaningful benefits to LC. The GOE Levee is shown in Figure 34.

4.2.6 On-going Natural Resources Management

This restoration action consists of on-going resource management practices that are necessary or desired in order to continue providing natural resources functions in the watershed. Current natural resource management practices include log jam removal and management on LC in PSP and at bridges and culverts throughout the watershed. Potential new natural resource management practices include invasive plant species management (prescribed burning, etc.) and native plantings for restoration purposes. Functional results of log jam management include restoring flows to pass sediments and reduced flooding issues. Functional results of invasive plants species management and native plantings are to restore native biological plant diversity key to supporting ecosystem health. Costs can vary widely on individual resource management practices. Land owner and public concerns are expected to be neutral to fully supporting. Figure 35 below depicts log jam removal on LC in PSP.

Figure 34: Lower Grand River Levee System Modifications

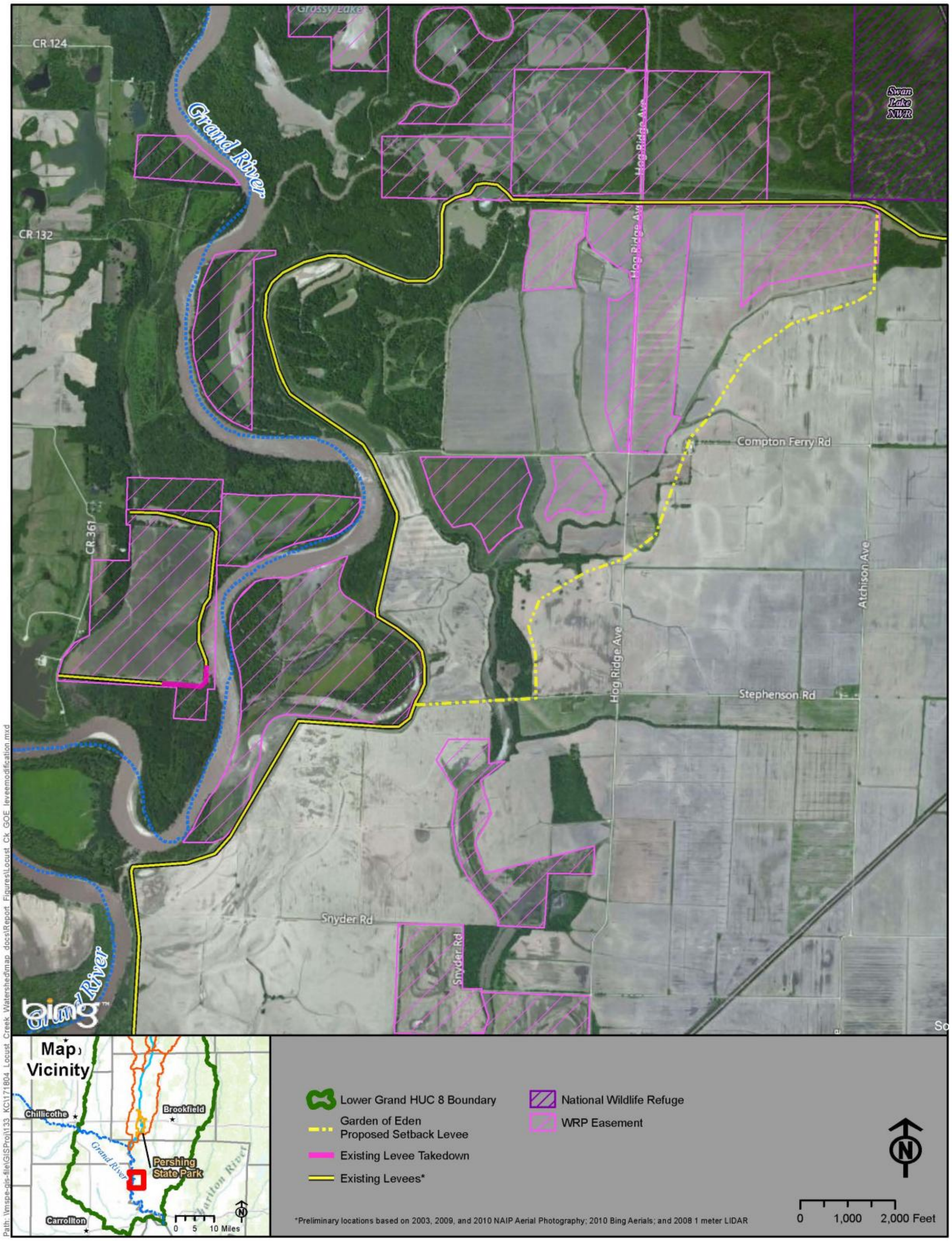


Figure 35: On-going Natural Resource Management – Log Jam Removal

Photos courtesy of Tom Woodward, MDNR

4.2.7 Agency Partnerships and Programs

This restoration action consists of partnering to share, build and expand upon technical and financial capacities and programs between natural resource agencies, county and city governments, and local non-government organizations (NGO's). Agency partnerships consists first and foremost working together towards meeting common goals and objectives in the watershed and, where possible, sharing administrative, technical and financial resources to implement projects to meet goals. Currently there is a young, but strong and active agency partnership of state and federal agencies that have been focusing on the Lower Grand River Conservation Opportunity Area (LGCOA), which includes the LCW. The agencies currently involved in the LGCOA include USFWS, NRCS, MDNR, MDC, and local Soil and Water Conservation Districts (SWCD). This group of internal natural resource agency stakeholders has met twice since 2010 at a seminar held in Chillicothe, Missouri. A major goal of this group is working on bringing those external stakeholders or "potential affected interests (PAI)" into the planning and implementation efforts of the LGCOA. An example of agency partnering was the various cost sharing and work-in-kind provided for the West and East Zell Tract's restoration projects at PSP by NRCS, MDNR, USFWS, and MDC. Another partnership example includes sharing of staff and equipment between MDC and MDNR for log jam removal, management and monitoring in LC. Functional results of agency partnerships and programs are working towards and meeting common goals and objectives, increased communication and cooperation, and increased tax payer benefit from sharing of financial, equipment and staff resources. Agency partnerships and program sharing is technically, financially and politically feasible and generally very effective. Figure 36 below is a photo of various agency staff meeting and discussing the LGCOA in Chillicothe, Missouri in July 2012.

Figure 36: Agency Partnerships at the LGCOA Seminar Meeting

4.2.8 Public Awareness and Education Action

This restoration action consists of providing watershed public awareness and education to those living and working daily in the LCW, those being PAIs. This action involves sharing information on the LCW problems and opportunities at different forum or media types including stakeholder focus groups, community workshops, newsletters, demonstration projects. Future efforts for the LGCOA working group agency partnership is to work on reaching those PAIs. Currently MDNR has been meeting with local SWCDs in respective LCW counties to listen to landowner concerns and solutions to soil erosion and drainage problems. Functional results of public awareness and education would be increased awareness land and water management issues over the long-term (generational in scope) and increased communication and cooperation on land management issues locally and regionally that help address problems and opportunities. A key challenge to this action is the sheer size of the watershed area and travel distances required for landowners and agencies to participate in awareness and education gatherings or demonstration projects. Implementing this action may require developing a unified awareness and education plan with listening and messaging opportunities that can be delivered at a more local level, mostly likely at the county level or below. This plan would be executed by training county staff, elected officials, and state and federal agencies or NGOs if they chose to embrace such an effort.

4.2.9 Organizational Structure Establishment Action

This restoration action consists of establishing a “watershed boundary” based organization to work on behalf of those PAIs living and working in the LCW to provide oversight, regulation and stewardship on a variety of natural resource issues, project funding, public awareness and education. A watershed based organization in the LC or LGR watershed could be modeled after Nebraska’s Natural Resource District (NRD) that was legislated into action over 40 years ago. Nebraska’s NRD model is based on local control and management of soils, water resources, and other natural resources, with twelve major areas of responsibility as required under state law. Each of Nebraska’s 23 NRDs have an elected board, are fully staffed and funded by local property taxes, and often leverage partnerships and programs available from state and federal agencies, city and county governments, and private organizations for the betterment of natural resources. Functional results of a watershed organizational structure would be increased communication, coordination, and cooperation, wider acceptance of a locally based governing body, potentially steady funding, changed attitudes on land use management over the long-term (generational in scope), all of which help address problems and opportunities.

4.3 Qualitative Analysis of Watershed Actions and Practices

Because of the sheer number of WAPs discussed in Section 4.0 previously, it was necessary to determine which WAPs would best serve the long terms needs of the LCW and PAIs. This section analyzes the myriad of WAPs in a qualitative manner by ranking each WAP based on criteria of technical feasibility, financial feasibility from the landowner/producer’s perspective, government cost-sharing ability, overall landowner/producer perception, and ability to potentially meet goals. A color coded ranking scale was developed using low, medium and high. Red or low means no benefit, bad or negative; blue or medium means being somewhat neutral or in the middle, and green or high means good or positive. Table 6 that follows shows the ranking of WAPs. Those WAPs with significant green ranking are potentially the most beneficial and practical actions and practices to consider implementing throughout the entire LCW.

Table 6: Scale Ranking of Potential Watershed Actions and Practices

Watershed Actions & Practices	Technical Feasibility *	Financial Feasibility *	Cost Sharing Ability *	Landowner Perception *	Potentially Meet Goals *
SOIL & WATER BMPs ACTION					
Sheet, Rill & Gully Erosion BMPs					
Permanent Vegetative Cover Establishment					
Permanent Vegetative Cover Improvement					
Terrace System					
Terrace System with Tile					
Windbreak/Shelterbelt Establishment					
No-till System (Residue & Till Management)					
Permanent Vegetative Cover - Critical Areas: Confined Animal Feed Lots					
Water Impoundment Reservoir					
Sediment Retention Water Control Structure					
Grade Stabilization					
Grassed (Sod) Waterway					
Diversion					
Contour Buffer Strips					
Contour Strip Cropping					
Cover Crops					
Conservation Crop Rotation					
Grazing Management BMPs					
Permanent Vegetative Cover Enhancement					
Grazing System Water Development					
Grazing System Water Distribution					
Grazing System Fencing					
Grazing System Lime					
Grazing System Seeding					
Prescribed Grazing					
Heavy Use Protection					
Off Channel Shade & Water Sources					
Irrigation Management BMPs					
Irrigation Water Conveyance					
Irrigation System, Sprinkler					
Irrigation System, Surface and Subsurface					
Irrigation System, Tailwater Recovery					
Drainage Water Management					
Structure for Water Control					

Watershed Actions & Practices	Technical Feasibility*	Financial Feasibility*	Cost Sharing* Ability	Landowner Perception*	Potentially Meet Goals*
Animal Waste Management BMPs	Green	Red	Green	Red	Red
Beef Waste Management	Green	Red	Green	Red	Red
Dairy Waste Management	Green	Red	Green	Red	Red
Poultry Waste Management	Green	Red	Green	Red	Red
Swine Waste Management	Green	Red	Green	Red	Red
Incinerator	Green	Red	Green	Red	Red
Composting Facility	Green	Red	Green	Red	Red
Nutrient and Pest Management BMPs	Green	Green	Green	Green	Blue
Nutrient Management	Green	Green	Green	Green	Blue
Pest Management	Green	Green	Green	Green	Blue
Sensitive Areas BMPs	Green	Blue	Green	Blue	Green
Windbreak/Shelterbelt Establishment	Green	Red	Green	Red	Red
Field Border	Green	Red	Green	Red	Green
Filter Strip	Green	Blue	Green	Green	Green
Riparian Forest Buffer	Green	Blue	Green	Red	Green
Stream Protection (Access Control)	Green	Blue	Green	Blue	Green
Streambank Stabilization	Green	Blue	Green	Green	Green
Spring Development	Red	Red	Red	Red	Red
Well Decommissioning	Green	Blue	Green	Green	Red
Sinkhole Treatment	Red	Red	Red	Red	Red
Sinkhole Improvement	Red	Red	Red	Red	Red
Sinkhole Improvement – Buffer	Red	Red	Red	Red	Red
Woodland Erosion BMPs	Green	Blue	Green	Blue	Green
Forest Plantation	Green	Blue	Green	Red	Red
Woodland Protection – Livestock Exclusion (Access Control)	Green	Blue	Green	Blue	Green
Use Exclusion (Access Control)	Green	Blue	Green	Blue	Green
Timber Harvest Plan	Green	Blue	Green	Blue	Blue
Restoration of Skids Trails, Logging Roads, Stream Crossings, and Log Landings	Green	Blue	Green	Blue	Blue
Floodplain Restoration Action	Green	Blue	Green	Blue	Green
Levee Breach	Green	Green	Green	Red	Green
Levee Removal or Relocation	Green	Blue	Green	Green	Green
Drainage Improvements	Green	Blue	Green	Blue	Green
Sediment and Woody Debris Catchment	Green	Blue	Red	Blue	Green
Wetland Restoration or Enhancement	Green	Blue	Green	Green	Green
Stream Restoration Action	Green	Green	Green	Green	Green
Channel Grade Control	Green	Green	Green	Green	Green

Watershed Actions & Practices	Technical Feasibility*	Financial Feasibility*	Cost Sharing Ability*	Landowner Perception*	Potentially Meet Goals*
Controlled Headcut – Channel Grade Control	Blue	Blue	Green	Blue	Green
Resistive Bank Stabilization	Green	Green	Green	Green	Green
Re-directive Bank Stabilization	Green	Green	Green	Green	Green
Bio-engineered Bank Stabilization	Green	Green	Green	Green	Green
Riparian Buffer Restoration & Enhancement	Green	Green	Green	Blue	Green
Stream Channel Re-alignment	Green	Blue	Green	Blue	Green
Lower Grand River Hwy 139/BNSF Floodway Drainage Improvements	Green	Red	Red	Blue	Green
Lower Grand River Floodway and Levee Modifications	Green	Blue	Green	Blue	Green
On-going Natural Resources Management	Green	Blue	Green	Green	Green
Agency Partnerships and Programs	Green	Green	Green	Blue	Green
Public Awareness and Education	Green	Blue	Blue	Blue	Green
Organizational Structure Establishment	Green	Blue	Blue	Blue	Green

***** *Red or low means no benefit, bad or negative; blue or medium means being neutral or in the middle; and green or high means good or positive.*

4.4 Recommended Watershed Actions and Practices

From Table 6, a more refined list of WAPs for potential implementation is shown in Table 7 below. Those individual practices from Table 6 that had significant red rankings of at least three or more per practice or were practices that clearly would not meet goals were eliminated. Essentially the Irrigation Management BMP, Animal Waste Management BMP, Nutrient and Pest Management BMP, and some of the Sensitive Area BMPs shown in Table 6 were completely eliminated.

Table 7: Recommended and Prioritized Watershed Actions and Practices

Watershed Actions & Practices	Technical Feasibility*	Financial Feasibility*	Cost Sharing Ability*	Landowner Perception*	Potentially Meet Goals*
SOIL & WATER BMPs ACTION	Green	Green	Green	Green	Green
Sheet, Rill & Gully Erosion BMPs	Green	Green	Green	Green	Blue
Permanent Vegetative Cover Establishment	Green	Green	Green	Blue	Green
Permanent Vegetative Cover Improvement	Green	Green	Green	Blue	Green
Terrace System	Green	Green	Green	Green	Green
Terrace System with Tile	Green	Green	Green	Green	Green
No-till System (Residue & Till Management)	Green	Green	Green	Blue	Blue
Permanent Vegetative Cover - Critical Areas: Confined Animal Feed Lots	Green	Green	Green	Blue	Blue

Watershed Actions & Practices	Technical Feasibility *	Financial Feasibility *	Cost Sharing Ability *	Landowner Perception *	Potentially Meet Goals *
Water Impoundment Reservoir					
Sediment Retention Water Control Structure					
Grade Stabilization					
Grassed (Sod) Waterway					
Diversion					
Contour Buffer Strips					
Contour Strip Cropping					
Cover Crops					
Conservation Crop Rotation					
Grazing Management BMPs					
Permanent Vegetative Cover Enhancement					
Grazing System Water Development					
Grazing System Water Distribution					
Grazing System Fencing					
Grazing System Lime					
Grazing System Seeding					
Prescribed Grazing					
Heavy Use Protection					
Off Channel Shade & Water Sources					
Sensitive Areas BMPs					
Field Border					
Filter Strip					
Riparian Forest Buffer					
Stream Protection (Access Control)					
Streambank Stabilization					
Woodland Erosion BMPs					
Forest Plantation					
Woodland Protection – Livestock Exclusion (Access Control)					
Use Exclusion (Access Control)					
Floodplain Restoration Action					
Levee Breach					
Levee Removal or Relocation					
Drainage Improvements					
Sediment and Woody Debris Catchment					
Wetland Restoration or Enhancement					
Stream Restoration Action					

Watershed Actions & Practices	Technical Feasibility*	Financial Feasibility*	Cost Sharing* Ability	Landowner* Perception	Potentially Meet* Goals
Channel Grade Control	Green	Green	Green	Green	Green
Controlled Headcut – Channel Grade Control	Blue	Blue	Green	Blue	Green
Resistive Bank Stabilization	Green	Green	Green	Green	Green
Re-directive Bank Stabilization	Green	Green	Green	Green	Green
Bio-engineered Bank Stabilization	Green	Green	Green	Green	Green
Riparian Buffer Restoration & Enhancement	Green	Green	Green	Blue	Green
Stream Channel Re-alignment	Green	Blue	Green	Blue	Green
Lower Grand River Hwy 139/BNSF Floodway Drainage Improvements	Green	Red	Red	Blue	Green
Lower Grand River Floodway and Levee Modifications	Green	Blue	Green	Blue	Green
On-going Natural Resources Management	Green	Blue	Green	Green	Green
Agency Partnerships and Programs	Green	Green	Green	Blue	Green
Public Awareness and Education	Green	Blue	Blue	Blue	Green
Organizational Structure Establishment	Green	Blue	Blue	Blue	Green

*****Red or low means no benefit, bad or negative; blue or medium means being somewhat neutral or in the middle; and green or high means good or positive.*

4.5 Current Projects and Activities

There are currently several projects completed in PSP using WAPs, as well as on-going maintenance activities, to start addressing symptoms and problems. The following is a brief overview of these.

4.5.1 Pershing State Park Avulsion Measures and Levee Breaches Project

The first project is the recently completed first and second phase construction of avulsion countermeasures and levee breaches completed in 2007 and 2012. Avulsion countermeasures include grade control and bank stabilization (Figure 9) through the main large avulsion and HD in PSP that now drains most of LC's flow. Five levee notches were also excavated east of LC concurrent with the first phase avulsion countermeasures to provide flood water relief and drainage (Figures 10 and 20). The purpose of the avulsion countermeasures project is largely to prevent a catastrophic head cut from migrating upstream in LC from the main avulsion. Secondary benefits of this project is that it should divert most of the sediment laden flows into HD and significantly reduce the amount of flow and sediment being carried through the reduced channel capacity of the un-channelized reach of LC through PSP. Of the approximately 4,000 cfs channel full flow discharge that passes collectively through LC and the main avulsion, about 75% or 3,000 cfs is now diverted through the avulsion (GRA, 2011 and Fobes, 2012d). Assuming sediment is proportionally distributed by discharge capacity of the main avulsion and LC (with reduced capacity); one could speculate that about 75% of the sediment from the watershed is now transported through the avulsion and HD. Hypothetically this will significantly reduce and slow channel bed and floodplain aggradation along LC in PSP because much sediment is now diverted. This should significantly slow the loss of natural resources, biodiversity and ecological functions over the long term in the park. According to Mr. Chris

Cash, engineer and author for the Geomorphic Assessment at PSP (GRA, 2011), the smaller avulsions throughout or near PSP are expected to heal naturally with sediment and woody debris that can plug forming avulsions (Fobes, 2012d). The main avulsion's ability to divert sediment is reported to be working well by Tom Woodward, PSP Superintendent (Fobes 2012b). Mr. Woodward stated he has observed reduced sediment volumes entrapped in log jams as a result of the avulsion and levee breach opposite the main avulsion in PSP, which suggests that the avulsion is now transporting much of the sediment runoff now. Mr. Woodward also indicated that while it is a benefit to LC and PSP that habitat loss is slowed because not as much sediment is transported through LC/PSP, HD and the Zell West restoration area are temporary will not provide unlimited sediment storage capacity. HD does not have a direct connection back into LC or any other stream capable of transporting any measurable quantities of large woody debris or bed-load material. At the present time high flows in HD are creating new avulsions and sand splays in the lower reaches of PSP.

4.5.2 Pershing State Park - Zell Tracts Acquisition and Restoration Project

The second project is the construction of wetlands on the newly acquired PSP West and East Zell Tracts (Figures 37, 38, 39, 40 and 41). In June of 2009, funding was secured to purchase two tracks of land from the Zell family consisting of approximately 1500 acres. The majority of the property is located between LC and HD immediately south of Hwy 36. The purchase was made possible by willing sellers and a group of public and not for profit organizations such as the NRCS, USFWS, DNR, Ducks Unlimited, Missouri Bird Conservation Initiative and The Conservation Fund. The NRCS developed a wetland restoration plan and completed the construction of the project in 2012. Wet prairie restoration began in 2013 with funds through MDNR State Parks and a Missouri Bird Conservation Grant. Seed and plant materials from the native wet prairie in PSP were collected and distributed onto Zell tract wetlands to initiate recovery of those natural communities. The area has been burned once, and a mowing and prescribed fire plan has begun. The PSP West Tract features are sediment entrapment, flood water storage, and wetlands restoration. The levee in the northwest corner is failing and will be breached (Figure 38) to capture flood waters and sediment, which will be guided through a berm constricted flow path. Sediment from flood waters will initially settle out on the north end of the tract and water will fill the remaining levee enclosed wetland basin and controlled with a water control structure on the southwest corner of the tract. Within the Zell West Tract, shallow excavations resembling remnant channel oxbows have been constructed, while re-using the excavated material as habitat mounds for diversity. Shallow dikes and floodway excavations have also being constructed to control movement and location of water on the tract. The PSP East Tract (Figures 40 and 41) will primarily function to store flood backwater and restore wetland habitat by constructing shallow excavations resembling remnant channel oxbows and re-using the excavated material as habitat mounds for diversity. Shallow dikes are also being constructed to control movement and location of water on the tract.

4.5.3 On-going Log Jam Removal at Pershing State Park

Personnel from PSP conduct low impact log jam management (Figure 35). Personnel at PSP do actively watch for early log jam formations during high flow events to try to catch and eliminate log jams early on before they become sizable. PSP personnel use two low impact methods for removal. Low impact methods are necessary due to the sensitive nature of adjacent floodplain wetlands and permitting considerations. One method involves operating a motor boat up to a log jam and using chainsaws and winches to cut up, move and re-mobilize woody debris to float downstream. The second and preferred method is to place woody material with an excavator on inside channel bends during low flow to form instant point bars, which collect sediment and lock into place. These bars natural re-vegetate over time with tree seedlings and herbaceous vegetation. This method induces some outside channel bend

Figure 37: Pershing State Park – Zell Tracts Wetland Restoration Location Overview

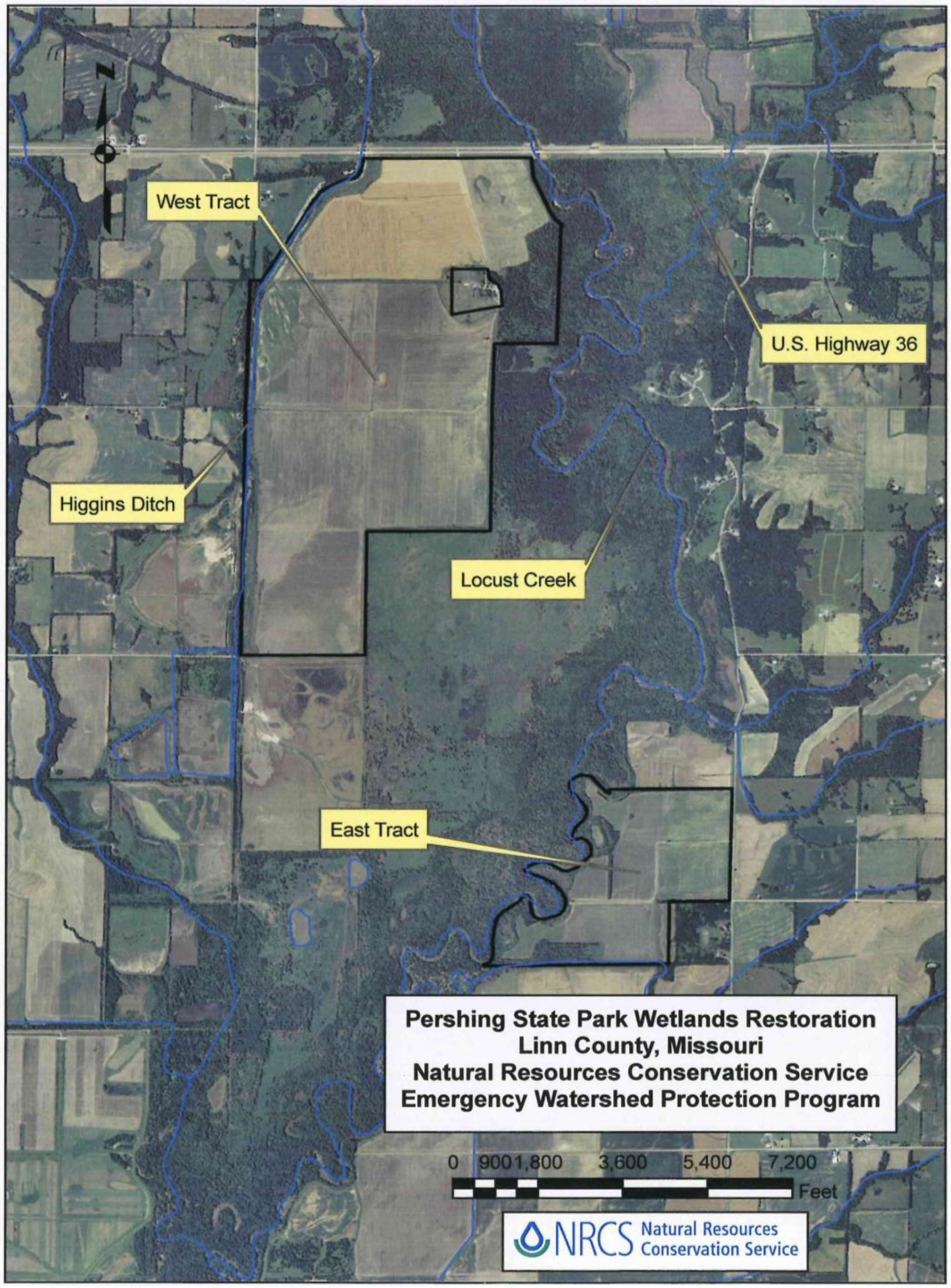


Figure taken from NRCS geopatial analysis of Zell Tract wetlands restoration (NRCS, ca. 2011).

Figure 38: Pershing State Park – Zell Tract West Wetland Restoration Plans

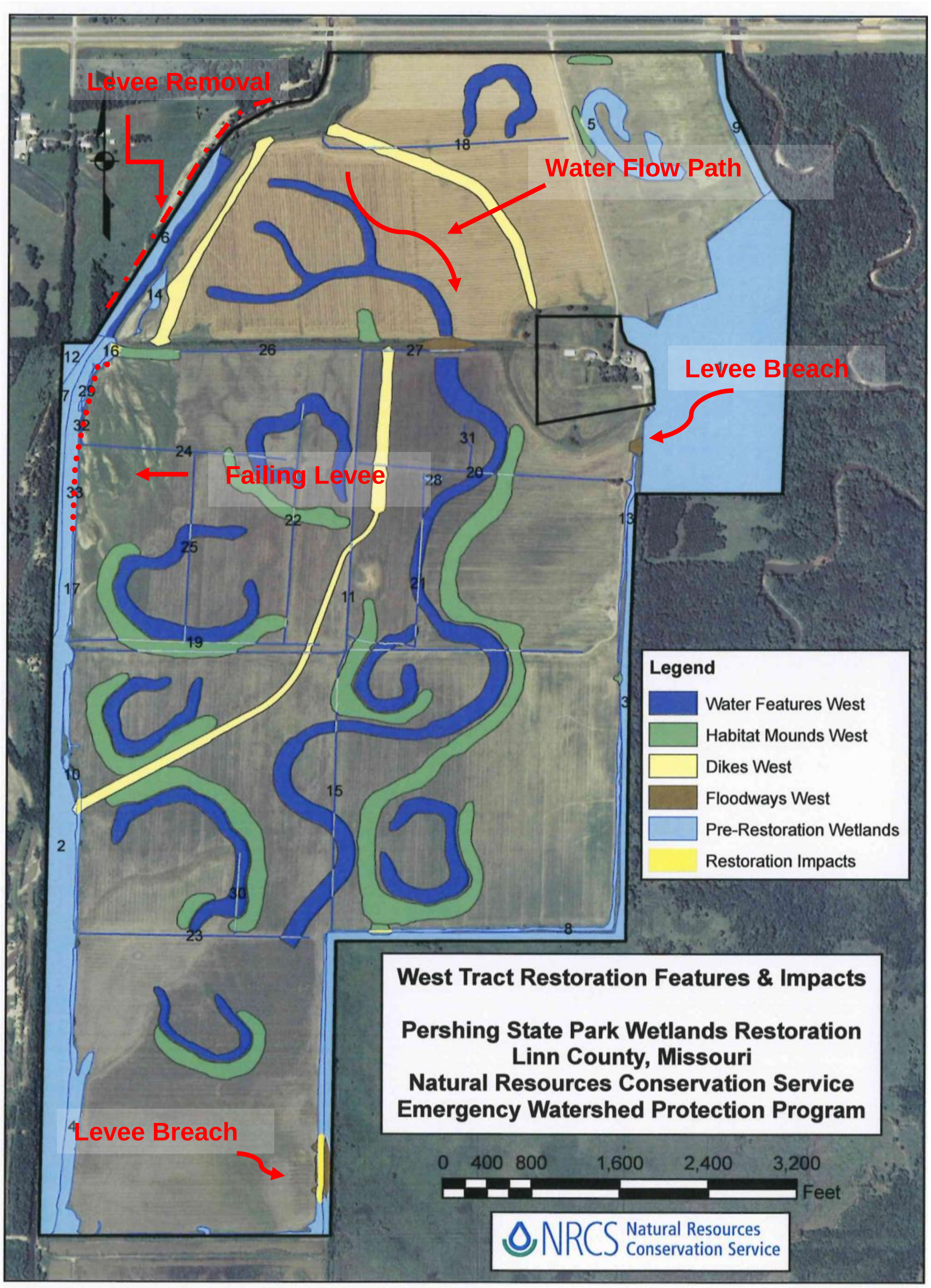


Figure taken from NRCS geopatial analysis of Zell Tract wetlands restoration (NRCS, ca. 2011)

Figure 39: Pershing State Park – Zell Tract West Wetland Restoration

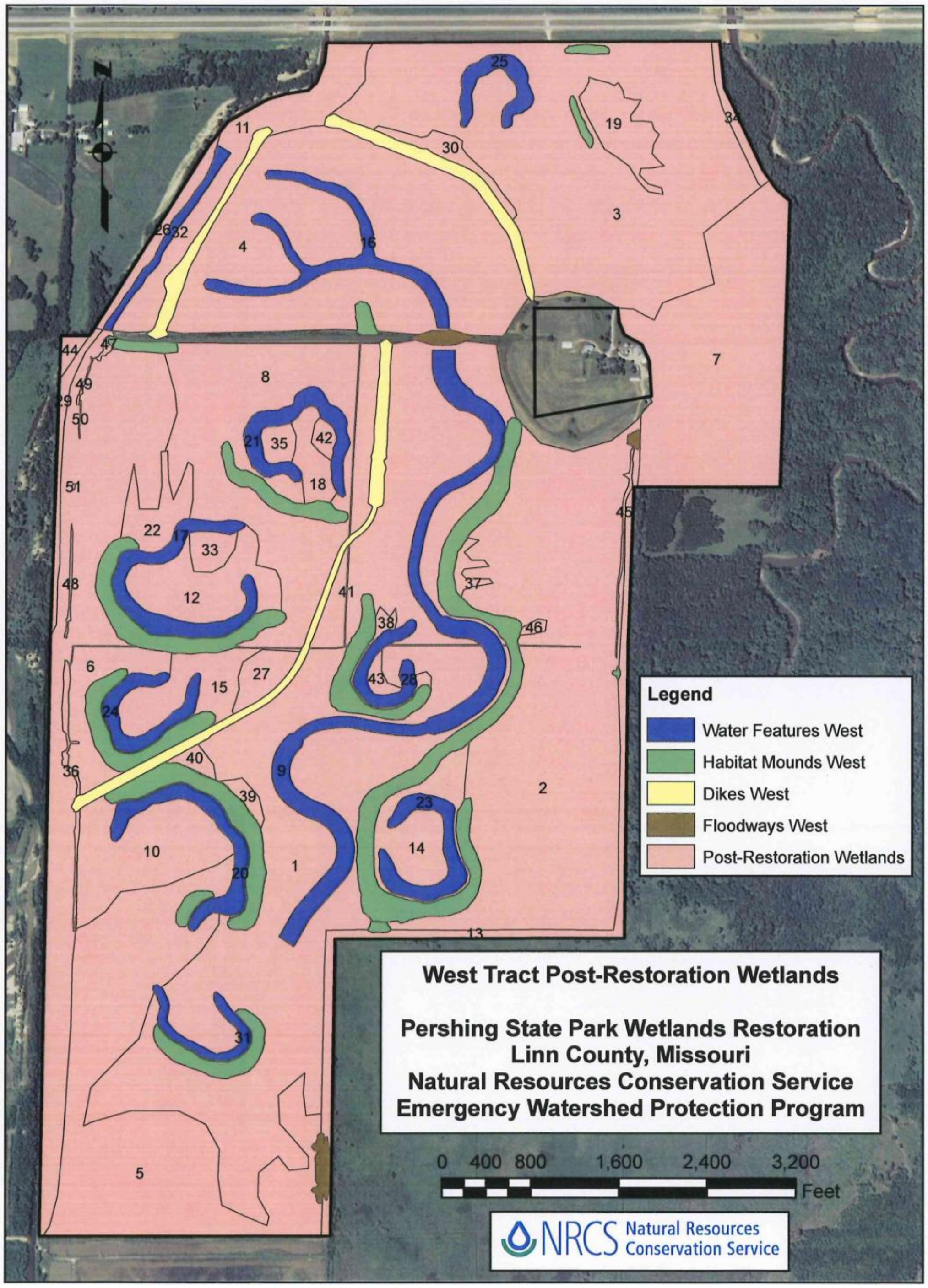


Figure taken from NRCS geopatial analysis of West Zell Tract wetlands restoration (NRCS, ca. 2011).

Figure 40: Pershing State Park – Zell Tract East Wetland Restoration Plans

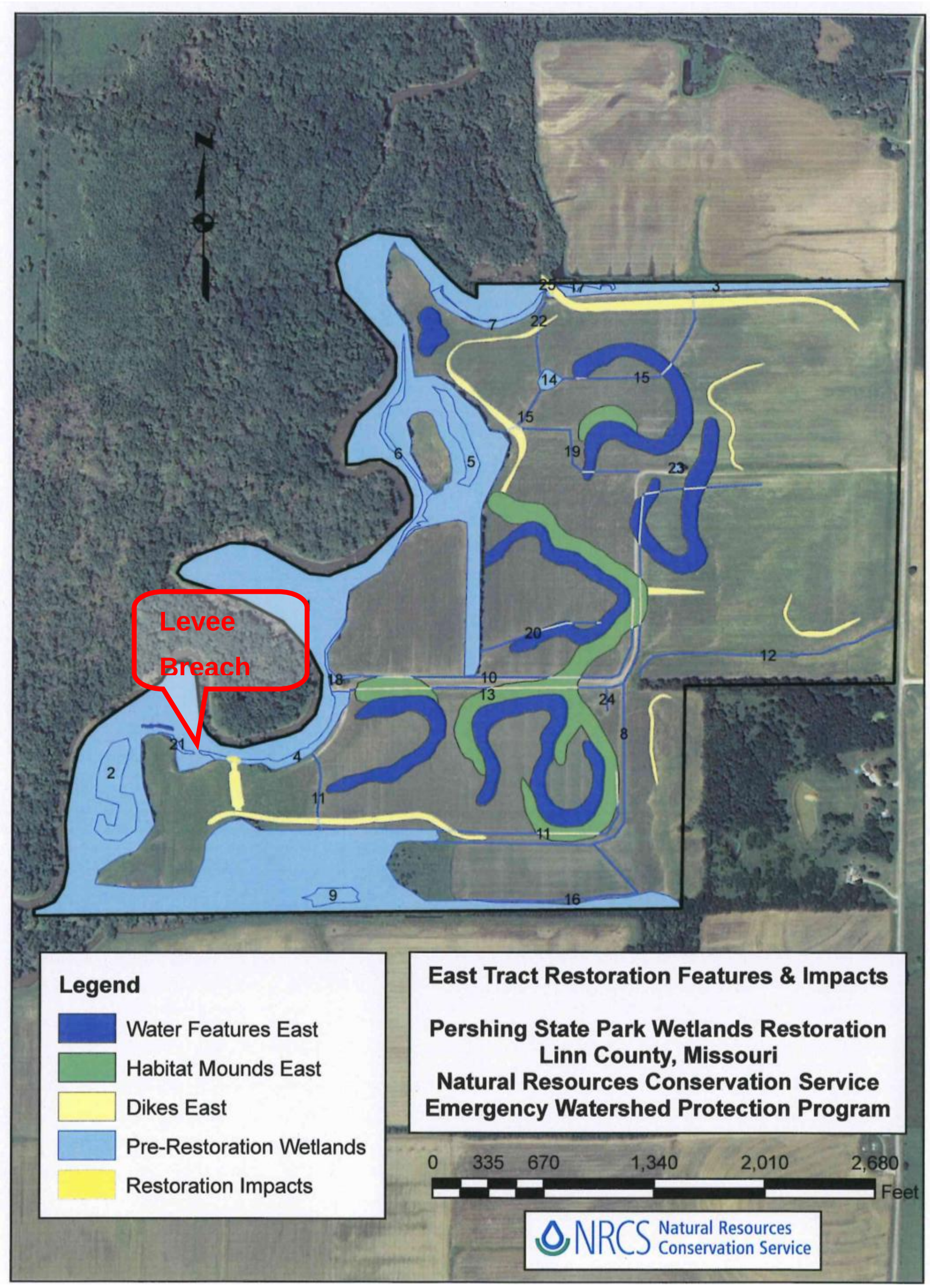


Figure taken from NRCS geopatial analysis of West Zell Tract wetlands restoration (NRCS, ca. 2011).

Figure 41: Pershing State Park – Zell Tract East Wetland Restoration Plans

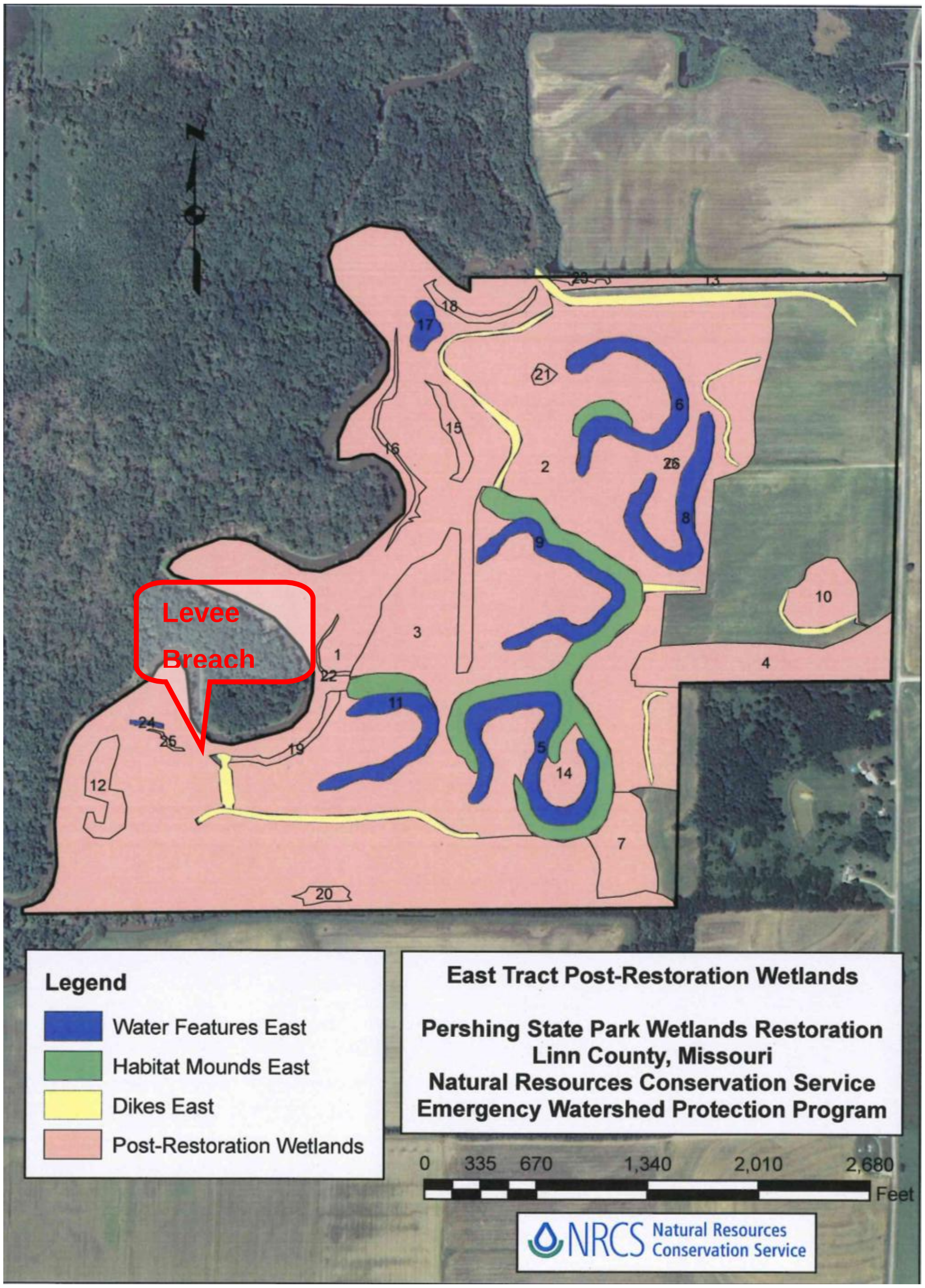


Figure taken from NRCS geopatial analysis of West Zell Tract wetlands restoration (NRCS, ca. 2011).

erosion to adjust the channel geometry to a proper dimension, mimicking the natural process of a stream on an accelerated time scale. Log jam management is an evolving tool at PSP as conditions change. Currently most silts and clays that bind these woody point bars are being transported down the avulsion to HD, thus making this second method difficult. Loss of flow to the avulsion limits the erosive power of LC to adjust channel geometry. Limited channel capacity for creating woody point bars is a long term concern with the large volumes of woody debris that float down LC. PSP personnel estimate over 18,000 feet of log jams have been dealt with over the past 16 years (Woodward, 2012) at a cost of about 1.3 million dollars.

4.5.4 On-going USDA-NRCS and MDNR Soil & Water Conservation Programs

There are USDA-NRCS and MDNR soil and water conservation cost-share programs and practices that have been conducted throughout the LCW. Several USDA-NRCS programs have been implemented in the watershed and include the WRP, Emergency Wetland Reserve Program, Grassland Reserve Program, Conservation Reserve Program, and Emergency Watershed Protection Program – Floodplain Easements. MDNR funds a statewide Soil & Water Conservation Program (SWCP) through a parks, soils and water sales tax. Those funds are largely administered through local Soil and Water Conservation District offices located in respective counties. A summary of SWCP projects funded for all four Missouri counties in the LCW from 2010 – 2012 indicate many practices were implemented. Permanent seeding, terrace and tile systems, water impoundment reservoir (ponds), sediment retention and water control structures, permanent vegetative cover establishment, grazing system fencing, grazing system seeding, grazing system lime, grazing system water development, grazing system water distribution, stream protection, well decommissioning, nutrient and pest management, riparian forest buffer, diversions, and sod waterways were implemented during that time frame. The MDNR's SWCP can query information about state cost-share funded projects at the HUC 8 and HUC 14 watershed unit and should be considered for use in the future for baseline analysis and progress tracking with the LCW. Exact details on the type, number, location, and acreage of USDA-NRCS cost-shared projects implemented throughout the LCW are difficult to obtain because of information privacy concerns and USDA-NRCS doesn't track programs at the watershed level.

5.0 Watershed Alternatives

5.1 Introduction

The purpose of this section is to formulate alternatives based on recommended WAPs, on goals, and on overall watershed system needs. The alternatives developed include a description of future work prioritizations to help focus work in such a large area.

5.2 Locust Creek Watershed Alternative

The LCW Alternative (LCWA) developed is shown in Appendix C. A major component of this alternative is implementing BMPs in areas that have good potential to reduce sediment loadings and related impacts throughout the LCW. Preliminary BMP siting analyses was performed (see Appendix B) to more accurately and precisely guide natural resource managers on where to place specific BMPs across the LCW landscape to help realize the highest return on invested capital and effort. In the LCW this means locating not only the worst or Critical Source Areas (CSA) shown in Figure 42, but also which BMPs best fit within them. A suite of five potential high value land cover/use BMPs were developed and correlated to certain WAPs as shown in

Table 8: WAPs Correlated to Specific Land Cover/Use BMPs

Watershed Actions & Practices	Off-channel Shade (Cattle Management)	Riparian BMP	Riparian Woodland / Shrubland Improvement	Row Crop Critical Area	Pasture/Hay Critical Area
SOIL & WATER BMPs ACTION					
Sheet, Rill & Gully Erosion BMPs					
Permanent Vegetative Cover Establishment				x	
Permanent Vegetative Cover Improvement				x	
Terrace System				x	
Terrace System with Tile				x	
No-till System (Residue & Till Management)				x	
Permanent Vegetative Cover - Critical Areas: Confined Animal Feed Lots				x	
Water Impoundment Reservoir				x	x
Sediment Retention Water Control Structure				x	
Grade Stabilization				x	
Grassed (Sod) Waterway				x	
Diversion				x	
Contour Buffer Strips				x	
Contour Strip Cropping				x	
Cover Crops				x	
Conservation Crop Rotation				x	
Grazing Management BMPs					
Permanent Vegetative Cover Enhancement					x
Grazing System Water Development					x
Grazing System Water Distribution					x
Grazing System Fencing					x
Grazing System Lime					x
Grazing System Seeding					x
Prescribed Grazing					x
Heavy Use Protection					x
Off-channel Shade	x				x
Sensitive Areas BMPs					
Field Border		x	x	x	
Filter Strip		x	x	x	
Riparian Forest Buffer		x	x	x	x
Stream Protection (Access Control)		x	x	x	x
Streambank Stabilization		x	x	x	
Woodland Erosion BMPs					
Woodland Protection – Livestock Exclusion (Access Control)		x	x		x
Use Exclusion (Access Control)		x	x		x

Figure 42: Landscape Level Recommended BMPs Locations within the LCW

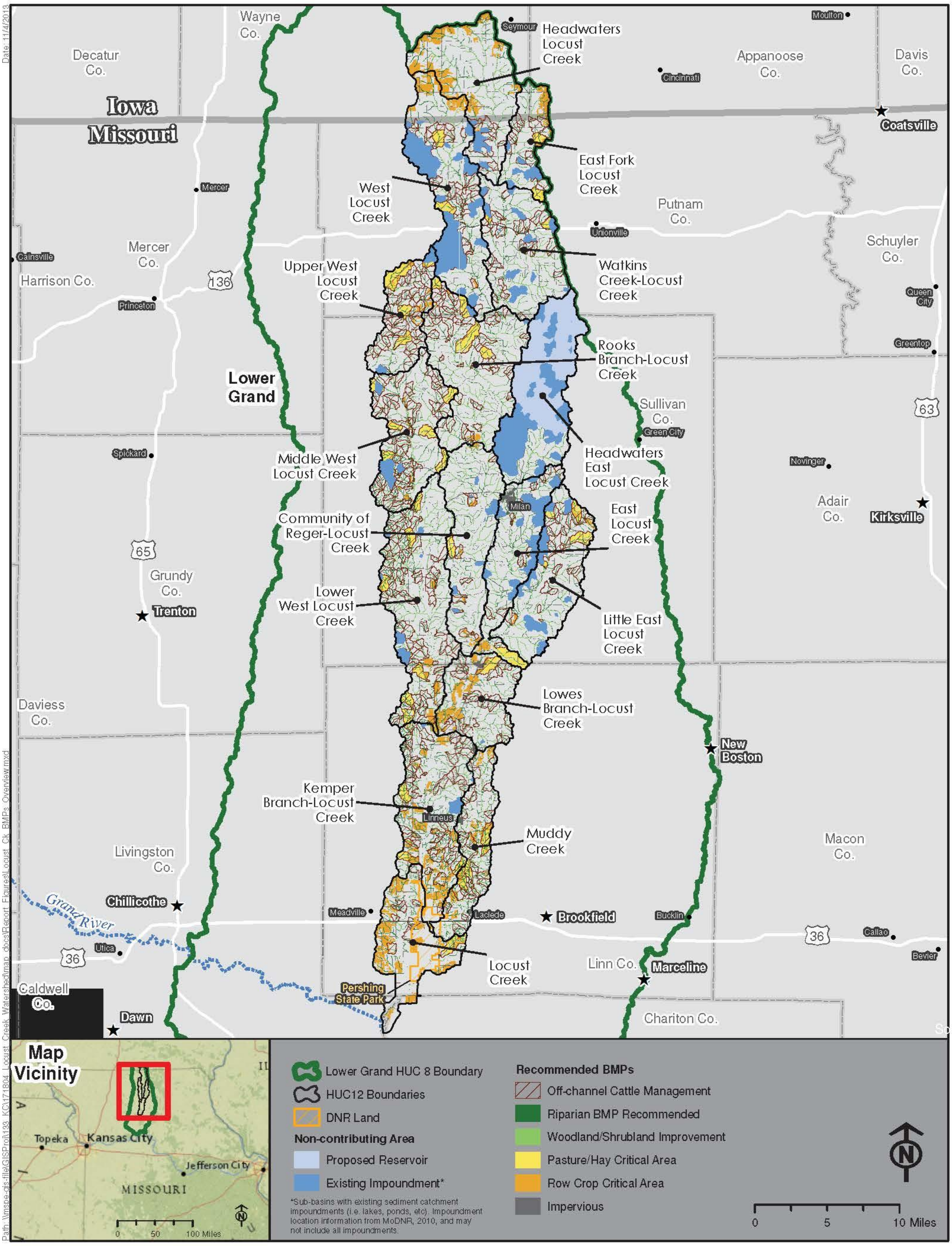


Table 8 below and sited in the LCW as shown in Figure 42. These land cover/use BMPs are Off-channel Shade (Cattle Management), Riparian (Buffer), Riparian Woodland/Shrubland Improvement, Row Crop Critical Area, and Pasture/Hay Critical Area. They were developed based on potential CSA's with high and very high RPLs, impervious areas, limited riparian buffer areas, and/or those pastures with limited off-channel shade for cattle (and other livestock) more than 100 feet away from streams. The BMP locations identified in Figure 42 are also detailed by sub-watershed in the Appendix C map book (sheets 1 – 16). Combining off-channel shade with off-channel livestock water sources could add even more benefit of reducing riparian and channel bank erosion through reduced use and behavioral changes of cattle. Little to no future BMP work should be conducted in areas of existing and/or future impoundments/reservoirs as shown on Figure 42 and in Appendix C. For example, several of the ELC HUC-12 sub-watersheds in Figure 42 have extensive existing and proposed future impoundments/reservoirs which would function as sediment catchment and thus BMPs implemented in those would do little to aid in downstream sensitive reach sediment loads.

In addition to BMP siting, the LCWA also focuses on addressing problematic eroding channel bank hot spots, head cutting, stream channelization, and levee confinement issues as restoration opportunities. These problem areas, with the exception of head cutting locations, are shown on the LCWA map in Appendix C. No methods or data were available to document suspected head cutting locations watershed wide. The alternative map in Appendix C doesn't provide individual site restoration practices or details for the many opportunity locations shown. No simple screening methods were available to help determine what specific practices might apply at each location, as local site specific conditions would need to be investigated first. In general, practices such as channel grade controls, stream channel re-alignment, engineered bank stabilization, riparian buffer restoration and/or enhancement, and modifying levees to manage floodwaters and catch sediment/woody debris are highly recommended. No screening methods were available to prioritize site restoration locations; however, it is highly recommended that future restoration projects should first be focused on the levee confined reach of LLC above PSP. This reach is heavily channelized and reverting back to a more natural channel plan form through bank erosion processes. This reach suffers extensive flooding and aggradation issues based on previous reports from agencies and anecdotal comments several resource agency staff members have heard from landowners in the Locust Creek Drainage District (LCDD). Strategically placed levee modifications would likely produce high benefits in this reach helping to capture floodwaters, woody debris and sediments. This would help reduce downstream flooding and aggradation issues. Combining levee modifications with other restoration practices at individual locations along this reach would likely yield significant benefits downstream in PSP to protect it from further degradation. Additional analysis would be needed to determine the locations of levee modifications and other restoration projects. If significant restoration progress is made in the levee confined reaches of LLC, then efforts should move upstream further on LC and into WLC (Appendix C). Less stream and floodplain restoration efforts should be placed on the ELC and tributaries networks due to less channelization and more existing and proposed impoundments when compared to the LC and WLC (Table 2). Private landowners should be consulted to determine interest in BMPs.

For the LCWA, the Recommended WAPs from Section 4.4 were screened for applicability and then qualitatively ranked in Table 9 to generally help prioritize for implementation to address likely impact factors; including dominant land cover/uses, stream bank and bed erosion, channelization, and levees. Priority ranking was primary (high), secondary (medium), and tertiary (low). Of those primary priority actions and practices, special emphasis should be placed on prioritizing those practices highlighted in green in Table 9.

Table 9: Prioritized Locust Creek Watershed Actions and Practices

Watershed Actions & Practices	**Primary Priority**	**Secondary Priority**	**Tertiary Priority**
SOIL & WATER BMPs ACTION	■		
Sheet, Rill & Gully Erosion BMPs		■	
Permanent Vegetative Cover Establishment		■	
Permanent Vegetative Cover Improvement		■	
Terrace System	■		
Terrace System with Tile		■	
No-till System (Residue & Till Management)	■		
Permanent Vegetative Cover - Critical Areas: Confined Animal Feed Lots			■
Water Impoundment Reservoir	■		
Sediment Retention Water Control Structure	■		
Grade Stabilization	■		
Grassed (Sod) Waterway	■		
Diversion	■		
Contour Buffer Strips		■	
Contour Strip Cropping			■
Cover Crops	■		
Conservation Crop Rotation			■
Grazing Management BMPs	■		
Permanent Vegetative Cover Enhancement			■
Grazing System Water Development		■	
Grazing System Water Distribution		■	
Grazing System Fencing		■	
Grazing System Lime			■
Grazing System Seeding			■
Prescribed Grazing	■		
Heavy Use Protection	■		
Off-channel Shade & Water Sources	■		
Sensitive Areas BMPs	■		
Field Border		■	
Filter Strip		■	
Riparian Forest Buffer		■	
Stream Protection (Access Control)	■		
Streambank Stabilization	■		
Woodland Erosion BMPs	■		
Forest Plantation			■

Watershed Actions & Practices	Primary Priority	Secondary Priority	Tertiary Priority
Woodland Protection – Livestock Exclusion (Access Control)	X (green)		
Use Exclusion (Access Control)	X (green)		
FLOODPLAIN RESTORATION ACTION	X		
Levee Breach	X (green)		
Levee Removal or Relocation		X	
Drainage Improvements		X	
Sediment and Woody Debris Catchment	X (green)		
Wetland Restoration or Enhancement		X	
STREAM RESTORATION ACTION		X	
Channel Grade Control	X		
Resistive Bank Stabilization	X		
Re-directive Bank Stabilization	X		
Bio-engineered Bank Stabilization	X		
Riparian Buffer Restoration & Enhancement	X		
Stream Channel Re-alignment		X	
ON-GOING NATURAL RESOURCES MANAGEMENT ACTION		X	
AGENCY PARTNERSHIPS AND PROGRAMS ACTION	X		
PUBLIC AWARENESS AND EDUCATION ACTION	X		
ORGANIZATIONAL STRUCTURE ESTABLISHMENT ACTION		X	

Primary priority practices highlight in green are considered to have greatest value.

Table 9 indicates that high priorities should be placed on the Soil and Water BMPs Action, with special emphasis on certain practices associated with Grazing Management BMPs, Sensitive Area BMPs, and Woodland Erosion BMPs. These BMPs address the impacts of livestock grazing land on stream and riparian corridors, as pasture/hayland is by far the largest land use in the LCW. Of these high priority BMPs, special emphasis should be placed on prioritizing those practices highlighted in green above. The Floodplain Restoration Action, Stream Restoration Action, Agency Partnerships and Programs Action, and the Public Awareness and Education Action are also primary priorities to consider implementing. Floodplain restoration practices that modify levees and catch sediment and woody debris are highly desirable. Agency Partnerships and Programs will be necessary to help coordinate and fund these other WAPs, while significant Public Awareness and Education will be necessary to communicate with landowners and the public. Secondary priorities for implementation include Sheet, Rill, and Gully Erosion BMPs in cultivated cropland areas, most Stream Restoration Action practices, On-going Natural Resources Management Action, and Organization Structure Establishment Action. A few tertiary priorities are in Table 9.

5.3 Pershing State Park Alternative

The PSP Alternative (PSPA) developed as shown in Appendix D encompasses the PSP boundary. At its heart, the PSPA is intended to help preserve and restore remaining high value wetland resources at PSP by more effectively managing high and flood flow events, effectively transporting sediment and large woody debris through LC in PSP. This alternative focuses on drainage improvements in the northern section of PSP around the Hwy 36 corridor to help manage and more evenly distribute flows. Drainage improvements consist of sediment removal at the MC and OC drainage structures, adding an additional drainage structure under Hwy 36 between HD and LC, and various drainage channel construction options for a more sinuous restored LC channel and/or higher elevation drainage overflow channels in the LC floodway/floodplain. This alternative includes the potential to eventually close off the main avulsion channel to HD, or to increase the height of the avulsion channel's grade control structures. This would divert more high flows back into the LC channel, assuming it's not aggrading further and perhaps is degrading somewhat such that additional flow capacity develops. A more balance sediment transport and signs of increased channel capacity may need to be present before implementing drainage improvements. On-going log jam removal will be necessary until watershed wide improvements are made to significantly reduce sediment loadings in LC and increase LC channel capacity such that sediments and woody debris transport through PSP during high flow events. With current methods and changing conditions to manage large woody debris from log jams, storage capacity may diminish over time to a point where alternative methods for dealing with large volumes of large woody debris becomes necessary to deal with log jams. Prescribed burning will be used to manage vegetation, including invasive species.

Table 10 below indicates WAP priorities in PSPA. Each WAP was qualitatively ranked for prioritization as primary (high), secondary (medium), and tertiary (low). Primary priorities are the Floodplain Restoration Action, some Stream Restoration Action practices, On-going Natural Resources Management Action, and the Agency Partnerships and Programs Action. Of these high priority actions and practices, special emphasis should be placed on prioritizing those practices highlighted in green. Secondary priorities include levee breaches, sediment and woody debris catchment, wetland restoration and enhancement, grade controls, and bank stabilization practices. A few tertiary priorities are shown in Table 10.

Table 10: Prioritized Pershing State Park Watershed Actions and Practices

Watershed Actions & Practices	Primary Priority	Secondary Priority	Tertiary Priority
FLOODPLAIN RESTORATION ACTION		■	
Levee Breach		■	
Levee Removal or Relocation			■
Drainage Improvements	■ (green)		
Sediment and Woody Debris Catchment		■	
Wetland Restoration or Enhancement		■	
STREAM RESTORATION ACTION		■	
Channel Grade Control		■	
Controlled Headcut – Channel Grade Control	■ (green)		

Resistive Bank Stabilization			
Re-directive Bank Stabilization			
Bio-engineered Bank Stabilization			
Riparian Buffer Restoration & Enhancement			
Stream Channel Re-alignment			
ON-GOING NATURAL RESOURCES MANAGEMENT ACTION			
AGENCY PARTNERSHIPS AND PROGRAMS ACTION			
PUBLIC AWARENESS AND EDUCATION ACTION			
ORGANIZATIONAL STRUCTURE ESTABLISHMENT ACTION			

Primary priority practices highlight in green are considered to have greatest value.

5.4 Lower Grand River Hwy 139/BNSF Floodway Drainage Improvements Alternative

The Lower Grand River Hwy 139/BNSF Floodway Drainage Improvements Alternative (139/BNSFFDIA) shown in Appendix E consists of improving floodway sediment transport and drainage capacity through the bridge openings and fill embankments of Hwy 139 and the BNSF Railway running across and constricting the Grand River floodway west of Sumner, Missouri. New bridge structures and/or additional bridging would potentially be highly effective in increasing sediment transport and flow capacity. Additional drainage structures could be added under the embankments to convey flood flows and drainage more efficiently and additional wetlands could be created. Levee modifications and flowage easements may be necessary on adjacent properties for this action as shown in Appendix E. This alternative, though outside the LCW, but within the Lower Grand watershed containing LC, is considered a potentially important alternative. This alternative would require further detailed hydrology & hydraulics and sediment transport analysis to determine need and whether meaningful benefits to LC and the LGR occur. Currently there is a WRP easement on the north side of these transportation corridors, which is reported by MDNR to capture floodwater primarily from LC flooding. This WRP easement appears to be providing substantial floodway benefits. Consideration for other floodway improvements should be investigated to see if additional modifications would be necessary. Future consideration and work should be given to the potential for a much larger system wide bed aggradation issue in the entire LGR as related to Missouri River channel bed influences.

5.5 Lower Grand River Floodway and Levee System Modifications Alternative

The Lower Grand River Floodway and Levee System Modifications Alternative (LGRFLSMA) shown in Appendix F would modify levees in the LGR watershed that may be constricting flood drainage causing backwater effects. The upper portion of the Garden of Eden Levee (GOE) located along the east bank of the Grand River south of Yellow Creek and Sumner, Missouri is likely acting as a major flow constriction that is causing increased backwater issues and more frequent flooding in tributary streams such as LC or Yellow Creek. This alternative considers relocating of portion of the GOE Levee (Appendix F). A past attempt was made by several natural resource agencies to acquire flood easement rights on about 1,700 acres of protected farmland at this location, but failed due to tax loss concerns by the GOELD. Different circumstances could present themselves in the future making this a viable project. This alternative, though outside the LCW, but within the Lower Grand 8-digit HUC watershed containing the LCW, is considered a potentially highly important alternative for drainage conveyance. It's not likely this alternative would significantly improve sediment transport. This alternative would require further detailed hydrology & hydraulics analysis to determine whether it could create meaningful benefits to both LC and the LGR.

5.6 No Action Alternative

The No Action Alternative consists of doing no future work in the LCW or in the LGR. Under the No Action Alternative, little change is expected to occur in the watershed. Gully, rill and sheet erosion from grazing, land clearing, and croplands will likely continue and contribute sediments to source and transport streams which create excessive sediment loads in sensitive response streams leading to aggradation. Flooding, stream bank erosion and head cutting will continue, as well as lost floodplain functions from levees. The LLC channel and floodplain may continue to aggrade, but likely at a slower rate through PSP, because the main avulsion in PSP will likely carry more of the sediment load that would have otherwise transported down LC through PSP. Sediment transport capabilities in LC through PSP will be reduced for the foreseeable future due to reduced discharge caused by the main avulsion to HD and continued log jams. Excessive flooding around the Hwy 36 corridor will likely continue for larger (> 2 year) flow events, but for smaller or approximately 1 – 2 year events, the main avulsion to HD mitigates those smaller flood event impacts. Log and ice jams will likely continue to occur in PSP and will likely gradually worsen, especially above Hwy 36 and Muddy/LC confluence. Existing levee breaches and the main avulsion along LC in PSP will only provide modest woody debris catchment due to entrance position relative to flow path. Forests, marshes, and wet prairie and overall plant species diversity in PSP will likely continue to decline, but potentially at a slower rate due to the flood reduction benefits of the main avulsion to HD. Backwater flooding into PSP and resultant impacts to vegetation in PSP, likely caused by LGR drainage constrictions from the GOE levee and Hwy 139/BNSF Railway embankments, and LGR channel aggradation, will continue. The aquatic diversity of LC in PSP will likely diminish and be lost and PSP's wet prairie ecosystem, one of only two large examples remaining in Missouri, is likely to be irreversibly altered in form and function. Note that the Missouri Natural Areas Committee recently initiated the de-listing process for the Cordgrass Bottoms Natural Area in PSP just below Highway 36 due to extensive floodplain sediment aggradation and irreversible impacts to native plant communities.

5.7 Evaluation of Alternative Plans for Completeness and Reformulation

Each action alternative plan previously discussed was reviewed for completeness against the ten goals listed in Section 3.0. After this review, and based on the available data and limited analysis conducted for this study, it was apparent that no single actionable alternative was potentially complete enough to have the potential to meet all goals. In order to meet these goals and create complementing system wide improvements in the LCW and in the LGR, alternative plan reformulation was necessary. The premise of this reformulation is that sediment and water are mobile and connected media across the landscape, thus all three action alternatives appear to be intimately linked. Therefore, these alternatives require consideration for a single larger alternative plan as described in the following section.

5.8 Systemwide Combined Alternative

This alternative consists of combining the LCWA, PSPA, LGR139/BNSFFDIA, and the LGRFLSMA, all of which were described previously, into a Systemwide Combined Alternative (SCA) as shown in Appendix G. This SCA, while bold in scale and untested, is potentially necessary to create sustainable change in sediment and water management that can potentially meet all ten goals. Below in Table 11 is a comprehensive list of prioritized WAPs associated with the SCA. Priority ranking was primary (high), secondary (medium), and tertiary (low) below. Of these high priority actions and practices, special emphasis should be placed on prioritizing those practices highlighted in green in Table 11.

Table 11: Prioritized Systemwide Combine Alternative WAPs

Watershed Actions & Practices	Primary Priority	Secondary Priority	Tertiary Priority
SOIL & WATER BMPs ACTION	■ (green)		
Sheet, Rill & Gully Erosion BMPs		■	
Permanent Vegetative Cover Establishment		■	
Permanent Vegetative Cover Improvement		■	
Terrace System	■		
Terrace System with Tile		■	
No-till System (Residue & Till Management)	■		
Permanent Vegetative Cover - Critical Areas: Confined Animal Feed Lots			■
Water Impoundment Reservoir	■		
Sediment Retention Water Control Structure	■		
Grade Stabilization	■		
Grassed (Sod) Waterway	■		
Diversion	■		
Contour Buffer Strips		■	
Contour Strip Cropping			■
Cover Crops	■ (green)		
Conservation Crop Rotation			■
Grazing Management BMPs	■ (green)		
Permanent Vegetative Cover Enhancement			■
Grazing System Water Development		■	
Grazing System Water Distribution		■	
Grazing System Fencing		■	
Grazing System Lime			■
Grazing System Seeding			■
Prescribed Grazing	■		
Heavy Use Protection	■		
Off Channel Shade & Water Sources	■ (green)		
Sensitive Areas BMPs	■ (green)		
Field Border		■	
Filter Strip		■	

Riparian Forest Buffer			
Stream Protection (Access Control)			
Streambank Stabilization			
Woodland Erosion BMPs			
Forest Plantation			
Woodland Protection – Livestock Exclusion (Access Control)			
Use Exclusion (Access Control)			
FLOODPLAIN RESTORATION ACTION			
Levee Breach			
Levee Removal or Relocation			
Drainage Improvements			
Sediment and Woody Debris Catchment			
Wetland Restoration or Enhancement			
STREAM RESTORATION ACTION			
Channel Grade Control			
Controlled Headcut – Channel Grade Control (PSP Only)			
Resistive Bank Stabilization			
Re-directive Bank Stabilization			
Bio-engineered Bank Stabilization			
Riparian Buffer Restoration & Enhancement			
Stream Channel Re-alignment			
LOWER GRAND RIVER HWY 139/BNSF FLOODWAY DRAINAGE IMPROVEMENTS			
LOWER GRAND RIVER FLOODWAY AND LEVEE MODIFICATIONS			
ON-GOING NATURAL RESOURCES MANAGEMENT ACTION			
AGENCY PARTNERSHIPS AND PROGRAMS ACTION			
PUBLIC AWARENESS AND EDUCATION ACTION			
ORGANIZATIONAL STRUCTURE ESTABLISHMENT ACTION			

Primary priority practices highlight in green are considered to have greatest value.

5.9 Recommended Alternative

The Recommended Alternative for this study is the SCA based on its comprehensive approach and ability to potentially meet all ten goals. It will effectively manage soils on lands, channel sediments, and water flow and distribution throughout LCW and LGR system. Table 12 below is a list of potential priority restorative projects by watershed location and channel network starting in higher elevation areas of the watershed with sediment sources, moving into lower elevation stream networks, and finally ending in the LGR.

Table 12: Priority SCA Projects by Watershed Location and Channel Network

1. Watershed wide Riparian Grass Buffers (addressing grazing/hayland and cultivated cropland)
2. No-till System and Cover Crops (addressing cultivated cropland)
3. Off-channel Shade and Water Source (addressing Cattle Management)
4. LLC and select watershed wide Bank Stabilization Projects
5. LLC Levee Breaches above PSP
6. PSP Sediment Removal at Hwy 36 Drainage Structures
7. PSP Additional Drainage Structure Hwy 36
8. PSP Stream Restoration/Drainage Overflow Channels and related Restorative Work
9. PSP Avulsion Modification/Closure (Rock)
10. PSP Controlled Headcut (Grade Controls)
11. PSP Monitor Channel/Floodplain Aggradation and Vegetation
12. PSP Riparian Restoration
13. PSP Riparian Enhancement (invasive species control)
14. PSP On-going Logjam Removal
15. LGR Hwy 139/BNSF Railway Floodway Improvements
16. LGR GOE Levee Setback

5.10 Data Gap Analysis

As stated periodically throughout this document, data used to prepare this report was available, but quite often limited. All alternatives considered are all conceptual in nature and based on professional judgment, and on limited data and data analysis conducted. Table 13 is a preliminary list of data and data analysis gaps that may be required going forward. Having these will help clarify existing conditions and problems; and further the planning, analysis, alternatives development, any refinements, prioritization, and preliminary design.

Table 13: Preliminary Data and Analysis Gaps

Locust Creek Watershed Modeling, Analysis & BMP Locations to evaluate: • Land use/cover changes • Additional pond/reservoir digitizing • Sediment characterization • Sediment loading estimation • Sediment source and yield analysis • Regional treatment potential • Local treatment potential (i.e. BMP locating) • Potential Models – TREX, SWAT, HSPF, Terrain Analysis
Floodplain and channel aggradation monitoring in PSP (including in HD)
Monitoring vegetation in PSP
Identify strategic levee breach/relocation sites
H & H modeling and sediment transport modeling in LLC, Hwy 36 and the LGR

Sediment depth probing & geotechnical material analysis in LLC and the LGR

5.11 Strategic Prioritization of the SCA Future Work Activities and Implementation

Given the scope of the problems and size of watershed, as well as a very lengthy implementation time frame, it is important to develop a strategy to prioritize the work activities and implementation associated with the SCA. Conceptually, prioritized preference should be given as follows:

1. Monitor channel/floodplain aggradation and vegetation in PSP
2. Model and refine sediment loadings and strategic BMP locating in LCW
3. Evaluate strategic levee breach/setback locations in LLC
4. Evaluate/model drainage improvements/stream restoration practices in PSP
5. Model LGR Hwy 139/BNSF Railway floodway improvements for suitability
6. Develop riparian restoration/enhancement plans for PSP
7. Implement riparian restoration/enhancement plans for PSP
8. Implement strategic BMPs in LCW
9. Implement levee breaches/drainage improvements/stream restoration in LLC/PSP
10. Implement LGR Hwy 139/BNSF Railway floodway improvements if feasible
11. Model LGR GOE Levee setback below Yellow Creek for suitability
12. Implement LGR GOE Levee setback below Yellow Creek if feasible

Priorities 1 – 5 above, which are study efforts in the LCW, PSP, and LGR, should be implemented first and on parallel pathways if possible. Priorities 6 – 8 above, which are essentially implementation or construction phases in the LCW and PSP, should follow next. And finally, priorities 9 – 12 are long term priorities to study, evaluate, design and implement floodway drainage improvements on the LGR.

6.0 Cost Estimates

Due to the sheer scale, limited data and analysis, and conceptual nature of the SCA, very crude preliminary cost estimates were determined on some key high priority restorative projects of the SCA shown in Table 12. The projects are shown in Table 14 below at rounded dollar values and without inflation factored in. This cost estimating was done only on key priorities where some limited data was available and major assumptions could be made. Significant additional analysis would be required to determine more detailed costs.

Table 14: Rough Cost Estimating for Systemwide Combined Alternative

RESTORATIVE PROJECTS	COST
Watershed wide Riparian Grass Buffers (addressing grazing/hayland and cultivated cropland). Assume 50' total native grassland buffer width (25' each side of channel) plus fencing.	$47,000,000
No-till System/Cover Crops (Row Crop Critical Area BMP) – (25 years)	$84,198,750
Off-channel Shade and Water Source (addressing Cattle Management). Assume one shade and one water source per 160 acres.	$10,700,000
Watershed wide Bioengineered Bank Stabilization (assume 177,571 linear feet of hotspots)	$13,500,000

LLC Levee Breaches and Vegetation Restoration above PSP (assume construction and land or flowage easement costs and seeding on 3,500 acres)	$14,770,000 – 15,100,000
PSP Sediment Removal at Hwy 36 Drainage Structures (one time)	$50,000
PSP Additional Drainage Structure Hwy 36	$200,000 – 300,000
PSP Stream Restoration/Drainage Overflow Channels and related Restorative Work (0.5 – 3.0 miles of channels)	$500,000 – 2,500,000
PSP Avulsion Modification/Closure with Rock (one time)	$30,000 – 100,000
PSP Controlled Headcut (Grade Controls) – assume two to ten grade controls and excavation	$100,000 – 1,000,000
PSP Monitor Channel/Floodplain Aggradation and Vegetation (25 years)	$250,000
PSP Riparian and Wet Prairie Vegetation Management (burning) – (25 years)	$500,000
PSP On-going Logjam Removal (25 years)	$3,750,000
LGR Hwy 139/BNSF Railway Floodway Improvements	$500,000 – 20,000,000
LGR GOE Levee Setback	$750,000
SUBTOTAL	$176,798,750 – 199,698,750
Future Planning, Studies, and Design @ 10% of Construction Costs	$17,679,875 – 19,969,875
Management and Administrative Costs @ 5% of Construction Costs	$8,839,937 – 9,984,937
TOTAL	$203,318,562 – 229,653,562

As shown in Table 14, rough costs can vary greatly between features, and final costs for full implementation could be between $203,318,562 and $229,653,562.

7.0 Implementation Strategies

Implementation strategies include several key understandings. First, effort must be put forth by all stakeholders to consider working towards common goals/projects from a single unified plan. Second, funding must be available. And third, implementation should align prioritized projects from the SCA with funding. This LCWS is the first step in providing that information which can be used by the local sponsor, other agencies, or other non-governmental interests to aid in working from a unified plan. For implementation to work, this LCWS should be shared by the local sponsor with other federal, state and local agencies as deemed necessary to start that process of working from a unified plan. For instance, the BMP maps of the LCWA (Appendix C) could be used by the NRCS and local Soil & Water Conservation Districts to target potential critical sediment source areas and landowners for soil and water conservation projects. This LCWS sets some initial priorities (see Section 5.11). The remainder of this section focuses on implementation and funding strategies.

A key to funding strategies is to develop a detailed implementation plan at some point to help guide overall funding sources, coordination and management of implementation. Developing an implementation plan that seeks multiple partners and funding sources can be a complex, but necessary administrative task. Another key to funding strategy is to have an overall single organization (or organizational structure), such as the local sponsor for this study or a new dedicated watershed organization, to develop and maintain strategic relationships with each funding agency. A single organization or organizational structure is highly recommended. Due to the variability of funding patterns, particularly at the federal level, it's important for this organization to have its own developed funding program and stream in place. A funding program that has a consistent strategy and stream of funding that can readily be made available for agency funding matches or to cover costs not funded by partnering agencies and their programs, will have the greatest long term success. It provides the greatest chance of maximizing long-term agency participation, particularly with federal agencies.

Sources of funding can be public or private. A wide variety of funding sources exist through multiple Federal and state agencies, while private (or non-governmental) funding sources may be more limited. Funding can be in several forms, including grants, cost-sharing, low interest loans, and fee collections. Since SCA is really an overall program of watershed restoration consisting of discrete but interdependent projects, it can best be accomplished by matching specific project purposes, with appropriate funding source missions and programs that best align. Ultimately, this can lead to multiple projects that will in turn contribute to the implementation of overall watershed restoration. A comprehensive list and description of agency funding sources/programs at the federal and state level, and indirect funding sources through mitigation banks (MB) or in-lieu fee (ILF) programs, are provided in Appendix H. The following Table 15 is a summary of the SCA priority projects matched with appropriate agency funding sources/programs selected from Appendix H, with high priority programs highlighted in green.

Table 15: Systemwide Combined Alternative Projects Funding Source Matching

RESTORATIVE PROJECTS	AGENCY/PROGRAM
Watershed wide Riparian Grass Buffers	***USDA*** –CRP, EQIP, GRP ***EPA*** – NPS 319 ***MDNR*** – SWCP ***USACE*** – 206 CAP AER, GI/SAP (GRBR) ***OTHER*** – MB, ILF
No-till System and Cover Crops	***USDA*** – EQIP ***MDNR*** – SWCP
Off-channel Shade and Water Sources (Cattle Management)	***USDA*** –EQIP ***EPA*** – NPS 319 ***MDNR*** – SWCP ***OTHER*** – MB, ILF
Watershed wide Bioengineered Bank Stabilization	***EPA*** – NPS 319 ***USACE*** – 206 CAP AER, GI/SAP (GRBR) ***MDNR/SWCD*** – SWCP ***OTHER*** – MB, ILF
LLC Levee Breaches above PSP	***USDA*** – WRP, EWP ***USACE*** – 205 CAP SFDRP, GI/SAP (GRBR) ***USFWS*** - NAWCAGP, PFWP ***OTHER*** – MB, ILF
PSP Sediment Removal at Hwy 36 Drainage Structures	***EPA*** – NPS 319 ***USACE*** – 205 CAP SFDRP, GI/SAP (GRBR) ***OTHER*** – MB, ILF
PSP Additional Drainage Structure Hwy 36	***USACE*** – 205 CAP SFDRP, GI/SAP (GRBR) ***OTHER*** – MB, ILF

PSP Stream Restoration/Drainage Overflow Channels and related Restorative Work	***USACE*** – 206 CAP AER, 205 CAP SFDRP, GI/SAP (GRBR) ***OTHER*** – MB, ILF
PSP Avulsion Modification/Closure (Rock)	***EPA*** – NPS 319 ***USACE*** – 206 CAP AER, GI/SAP (GRBR)
PSP Controlled Headcut (Grade Controls)	***USACE*** – 206 CAP AER, GI/SAP (GRBR) ***OTHER*** – MB, ILF
PSP Monitor Channel/Floodplain Aggradation and Vegetation	***USDA*** – NIWQP ***USACE*** – 22 CAP PAS
PSP Riparian Restoration	***USACE*** – 206 CAP AER, GI/SAP (GRBR) ***OTHER*** – MB, ILF
PSP Riparian Enhancement Invasive Species Control	***USACE*** – 206 CAP AER, GI/SAP (GRBR) ***OTHER*** – MB, ILF
PSP On-going Logjam Removal	***USACE*** – 208 CAP SCFC
LGR Hwy 139/BNSF Railway Floodway Improvements	***USDA*** –WRP, EWP ***USACE*** – 205 CAP SFDRP, GI/SAP (GRBR)
LGR GOE Levee Setback	***USDA*** – WRP, EWP ***USACE*** – 205 CAP SFDRP, GI/SAP (GRBR)

CRP – Conservation Reserve Program, EQIP – Environmental Quality Incentives Program, GRP – Grassland Reserves Program, WRP – Wetland Reserve Program, EWP – Emergency Watershed Protection, NIWQP – National Integrated Water Quality Program, NPS 319 – Nonpoint Source 319 Grant, SWCP – Soil & Water Conservation Program, 205 CAP SFDRP – Section 205 Continuing Authority Program Small Flood Damage Reduction Project, 206 CAP AER – Section 206 Continuing Authorities Program Aquatic Ecosystem Restoration, GI/SAP (GRBR) – General Investigation/Specially Authorized Project (Grand River Basin Resolution), 208 CAP SCFC – Section 208 Continuing Authorities Program Snagging and Clearing for Flood Control, NAWCAGP – North American Wetlands Conservation Act Grants Program, PFWP – Partners for Fish and Wildlife Program, MB – Mitigation Bank, ILF – In-lieu Fee Program

As shown in Table 15, there are many high priority agency funding sources/programs matched to projects. For watershed wide riparian buffers, USDA programs and the MDNR SWCP are best suited. For no-till and cover crops, the USDA EQIP is best suited; however, MDNR's SWCP does currently cost-share no-till. For off-channel shade and water sources, a combination of USDA and MDNR are best suited for water source funding, but currently these programs don't appear to fund shade construction unless tied to riparian buffer. Therefore, programs like the EPA NPS 319 or possible an ILF program could fund off-channel livestock shade structures or tree plantings. Many of the USACE programs listed in Table 15 are better aligned and more focused on floodplains, streams, rivers, and wetlands. Some more site specific opportunities for ILF programs exist in PSP and LLC above PSP.

A funding and implementation strategy follows. It consists of aligning the SCA work activities/implementation priorities (Section 5.11) with agency funding sources/programs shown in Table 14. Table 16 below attempts to align these and indicates that study and design related priorities (1 – 6) could largely be conducted through USACE cost-share programs. Of particular note is the current federal Grand River Basin Resolution (GRBR) that allows the USACE to conduct multi-purpose water resource projects in the Grand River basin. While not currently funded, the GRBR is a specialized authorized project intended to deal with the larger and more complex water resources issues in the Grand River basin and should be given strong consideration for future work activities and implementation. Priorities 7 – 12 in Table 16 indicate USACE, USDA, and MDNR programs would work well for implementation. Also, the establishment of a MB and/or ILF program could also be used indirectly to implement projects throughout the LCW and LGR.

Table 16: SCA Prioritized Work Activities/Implementation Matched with Funding Source

PRIORITIZED WORK ACTIVITIES/IMPLEMENTATION	AGENCY/PROGRAM
1. Monitor channel/floodplain aggradation and vegetation in PSP	***USDA*** – NIWQP ***USACE*** – 22 CAP PAS, GI/SAP (GRBR)
2. Refine sediment loadings/sources and strategic BMP locating in LCW	***USACE*** – 22 CAP PAS, GI/SAP (GRBR)
3. Evaluate strategic levee breach/setback locations in LLC	***USACE*** – 205 CAP SFDRP PAS, GI/SAP (GRBR) ***OTHER*** – MB, ILF
4. Evaluate/model drainage improvements/stream restoration practices in PSP	***USACE*** – 206 CAP AER, 205 CAP SFDRP, GI/SAP (GRBR)
5. Model LGR Hwy 139/BNSF Railway floodway improvements for suitability	***USACE*** – 205 CAP SFDRP PAS, GI/SAP (GRBR)
6. Develop riparian restoration/enhancement plans for PSP	***USACE*** – 206 CAP AER, GI/SAP (GRBR) ***OTHER*** –ILF
7. Implement riparian restoration/enhancement in PSP	***USACE*** – 206 CAP AER, GI/SAP (GRBR) ***OTHER*** – ILF
8. Implement strategic BMPs in LCW	***USDA*** – CRP, EQIP, GRP ***MDNR*** – SWCP ***EPA –*** NPS 319 ***OTHER*** - ILF
9. Implement levee breaches/drainage improvements/stream restoration in PSP	***USACE*** – 206 CAP AER, 205 CAP SFDRP, GI/SAP (GRBR) ***OTHER*** – ILF
10. Implement LGR Hwy 139/BNSF Railway floodway improvements (if feasible)	***USDA*** – WRP, EWP ***USACE*** – 205 CAP SFDRP, GI/SAP (GRBR)
11. Model LGR GOE Levee setback below Yellow Creek for suitability	***USACE*** – 205 CAP SFDRP, GI/SAP (GRBR)
12. Implement LGR GOE Levee setback below Yellow Creek (if feasible)	***USDA*** – WRP, EWP ***USACE*** – 205 CAP SFDRP, GI/SAP (GRBR)

CRP – Conservation Reserve Program, EQIP – Environmental Quality Incentives Program, GRP – Grassland Reserves Program, WRP – Wetland Reserve Program, EWP – Emergency Watershed Protection, NIWQP – National Integrated Water Quality Program, SWCP – Soil & Water Conservation Program, 205 CAP SFDRP – Section 205 Continuing Authority Program Small Flood Damage Reduction Project, 206 CAP AER – Section 206 Continuing Authorities Program Aquatic Ecosystem Restoration, GI/SAP (GRBR) – General Investigation/Specially Authorized Project (Grand River Basin Resolution), MB – Mitigation Bank, ILF – In-lieu Fee Program

An ILF or MB program would align well with potential projects in PSP and possibly throughout the LCW and LLC based on current (2008) USACE federal mitigation guidelines. However, it may not be possible to use federal cost-share funding to implement these because of potential conflicts of interest with use of federal dollars supporting non-federal mitigation. An ILF and/or MB could establish on properties in the watershed. Should other lands adjacent to PSP or upstream in LLC within the LCDD become available for restoration, then those lands could be incorporated into an ILF or MB. The local sponsor (or other watershed based organization) should consider using cost-share dollars for studies and evaluation initially to further analyze watershed issues, while concurrently evaluating in more detail the feasibility of establishing an ILF mitigation program for sites in the LCW (including PSP) and/or the LGR.

8.0 Operations & Maintenance Consideration

Operations & Maintenance (O&M) are those post construction requirements to operate and maintain restoration project specific features. O&M can vary greatly depending on project specific features, agency program rules, and long-term contractual agreements made between agencies and landowners. O&M requirements could include vegetation and infrastructure management, inspections, repairs, replacement, and rehabilitation. Monitoring, though not specifically O&M in nature, can be useful to help manage O&M requirements for compliance and performance purposes. Generally speaking, O&M implementation is the responsibility of a local sponsor, individual landowners participating in federal, state or local programs, or other responsible parties such as ILF or MB sponsors.

9.0 Recommendations

Based on the preliminary studies and assessment provided in this LCWS report, it is recommended that the local sponsor and/or cooperating agencies with the local sponsor, or a yet to be determined watershed based organization, implement the Recommended Alternative and make modifications to it as needed. If available, cost-share funding for studies and evaluation should be sought to further analyze watershed issues. The local sponsor could concurrently evaluate in more detail and start establishing an ILF mitigation program within the LCW (including PSP) and/or the LGR.

10.0 References

ASM, 2012. Audubon Society of Missouri. http://mobirds.org/CACHE/AreaChecklist.

Culler, 2013. Written communication from Mary Culler to Tim Fobes.

EPA, 2012. Watershed Assessment of River Stability & Sediment Supply - Channel Processes: Streambank Erosion. http://water.epa.gov/scitech/datait/tools/warsss/streamero.cfm.

Files, 2012. LC Problems - A white paper review on LC problems prepared by Missouri DNR Regional Supervisor Mr. Dan Files.

Files, 2012a. Email communication from Dan Files to Tim Fobes.

Fobes, 2012. Personal communication with Dr. Joseph Ely – University of Central Missouri.

Fobes, 2012a. Presentation and field visit led by Mr. Tom Woodward, Pershing State Park Superintendent, Missouri Department of Natural Resources.

Fobes, 2012b. Personal communication with Mr. Tom Woodward, Pershing State Park Superintendent, Missouri Department of Natural Resources.

Fobes, 2012c. Personal communication with Mr. Steve McIntosh, Missouri Department of Natural Resources.

Fobes, 2012d. Personal communication from Chris Cash, engineer of record for avulsion analysis and countermeasures design plan at Pershing State Park.

Great River Associates, 2011. *Geomorphic Engineering Assessment - Pershing State Park*. Prepared for Missouri Department of Natural Resources.

Kennen, J.G. et al. 2009. Application of the Hydroecological Integrity Process for Missouri Streams. U.S. Geological Survey Open File Report 2009-1138.

Laclede Blade Newspaper, 1935. *LC Valley Drainage Project*. Article published August 16th, 1935.

Laclede Blade Newspaper, 1942. *Flood Control Ditch Project Favored*. Article published June, 1942.

MDC, 1994. *LC Basin Management Plan*. Missouri Department of Conservation.

MDC, 2012. Mussel Inventory of Pershing State Park and Fountain Grove Conservation Area Locust Creek, Hickory Branch, and Grand River. Jane E. Cotton, Missouri Department of Conservation, Chillicothe, Missouri.

MDC, 2012a. Email communication and head cutting photograph from Greg Pitchford, Missouri Department of Conservation Regional Fisheries Biologist.

MDC, 2013. Locust Creek Fish Tissue Contamination Sampling Spreadsheet. Spreadsheet provided by Michael McKee, Environmental Health Unit, Missouri Department of Conservation.

MDC, 2013a. Report of Pollution Investigations and Fish Kills – Major Streams in the Locust Creek Watershed. Reports provided by Rebecca O'heara, Fisheries Biologist, Missouri Department of Conservation, Columbia Research Center.

MDNR, 2005. *East Locust Creek Watershed Plan Revision*. Missouri Department of Natural Resources.

MDNR, 2008. *Biological Assessment and Habitat Study – West LC, Linn and Sullivan Counties.* Missouri Department on Natural Resources Field Services Division, WQM Section.

MDNR, 2010. *Total Maximum Daily Load Information Sheet for LC*. Missouri Department of Natural Resources. http://www.dnr.mo.gov/env/wpp/tmdl/info/0606-locust-ck-info.pdf.

MDNR, 2010a. *Biological Assessment and Habitat Study – West LC, Putnam County.* Missouri Department on Natural Resources Field Services Division, WQM Section.

MDNR, 2012. *LC Briefing Document*. Missouri Department of Natural Resources.

MDNR, 2012a. *Birds from Pershing State Park and Vicinity*. Missouri Department of Natural Resources. http://mostateparks.com/sites/default/files/Pershing%20Birds.pdf.

MDNR, 2012b. Pershing State Park Conceptual Development Plan – November 2004. Missouri Department of Natural Resources http://mostateparks.com/page/55131/park-plans.

MDNR, 2013. Water Quality Assessment System - Water Quality Data Search. http://dnr.mo.gov/mocwis_public/wqa/waterbodySearch.do

DNR, 2013a. Statewide Cost-share Practices List. Missouri Department of Natural Resources Soil and Water Conservation Program, provided courtesy of Mary Culler, MDNR Environmental Specialist and Regional Watershed Coordinator.

NPS, 2012. Nationwide River Inventory. Information accessed online at http://www.nps.gov/ncrc/programs/rtca/nri/states/mo.html.

NRCS, 1990. *Soil Survey of Linn County Missouri*. U.S. Department of Agriculture, Natural Resources Conservation Service.

NRCS, 1995. *Soil Survey of Sullivan County Missouri*. U.S. Department of Agriculture, Natural Resources Conservation Service.

NRCS, 2006. *East Locust Creek Watershed Project, Sullivan County, Missouri*. U.S. Department of Agriculture, Natural Resources Conservation Service.

NRCS, (ca. 2011). Geospatial Analysis of Pre-Restoration Wetlands, Restoration Impacts, and Post-Restoration Impacts – Pershing State Park Wetland Restoration, Linn County, MO. USDA – NRCS Emergency Watershed Protection Program – Floodplain Easement.

NRCS, 2012. Livingston and Carroll Counties Lower Grand River Watershed Project 2012 Environmental Quality Incentives (EQIP) Program Policies 2/3/2012.

Pflieger, W.L., 1975. Fishes of Missouri. Missouri Department of Conservation. 343 pp.

Pitchford, 2012. Grand River Watershed Online Information Summary. Information found at http://mdc.mo.gov/landwater-care/stream-and-watershed-management/missouri-watersheds/grand-river. Missouri Department of Conservation.

USACE, 2008. Garden of Eden Drainage District Section 3, Emergency Levee Rehabilitation Project NEPA Review Environmental Assessment & Finding of No Significant Impact. Chariton County, MO. U.S. Army Corps of Engineers Kansas City District.

USDA – National Agricultural Statistics Service. Cropland Data Layer, 2006-2012. Published crop-specific data layer [Online]. Available at http://nassgeodata.gmu.edu/CropScape/ (accessed 2 January 2013; verified 2 January 2013). USDA-NASS, Washington, DC.

USFWS, 2012. Swan Lake Wildlife. http://www.fws.gov/midwest/SwanLake/Wildlife.html.

USGS, 1997. *Hydraulic Analyses of Alternative Methods for Reducing Backwater from Log Jams on LC near Pershing State Park, Linn County, Missouri*. Open-File Report 97-238. Rolla, Missouri. Prepared for Missouri DNR.

USGS, 2012. Online access to current stream gage and flow information that are found at this URL http://waterwatch.usgs.gov/?m=real&r=mo&w=map.

Vokoun, J.C and C.F. Rabeni, 2003. Recovery of Prairie Fish Assemblages at the Transition from Channelized to Nonchannelized: Implications for Conservation of Natural Channels. Natural Areas Journal, Volume 23(4), pp. 349 – 355.

Winston, M.R., S.A. Bruenderman, and T.R. Russell, 1998. A Regional Perspective on Aquatic Fauna of Pershing State Park. Missouri Department of Conservation. 17 pp.

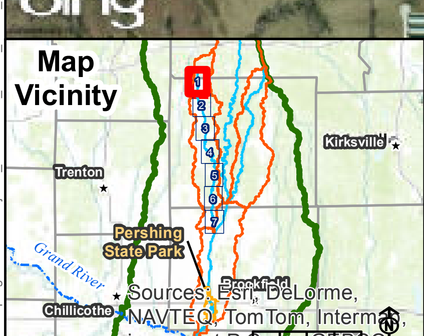
Woodward, 2012. Missouri Department of Natural Resources, Pershing State Park Activities & Update. Lower Grand Conservation Opportunity (LGCOA) Seminar, July 12-13, Chillicothe, Missouri.

Appendix A – Detailed Mapbooks for the Major Locust Creek Sub-Watershed Units*

- **West Locust Creek Subwatershed Mapbook on Aerial Photos**
- **Locust Creek Subwatershed Mapbook on Aerial Photos**
- **Locust Creek Subwatershed Mapbook on LIDAR Imagery**
- **East Locust Creek Subwatershed on Aerial Photos**

*Historic alignments and eroding hotspots need to be field verified.

West Locust Creek



Historic Alignment (Approximate)*
- Locust Creek
- West Locust Creek

Reviewed Reach*
- Eroding
- Not Visibly Eroding

- Lower Grand HUC 8 Boundary
- Locust Creek HUC 10 Watershed

NRCS - Private Conservation Areas
- EWPP-FPE
- EWRP
- WRP
- County Boundary

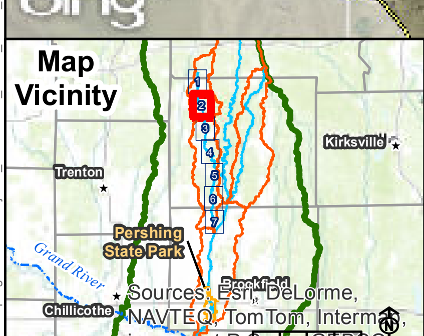
0 0.25 0.5 Miles

*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR

Date: 8/15/2013

Path: \\mspe-gis-file\GISProj\133_KC171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Creek_West_Mapbook_11X17P_final_aerial.mxd

West Locust Creek



Historic Alignment (Approximate)*
- Locust Creek
- West Locust Creek

Reviewed Reach*
- Eroding
- Not Visibly Eroding

- Lower Grand HUC 8 Boundary
- Locust Creek HUC 10 Watershed

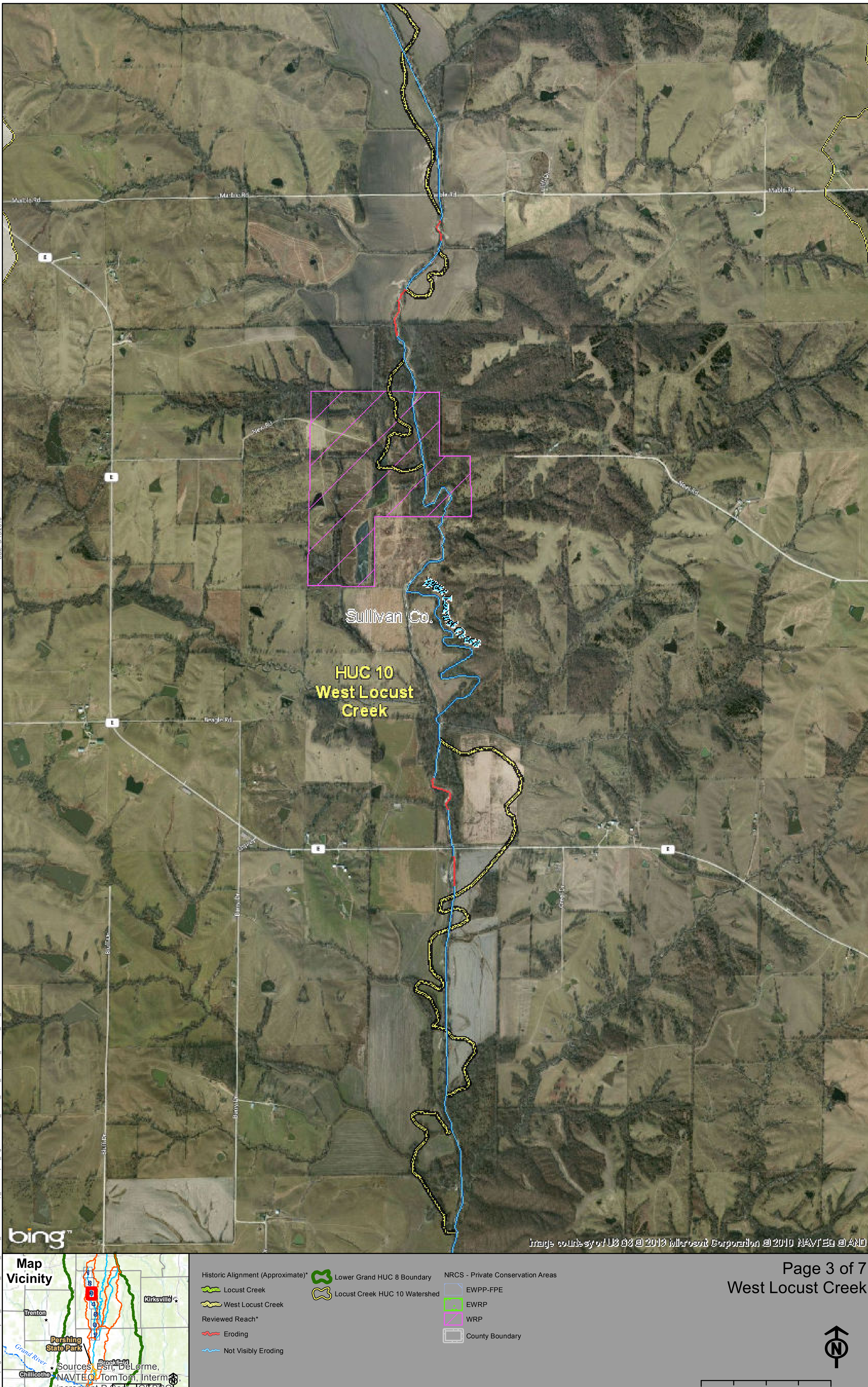
NRCS - Private Conservation Areas
- EWPP-FPE
- EWRP
- WRP
- County Boundary

0 0.25 0.5 Miles

*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR

Date: 8/15/2013

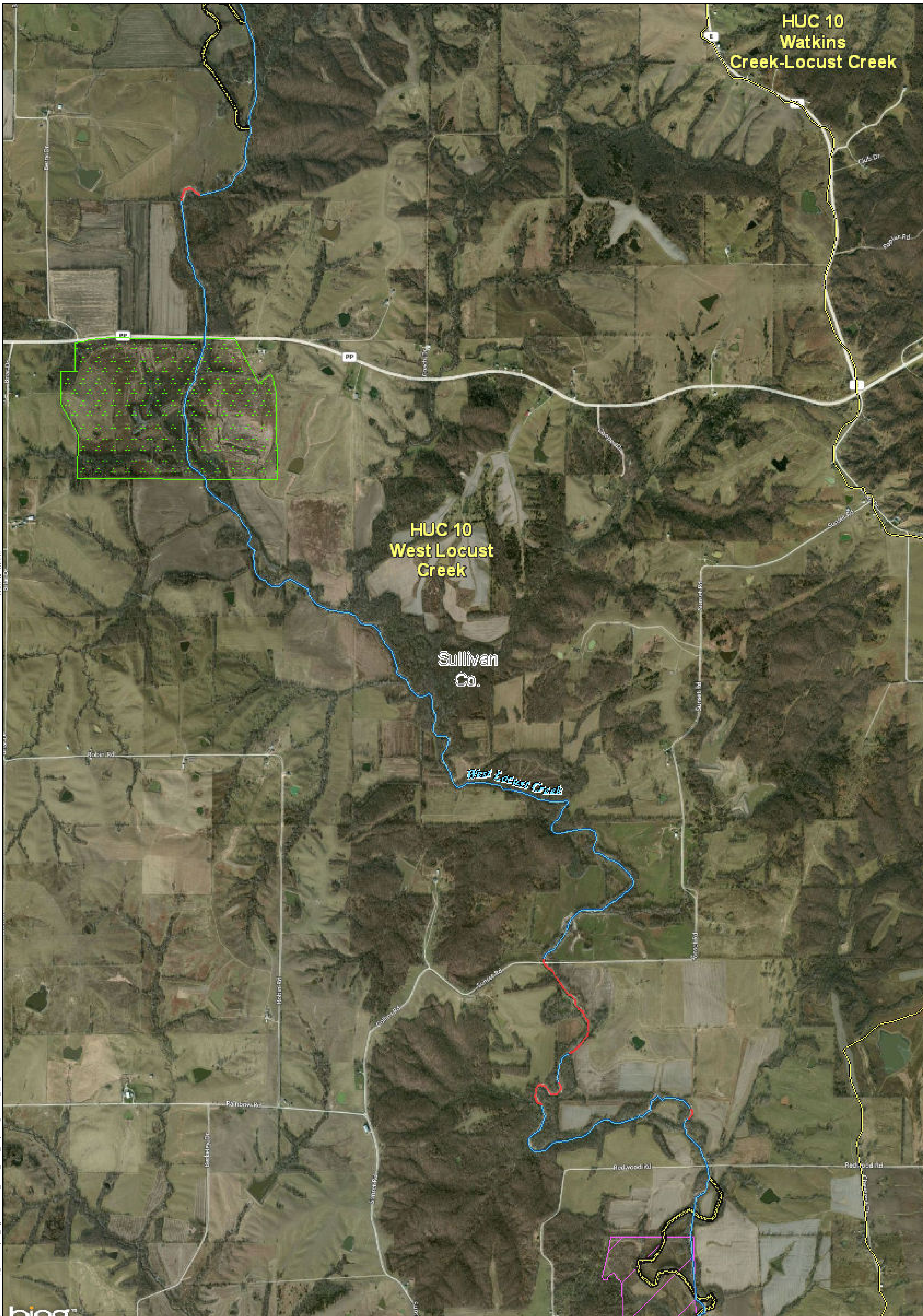
Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Creek_West_Mapbook_11X17P_final_aerial.mxd

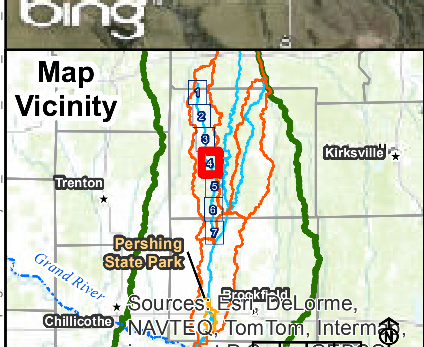


West Locust Creek

Date: 8/15/2013

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Creek_West_Mapbook_11X17P_final_aerial.mxd





Historic Alignment (Approximate)*
Locust Creek
West Locust Creek
Reviewed Reach*
Eroding
Not Visibly Eroding

Lower Grand HUC 8 Boundary
Locust Creek HUC 10 Watershed

NRCS - Private Conservation Areas
EWPP-FPE
EWRP
WRP
County Boundary

*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR

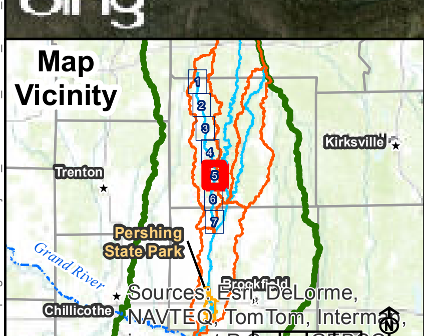
West Locust Creek

N

0 0.25 0.5 Miles

Date: 8/15/2013

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Creek_West_Mapbook_11X17P_final_aerial.mxd



Historic Alignment (Approximate)*
- Locust Creek
- West Locust Creek

Reviewed Reach*
- Eroding
- Not Visibly Eroding

- Lower Grand HUC 8 Boundary
- Locust Creek HUC 10 Watershed

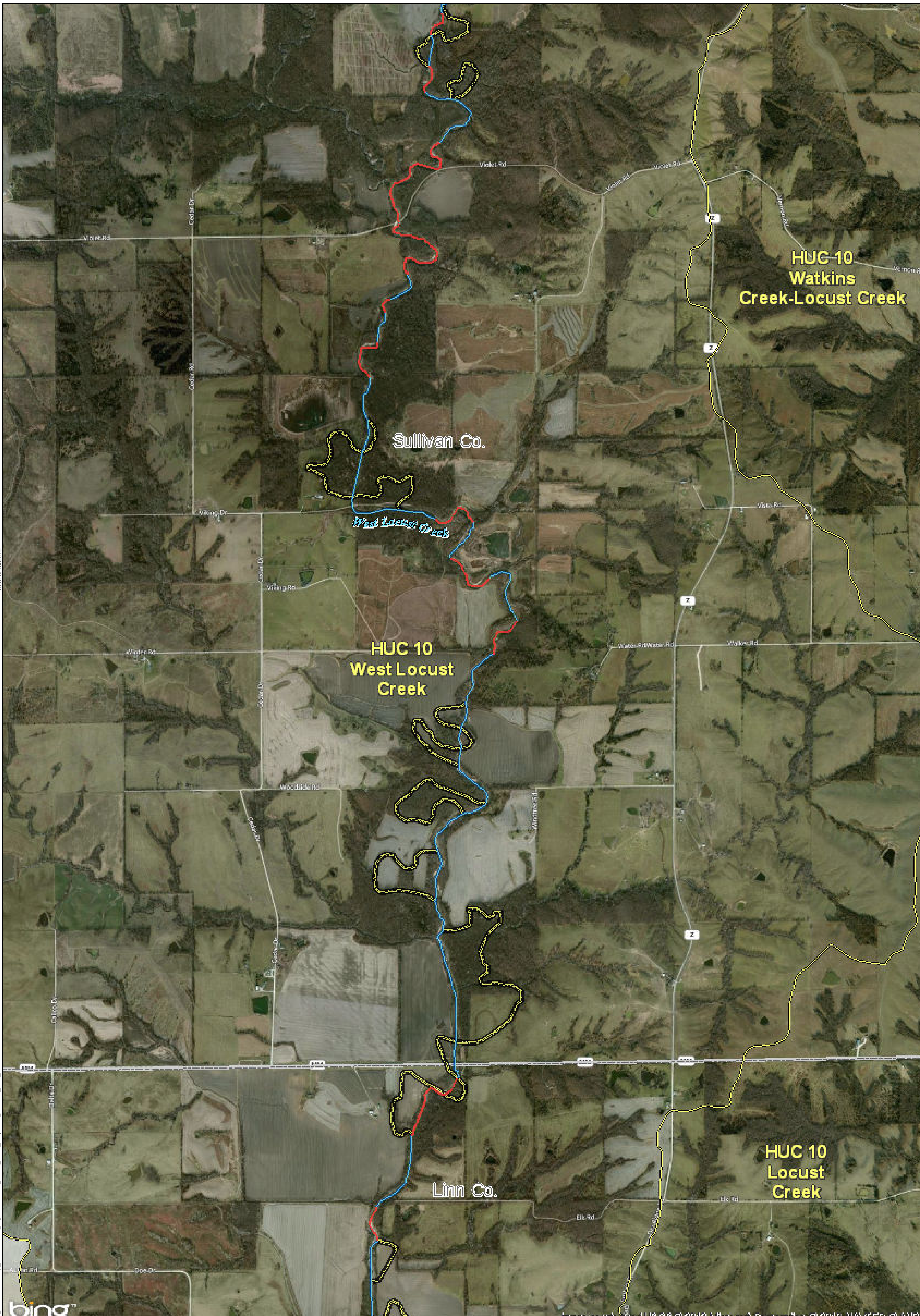
NRCS - Private Conservation Areas
- EWPP-FPE
- EWRP
- WRP
- County Boundary

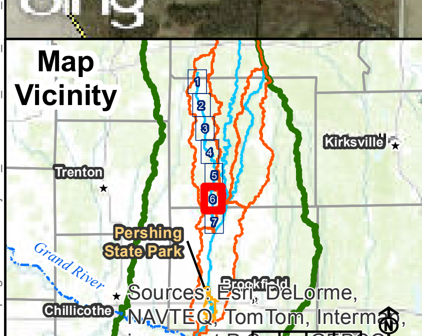
*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR

0 0.25 0.5 Miles

Date: 8/15/2013

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Creek_West_Mapbook_11X17P_final_aerial.mxd





Historic Alignment (Approximate)*
- Locust Creek
- West Locust Creek

Reviewed Reach*
- Eroding
- Not Visibly Eroding

- Lower Grand HUC 8 Boundary
- Locust Creek HUC 10 Watershed

NRCS - Private Conservation Areas
- EWPP-FPE
- EWRP
- WRP
- County Boundary

*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR

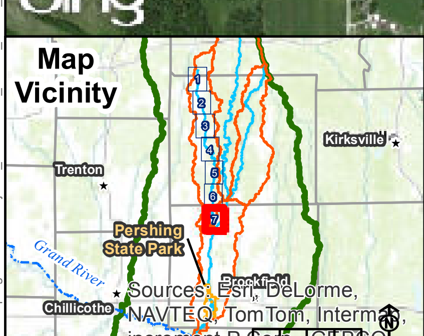
West Locust Creek

N

0 0.25 0.5 Miles

Date: 8/15/2013

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Creek_West_Mapbook_11X17P_final_aerial.mxd



Historic Alignment (Approximate)*
- Locust Creek
- West Locust Creek

Reviewed Reach*
- Eroding
- Not Visibly Eroding

- Lower Grand HUC 8 Boundary
- Locust Creek HUC 10 Watershed

NRCS - Private Conservation Areas
- EWPP-FPE
- EWRP
- WRP
- County Boundary

*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR

West Locust Creek

N

0 0.25 0.5 Miles

Date: 8/15/2013

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Creek_West_Mapbook_11X17P_final_aerial.mxd

Historic Alignment (Approximate)*
- East Locust Creek
- Locust Creek
- West Locust Creek

Reviewed Reach*
- Eroding
- Not Visibly Eroding

- Primary avulsion*
- Secondary avulsion*
- Constricted Channel (<60 ft)*
- Locust Creek Log Jam 404 Permit Locations
- Lower Grand HUC 8 Boundary
- Locust Creek HUC 10 Watersheds
- Breeched Levee (2010)
- Levees*

- County Boundary
- State Boundary
- MDC Land
- DNR Land

NRCS - Private Conservation Areas
- EWPP-FPE
- EWRP
- WRP

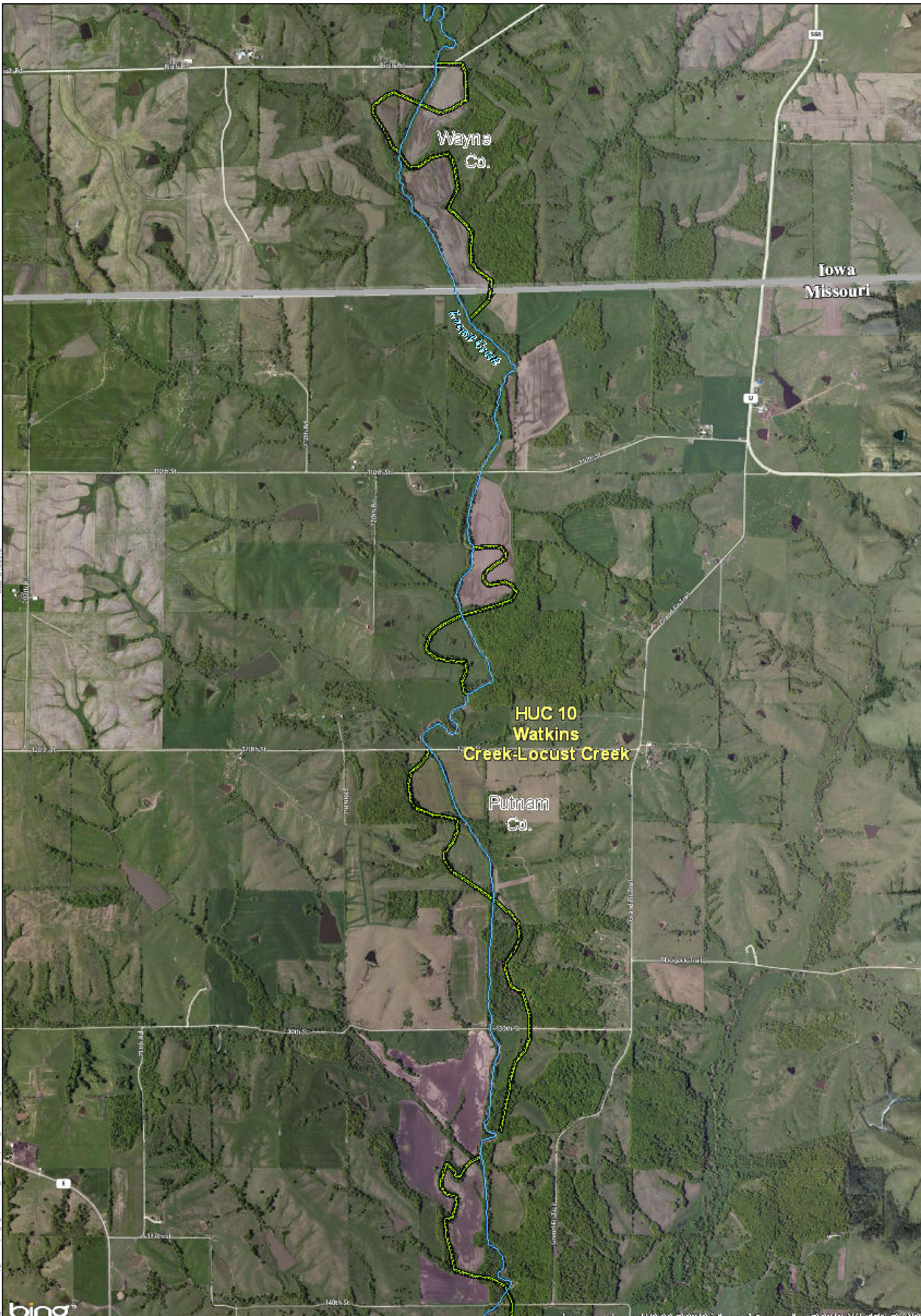
*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR

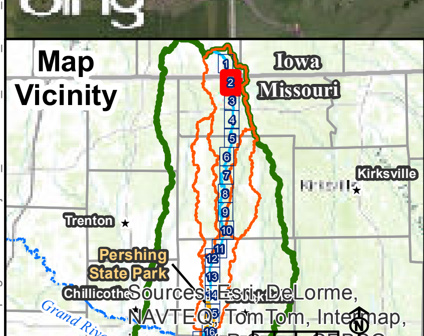
Locust Creek

0 0.25 0.5 Miles

Date: 8/15/2013

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Creek_Mapbook_11X17P_final_aerial.mxd





Historic Alignment (Approximate)*
- East Locust Creek
- Locust Creek
- West Locust Creek

Reviewed Reach*
- Eroding
- Not Visibly Eroding

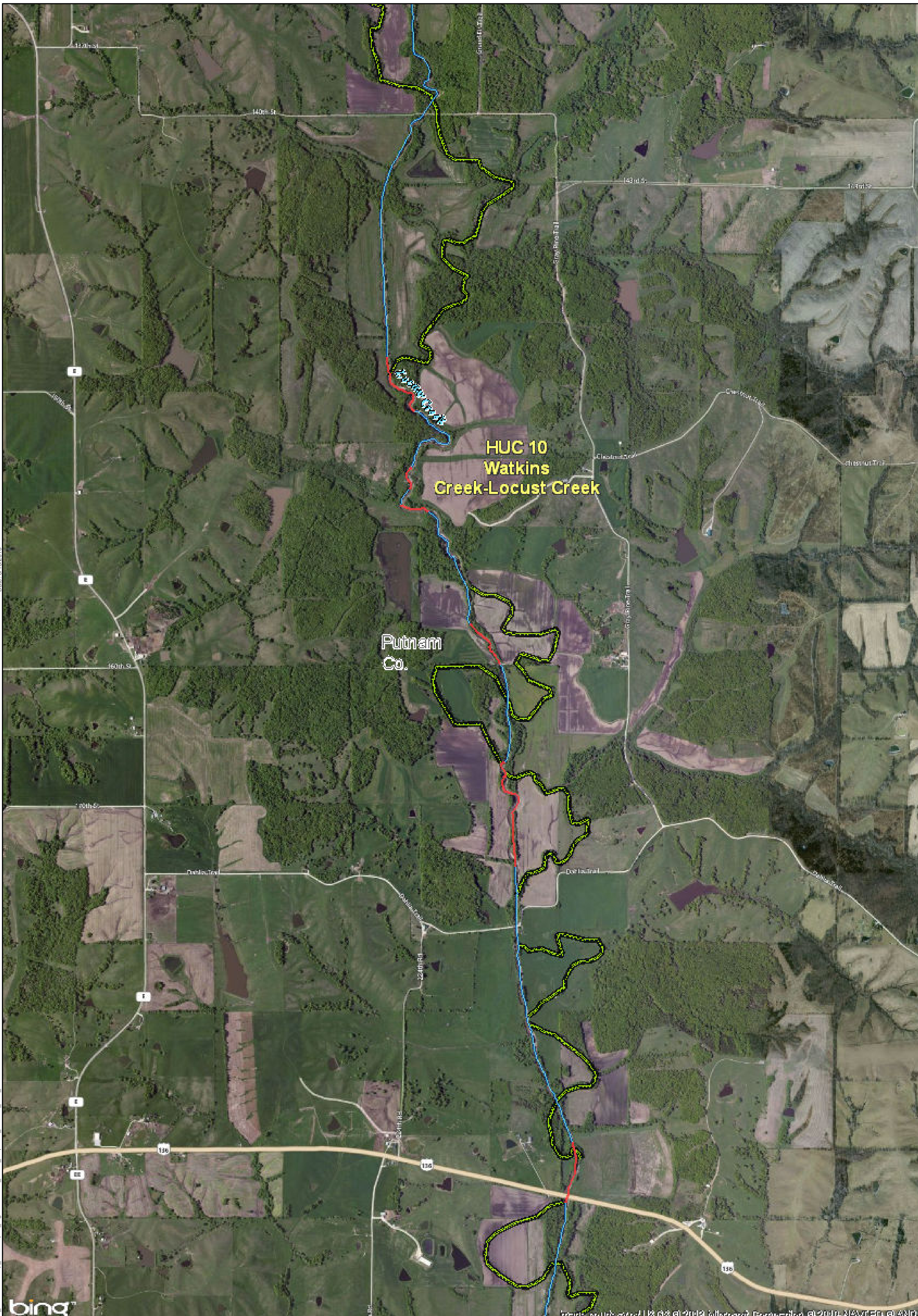
- Primary avulsion*
- Secondary avulsion*
- Constricted Channel (<60 ft)*
- Locust Creek Log Jam 404 Permit Locations
- Lower Grand HUC 8 Boundary
- Locust Creek HUC 10 Watersheds
- Breeched Levee (2010)
- Levees*

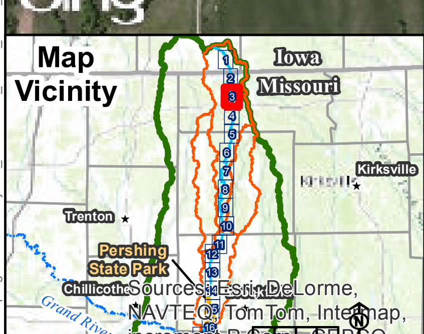
- County Boundary
- State Boundary
- MDC Land
- DNR Land

NRCS - Private Conservation Areas
- EWPP-FPE
- EWRP
- WRP

*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR

0 0.25 0.5 Miles





Historic Alignment (Approximate)*
- East Locust Creek
- Locust Creek
- West Locust Creek

Reviewed Reach*
- Eroding
- Not Visibly Eroding

- Primary avulsion*
- Secondary avulsion*
- Constricted Channel (<60 ft)*
- Locust Creek Log Jam 404 Permit Locations
- Lower Grand HUC 8 Boundary
- Locust Creek HUC 10 Watersheds
- Breeched Levee (2010)
- Levees*

- County Boundary
- State Boundary
- MDC Land
- DNR Land

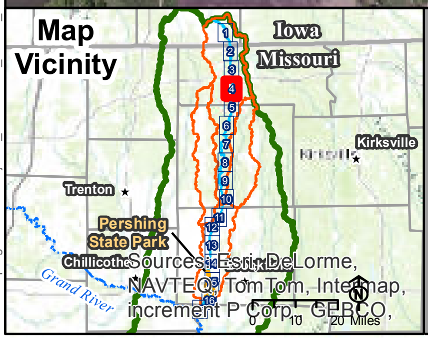
NRCS - Private Conservation Areas
- EWPP-FPE
- EWRP
- WRP

*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR

Page 3 of 17
Locust Creek

0 0.25 0.5 Miles

N



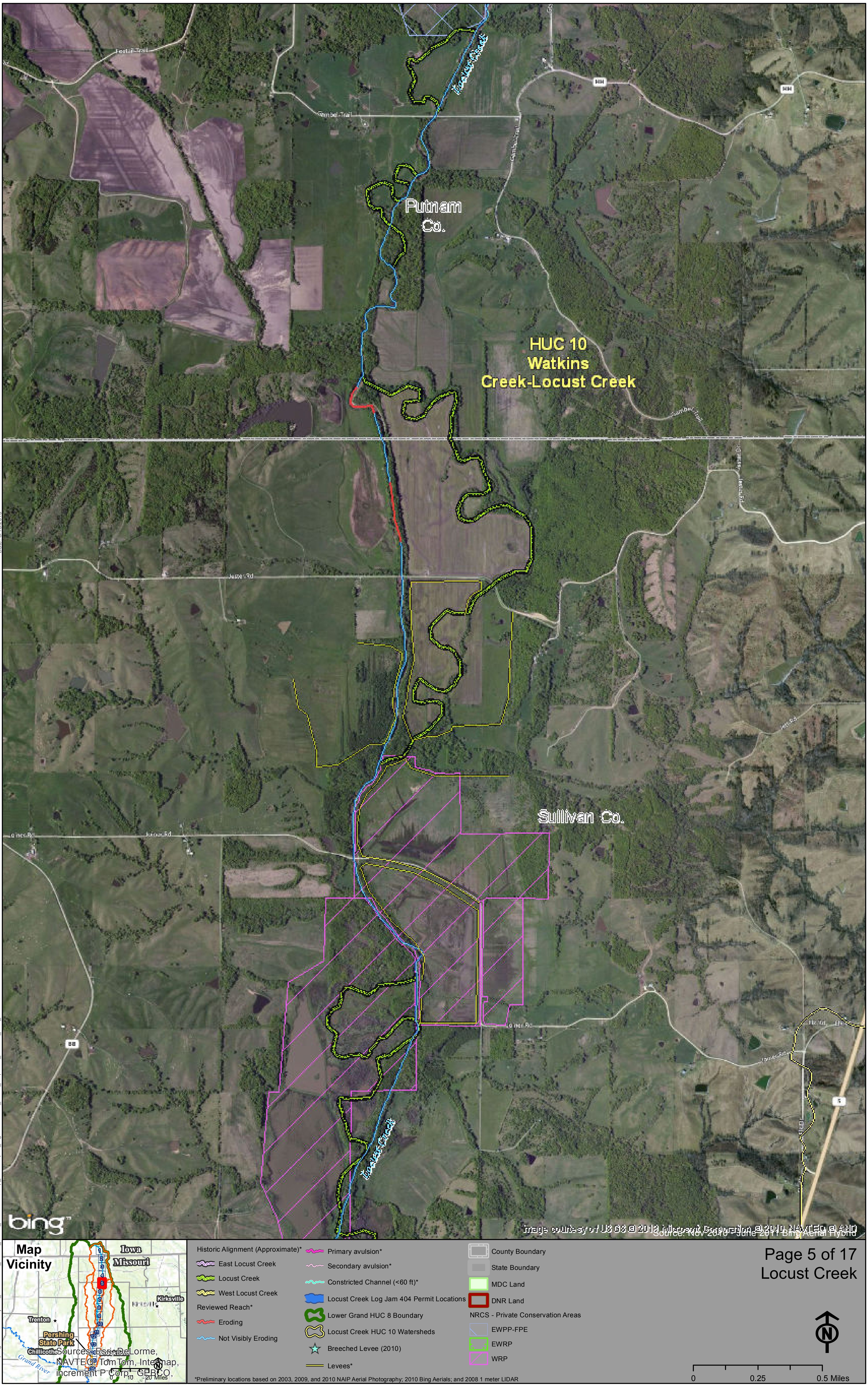
Historic Alignment (Approximate)*
East Locust Creek
Locust Creek
West Locust Creek
Reviewed Reach*
Eroding
Not Visibly Eroding
Primary avulsion*
Secondary avulsion*
Constricted Channel (<60 ft)*
Locust Creek Log Jam 404 Permit Locations
Lower Grand HUC 8 Boundary
Locust Creek HUC 10 Watersheds
Breeched Levee (2010)
Levees*
County Boundary
State Boundary
MDC Land
DNR Land
NRCS - Private Conservation Areas
EWPP-FPE
EWRP
WRP

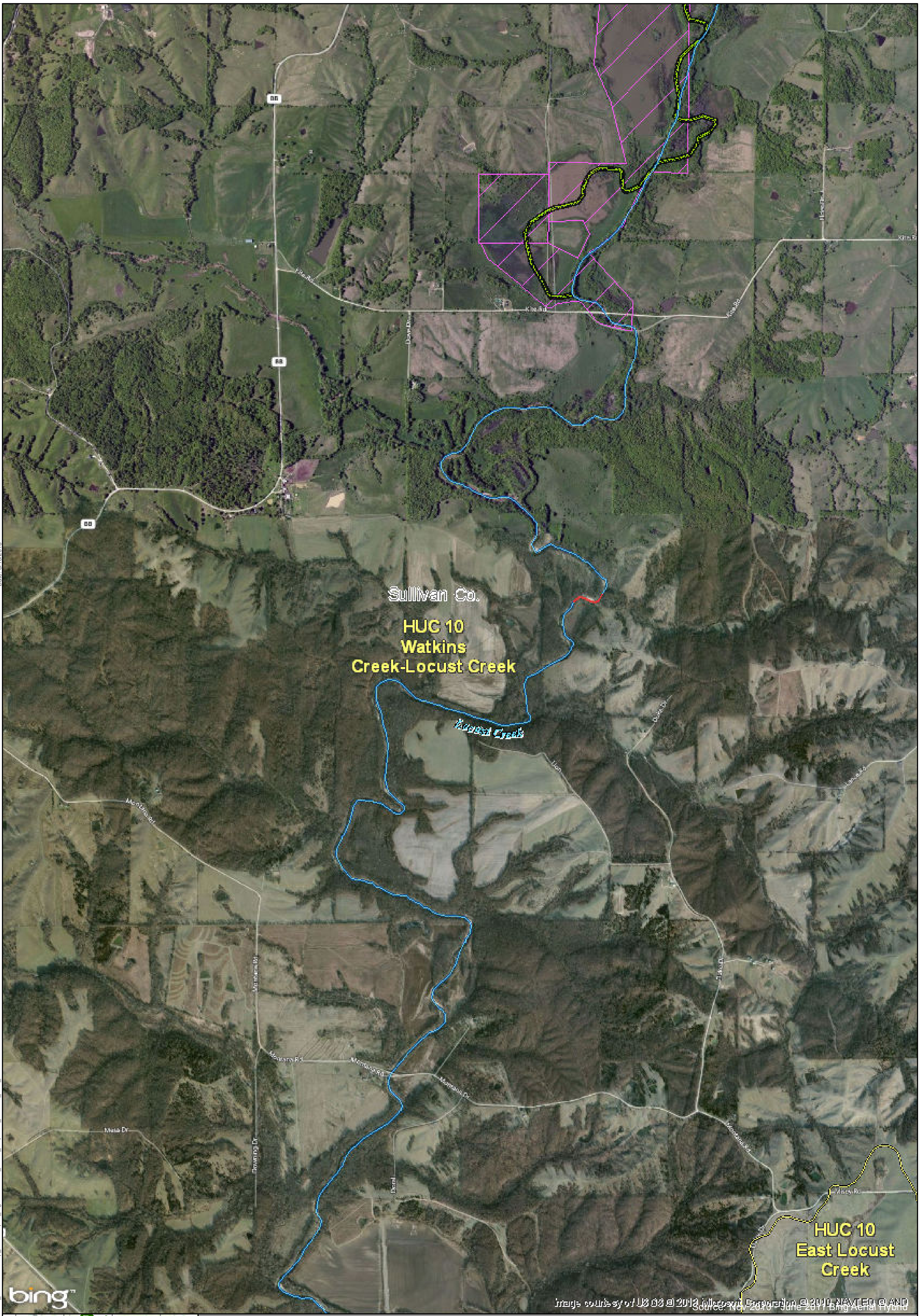
*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR

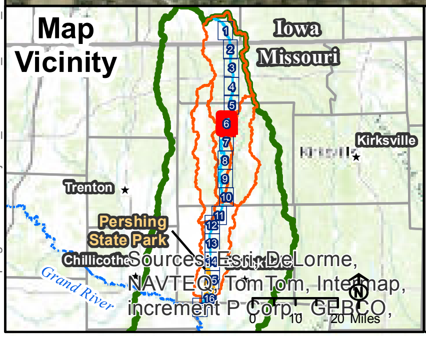
0 0.25 0.5 Miles

Page 4 of 17
Locust Creek

Date: 8/15/2013


Putnam Co.
HUC 10 Watkins Creek-Locust Creek
Sullivan Co.
Locust Creek
Jesse Rd
Map Vicinity
Iowa
Missouri
Kirksville
Trenton
Pershing State Park
Chillicothe
Grand River
Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO,
0 10 20 Miles
Historic Alignment (Approximate)*
East Locust Creek
Locust Creek
West Locust Creek
Reviewed Reach*
Eroding
Not Visibly Eroding
Primary avulsion*
Secondary avulsion*
Constricted Channel (<60 ft)*
Locust Creek Log Jam 404 Permit Locations
Lower Grand HUC 8 Boundary
Locust Creek HUC 10 Watersheds
Breeched Levee (2010)
Levees*
County Boundary
State Boundary
MDC Land
DNR Land
NRCS - Private Conservation Areas
EWPP-FPE
EWRP
WRP
*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR
Source: Nov 2010 - June 2011 Bing Aerial Hybrid
Page 5 of 17
Locust Creek
0 0.25 0.5 Miles





Historic Alignment (Approximate)*
East Locust Creek
Locust Creek
West Locust Creek
Reviewed Reach*
Eroding
Not Visibly Eroding

Primary avulsion*
Secondary avulsion*
Constricted Channel (<60 ft)*
Locust Creek Log Jam 404 Permit Locations
Lower Grand HUC 8 Boundary
Locust Creek HUC 10 Watersheds
Breeched Levee (2010)
Levees*

County Boundary
State Boundary
MDC Land
DNR Land
NRCS - Private Conservation Areas
EWPP-FPE
EWRP
WRP

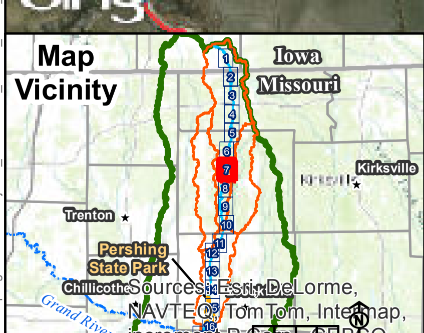
*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR

N

0 0.25 0.5 Miles

Date: 8/15/2013

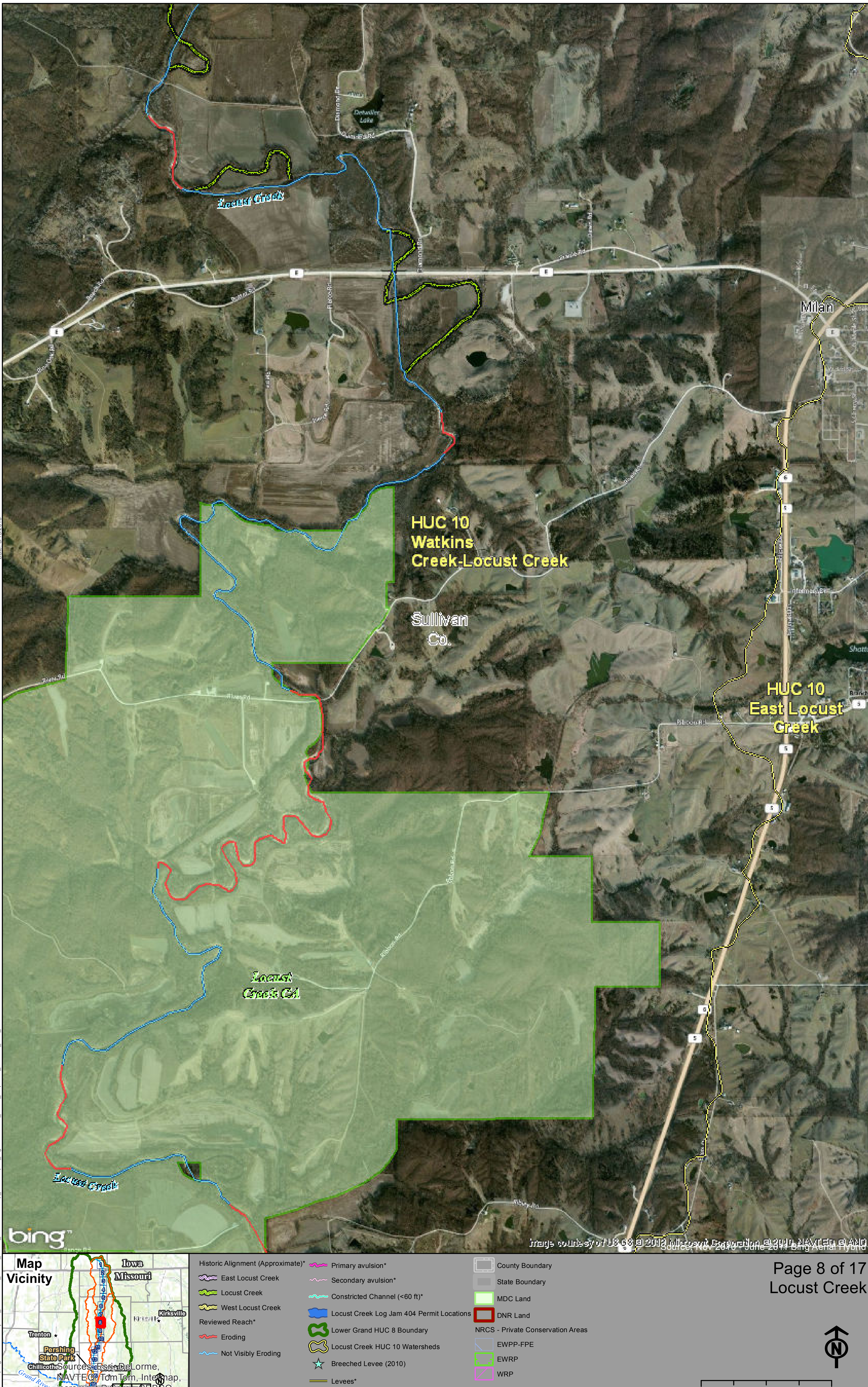
Path: \\mspe-gis-file\GISProj\133_KC171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Creek_Mapbook_11X17P_final_aerial.mxd



Historic Alignment (Approximate)*
East Locust Creek
Locust Creek
West Locust Creek
Reviewed Reach*
Eroding
Not Visibly Eroding
Primary avulsion*
Secondary avulsion*
Constricted Channel (<60 ft)*
Locust Creek Log Jam 404 Permit Locations
Lower Grand HUC 8 Boundary
Locust Creek HUC 10 Watersheds
Breeched Levee (2010)
Levees*
County Boundary
State Boundary
MDC Land
DNR Land
NRCS - Private Conservation Areas
EWPP-FPE
EWRP
WRP

*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR

0 0.25 0.5 Miles

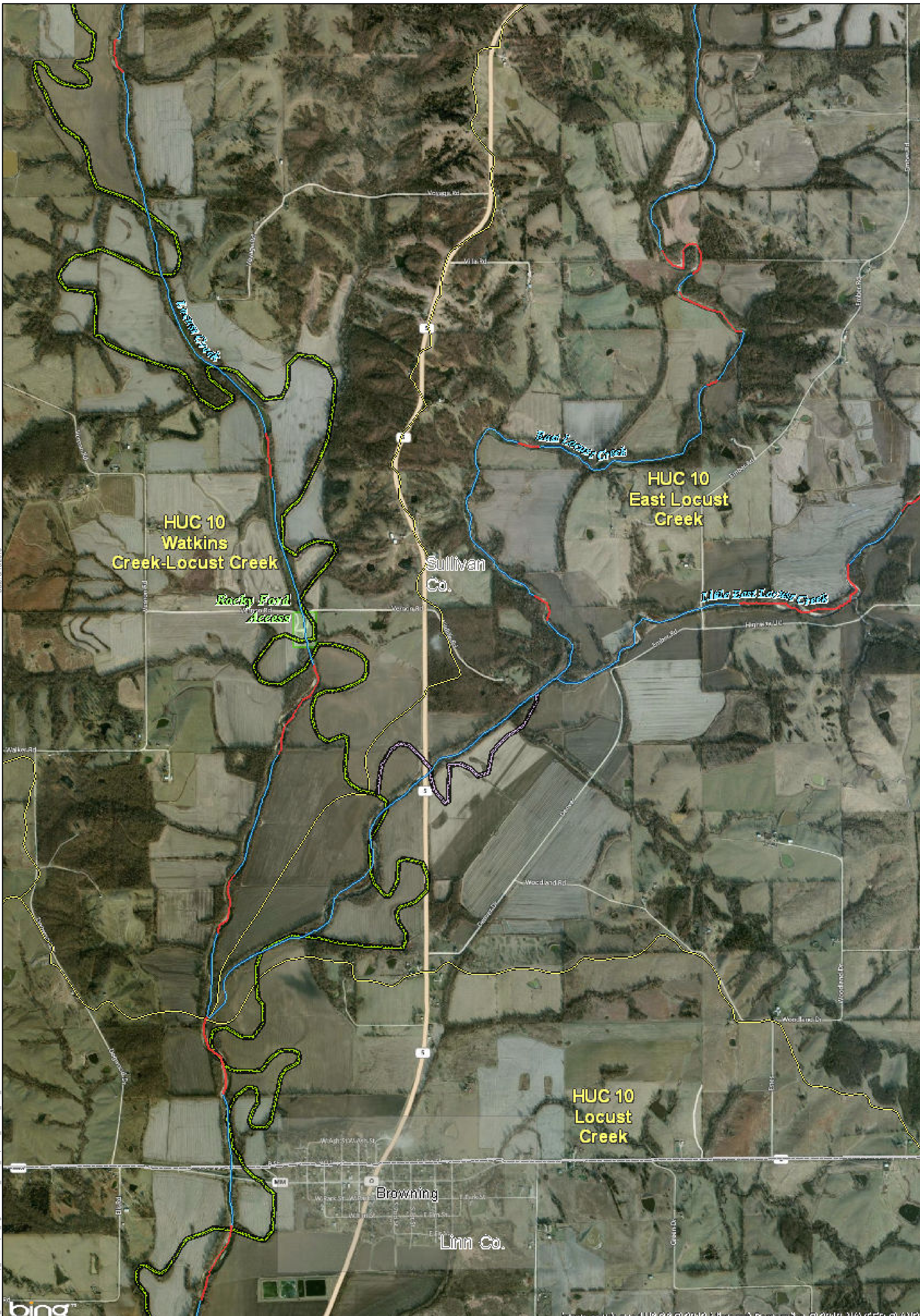


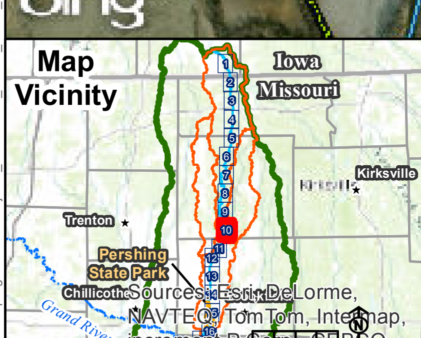
Locust Creek
HUC 10
Watkins
Creek-Locust Creek
Sullivan
Co.
Milan
HUC 10
East Locust
Creek
Locust
Creek CA
Locust Creek
Image courtesy of USGS © 2012 Microsoft Corporation © 2010 NAVTEQ © AND
Source: Nov 2010 - June 2011 Bing Aerial Hybrid
Map
Vicinity
Iowa
Missouri
Kirksville
Trenton
Pershing
State Park
Chillicothe
Grand River
Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO,
Historic Alignment (Approximate)*
East Locust Creek
Locust Creek
West Locust Creek
Reviewed Reach*
Eroding
Not Visibly Eroding
Primary avulsion*
Secondary avulsion*
Constricted Channel (<60 ft)*
Locust Creek Log Jam 404 Permit Locations
Lower Grand HUC 8 Boundary
Locust Creek HUC 10 Watersheds
Breeched Levee (2010)
Levees*
County Boundary
State Boundary
MDC Land
DNR Land
NRCS - Private Conservation Areas
EWPP-FPE
EWRP
WRP
Page 8 of 17
Locust Creek
0
0.25
0.5 Miles
*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR

*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR

Date: 8/15/2013

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Creek_Mapbook_11X17P_final_aerial.mxd





Historic Alignment (Approximate)*
- East Locust Creek
- Locust Creek
- West Locust Creek

Reviewed Reach*
- Eroding
- Not Visibly Eroding

- Primary avulsion*
- Secondary avulsion*
- Constricted Channel (<60 ft)*
- Locust Creek Log Jam 404 Permit Locations
- Lower Grand HUC 8 Boundary
- Locust Creek HUC 10 Watersheds
- Breeched Levee (2010)
- Levees*

- County Boundary
- State Boundary
- MDC Land
- DNR Land

NRCS - Private Conservation Areas
- EWPP-FPE
- EWRP
- WRP

*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR

Locust Creek

N

0 0.25 0.5 Miles

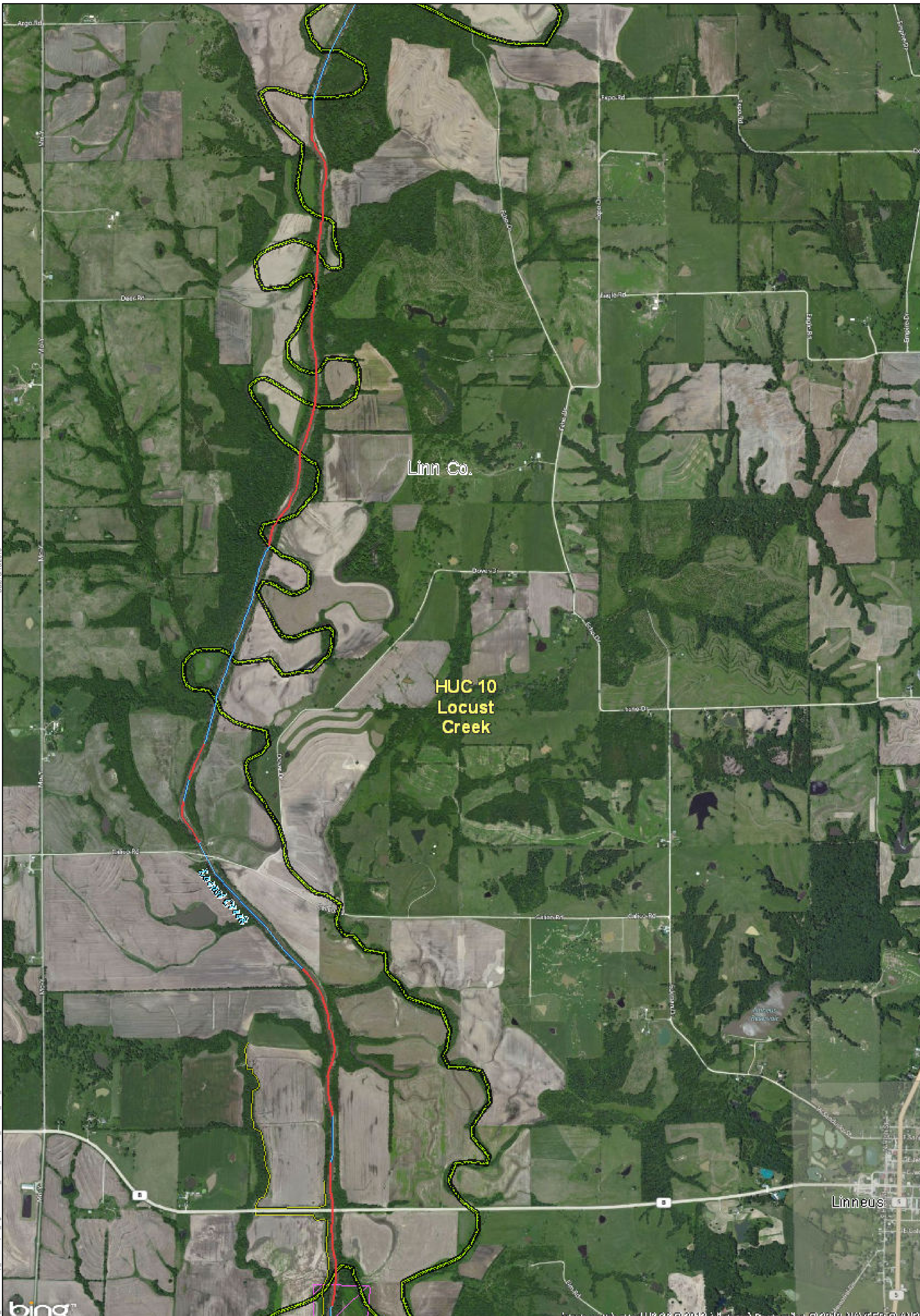
Date: 8/15/2013

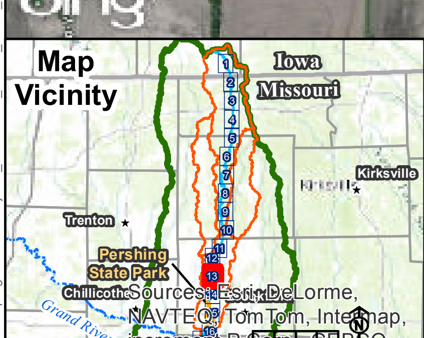
Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Creek_Mapbook_11X17P_final_aerial.mxd

Date: 8/15/2013

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Creek_Mapbook_11X17P_final_aerial.mxd


HUC 10
West Locust
Creek
HUC 10
Locust
Creek
Linn Co.
West Locust Creek
Locust Creek
Daisy Rd
Dill Rd
Cotton Rd
Brook Rd
Argo Rd
Eagle Rd
Easton Rd
Elder Rd
Iowa Rd
Expo Rd
3
5
Image courtesy of USGS © 2010 Microsoft Corporation © 2010 NAVTEQ © AND
Source: Nov 2010 - June 2011 Bing Aerial Hybrid
Map Vicinity
Iowa
Missouri
Kirksville
Trenton
Pershing State Park
Chillicothe
Grand River
Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO
0 10 20 Miles
Historic Alignment (Approximate)*
East Locust Creek
Locust Creek
West Locust Creek
Reviewed Reach*
Eroding
Not Visibly Eroding
Primary avulsion*
Secondary avulsion*
Constricted Channel (<60 ft)*
Locust Creek Log Jam 404 Permit Locations
Lower Grand HUC 8 Boundary
Locust Creek HUC 10 Watersheds
Breeched Levee (2010)
Levees*
County Boundary
State Boundary
MDC Land
DNR Land
NRCS - Private Conservation Areas
EWPP-FPE
EWRP
WRP
Page 12 of 17
Locust Creek
0 0.25 0.5 Miles
*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR
Date: 8/15/2013





Historic Alignment (Approximate)*
- East Locust Creek
- Locust Creek
- West Locust Creek

Reviewed Reach*
- Eroding
- Not Visibly Eroding

- Primary avulsion*
- Secondary avulsion*
- Constricted Channel (<60 ft)*
- Locust Creek Log Jam 404 Permit Locations
- Lower Grand HUC 8 Boundary
- Locust Creek HUC 10 Watersheds
- Breeched Levee (2010)
- Levees*

- County Boundary
- State Boundary
- MDC Land
- DNR Land

NRCS - Private Conservation Areas
- EWPP-FPE
- EWRP
- WRP

*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR

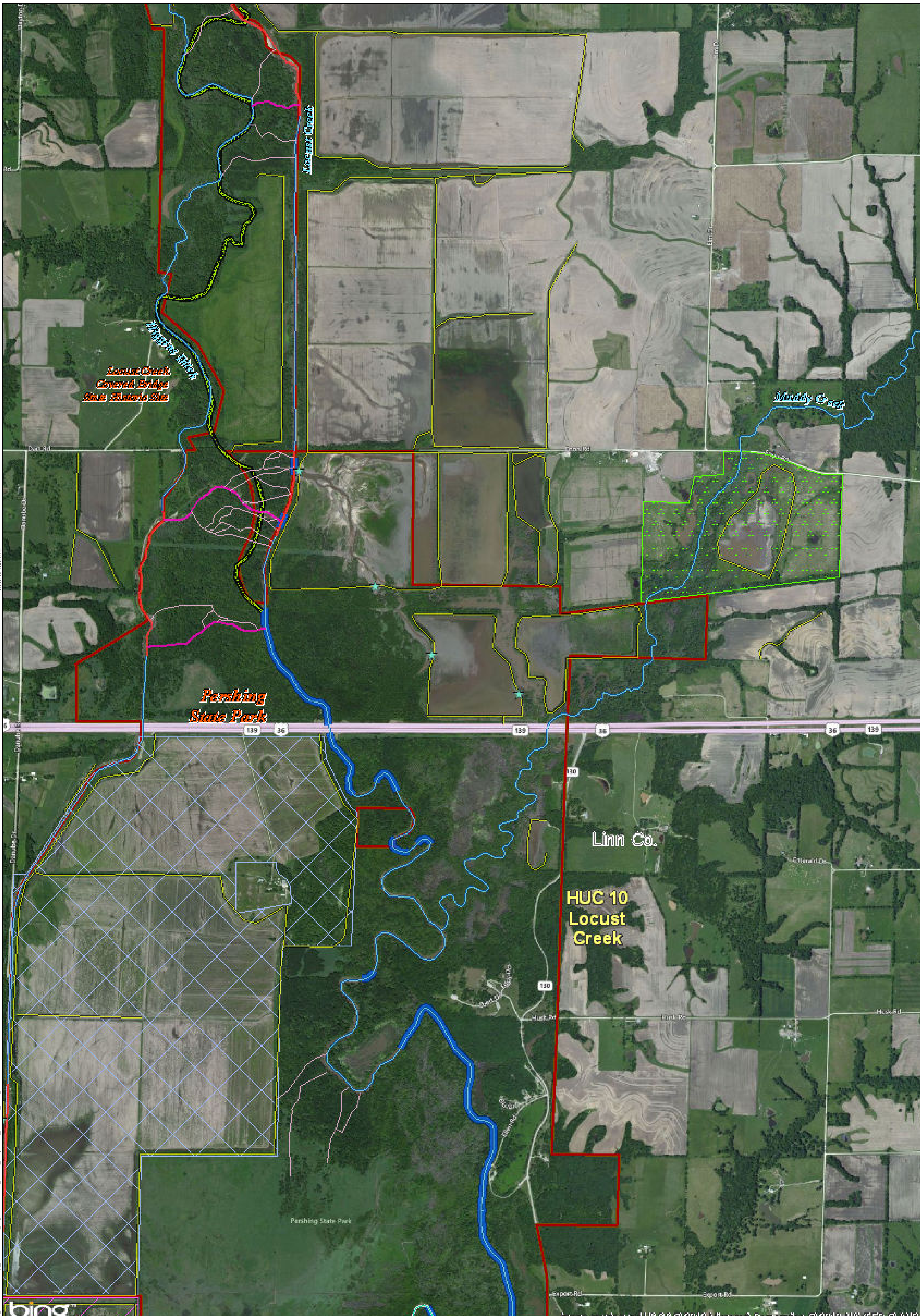
0 0.25 0.5 Miles

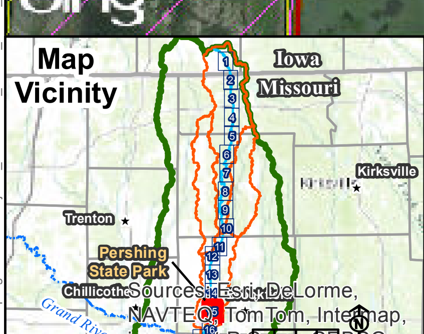
Date: 8/15/2013

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Creek_Mapbook_11X17P_final_aerial.mxd

Date: 8/15/2013

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Creek_Mapbook_11X17P_final_aerial.mxd





Historic Alignment (Approximate)*
East Locust Creek
Locust Creek
West Locust Creek
Reviewed Reach*
Eroding
Not Visibly Eroding

Primary avulsion*
Secondary avulsion*
Constricted Channel (<60 ft)*
Locust Creek Log Jam 404 Permit Locations
Lower Grand HUC 8 Boundary
Locust Creek HUC 10 Watersheds
Breeched Levee (2010)
Levees*

County Boundary
State Boundary
MDC Land
DNR Land
NRCS - Private Conservation Areas
EWPP-FPE
EWRP
WRP

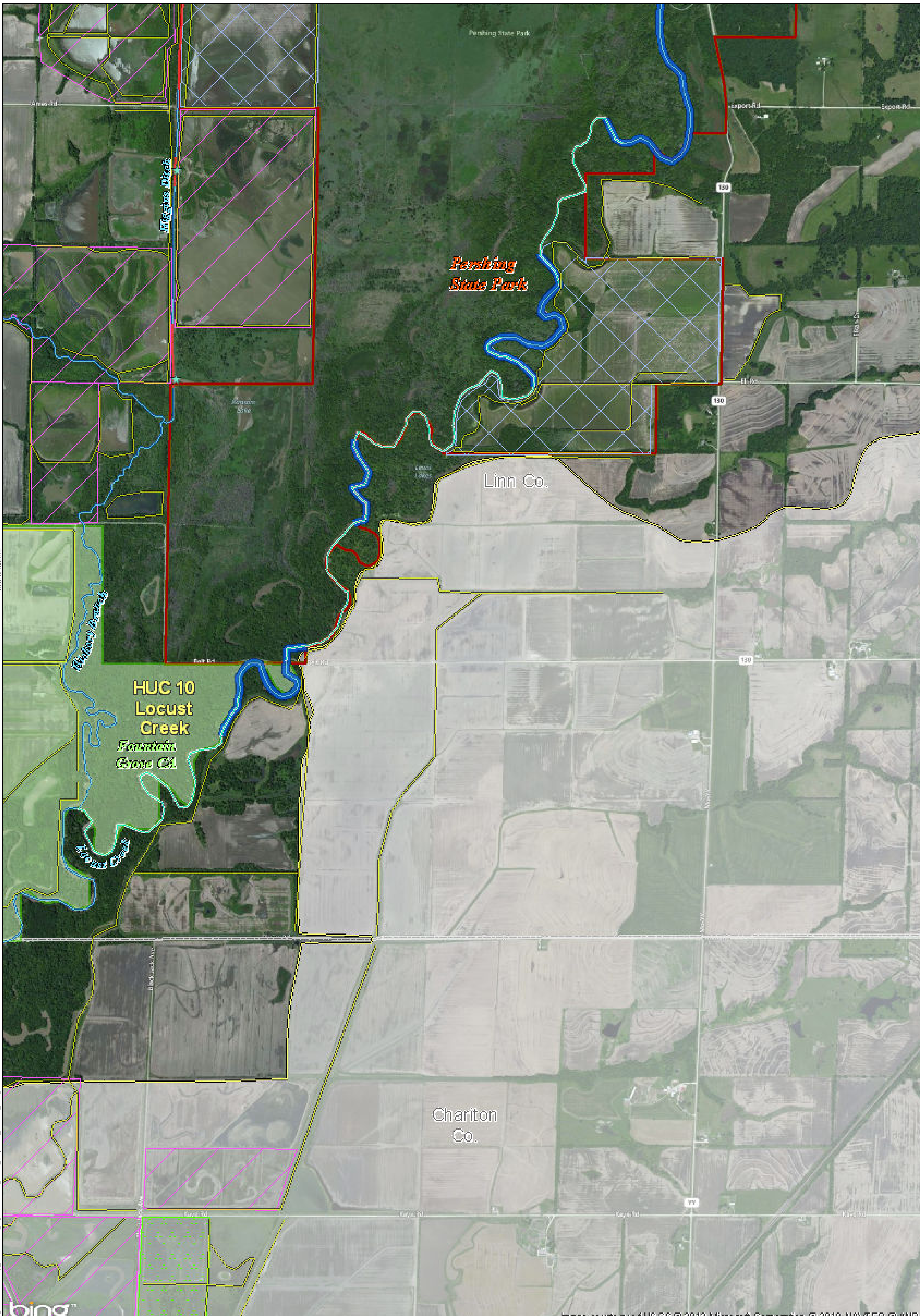
*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR

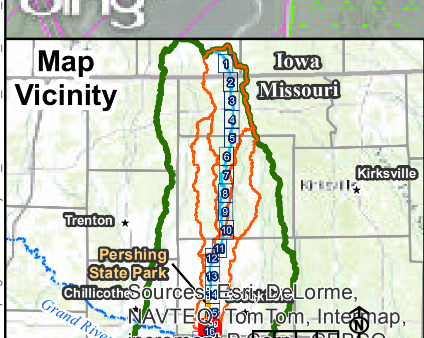
Page 15 of 17
Locust Creek

0 0.25 0.5 Miles

Date: 8/15/2013

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Creek_Mapbook_11X17P_final_aerial.mxd





Historic Alignment (Approximate)*
East Locust Creek
Locust Creek
West Locust Creek
Reviewed Reach*
Eroding
Not Visibly Eroding

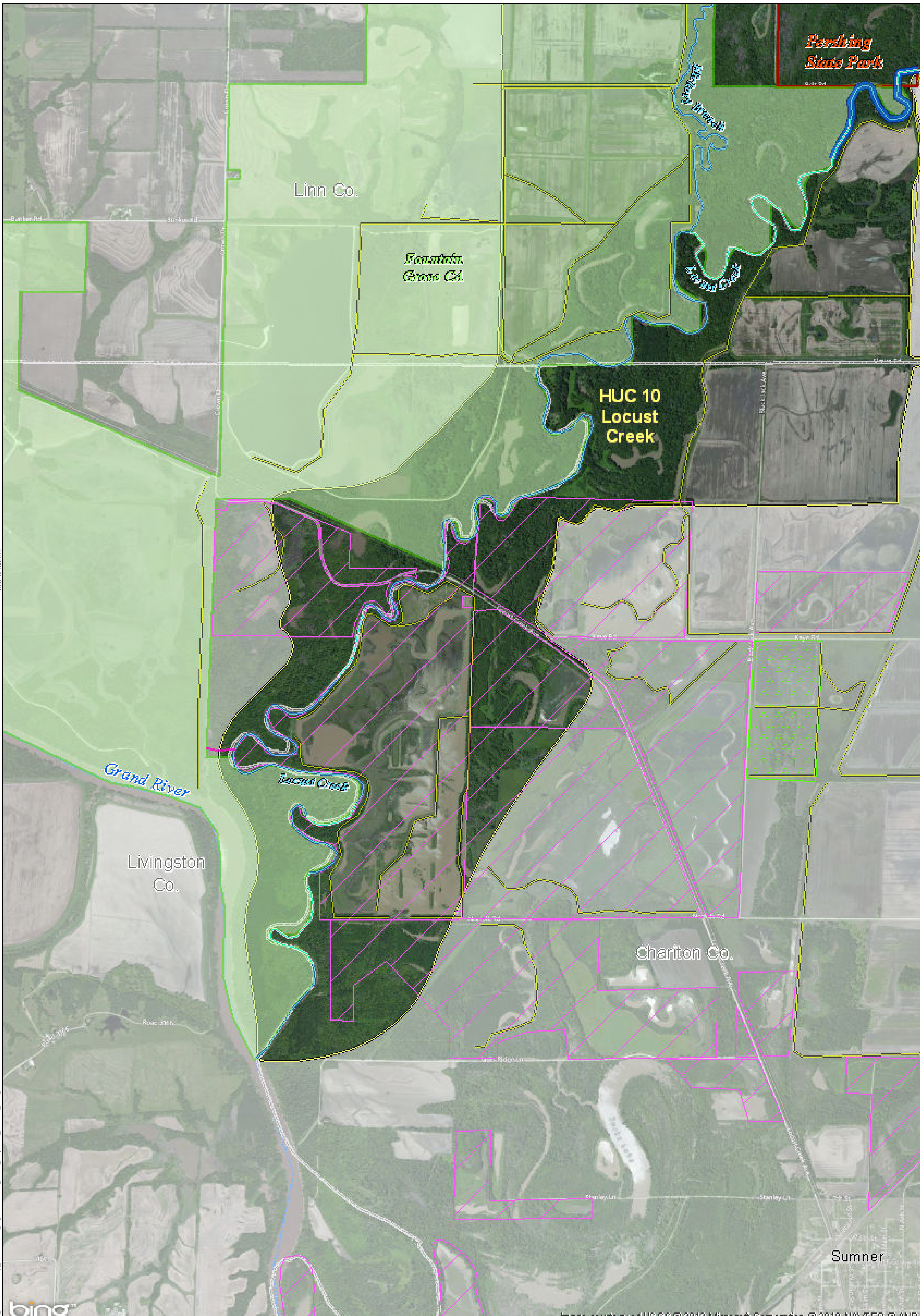
Primary avulsion*
Secondary avulsion*
Constricted Channel (<60 ft)*
Locust Creek Log Jam 404 Permit Locations
Lower Grand HUC 8 Boundary
Locust Creek HUC 10 Watersheds
Breeched Levee (2010)
Levees*

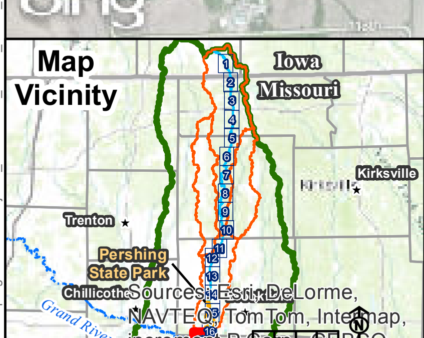
County Boundary
State Boundary
MDC Land
DNR Land
NRCS - Private Conservation Areas
EWPP-FPE
EWRP
WRP

*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR

0 0.25 0.5 Miles

Date: 8/15/2013
Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Creek_Mapbook_11X17P_final_aerial.mxd





Historic Alignment (Approximate)*
East Locust Creek
Locust Creek
West Locust Creek
Reviewed Reach*
Eroding
Not Visibly Eroding

Primary avulsion*
Secondary avulsion*
Constricted Channel (<60 ft)*
Locust Creek Log Jam 404 Permit Locations
Lower Grand HUC 8 Boundary
Locust Creek HUC 10 Watersheds
Breeched Levee (2010)
Levees*

County Boundary
State Boundary
MDC Land
DNR Land
NRCS - Private Conservation Areas
EWPP-FPE
EWRP
WRP

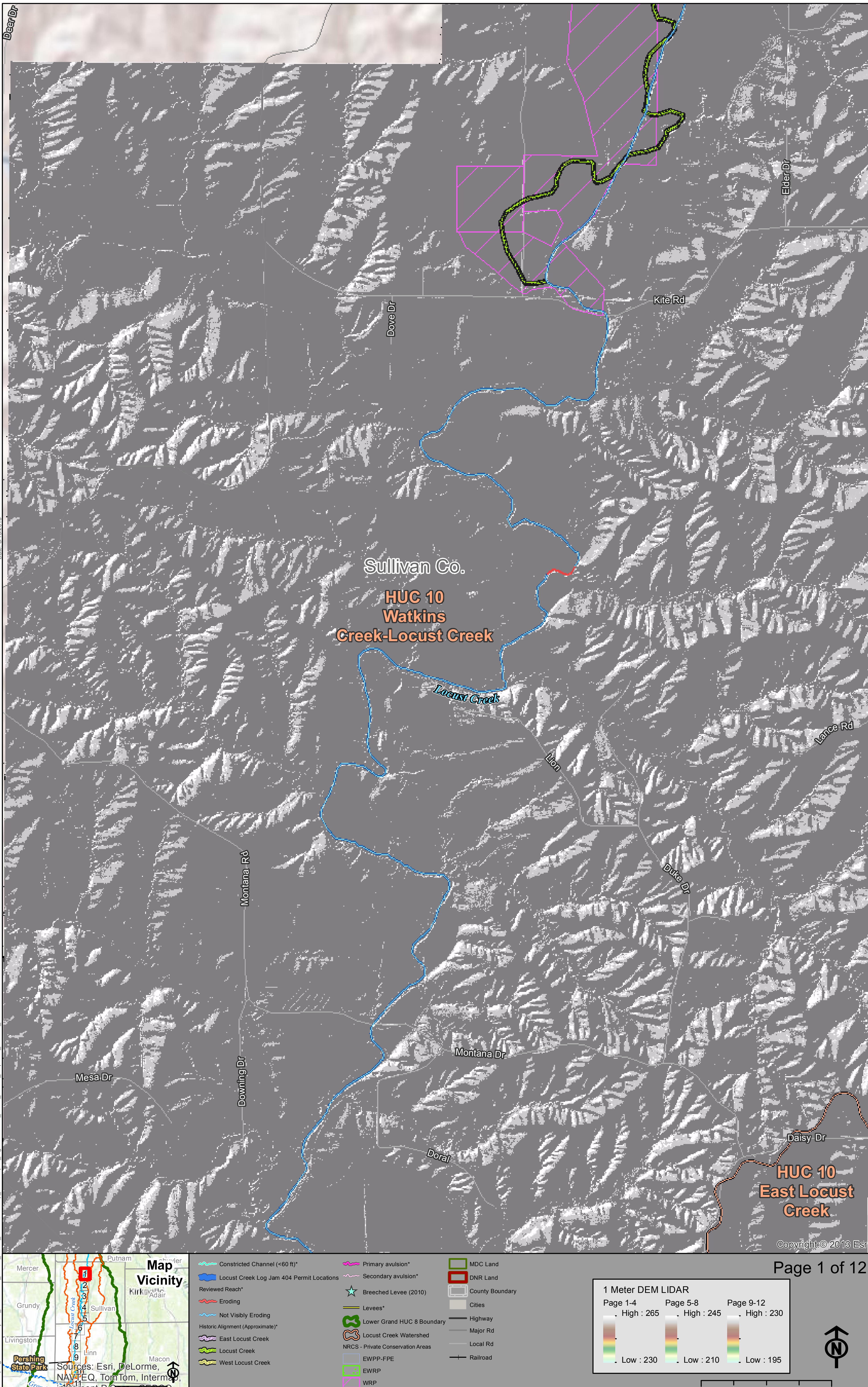
*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR

Page 17 of 17
Locust Creek

0 0.25 0.5 Miles

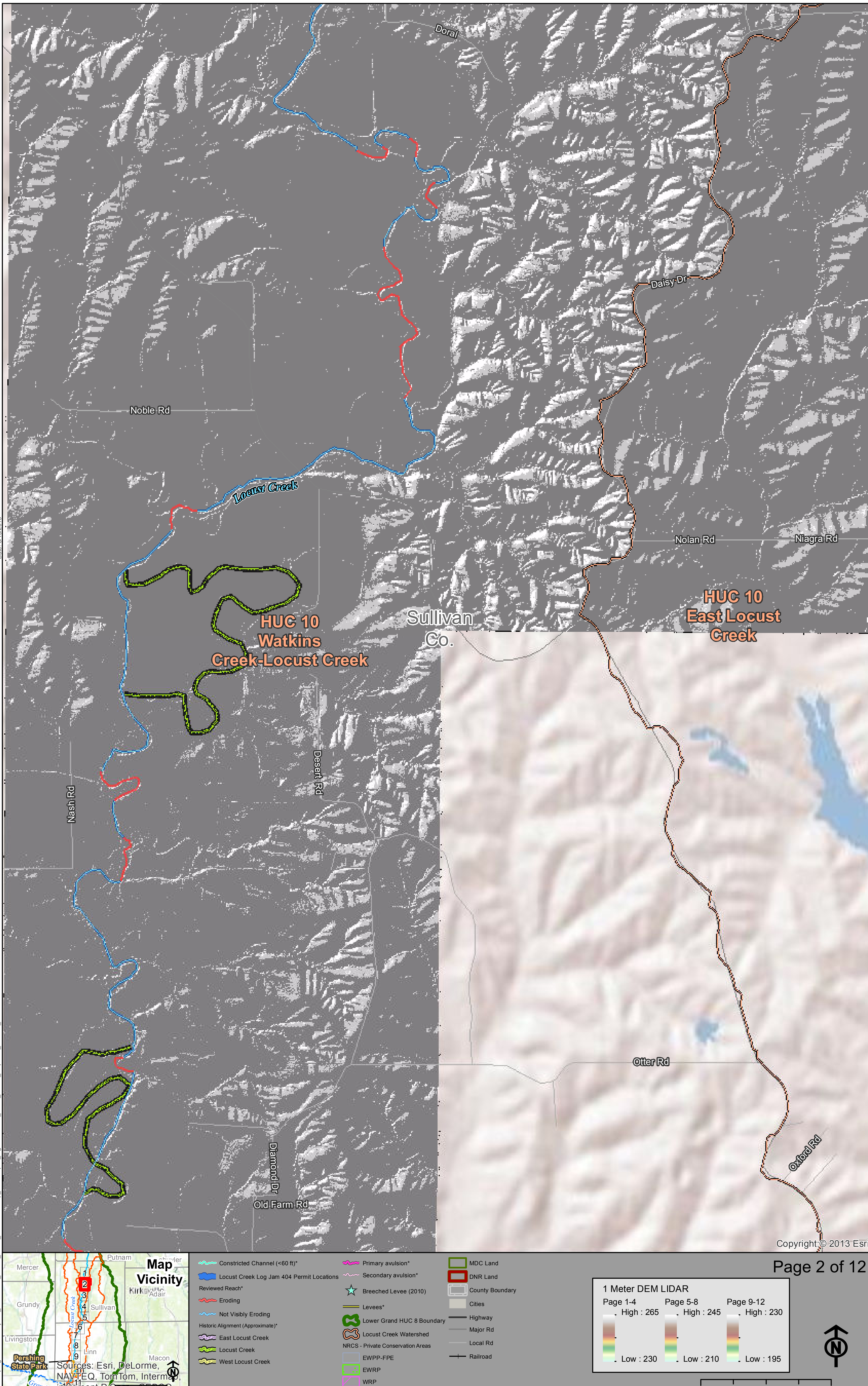
Date: 8/15/2013

Path: \\mspe-gis-file\GIS\Proj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Creek_Mapbook_11X17P_final_aerial.mxd

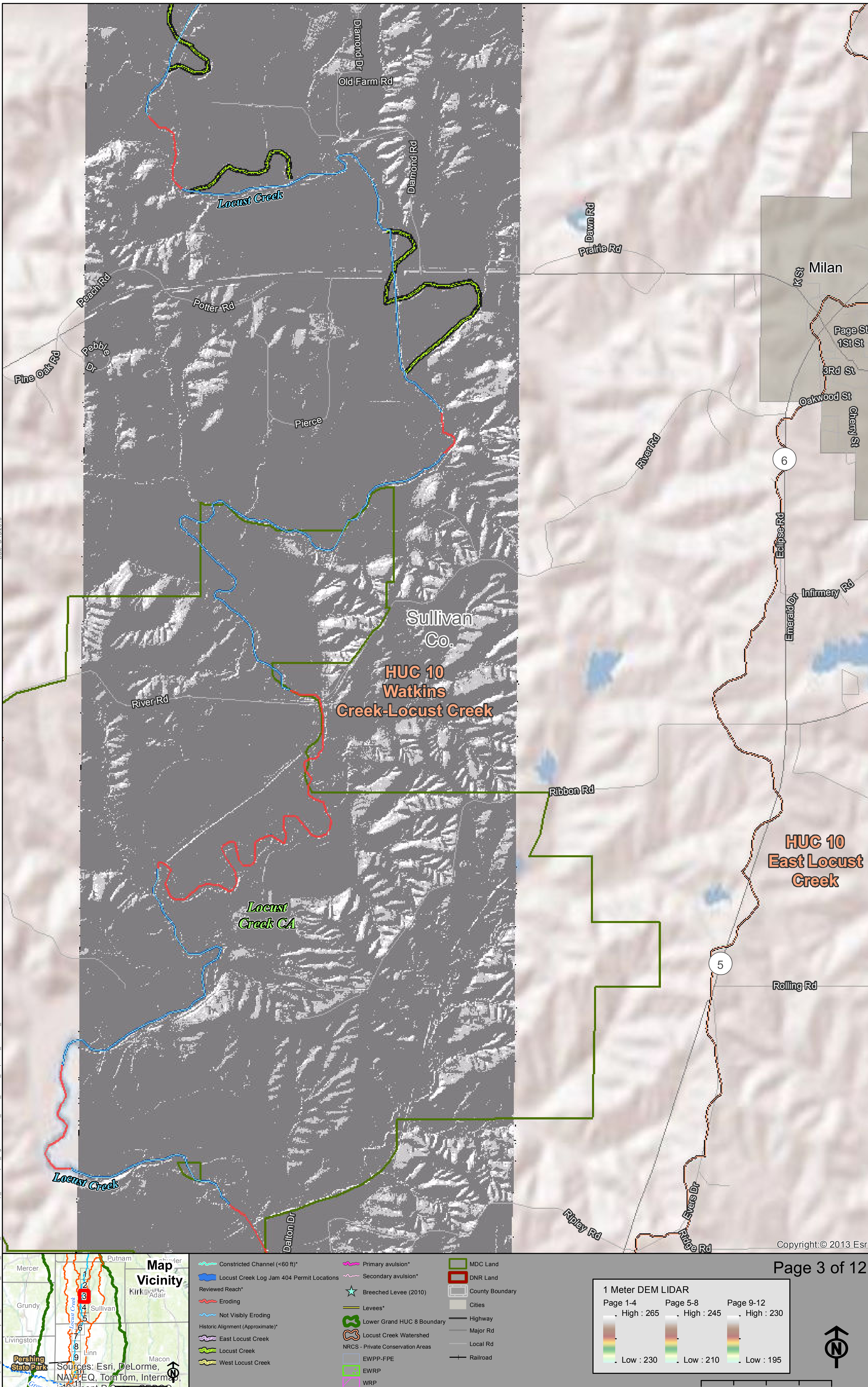


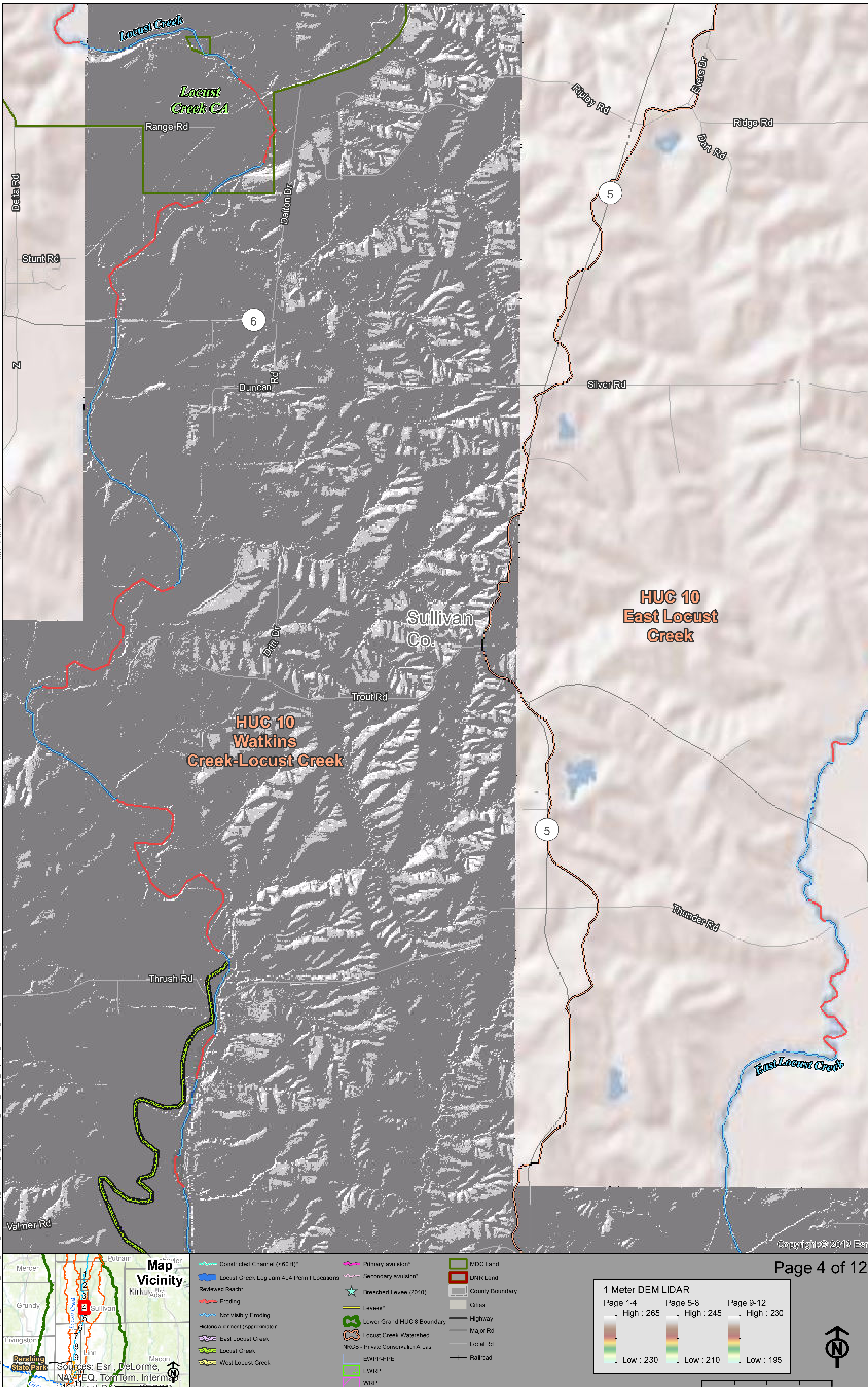
Date: 8/15/2013

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Creek_LIDAR_Mapbook_11X17P_final.mxd



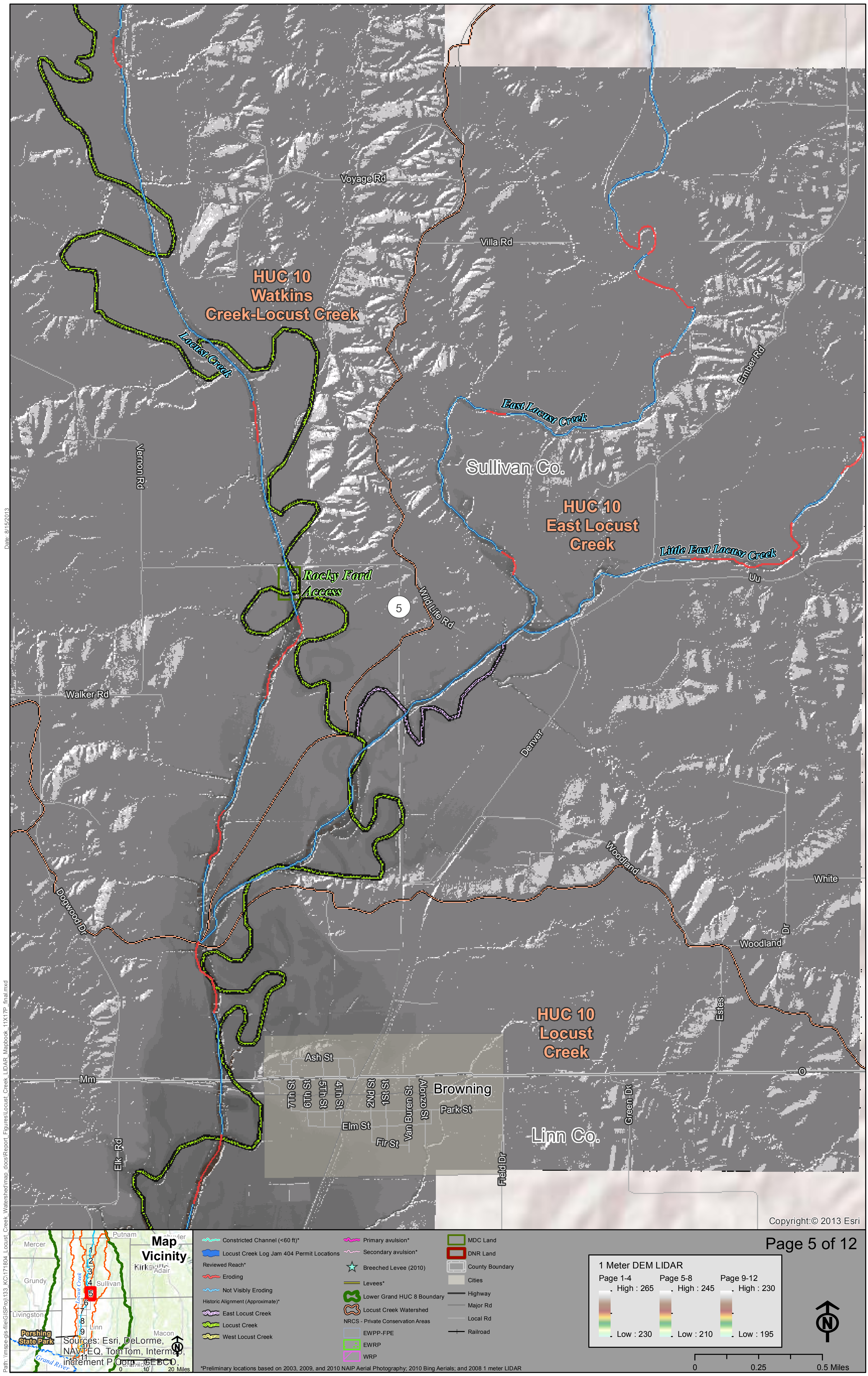
Doral
Daisy Dr
Noble Rd
Locust Creek
Nolan Rd
Niagra Rd
HUC 10 East Locust Creek
HUC 10 Watkins Creek-Locust Creek
Sullivan Co.
Desert Rd
Nash Rd
Otter Rd
Oxford Rd
Diamond Dr
Old Farm Rd
Copyright:© 2013 Esri
Map Vicinity
Mercer
Putnam
Grundy
Sullivan
Livingston
Linn
Macon
Pershing State Park
Grand River
Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO
Constricted Channel (<60 ft)*
Locust Creek Log Jam 404 Permit Locations
Reviewed Reach*
Eroding
Not Visibly Eroding
Historic Alignment (Approximate)*
East Locust Creek
Locust Creek
West Locust Creek
Primary avulsion*
Secondary avulsion*
Breeched Levee (2010)
Levees*
Lower Grand HUC 8 Boundary
Locust Creek Watershed
NRCS - Private Conservation Areas
EWPP-FPE
EWRP
WRP
MDC Land
DNR Land
County Boundary
Cities
Highway
Major Rd
Local Rd
Railroad
*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR
Page 2 of 12
1 Meter DEM LIDAR
Page 1-4
High : 265
Low : 230
Page 5-8
High : 245
Low : 210
Page 9-12
High : 230
Low : 195
0
0.25
0.5 Miles
N


Diamond Dr
Old Farm Rd
Diamond Rd
Locust Creek
Dawn Rd
Prairie Rd
Milan
K St
Peach Rd
Potter Rd
Page St
1St St
Pebble Dr
Pine Oak Rd
3Rd St
Oakwood St
Cherry St
Pierce
River Rd
6
Eclipse Rd
Infirmery Rd
Emerald Dr
Sullivan Co.
HUC 10 Watkins Creek-Locust Creek
River Rd
Ribbon Rd
HUC 10 East Locust Creek
Locust Creek CA
5
Rolling Rd
Locust Creek
Evers Dr
Dalton Dr
Ripley Rd
Ridge Rd
Copyright:© 2013 Esri
Date: 8/15/2013
Map Vicinity
Mercer
Putnam
Schuyler
Grundy
Sullivan
Adair
Livingston
Linn
Macon
Pershing State Park
Grand River
Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO
0 10 20 Miles
Constricted Channel (<60 ft)*
Locust Creek Log Jam 404 Permit Locations
Reviewed Reach*
Eroding
Not Visibly Eroding
Historic Alignment (Approximate)*
East Locust Creek
Locust Creek
West Locust Creek
Primary avulsion*
Secondary avulsion*
Breached Levee (2010)
Levees*
Lower Grand HUC 8 Boundary
Locust Creek Watershed
NRCS - Private Conservation Areas
EWPP-FPE
EWRP
WRP
MDC Land
DNR Land
County Boundary
Cities
Highway
Major Rd
Local Rd
Railroad
*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR
Page 3 of 12
1 Meter DEM LIDAR
Page 1-4
High : 265
Low : 230
Page 5-8
High : 245
Low : 210
Page 9-12
High : 230
Low : 195
0 0.25 0.5 Miles
N

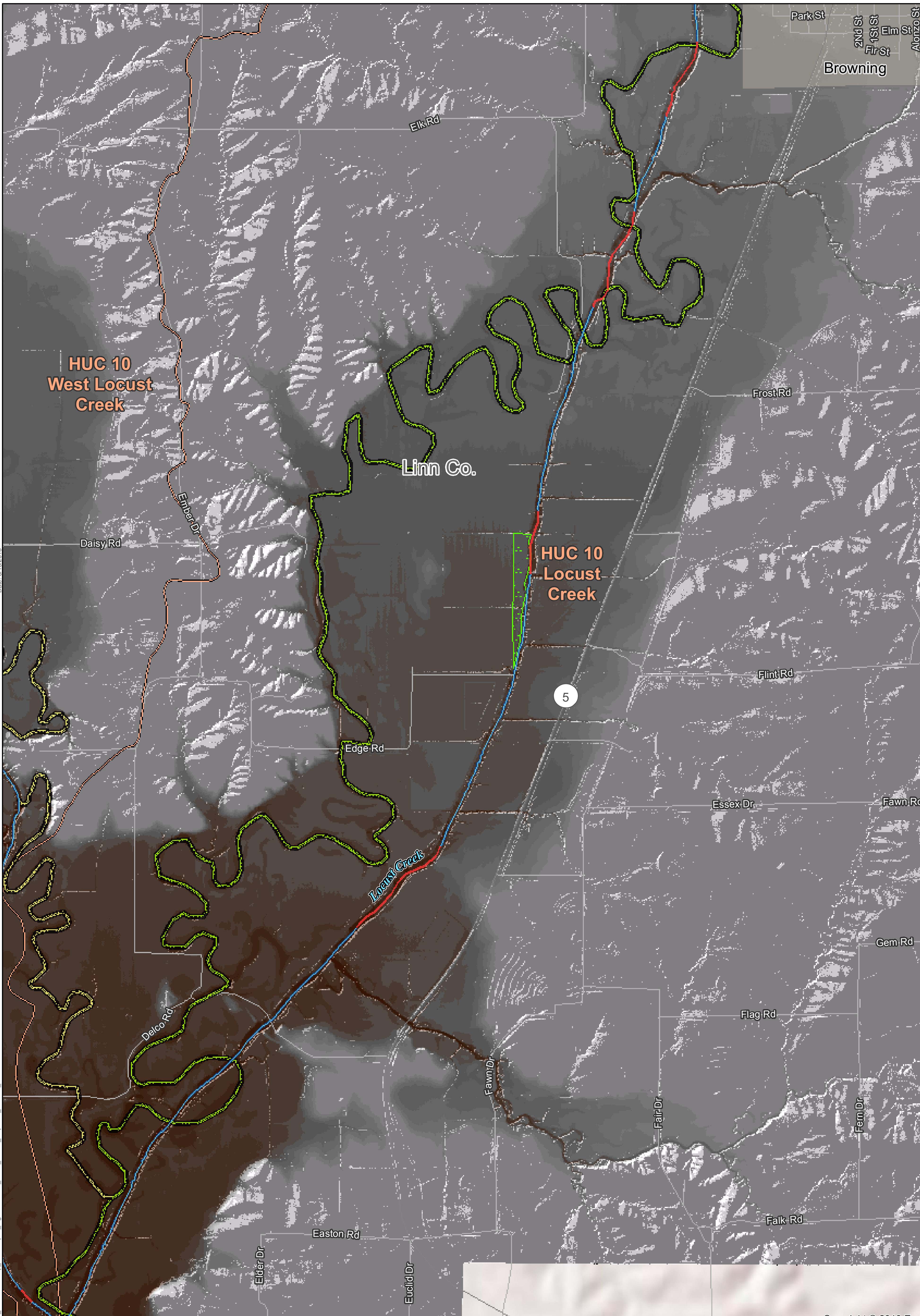


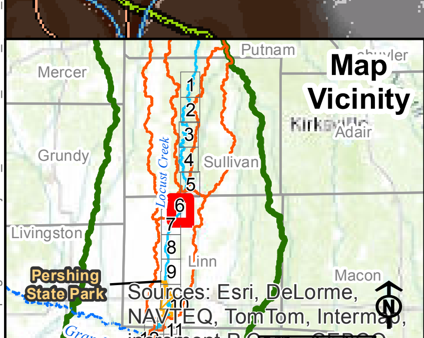
Date: 8/15/2013

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Creek_LIDAR_Mapbook_11X17P_final.mxd



HUC 10
Watkins
Creek-Locust Creek
Locust Creek
Voyage Rd
Villa Rd
Vernon Rd
Rocky Ford
Access
5
Wild Life Rd
East Locust Creek
Sullivan Co.
HUC 10
East Locust
Creek
Little East Locust Creek
Ember Rd
Uu
Walker Rd
Denver
Woodland
White
Woodland
Dr
Dogwood Dr
Estes
HUC 10
Locust
Creek
Ash St
7Th St
6Th St
5Th St
4Th St
2Nd St
1St St
Van Buren St
Alonzo St
Browning
Park St
Elm St
Fir St
Mm
O
Green Dr
Linn Co.
Elk Rd
Field Dr
Copyright:© 2013 Esri
Date: 8/15/2013
Map
Vicinity
Putnam
Mercer
Grundy
Sullivan
Adair
Livingston
Linn
Macon
Pershing
State Park
Grand River
Locust Creek
Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO,
0
10
20 Miles
Constricted Channel (<60 ft)*
Locust Creek Log Jam 404 Permit Locations
Reviewed Reach*
Eroding
Not Visibly Eroding
Historic Alignment (Approximate)*
East Locust Creek
Locust Creek
West Locust Creek
Primary avulsion*
Secondary avulsion*
Breeched Levee (2010)
Levees*
Lower Grand HUC 8 Boundary
Locust Creek Watershed
NRCS - Private Conservation Areas
EWPP-FPE
EWRP
WRP
MDC Land
DNR Land
County Boundary
Cities
Highway
Major Rd
Local Rd
Railroad
*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR
Page 5 of 12
1 Meter DEM LIDAR
Page 1-4
High : 265
Low : 230
Page 5-8
High : 245
Low : 210
Page 9-12
High : 230
Low : 195
0
0.25
0.5 Miles
Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Creek_LIDAR_Mapbook_11X17P_final.mxd





- Constricted Channel (<60 ft)*
- Locust Creek Log Jam 404 Permit Locations

Reviewed Reach*

- Eroding
- Not Visibly Eroding

Historic Alignment (Approximate)*

- East Locust Creek
- Locust Creek
- West Locust Creek
- Primary avulsion*
- Secondary avulsion*
- Breeched Levee (2010)
- Levees*
- Lower Grand HUC 8 Boundary
- Locust Creek Watershed

NRCS - Private Conservation Areas

- EWPP-FPE
- EWRP
- WRP
- MDC Land
- DNR Land
- County Boundary
- Cities
- Highway
- Major Rd
- Local Rd
- Railroad

*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR

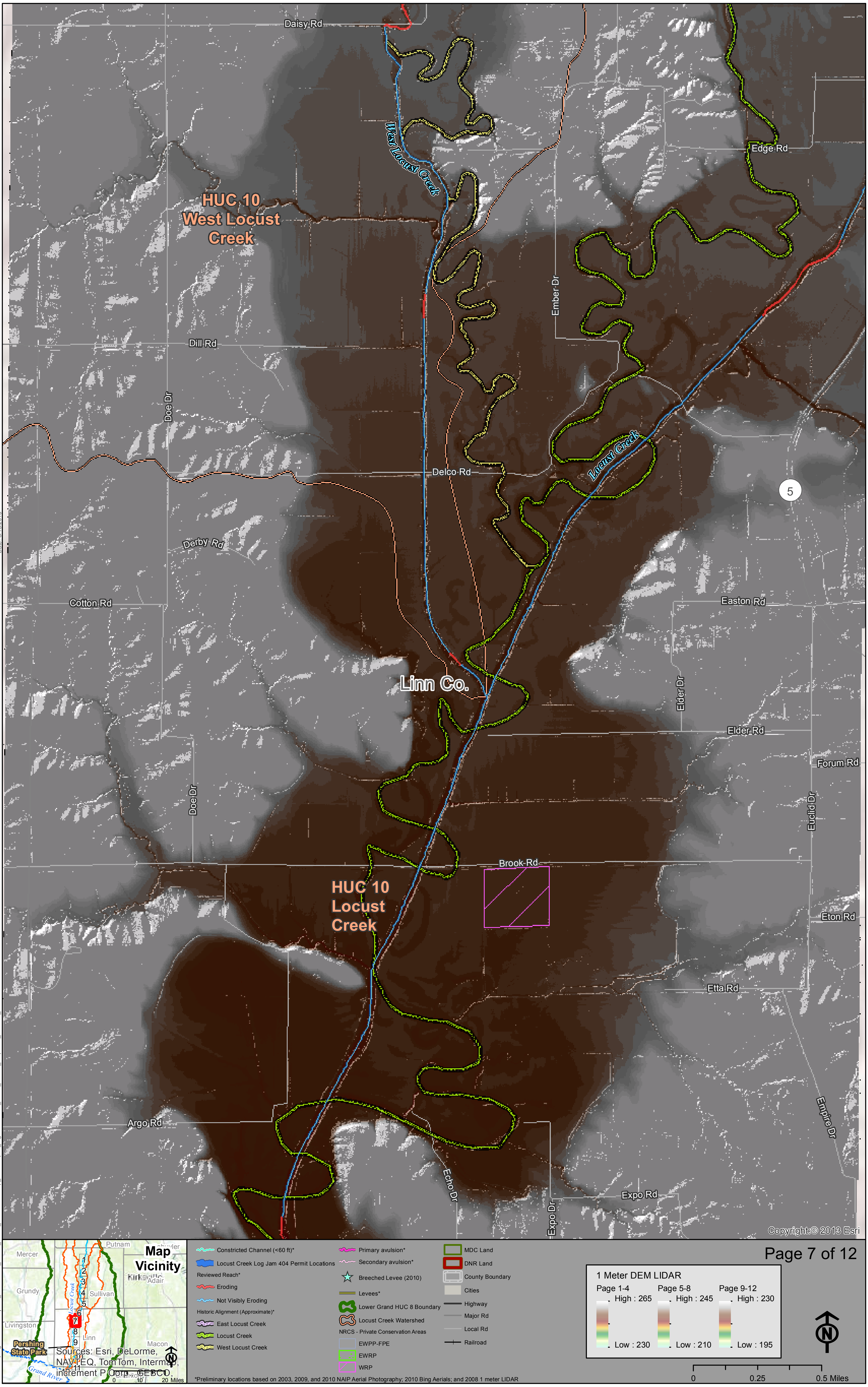
1 Meter DEM LIDAR

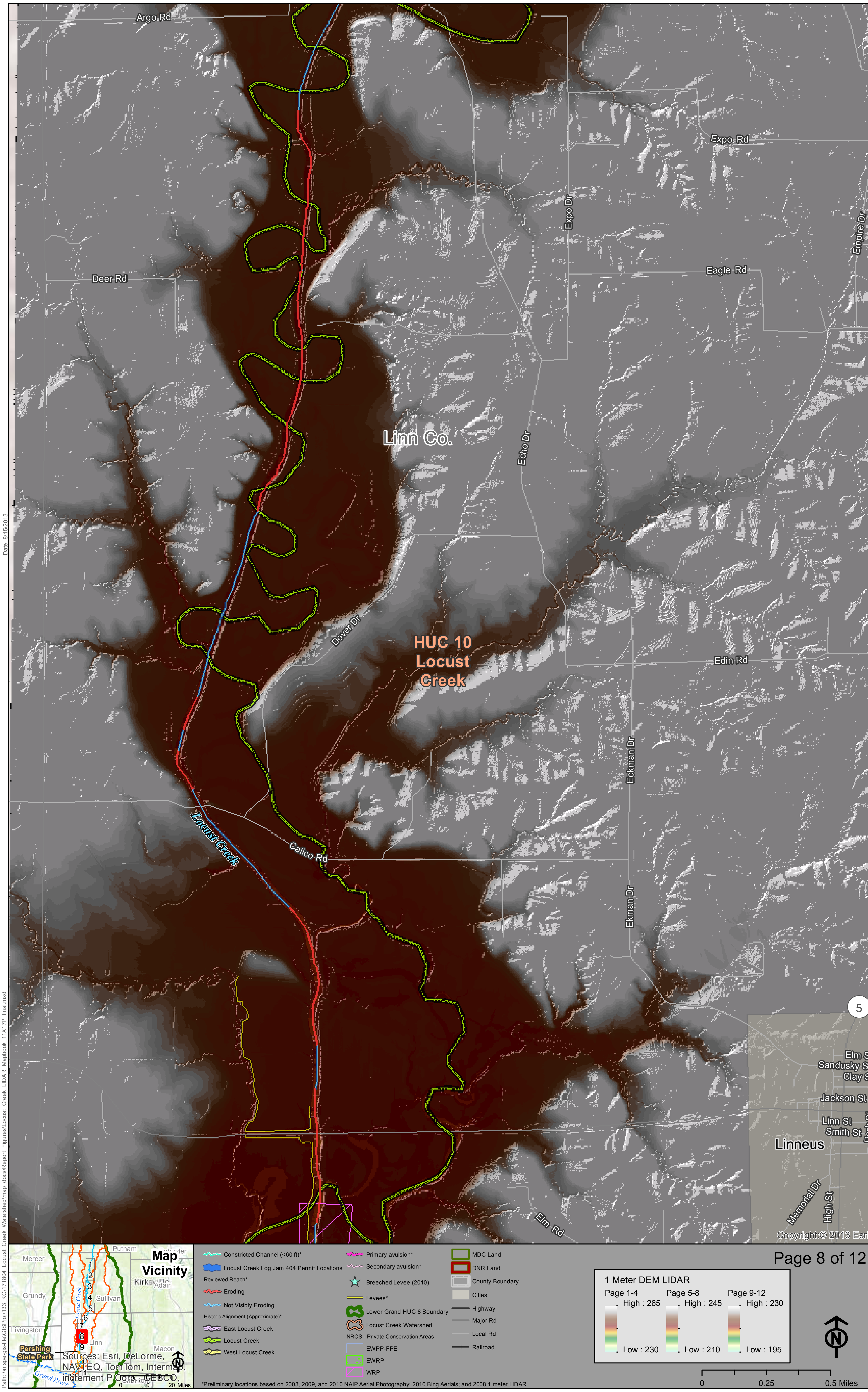
Page 1-4	Page 5-8	Page 9-12
High : 265	High : 245	High : 230
Low : 230	Low : 210	Low : 195

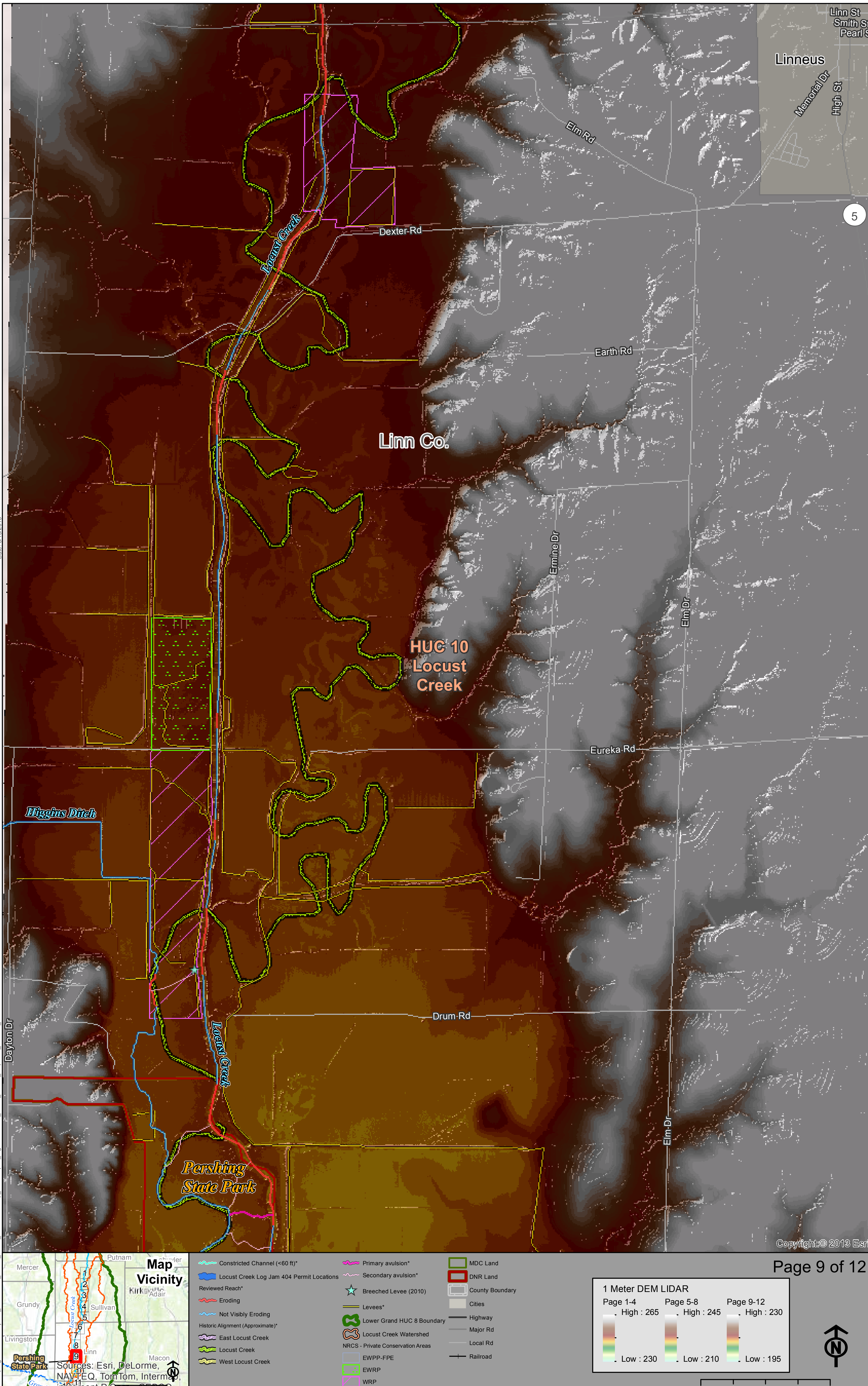
0 0.25 0.5 Miles

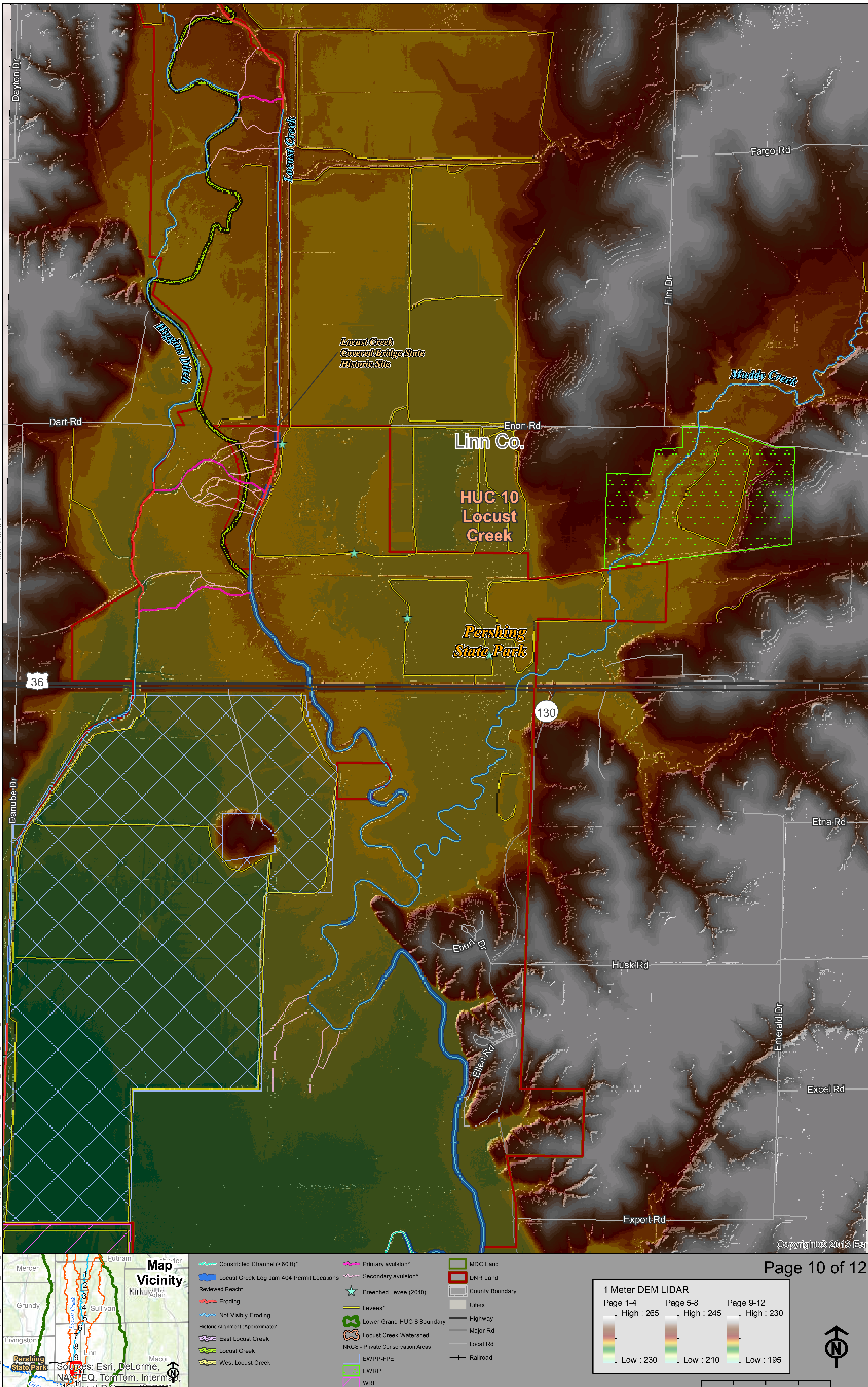
Date: 8/15/2013

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Creek_LIDAR_Mapbook_11X17P_final.mxd


Daisy Rd
West Locust Creek
Edge Rd
HUC 10
West Locust
Creek
Ember Dr
Dill Rd
Doe Dr
Locust Creek
Delco Rd
5
Derby Rd
Cotton Rd
Easton Rd
Linn Co.
Elder Dr
Elder Rd
Forum Rd
Doe Dr
Euclid Dr
Brook Rd
HUC 10
Locust
Creek
Eton Rd
Etta Rd
Empire Dr
Argo Rd
Echo Dr
Expo Rd
Expo Dr
Copyright:© 2013 Esri
Map
Vicinity
Putnam
Mercer
Grundy
Sullivan
Livingston
Linn
Macon
Pershing
State Park
Grand River
Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO
0 10 20 Miles
Constricted Channel (<60 ft)*
Locust Creek Log Jam 404 Permit Locations
Reviewed Reach*
Eroding
Not Visibly Eroding
Historic Alignment (Approximate)*
East Locust Creek
Locust Creek
West Locust Creek
Primary avulsion*
Secondary avulsion*
Breeched Levee (2010)
Levees*
Lower Grand HUC 8 Boundary
Locust Creek Watershed
NRCS - Private Conservation Areas
EWPP-FPE
EWRP
WRP
MDC Land
DNR Land
County Boundary
Cities
Highway
Major Rd
Local Rd
Railroad
*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR
Page 7 of 12
1 Meter DEM LIDAR
Page 1-4
High : 265
Low : 230
Page 5-8
High : 245
Low : 210
Page 9-12
High : 230
Low : 195
0 0.25 0.5 Miles
Date: 8/15/2013
Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Creek_LiDAR_Mapbook_11X17P_final.mxd

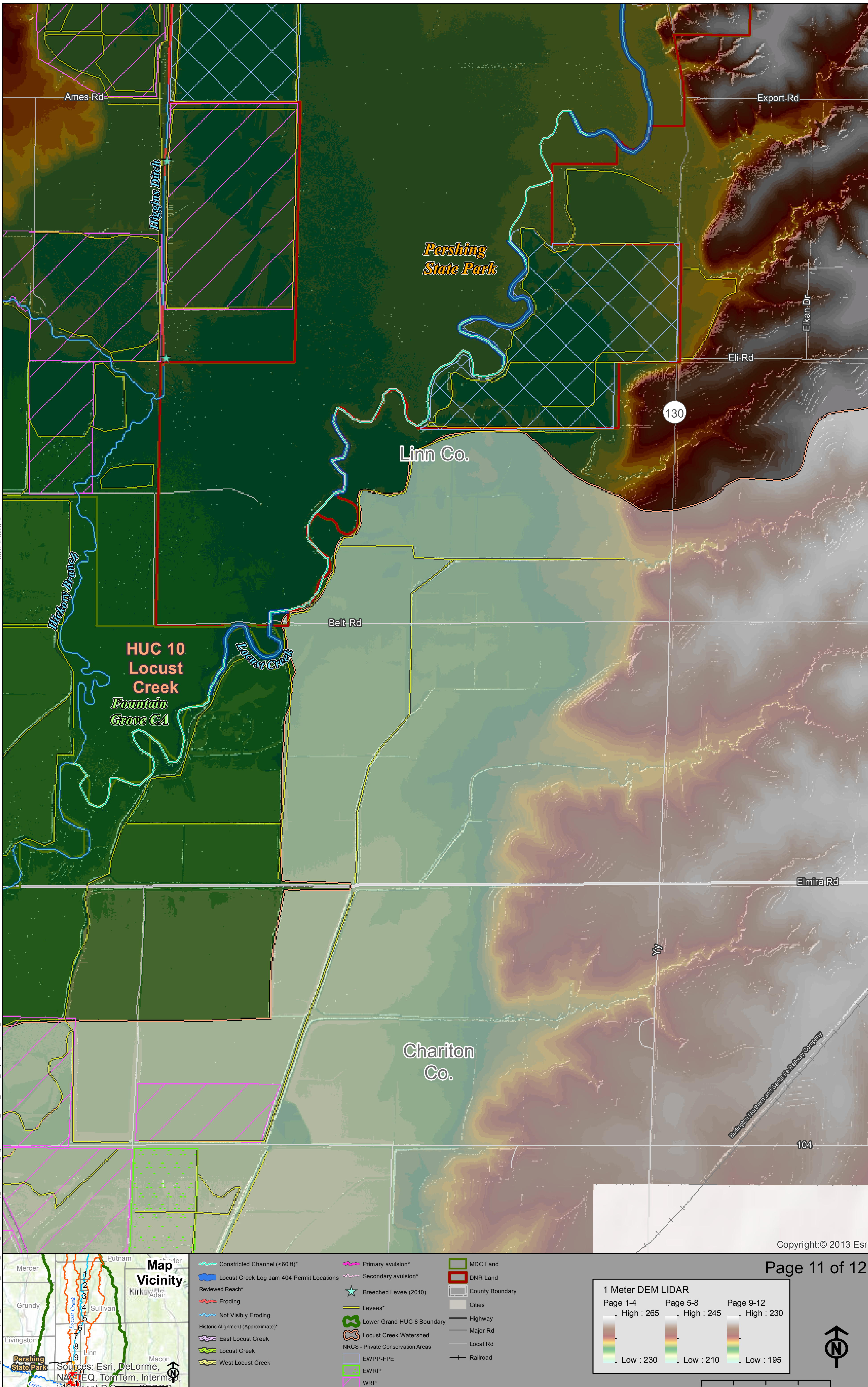

Argo Rd
Expo Rd
Expo Dr
Empire Dr
Eagle Rd
Deer Rd
Linn Co.
Echo Dr
Dover Dr
HUC 10
Locust
Creek
Edin Rd
Eckman Dr
Locust Creek
Calico Rd
Ekman Dr
5
Elm St
Sandusky St
Clay St
Jackson St
Linn St
Smith St
Park St
Linneus
Memorial Dr
High St
Elm Rd
Copyright:© 2013 Esri
Map Vicinity
Mercer
Putnam
Grundy
Adair
Sullivan
Livingston
Linn
Macon
Pershing State Park
Grand River
Locust Creek
1
2
3
4
5
6
7
8
9
10
11
Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO,
0 10 20 Miles
Constricted Channel (<60 ft)*
Locust Creek Log Jam 404 Permit Locations
Reviewed Reach*
Eroding
Not Visibly Eroding
Historic Alignment (Approximate)*
East Locust Creek
Locust Creek
West Locust Creek
Primary avulsion*
Secondary avulsion*
Breeched Levee (2010)
Levees*
Lower Grand HUC 8 Boundary
Locust Creek Watershed
NRCS - Private Conservation Areas
EWPP-FPE
EWRP
WRP
MDC Land
DNR Land
County Boundary
Cities
Highway
Major Rd
Local Rd
Railroad
*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR
Page 8 of 12
1 Meter DEM LIDAR
Page 1-4
High : 265
Low : 230
Page 5-8
High : 245
Low : 210
Page 9-12
High : 230
Low : 195
N
0 0.25 0.5 Miles
Date: 8/15/2013


Linn St
Smith St
Pearl St
Linneus
Memorial Dr
High St
Elm Rd
5
Dexter Rd
Locust Creek
Earth Rd
Linn Co.
Ermine Dr
Elm Dr
HUC 10
Locust
Creek
Eureka Rd
Higgins Ditch
Drum Rd
Dayton Dr
Locust Creek
Elm Dr
Pershing
State Park
Copyright:© 2013 Esri
Map
Vicinity
Mercer
Putnam
Grundy
Sullivan
Livingston
Linn
Macon
Pershing
State Park
Grand River
Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO
20 Miles
Constricted Channel (<60 ft)*
Locust Creek Log Jam 404 Permit Locations
Reviewed Reach*
Eroding
Not Visibly Eroding
Historic Alignment (Approximate)*
East Locust Creek
Locust Creek
West Locust Creek
Primary avulsion*
Secondary avulsion*
Breeched Levee (2010)
Levees*
Lower Grand HUC 8 Boundary
Locust Creek Watershed
NRCS - Private Conservation Areas
EWPP-FPE
EWRP
WRP
MDC Land
DNR Land
County Boundary
Cities
Highway
Major Rd
Local Rd
Railroad
Page 9 of 12
1 Meter DEM LIDAR
Page 1-4
High : 265
Low : 230
Page 5-8
High : 245
Low : 210
Page 9-12
High : 230
Low : 195
0
0.25
0.5 Miles
*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR



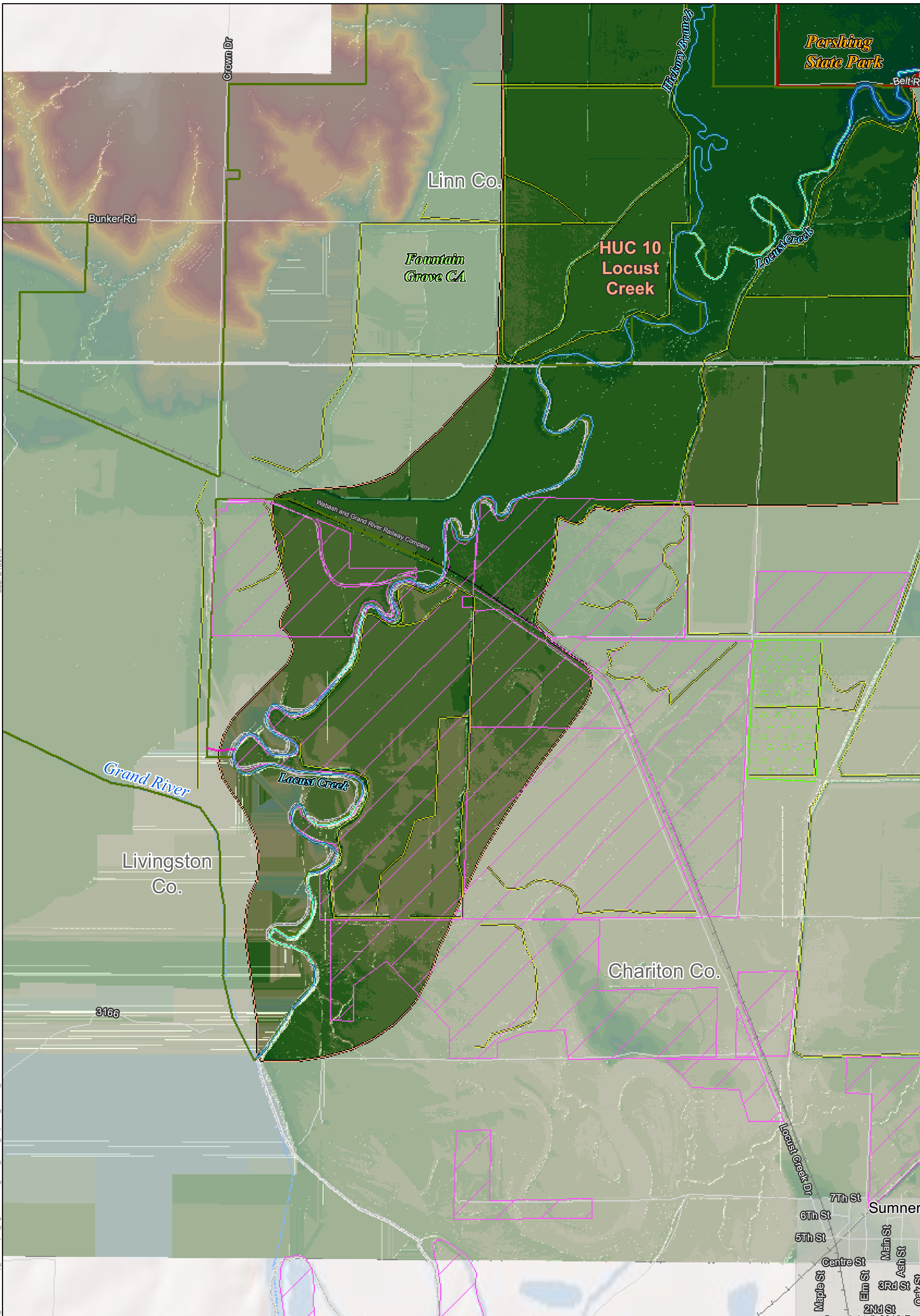
*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR

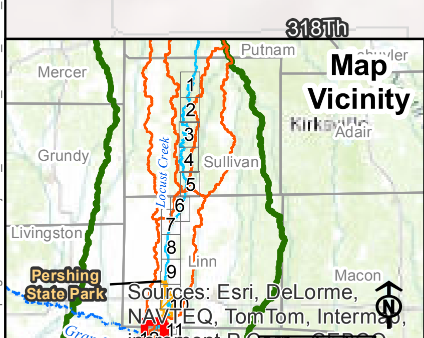
Date: 8/15/2013



Date: 8/15/2013

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Creek_LIDAR_Mapbook_11X17P_final.mxd





Constricted Channel (<60 ft)*
Locust Creek Log Jam 404 Permit Locations
Reviewed Reach*
Eroding
Not Visibly Eroding
Historic Alignment (Approximate)*
East Locust Creek
Locust Creek
West Locust Creek

Primary avulsion*
Secondary avulsion*
Breeched Levee (2010)
Levees*
Lower Grand HUC 8 Boundary
Locust Creek Watershed
NRCS - Private Conservation Areas
EWPP-FPE
EWRP
WRP

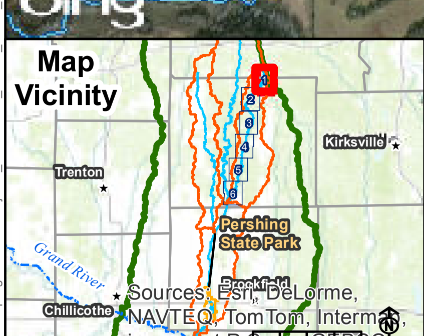
MDC Land
DNR Land
County Boundary
Cities
Highway
Major Rd
Local Rd
Railroad

1 Meter DEM LIDAR

Page 1-4	Page 5-8	Page 9-12
High : 265	High : 245	High : 230
Low : 230	Low : 210	Low : 195

0 0.25 0.5 Miles

*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR



Reviewed Reach*
- Eroding
- Not Visibly Eroding

Historic Alignment (Approximate)*
- East Locust Creek
- Locust Creek

- Lower Grand HUC 8 Boundary
- Locust Creek HUC 10 Watersheds
- County Boundary

- MDC Land

NRCS - Private Conservation Areas
- EWPP-FPE
- EWRP
- WRP

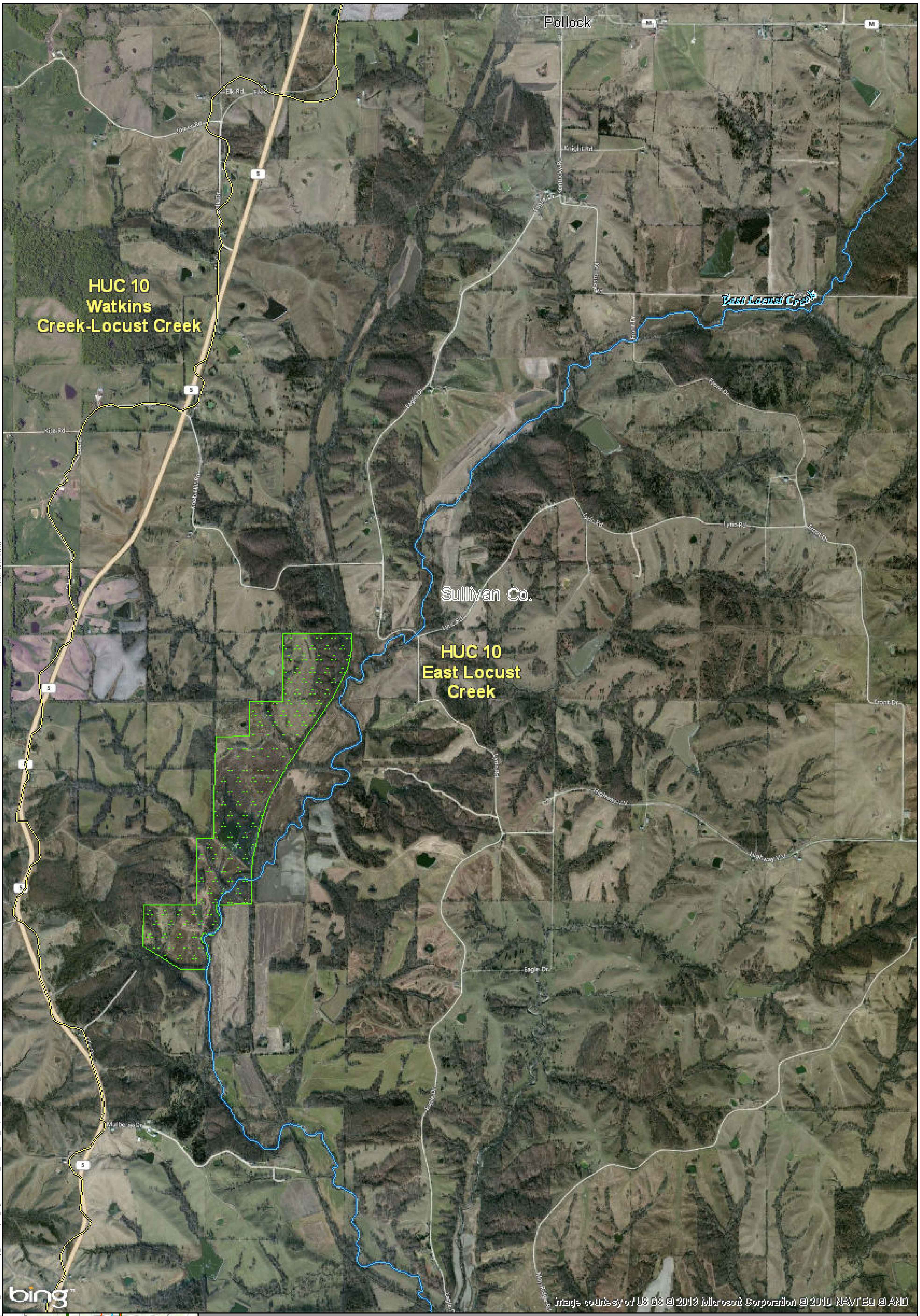
Page 1 of 6
East Locust Creek

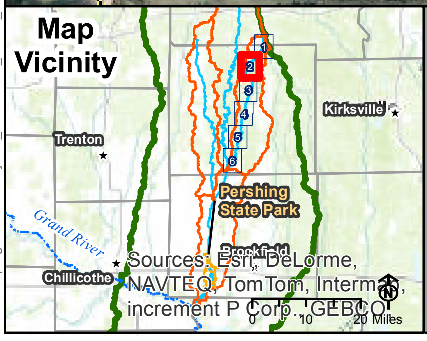
0 0.25 0.5 Miles

*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR

Date: 8/15/2013

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Creek_East_Mapbook_11X17P_final_aerial.mxd





Reviewed Reach*
Eroding
Not Visibly Eroding
Historic Alignment (Approximate)*
East Locust Creek
Locust Creek

Lower Grand HUC 8 Boundary
Locust Creek HUC 10 Watersheds
County Boundary

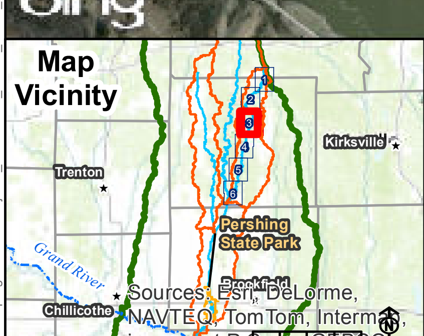
MDC Land
NRCS - Private Conservation Areas
EWPP-FPE
EWRP
WRP

*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR

Page 2 of 6
East Locust Creek

0 0.25 0.5 Miles

Date: 8/15/2013
Path: \\mspe-gis-file\GISProj\133_KC171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Creek_East_Mapbook_11X17P_final_aerial.mxd



Reviewed Reach*
Eroding
Not Visibly Eroding

Historic Alignment (Approximate)*
East Locust Creek
Locust Creek

Lower Grand HUC 8 Boundary
Locust Creek HUC 10 Watersheds
County Boundary

MDC Land
NRCS - Private Conservation Areas
EWPP-FPE
EWRP
WRP

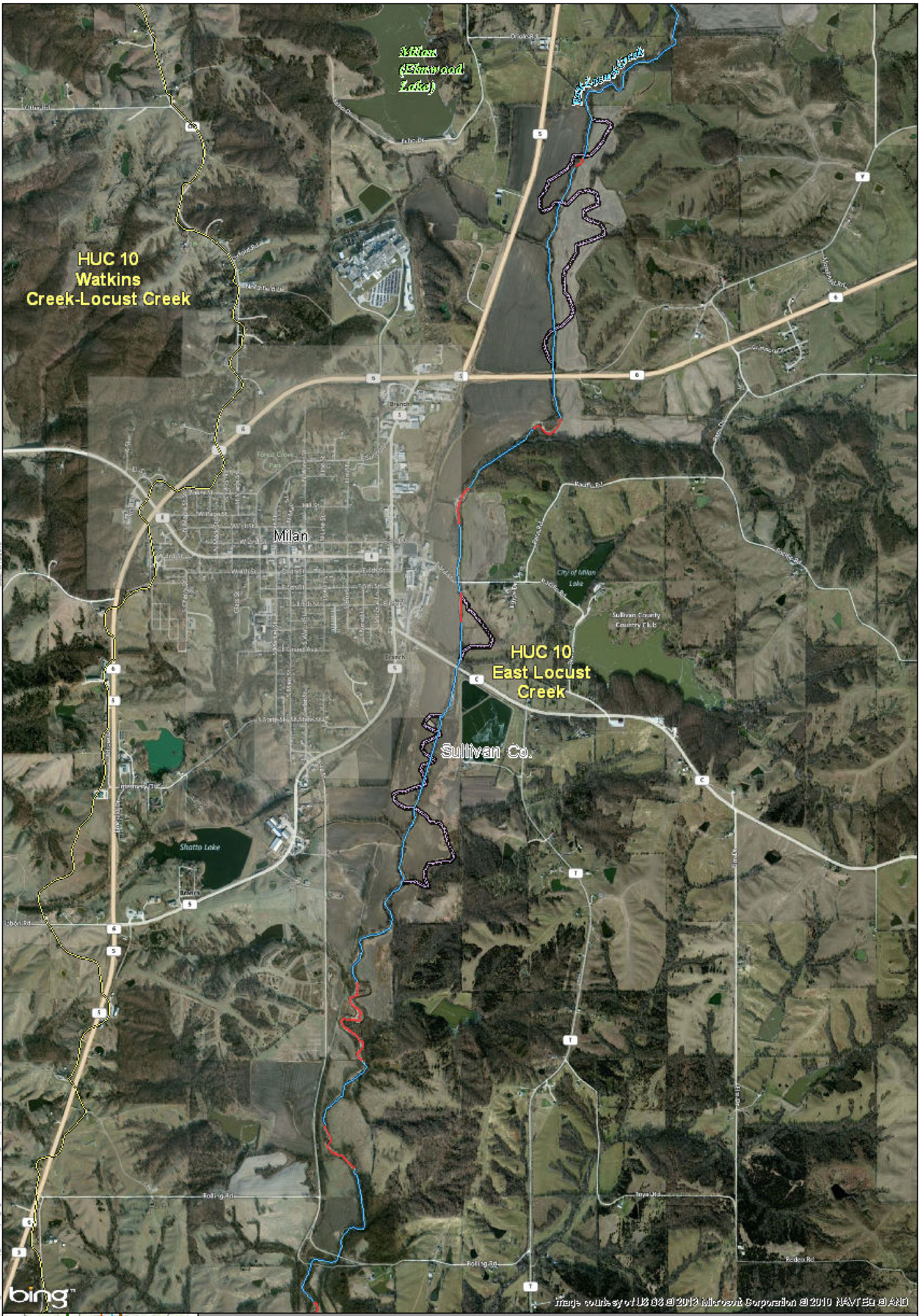
*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR

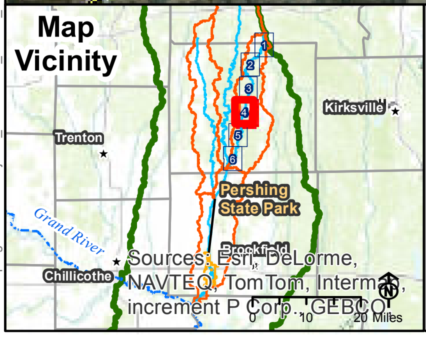
Page 3 of 6
East Locust Creek

0 0.25 0.5 Miles

Date: 8/15/2013

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Creek_East_Mapbook_11X17P_final_aerial.mxd





Reviewed Reach*
Eroding
Not Visibly Eroding
Historic Alignment (Approximate)*
East Locust Creek
Locust Creek

Lower Grand HUC 8 Boundary
Locust Creek HUC 10 Watersheds
County Boundary

MDC Land
NRCS - Private Conservation Areas
EWPP-FPE
EWRP
WRP

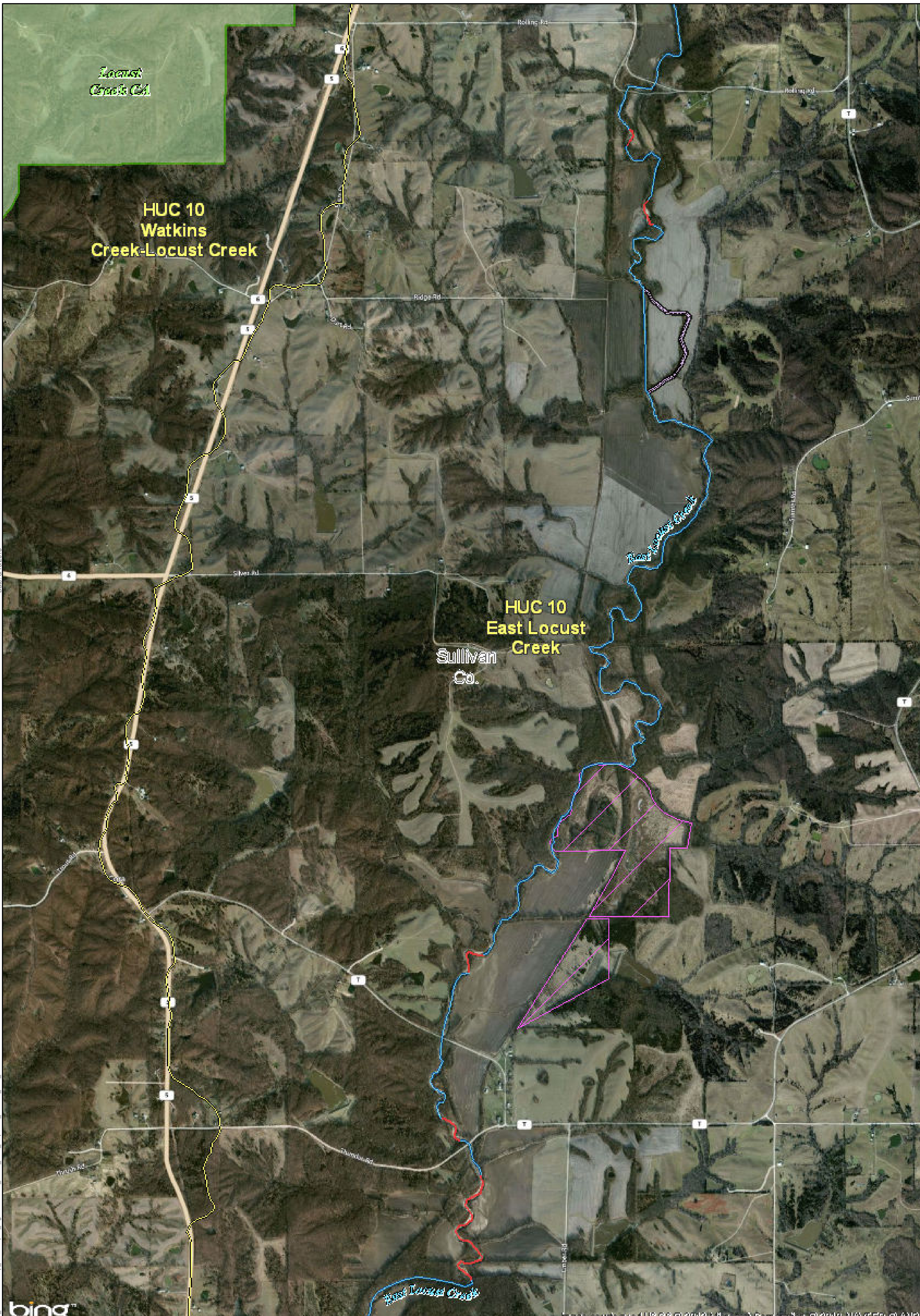
*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR

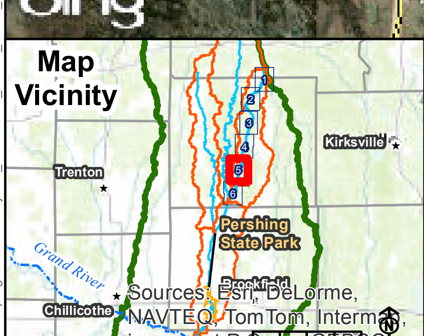
East Locust Creek

0 0.25 0.5 Miles

Date: 8/15/2013

Path: \\mspe-gis-file\GISProj\133_KC171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Creek_East_Mapbook_11X17P_final_aerial.mxd





Reviewed Reach*
- Eroding
- Not Visibly Eroding

Historic Alignment (Approximate)*
- East Locust Creek
- Locust Creek

- Lower Grand HUC 8 Boundary
- Locust Creek HUC 10 Watersheds
- County Boundary

- MDC Land

NRCS - Private Conservation Areas
- EWPP-FPE
- EWRP
- WRP

*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR

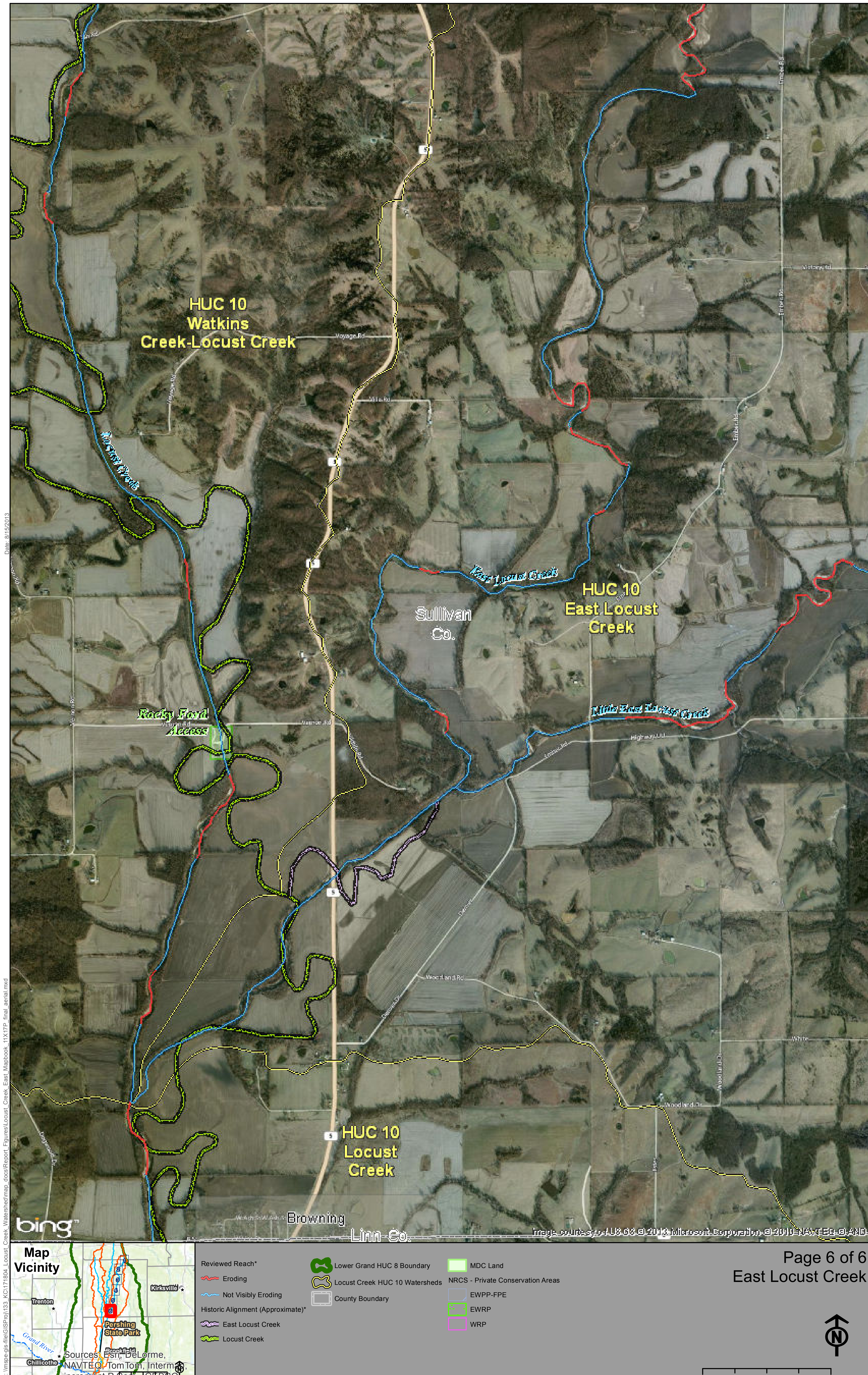
East Locust Creek

N

0 0.25 0.5 Miles

Date: 8/15/2013

Path: \\mspe-gis-file\GISProj\133_KC171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Creek_East_Mapbook_11X17P_final_aerial.mxd



HUC 10
Watkins
Creek-Locust Creek
HUC 10
East Locust
Creek
HUC 10
Locust
Creek
Sullivan
Co.
Linn Co.
Browning
Rocky Ford
Access
East Locust Creek
Little East Locust Creek
Locust Creek
Voyage Rd
Highway UU
Woodland Rd
White
Image courtesy of USGS © 2013 Microsoft Corporation © 2010 NAVTEQ © AND
Map
Vicinity
Trenton
Kirksville
Pershing
State Park
Brookfield
Chillicothe
Grand River
Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO
0 10 20 Miles
Reviewed Reach*
Eroding
Not Visibly Eroding
Historic Alignment (Approximate)*
East Locust Creek
Locust Creek
Lower Grand HUC 8 Boundary
Locust Creek HUC 10 Watersheds
County Boundary
MDC Land
NRCS - Private Conservation Areas
EWPP-FPE
EWRP
WRP
*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR
Page 6 of 6
East Locust Creek
N
0 0.25 0.5 Miles
Date: 8/15/2013
Path: \\mspe-gis-file\GISProj\133_KC171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Creek_East_Mapbook_11X17P_final_aerial.mxd

Appendix B

Relative Potential Sediment Loading, BMP Siting, and Stream Sensitivity Analysis

With Related Mapping

HDR ONE COMPANY *Many Solutions*℠ **Draft Technical Memorandum**

Subject:	Relative Potential Loadings, Stream Sensitivity, and BMP Siting Analysis Technical Memorandum		
Client:	U.S. Army Corps of Engineers - Kansas City District, Missouri Department of Natural Resources		
Project:	Locust Creek Watershed Study	Project No:	171804
Date:	February 18, 2013		
By:	Shawn Tracy		

Purpose

INTRODUCTION

The purpose of this technical memorandum is to gain some preliminary understanding of critical sediment loading areas in the Locust Creek Watershed (LCW), along with a preliminary Best Management Practice (BMP) siting analysis to support targeted future soil and water conservation improvements and work within the LCW. This memorandum also addresses potential sediment source streams and sensitive (response) streams throughout the watershed to help target BMP work further and identify potential aggrading sensitive streams.

METHODS

Critical Source Area Identification

Alteration in hydrology and/or sediment supply to stream channels can alter the hydraulics, geomorphology, bed-form habitat structure, physio-chemistry and biological community structure of downstream reaches (Harman et al., 2012). The cumulative effects of landscape alteration on the natural causal factors that lead to a stream's initial morphology cause shifts from "stable" to "unstable" stream systems. Individual stream vulnerability to landscape alterations is different, dependent on a given stream's location in the network, watershed sediment supply and large woody debris inputs, and in changes to bed slope (Montgomery and Buffington 1993, 1997; Rosgen 1996). Investigation of watershed inputs and stream channel sediment transport capacity relationships allows us to identify areas that are more likely to generate and transport sediment to reaches that are more vulnerable to increased sediment loads.

To relatively describe how and where sediment is generated (mobilized) on the landscape and transferred to sensitive channel reaches, we investigated the relationships between watershed land cover, its effects on cattle movement within riparian areas, stream buffer density, and stream channel capacity to transport or store sediment. This relationship between land cover and cattle movement was used because the Locust Creek watershed is predominantly pasture/hayland land cover at 55.7% and beef cattle production is a major agricultural activity in the watershed. The overlaying of these parameters produced unique hydrologic response unit (HRU) typologies that identified an estimated annual Relative Potential Load (RPL) of sediment for each HRU. The resulting gradient of expected sediment sourcing from HRUs provide natural resource managers valuable information on where their soil and water conservation efforts may yield the highest return on investment (ROI), both on the watershed landscape surface and in downstream stream restoration efforts as related to sediment load. For instance, the results of the analysis determined potential critical source areas that warrant field investigation efforts to confirm the assumptions of this assessment and to locate appropriate BMPs that will likely have the most profound effect on downstream channel sediment aggradation rates in sensitive (response) reaches.

The following calculation was used to produce RPL estimates:

$$\mathbf{RPL = SL \times (OC \times SB)^{1/2}}$$

Where:
RPL = The relative amount of sediment generated AND transferred from a HRU in the watershed to a sensitive downstream (response) stream reach in pounds per year (lb/yr)
SL = Simple Loading Method (lb/yr)
OC = Off-Channel Shade Factor (unitless)
SB = Stream Buffer Factor (unitless)

For mapping purposes of RPLs, sediment loading estimates were classified based on natural breaks in the generated data set as follows:

Very High =	113,741 – 271,014 lb/yr
High =	55,939 – 113,740 lb/yr
Moderate =	24,961 – 55,938 lb/yr
Low =	7,403 – 24,960 lb/yr
Very Low =	0 – 7,402 lb/yr

Simple Loading Method

Sediment generation and transport from uplands to a stream channel was defined for each HRU. Land use data from the *National Land Cover-Land Use* 2011 database was used in conjunction with published event mean concentrations and runoff coefficients (Table 1) to estimate potential annual RPL for each watershed. Stream center line data from the *National Hydrologic Dataset* (USDA-NRCS 2012) was used with a 10m DEM from the *National Elevation Dataset* (Gesch 2007, Gesch et al 2002) to delineate watersheds at each confluence within the four Locust Creek HUC 10 watersheds of the study area using ArcHYDRO tools within an ESRI ArcGIS platform.

For those areas with digitally documented ponds and impoundments (MDNR, Water Resources Center), upstream drainage areas were similarly delineated for exclusion from further RPL analysis, as it was assumed that these impoundments would significantly attenuate the annual sediment loading as compared to un-impounded areas of the study area. Note that not all ponds and impoundments in the LCW have been digitized in the MDNR data set, as some ponds/impoundments were observed on aerial photography that have not yet been digitized.

Table 1. Land Use-Cover, Event Mean Concentrations (EMC), and Runoff Coefficients (Rv)

Land Use/Cover	EMC* (mg/L)	Rv*
Barren	300	0.2
Dense Ground Cover	43	0.050
Developed/Medium Intensity	107.3	0.392
Developed/Low Intensity	107.3	0.212
Developed/Open Space	131	0.300
Fallow/Idle Cropland	131	0.113
Pasture/Hay	200	0.038
Row Crops	159	0.250
Row Crops + Winter Wheat	131	0.150
Water	0	0.000
Woodland/Shrubland	51	0.025

*Byers, et al. 2005; Cave et al, 1994; Fleming et al, 2010; Harmel et al, 2006; Lin, 2004; Ockerman, 2002; Reckhow et al., 1980; Sanjari et. al, 2010; Wohl and Caroline, 1996.

Using the coefficients from Table 1 based on the land uses found in the watershed from the *National Land Cover Land* Use database, the estimated annual sediment loads from each catchment was calculated using the Simple Method below:

<u>Annual Load (Simple Method)</u>
L = R x EMC x A x 0.226

Where:
L = Annual load (lbs/yr)
R = Annual runoff (inches) = Annual rainfall (40 inches/yr) x Rv (runoff coefficient)
EMC = Event Mean Concentration [(pollutant concentration) mg/L]
A = Area (acres)
0.226 = Unit conversion factor

<u>Off-Channel Shade Factor</u>

Cattle behavior has been shown to increase sediment transport from drainage areas based on bank erosion not only from absence of fencing exclusions, but also in relation to the presence of off-channel shade and water sources (Ockerman, 2002; Harmel et al 2006; Sanjari et al, 2010; Wohl

Caroline, 1996). A paired watershed study by Byers, et. al. (2005) found correlation between Off-Channel Shade (OC) availability and sediment load in rangelands.

Although it was beyond the scope of this analysis to provide more than a relative measure between catchments for potential total suspended solids (TSS) loading, we accommodated for this effect by manually adjusting certain rangeland's expected contribution to watershed sediment loading considering literature values (Byers, et al. 2005; Cave et al, 1994; Fleming et al, 2010; Harmel et al, 2006; Lin, 2004; Ockerman, 2002). Byers, et al (2005) found that for the pasture with limited off channel shade (an off-channel habitat to pasture area ratio of 0.037), stormflow loads (median TSS per storm event divided by pasture area) were 5.5 times greater than pastures with off-channel habitat (an off-channel habitat:pasture area ratio of 0.130). Therefore, for those catchments containing more than 50% grazing/pasture land use and if off-channel shade habitat (woodland/shrubland land cover beyond a minimum of 100 feet from stream center lines) was less than 10% (the approximate midway point land cover percentage between the two study watersheds; 6% and 16% low shade cover and high shade cover, respectively), then a multiplier of 5 was applied to the potential loads.

<u>Off-Channel Shade Factor</u>:
> 50% grazing or pasture land use; and
< 10% off-channel shade habitat

<u>Stream Buffer Factor</u>

The availability of uncontrolled channel access by cattle paired with dysfunctional (non-sediment-filtering) riparian systems is more likely to generate and allow transport of sediment to fluvial channels (Byers et. al., 2005). To estimate the presence or absence of Stream Buffer (SB) and existing filtering effect on sediment transport to stream channels, a 100-ft buffer from the stream centerlines was created. Although mature native prairies can completely filter out moderate sediment loads within 20-50 ft, coarse woody vegetation stem density and morphology inhibits the woodland/shrubland filtering capacity. As such, a greater buffer width was considered that would likely allow for depressional sediment deposition, as well as for the possible correlation of denser grass cover within woody buffers protected from grazing pressure. This buffer was overlaid onto the land cover/use data to identify segments with areas of complete buffers (100 feet of buffer on each side of the center line) and those without discontinuous or missing woody buffers (those with partial cover or no cover within the buffer polygon). Segments were then classified as to their presence, or absence, of a buffer and assigned a coefficient as follows:

<u>Stream Buffer Factor</u>:
< 25% riparian cover in 100-ft stream buffer = 2
25 – 75% riparian cover in 100-ft stream buffer = 1
>75% riparian cover in 100-ft stream buffer = 0.5

RPL Calculation Example

To illustrate the calculation of the RPL of a hypothetical hydrologic response unit, we consider 100 acres of land with more than 50% grazing land use, no off-channel shade habitat and a full riparian buffer and calculate the HRU's contribution to the annual sediment loading as follows:

1. Simple Method Loading:
   SL = R x EMC x A x 0.226SL = (0.038 x 200 x 100 x 0.226) = 171.6 lb/yr
2. Off-Channel Shade Factor (OC) = 5
3. Stream Buffer Factor (SB) = 1
4. Relative Potential Loading:

   $RPL = SL \times (OC \times SB)^{1/2}$

   $RPL = 171.6 \times (5 \times 1)^{1/2} = 384.7$ lb/yr

Please note that potential pounds per year (lb/yr) results are not reported in this technical memorandum, nor on figures developed for this appendix, as a relative loading analysis was deemed more appropriate in highlighting critical source areas at this stage of the project development.

General Best Management Practice Siting

The RPL analysis helped identify potential critical source areas in terms of expected sediment loading from the watershed to an adjacent stream channel. The analysis was used to identify key locations in the landscape for BMPs and then correlated these locations to suitable Watershed Actions and Practices (report Section 3.2.1).

For illustrative clarity, we grouped the potential suite of BMPs shown in Table 2 below based on potential critical sediment loading areas (labeled as "High" and "Very High", and as shown in report Figure 13[*] and Appendix B RPL sheets 1 – 16[*]), impervious areas, riparian areas and rangelands with limited off-channel shade (as defined under Off-channel Shade, above). These BMP groupings (shown in Appendix B BMPs Sheets 1 -16[*]) were then correlated to the Watershed Actions and Practices shown in Table 2.

[*]Regarding the BMP implementation locations shown on maps Appendix B Sheets 1 – 16 and report Figure 13, these intended to provide an estimate of the location, type and amount of different BMPs that are suitable for the different land uses for future watershed planning and budgeting purposes only. These BMPs were developed solely on available mapping data (land use, slope, etc.) and are not targeted to towards any specific private properties. Site specific evaluation is needed to fully determine the BMPs suitable for private property sites. If private landowners are interested in implementing BMPs on their property, they should contact their local USDA/Soil and Water Conservation office. Implementing BMPs would be on a voluntary basis.

Table 2. Recommended Watershed Actions and Practices and their Prioritized Correlation to the BMP Groups in Appendix B BMP Sheets 1 - 16.

WATERSHED ACTIONS & PRACTICES **Soil & Water BMP Action**	Off-Channel Shade & Cattle Management	Riparian Buffer BMP	Riparian Woodland/ Shrubland Improvement	Row Crop Critical Area	Pasture/Hay Critical Area
Sheet, Rill & Gully Erosion BMPs					
Permanent Vegetative Cover Establishment				x	
Permanent Vegetative Cover Improvement				x	
Terrace System				x	
Terrace System with Tile				x	
No-till System (Residue & Till Management)				x	
Permanent Vegetative Cover - Critical Areas: Confined Animal Feed Lots				x	x
Water Impoundment Reservoir				x	
Sediment Retention Water Control Structure				x	x
Grade Stabilization				x	x
Grassed (Sod) Waterway				x	x
Diversion				x	
Contour Buffer Strips				x	x
Contour Strip Cropping				x	
Cover Crops				x	
Conservation Crop Rotation				x	

Table 2, continued. Recommended Watershed Actions and Practices and their Prioritized Correlation to the BMP Groups in Appendix B BMP Sheets 1 - 16.

WATERSHED ACTIONS & PRACTICES **Soil & Water BMP Action**	Off-Channel Shade & Cattle Management	Riparian Buffer BMP	Riparian Woodland/ Shrubland Improvement	Row Crop Critical Area	Pasture/Hay Critical Area
Grazing Management BMPs					
Permanent Vegetative Cover Enhancement					x
Grazing System Water Development					x
Grazing System Water Distribution					x
Grazing System Fencing					x
Grazing System Lime					x
Grazing System Seeding					x
Prescribed Grazing					x
Heavy Use Protection					x
Off-channel Shade and Water Establishment	x				x
Sensitive Areas BMPs					
Field Border		x	x	x	
Filter Strip		x	x	x	
Riparian Forest Buffer		x	x	x	x
Stream Protection (Access Control)		x	x	x	x
Streambank Stabilization		x	x	x	

Table 2, continued. Recommended and Watershed Actions and Practices and their Prioritized Correlation to the BMP Groups in Appendix B BMP Sheets 1 - 16.

WATERSHED ACTIONS & PRACTICES **Soil & Water BMP Action**	Off-Channel Shade & Cattle Management	Riparian Buffer BMP	Riparian Woodland/ Shrubland Improvement	Row Crop Critical Area	Pasture/Hay Critical Area
Woodland Erosion BMPs					
Woodland Protection – Livestock Exclusion (Access Control)		x	x		x
Use Exclusion (Access Control)		x	x		x

Stream Sensitivity Characterization

A watershed and stream system work together in sourcing, transporting and storing sediment. It is important to understand the correlation between landscape areas with potentially high sediment loads (watershed sources) and a receiving stream's power to move that load. Areas with high watershed loads and high channel transport capacity are important sources of aggrading sediment to reaches with lower gradients (response reaches). Channel morphology, habitat, water quality and biological community makeup are strongly influenced by the amount and rate of water and sediment supply. Shifts in these parameters triggers a cascading response across several of the five major levels of stream functioning (hydrologic, hydraulic, geomorphological, physio-chemical, and biological; Harmon, et. al., 2012; Montgomery and Buffington,1993 & 1997).

Streams were classified based on their sensitivity to watershed changes in hydrology and/or sediment transport; the resulting metric was termed Stream Sensitivity (SS). The 10m DEM surface from the National Elevation Dataset was used to estimate average slopes along the stream centerlines in GIS, in segments from confluence to confluence or, in the case of headwaters, from the stream's head to the first downstream confluence. Using a slight modification to the Montgomery and Buffington channel regime type (1997) each of these segments were then classified based on the average channel slope (Table 3).

Table 3. Slope ranges for Stream Reach (SR) classifications (adapted from Montgomery and Buffington, 1997).

	Sensitive		**Source**				
Regime	Dune Ripple	Pool Riffle	Plane Bed	Step Pool	Cascade	Bedrock	Colluvial

Slope	<0.001	0.001-0.015	0.015-0.03	0.03-0.08	0.08-0.20	N/A	>0.20
Coefficient	1	1	2	2	2	2	2

Using these classifications, we can determine the likely stream characteristics for un-impacted streams and use this to describe existing departure from the norm in altered watersheds (Table 4). Each segment type responds uniquely to changes in hydrology and sediment supply allowing identification of Sensitive Reaches, scour and transport reaches were classified as Source Reaches (Figure 1 and Tables 3 and 5). Sediment transferred by source reaches typically aggrades at their interface with sensitive reaches. It is at these locations that slopes flatten and flow rates are reduced to a point where the sediment load can fall from suspension.

Table 4. Diagnostic features of each channel regime type (adapted from Montgomery and Buffington, 1997)

	Dune Ripple	Pool Riffle	Plane Bed	Step Pool	Cascade	Bedrock	Colluvial
Typical bed material	Sand	Gravel	Gravel-cobble	Cobble-boulder	Boulder	Rock	Variable
Bedform pattern	Multilayered	Laterally oscillatory	Featureless	Vertical oscillatory	Random	Irregular	Variable
Dominant roughness elements	Sinuosity, bedforms (dunes, ripples, bars), grains, banks	Bedforms (bars, pools), grains, sinuosity, banks	Grains, banks	Bedforms (steps, pools), grains, banks	Grains, banks	Boundaries (bed and banks)	Grains
Dominant sediment sources	Fluvial, bank failure	Fluvial, bank failure	Fluvial, bank failure, debris flows	Fluvial, hillslope, debris flows	Fluvial, hillslope, debris flows	Fluvial, hillslope, debris flows	Hillslope, debris flows
Sediment storage elements	Overbank, bedforms	Overbank, bedforms	Overbank	Bedforms	Lee and stoss sides of flow obstructions	Pockets	Bed
Typical confinement	Unconfined	Unconfined	Variable	Confined	Confined	Confined	Confined
Typical pool spacing (channel width)	5 to 7	5 to 7	None	1 to 4	<1	Variable	Variable

Figure 1. Transport capacities relative to sediment supply for reach level types (adapted from Montgomery and Buffington, 1997; Q_s = sediment supply; Q_c = transport capacity).

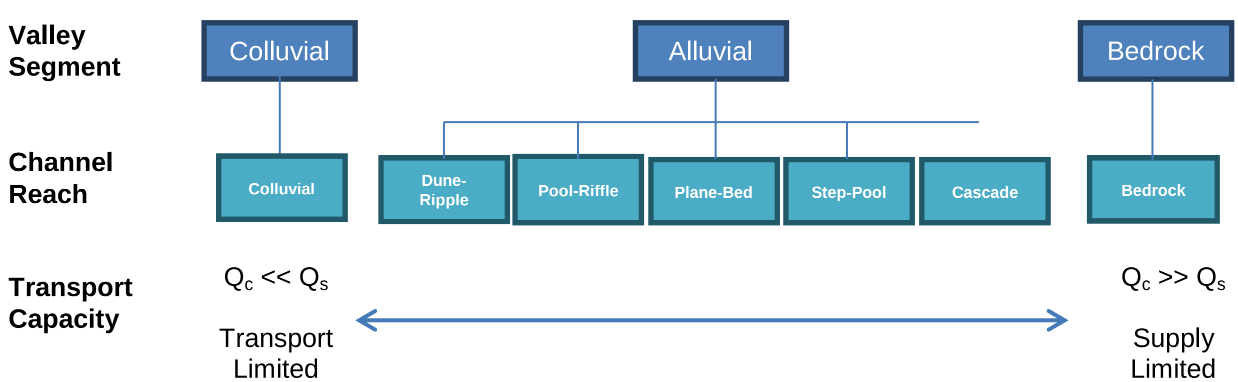


Table 5. Interpreted reach-level channel response potential to moderate changes in sediment supply and discharge (adapted from Montgomery and Buffington, 1997).

	Width	Depth	Roughness	Scour Depth	Grain Size	Slope	Sediment storage
Dune Ripple	+	+	+	+	o	+	+
Pool Riffle	+	+	+	+	+	+	+
Plane Bed	p	+	p	+	+	+	p
Step Pool	o	p	p	p	p	p	p
Cascade	o	o	p	o	p	o	o
Bedrock	o	o	o	o	o	o	o
Colluvial	p	p	o	p	p	o	+

+ = Likely to change p = Possible change o = Not likely to change

RESULTS

The results of the SS characterization should be considered in conjunction with the results from the RPL analysis (critical source areas and general BMP siting) when scouting for potential BMP locations with the highest return on investment (ROI). Appendix B RPL series of sheets 1 - 16 and the BMP series of sheets 1 - 16 have been included to aid in selecting the possible “low-hanging fruit” locations for BMPs and the most-appropriate type of BMPs for these locations in the Locust Creek Watershed.

References

Byers HL, et. al. (2005). *Phosphorous, sediment, and E. Coli loads in unfences streams of the Georgia Piedmont, USA*. Proceedings of the 2005 Georgia Water Resources Conference, held April 25-26, 2005, at the University of Georgia, Kathyrn J. Hatcher, editor, Institute of Ecology, the University of Georgia, Athens, Georgia.

Cave K, Quasebarth T, and Harold E (1994*). Technical memorandum: selection of stormwater pollutant loading factors. Rouge River national wet weather demonstration project, Wayne County, Michigan.*

Fleming, N.K., Cox, J.W., He, Y., Thomas, S. and Firzenschaf, J. (2010). *Analysis of Total Suspended Sediment and Total Nutrient Concentration data in the Mount Lofty Ranges to derive event mean concentrations*, eWater Cooperative Research Centre Technical Report, August 2010. ISBN 978-1-921543-32-6.

Gesch, D.B., 2007, The National Elevation Dataset, in Maune, D., ed., Digital Elevation Model Technologies and Applications: The DEM Users Manual, 2nd Edition: Bethesda, Maryland, American Society for Photogrammetry and Remote Sensing, p.99-118.

Gesch, D., Oimoenm, M. Greenlee, S., Nelson, C., Steuck, M. and Tyler, D., 2002, The National Elevation Dataset: Photogrammetric Engineering and Remote Sensing, v68, no. 1, p. 5-11.

Harmel D, Potter S, Casebolt P, Reckhow, K, Green C, and Haney R (2006). *Compilation of measured nutrient load data for agricultural land uses in the United States*. Journal of the American Water Resources Association. 42(5):1163-1178.

Harman, W., R. Starr, M. Carter, K. Tweedy, M. Clemmons, K. Suggs, C. Miller (2012*). A Function-Based Framework for Stream Assessment and Restoration Projects*. US Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Washington, DC EPA 843-K-12-006.

Lin JP (2004). *Review of published export coefficient and event mean concentration (EMC) data*. ERDC TN-WRAP-04-3, Wetlands Regulatory Assistance Program.

Montgomery, D. R., and J. M. Buffington (1993). *Channel classification, prediction of channel response, and assessment of channel condition: Olympia, Washington State Department of Natural Resources* Report TFW-SH10-93-002, 84 p.

Montgomery, D. R. and J. M. Buffington (1997). *Channel-reach morphology in mountain drainage basins*. GSA Bulletin v. 109(5):596-611.

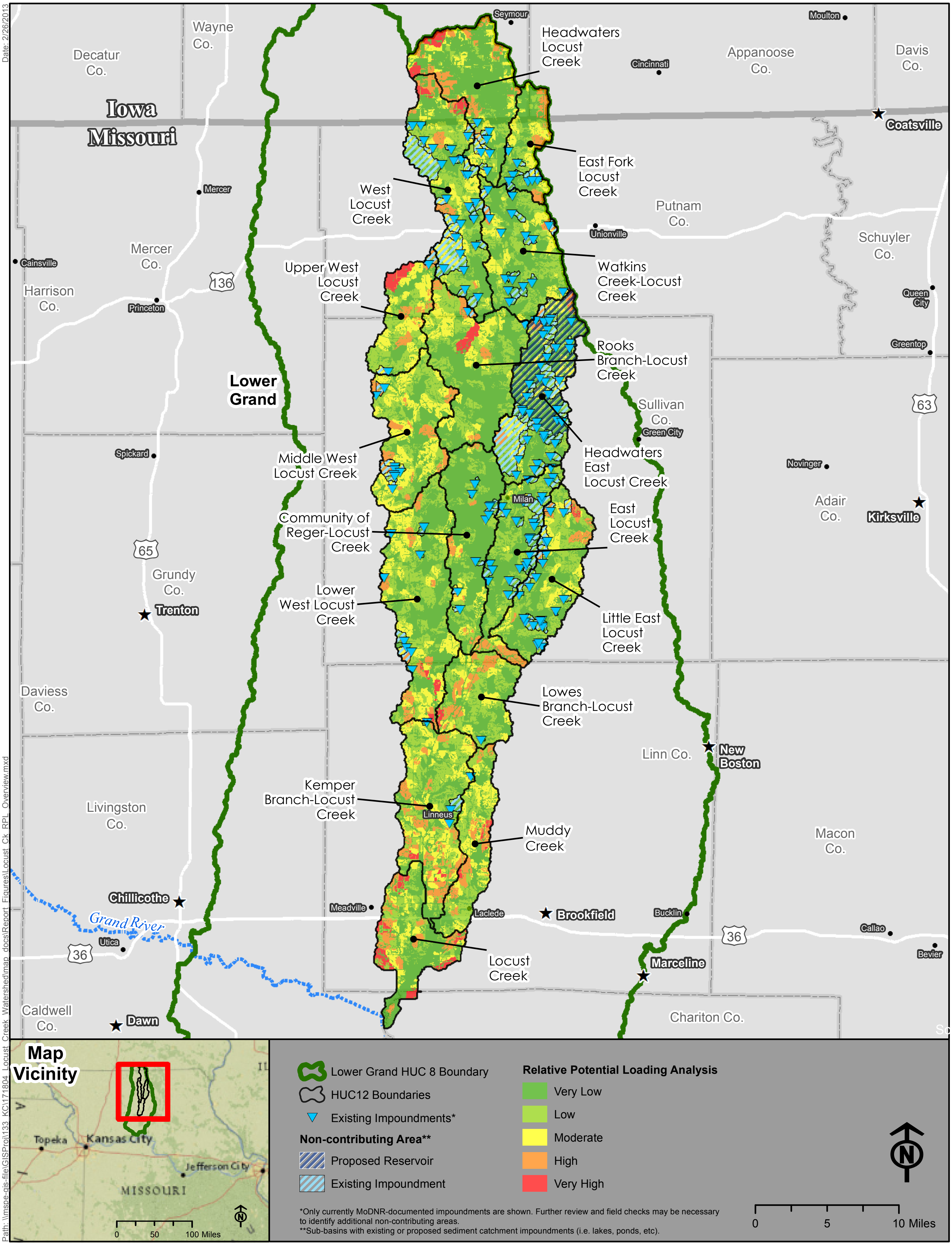
Ockerman DJ (2002). *Hydrologic conditions and quality of rainfall and storm runoff in agricultural and rangeland areas in San Patricio County, Texas, 2000-2001*. U.S. Geological Survey Open-File Report 02-291.

Reckhow et al. (1980). *Modeling phosphorous loading and lake response under uncertainty: a manual and compilation of export coefficients*. U.S. Environmental Protection Agency.

Sanjari G, Yu B, Ghadiri H, Ciesiolka CAA and Rose CW (2010). *Time-controlled grazing and soil erosion control under a catchments scale experiment in South-east Queensland, Australia*. 19th World Congress of Soil Science, Soil Solutions for a Changing World. 1-6 August 2010.

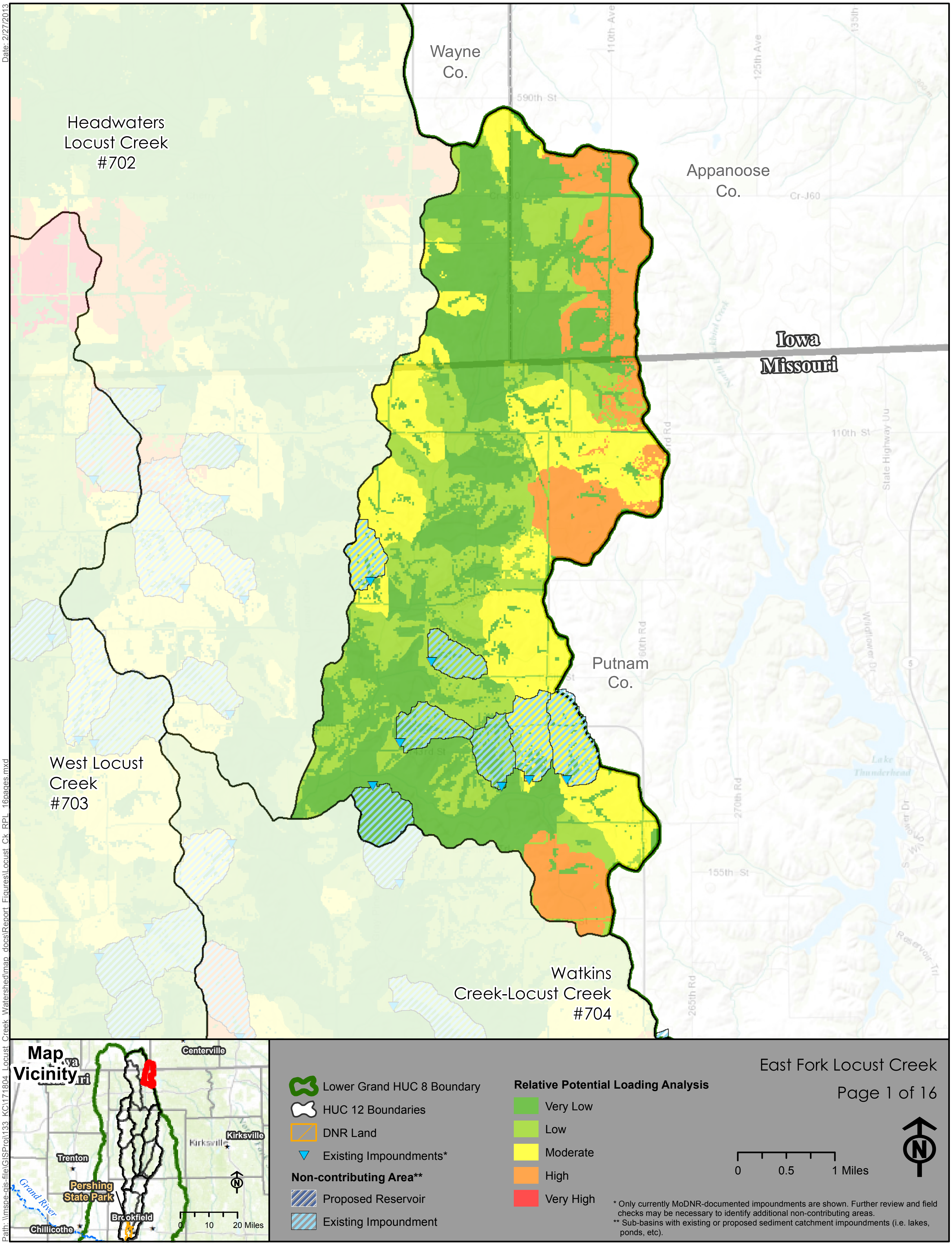
United States Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS), the United States Geological Survey (USGS), and the Environmental Protection Agency (EPA), 2012. Watershed Boundary Dataset for HUC1028, Missouri [Online ftp://nhdftp.usgs.gov/DataSets/Staged/SubRegions/FileGDB/HighResolution/NHDH1028_931 v210.zip]. Available URL: http://datagateway.nrcs.usda.gov [Accessed 01/03/2013].

Wohl NE and Caroline RF (1996). *Relations among riparian grazing, sediment loads, macroinvertebrates, and fishes in three central Pennsylvania streams*. Can. J. Fish. Aquat. Sci. 53(suppl. 1):260-266.



Date: 2/26/2013

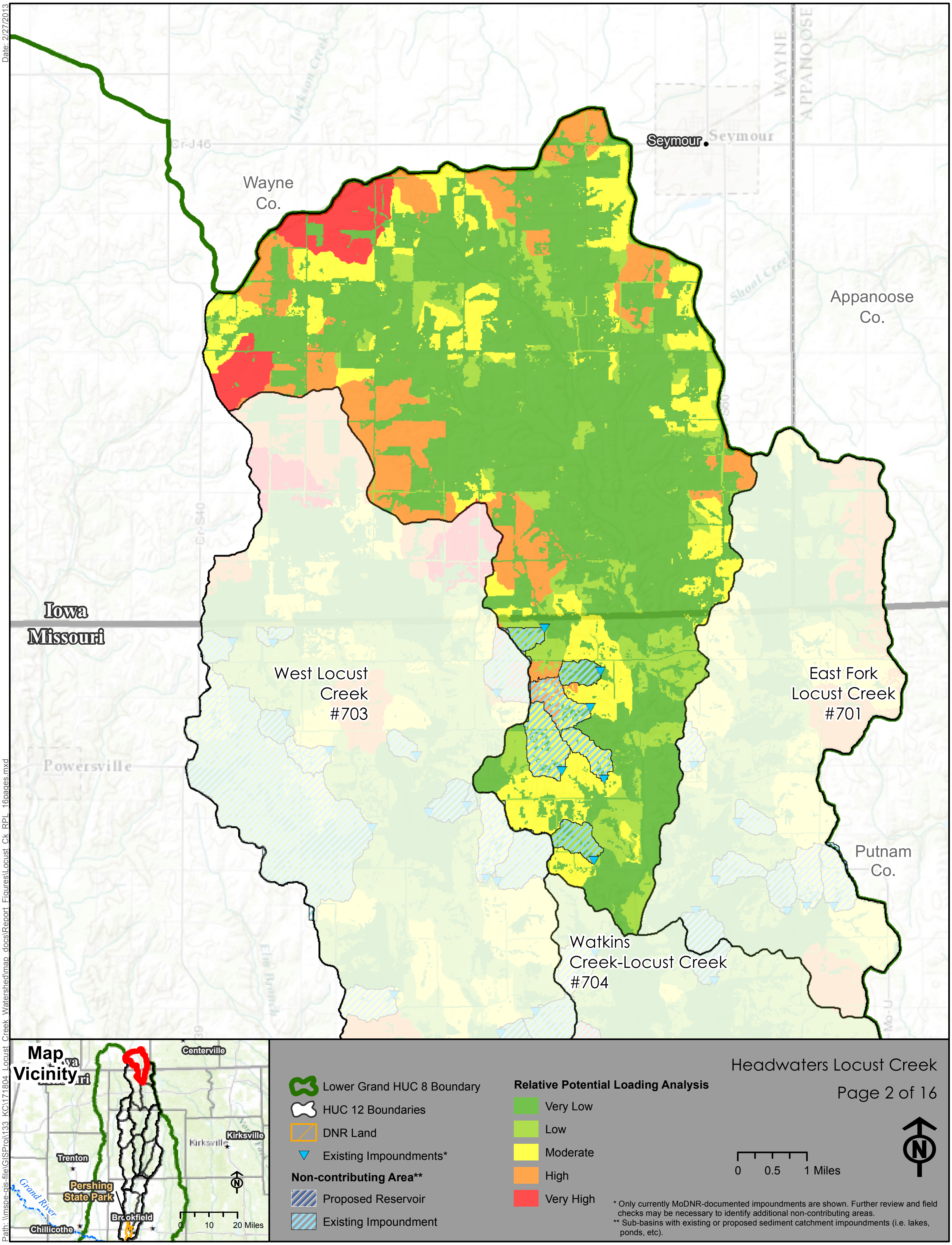
Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_RPL_Overview.mxd



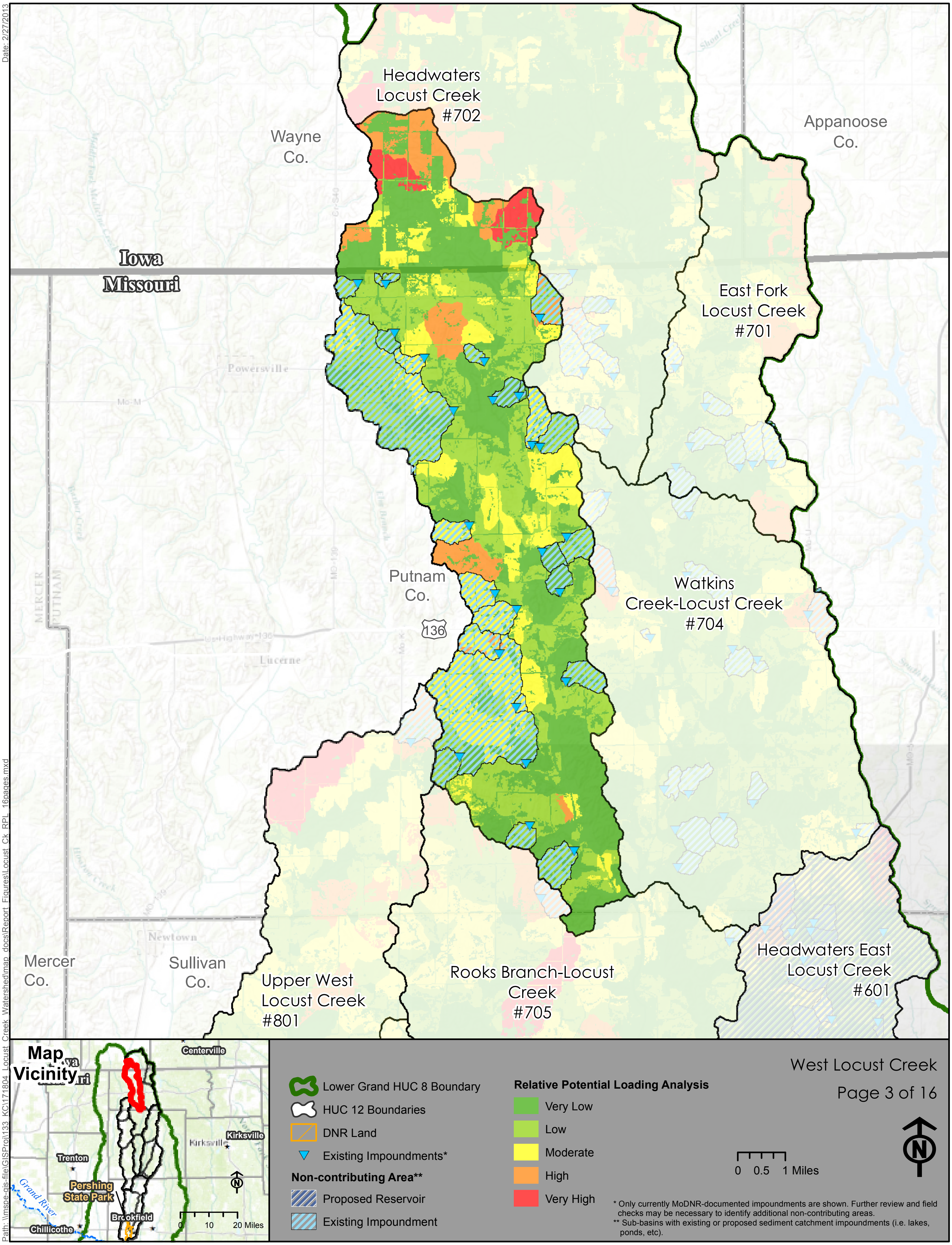
Date: 2/27/2013

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_RPL_16pages.mxd

Date: 2/27/2013

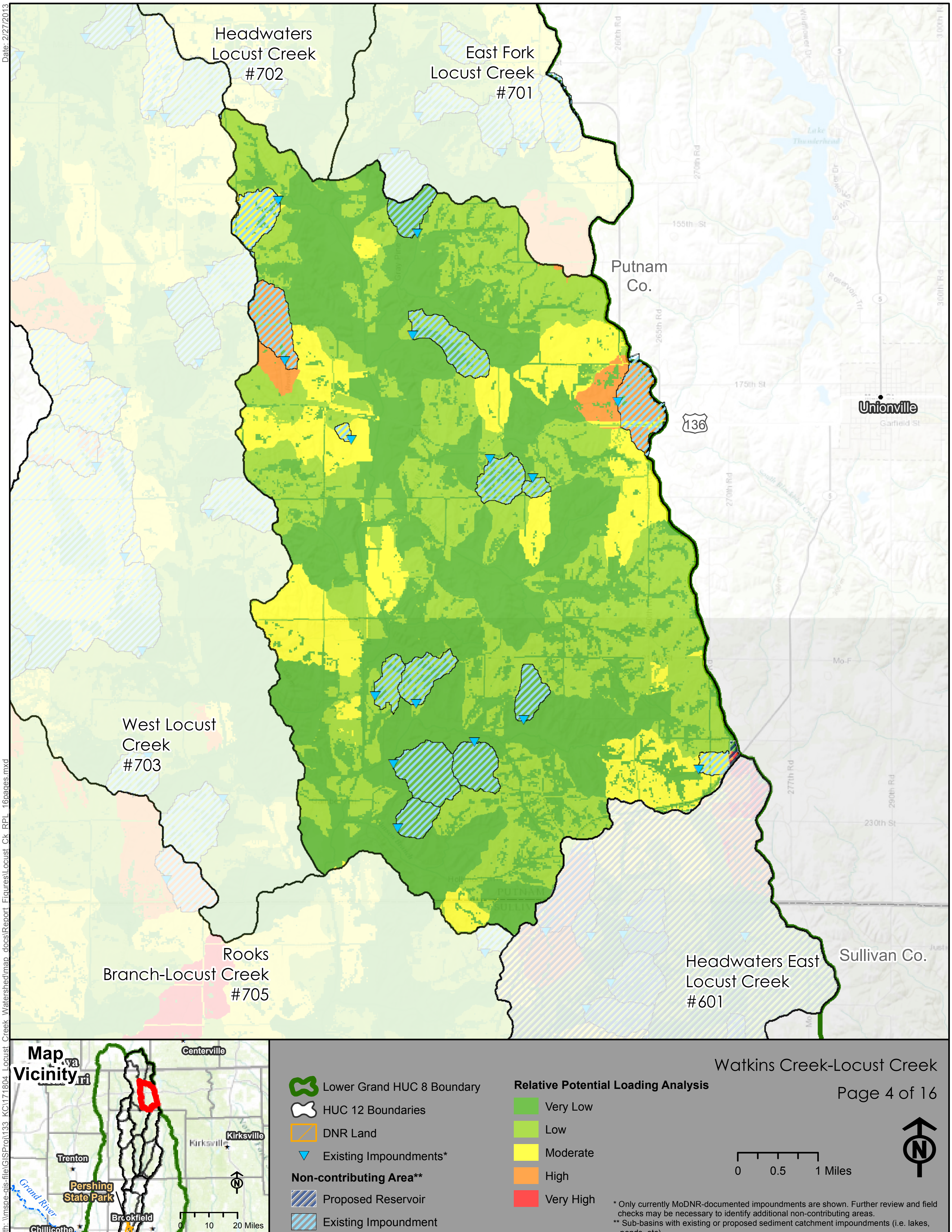


Path: \\mspe-gis-file\GISProj\1333_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_RPL_16pages.mxd



Date: 2/27/2013

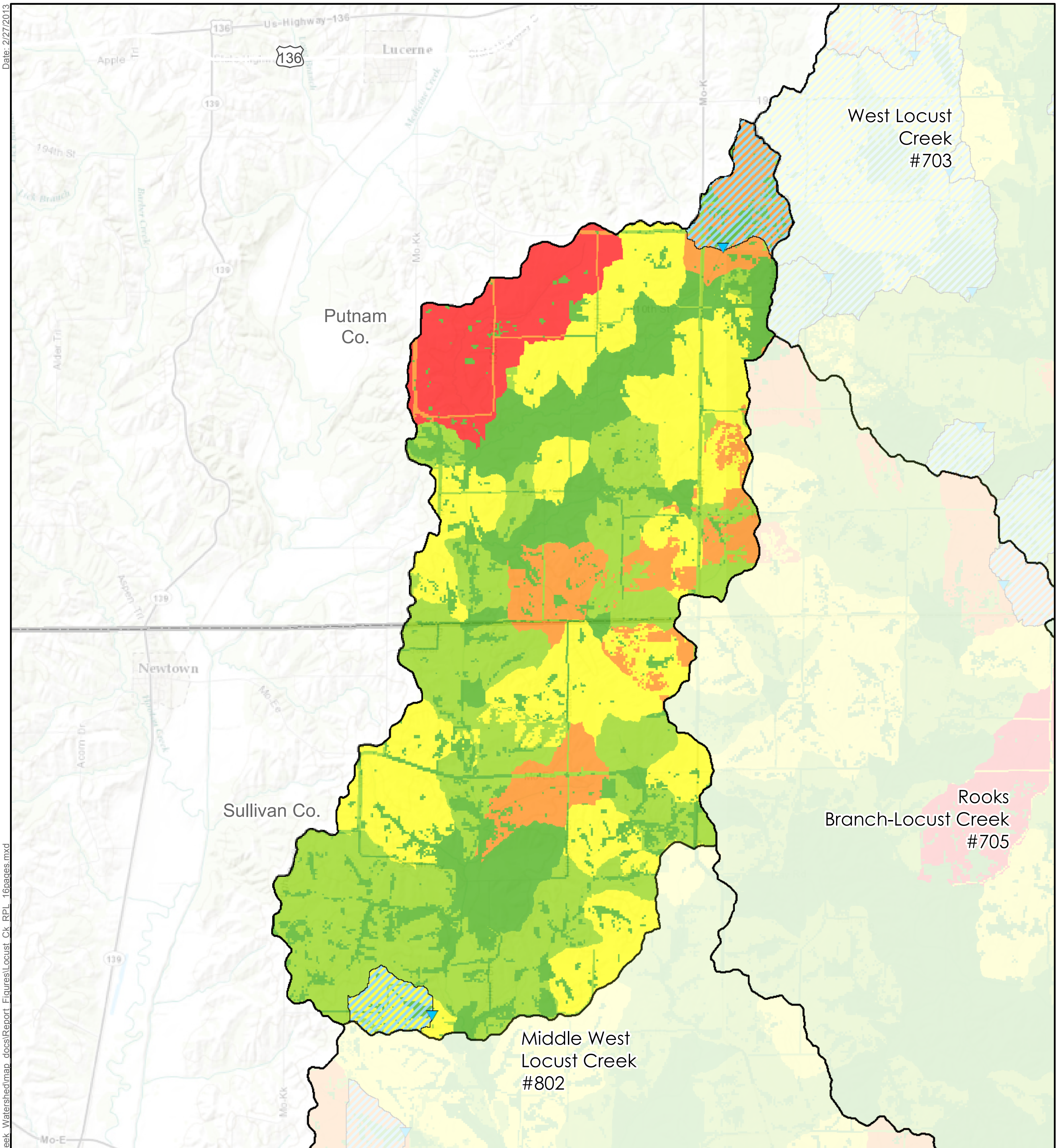
Path: \\mspe-gis-file\GISProj\1333_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_RPL_16pages.mxd

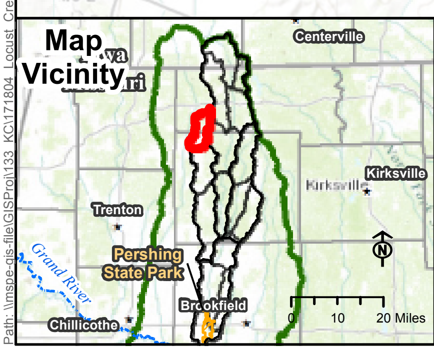


Date: 2/27/2013

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_RPL_16pages.mxd

Date: 2/27/2013





Lower Grand HUC 8 Boundary

HUC 12 Boundaries

DNR Land

Existing Impoundments*

Non-contributing Area**

Proposed Reservoir

Existing Impoundment

Relative Potential Loading Analysis

- Very Low
- Low
- Moderate
- High
- Very High

Upper West Locust Creek

Page 5 of 16

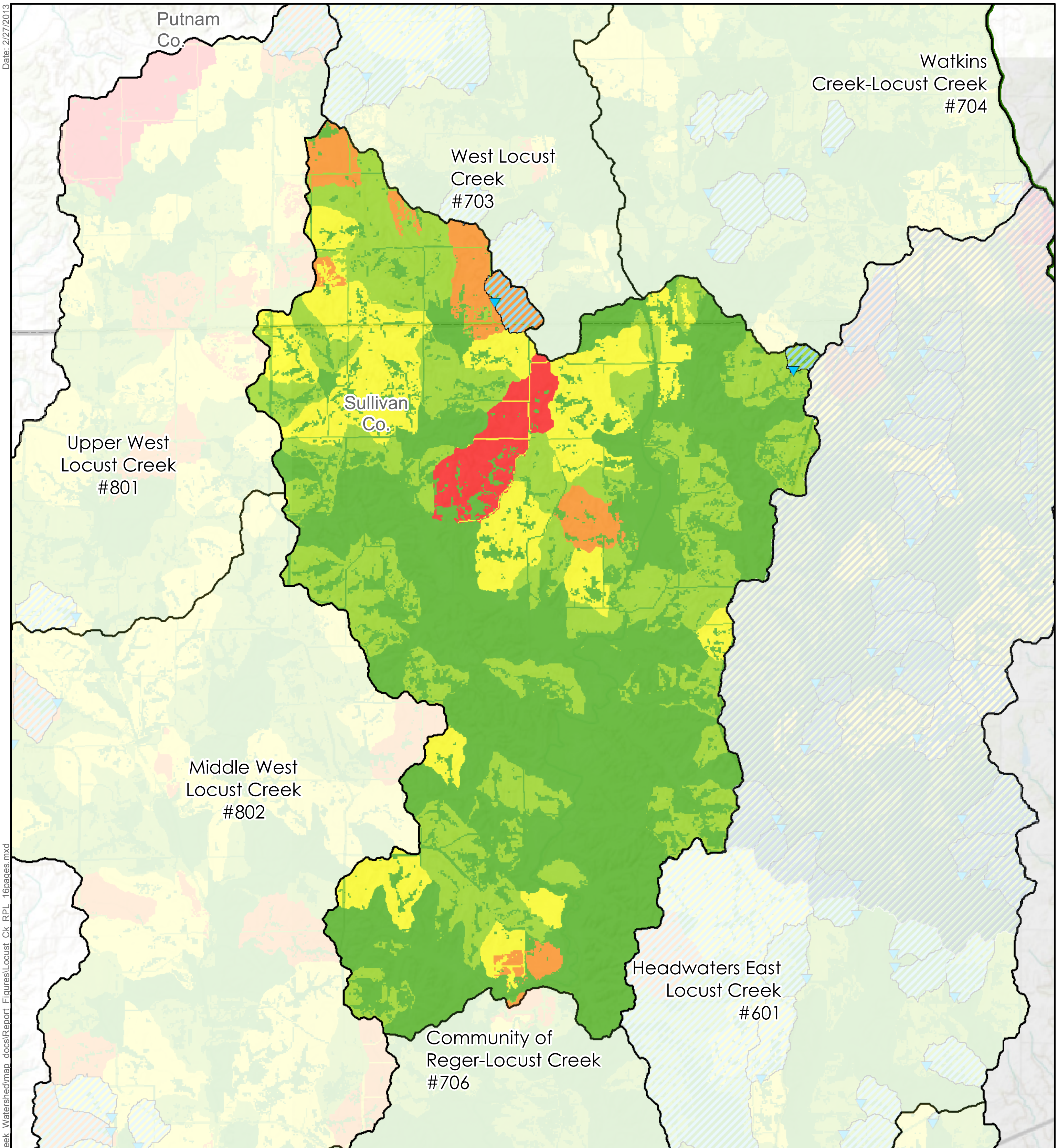
0 0.5 1 Miles

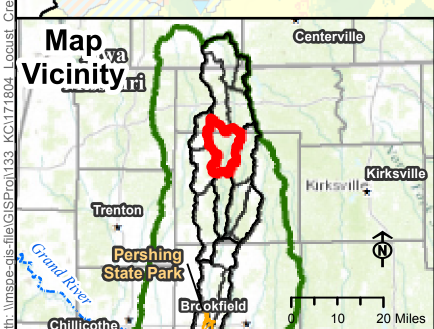
N

* Only currently MoDNR-documented impoundments are shown. Further review and field checks may be necessary to identify additional non-contributing areas.

** Sub-basins with existing or proposed sediment catchment impoundments (i.e. lakes, ponds, etc).

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_RPL_16pages.mxd





Rooks Branch-Locust Creek

- Lower Grand HUC 8 Boundary
- HUC 12 Boundaries
- DNR Land
- Existing Impoundments*

Non-contributing Area**

- Proposed Reservoir
- Existing Impoundment

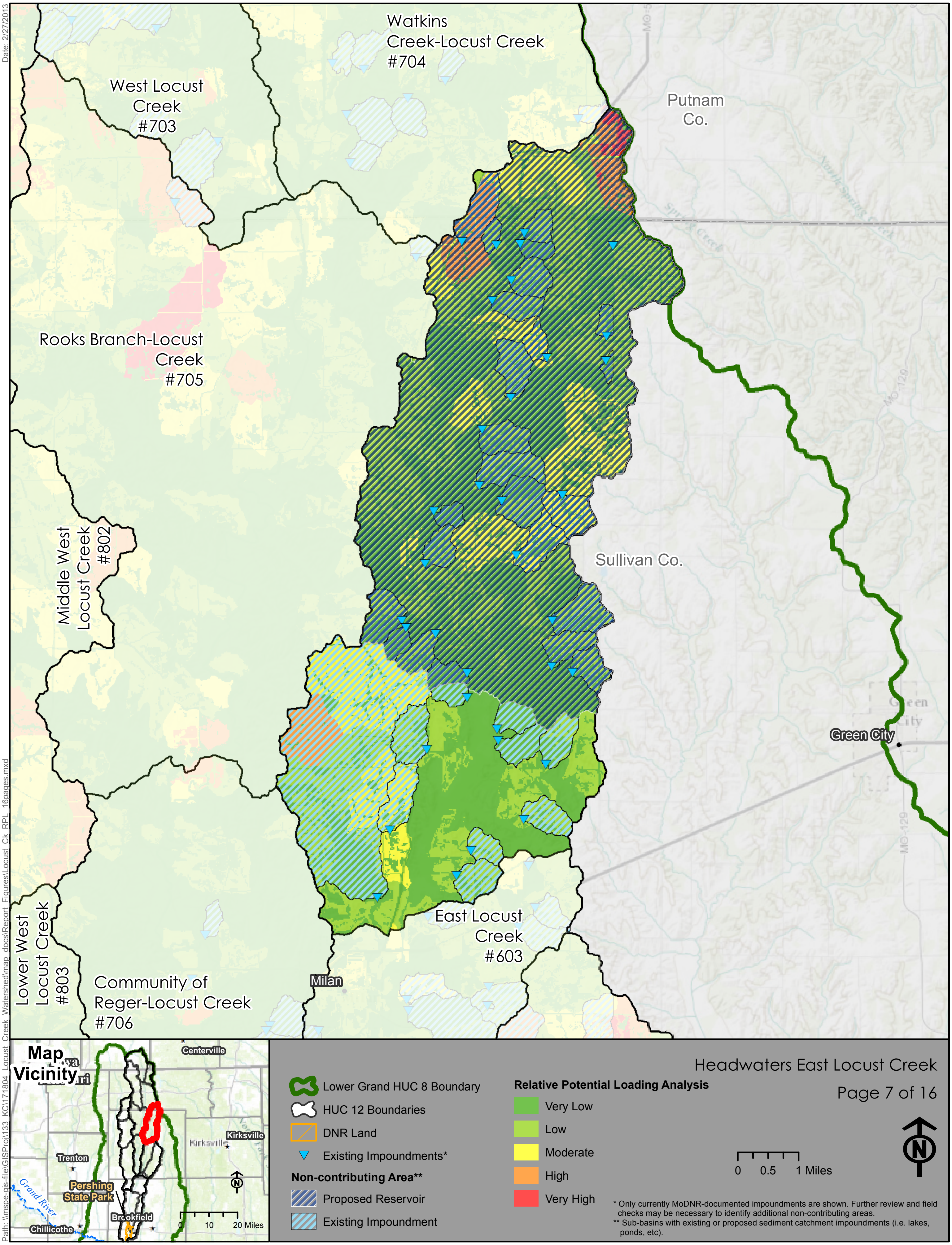
Relative Potential Loading Analysis

- Very Low
- Low
- Moderate
- High
- Very High

0 0.5 1 Miles

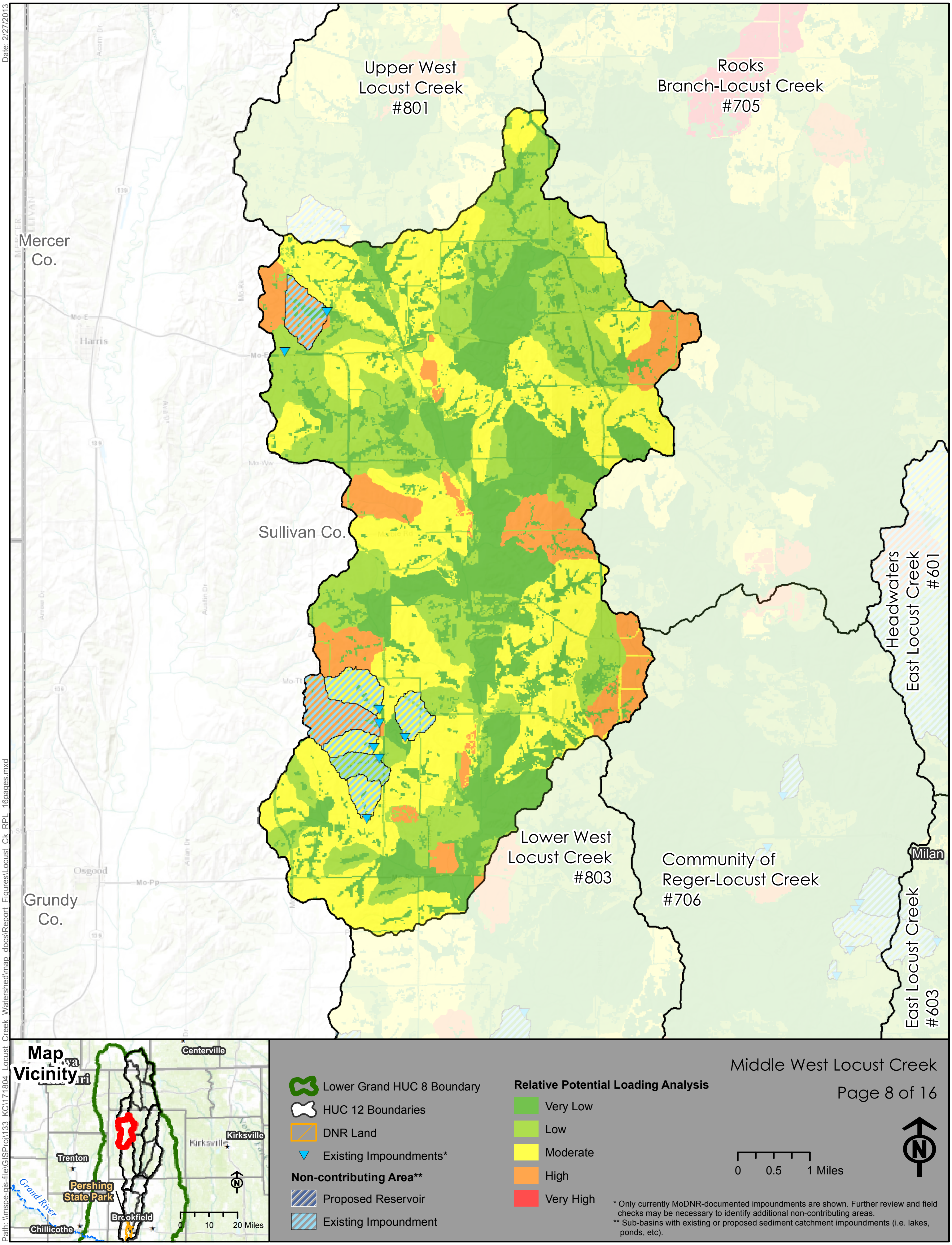
N

* Only currently MoDNR-documented impoundments are shown. Further review and field checks may be necessary to identify additional non-contributing areas.
** Sub-basins with existing or proposed sediment catchment impoundments (i.e. lakes, ponds, etc).



Path: \\mspe-gis-file\GISProj\1338_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_RPL_16pages.mxd

Date: 2/27/2013



Date: 2/27/2013

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_RPL_16pages.mxd

Lower Grand HUC 8 Boundary

HUC 12 Boundaries

DNR Land

Existing Impoundments*

Non-contributing Area**

Proposed Reservoir

Existing Impoundment

Relative Potential Loading Analysis

Very Low

Low

Moderate

High

Very High

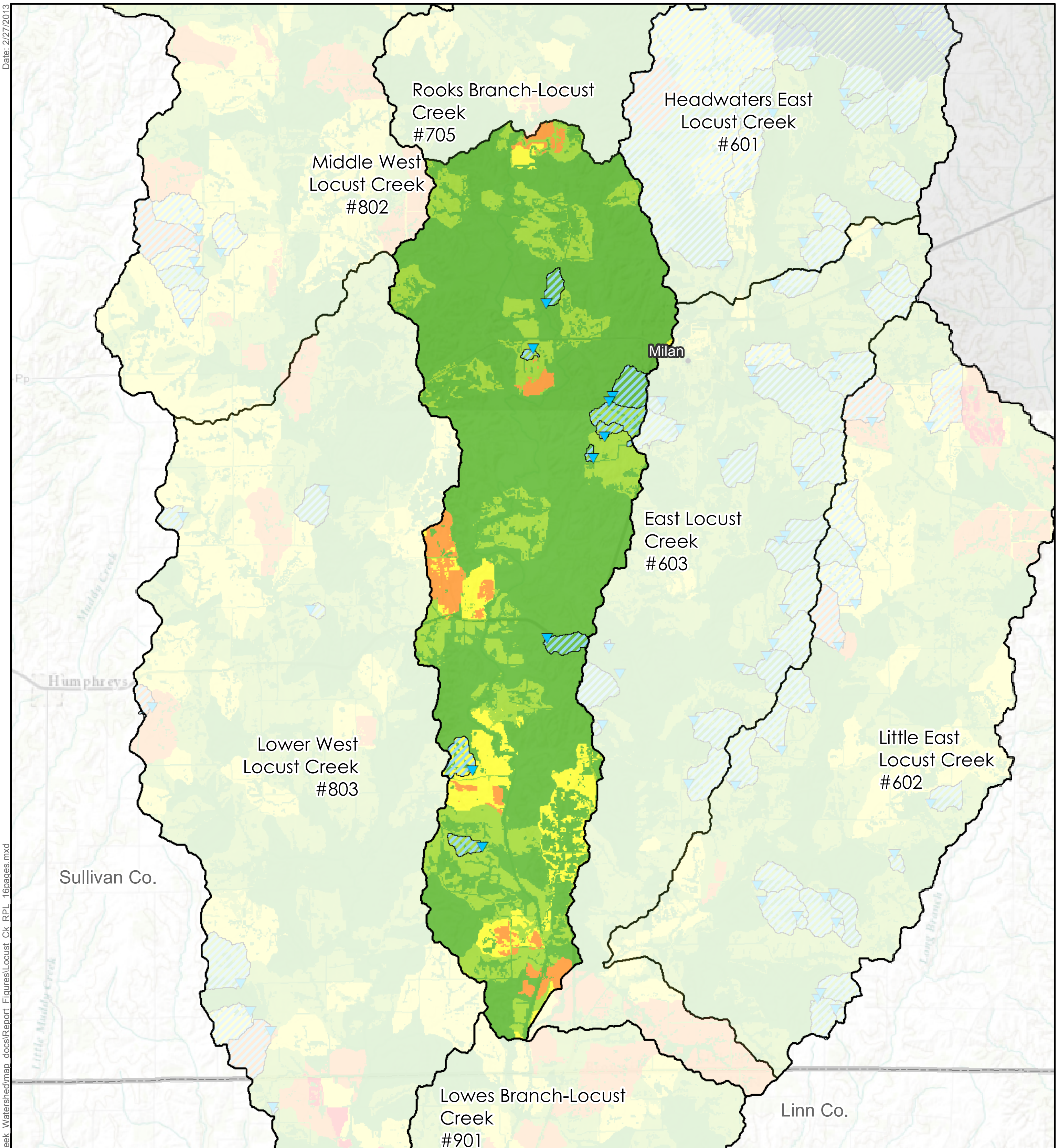
Middle West Locust Creek

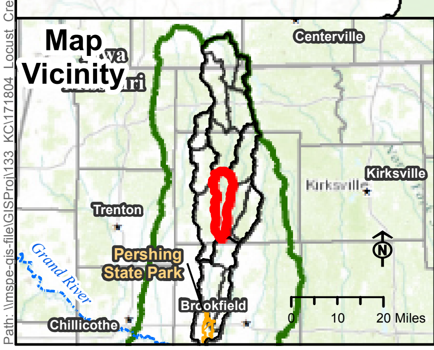
0 0.5 1 Miles

N

* Only currently MoDNR-documented impoundments are shown. Further review and field checks may be necessary to identify additional non-contributing areas.

** Sub-basins with existing or proposed sediment catchment impoundments (i.e. lakes, ponds, etc).





Lower Grand HUC 8 Boundary
HUC 12 Boundaries
DNR Land
Existing Impoundments*

Non-contributing Area**
Proposed Reservoir
Existing Impoundment

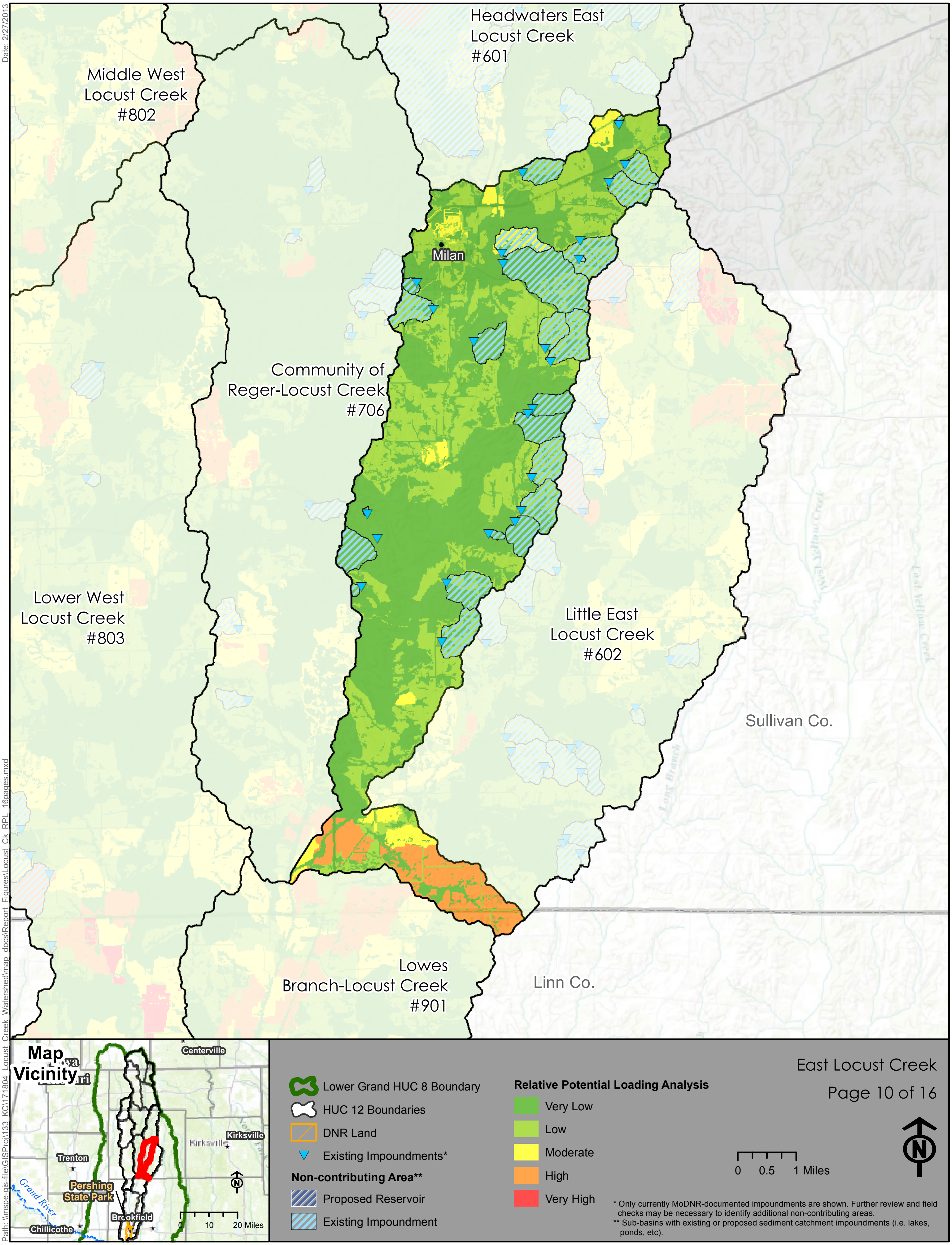
Relative Potential Loading Analysis
Very Low
Low
Moderate
High
Very High

Community of Reger-Locust Creek

0 0.5 1 Miles

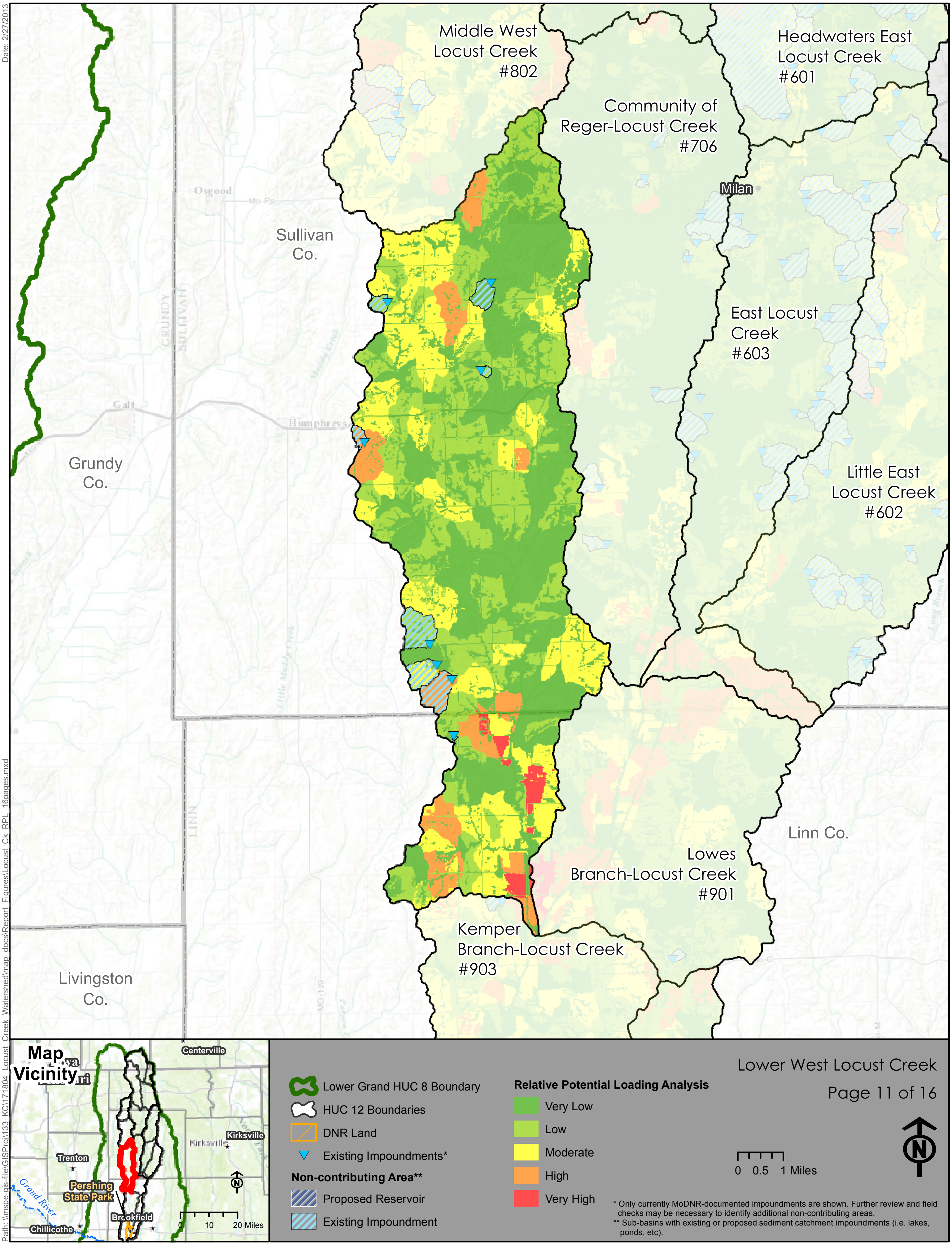
N

* Only currently MoDNR-documented impoundments are shown. Further review and field checks may be necessary to identify additional non-contributing areas.
** Sub-basins with existing or proposed sediment catchment impoundments (i.e. lakes, ponds, etc).



Date: 2/27/2013

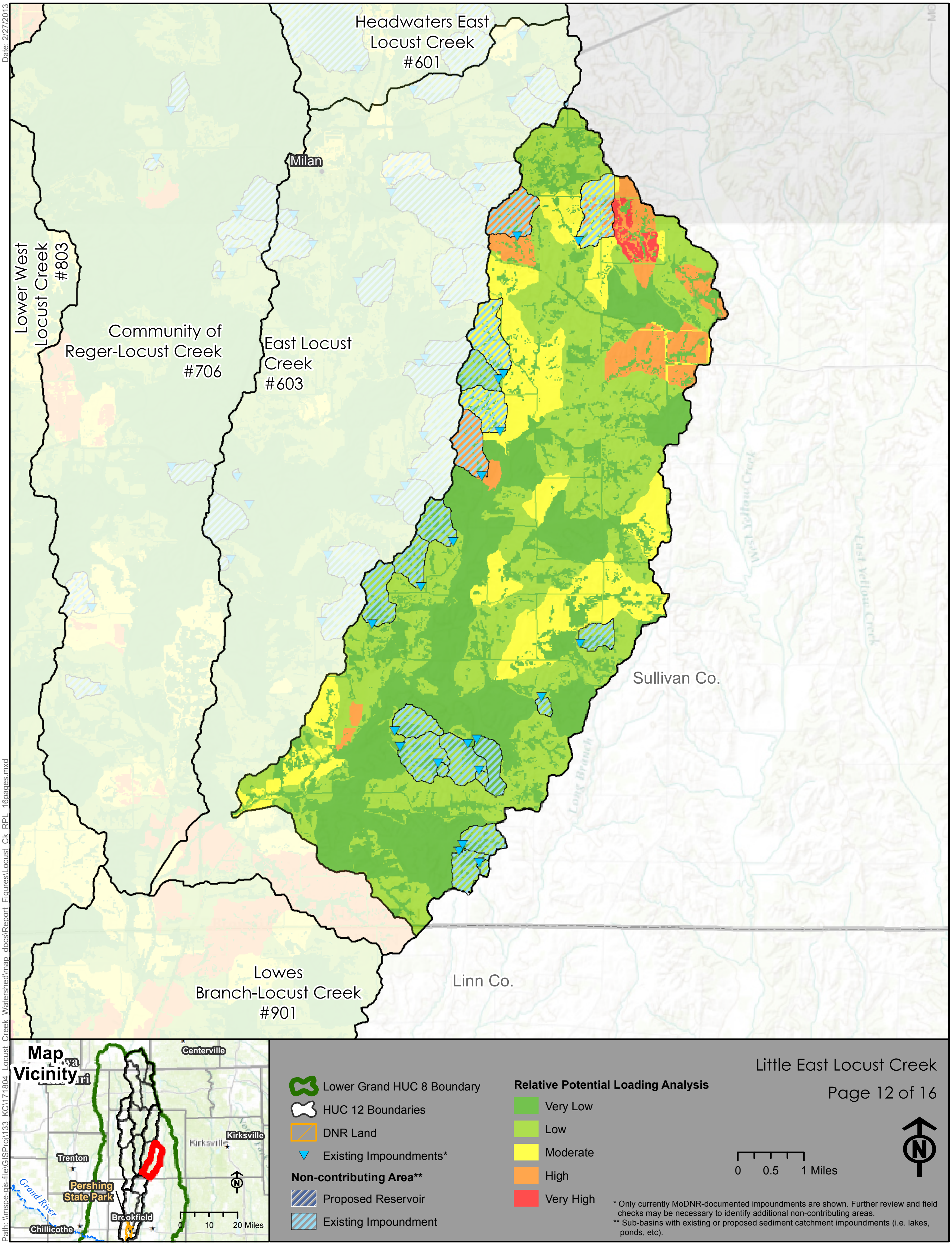
Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_RPL_16pages.mxd



Lower West Locust Creek

Date: 2/27/2013

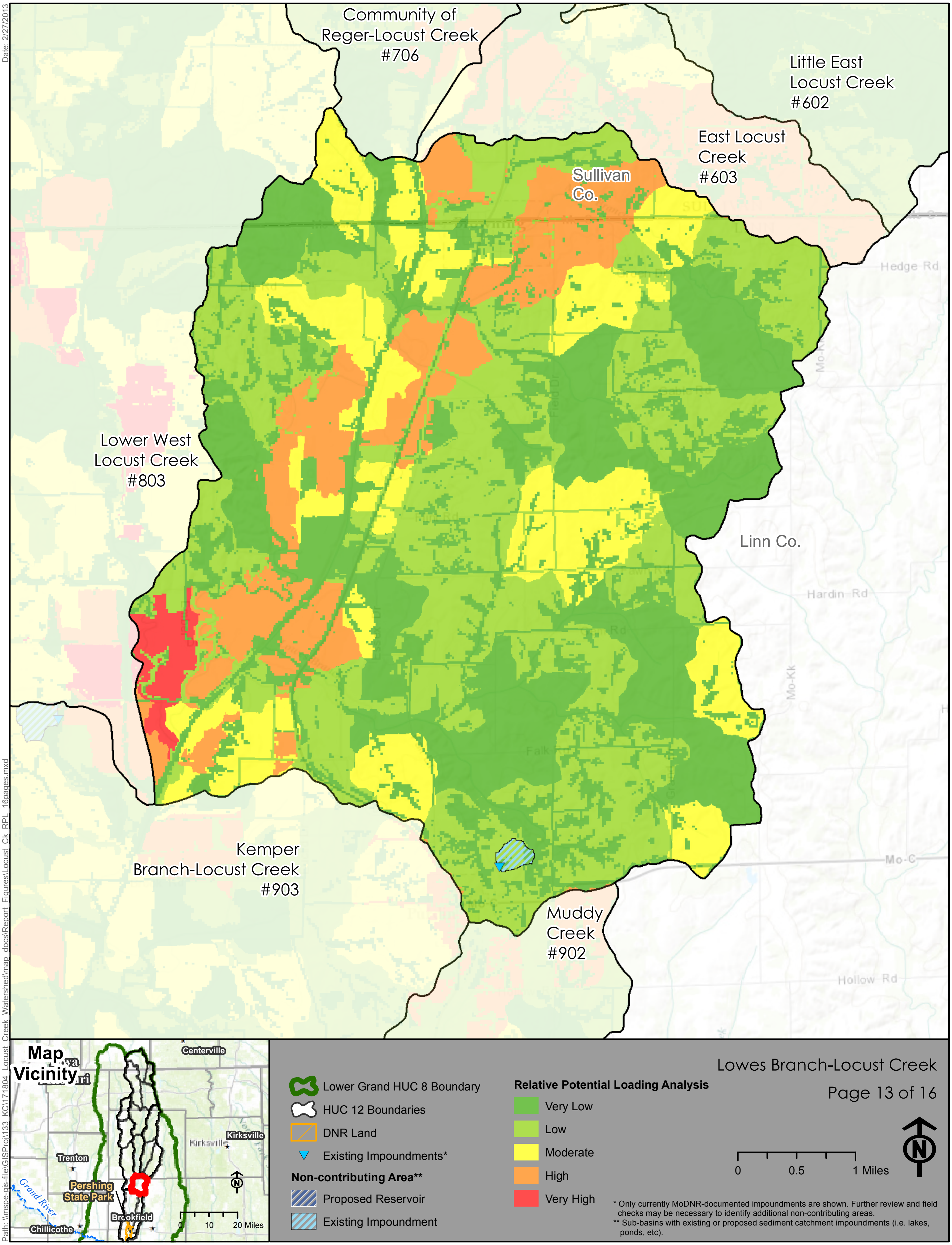
Path: \\mspe-gis-file\GISProj\1333_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_RPL_16pages.mxd



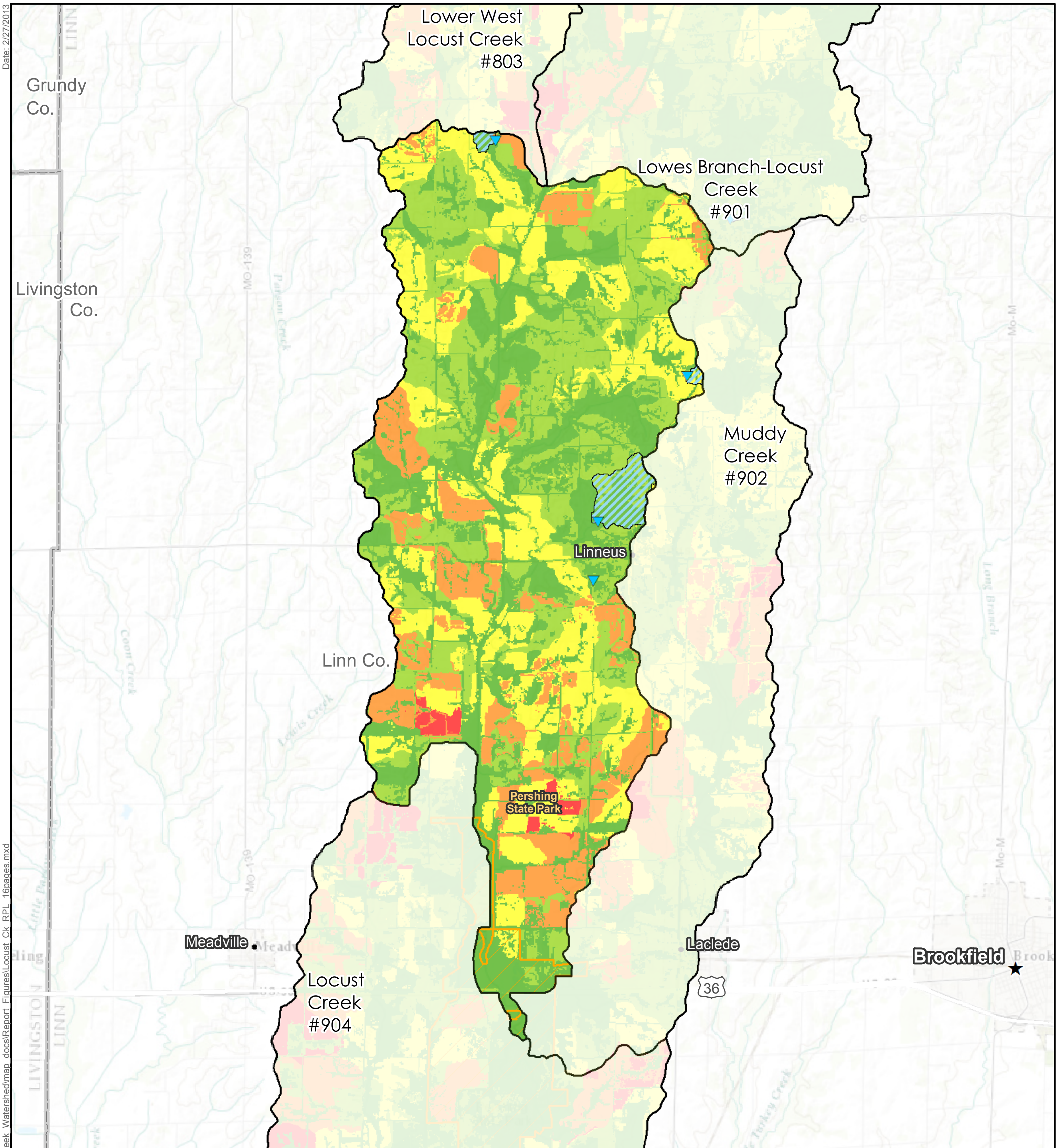
Date: 2/27/2013

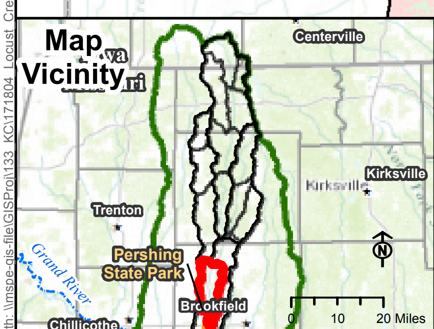
Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_RPL_16pages.mxd

Date: 2/27/2013



Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_RPL_16pages.mxd





Lower Grand HUC 8 Boundary
HUC 12 Boundaries
DNR Land
Existing Impoundments*

Non-contributing Area**
Proposed Reservoir
Existing Impoundment

Relative Potential Loading Analysis
Very Low
Low
Moderate
High
Very High

Kemper Branch-Locust Creek

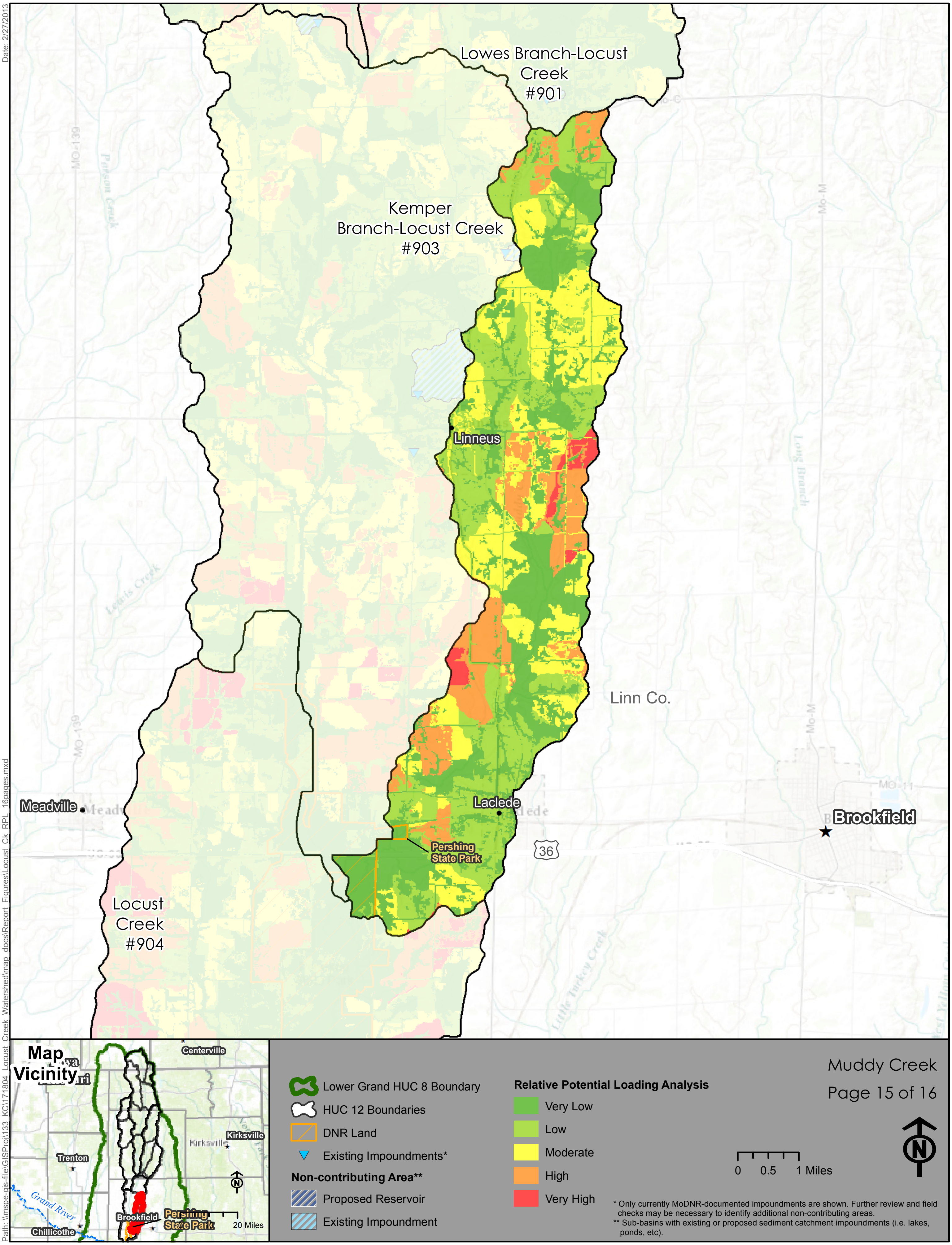
0 0.5 1 Miles

N

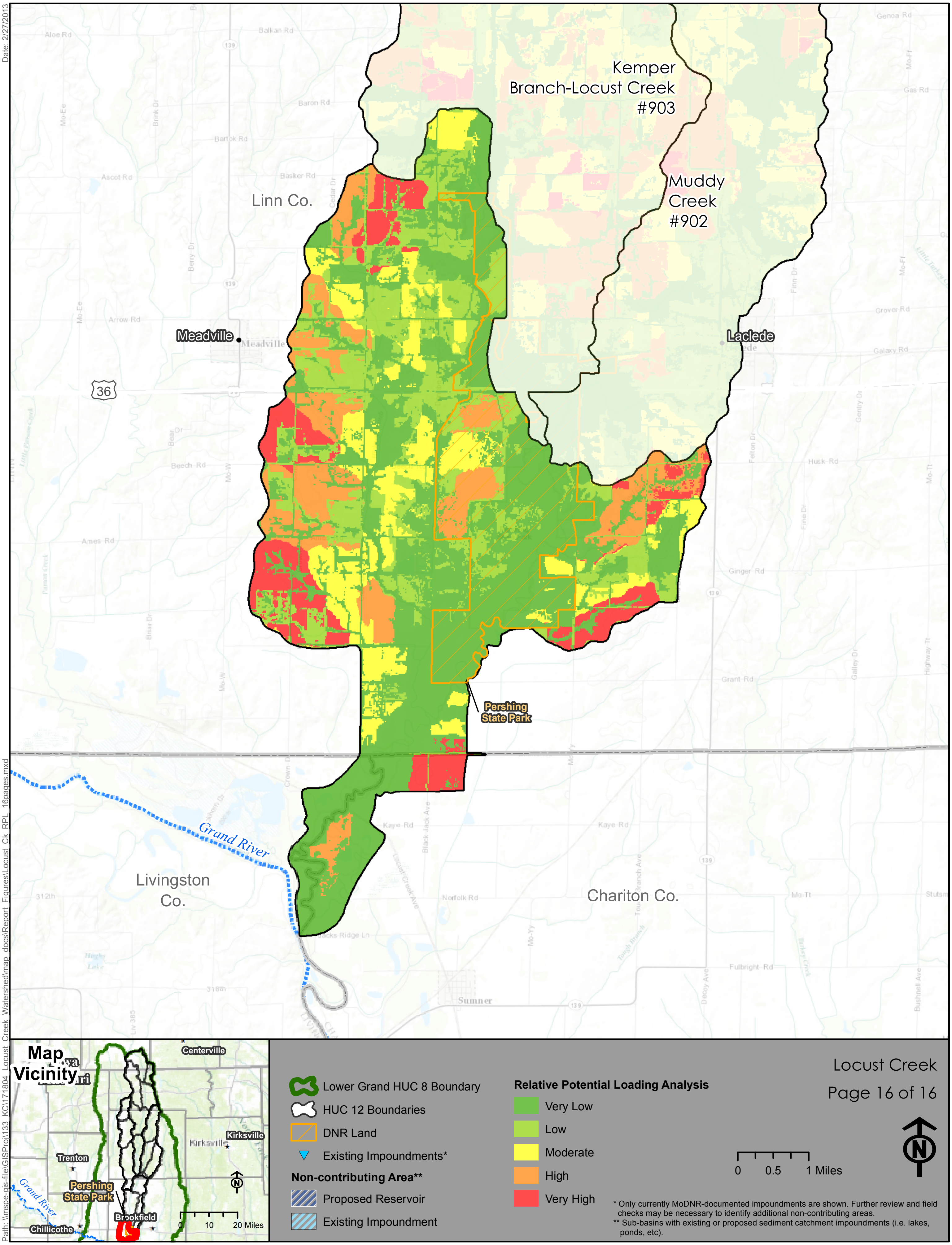
* Only currently MoDNR-documented impoundments are shown. Further review and field checks may be necessary to identify additional non-contributing areas.
** Sub-basins with existing or proposed sediment catchment impoundments (i.e. lakes, ponds, etc).

Date: 2/27/2013
Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_RPL_16pages.mxd

Date: 2/27/2013



Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_RPL_16pages.mxd



Lower Grand HUC 8 Boundary
HUC 12 Boundaries
DNR Land
Existing Impoundments*

Non-contributing Area**

Proposed Reservoir
Existing Impoundment

Relative Potential Loading Analysis

- Very Low
- Low
- Moderate
- High
- Very High

Locust Creek

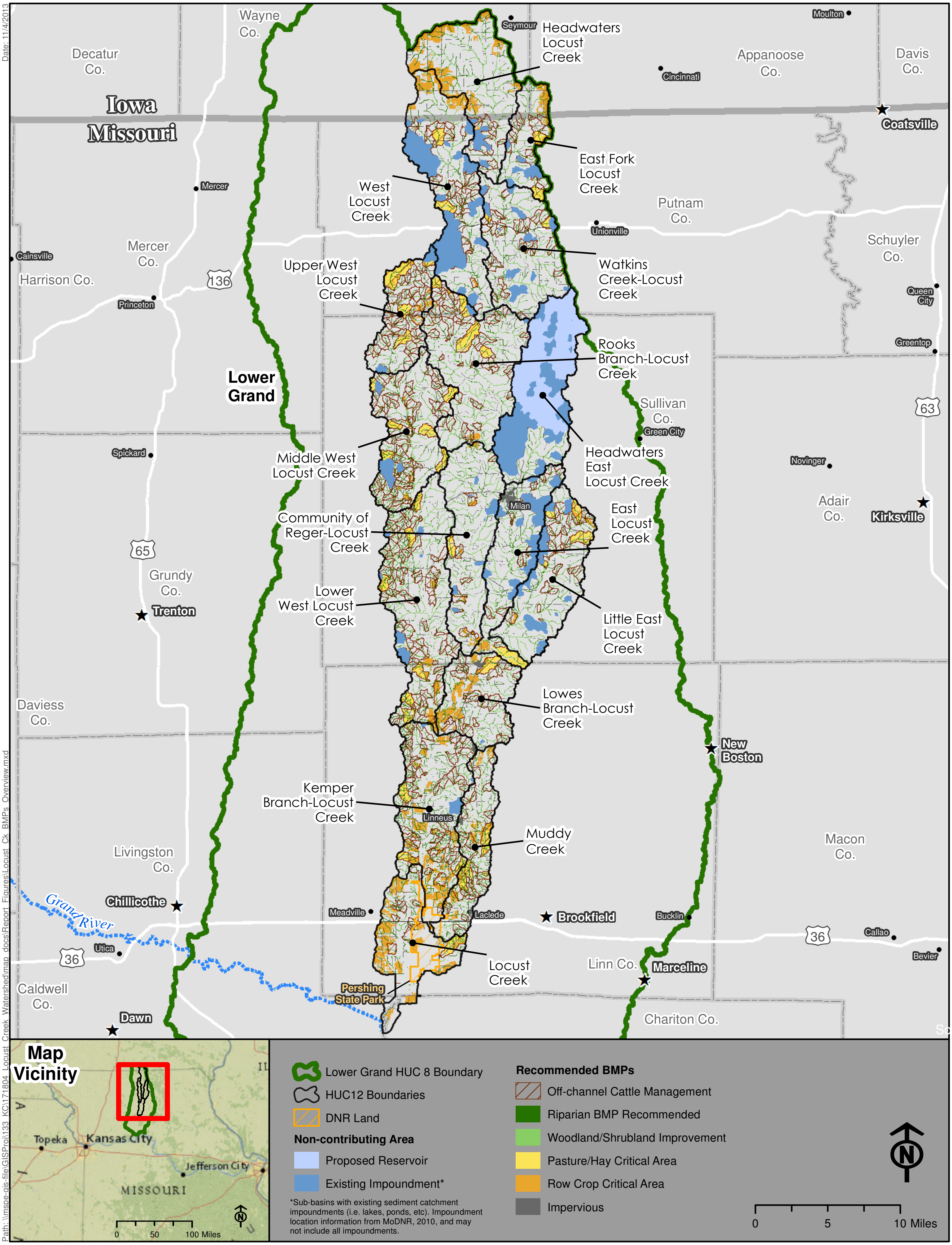
Page 16 of 16

0 0.5 1 Miles

* Only currently MoDNR-documented impoundments are shown. Further review and field checks may be necessary to identify additional non-contributing areas.
** Sub-basins with existing or proposed sediment catchment impoundments (i.e. lakes, ponds, etc).

Date: 2/27/2013

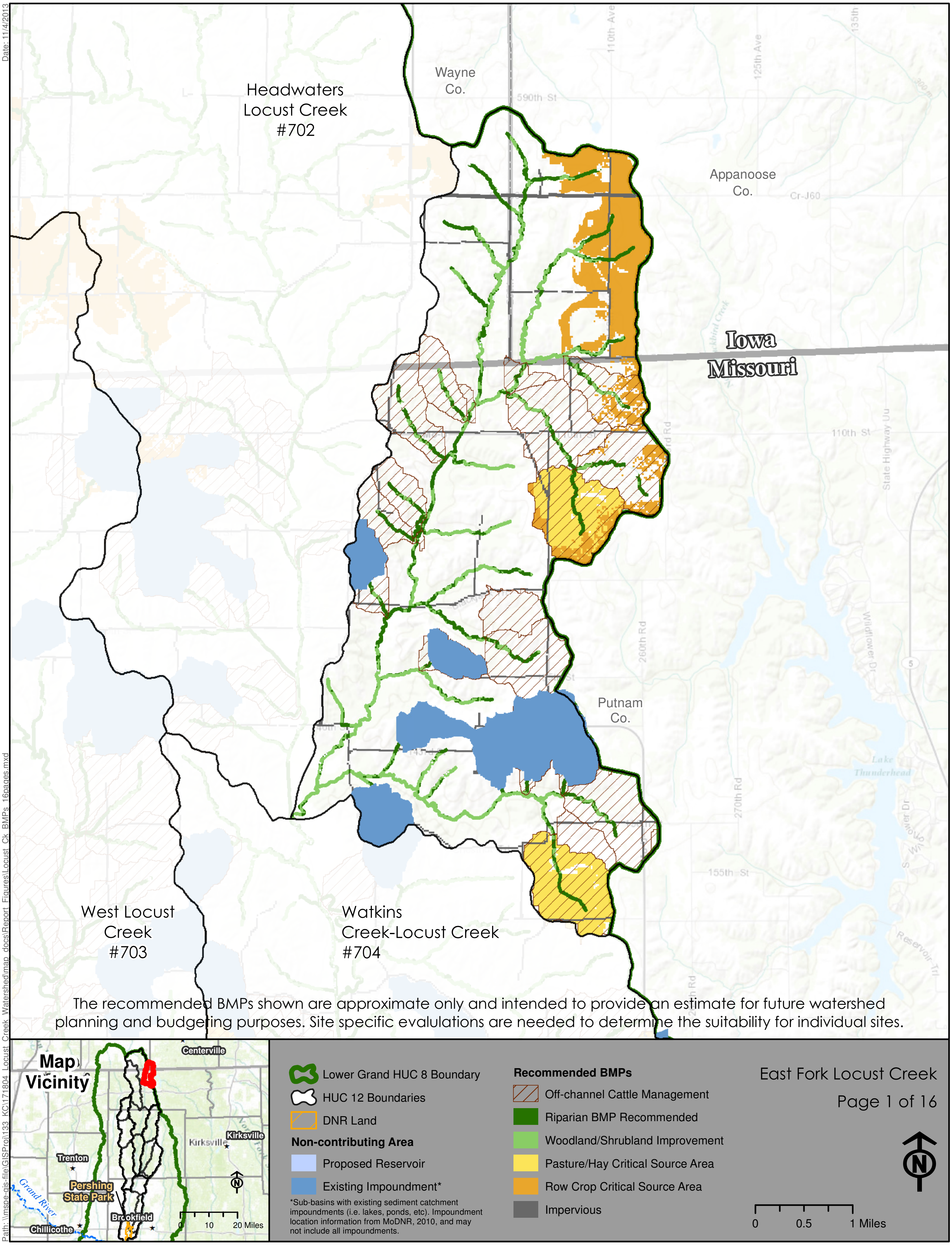
Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_RPL_16pages.mxd



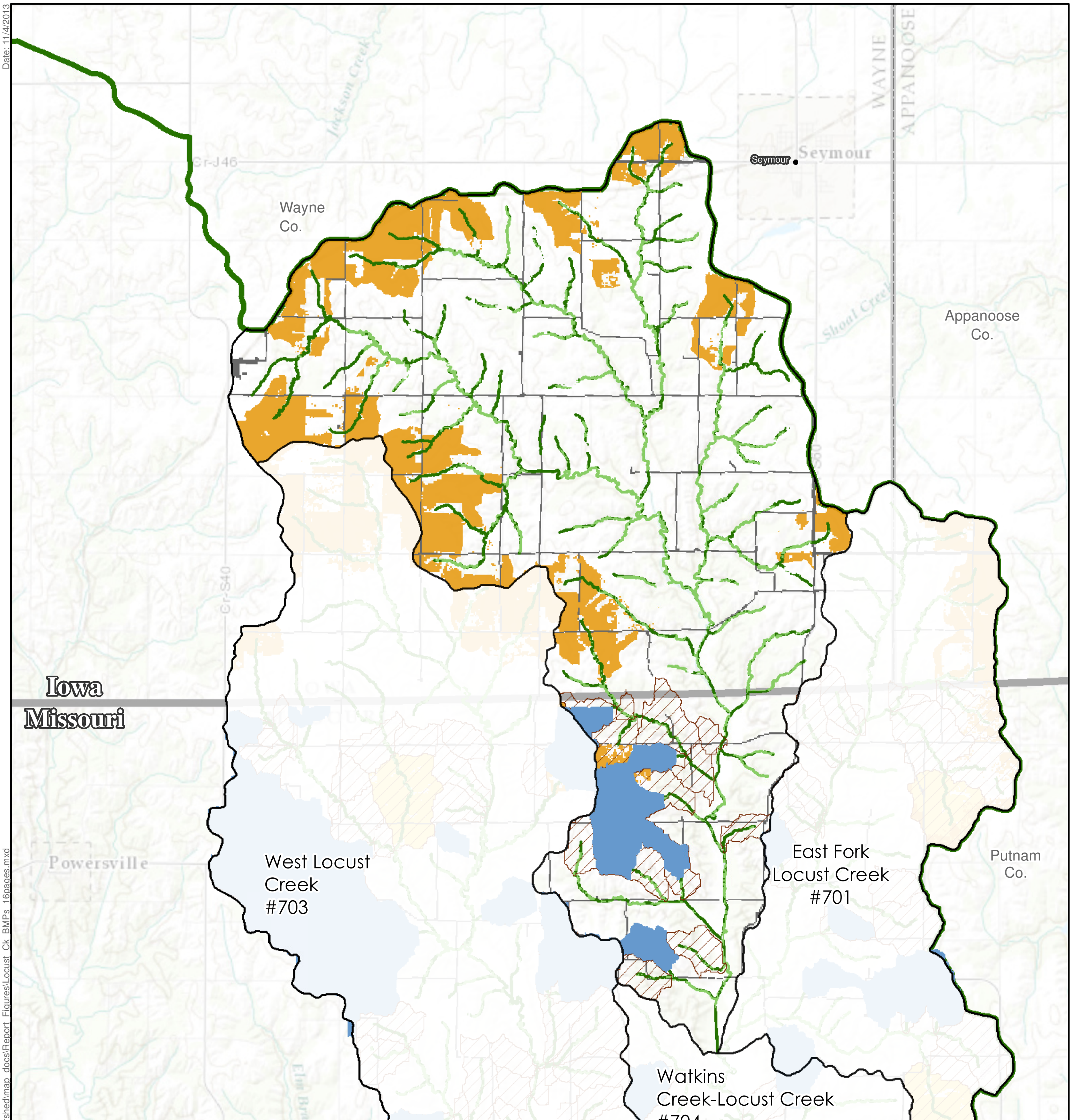
Date: 11/4/2013

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_BMPs_Overview.mxd

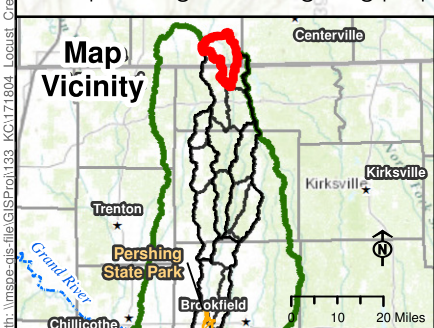
Date: 11/4/2013



Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_BMPs_16pages.mxd



The recommended BMPs shown are approximate only and intended to provide an estimate for future watershed planning and budgeting purposes. Site specific evalutations are needed to determine the suitability for individual sites.



Lower Grand HUC 8 Boundary
HUC 12 Boundaries
DNR Land

Non-contributing Area

Proposed Reservoir
Existing Impoundment*

*Sub-basins with existing sediment catchment impoundments (i.e. lakes, ponds, etc). Impoundment location information from MoDNR, 2010, and may not include all impoundments.

Recommended BMPs

Off-channel Cattle Management
Riparian BMP Recommended
Woodland/Shrubland Improvement
Pasture/Hay Critical Source Area
Row Crop Critical Source Area
Impervious

Headwaters Locust Creek

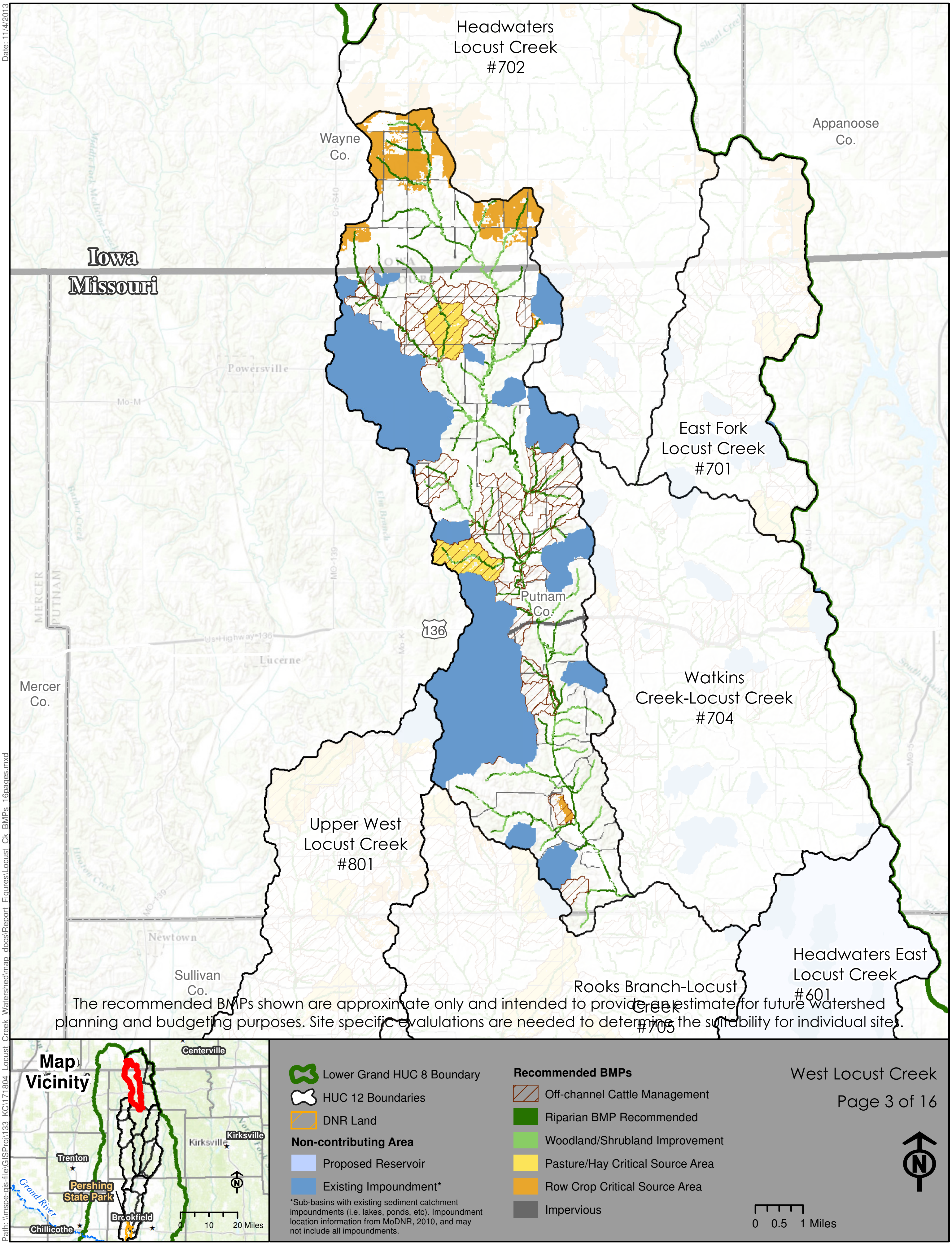
N

0 0.5 1 Miles

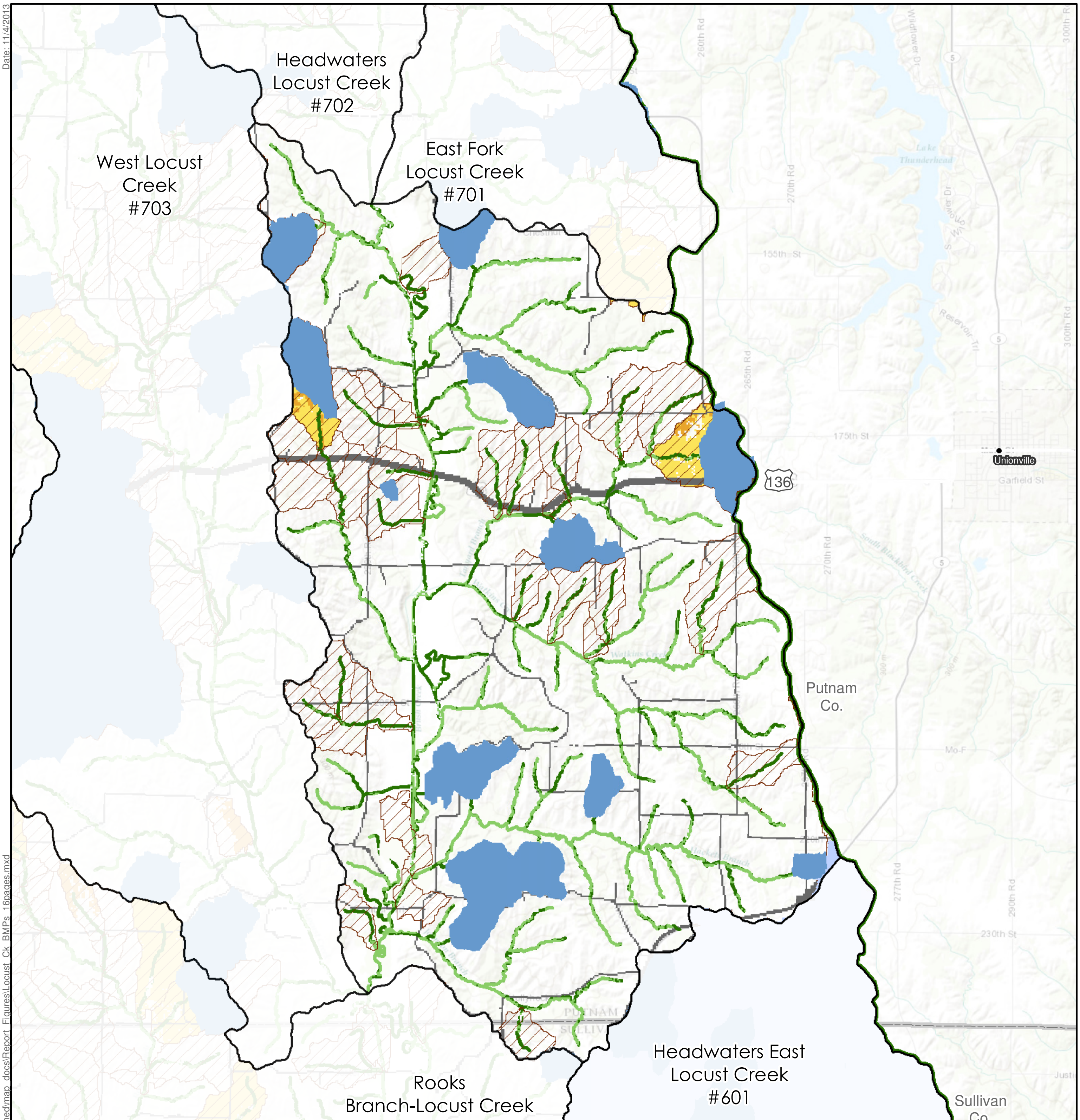
Date: 11/4/2013

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_BMPs_16pages.mxd

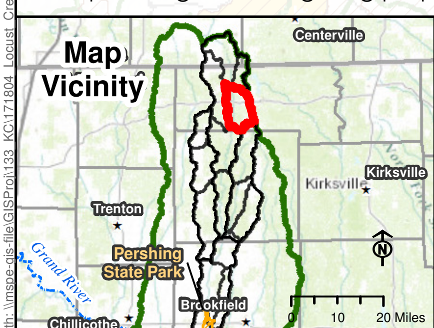
Date: 11/4/2013



Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_BMPs_16pages.mxd



The recommended BMPs shown are approximate only and intended to provide an estimate for future watershed planning and budgeting purposes. Site specific evalulations are needed to determine the suitability for individual sites.



- Lower Grand HUC 8 Boundary
- HUC 12 Boundaries
- DNR Land

Non-contributing Area

- Proposed Reservoir
- Existing Impoundment*

*Sub-basins with existing sediment catchment impoundments (i.e. lakes, ponds, etc). Impoundment location information from MoDNR, 2010, and may not include all impoundments.

Recommended BMPs

- Off-channel Cattle Management
- Riparian BMP Recommended
- Woodland/Shrubland Improvement
- Pasture/Hay Critical Source Area
- Row Crop Critical Source Area
- Impervious

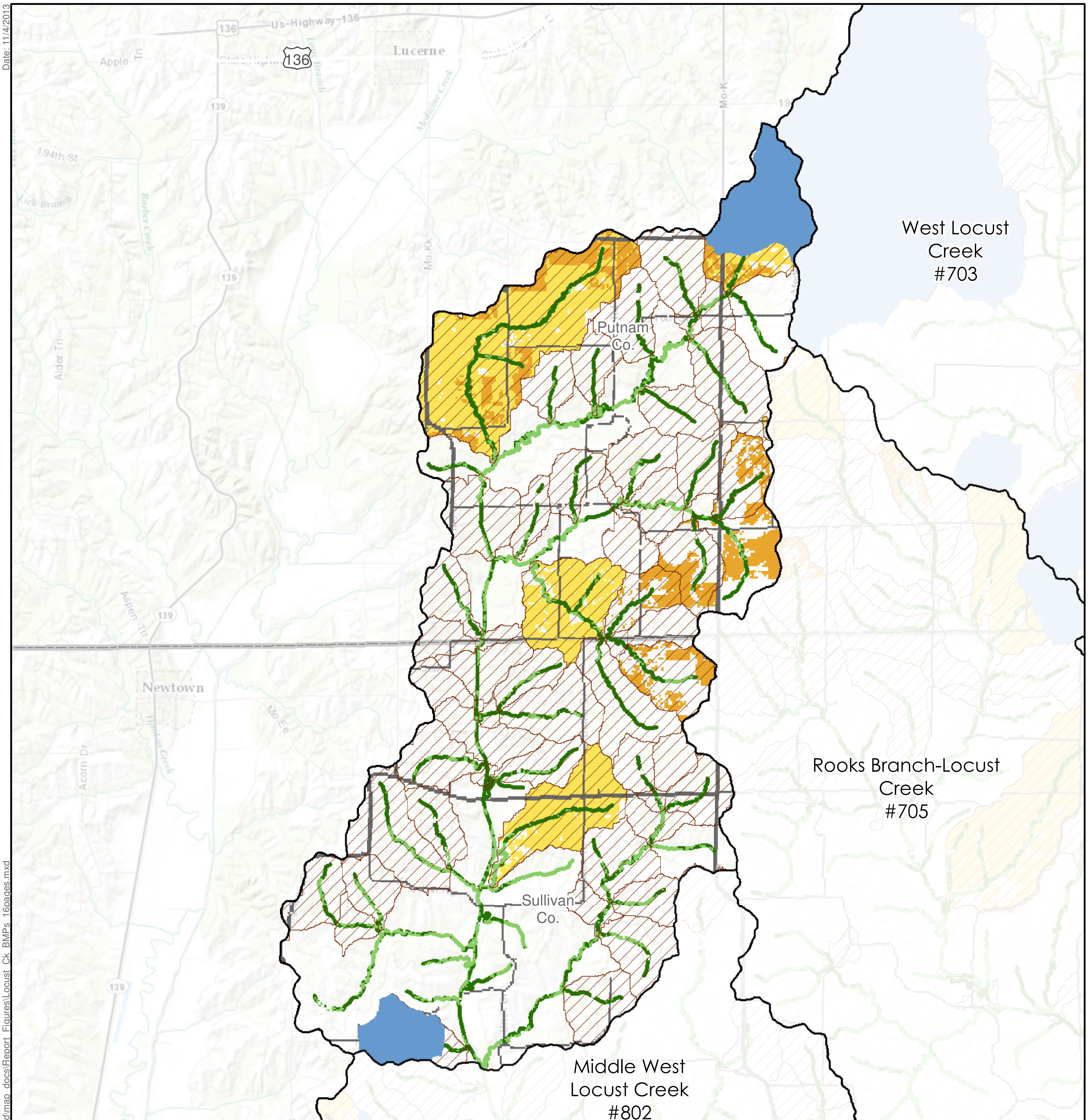
Watkins Creek-Locust Creek

0 0.5 1 Miles

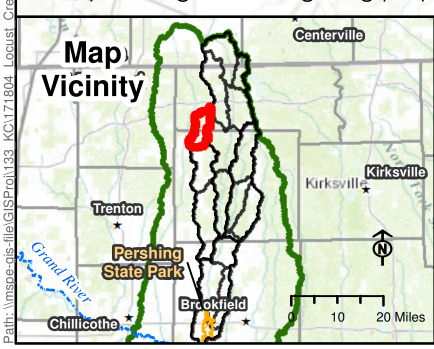
Date: 11/4/2013

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_BMPs_16pages.mxd

Date: 11/4/2013



The recommended BMPs shown are approximate only and intended to provide an estimate for future watershed planning and budgeting purposes. Site specific evalulations are needed to determine the suitability for individual sites.



Lower Grand HUC 8 Boundary
HUC 12 Boundaries
DNR Land

Non-contributing Area

Proposed Reservoir
Existing Impoundment*

*Sub-basins with existing sediment catchment impoundments (i.e. lakes, ponds, etc). Impoundment location information from MoDNR, 2010, and may not include all impoundments.

Recommended BMPs

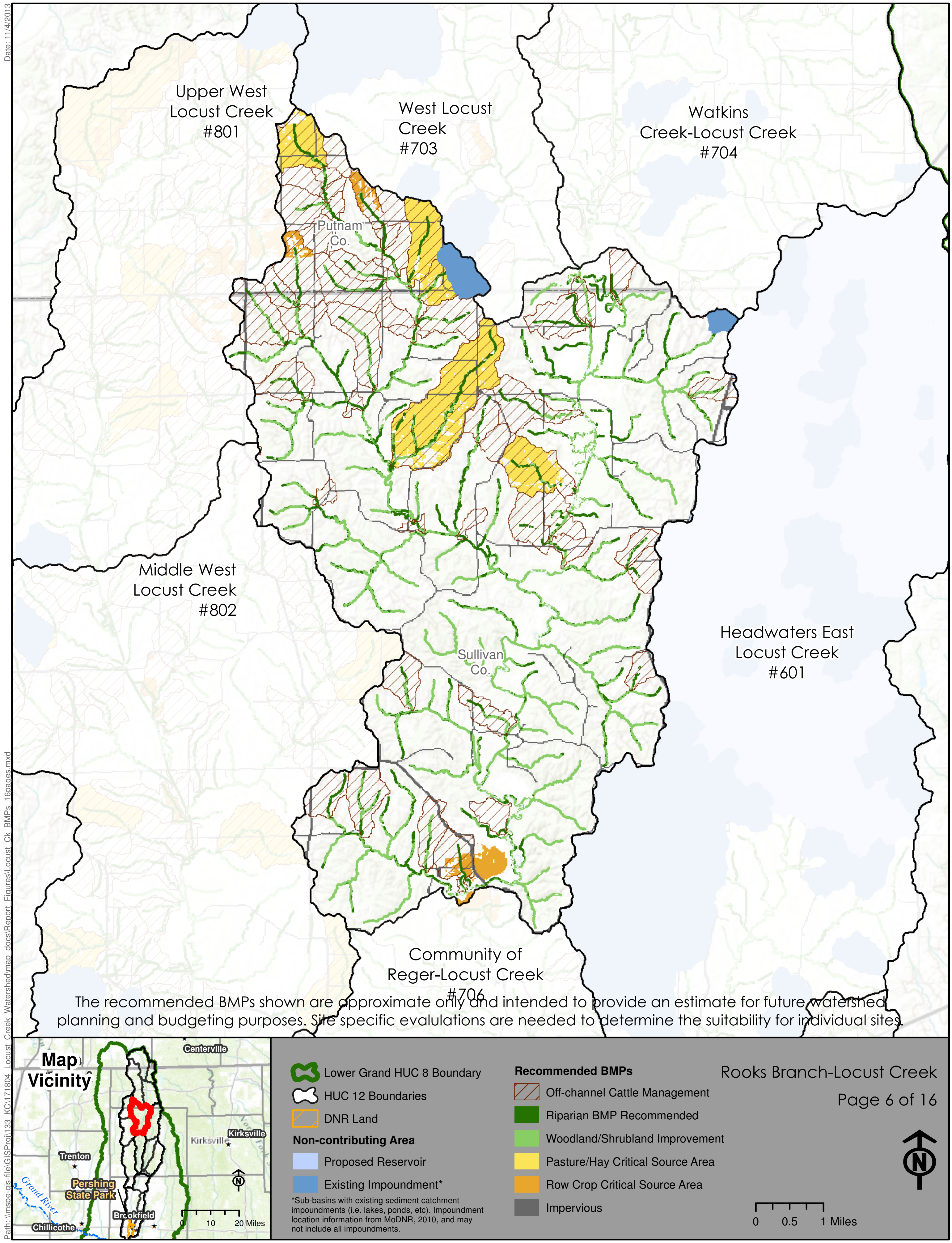
Off-channel Cattle Management
Riparian BMP Recommended
Woodland/Shrubland Improvement
Pasture/Hay Critical Source Area
Row Crop Critical Source Area
Impervious

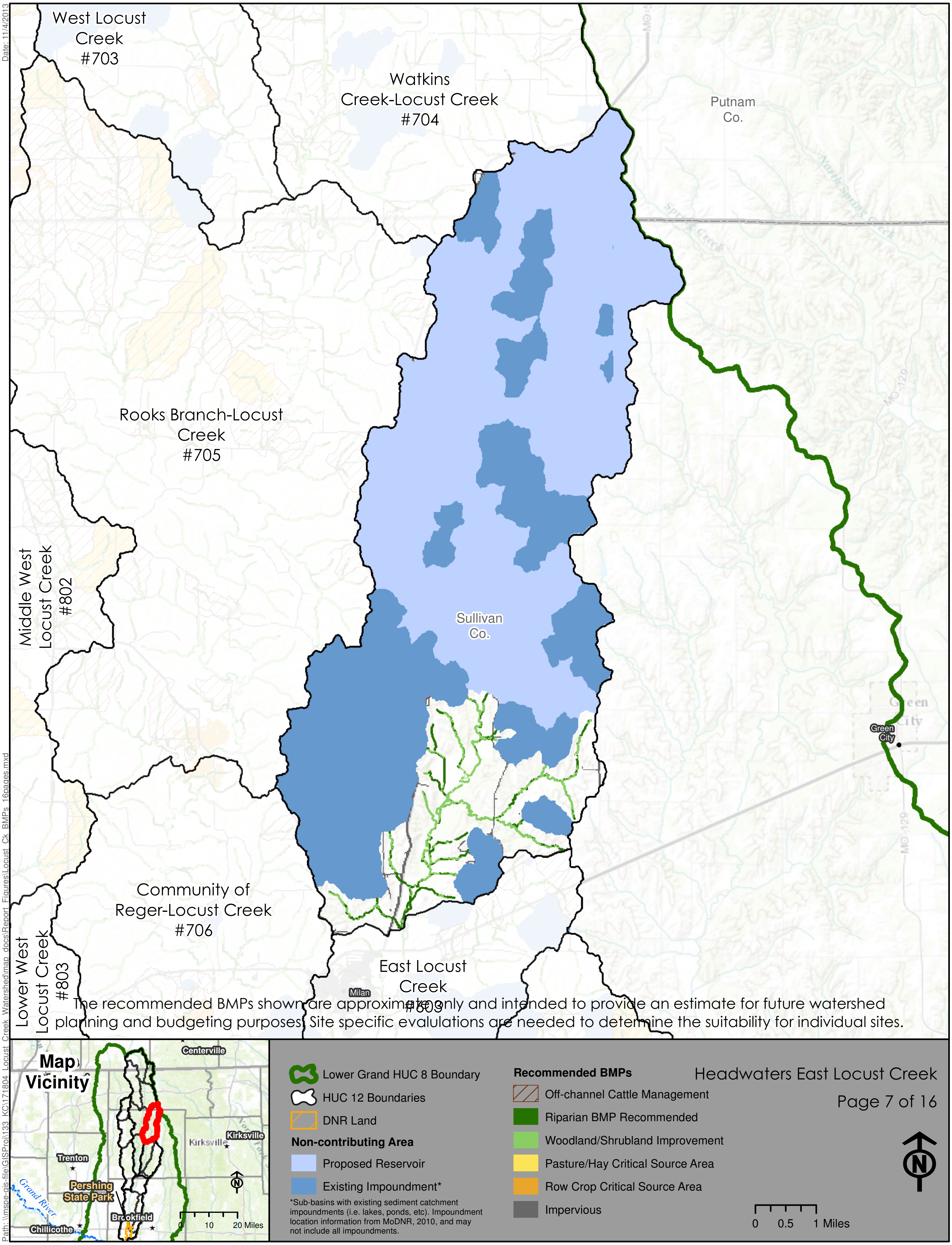
Upper West Locust Creek

N

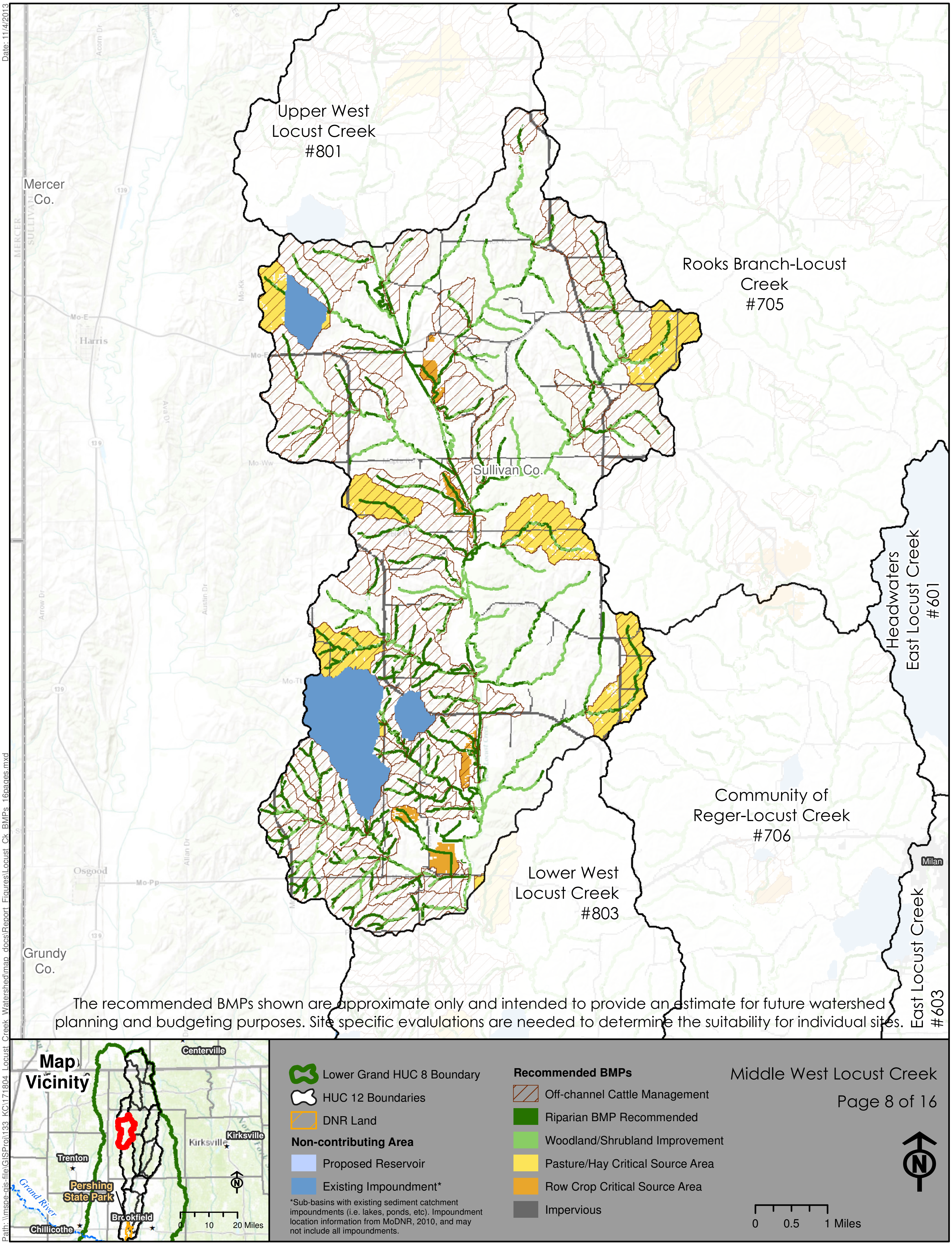
0 0.5 1 Miles

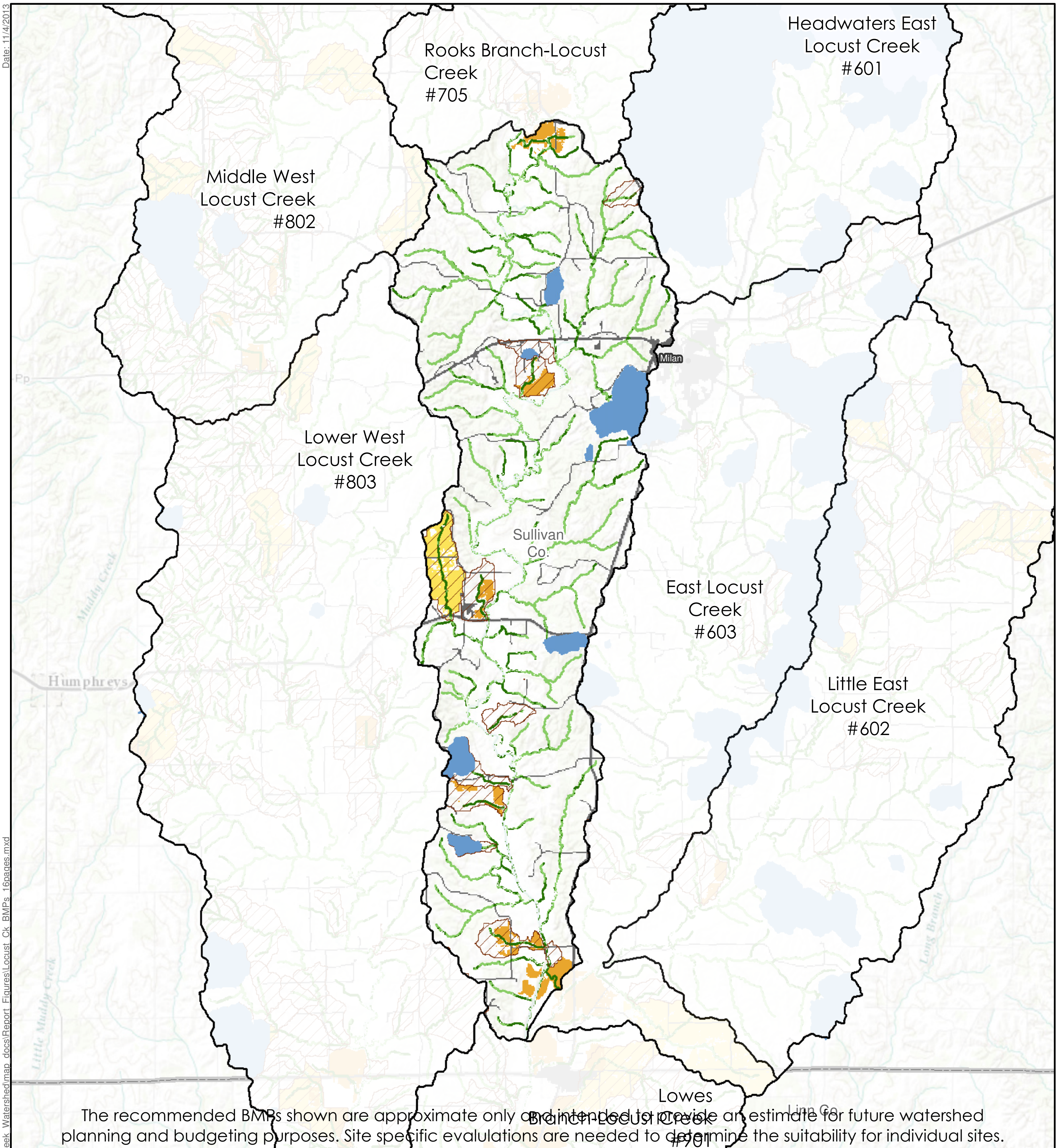
Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_BMPs_16pages.mxd


Upper West
Locust Creek
#801
West Locust
Creek
#703
Watkins
Creek-Locust Creek
#704
Putnam
Co.
Middle West
Locust Creek
#802
Headwaters East
Locust Creek
#601
Sullivan
Co.
Community of
Reger-Locust Creek
#706
The recommended BMPs shown are approximate only and intended to provide an estimate for future watershed planning and budgeting purposes. Site specific evalulations are needed to determine the suitability for individual sites.
Map
Vicinity
Centerville
Kirksville
Kirksville
Trenton
Pershing
State Park
Grand River
Brookfield
Chillicothe
0
10
20 Miles
Lower Grand HUC 8 Boundary
HUC 12 Boundaries
DNR Land
Non-contributing Area
Proposed Reservoir
Existing Impoundment*
*Sub-basins with existing sediment catchment impoundments (i.e. lakes, ponds, etc). Impoundment location information from MoDNR, 2010, and may not include all impoundments.
Recommended BMPs
Off-channel Cattle Management
Riparian BMP Recommended
Woodland/Shrubland Improvement
Pasture/Hay Critical Source Area
Row Crop Critical Source Area
Impervious
Rooks Branch-Locust Creek
Page 6 of 16
N
0
0.5
1 Miles
Date: 11/4/2013
Path: \\mspe-gis-file\GISProj\133 KC\171804 Locust Creek Watershed\map docs\Report Figures\Locust Ck BMPs 16pages.mxd

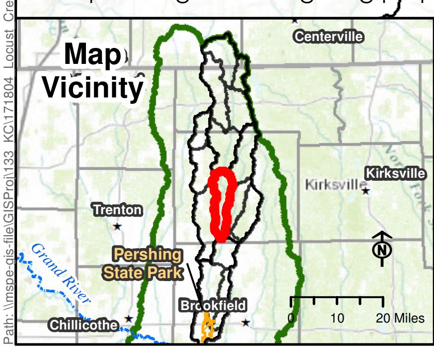


Date: 11/4/2013
West Locust Creek #703
Watkins Creek-Locust Creek #704
Putnam Co.
Rooks Branch-Locust Creek #705
Middle West Locust Creek #802
Sullivan Co.
Green City
Community of Reger-Locust Creek #706
Lower West Locust Creek #803
East Locust Creek #603
Milan
The recommended BMPs shown are approximate only and intended to provide an estimate for future watershed planning and budgeting purposes. Site specific evalulations are needed to determine the suitability for individual sites.
Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_BMPs_16pages.mxd
Map Vicinity
Centerville
Kirksville
Trenton
Pershing State Park
Grand River
Brookfield
Chillicothe
0 10 20 Miles
Lower Grand HUC 8 Boundary
HUC 12 Boundaries
DNR Land
Non-contributing Area
Proposed Reservoir
Existing Impoundment*
*Sub-basins with existing sediment catchment impoundments (i.e. lakes, ponds, etc). Impoundment location information from MoDNR, 2010, and may not include all impoundments.
Recommended BMPs
Off-channel Cattle Management
Riparian BMP Recommended
Woodland/Shrubland Improvement
Pasture/Hay Critical Source Area
Row Crop Critical Source Area
Impervious
Headwaters East Locust Creek
Page 7 of 16
0 0.5 1 Miles


Upper West Locust Creek #801
Rooks Branch-Locust Creek #705
Headwaters East Locust Creek #601
Community of Reger-Locust Creek #706
Lower West Locust Creek #803
East Locust Creek #603
Mercer Co.
Sullivan Co.
Grundy Co.
Harris
Osgood
Milan
The recommended BMPs shown are approximate only and intended to provide an estimate for future watershed planning and budgeting purposes. Site specific evalulations are needed to determine the suitability for individual sites.
Map Vicinity
Centerville
Kirksville
Trenton
Pershing State Park
Grand River
Brookfield
Chillicothe
0 10 20 Miles
Lower Grand HUC 8 Boundary
HUC 12 Boundaries
DNR Land
Non-contributing Area
Proposed Reservoir
Existing Impoundment*
*Sub-basins with existing sediment catchment impoundments (i.e. lakes, ponds, etc). Impoundment location information from MoDNR, 2010, and may not include all impoundments.
Recommended BMPs
Off-channel Cattle Management
Riparian BMP Recommended
Woodland/Shrubland Improvement
Pasture/Hay Critical Source Area
Row Crop Critical Source Area
Impervious
Middle West Locust Creek
Page 8 of 16
0 0.5 1 Miles
Date: 11/4/2013
Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_BMPs_16pages.mxd



The recommended BMPs shown are approximate only and intended to provide an estimate for future watershed planning and budgeting purposes. Site specific evalulations are needed to determine the suitability for individual sites.



Lower Grand HUC 8 Boundary

HUC 12 Boundaries

DNR Land

Non-contributing Area

Proposed Reservoir

Existing Impoundment*

*Sub-basins with existing sediment catchment impoundments (i.e. lakes, ponds, etc). Impoundment location information from MoDNR, 2010, and may not include all impoundments.

Recommended BMPs

Off-channel Cattle Management

Riparian BMP Recommended

Woodland/Shrubland Improvement

Pasture/Hay Critical Source Area

Row Crop Critical Source Area

Impervious

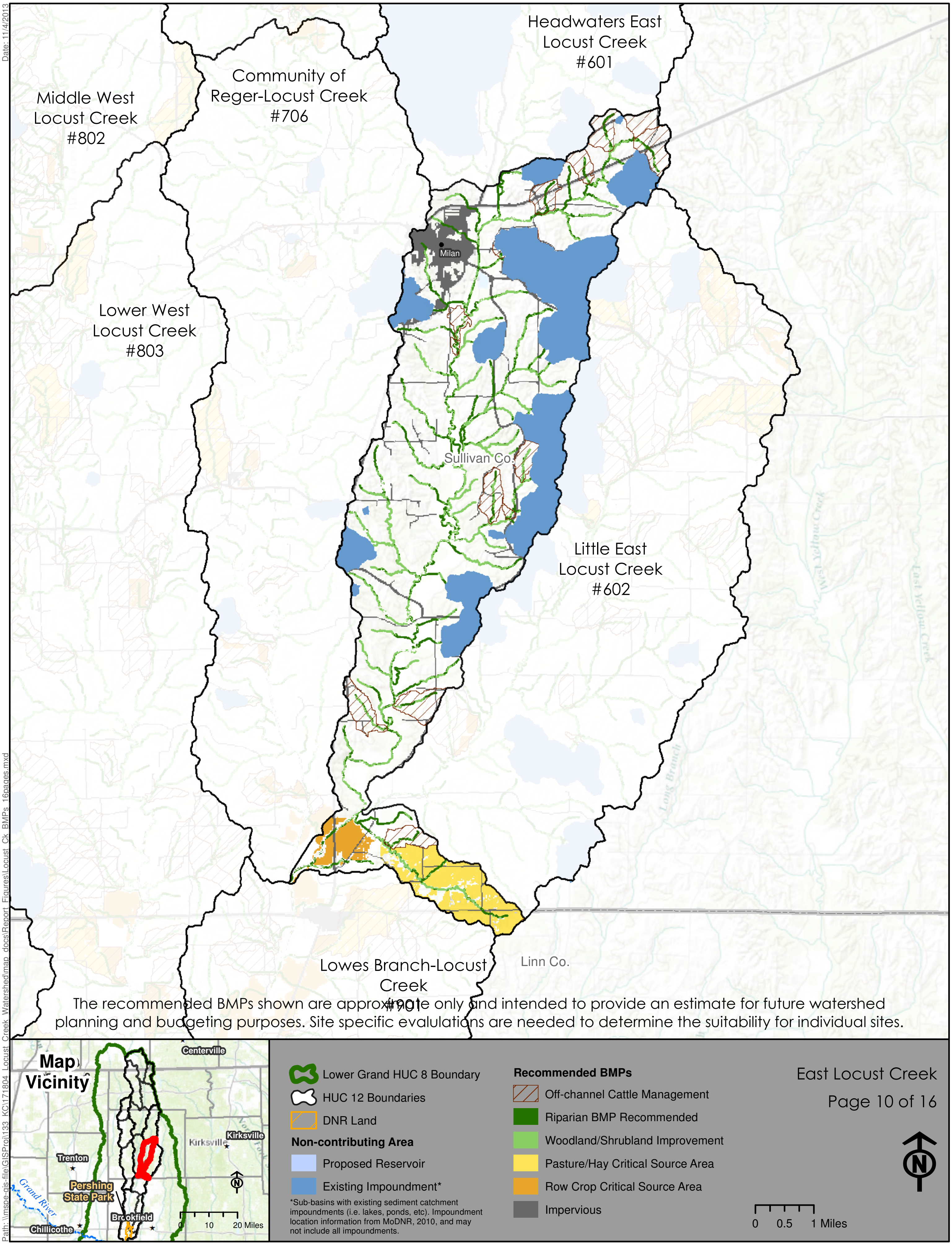
Community of Reger-Locust Creek

Page 9 of 16

0 0.5 1 Miles

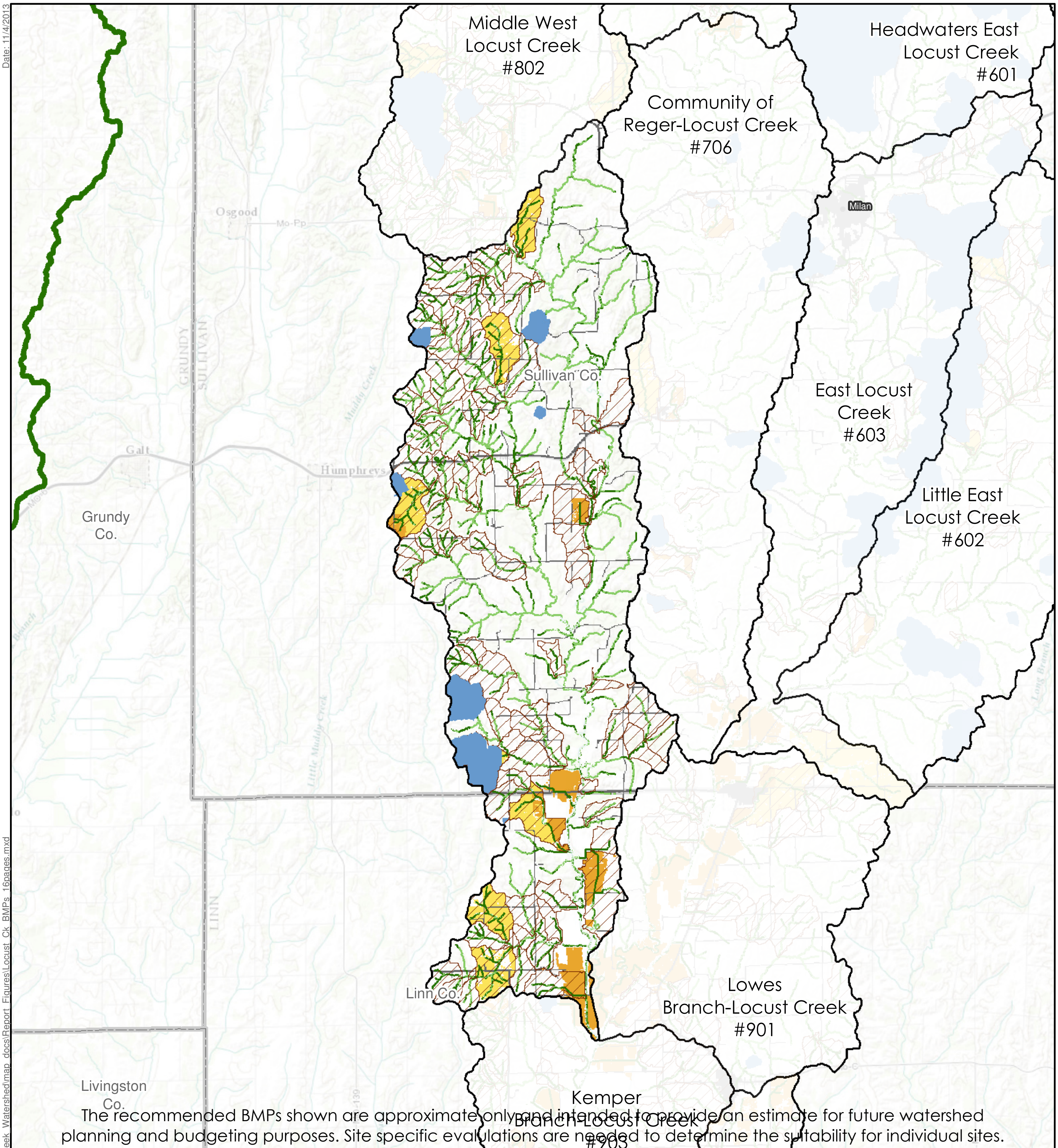
Date: 11/4/2013

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_BMPs_16pages.mxd

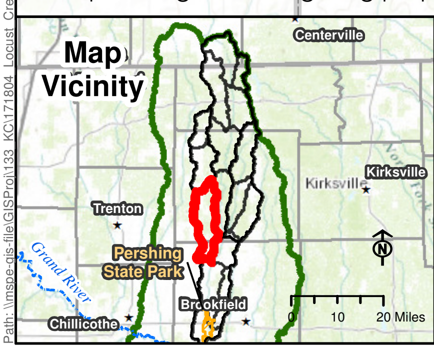


Date: 11/4/2013

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_BMPs_16pages.mxd



The recommended BMPs shown are approximate only and intended to provide an estimate for future watershed planning and budgeting purposes. Site specific evaluations are needed to determine the suitability for individual sites.



- Lower Grand HUC 8 Boundary
- HUC 12 Boundaries
- DNR Land

Non-contributing Area

- Proposed Reservoir
- Existing Impoundment*

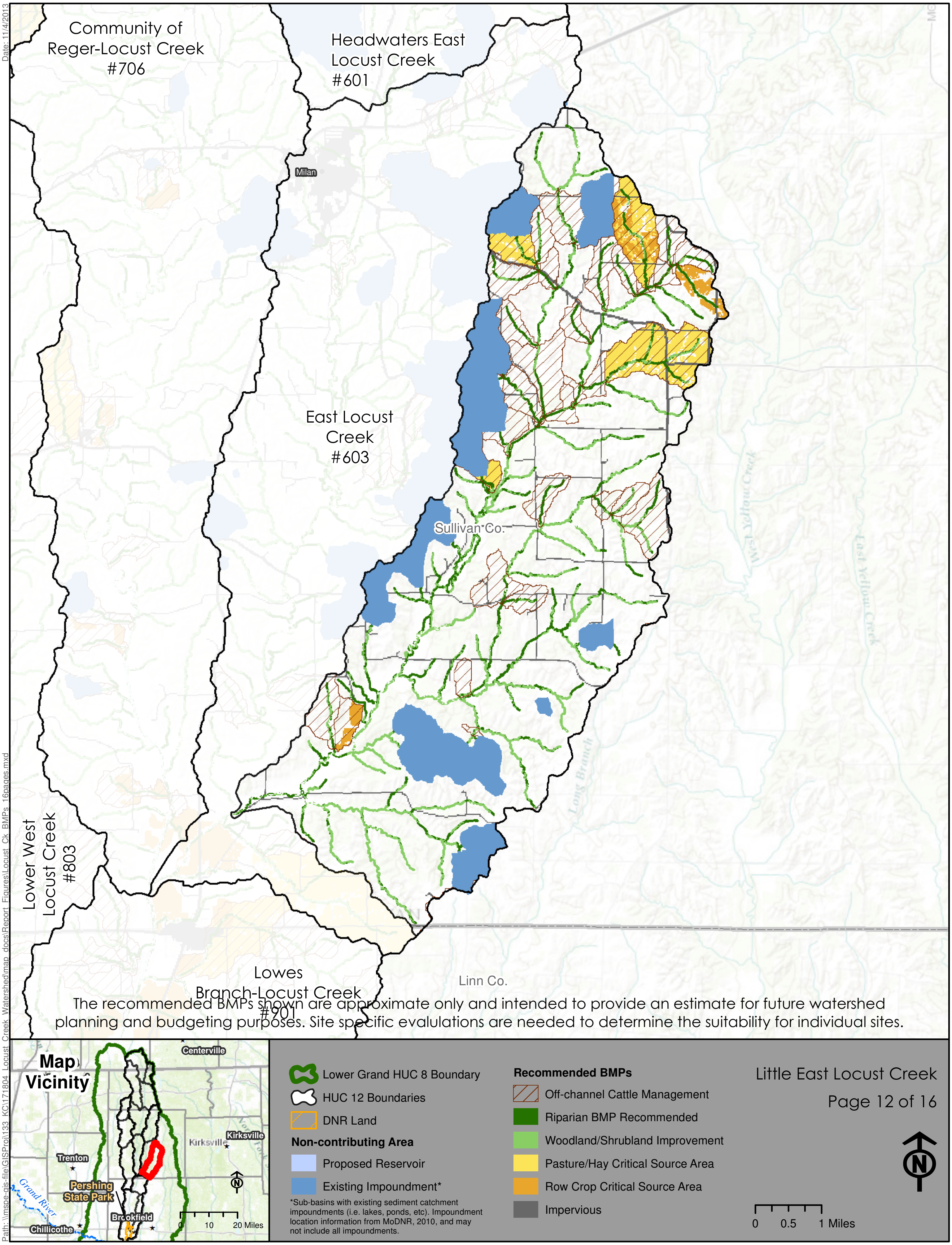
*Sub-basins with existing sediment catchment impoundments (i.e. lakes, ponds, etc). Impoundment location information from MoDNR, 2010, and may not include all impoundments.

Recommended BMPs

- Off-channel Cattle Management
- Riparian BMP Recommended
- Woodland/Shrubland Improvement
- Pasture/Hay Critical Source Area
- Row Crop Critical Source Area
- Impervious

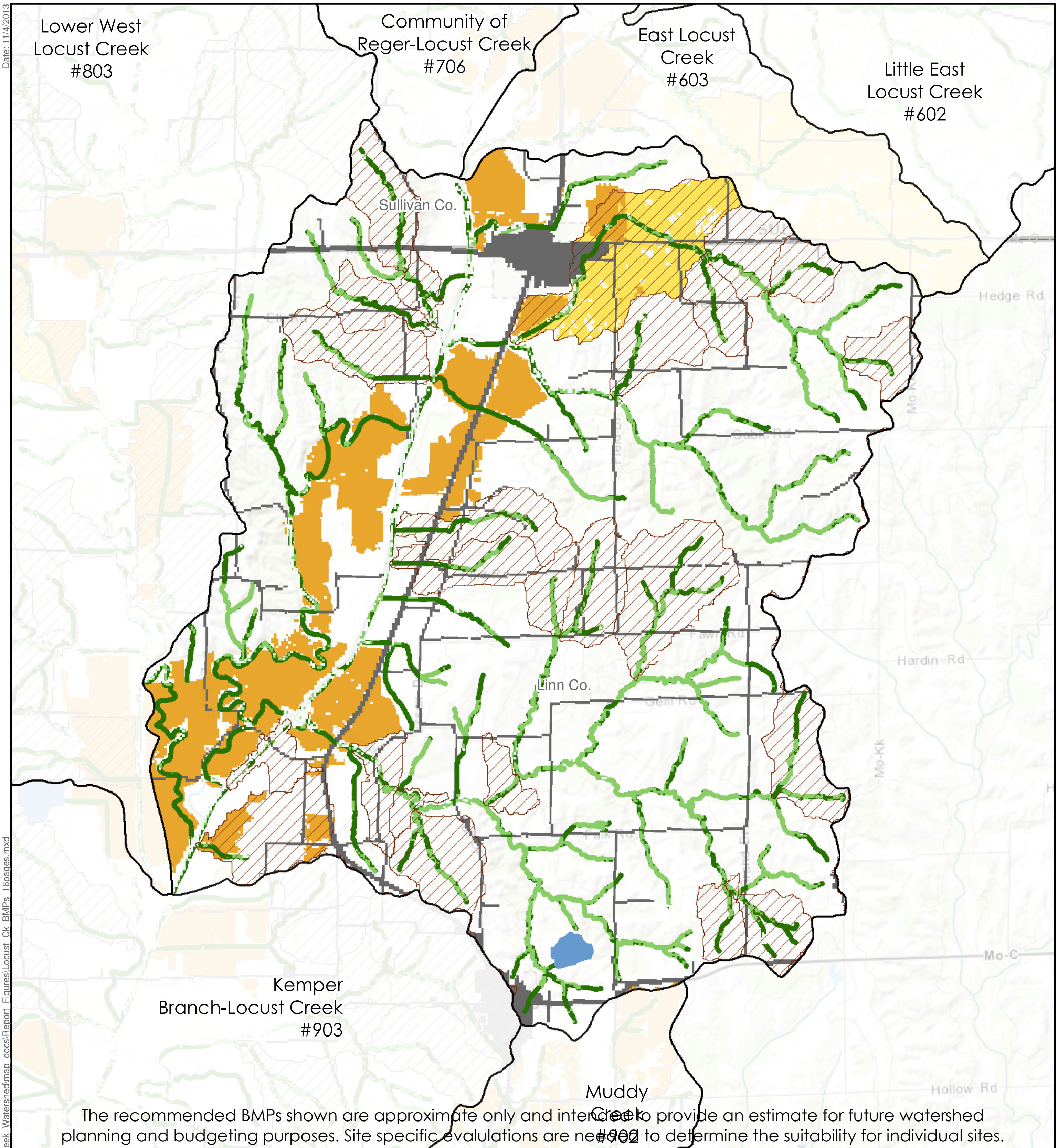
Lower West Locust Creek

0 0.5 1 Miles

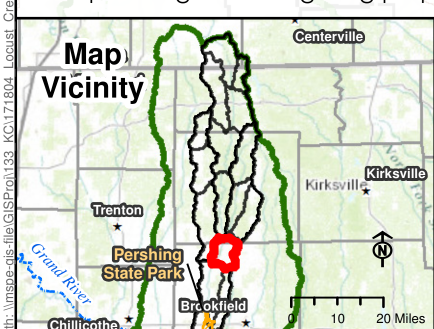


Date: 11/4/2013

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_BMPs_16pages.mxd



The recommended BMPs shown are approximate only and intended to provide an estimate for future watershed planning and budgeting purposes. Site specific evalulations are needed to determine the suitability for individual sites.



Lower Grand HUC 8 Boundary
HUC 12 Boundaries
DNR Land

Non-contributing Area
Proposed Reservoir
Existing Impoundment*

*Sub-basins with existing sediment catchment impoundments (i.e. lakes, ponds, etc). Impoundment location information from MoDNR, 2010, and may not include all impoundments.

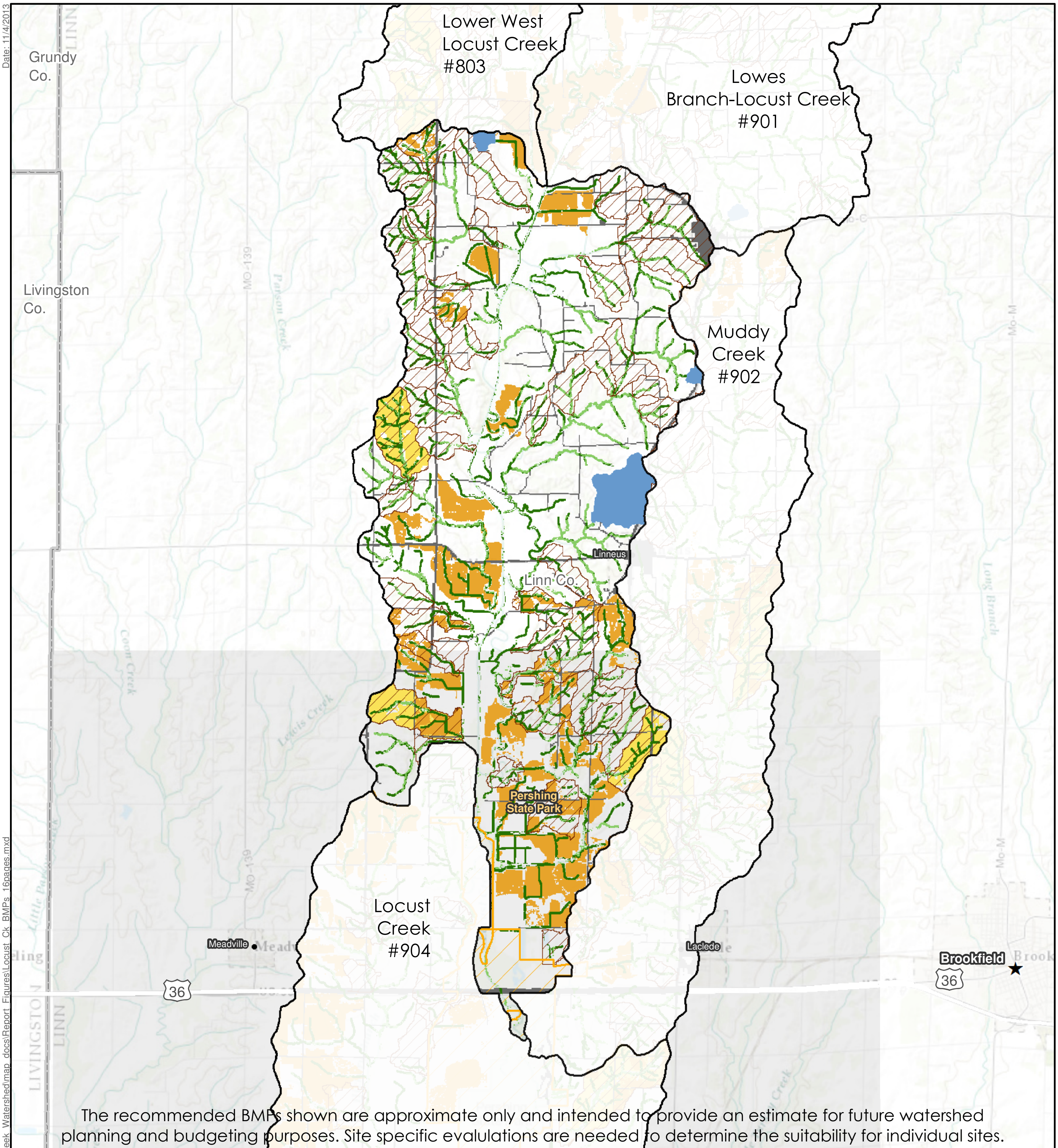
Recommended BMPs
Off-channel Cattle Management
Riparian BMP Recommended
Woodland/Shrubland Improvement
Pasture/Hay Critical Source Area
Row Crop Critical Source Area
Impervious

Lowes Branch-Locust Creek

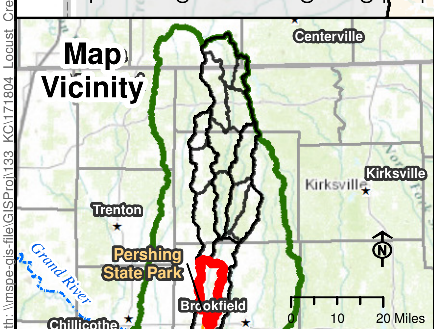
0 0.5 1 Miles

Date: 11/4/2013

Path: \\mspe-gis-file\GISProj\133 KC\171804 Locust Creek Watershed\map docs\Report Figures\Locust Ck BMPs 16pages.mxd



The recommended BMPs shown are approximate only and intended to provide an estimate for future watershed planning and budgeting purposes. Site specific evalutations are needed to determine the suitability for individual sites.



Lower Grand HUC 8 Boundary

HUC 12 Boundaries

DNR Land

Non-contributing Area

Proposed Reservoir

Existing Impoundment*

*Sub-basins with existing sediment catchment impoundments (i.e. lakes, ponds, etc). Impoundment location information from MoDNR, 2010, and may not include all impoundments.

Recommended BMPs

Off-channel Cattle Management

Riparian BMP Recommended

Woodland/Shrubland Improvement

Pasture/Hay Critical Source Area

Row Crop Critical Source Area

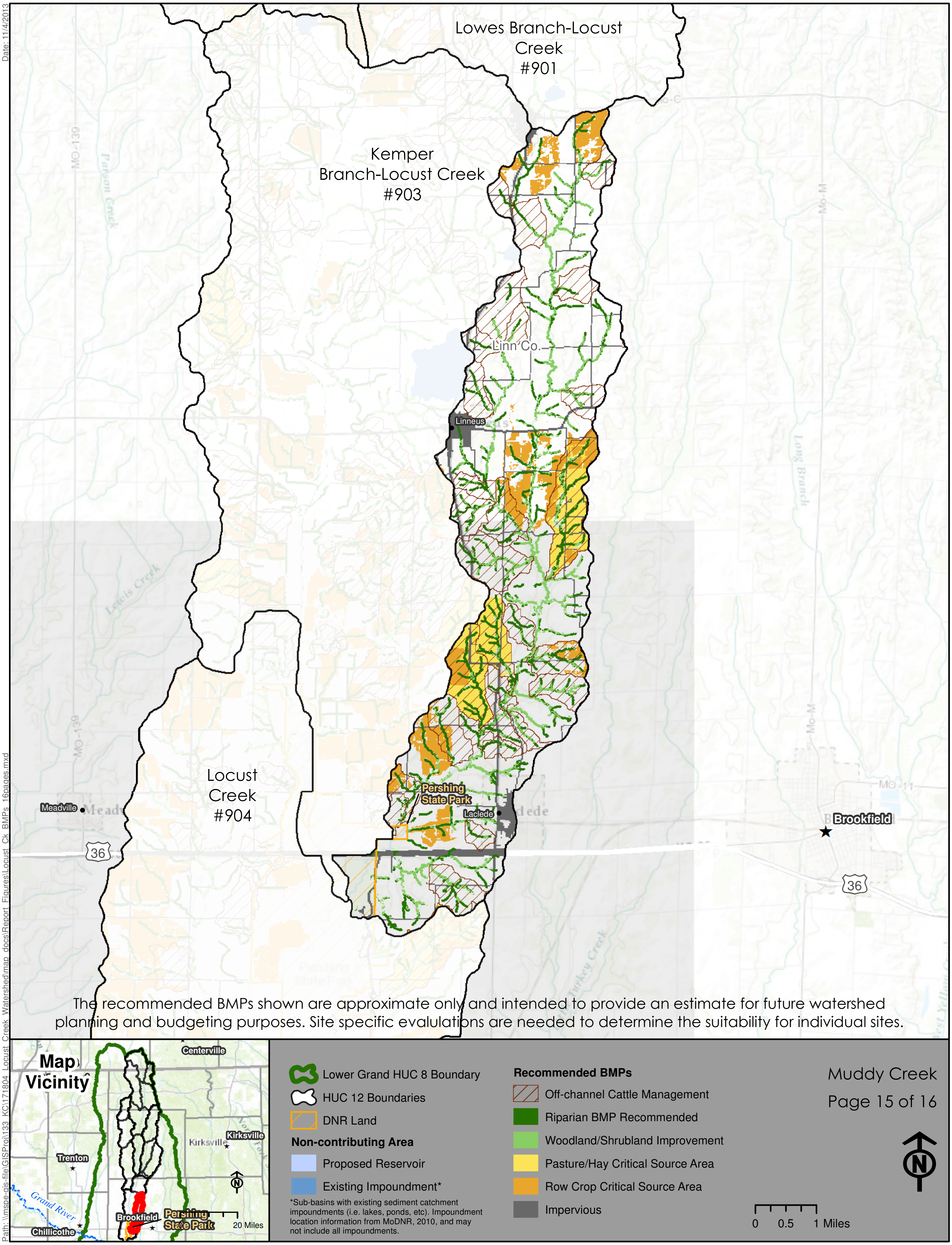
Impervious

Kemper Branch-Locust Creek

0 0.5 1 Miles

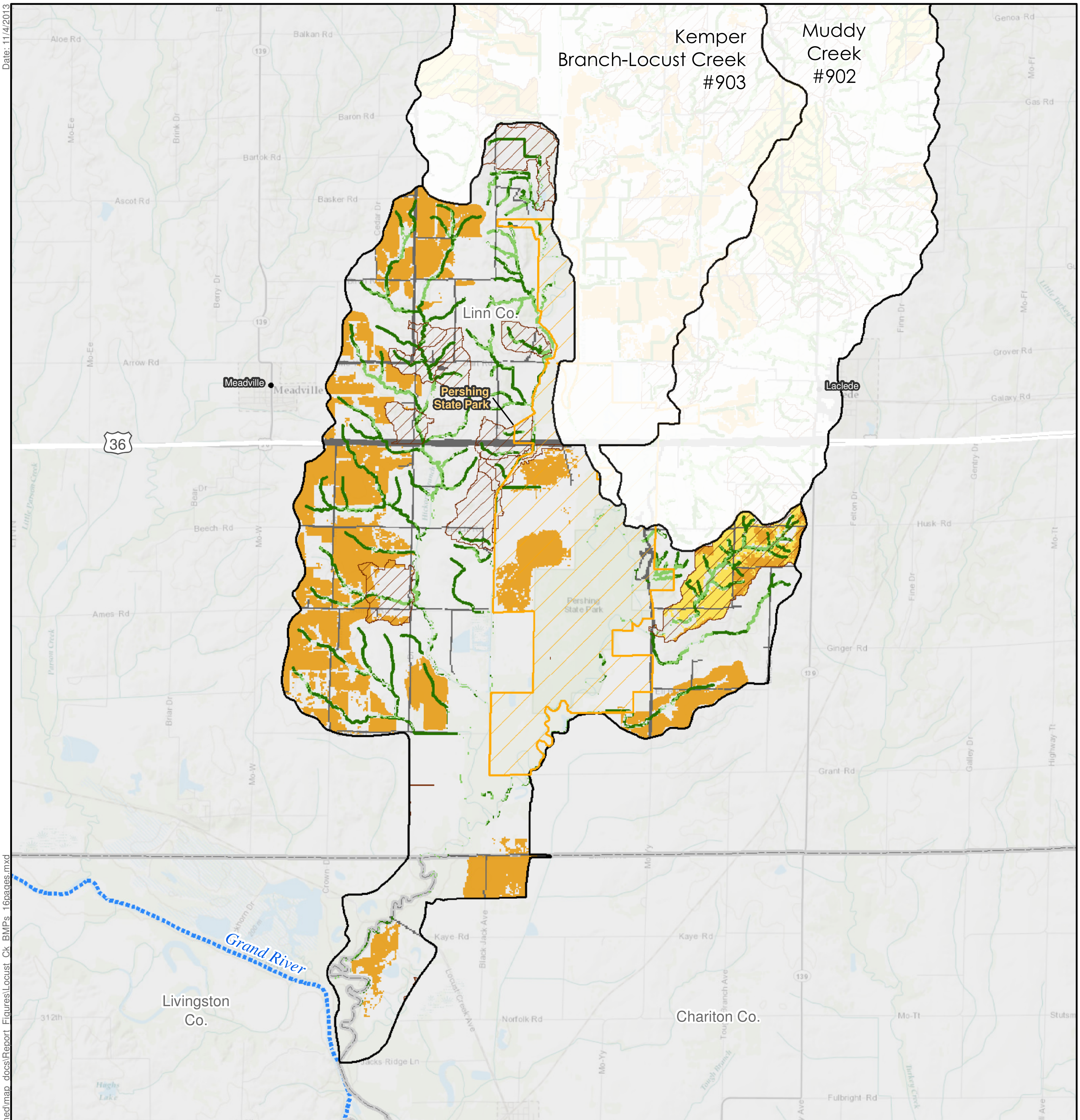
Date: 11/4/2013

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_BMPs_16pages.mxd

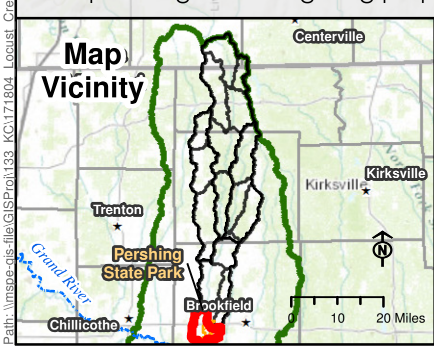


Date: 11/4/2013

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_BMPs_16pages.mxd



The recommended BMPs shown are approximate only and intended to provide an estimate for future watershed planning and budgeting purposes. Site specific evalulations are needed to determine the suitability for individual sites.



- Lower Grand HUC 8 Boundary
- HUC 12 Boundaries
- DNR Land

Non-contributing Area

- Proposed Reservoir
- Existing Impoundment*

*Sub-basins with existing sediment catchment impoundments (i.e. lakes, ponds, etc). Impoundment location information from MoDNR, 2010, and may not include all impoundments.

Recommended BMPs

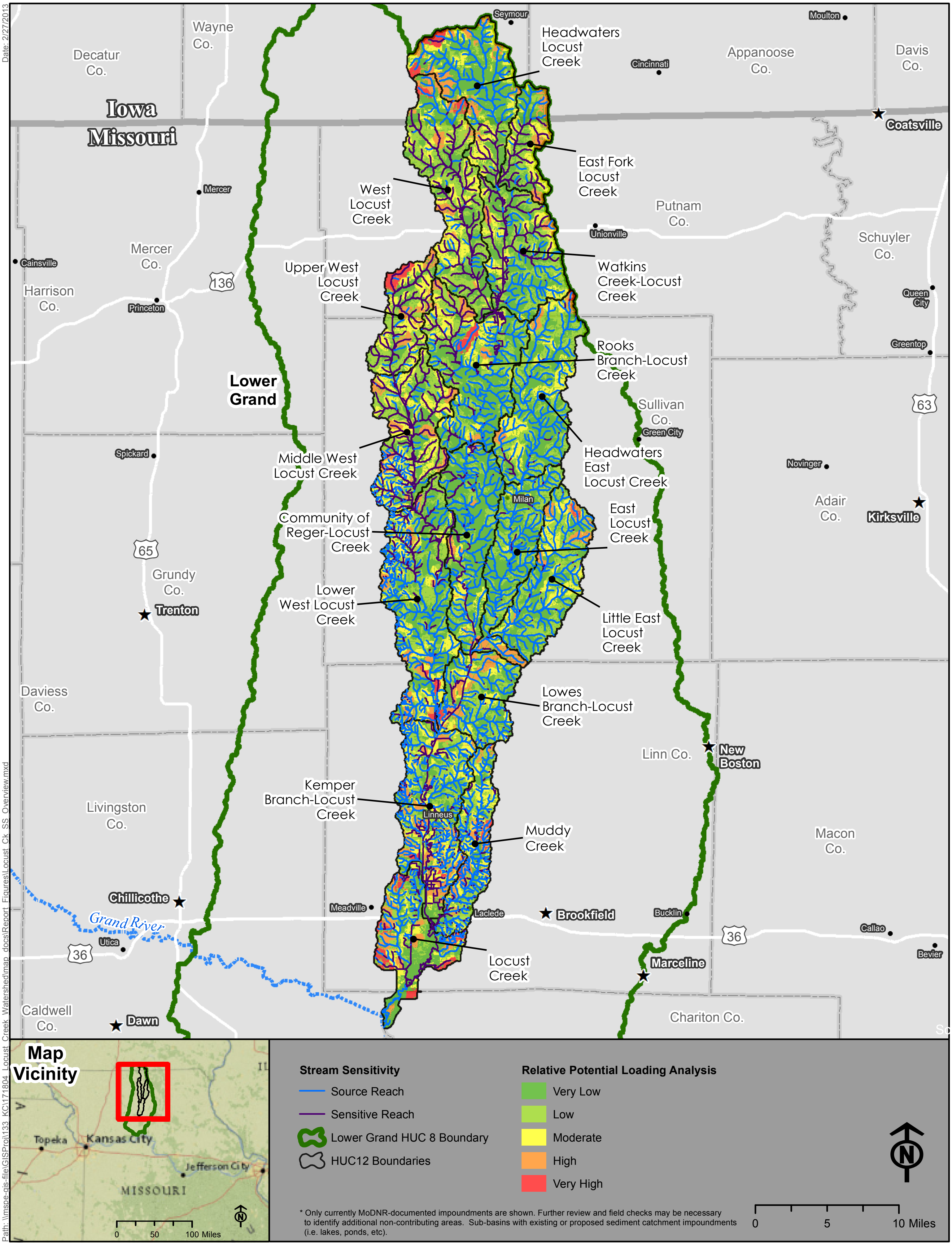
- Off-channel Cattle Management
- Riparian BMP Recommended
- Woodland/Shrubland Improvement
- Pasture/Hay Critical Source Area
- Row Crop Critical Source Area
- Impervious

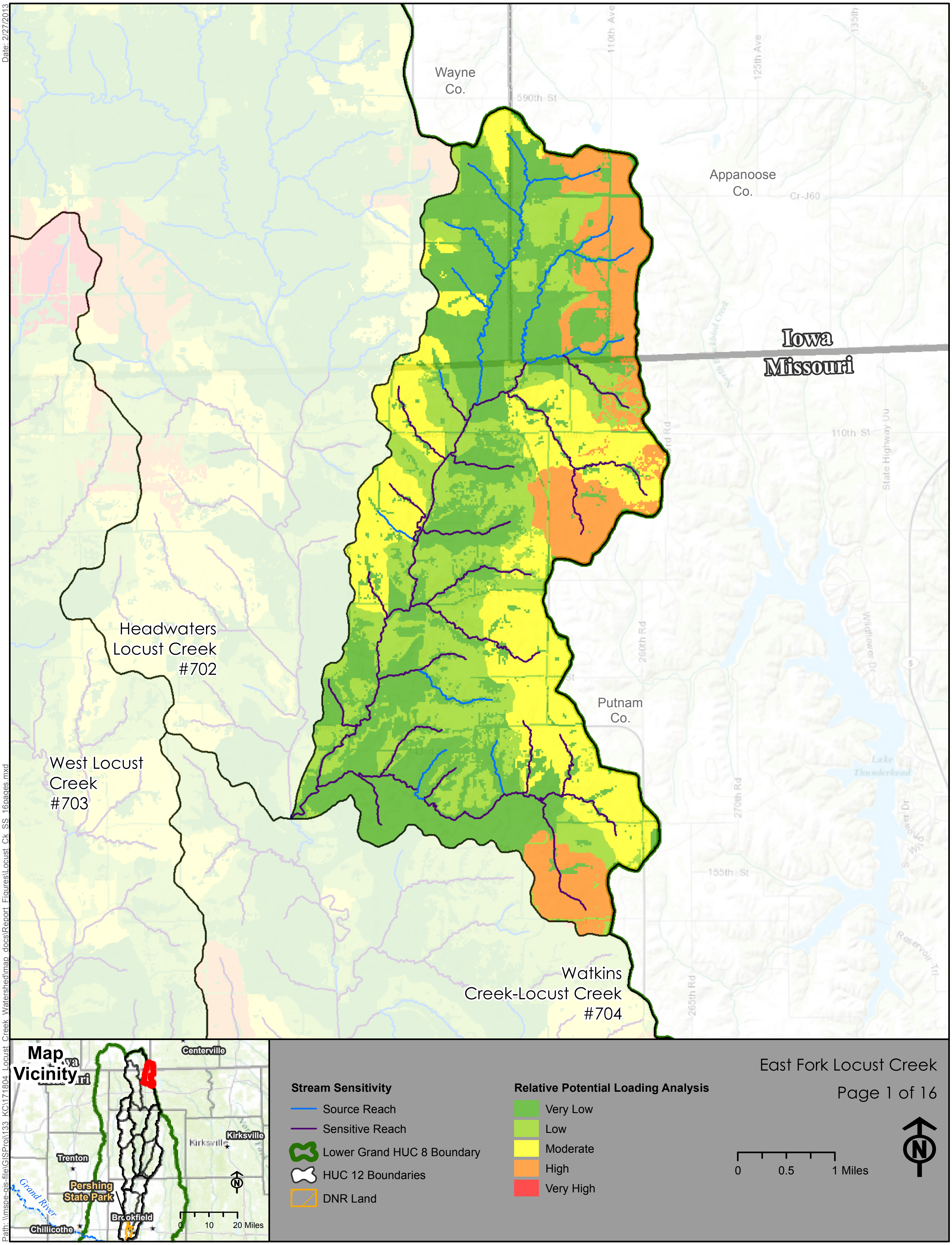
0 0.5 1 Miles

Locust Creek

Date: 11/4/2013

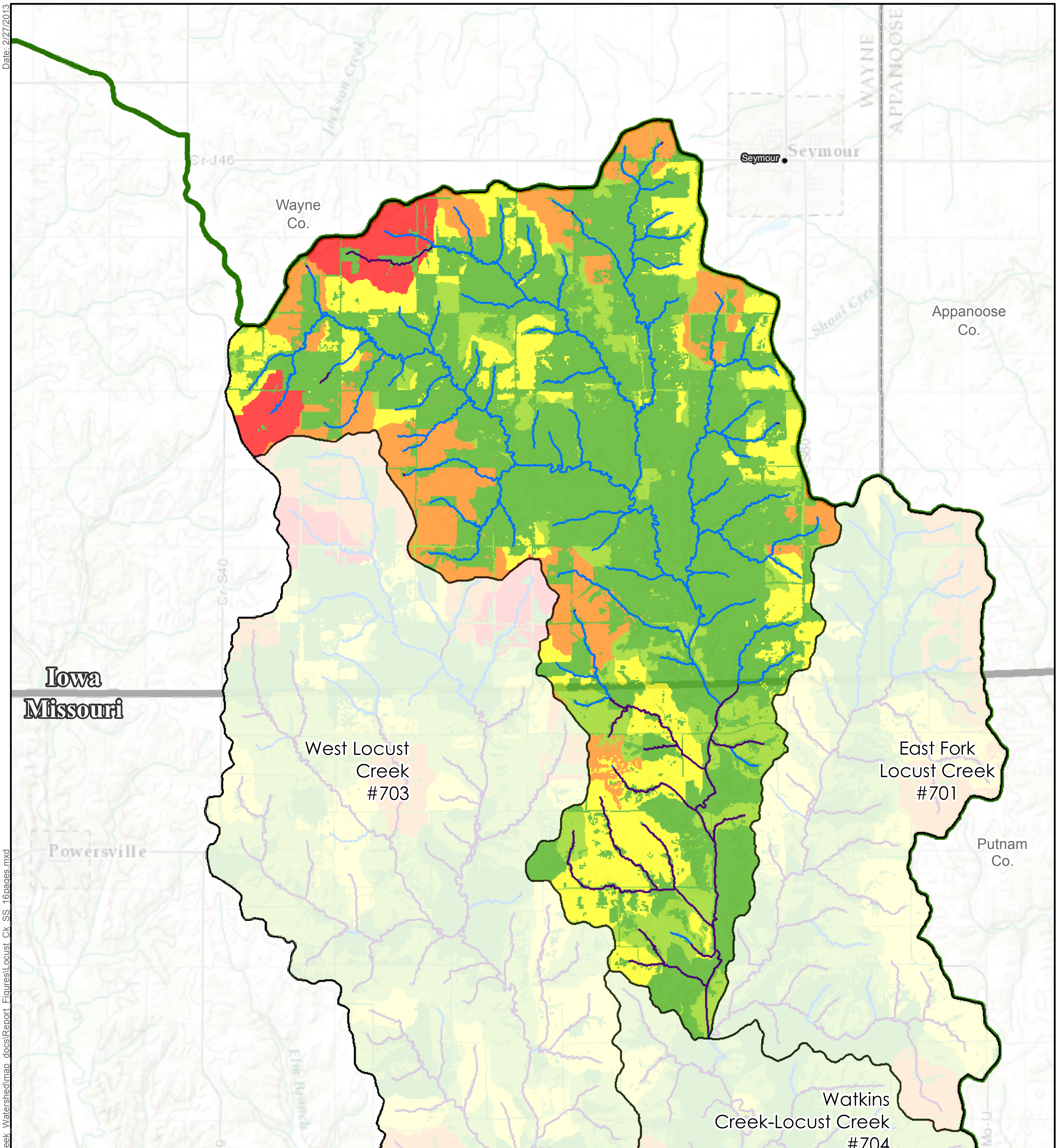
Path: \\mspe-gis-file\GISProj\133 KC\171804 Locust Creek Watershed\map docs\Report Figures\Locust Ck BMPs 16pages.mxd

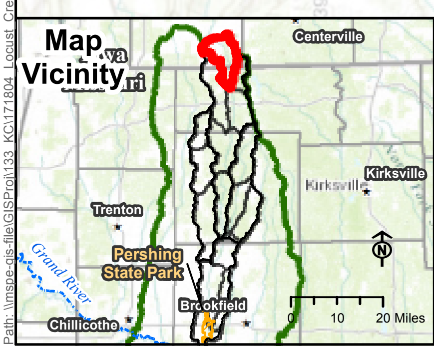

Headwaters Locust Creek
East Fork Locust Creek
West Locust Creek
Watkins Creek-Locust Creek
Upper West Locust Creek
Rooks Branch-Locust Creek
Headwaters East Locust Creek
Middle West Locust Creek
Community of Reger-Locust Creek
East Locust Creek
Lower West Locust Creek
Little East Locust Creek
Lowes Branch-Locust Creek
Kemper Branch-Locust Creek
Muddy Creek
Locust Creek
Lower Grand
Iowa
Missouri
Decatur Co.
Wayne Co.
Appanoose Co.
Davis Co.
Putnam Co.
Schuyler Co.
Mercer Co.
Harrison Co.
Sullivan Co.
Adair Co.
Grundy Co.
Daviess Co.
Linn Co.
Livingston Co.
Macon Co.
Caldwell Co.
Chariton Co.
Seymour
Moulton
Cincinnati
Coatsville
Mercer
Unionville
Cainsville
Princeton
Queen City
Greentop
Green City
Spickard
Novinger
Milan
Kirksville
Trenton
New Boston
Linneus
Chillicothe
Meadville
Laclede
Brookfield
Bucklin
Callao
Bevier
Utica
Marceline
Dawn
Grand River
136
65
63
36
Map Vicinity
Topeka
Kansas City
Jefferson City
MISSOURI
0 50 100 Miles
Stream Sensitivity
Source Reach
Sensitive Reach
Lower Grand HUC 8 Boundary
HUC12 Boundaries
Relative Potential Loading Analysis
Very Low
Low
Moderate
High
Very High
* Only currently MoDNR-documented impoundments are shown. Further review and field checks may be necessary to identify additional non-contributing areas. Sub-basins with existing or proposed sediment catchment impoundments (i.e. lakes, ponds, etc).
0 5 10 Miles
N



Date: 2/27/2013

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_SS_16pages.mxd



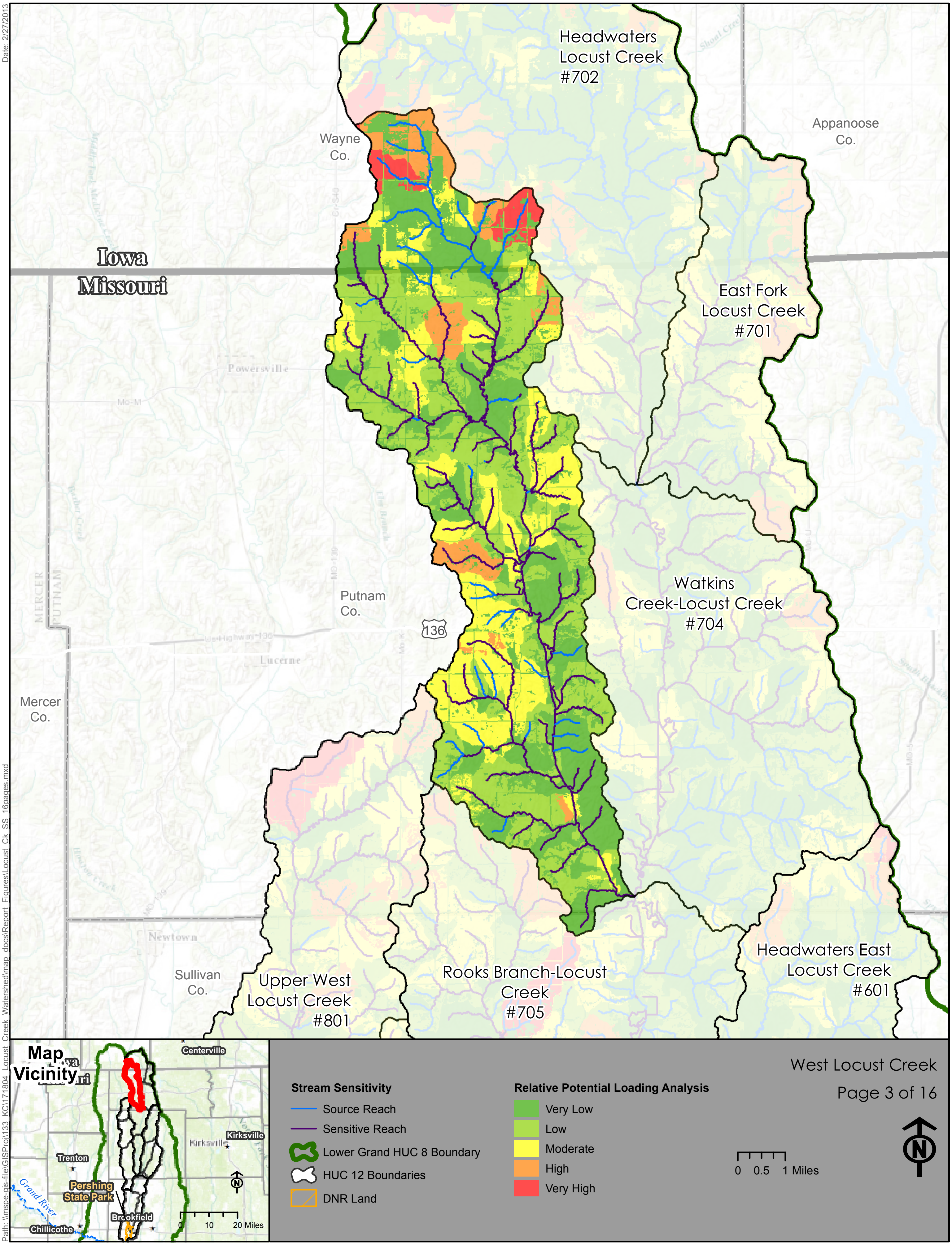


Headwaters Locust Creek

Date: 2/27/2013

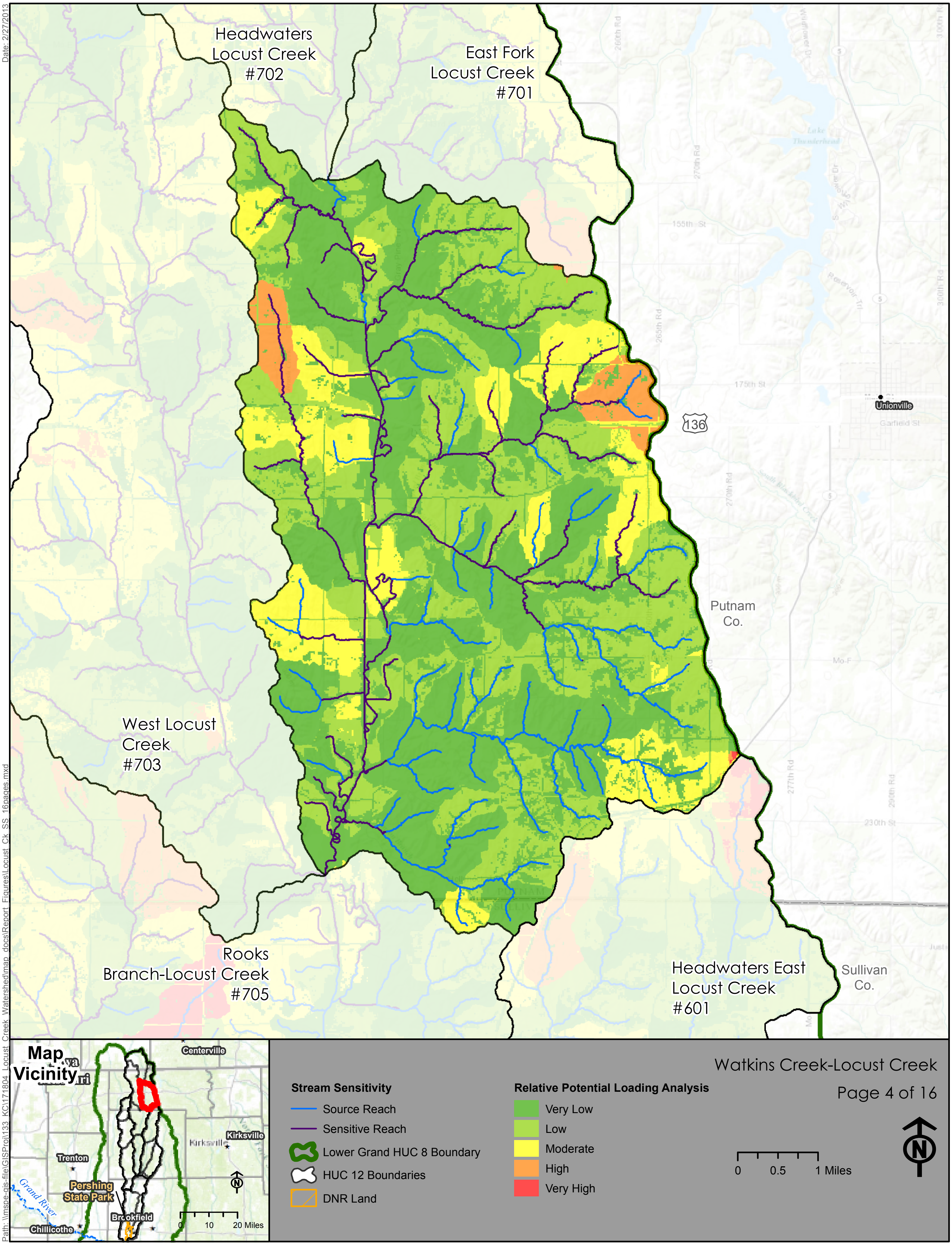
Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_SS_16pages.mxd

Date: 2/27/2013



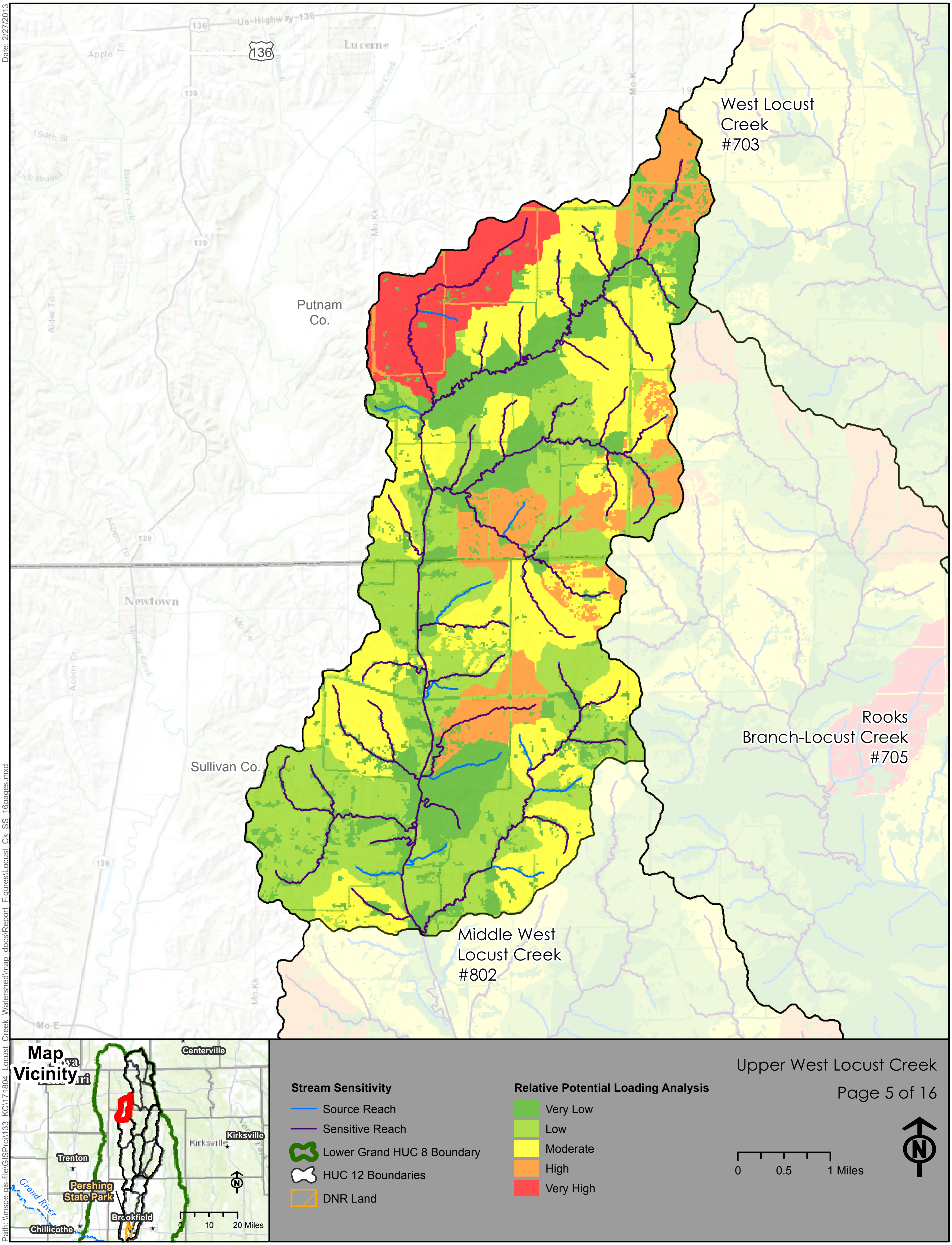
West Locust Creek

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_SS_16pages.mxd



Date: 2/27/2013

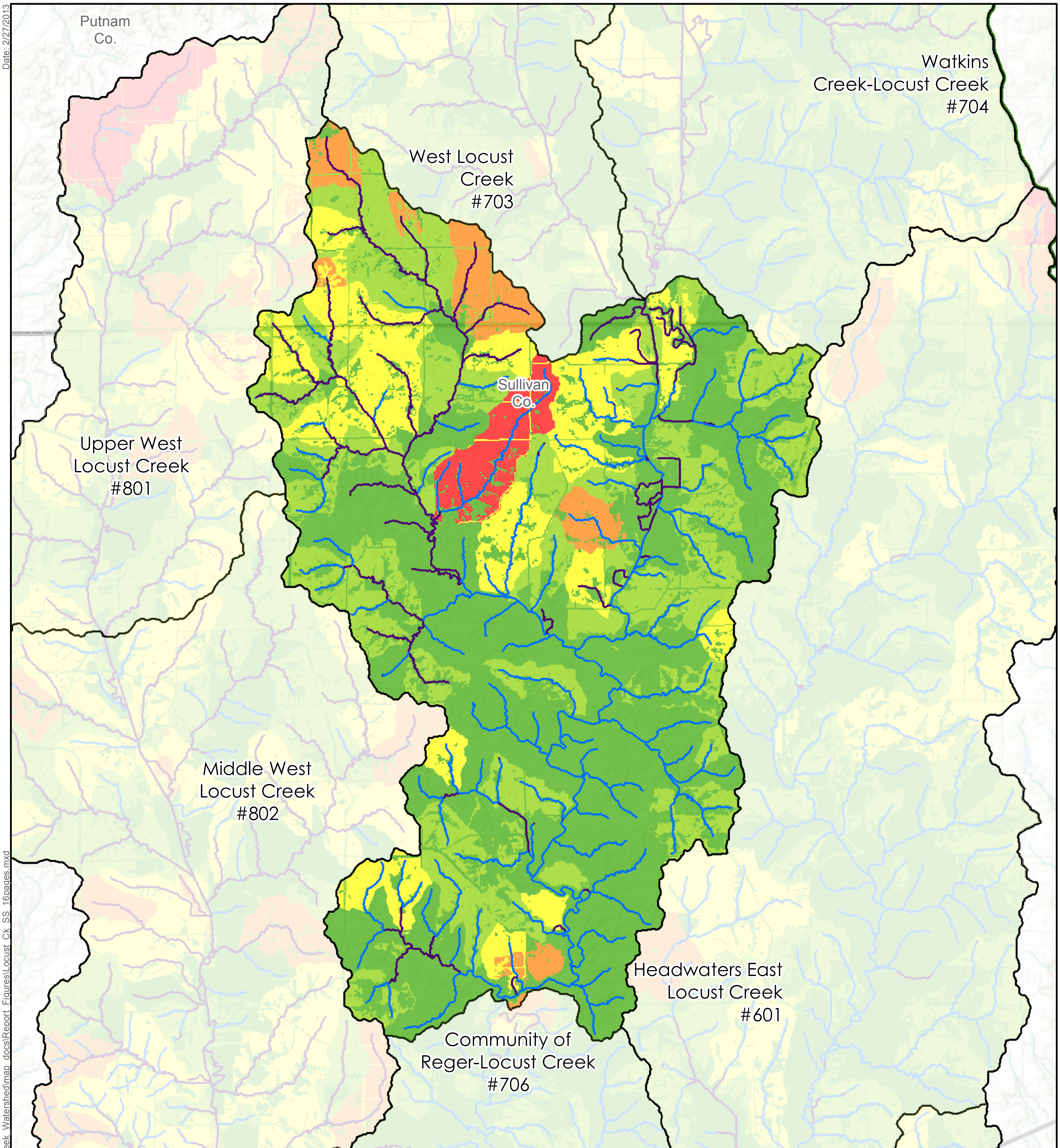
Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_SS_16pages.mxd

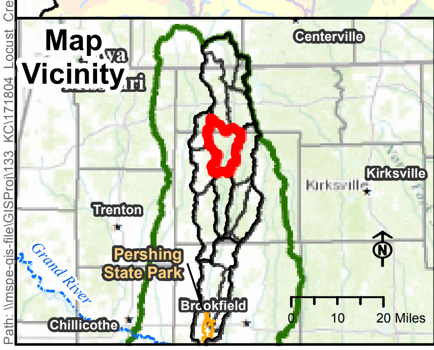


Upper West Locust Creek

Date: 2/27/2013

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_SS_16pages.mxd





Rooks Branch-Locust Creek

Stream Sensitivity

- Source Reach
- Sensitive Reach
- Lower Grand HUC 8 Boundary
- HUC 12 Boundaries
- DNR Land

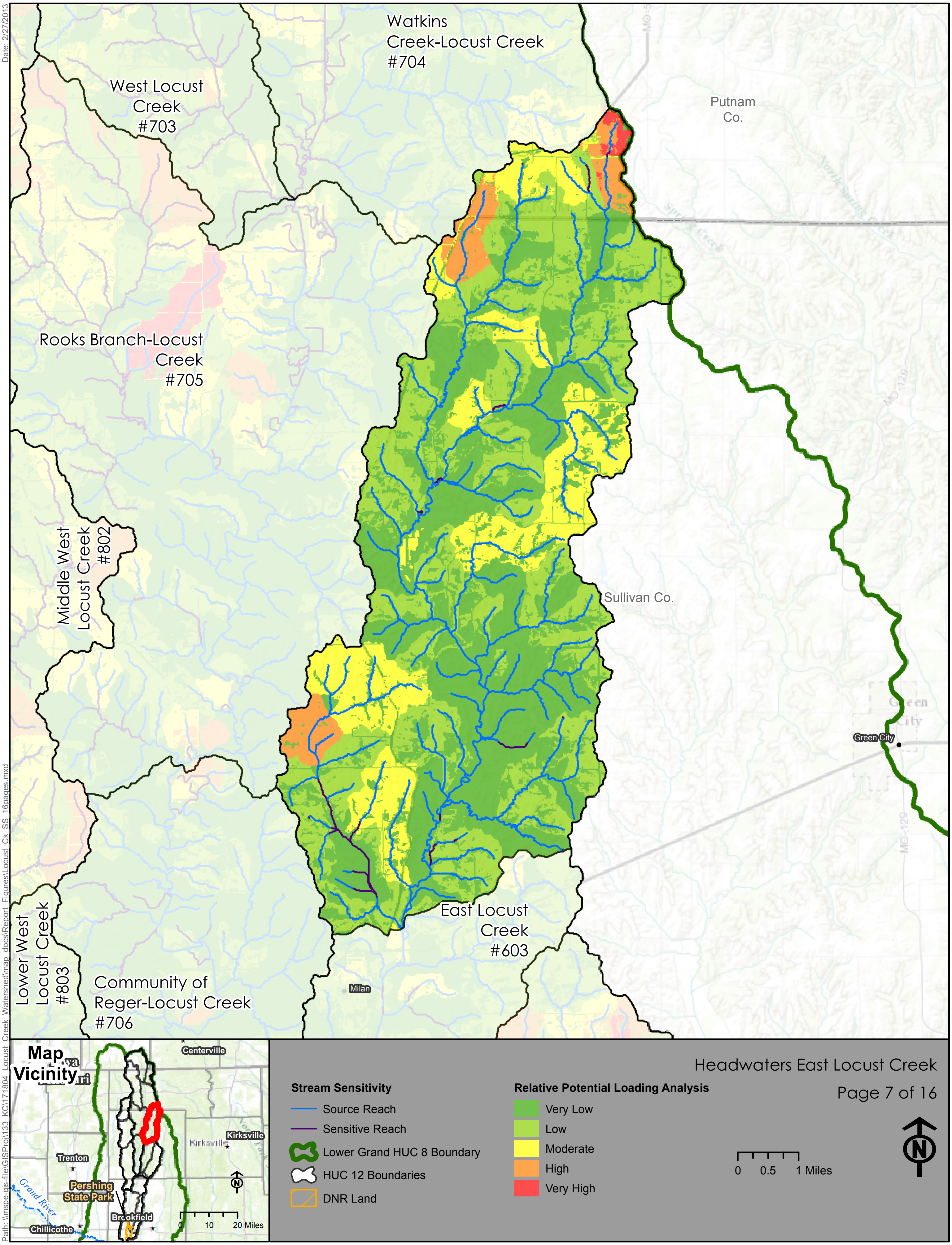
Relative Potential Loading Analysis

- Very Low
- Low
- Moderate
- High
- Very High

0 0.5 1 Miles

N

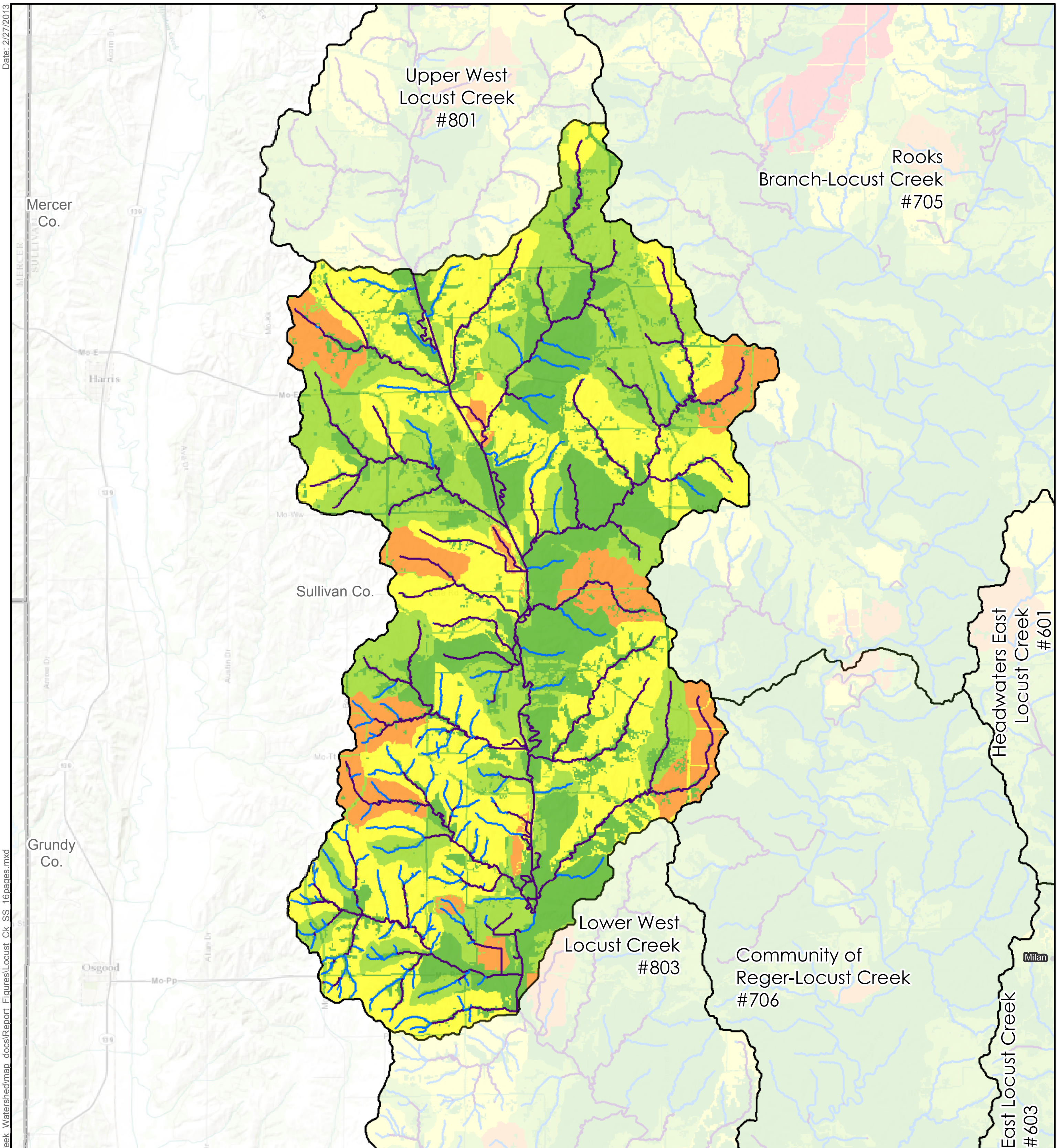
Date: 2/27/2013
Path: \\mspe-gis-file\GISProj\133 KC\171804 Locust Creek Watershed\map docs\Report Figures\Locust Ck SS 16pages.mxd

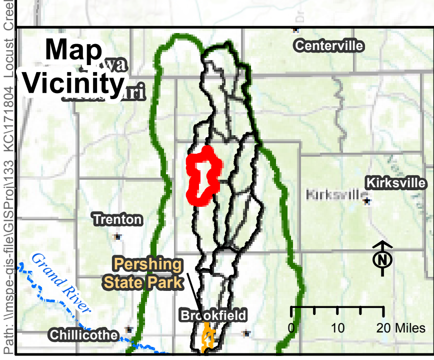


Date: 2/27/2013

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_SS_16pages.mxd

Date: 2/27/2013





Stream Sensitivity

- Source Reach
- Sensitive Reach
- Lower Grand HUC 8 Boundary
- HUC 12 Boundaries
- DNR Land

Relative Potential Loading Analysis

- Very Low
- Low
- Moderate
- High
- Very High

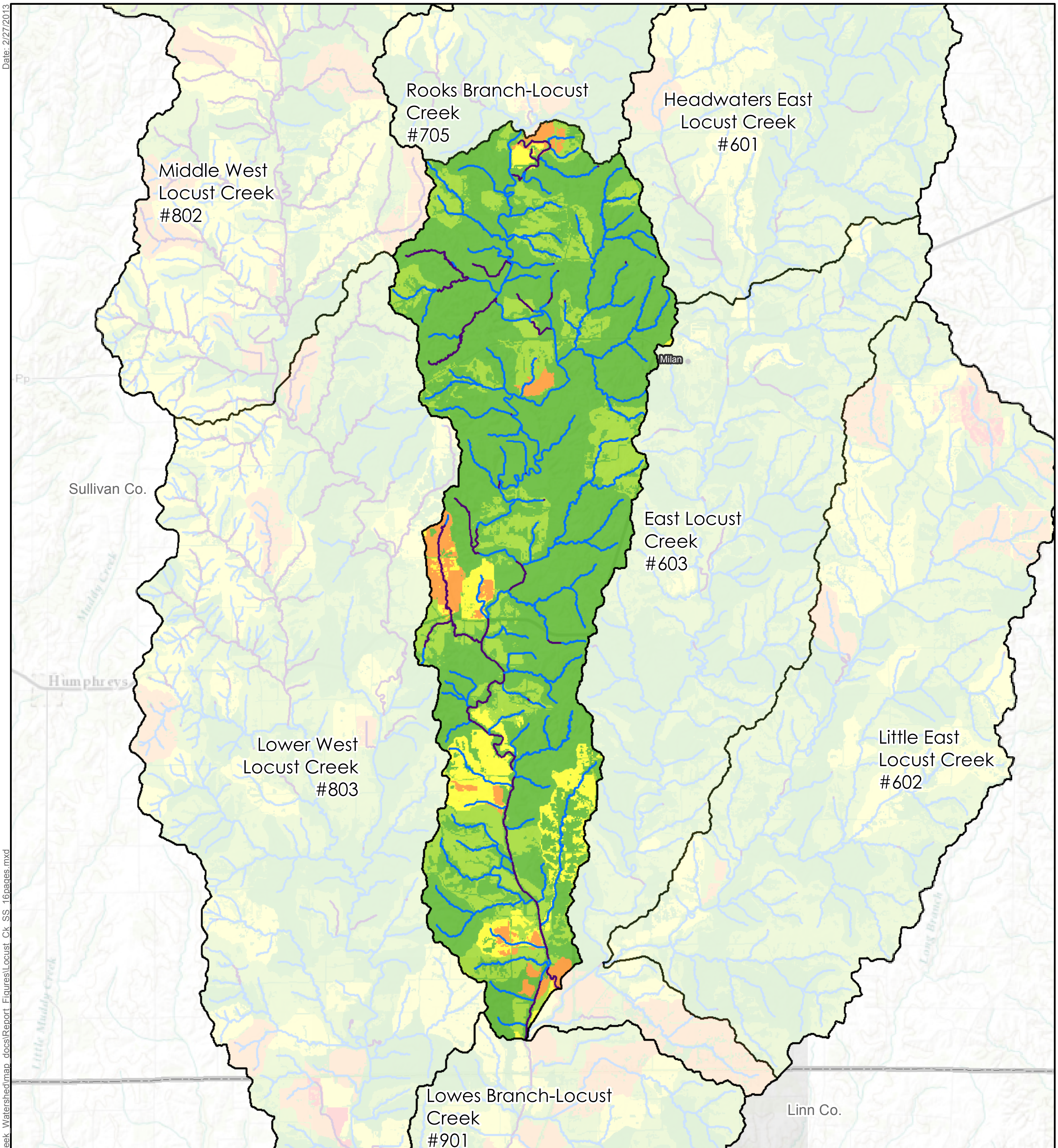
Middle West Locust Creek

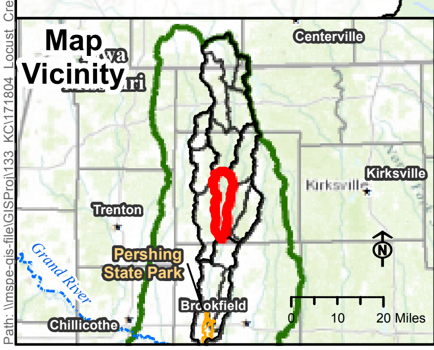
0 0.5 1 Miles

N

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_SS_16pages.mxd

Date: 2/27/2013





Path: \\mspe-gis-file\GISProj\1333_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_SS_16pages.mxd

Stream Sensitivity

- Source Reach
- Sensitive Reach
- Lower Grand HUC 8 Boundary
- HUC 12 Boundaries
- DNR Land

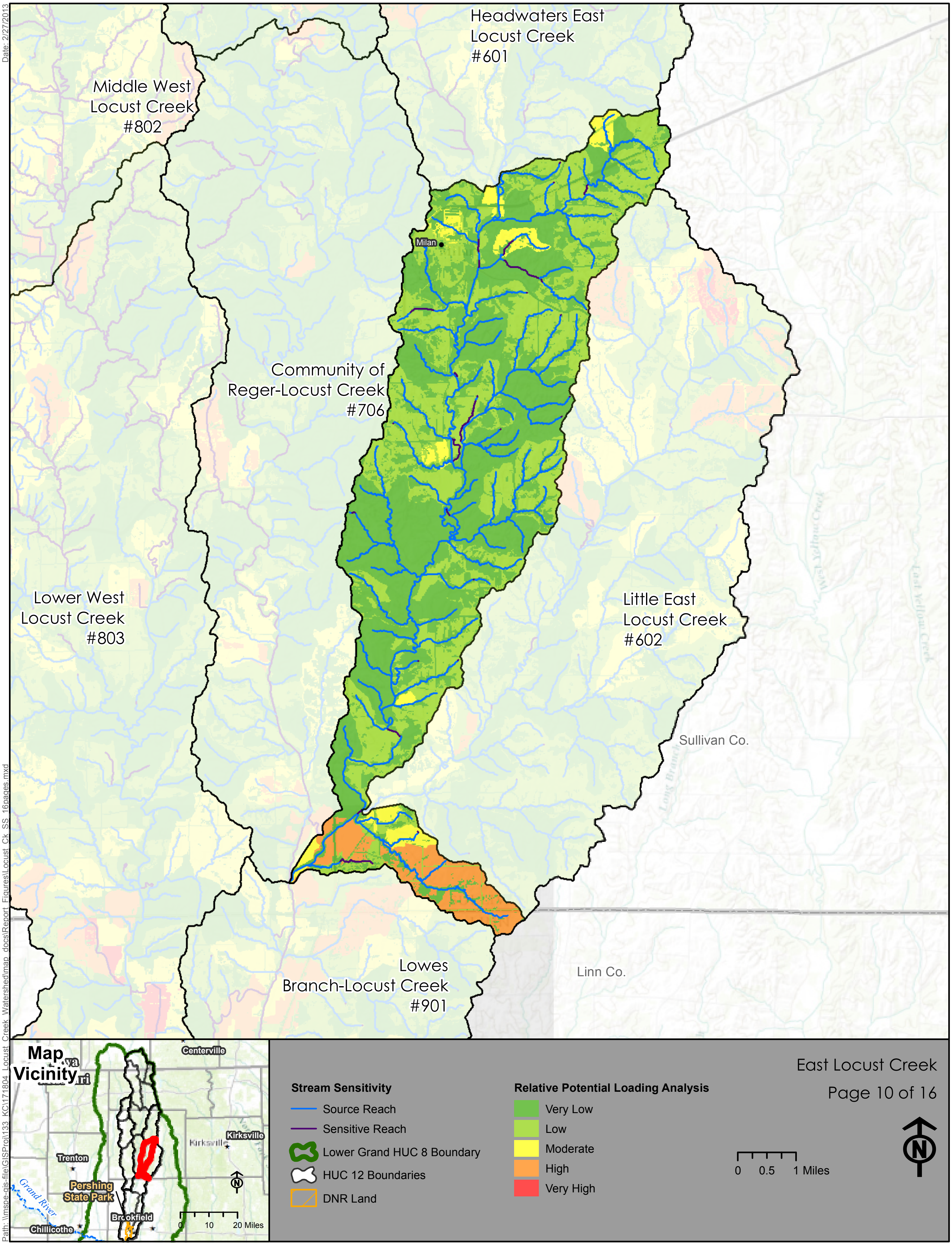
Relative Potential Loading Analysis

- Very Low
- Low
- Moderate
- High
- Very High

0 0.5 1 Miles

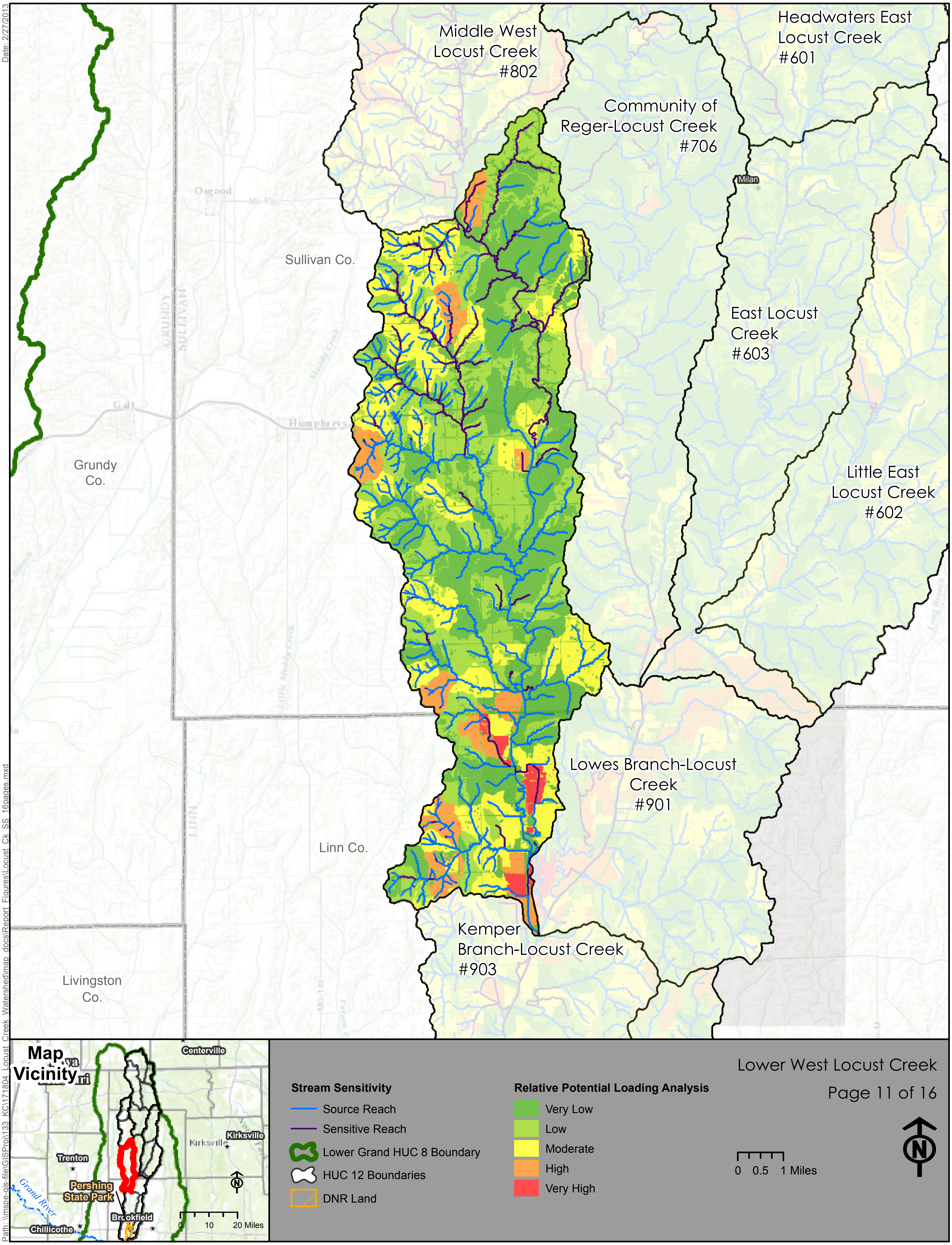
N

Community of Reger-Locust Creek



Date: 2/27/2013

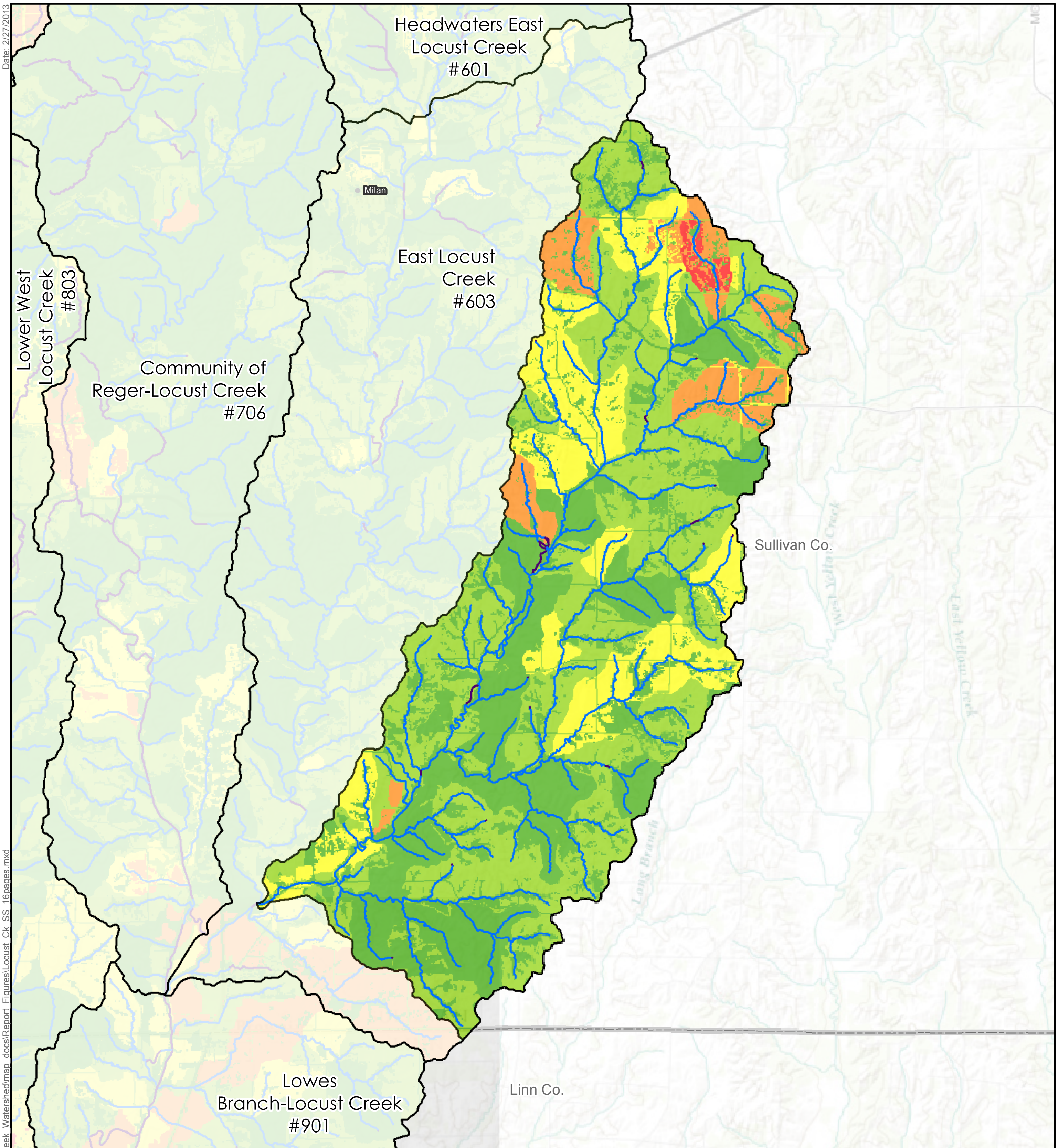
Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_SS_16pages.mxd

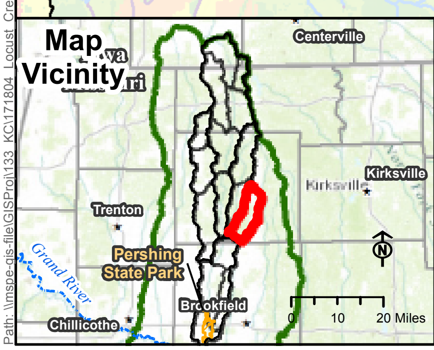


Date: 2/27/2013

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_SS_16pages.mxd

Date: 2/27/2013





Stream Sensitivity

- Source Reach
- Sensitive Reach
- Lower Grand HUC 8 Boundary
- HUC 12 Boundaries
- DNR Land

Relative Potential Loading Analysis

- Very Low
- Low
- Moderate
- High
- Very High

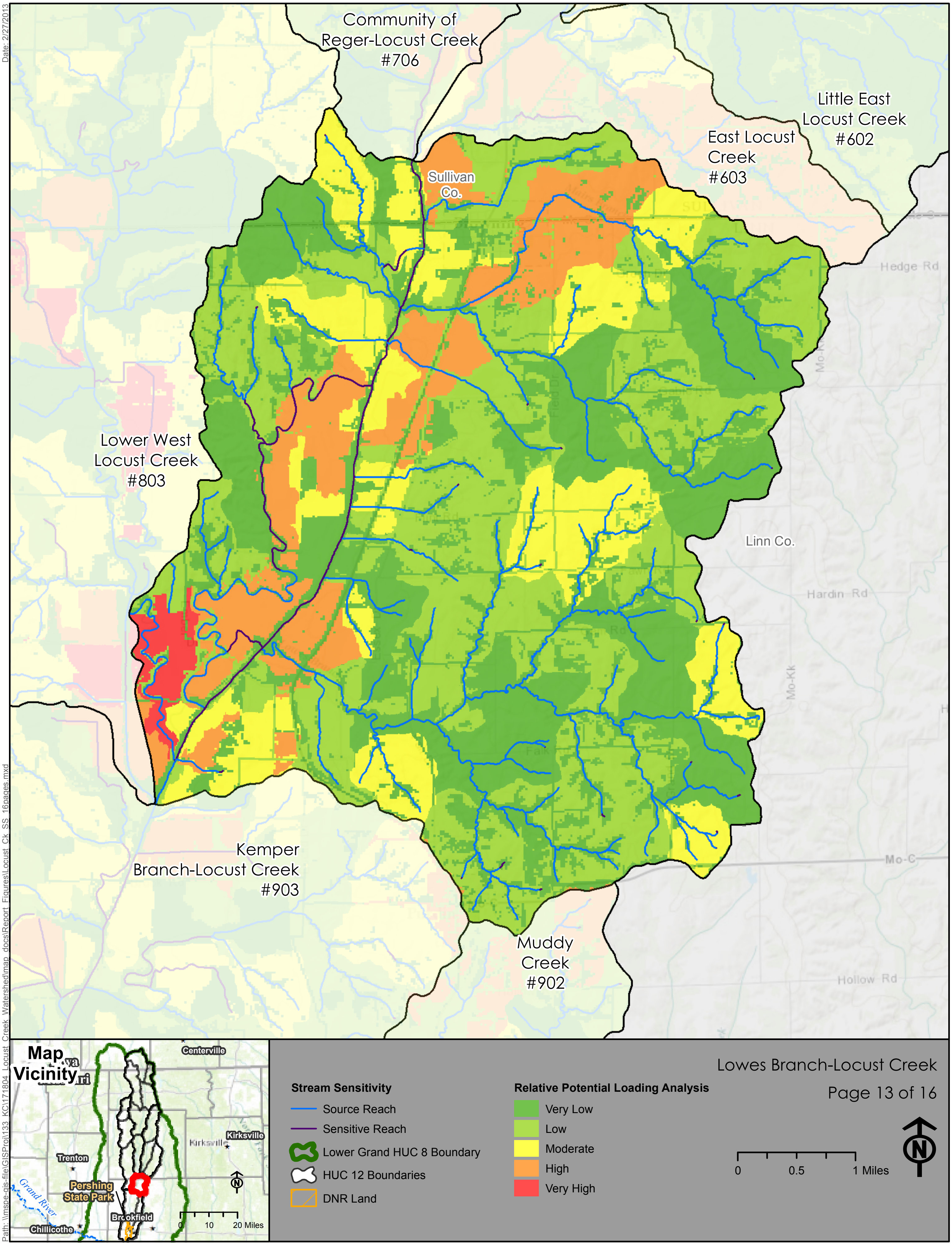
Little East Locust Creek

0 0.5 1 Miles

N

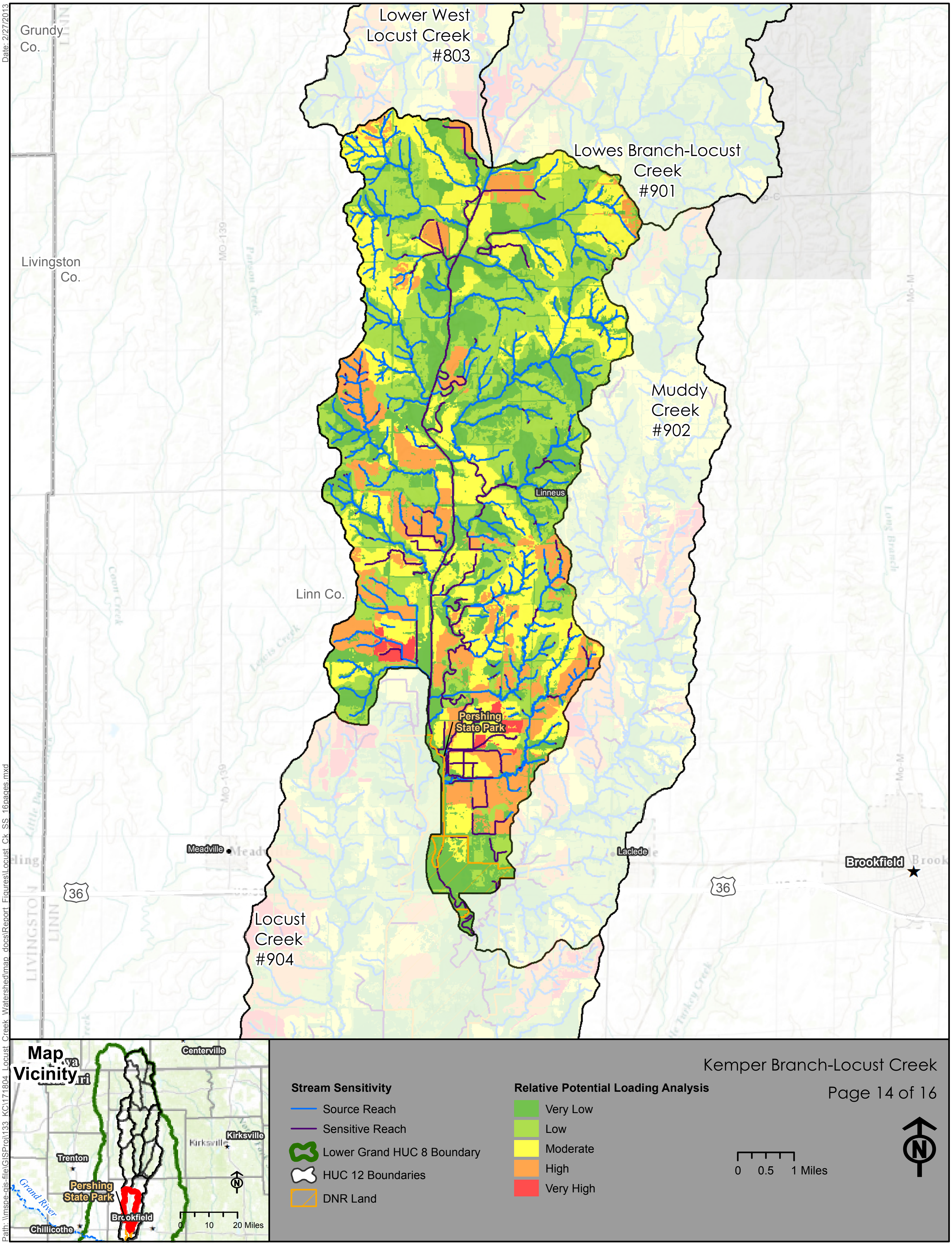
Path: \\mspe-gis-file\GISProj\1333_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_SS_16pages.mxd

Date: 2/27/2013



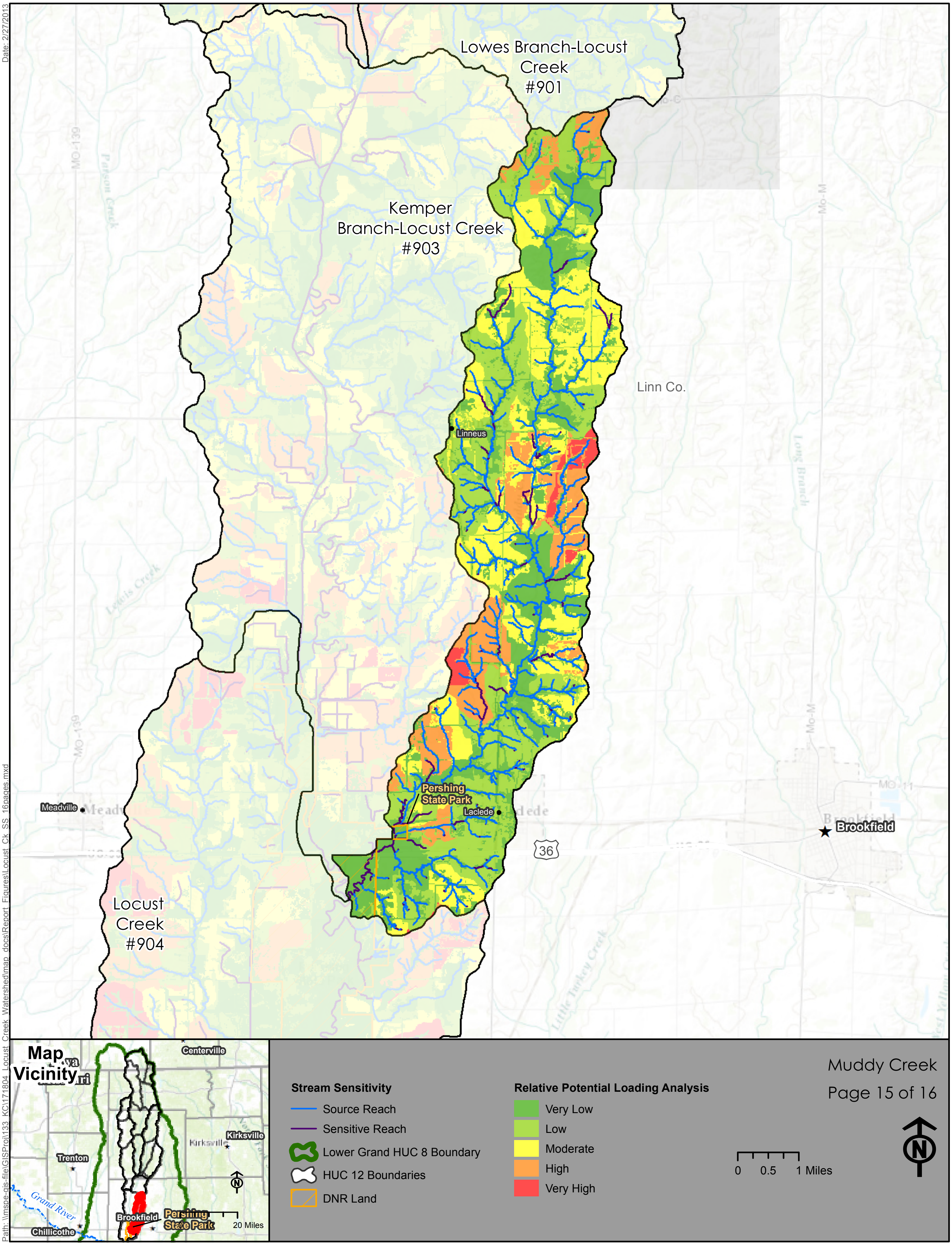
Path: \\mspe-gis-file\GISProj\133 KC\171804 Locust Creek Watershed\map docs\Report Figures\Locust Ck SS 16pages.mxd

Date: 2/27/2013



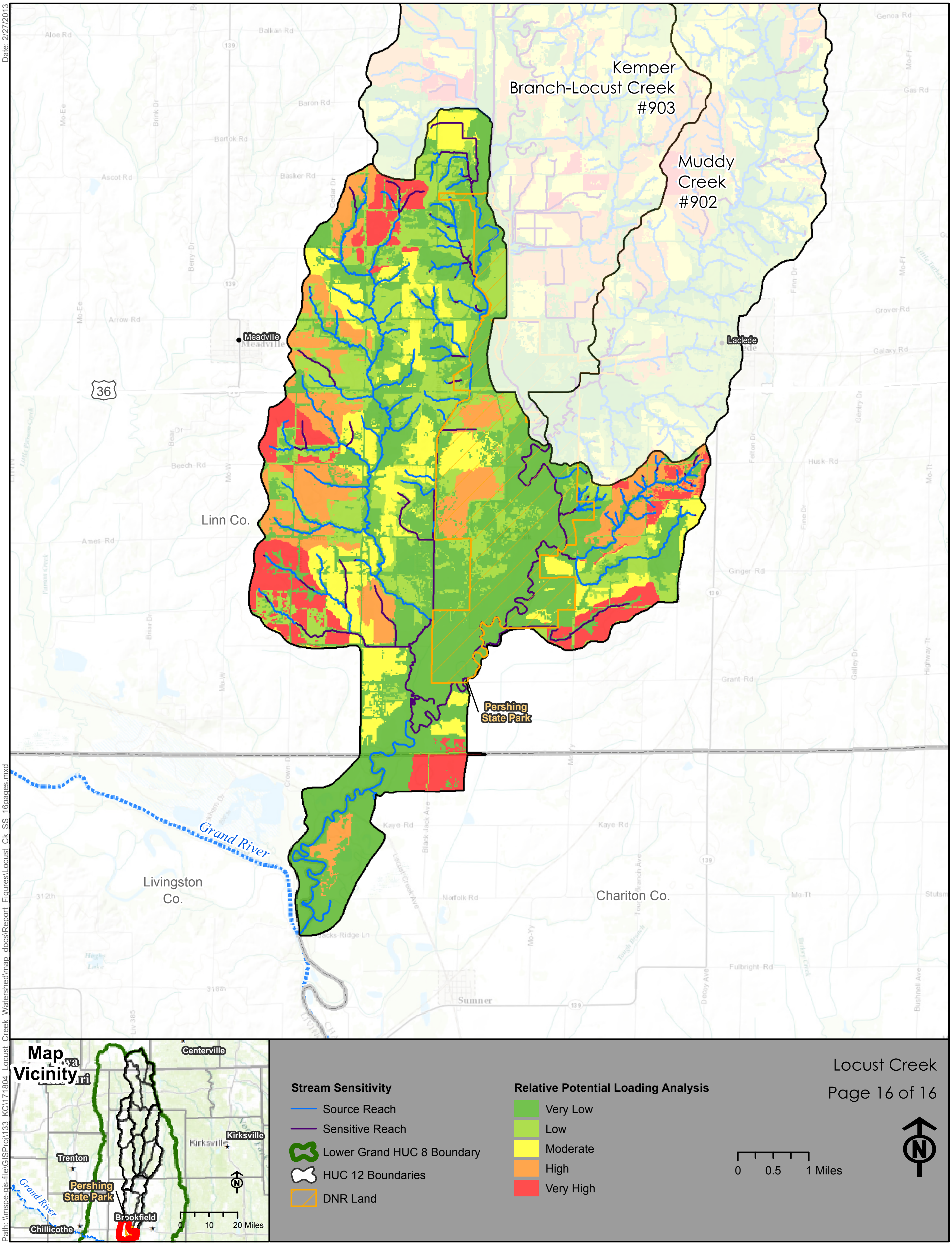
Kemper Branch-Locust Creek

Path: \\mspe-gis-file\GISProj\1133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_SS_16pages.mxd



Date: 2/27/2013

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_SS_16pages.mxd



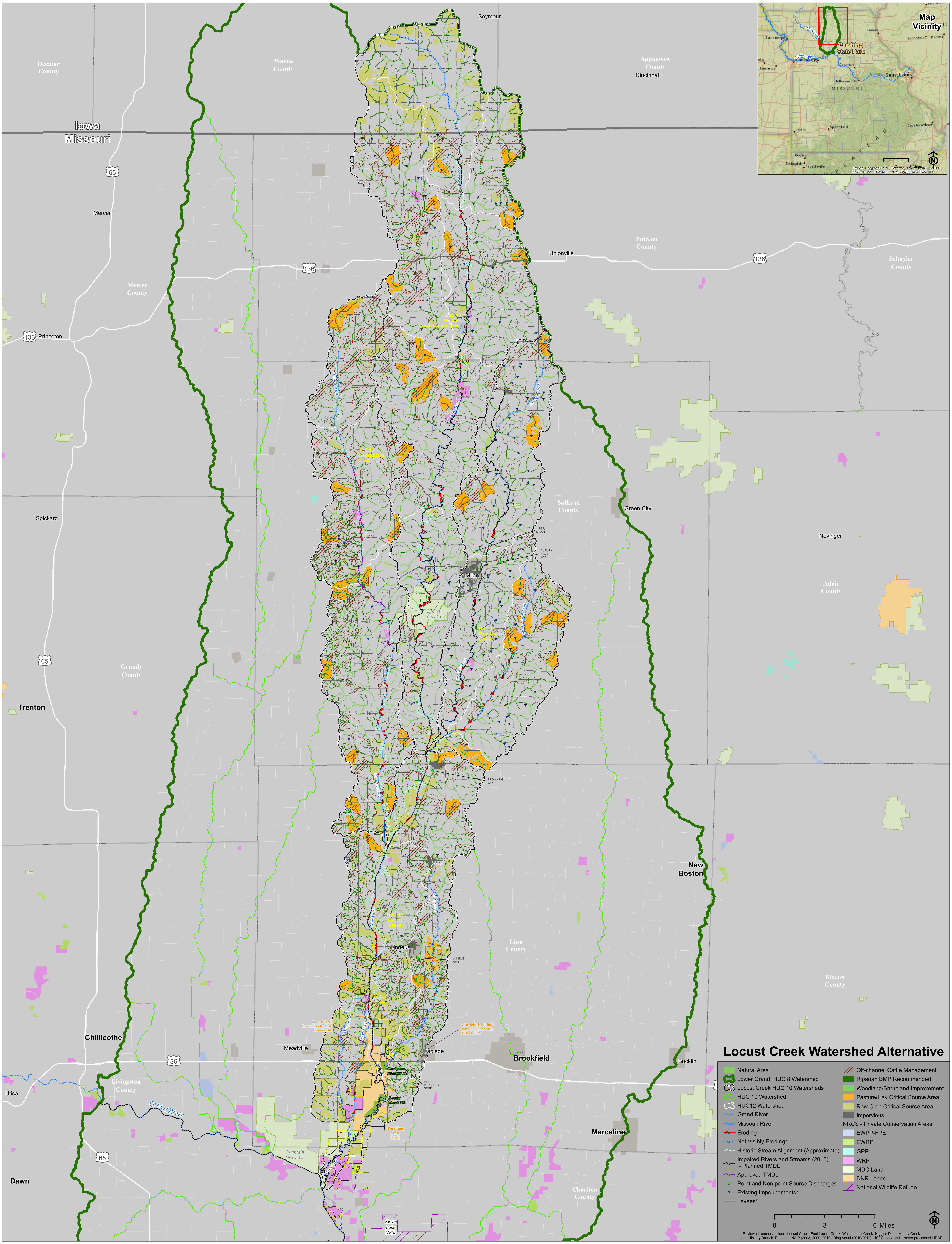
Locust Creek

Date: 2/27/2013

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_SS_16pages.mxd

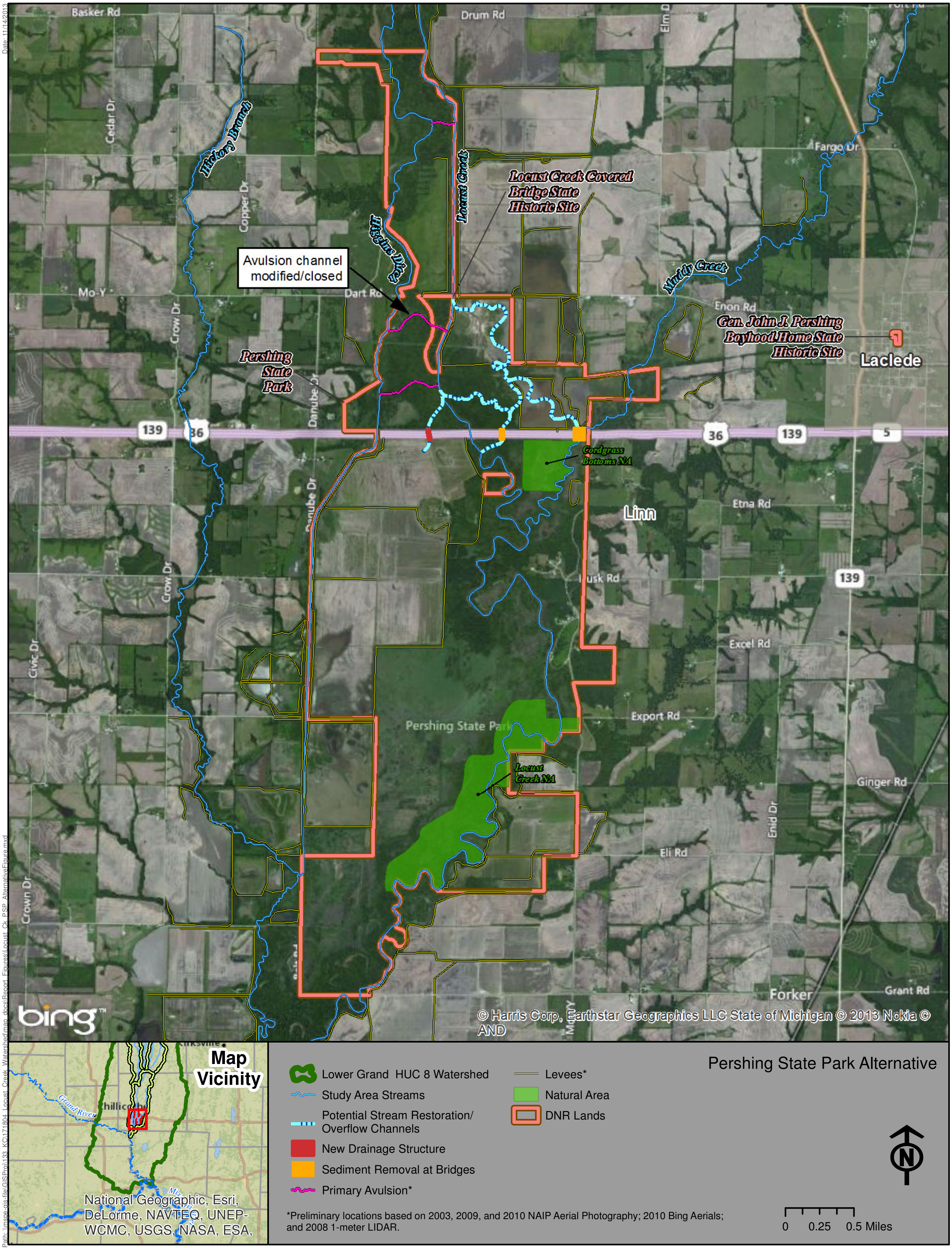
Appendix C

Locust Creek Watershed Alternative


Locust Creek Watershed Alternative
Natural Area
Lower Grand HUC 8 Watershed
Locust Creek HUC 10 Watersheds
HUC 10 Watershed
HUC12 Watershed
Grand River
Missouri River
Eroding*
Not Visibly Eroding*
Historic Stream Alignment (Approximate)
Impaired Rivers and Streams (2010) - Planned TMDL
Approved TMDL
Point and Non-point Source Discharges
Existing Impoundments*
Levees*
Off-channel Cattle Management
Riparian BMP Recommended
Woodland/Shrubland Improvement
Pasture/Hay Critical Source Area
Row Crop Critical Source Area
Impervious
NRCS - Private Conservation Areas
EWPP-FPE
EWRP
GRP
WRP
MDC Land
DNR Lands
National Wildlife Refuge
0
3
6 Miles
N
*Reviewed reaches include: Locust Creek, East Locust Creek, West Locust Creek, Higgins Ditch, Muddy Creek, and Hickory Branch. Based on NAIP (2003, 2009, 2010); Bing Aerial (2010/2011); USGS topo; and 1 meter processed LIDAR.
Map Vicinity
Pershing State Park
Iowa
Missouri
Decatur County
Wayne County
Appanoose County
Seymour
Cincinnati
Mercer
Mercer County
Princeton
Putnam County
Unionville
Schuyler County
Sullivan County
Green City
Spickard
Novinger
Milan
Locust Creek CA
Adair County
Grundy County
Trenton
New Boston
Linneus
Linn County
Macon County
Chillicothe
Meadville
Laclede
Brookfield
Bucklin
Livingston County
Utica
Grand River
Fountain Grove CA
Pershing State Park
Marceline
Dawn
Chariton County
Swan Lake NWR
BROWNING WWTF
LINNEUS WWTF
MDNR PERSHING ST PK
PSF MILAN
AUBURN HILLS WWTF
65
136
36

Appendix D

Pershing State Park Alternative

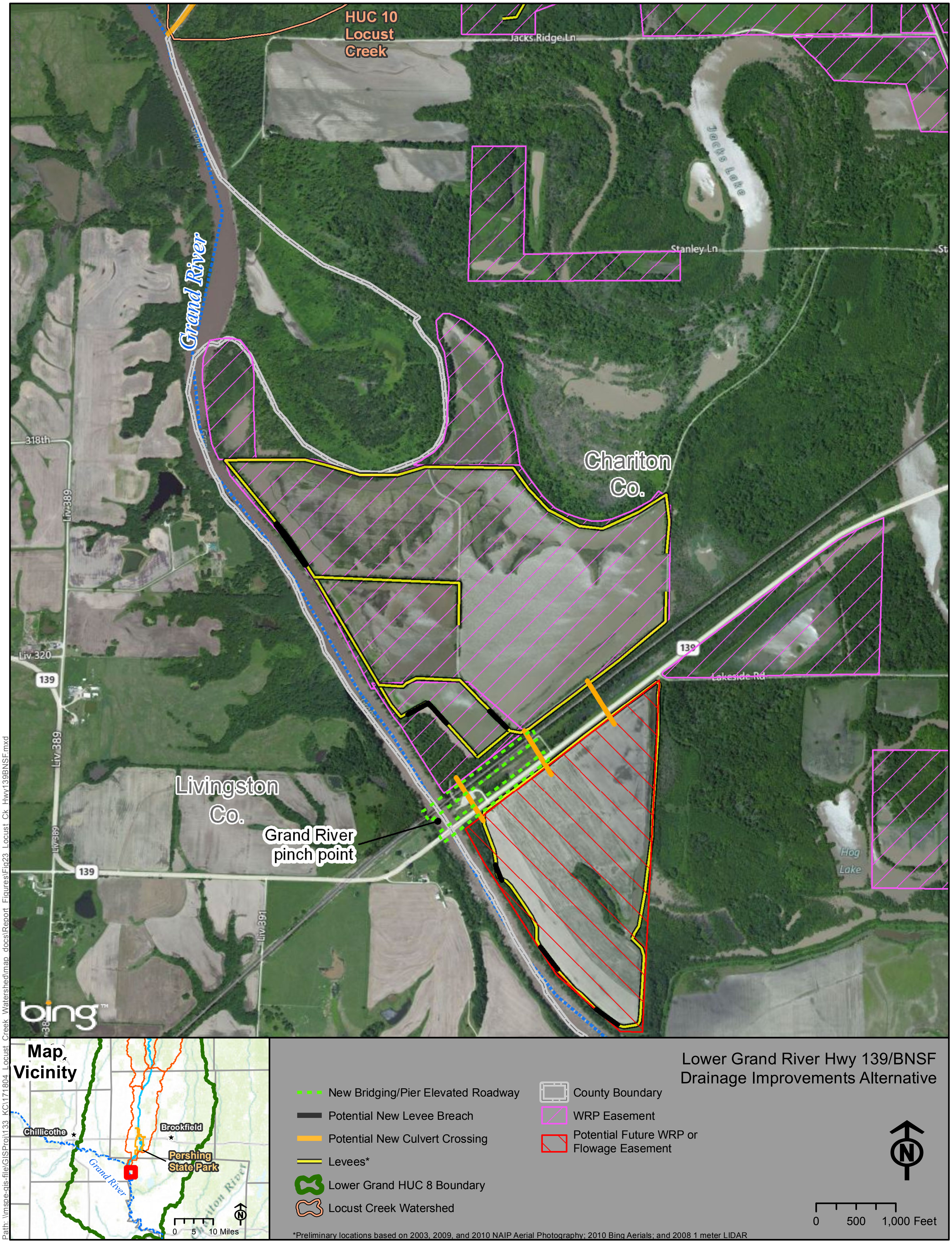


Date: 11/14/2013

Path: \\mspe-gis-file\GISProj\133_KC\171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_PSP_AlternativeFigure.mxd

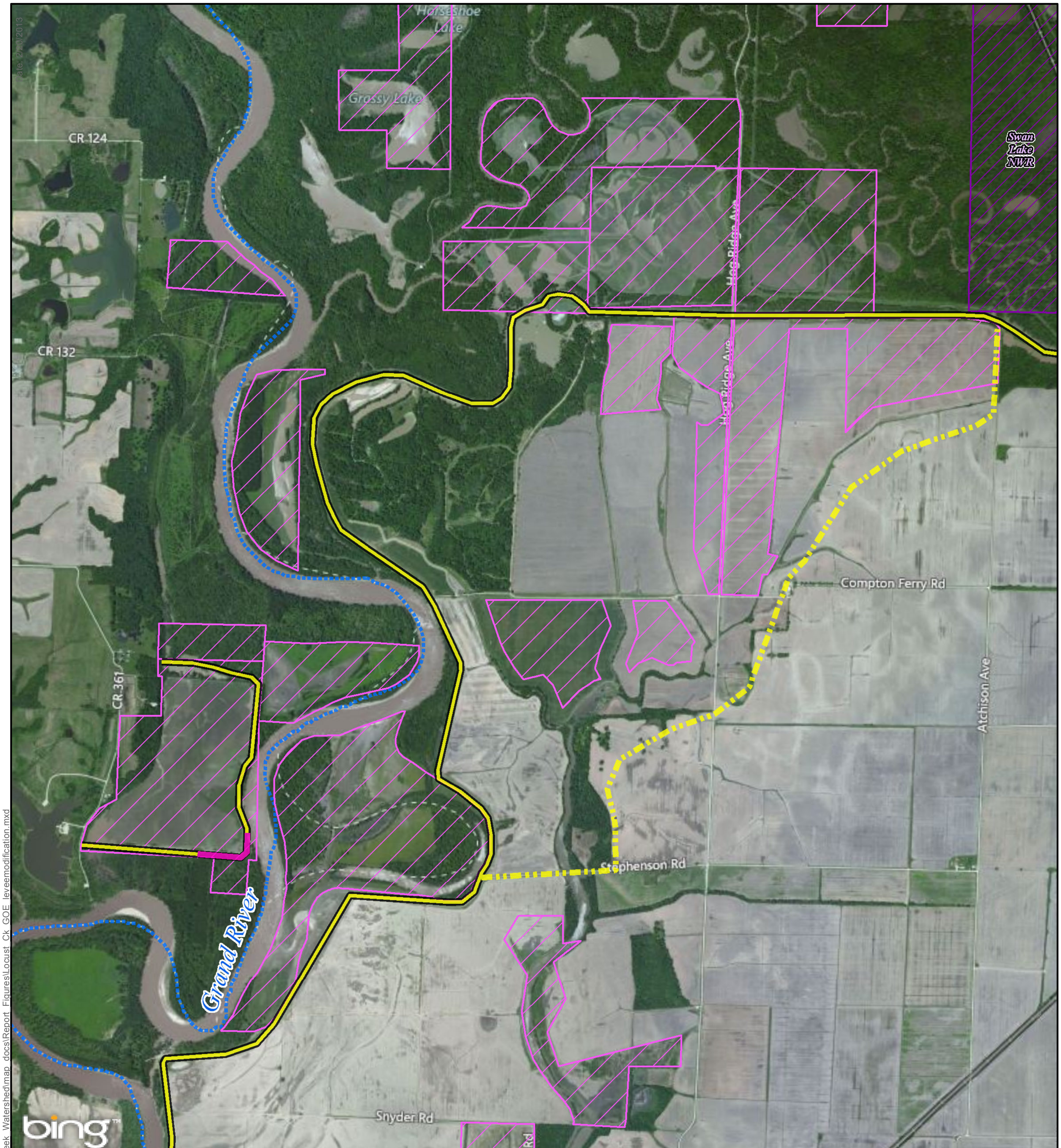
Appendix E

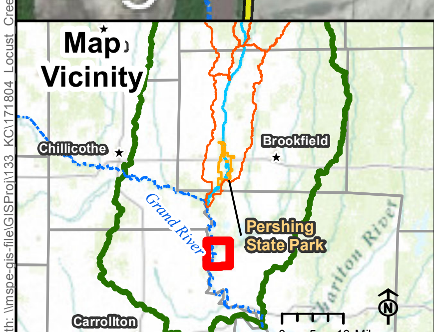
Hwy 139/BNSF Floodway Drainage Improvements Alternative


HUC 10
Locust
Creek
Jacks Ridge Ln
Jacks Lake
Stanley Ln
Grand River
318th
Liv 389
Liv 320
139
Chariton
Co.
Livingston
Co.
Grand River
pinch point
Lakeside Rd
Liv 391
Hog
Lake
bing
Map
Vicinity
Chillicothe
Brookfield
Pershing
State Park
Grand River
0 5 10 Miles
Lower Grand River Hwy 139/BNSF
Drainage Improvements Alternative
New Bridging/Pier Elevated Roadway
Potential New Levee Breach
Potential New Culvert Crossing
Levees*
Lower Grand HUC 8 Boundary
Locust Creek Watershed
County Boundary
WRP Easement
Potential Future WRP or
Flowage Easement
0 500 1,000 Feet
*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR

Appendix F

Lower Grand River Floodway and Levee System Modifications Alternative





Lower Grand River Floodway and Levee System Modifications Alternative

Lower Grand HUC 8 Boundary

Garden of Eden Proposed Setback Levee

Existing Levee Takedown

Existing Levees*

National Wildlife Refuge

WRP Easement

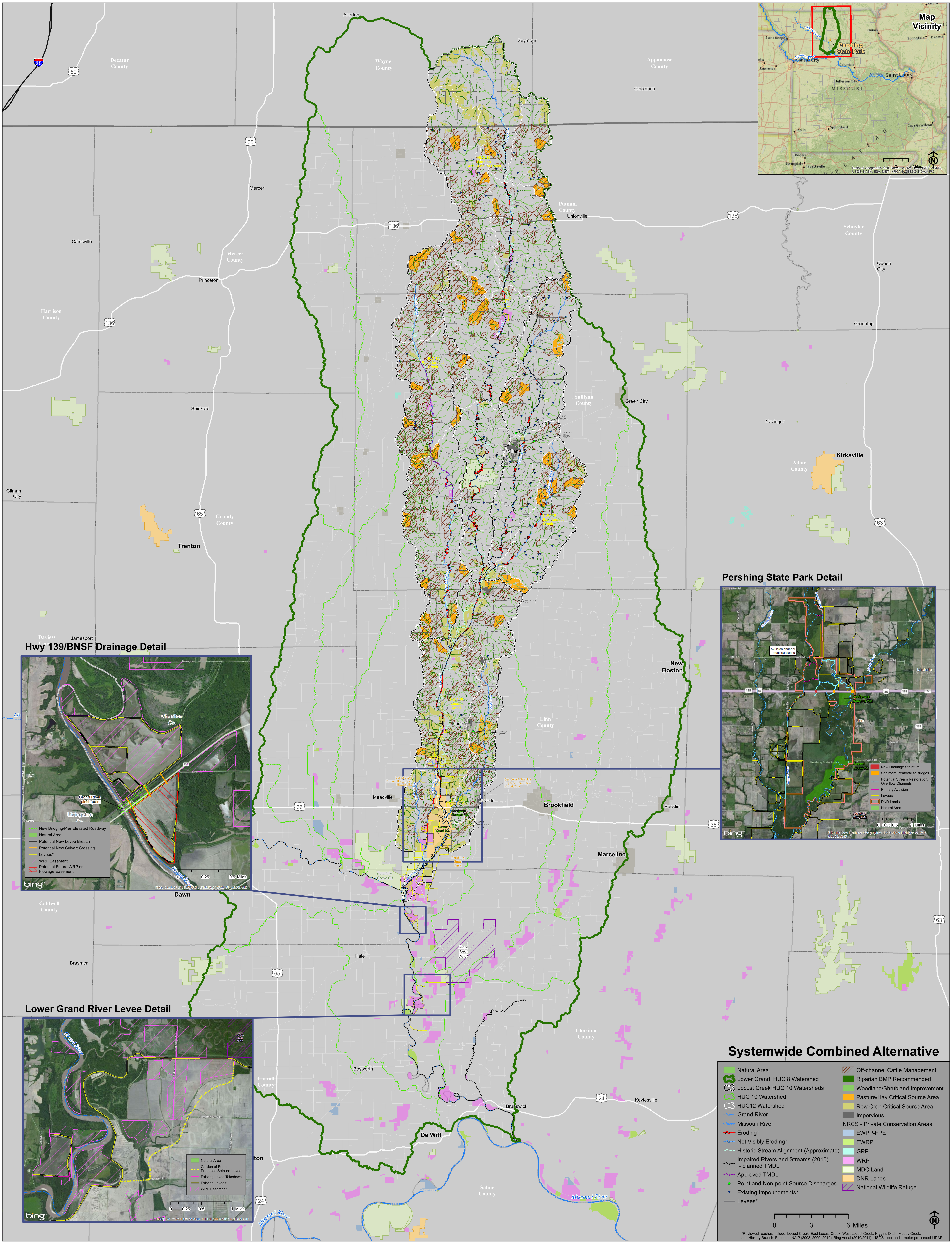
*Preliminary locations based on 2003, 2009, and 2010 NAIP Aerial Photography; 2010 Bing Aerials; and 2008 1 meter LIDAR

0 1,000 2,000 Feet

Path: \\mspe-gis-file\GISProj\133_KC171804_Locust_Creek_Watershed\map_docs\Report_Figures\Locust_Ck_GOE_leveemodification.mxd

Appendix G

Systemwide Combined Alternative



Systemwide Combined Alternative
Map Vicinity
Pershing State Park
Kansas City
Saint Louis
Columbia
Jefferson City
Springfield
MISSOURI
Pershing State Park Detail
Avulsion channel modified/closed
Laclede
New Drainage Structure
Sediment Removal at Bridges
Potential Stream Restoration/ Overflow Channels
Primary Avulsion
Levees
DNR Lands
Natural Area
Hwy 139/BNSF Drainage Detail
Chariton Co.
Grand River pinch point
Livingston
New Bridging/Pier Elevated Roadway
Natural Area
Potential New Levee Breach
Potential New Culvert Crossing
Levees*
WRP Easement
Potential Future WRP or Flowage Easement
Lower Grand River Levee Detail
Natural Area
Garden of Eden Proposed Setback Levee
Existing Levee Takedown
Existing Levees*
WRP Easement
Allerton
Seymour
Decatur County
Wayne County
Appanoose County
Cincinnati
Mercer
Putnam County
Unionville
Schuyler County
Cainsville
Mercer County
Princeton
Queen City
Harrison County
Greentop
Green City
Sullivan County
Spickard
Novinger
Milan
Kirksville
Adair County
Gilman City
Grundy County
Trenton
New Boston
Daviess County
Jamesport
Linn County
Linneus
Meadville
Laclede
Brookfield
Bucklin
Marceline
Fountain Grove CA
Dawn
Caldwell County
Swan Lake NWR
Hale
Braymer
Chariton County
Carroll County
Bosworth
Brunswick
Keytesville
De Witt
Saline County
Missouri River
Natural Area
Lower Grand HUC 8 Watershed
Locust Creek HUC 10 Watersheds
HUC 10 Watershed
HUC12 Watershed
Grand River
Missouri River
Eroding*
Not Visibly Eroding*
Historic Stream Alignment (Approximate)
Impaired Rivers and Streams (2010) - planned TMDL
Approved TMDL
Point and Non-point Source Discharges
Existing Impoundments*
Levees*
Off-channel Cattle Management
Riparian BMP Recommended
Woodland/Shrubland Improvement
Pasture/Hay Critical Source Area
Row Crop Critical Source Area
Impervious
NRCS - Private Conservation Areas
EWPP-FPE
EWRP
GRP
WRP
MDC Land
DNR Lands
National Wildlife Refuge
0 3 6 Miles
*Reviewed reaches include: Locust Creek, East Locust Creek, West Locust Creek, Higgins Ditch, Muddy Creek, and Hickory Branch. Based on NAIP (2003, 2009, 2010); Bing Aerial (2010/2011); USGS topo; and 1 meter processed LIDAR.

Appendix H

Funding Sources and Programs

Program Name	Agency	Description	Website
Planning Assistance to States (CAP Section 22)	USACE	The Section 22 PAS program's objective is to cooperate with any State in the preparation of comprehensive plans for the development, utilization and conservation of water and related land resources of drainage basins located within the boundaries of such state. The Section 22 PAS program has commonly been used for broad comprehensive watershed assessment and water related planning topics by local sponsors.	http://www.lre.usace.army.mil/planning/assist.html
Aquatic Ecosystem Restoration (CAP Section 206)	USACE	Work under this authority may carry out aquatic ecosystem restoration projects that will improve the quality of the environment, are in the public interest, and are cost-effective. There is no requirement that an existing Corps project be involved.	www.lrl.usace.army.mil/
General Investigations/ Specially Authorized Projects Grand River Basin Resolution	USACE	Large-scale, complex water resource problems normally require specific authorization from Congress. Currently the Corps has authority through Congressional resolution to conduct multi-purpose water resource projects on th Lower Grand River.	http://www.mvn.usace.army.mil/pd/pppmd_authorized_projects.asp
Project Modifications for Improvement of the Environment (CAP Section 1135)	USACE	Work under this authority provides for modifications in the structures and operations of water resources projects constructed by the Corps of Engineers to improve the quality of the environment. Additionally, the Corps may undertake restoration projects at locations where an existing Corps project has contributed to the degradation. The primary goal of these projects is ecosystem restoration with an emphasis on projects benefiting fish and wildlife. The project must be consistent with the authorized purposes of the project being modified, environmentally acceptable, and complete within itself	www.lrl.usace.army.mil
Small Flood Damage Reduction Projects (CAP Section 205)	USACE	Work under this authority provides for local protection from flooding by the construction or improvement of structural flood damage reduction features such as levees, channels, and dams. Non-structural alternatives are also considered and may include measures such as installation of flood warning systems, raising and/or flood proofing of structures, and relocation of flood prone facilities.	www.lrl.usace.army.mil
Snagging and Clearing for Flood Control (CAP Section 208)	USACE	Work under this authority provides for local protection from flooding by channel clearing and excavation, with limited embankment construction by use of materials from the clearing operation only. The non-Federal sponsor is responsible for a minimum of 35% to a maximum of 50% of total project costs and the Federal Government is responsible for the remainder of total project costs. The Federal share of planning, design, and construction cannot exceed $500,000 for each project.	www.lrl.usace.army.mil
National Integrated Water Quality Program (NIWQP)	USDA	The National Integrated Water Quality Program (NIWQP) provides funding for research, education, and extension projects aimed at improving water quality in agricultural and rural watersheds. The NIWQP has identified eight "themes" that are being promoted in research, education and extension. The eight themes are: (1) Animal manure and waste management, (2) Drinking water and human health, (3) Environmental restoration, (4) Nutrient and pesticide management, (5) Pollution assessment and prevention, (6) Watershed management, (7) Water conservation and agricultural water management, (8) Water policy and economics. Awards are made in four program areas - National Projects, Regional Coordination Projects, Extension Education Projects, and Integrated Research, Education and Extension Projects. Please note that funding is only available to universities.	http://www.csrees.usda.gov/funding/rfas/water_quality.html
Conservation Reserve Program	USDA – FSA	The Conservation Reserve Program (CRP) is a voluntary program for agricultural landowners. Through CRP, owners can receive annual soil rental payments and cost-share assistance to establish long-term, resource conserving covers on eligible farmland.	http://www.fsa.usda.gov

Program Name	Agency	Description	Website
Wetland Reserve Program	USDA - NRCS	The Wetland Reserve Program (WRP) is a voluntary program for agricultural landowners. Through the program, NRCS provides technical and financial assistance to help landowners voluntarily restore and protect wetland ecosystems. Landowners may select either a permanent or 30-year easement, retaining ownership of the land once the easement is in place.	
Emergency Watershed Protection	USDA – NRCS	The USDA Natural Resources Conservation Service's Emergency Watershed Protection (EWP) program helps protect lives and property threatened by natural disasters such as floods, hurricanes, tornadoes, droughts, and wildfires. EWP provides funding for such work as clearing debris from clogged waterways, restoring vegetation, and stabilizing river banks. The measures that are taken must be environmentally and economically sound and generally benefit more than one property owner. EWP also provides funds to purchase floodplain easements as an emergency measure. Floodplain easements restore, protect, maintain, and enhance the functions of the floodplain; conserve natural values including fish and wildlife habitat, water quality, flood water retention, ground water recharge, and open space; reduce long-term federal disaster assistance; and safeguard lives and property from floods, drought, and the products of erosion. EWP cost-share rate is paid at a 75/25 percent ratio, but can provide up to 90 percent cost share if an area qualifies as a limited resource areas, as determined by the federal, state, and local census data.	www.nrcs.usda.gov/programs/ewp/
Environmental Quality Incentives Program	USDA – NRCS	The USDA Natural Resources Conservation Service's Environmental Quality Incentives Program (EQIP) was established to provide a voluntary conservation program for farmers and ranchers to address significant natural resource needs and objectives. Through a competitive process, EQIP offers contracts with a minimum term that ends one year after the implementation of the last scheduled practices and a maximum term of ten years. These contracts provide financial assistance to program participants to implement eligible conservation practices. Persons or legal entities, who are owners of land under agricultural production or who are engaged in livestock or agricultural production on eligible land, including private non-industrial forest land, may participate in EQIP. Conservation practices implemented through EQIP are subject to NRCS technical standards adapted for local conditions. NRCS approves a plan of operations which identifies practices needed to address natural resource concerns and obligates program funds to help producers implement the approved practices. EQIP-related programs include Conservation Innovation Grants (CIG), Cooperative Conservation Partnership Initiative (CCPI), and Agricultural Water Enhancement Program (AWEP).	www.nrcs.usda.gov/programs/eqip
Farm and Ranch Lands Protection Program (FRPP)	USDA – NRCS	The USDA Natural Resources Conservation Service's Farmland Protection Program (FPP) is a voluntary program that helps farmers and ranchers to keep their land in agriculture and prevents conversion of agricultural land to non-agricultural uses. The program provides matching funds to agencies and organizations with existing farmland protection programs that enable them to purchase conservation easements. These cooperating entities purchase easements from landowners in exchange for a lump sum payment. The Federal contribution cannot to exceed 50 percent of the appraised fair market value of the land's development rights. The easements are for perpetuity unless prohibited by state law. Eligible land is land on a farm or ranch that has prime, unique, statewide, or locally important soil, that contains historical or archaeological resources; or that supports the policy of a State or local farm and ranch land protection policy; is subject to a pending offer by an eligible entity; and includes cropland, rangeland, grassland, pasture land, forest land and other incidental land that is part of an agricultural operation.	www.nrcs.usda.gov/programs/frpp
Grassland Reserve Program	USDA – NRCS	The 2002 Farm Bill established the Grassland Reserve Program (GRP) for the purpose of restoring and conserving two million acres of grassland, rangeland, and pastureland. GRP will do this through the use of up to 30-year rental agreements and 30-year or permanent easements. GRP allows participants to enroll in 10, 15, 20, or 30-year rental agreement contracts, or 30-year permanent easements. GRP lands may be used for haying and grazing under a conservation plan.	http://www.nrcs.usda.gov/programs/GRP/

Program Name	Agency	Description	Website
Clean Water State Revolving Fund	USEPA	The EPA's Clean Water State Revolving Fund (CWSRF) program provides a permanent source of low-cost financing for a wide range of water quality infrastructure projects. These projects include traditional wastewater treatment and collection, nonpoint source pollution controls, and estuary management. Funds to capitalize the program are provided annually through federal grants and state matching funds (equal to 20 percent of federal grants). Monies are loaned to assistance recipients at below-market rates. In addition, states also have the ability to customize loan terms to benefit small and disadvantaged communities. Loan repayments are recycled back into the programs to fund additional projects. Since its inception, the CWSRF has provided over $89.5 billion in assistance to eligible borrowers, including communities of all sizes, farmers, small businesses, and nonprofit organizations.	epa.gov/owm/cwfinance/cwsrf/index.htm
Environmental Education Grants	USEPA	Under the Environmental Education (EE) Grant Program, EPA seeks grant proposals from eligible applicants to support environmental education projects that promote environmental stewardship and help develop knowledgeable and responsible students, teachers, and citizens. This grant program provides financial support for projects that design, demonstrate, and/or disseminate environmental education practices, methods, or techniques as described in the solicitation notices. EPA expects to award two rounds of environmental education grants from the ten EPA Regional offices.	http://www.epa.gov/enviroed
Five-Star Restoration Program	USEPA	The EPA supports the Five-Star Restoration Program by providing funds to the National Fish and Wildlife Foundation and its partners, the National Association of Counties, NOAA's Community-based Restoration Program and the Wildlife Habitat Council. These groups then make subgrants to support community-based wetland and riparian restoration projects. Competitive projects will have a strong on-the-ground habitat restoration component that provides long-term ecological, educational, and/or socioeconomic benefits to the people and their community. Preference will be given to projects that are part of a larger watershed or community stewardship effort and include a description of long-term management activities. Projects must involve contributions from multiple and diverse partners, including citizen volunteer organizations, corporations, private landowners, local conservation organizations, youth groups, charitable foundations, and other federal, state, and tribal agencies and local governments. Each project would ideally involve at least five partners who are expected to contribute funding, land, technical assistance, workforce support, or other in-kind services that are equivalent to the federal contribution.	http://water.epa.gov/grants_funding/wetlands/restore/index.cfm
Nonpoint Source Implementation Grants (319 Program)	USEPA	Through its 319 program, EPA provides formula grants to the states and tribes to implement nonpoint source projects and programs in accordance with section 319 of the Clean Water Act (CWA). Nonpoint source pollution reduction projects can be used to protect source water areas and the general quality of water resources in a watershed. Examples of previously funded projects include installation of best management practices (BMPs) for animal waste; design and implementation of BMP systems for stream, lake, and estuary watersheds; basinwide landowner education programs; and lake projects previously funded under the CWA section 314 Clean Lakes Program.	www.epa.gov/owow/nps/contacts.html

Program Name	Agency	Description	Website
Targeted Watershed Grants Program	USEPA	EPA is asking the nation's Governors, Tribal Leaders, and leading watershed organizations to apply for the next round of funding to support collaborative partnerships to protect and restore the nation's water resources. The Agency will select up to 12 watershed organizations to receive grants to implement watershed-based, on-the-ground implementation projects and up to 5 training and educational organizations to receive grants or cooperative agreements to help build capacity of the many grass roots watershed organizations across the country. Both grants will focus on strong stakeholder support and producing improved environmental change. In a third part of the program, the Agency will also award Targeted Watershed funds to support nutrient management projects in the Chesapeake Bay Watershed. Currently this program is no longer taking applications.	www.epa.gov/owow/watershed/initiative/
Water Pollution Control Program Grants (Section 106)	USEPA	Section 106 of the Clean Water Act authorizes EPA to provide federal assistance to states (including territories, the District of Columbia, and Indian Tribes) and interstate agencies to establish and implement ongoing water pollution control programs. Prevention and control measures supported by pollution control programs include permitting, development of water quality standards and total maximum daily loads, surveillance, ambient water quality monitoring, and enforcement; advice and assistance to local agencies; and the provision of training and public information. Increasingly, EPA and states are working together to develop basin-wide approaches to water quality management. The Water Pollution Control Program is helping to foster a watershed protection approach at the state level by looking at states' water quality problems holistically, and targeting the use of limited finances available for effective program management. At present, the program is seeking ways to streamline the grants process to ease the administrative burden on states.	http://water.epa.gov/grants_funding/cwf/pollutioncontrol.cfm
State/Tribal/Local Wetlands Grant Program	USEPA	Since 1990, this Federal grants program has supported State, Tribal, and local efforts to protect wetlands by providing funds to enhance existing programs or develop new programs.	http://water.epa.gov/type/wetlands/initiative_index.cfm
North American Wetlands Conservation Act Grants Program	USFWS	The U.S. Fish and Wildlife Service's Division of Bird Habitat Conservation administers this matching grants program to carry out wetlands and associated uplands conservation projects in the United States, Canada, and Mexico. Grant requests must be matched by a partnership with nonfederal funds at a minimum 1:1 ratio. Conservation activities supported by the Act in the United States and Canada include habitat protection, restoration, and enhancement. Mexican partnerships may also develop training,educational, and management programs and conduct sustainable-use studies. Project proposals must meet certain biological criteria established under the Act.	http://birdhabitat.fws.gov
Partners for Fish and Wildlife Program	USFWS	The Partners for Fish and Wildlife Program provides technical and financial assistance to private landowners to restore fish and wildlife habitats on their lands via cooperative agreements. Since 1987, the program has partnered with more than 37,700 landowners to restore 765,400 acres of wetlands; over 1.9 million acres of grasslands and other upland habitats; and 6,560 miles of in-stream and streamside habitat. In addition, the program restores stream habitat for fish and other aquatic species by removing barriers to passage.	http://www.fws.gov/partners
State Wildlife Grant Program (Non-Tribal and Non-Competitive)	USFWS	The U.S. Fish and Wildlife Service's (USFWS) State Wildlife Grant (SWG) program provides grants to states, territories, and the District of Columbia for wildlife conservation.The SWG program provides funds to help develop and implement programs that benefit wildlife and their habitat, including species that are not hunted or fished. Although not directly eligible for these grants, third parties such as nonprofit organizations may benefit from these funds by working directly with their states to see if either grants or partnering opportunities are available.	http://wsfrprograms.fws.gov/Subpages/GrantPrograms/SWG/SWG_Funding.htm

Program Name	Agency	Description	Website
Soil & Water Conservation Program	MO DNR	The Missouri DNR funds soil & water conservation programs in each county through a parks, soils and water sales tax and administers the program through local Soil & Water Conservation Conservation District offices.	http://dnr.mo.gov/env/swcp/
Wetland & Stream Mitigation Banks	Private For Profit Organizations	Wetland & Stream Mitigation Banks function to restore wetlands and streams (as measured by establishing wetland and stream credits) that can be withdrawn or debited from the bank for a fee paid typically by CWA Section 404/401 permit applicants to offset or mitigate dredge and fill impacts within a certain geographic area. Credits are typically established and certified in advance of debiting. Mitigation bankers establish credit prices and assume all permittee mitigation responsibilities. Mitigation bankers are not funding agencies; however, they can develop and implement mitigation projects that collectively benefit the watershed that are funded or "paid for" by permit applicants. Corps approved in-lieu fee programs typically service distinctive geographic areas.	
Wetland & Stream In-lieu Fee Programs	Private non-profit organizations - typically non-governmental	Wetland & Stream Mitigation In-lieu fee Programs function to restore wetlands and streams by pooling fees from multiple CWA Section 404/401 permit applicants for purposes of offsetting or mitigating dredge and fill impactswithin a certain geographic area. Credits are typically established after debiting or impacts occur. In-lieu fee programs typically establish credit prices. In-lieu fee programs are not funding agencies; however, they can develop and implement mitigation projects that collectively benefit the watershed that are funded or "paid for" by permit applicants. Corps approved in-lieu fee programs typically service distinctive geographic areas.	