Bear Branch
Watershed Management Plan

City of Murfreesboro,
Rutherford County, Tennessee

May 2013

U.S. Army Corps of Engineers
Nashville District

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Executive Summary

The Bear Branch Watershed Management Plan has been prepared by the U.S. Army Corps of Engineers, Nashville District (USACE LRN) in partnership with the City of Murfreesboro, Tennessee. The Bear Branch Watershed Management Plan is intended to assist policy-makers with decisions to improve water quality, terrestrial conditions, and environmental quality of Bear Branch and its tributaries. Best Management Practices (BMPs) are recommended to improve water quality and riparian stream conditions. They will address Bear Branch's listing on the Tennessee Department of Environment and Conservation, Division of Water Resources (TDEC DWR) 303 (d) list of impaired waters of the State of Tennessee.

Bear Branch is a tributary of the East Fork Stones River, northeast of Murfreesboro, Tennessee. The Bear Branch watershed encompasses 5 square miles and includes the Dry Branch tributary.

Bear Branch Watershed Management Plan identifies and involves key watershed stakeholders such as TDEC, Tennessee Department of Agriculture (TDA), and Natural Resources Conservation Service (NRCS). The plan includes discussion of the existing stream and riparian conditions, an inventory of resources to both protect and repair, and description of the gaining and losing stream segments (stream segments which are either above or below the groundwater table) to better understand stream dynamics and geomorphology of Bear Branch and its tributaries. The plan also includes recommendations to improve the streams' aquatic habitat.

Funds for this study were provided under the Planning Assistance to States (PAS) Program authorized by Section 22 of the Water Resources Development Act of 1974, as amended, and the City of Murfreesboro. The PAS Program provides authority for the USACE to assist states, local governments, and other non-federal entities in preparation of comprehensive plans for development, utilization, and conservation of water and related land resources.

Recommendations to improve water quality, restore channel functionality and stability, enhance aquatic habitat, and restore riparian buffer function involve identifying and addressing sedimentation and other sources of pollution, limiting livestock access from riparian areas, addressing accelerated bank erosion problems, and re-establishment of in-stream and riparian habitat. Locations for applying BMPs are included in Section 7 – Proposed Best Management Practices, and Section 8 – Site-Specific Recommendations for Bear Branch and Dry Branch. A list of prioritized locations in the Bear Branch watershed for application of BMPs is provided, and supports information from a previous study conducted by the Murfreesboro Water and Sewer Department. Site description, severity, correctability, and access to each site were used to prioritize the list included in Section 7, Table 9.

1.a Introduction

The Bear Branch Watershed Management Plan includes a detailed description of existing conditions along Bear and Dry Branches to assist the evaluation of measures to improve the water quality of the streams. The overall goal of the plan is to improve water quality conditions in the stream significantly enough to consider removal of Bear Branch from TDEC's 303(d) list of Impaired Waters.

Bear Branch is in Rutherford County, about 3 miles northeast of downtown Murfreesboro, Tennessee. It converges with Dry Branch about 1/2 mile upstream from the confluence with the East Fork of the Stones River. See Figure 1 for project orientation. Bear Branch is about 3.5 miles in length, and the watershed drains about 5 square miles (4,100 acres). TDEC Division of Water Resources lists the Hydrologic Unit Code (HUC) for Bear and Dry Branch sub-watershed as 05130203023. See Figure 2 for watershed location.

The Bear Branch Watershed Management Study was conducted by the City of Murfreesboro and the Nashville District Corps of Engineers. Funds were provided under the Planning Assistance to States (PAS) Program as authorized by Section 22 of the Water Resources Development Act of 1974, as amended, and the City of Murfreesboro. The PAS Program provides authority for the USACE to assist states, local governments, and other non-federal entities in the preparation of comprehensive plans for the development, utilization, and conservation of water and related land resources. Studies costs are shared 50% federal and 50% non-federal.

The plan has engaged federal, state, and local watershed stakeholders in addressing watershed management issues. The study team gathered and evaluated existing watershed information including soils and geology data; threatened, endangered, and rare species presence or absence; water quality information; City of Murfreesboro stormwater regulations; wastewater collection system history (includes past occurrences of sewage overflows and/or bypasses within the watershed); presence of on-site septic systems; and known problems. The study team conducted a stream visual assessment and inventoried and mapped problem sites within the watershed such as lack of riparian buffers, bank erosion, stream alteration sites, and sensitive habitats, such as headwaters, wetlands forests, springs/seeps, and limestone glades. They also gathered and evaluated existing land use and development patterns and forecasted changes in those patterns and evaluated measures to improve the water quality of the stream.

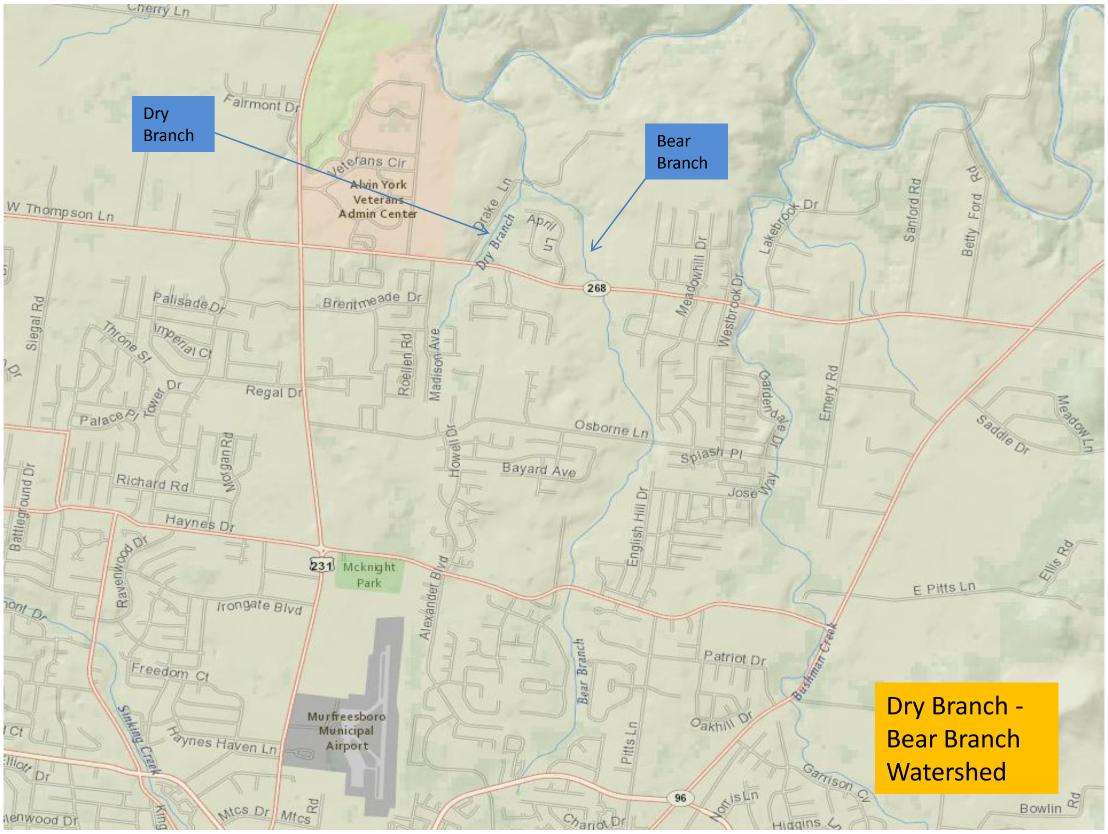


Figure 1 - Bear Branch - Dry Branch Watershed. Photo courtesy Rutherford County GIS Department

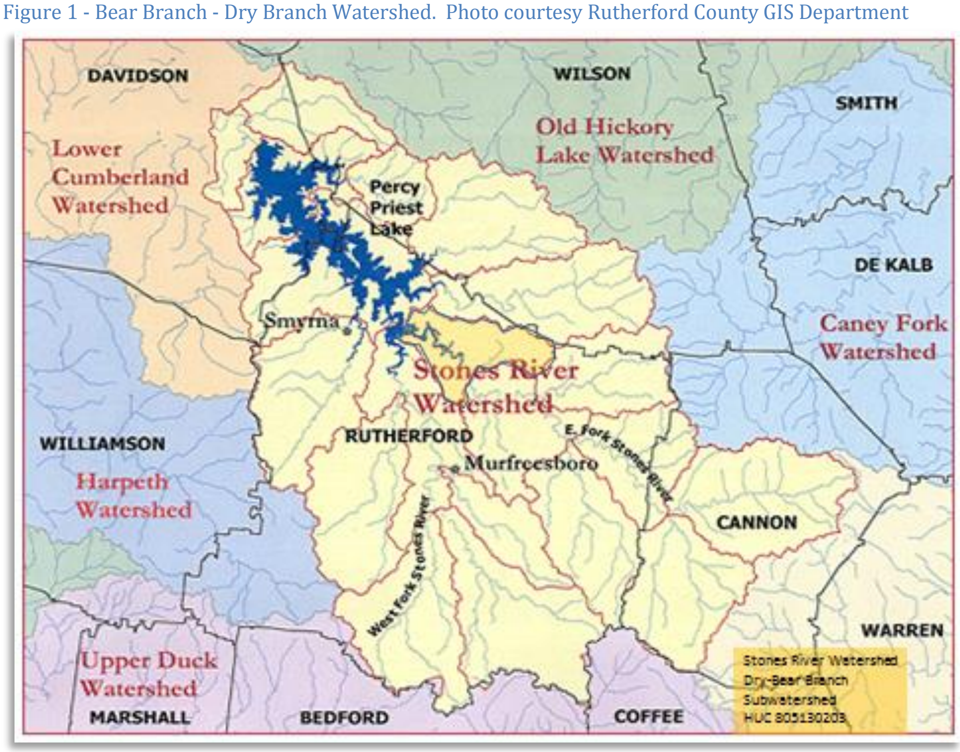


Figure 2 - Stones River Watershed, Bear Branch-Dry Branch Sub-watershed - HUC 051302030105 - Courtesy of Stones River Watershed Association

1.b **Watershed Partnerships**
Federal, state, and local watershed partners for this effort include the following:

U.S. Army Corps of Engineers, Nashville and Louisville Districts
U.S. Department of Agriculture (USDA)
U.S. Fish and Wildlife Service (USFWS)
Natural Resources Conservation Service (NRCS)
Environmental Protection Agency, Region IV, Watersheds and Nonpoint Sources (EPA)
U.S. Geological Survey (USGS)
The Nature Conservancy (TNC)
Tennessee Department of Environment & Conservation, Div. of Water Resources (TDEC DWR)
Tennessee Department of Environment & Conservation, Div. of Natural Heritage (TDEC DNH)
Tennessee Wildlife Resources Agency (TWRA)
Rutherford County Planning Department (RCPD)
Murfreesboro Water and Sewer Department (MWSD)
Murfreesboro Geographic Information System (GIS) Department
Murfreesboro Planning and Engineering Department (MPED)
Stones River Watershed Association (SRWA)
Middle Tennessee State University (MTSU)
Austin Peay State University (APSU)

1.c **Visual Stream Assessment – August-September 2012**
Between August and September 2012, members of MWSD and USACE conducted site assessments of Bear and Dry Branches. TDEC DNH, MTSU Biology Department, and APSU Biology Department also assisted. The teams conducted visual stream assessments and collected wetlands, stream benthic macroinvertebrates, potential threatened and endangered species, and other field-related information. Problem areas along the streams were identified, photographed, and located using GPS. Wetlands, losing and gaining stream segments, and other issues pertaining to Bear and Dry Branches were also investigated and researched. Special thanks to Bruce Ross, Josh Upham, and the MWSD for their assistance. A detailed analysis of Bear Branch watershed is included in Appendix A. Specific stream characteristics for wetlands, water quality, macroinvertebrates, sanitary sewer wastewater, and septic systems are discussed in the following section.

Bear Branch is typical of many small streams in the Stones River Basin. It is relatively flat, with sinks and springs along its course. The springs often form wetlands. Appreciable stream flow is also lost during drier periods due to stream flow disappearing within the karst topography of the area. Soils are shallow and streambanks are only a few feet high. The watershed is suburban. The majority of development is residential in the upper reaches, shifting to agricultural nearer the East Fork Stones River.

2. Bear Branch Watershed Characterization

2.a Wetlands

A review of the USFWS National Wetlands Inventory (NWI) database revealed the following wetlands within the Bear Branch watershed as indicated in Table 1.

Table 1 - USFWS, NWI Wetlands within Bear Branch Watershed

Description	Acreage	Location
Freshwater emergent wetland	1.15	NE Bear Branch/ US E Northfield Blvd
Freshwater emergent wetland	1.46	SE Macedonia Drive
Freshwater pond	0.13	SE E Northfield Blvd
Freshwater pond	1.27	E Northfield-Dejarnette Lane
Freshwater emergent wetland	0.39	US .5 mile from Dry Creek confluence
Freshwater pond	0.46	SW .3 mile from Bear Branch confluence

USFWS, National Wetland Inventory, 2012

A component of the site and visual stream assessments included informal wetland assessments of those sites identified in the NWI as well as identifying additional wetland sites. Thirteen additional locations were identified as shown in Table 2 below. The total watershed acreage identified includes 4.86 acres from NWI mapping and approximately 106.1 acres from additional field reconnaissance. Figure 3 is an aerial with the largest, most comprehensive network of wetlands identified.

Table 2 - Visual Stream Assessment, Informal Wetland Assessment

Description	Est Acreage	Location
Freshwater Emergent Wetland	2.6	Above E Northfield Blvd
Freshwater Wetland/Glade	17.4	Below E Northfield Blvd
Freshwater Wetland	5.8	East of Shagbark Trail
Freshwater Wetland	2.2	Above Dejarnette Lane
Freshwater Wetland	4.2	Below Dejarnette Lane
Freshwater Emergent Wetland	13.0	Above Osborne Lane – Dry Dam
Freshwater Emergent Wetland	6.3	Below Osborne Lane
Freshwater Wetland	0.7	Below Compton Road
Freshwater Wetland	0.9	Below Compton Road – Lufkin Spring
Freshwater Wetland	0.1	Dry Branch – Drake Lane
Freshwater Emergent Wetland	4.9	Dry Branch – Above Compton Road
Freshwater Emergent Wetland	43.5	Dry Branch – Above Osborne Lane
Freshwater Emergent Wetland	4.5	Dry Branch – Above Dejarnette Lane

Figure 3 - Bear Branch Watershed, informal wetland assessment locations

2.b Gaining/Losing Stream Reaches

Bear Branch maintains flow from springs located within the stream such as at Lufkin and Ayers springs (gaining reaches), while losing reaches, where the water moves underground, are located between Dejarnette Lane - Osborne Lane and Osborne Lane - Compton Road. Table 3 includes gaining reaches within Bear Branch watershed, while Figure 4 indicates portions of gaining-losing reaches within the watershed.

Table 3 - Gaining Stream Reaches on Bear Branch*

Location	Gaining Reach Location	Description	Coordinates
BB 1	700' below E Northfield Blvd to 700' above Dejarnette	Wetland Site	N 35 52 27.62 W 86 21 58.72
BB 2	675' above to 650' below Dejarnette	Wetland, riparian area	N 35 53 06.15 W 86 21 49.92
BB 3	750' to 1350' below Dejarnette Drive	Unnamed spring & wetland site	N 35 53 21.94 W 86 21 48.19
BB 4	900' above to 1,500 ' below Osborne	Wetland site	N 35 53 40.91 W 86 21 31.24
BB 5	200' above Compton Road to East Fork Confluence	Lufkin Spring, Ayers Spring, Wetland sites	N 35 54 24.80 W 86 21 39.34
DB 1	200' above Dejarnette Drive to 3,000' below Osborne Lane	Wetlands, unnamed spring site	N 35 52 59.59 W 86 22 39.63
DB 2	1,300' above Compton Road to Bear Branch confluence	Unnamed spring site	N 35 54 20.69 W 86 22 21.73

*Locations correspond to existing city mapping.

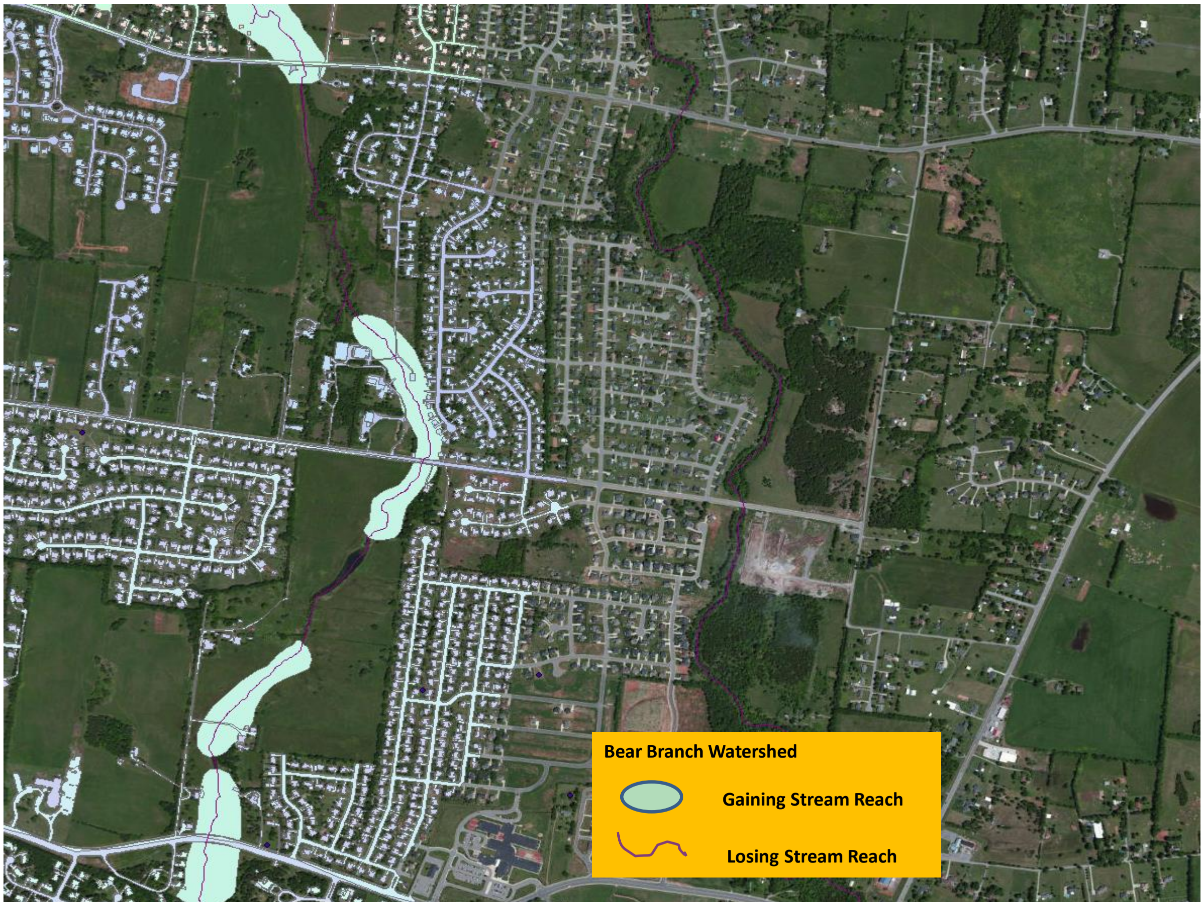


Figure 4 - Bear Branch - stream gaining and losing reaches

2. c Water Quality

The goal of the Clean Water Act (CWA) is "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters". If the stream cannot support all if its uses, it is placed on the 303(d) list. Under section 303(d) of the CWA, states are required to develop 303(d) lists of impaired waters that identify streams that require pollution controls to attain or maintain applicable water quality standards. States must evaluate all existing and readily available information in developing their 303(d) lists and EPA must approve revisions to the list. Once a stream has been placed on the 303(d) list, it is considered a priority for water quality improvement efforts. The 303(d) list is a flexible document that can be updated as new information becomes available. If the quality of the stream improves and supports all its designated uses and no longer violates the parameters of concern, the stream can be removed from the list. Documentation of the improvement is necessary.

The Tennessee Water Quality Control Board is responsible for the designation of beneficial uses of streams, rivers, lakes, and reservoirs in Tennessee (Chapter 1200-4-4 Use Classifications for Surface Waters). All waters in Tennessee have Fish and Aquatic Life (FAL) and Recreation (REC) use classifications to support fish, aquatic insects, snails, clams, and crayfish and the public's ability to swim, wade, and fish. Most waters are also classified for the Irrigation (IRR) use to protect the ability of farmers to use streams or reservoirs as a source of water to irrigate crops; Livestock Watering and Wildlife (LWW) use protects waters for use as an untreated drinking water source for livestock and wildlife. Bear Branch is classified all four of these uses: FAL, REC, IRR, and LWW.

The entire length of Bear Branch has been on the TDEC 303(d) list for the same causes since 1998 and remains on the 2012 list. The parameters of concern are habitat alteration, sediment, and nutrients, all of which impact FAL use. Although the stream goes dry frequently, physical, biological, and chemical data have been collected. Physical evidence includes observations of sediment/silt covering the stream substrate (sand, gravel, and cobble) as documented by the MSWD in Figure 5. In 1998, Dry Branch was listed for only partially supporting the FAL use. Subsequent sampling showed that Dry Branch met the FAL use by supporting an acceptable macroinvertebrate community since 1998. The REC use is impacted by *E. coli* contamination. Currently neither Dry Branch nor Bear Branch has been placed on the 303(d) list for bacterial (*E. coli*) contamination.

Figure 5 - Turbidity in Bear Branch upper reach

Figure 6 - Blackfoot quillwort (Isoetes melanopoda) Image courtesy Thomas G. Barnes, USDA-NRCS Plants Database, 2004

A portion of Bear Branch (from Dry Branch confluence to origin) is designated as exceptional Tennessee Waters due to the presence of the state endangered blackfoot quillwort *(Isoetes melanopoda)* (Figure 6). Research by APSU Biology Department indicates the presence of blackfoot quillwort within a limestone glade streamside meadow habitat located below East Northfield Boulevard.

2.d <u>Low-Flow and Flood Statistics</u>

Bear Branch is a flashy stream as shown in Table 4. Due to little water storage capacity in the thin soil layer within the watershed, the lowest flow for 3 consecutive days in a two year period (3-day 2 year lowest flow) is about 0.0129 cubic feet per second (cfs) or about 5.7 gallons per minute (GPM). Conversely, the 2-year peak flow for a flood event is approximately 477 cfs, or about 200,703 GPM. This stream velocity is erosive for banks with exposed soil. In addition, storm water ditches can flush sediment into the stream, further adding to turbidity. Sediment can deposit on the stream bottom, and when disturbed the water becomes cloudy and turbid (muddy). As a result, Bear Branch can be choked with sediment in an area with a good riparian buffer because the source of the sediment problem is well upstream.

Table 4 - Low Flow and Flood Statistics for Bear Branch

Low-Flow	Flow (cfs)	Flow (gpm)	Peak-Flow	Flow (cfs)	Flow (gpm)
3-day 2 year lowest flow	0.0129	5.7	2 year flood	477	200,703
3-day 10 year lowest flow	0.0029	1.3	5 year flood	751	337,199
3-day 20 year lowest flow	0.00182	0.8	10 year flood	940	422,060
7-day 10 year lowest flow	0.00369	1.7	25 year flood	1180	529,820
			50 year flood	1360	610,640
			100 year flood	1530	686,970
			500 year flood	1940	871,060

2.e. Biological and Chemical Sampling

Biological data includes fish and macroinvertebrates. Collections were made by TDEC, USACE, and MWSD. On September 25, 2012, USACE and MWSD performed a bio-reconnaissance (bio-recon) at several sites in the watershed. However, conditions were less than ideal and high water could have skewed the results. As can be seen below, most of the species found at the sampling locations on Bear Branch are pollutant tolerant. A few intolerant species are found at the Dry Branch sites. In addition, the variety of species is greater on Dry Branch than Bear Branch and Dry Branch is not on the 303(d) list. The sampling sites are shown on Figure 7.

Table 5 – Biometric Scoring for Family Level Bioregion 7li*

Bioregion	Season	Drainage Area*	Taxa Richness (TR)			EPT			Intolerant Taxa (IT)		
TBI Score			**5**	**3**	**1**	**5**	**3**	**1**	**5**	**3**	**1**
71i	Jan-Dec	>2	>19	10-19	<10	>6	4-6	<4	>4	2-4	<2
71i	Jan-Dec	< 2	>12	7-12	<7	>4	3-4	<3	>2	2	<2

*Caution should be used in streams < or = 2 square miles drainage.

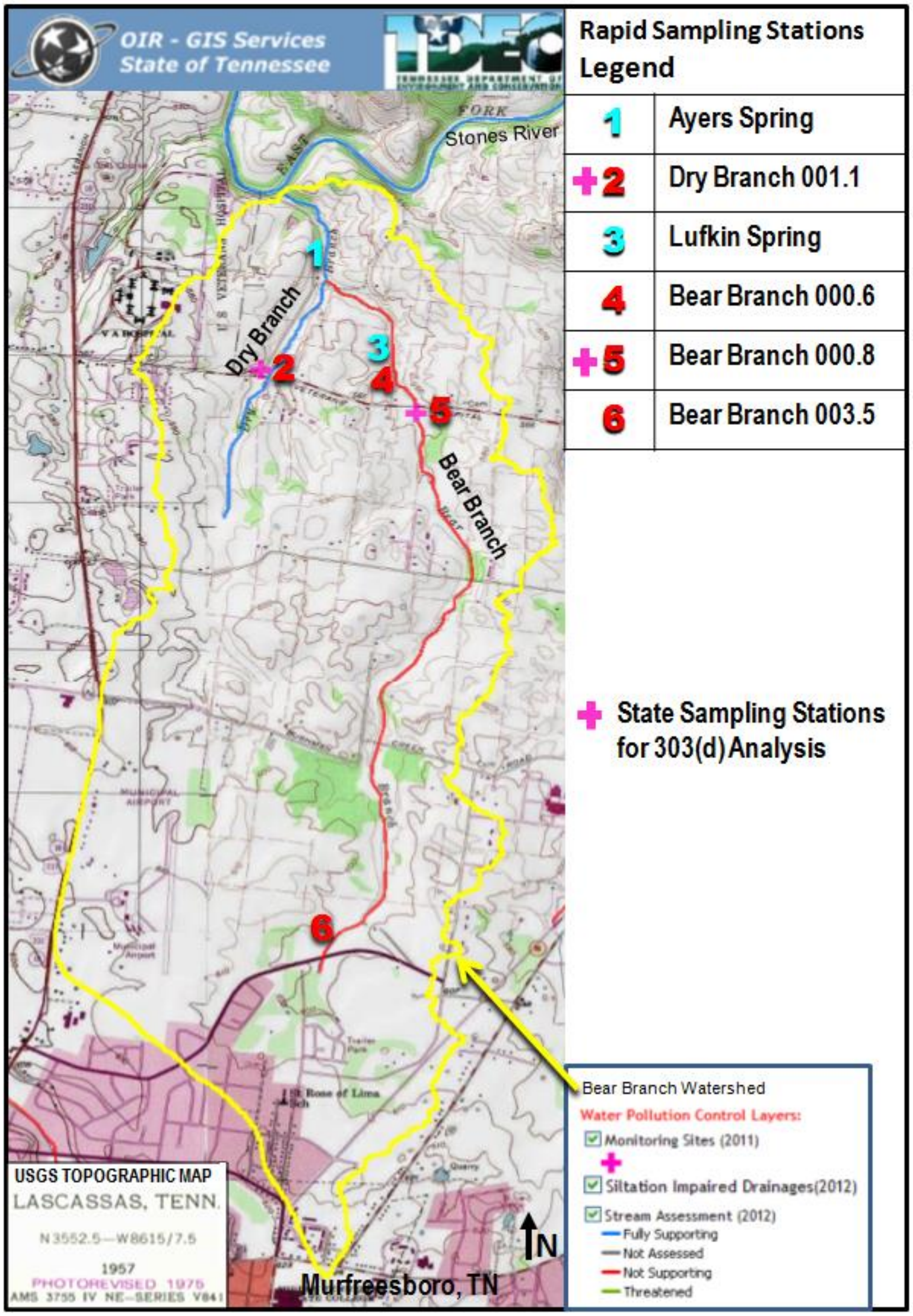


Figure 7 - Macroinvertebrate sampling locations and collection agency

2.f. Biological Monitoring Considerations

The three biometrics used in bio-recons in Ecoregion 71i, Inner Nashville Basin, to evaluate the health of an aquatic community are Taxa Richness (TR), Ephemeroptera, Plecoptera, and Trichoptera (EPT), and Intolerant taxa (IT) (TDEC, 2011). Taxa Richness (TR) is a measure of community diversity. The greater number of different taxonomic groups found, the greater the diversity and heath of the aquatic community. The insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) are used in the EPT biometric. Many, but not all, families in these groups are intolerant to water pollution and therefore are very useful indicators of water quality. The higher the number of intolerant EPT individuals in a sample, the better the water quality. Intolerant taxa (IT) are groups of macroinvertebrates that cannot survive in streams with poor water quality. Psephenidae is a family of aquatic beetles (Coleoptera) that is intolerant to pollution in addition to some EPT families. The higher the number of IT groups, the higher the score as these individuals are found in streams of good water quality.

Total Biotic Index (TBI) is a score that measures aquatic macroinvertebrate success, and therefore a healthy stream condition. The TBI score is calculated by adding the TR, EPT, and IT scores together. High TBI scores indicate that the stream supports a healthy macroinvertebrate community. Low TBI scores indicate that the stream is impaired and the macroinvertebrate community is in poor condition. Impaired streams are placed on the 303(d) list because they do not support the FAL use. TBI score interpretation for family level bio-recons in Bioregion 71i (Table 5) are as follows: 11-15 = Non-impaired (Supporting); 6-10 = Ambiguous (Need Additional Data); and ≤ 5 = Severely Impaired (Partially or Not-Supporting). See Table 6.

Table 6 - Biometric Scores for Sampling Sites

Taxa	**1 Ayers Spring**	**2 Dry 001.1**	**5-10 Dry 001.1**	**2-07 Dry 001.1**	**3 Lufkin Spring**	**4 Bear 000.6**	**5 Bear 000.8**	**5-07 Bear 000.8**	**6 Bear 003.5**
Total Taxa	3	10	14	17	8	8	2	5	11
Stream Order Drainage Area	≤2	≤2	≤2	≤2	≤2	>2	>2	>2	≤2
Taxa Richness (Score)	<7 (1)	7-12 (3)	>12 (5)	>12 (5)	7-12 (3)	<10 (1)	<10 (1)	<10 (1)	7-12 (3)
EPT (Score)	<3 (1)	<3 (1)	>4 (5)	>4 (5)	<3 (1)	<4 (1)	<4 (1)	<4 (1)	<3 (1)
Intolerant Taxa (Score)	<2 (1)	<2 (1)	>2 (5)	>2 (5)	<2 (1)	<2 (1)	<2 (1)	<2 (1)	<2 (1)
TBI Score	**3** **Impaired**	**5** **Impaired**	**15** **Supporting**	**15** **Supporting**	**5** **Impaired**	**3** **Impaired**	**3** **Impaired**	**3** **Impaired**	**5** **Impaired**

Sample Collection Data and Dates: Sites 1-6 on 25 Sept 2012 (Blue = spring sites), Red = 5-02 on 10 April 2002; Green = 2-07 on 7 Feb 2002, Brown = 10 Apr 2007

Springs (locations 1 and 3 on Figure 7) are typically not sampled because they do not represent a stream condition. They are generally not affected by seasons. Aquatic communities are normally poor because groundwater does not provide a food source (algae, leaf litter, fine particulate matter) for a macroinvertebrate community. Collections at Ayers and Lufkin Springs are provided for information only in Table 6 and are not to be considered in assessing FAL use.

Stream samples 2, 4, 5, and 6 were collected in September when streams often go dry or habitat is unavailable due to low flow. The low TBI scores could have been depressed by the seasonal effect. It is a likely cause for the low TBI for Dry Branch which historically has high TBI scores in the range of supporting the FAL use. Bear Branch has been historically and currently appears to be, impacted no matter when or where collections are taken. Its continued loss of biological integrity is noted by low TBI scores. Causes for this loss may be attributed to nutrients, sediment, and habitat loss. Influences of gaining and losing reaches of stream could also impact sampling results. The TDEC sampling location on Bear Branch below Compton Road is downstream of a losing reach.

3. Causes of Impairment

3a. <u>Riparian Habitat Loss</u>

Loss of streamside vegetation is an important feature that impacts stream quality in many ways and negatively affects macroinvertebrate communities. Adequate, deep-rooted streamside vegetation maintains the stream channel and reduces bank erosion. Deep rooted plants and trees act as filters to remove pollutants before they enter a stream. Submerged root wads and logs provide habitat for fish and macroinvertebrate communities. Shade keeps the stream cool during the spring, summer, and fall. Cool water holds more dissolved oxygen (DO) than warm water and hinders algal growth even in the presence of excessive nutrients. Suppressing algal growth reduces the loss of DO during algal die-offs and decomposition. Adequate dissolved oxygen levels provide more favorable aquatic habitat and increases species diversity.

Less than 10% of the Bear Branch Watershed contains forests. Urban development and agriculture make up approximately 50% and 40% of the remaining land use within the Bear Branch watershed respectively. Urban development and agriculture are main causes for streamside vegetation loss. Field surveys revealed that many homeowners mow to the edge of Bear Branch. Farmers were observed haying to the edge of the stream bank. Sewer lines were observed running adjacent to nearly 60% of Bear Branch. Many utilities do not allow trees growing near sewer lines because of the potential for tree roots to invade the sewers lines and fracture the pipes. The lack of riparian buffer has been documented by MWSD (2011) as shown in Figure 8. BMPs to consider for riparian restoration are provided in the Proposed BMPs and Recommendations sections.

Figure 8 - MWSD 2011 Visual Stream Assessment noting riparian loss

3.b <u>Sedimentation</u>

The lack of streamside vegetation has not changed much along Bear Branch in nearly 45 years. Tree roots hold the soil in place during high flow and prevent bank sloughing during normal conditions. It is apparent that flow volume and velocity have increased. Since 1966 Bear Branch has increased in width and depth as can be seen in Figure 9. Without vegetation, the exposed bank is subject to continued erosion and sediment entering the stream. Development pressures continue to impact the stream. Past residential development caused extensive ground disturbance, erosion, and sedimentation. The 2002 TDEC Stones River TMDL Sediment and Habitat Alteration Report indicates existing sediment loads in the Bear Branch Watershed averaged 515 pounds/acre/year, while the recommended average annual sediment load is 220 lbs/acre/year.

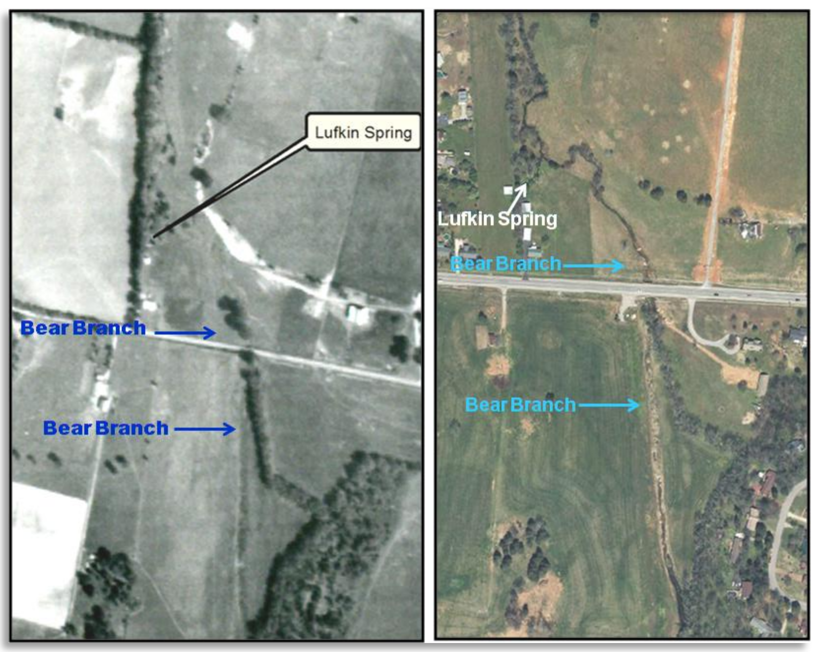


Figure 9 - Bear Branch at Compton Road (left 1966, right 2011) - note few trees along the stream

Excessive sedimentation is harmful to macroinvertebrate communities. Sediment not only buries the macroinvertebrates and clogs their gills, which results in suffocation, it also fills in the spaces between the cobble and gravel stream substrate where they live. Many aquatic fauna need the open space to lay their eggs. MWSD (2011) noted that there were some sites in Bear Branch where the stream rocks were 50% embedded in sediment. Sedimentation can be severe enough to completely fill in the stream channel (Figure 10). MWSD (2011) has documented sediment sources from bank erosion due to lack of a riparian buffer and mowing to the edge of Bear Branch (Figure 10), haying to the stream bank edge, and to storm water runoff (Figure 11).

Figure 10 - Bear Branch at Compton Road - note the downstream channel is filled with sediment

Figure 11 - MWSD 2011 Visual Stream Assessment noting sediment sources

3.c Dissolved Oxygen Levels

Low DO levels are caused by many conditions within a watershed. Nutrients, such as nitrogen and total phosphorus, act as fertilizer for algal growth in a stream. Abundant nutrients can create algae mats (Figure 10). Algal decomposition then uses so much DO from the stream that aquatic life can die; a major factor in fish kills. The lack of DO also kills the aquatic insects that serve as fish food. A few species of aquatic insects can tolerate short periods of low oxygen, but the majority is intolerant of this condition. Many aquatic insects live in streams for years and therefore are good indicators of stream quality. If the aquatic community contains few or no intolerant species, then the stream has likely been suffering from low DO.

Bear Branch Watershed DO concentrations are affected by a number of physical factors such as amount of available sunlight, water velocity, ambient temperature, and pollutant loading. Pollutant loading is further discussed in Section 4.d. Efforts to improve DO levels on Bear Branch include those previously mentioned for riparian buffers and sedimentation. Shading the stream from sunlight, lowering ambient water temperatures, and reducing the amount of oxygen lost due to sunlight exposure and sedimentation also improves DO.

3.d Nutrient Levels

The most significant pollution loading parameters include total nitrogen, total phosphorous, and combined oxygen demand (CBOD). TDEC recommends the target nutrient concentrations for Ecoregion 71i should not exceed total nitrogen (TN) of 0.755 milligrams per liter (mg/l) nor exceed a total phosphorus (TP) of 0.160 mg/l. While TP concentrations are currently being met, TN concentrations were exceeded by 75% of chemical samples collected in Bear Branch under various flow conditions (Table 7).

Table 7 - Recommended Nutrient Reductions for Bear Branch

Sample Date	Flow	PDFE (Approx)	Total Nitrogen				Total Phosphorus			
			*Sample Concen	Sample Load	Target Load	Reqd Reduct	Sample Concen	Sample Load	Target Load	Reqd Reduction
	(cfs)	(%)	(mg/l)	(lbs/day)	(lbs/day)	(%)	(mg/l)	(lbs/day)	(lbs/day)	(%)
9/26/06	0.75	61.1	0.76	3.07	3.05	0.7	0.005	0.02	0.65	NR
10/1/06	1.33	45.4	0.51	3.66	5.41	NR	0.020	0.14	1.15	NR
1/22/07	5.98	13.6	1.18	**38.04**	24.29	**36.1**	0.005	0.16	5.15	NR
3/6/07	3.95	20.1	1.48	**31.52**	16.07	**49.0**	0.004	0.07	3.41	NR
					Geometric Mean	10.5				NR

Sources: TDEC, 2008. Notes: NR = Sample load is lower than the target load; no reduction required

Murfreesboro's municipal separate storm sewer system (MS4) program addresses point sources of nutrients and organic matter, thereby reducing potential influence to negative stream conditions and low DO concentrations. Nonpoint sources for nutrients, such as atmospheric decomposition, and geology are not easily evaluated or addressable; however, failing septic systems and agricultural runoff from fertilizer use and livestock waste, contribute to high nutrient levels. (TDEC, 2005); these influencers can be targeted for management

Cattle were not seen on September 25, 2012, however numerous cow patties and hoof prints were observed adjacent to and within Bear Branch downstream of Compton Road. In addition, there are 216 septic tanks in the Bear Branch Watershed (TDEC, 2008). Nutrients could be washing into Bear Branch during regular rain events. TDEC notes that water quality would likely improve if TN loading could be reduced by approximately 10% (TDEC, 2008). BMPs to consider for nutrient reduction are provided in the Proposed BMPs section.

4. Bear and Dry Branches Stream Segments – Site Assessments

The watershed is divided into stream segments to allow for detailed description of each segment along with potential watershed management measures. Segments are depicted in Figure 12, and a more detailed discussion of benefits received from implementation measures are discussed at the end of this section.

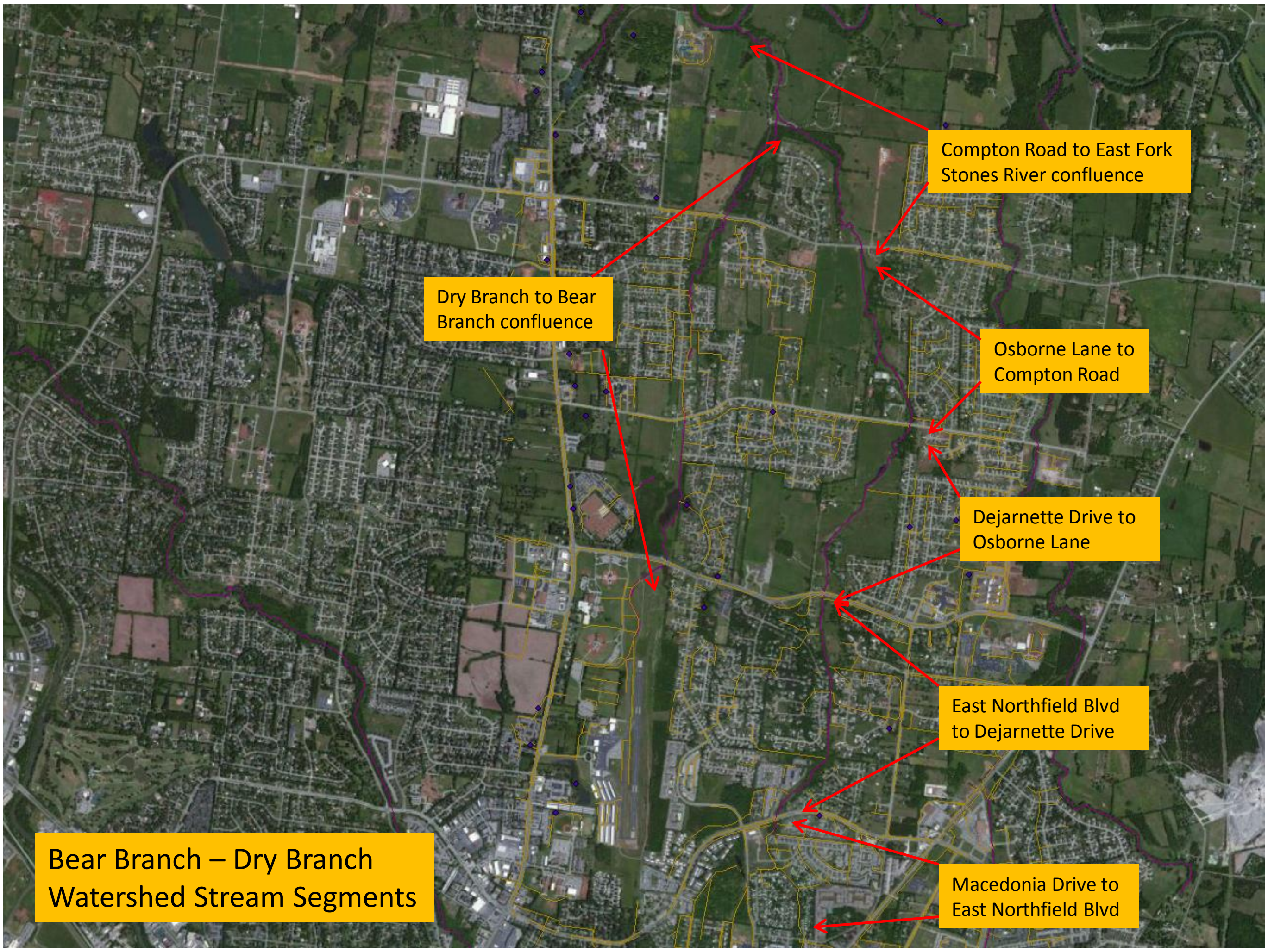


Figure 12 - Bear Branch Stream Segments

4.a <u>Macedonia Drive to East Northfield Boulevard</u>

<u>Existing Conditions</u>

The headwaters of Bear Branch originate above Macedonia Drive where two small wet-weather conveyances join, and begin a northerly course downstream. About 1,100 feet of stream is above East Northfield Blvd. The stream course has been altered to avoid existing development. Large limestone boulders were placed along the stream edge to direct flow away from the developed area. Just before passing under East Northfield, Bear Branch loses its defined course and spreads out within a 1.5 acre forested area. Two of the three existing box culverts under the road are partially blocked with debris, vegetation and accumulated sediments from previous high flow events (Figure 13). Several stormwater drains converge at the bridge and contribute additional stormwater runoff. Portions of the riparian area are devoid of woody vegetation, while exotic invasive plants such as common privet (*Ligustrum vulgare*) grow along portions of the stream bank (Figure 13). Existing land uses within this portion of Bear Branch include residential, commercial, and undeveloped property.

Figure 13 - Debris/sedimentation above East Northfield Blvd, riparian alteration and privet

<u>Proposed Actions</u>

Measures to improve stream conditions include restoration of stream channel, reestablishment of missing or insufficient stream buffers, elimination of channel crossings, and removal of debris and trash above East Northfield Boulevard. The existing wetland above East Northfield Boulevard filters stormwater runoff and should be preserved. A trash collection grate could collect accumulated trash and debris, but would need to be monitored and serviced regularly to assure stormwater flow passage.

4.b <u>East Northfield Boulevard to Dejarnette Lane</u>

<u>Existing Conditions</u>

Bear Branch continues a generally northerly flow between East Northfield Boulevard and Dejarnette Lane for about a mile. The channel is restricted to about 50 feet wide as it travels underneath East Northfield Boulevard. Several small spring flows run through the Northfield Ridge Apartments on the west bank c and contribute spring and stormwater flow. Considerable trash and debris accumulate within this reach and contribute to degradation of water quality and aesthetics. The riparian corridor is fairly well defined, but residential and multi-family developments contribute to loss of riparian integrity within portions of this reach.

The upper reach includes a 12-acre limestone wetland glade streamside meadow complex that contains several rare plant species. Springs in this reach contribute flow to the stream including one within the limestone wetland glade. Additional small pocket wetlands, 2 acres and 1.3 acres, are located above Dejarnette Lane. Several landowners have cleared riparian vegetation in an attempt to maintain fescued lawns to the stream edge. Stormwater runoff from adjacent residential development contributes flow to Bear Branch, and subsequently degrades water quality within the stream (Figure 14).

Figure 14 - Bear Branch felled trees and debris, and erosion along unprotected riparian area

Proposed Actions

Two sections have insufficient riparian buffers. About 800 feet of stream would benefit from additional riparian buffer including native tree plantings. Adjacent private development within the watershed will continue to impact sediments carried by Bear Branch, but maintaining a healthy riparian buffer will slow stormwater and allow sediments to settle out.

Debris dams behind the Summit Apartments and behind several homes along Shagbark Trail continue to trap trash and woody debris, causing additional erosion and riparian loss (Figure 14). Removing these obstructions would serve to improve water quality and stormwater flow conditions. A wet weather spring behind Summit Apartments contributes flow to Bear Branch, and efforts to test water quality conditions above and below spring for *E. coli* and other contaminant sources should be undertaken. A small stream segment behind the apartments that appears to have been channelized would benefit from restoring meanders and riffles. Behind Shagbark Trail the left bank is devoid of riparian buffer and would benefit from riparian plantings. Informing adjacent landowners of the importance of maintaining healthy riparian buffers would be a cost-effective way to improve conditions.

A small seep originating on private property follows an open ditch to Bear Branch near a wetland on the right bank. In this area Bear Branch forms several deep pools that support bluegill (*Lepomis macrochirus*) and largemouth bass (*Micropterus salmoides*). Riparian buffer is sparse immediately downstream on both banks with remains of an old concrete crossing within the stream. Removing the concrete and allowing stream bank riparian areas to revegetate would benefit this section of stream.

An existing 5.8-acre linear wetland behind Shagbark Trail also serves to filter and slow stormwater. Educating adjacent landowners of its importance should be a priority. Continuing downstream, inadequate stream buffer and a small wetland were noted above Dejarnette Lane. Ecological enhancements could include tree plantings, maintaining an unmowed stream buffer, and protection of the wetland areas.

4.c Dejarnette Lane to Osborne Lane

Existing Conditions

Bear Branch continues its northerly course as it passes under Dejarnette Lane through an unobstructed single concrete box culvert for about 0.8 miles to Osborne Lane (Figure 15).

Figure 15 - Bear Branch above Dejarnette Lane, Bear Branch looking upstream above low-head dam

A wet-weather spring enters about 1,000 feet downstream from Dejarnette Lane contributing considerable flow to Bear Branch. Downstream of the spring, Bear Branch is outside city limits. Two wetlands, 3.5 and 8.2 acres, an altered/straightened channel, and a small low-head dam characterize this area. The dam does not appear to impound water. It seeps underneath and resurfaces again downstream from Osborne Lane (Figure 15). A portion of the stream is rock-lined, and sections have insufficient riparian buffer on either side of the stream. A sink within the stream channel was also noted above Osborne Lane.

Proposed Actions

Improvements to this segment of Bear Branch include establishment of a better-defined riparian buffer and protection of existing spring and wetlands.

4.d Osborne Lane to Compton Road

Existing Conditions

Immediately below Osborne Lane, Bear Branch enters a sink that captures most normal flow for about 0.4 miles (Figure 16). A major spring originates about midway between Osborne Lane and the next sink at Compton Road that contributes significantly to stream flow and creates an estimated 6.3-acre wetland (Figure 16). There are considerable obstacles within this reach including debris and drift that impede stormwater flow (Figure 17). Efforts by an adjacent landowner to stabilize a portion of stream bank with broken concrete above Compton Road was noted (Figure 17).

Figure 16- Dry streambed below sink near Osborne Lane, wetland site below major spring site

Figure 17 - Debris dam above Osborne Lane, concrete bank stabilization

Proposed Actions

Downstream of the wetland, a concrete crossing acts as a dam, catching significant debris. It should be removed. An inadequate riparian buffer exists in this area. Establishment of a riparian buffer along with additional tree plantings would help to alleviate additional erosion concerns and benefit stream conditions within this reach.

4.e <u>Compton Road to East Fork Stones River Confluence</u>

<u>Existing Conditions</u>

Bear Branch travels northwesterly about 0.7 miles until it joins with Dry Branch. Lufkin Spring enters Bear Branch below Compton Road and provides a substantial flow. Bear Branch sustains year-round flow from this point to its confluence with East Fork Stones River. Two wetlands of note within this reach include a 1.3-acre wetland immediately below Compton Road and a 1.8-acre wetland about 0.3 miles upstream from Bear-Dry Branch confluence.

Issues within this reach of Bear Branch include unimpeded access to stream by livestock, which is causing erosion within several locations. Streambank erosion is degrading water quality, and impacts aquatic habitat (Figure 18).

After converging with Dry Branch, Bear Branch continues another 0.5 miles until it reaches the East Fork Stones River about 2.8 miles above Walter Hill Dam. The lower 1/2 mile is influenced by Walter Hill Dam which impounds the East Fork Stones River. Upstream water contributions from Lufkin and Ayers Springs support year-round flow within this reach.

Figure 18 - livestock access below Compton Road, Lufkin spring

<u>Proposed Actions</u>

Bear Branch below Lufkin Spring supports a limited array of low quality aquatic organisms . While there is some riparian buffer, increasing its width would improve streamside and insteam conditions. Information and assistance is available from the NRCS regarding fencing and streamside riparian buffer establishment for livestock use. Placement of hardened stream access points for livestock where in-stream bedrock exists would minimize impacts to stream substrate and reduce erosion.

Agricultural stream crossings near the Dry Branch confluence cause minimal impacts because the hardened limestone stream bed limits erosion (Figure 19). Limited riparian buffers would benefit by maintaining an unmowed buffer strip and additional tree plantings. Ayers Spring enters Bear Branch in this area. Sampling for *E. coli* concentrations above and below Lufkin and Ayers Springs would help to identify potential sources of contamination and address water quality concerns within these stream reaches.

4.f <u>Dry Branch</u>

<u>Existing Conditions</u>

Dry Branch travels in a north-northeasterly direction about 2 miles to its confluence with Bear Branch. Portions of Dry Branch have intact riparian buffers, while other areas are impacted by residential development. The headwaters of Dry Branch are located north of Murfreesboro Regional Airport. An extensive sink, north of Dejarnette Lane, collects stormwater from the airport area and then disappears. Surface runoff continues downstream past Osborne Lane and receives flow from additional springs as it flows north. A wetland site is upstream from Compton Road. Dry Branch then travels through an intact area of riparian buffer for about 1/2 mile before entering Bear Branch.

Figure 19 - Access road across Bear Branch below Ayers spring, Dry Branch wetland site

<u>Proposed Actions</u>

Portions of the riparian area around Dry Branch have been impacted by residential development and channelization. Stream segments above and below Osborne Lane have been cleared of riparian vegetation and would benefit from establishment of an unmowed buffer area.

Additional tree plantings would improve water infiltration, slow stormwater flows, and benefit water quality. Stream meander restoration above and below Osborne Lane would help restore a more natural course flow. Important wetland sites including a 43.5 site north of Murfreesboro Regional Airport, a 4.85-acre site (Figure 19) above Compton Road, and a 0.1-acre site along Drake Lane, contribute to slowing stormwater flow and provide infiltration opportunities. Protection of these sites would serve to improve overall water quality within the Dry Branch Watershed. Agricultural stream crossings near Bear – Dry Branch confluence (Figure 19) appear to cause minimal disturbance due to hardened bedrock substrate and infrequent use. Riparian buffer establishment along with additional tree planting has been initiated below the agricultural stream crossings (Figure 20). These segments could be augmented with additional vegetative plantings.

Figure 20 - Bear Branch near East Fork Stones River confluence

5. STEPL Model – Spreadsheet Tool for Estimating Pollutant Load

Based on a review of conditions within each stream segment described for the Bear Creek watershed, a model analysis of potential pollutant load reductions was conducted for those pollutants listed on TDEC 303 (d) list for Bear Branch Watershed. The Spreadsheet Tool for Estimating Pollutant Load (STEPL) model is a simplified spreadsheet tool for estimating load reductions for such pollutants as nitrogen (N), phosphorus (P), and CBOD that result from implementing various best management practices (BMPs). Types of BMPs considered include contour farming, filter strips, reduced-tillage farming, streambank stabilization, fencing, terracing, forest road practices, forest site preparation practices, animal feedlot practices, and various urban and low-impact developments such as detention basins, infiltration practices, or swale/buffer strips.

STEPL is designed as a customized Excel spreadsheet model that is easy to use. Users can modify the formulas and default parameter values without any specialized programming skills.

STEPL includes a management practice calculator that computes the combined effectiveness of multiple management practices implemented in serial or parallel configurations (or both) in a watershed. Management measures that affect hydrology or sediment can be estimated with empirical factors, such as the NRCS curve number method for estimating runoff and Universal Soil Loss Equation (USLE) C and P factors (carbon and phosphorus) representing vegetative cover and conservation practices, respectively.

Pollutant load reductions attributable to the management practices are estimated with reduction factors (or management practice effectiveness) applied to the pre-management practice loads from the various land uses. The user's guide, model, default database, and other supporting information are available on the STEPL website (**http://it.tetratech-ffx.com/stepl**). Application of the STEPL tool requires users to have a basic knowledge of hydrology, erosion, and pollutant loading processes. Familiarity with the use and limitations of environmental data is also helpful.

Program strengths are that it is easy to use, gives quick and rough estimates, and includes most major types of management practices. Limitations of the program are that it provides a simplified representation of management practices using long-term average removal percentages which does not represent physical processes, and is developed based on available literature information that might not be representative of all conditions (EPA, 2012).

The STEPL model runs are shown below by stream segment and include estimated existing N, P, CBOD, and sediment loads and projected pollutant reduction loads. BMPs and estimated load reductions from implementing those specific BMPs for each stream segment are listed below. Existing pollutant measurements are calculated using data for the specific watershed (such as HUC and rainfall averages). These calculations remain the same for all stream segments as they are reflective of the entire watershed. The amounts of reduction vary based on the maximum implementation of BMPs applicable to the specific stream segment.

STEPL model runs for each stream segment are summarized in Table 8.

Table 8 - STEPL Watershed Measure Results

Reach	N Reduction Lb/year	P Reduction lb/year	BOD Reduction Lb/year	Sediment Reduction Ton/year	BMPS Implemented
Existing Conditions	37471	67369.0	109615.2	2927.4	
Macedona-E. Northfield	2498.5	850.6	2284.0	356.9	wetland detention, weekly street sweeping, vegetative filter strips
	6.6%	11.5%	2.1%	12.1%	
E. Northfield-Dejarnette	2498.5	850.6	2284.0	356.9	streambank stabilization, vegetative filter strip, weekly street sweeping, wetland detention, grass swales
	6.6%	11.5%	2.1%	12.1%	
Dejarnette-Osborne Run 1	2498.5	850.6	2284.0	356.9	streambank stabilization, wetland detention, grass swales, water quality inlets, vegetative swales
	6.6%	11.5%	2.1%	12.1%	
Dejarnette-Osborne Run 2	2096.2	731.8	1945.9	304.1	Contour farming, vegetative filter strips, streambank stabilization, grass swales
	5.5%	9.9%	1.7%	10.3%	
Osborne-Compton	4334.8	1429.8	4176.7	652.6	Contouring farming, reduced tillage, vegetative filter strips, streambank stabilization, tree planting, wetland detention
	11.5%	19.3%	3.8%	22.2%	
Compton-E Fork Stones	4334.8	1429.8	4176.7	652.6	Contouring farming, reduced tillage, vegetative filter strips, streambank stabilization, tree planting, wetland detention
	11.5%	19.3%	3.8%	22.2%	
Dry Branch	5139.4	1667.4	4852.7	758.2	streambank stabilization, tree planting, wetland detention, vegetative filter strips
	13.7%	22.6%	4.4%	25.9%	

6. Recommendations for Bear and Dry Branches

The results from the site assessments discussed in Section 5 and the STEPL modeling discussed in Section 6 can be combined to form specific recommendations to improve water and habitat quality for both Bear and Dry Branches. Both streams are impaired by sedimentation, nutrients, and loss of riparian integrity.

6.a Water Quality Sampling Location

Bear Branch has gaining and losing reaches. TDEC's Hydrologic Determination Field Data reports indicate water presence varied greatly between the 2002 and 2007 reports. The sampling location for both reports was upstream of Compton Road (TN Hwy 268) about 150 feet downstream from an observed sink that captures appreciable stream flow. It is likely that the lower volume of water at the sampling location negatively impacts water quality samplings. In other words, the existing sampling location may never be able to meet biological quality standards because there is not a reliable quantity of water. Some reaches of Bear Branch lose so much water to sinks that they may not meet the definition of a stream for regulatory purposes. Because flow is not always present at the established sample site, we recommend relocating the sampling site for Bear Branch to below Lufkin Spring. This would provide the potential for year-round flow, improve the reliability of water quality sampling, and offer a greater potential for improved benthic aquatic macroinvertebrates. A site below Lufkin Spring would likely provide sufficient water to support a healthy benthic community as opposed to a site downstream of a sink. Implementation of this recommendation would be dependent upon TDEC agreeing to relocate its current sampling location.

6.b Water Quality Protection Areas

The City of Murfreesboro adopted a Water Quality Protection Area (WQPA) ordinance on March 8, 2007 to protect and enhance stream riparian areas within the City. Water quality buffers protect stream function and aquatic life by maintaining trees, shrubs, grasses and other riparian vegetation. The WQPA ordinance requires that land developers and subsequent property owners preserve a buffer zone of natural vegetation alongside streams and associated wetlands. Minimum widths of 35 or 50 feet on either side of the stream, depending on the USGS-cartographic depiction of the stream, are recommended. When wetlands extend beyond the edge of required WQPA width, the WQPA is adjusted to include the wetland plus 35 feet. This ordinance will benefit all streams in the city and help to establish a riparian corridor on Bear Branch as property redevelops. However, it does little to improve existing conditions and does not address the portion of the watershed in the County. Small-scale opportunities for watershed restoration projects such as developing wetlands, rain gardens, swales, and other watershed management efforts would be beneficial. Additional measures as discussed below will also be needed to see improvement more quickly.

Watershed improvement recommendations (BMPs) that follow are correlated to stream segments in Table 9 in section 7.

6.c Streambank Stabilization through Bioengineering

Bioengineering refers to the installation of living plant material as a main structural component in controlling problems of land instability where erosion and sedimentation are occurring. There are several techniques for stabilizing streambanks with vegetation. For relatively shallow streambanks, such as those on Bear and Dry Branches, simply planting the streambank with local cuttings such as willows, cottonwoods, and other indigenous plant material may be sufficient. In other more severely eroded areas a toe should be established at the base of the slope using a staked coconut fiber, coir roll, or stone. The hardened toe helps keep the bank in place long enough to establish plants. (See Figure 21.)

The foremost objective is for the natural encroachment of a diverse plant community to stabilize the streambank through development of a vegetative cover and a reinforcing root matrix. The practice brings together biological, ecological, and engineering concepts to produce living, functioning systems that prevent erosion, stabilize slopes, and enhance wildlife habitats. Conditions needed for successful bioengineering project include sunlight, suitable soils, stable slope, water, plant nutrients, and planting during the proper season when plants are dormant. Table 8 describes benefits derived from implementation of specific BMPs within each stream reach, and prioritizes benefits derived from BMP implementation.

Costs associated with bioengineering measures would be a consideration. Assistance through state and federal programs should be investigated. Coordination would be required for necessary state and federal permits.

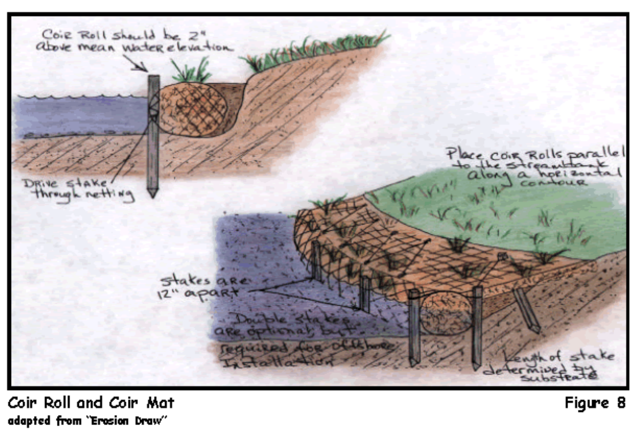


Figure 21 - Bioengineering for stream stabilization project

6.d Wetlands Protection Opportunities

Protecting existing wetlands is an important aspect in maintaining and improving water quality conditions in the Bear Branch Watershed. Wetlands slow the erosive forces of water and retain stormwater flow. Hydrology, vegetation, and hydric soils are used as wetland indicators. Wetlands also collect sediments and reduce the overall quantity of sediments within the stream, provide valuable habitat to wetland plants and animals, and remove toxins and nutrients from the water. Conservation easements should be established around existing wetlands to protect their integrity and function, and incorporate wetland WQPA to further protect such sites. Wetland sites identified during informal wetland assessments would provide additional stream and water quality improvements. Wetland sites such as those identified below East Northfield Boulevard, above Osborne Lane, and also on Dry Branch above Compton Lane would provide the greatest benefits due to their size and upstream location. Emphasis should be placed on protection of such sites by purchasing conservation easements to protect them from additional development pressures, and education of adjacent landowners with respect to wetlands protection would serve to benefit Bear Branch Watershed. Success of this recommendation would include willingness of property owners to provide conservation easements and likely costs for purchasing such easements.

6.e Channel Reconstruction (Stream Meander Restoration)

Channel meander restoration means the restoration of the natural alignment, channel capacity and meander relationships to assure a functional, stable stream (Figure 22). Meandering channels offer physical stability and support natural ecological functions of the stream corridor. They slow down water, absorbing some of its energy, thereby helping to reduce the potential for erosion. Meandering channels typically have higher levels of physical habitat diversity than straightened channels. Channel reconstruction can be accomplished by replicating the characteristics found in relatively stable, balanced stream segments. Meander reinstatement requires adequate space. Adjacent land uses may constrain locations. Therefore meander reinstatement may not be feasible for streams in watersheds experiencing rapid changes in land uses. Limiting factors to implementing this recommendation would include the need for land to accommodate new stream area and costs associated with design and construction. Coordination would be required for necessary state and federal permits.

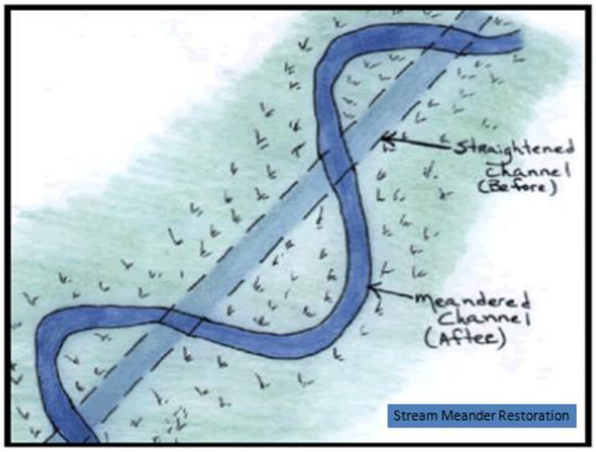


Figure 22 - Stream meander restoration, from "Stream Corridor Restoration Handbook" and Healthy riparian forest buffer

6.f <u>Stream Corridor Measures: Riparian Forest Buffer</u>

A riparian forest buffer is an area of trees and/or shrubs located adjacent to and up-gradient from water bodies. Riparian forest buffers are used to create shade and lower water temperatures to improve habitat for fish and other aquatic organisms; provide a source of detritus and large woody debris for fish and other aquatic organisms and riparian habitat and corridors for wildlife; and reduce excess amounts of sediment, organic material, nutrients, and pesticides and other pollutants in surface runoff and reduce excess nutrients and other chemicals in shallow ground water flow. Some other important benefits include corridors for wildlife, a stabilizing effect on eroding streambanks, additional products (timber, firewood, fiber, nuts, etc.) for the farm enterprise, and improvement of aesthetics and recreational opportunities at the site and landscape level. An example of a healthy riparian forest buffer is depicted in Figure 22. Riparian buffers can be created by adding trees to existing water quality buffers currently mandated by the city or by additional planting along the streambank. Buffer width can vary, but should be a minimum of 10-15 feet on a small stream like Bear Branch. This practice could be easily implemented through volunteer efforts with landowner willingness or by including mandatory buffers as County ordinances. Minimal costs would be associated with acquiring native trees and shrubs. Tennessee Division of Forestry nurseries are a source for purchasing large quantities of native plants.

6.g <u>Trash/Debris Removal</u>

Trash and debris that is transported through runoff should be collected and disposed of before the addition of any urban BMPs. Efforts to determine source of trash and debris to alleviate or reduce future stream blockage should be considered. Bear Branch would also benefit from community cleanup activities that improve aesthetics and overall water quality conditions. Bear Branch stormwater flow would improve above East Northfield Boulevard if accumulated sediments and trash/debris were addressed. Stormwater flow is impeded across two of the three culverts, forcing the majority of stormwater flow to pass through the remaining culvert. A trash rack would collect trash and debris at this location.

6.h <u>Stream Corridor Measures: Livestock Exclusion/Management</u>

Livestock exclusion is the protection of an area by preventing the entry of livestock. Fencing and an alternate water source and shelter are generally key components of this practice. Livestock exclusion maintains or improves the quality of riparian plant and animal resources, maintains cover and surface litter needed for soil and associated organisms, maintains soil moisture and nutrient cycling/retention, maintains riparian cover and shading, and protects water quality. More detailed information is provided at the following link. http://www.pmcl.com/mmdl/MM_Description.asp?ID=71. Evidence of livestock damage to the stream bank can be found on Dry Branch and lower portions of Bear Branch.

Cost to implement this action would be dependent upon the area of exclusion or size of alternate sources needed. As previously mentioned, NRCS has programs to assist with these measures; this opportunity should be further explored. Coordination would be required for necessary state and federal permits if design included work within the streams.

6.i Additional resources for watershed restoration project assistance

In addition to resource agencies previously mentioned that are possible sources for design, construction, and financial assistance, the following agencies should be contacted to determine if their programs could assist with restoration efforts in the Bear Branch Watershed.

The Tennessee Department of Agriculture (TDA) accepts grant proposals to improve water quality and reduce or eliminate nonpoint source pollution. Local governments, regional agencies, public institutions, nonprofit organizations, and other state agencies are eligible. Project to improve nonpoint source pollution are a priority. Nonpoint source pollution is soil, urban runoff, fertilizers, chemicals and other contaminants that come from many different sources and degrades surface and groundwater quality. TDEC assesses water quality and compiles a list of impaired waters. The list can be found online at http://www.tn.gov/environment/wpc/publications/ . Other funding priorities include water quality educational programs, projects that implement an approved TMDL and projects that reduce urban runoff. Request for 2013 proposals are located at http://www.TN.gov/agriculture/water/nps.html, or for more information contact TDA's Nonpoint Pollution Program at 615-837-5306.

The Tennessee Stream Mitigation Program (TSMP), established under the Tennessee Wildlife Resources Foundation in 2002 as an in-lieu fee program, develops stream restoration projects statewide, and uses the watershed approach to complete large-scale restoration projects. The TSMP works with private landowners, non-profit organizations, municipalities, and state and federal agencies on projects with significantly degraded streams to address stream bank erosion, improve water quality, and restore aquatic and riparian habitat. Information pertaining to TSMP can be found at http://tsmp.us/.

The NRCS provides grants for innovative conservation measures, including grants for livestock management, to improve conservation measures on private lands. NRCS grant information can be found at
http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/home/?cid=STELPRDB1081433

U.S. Environmental Protection Agency (EPA) New Urban Waters Outreach Toolkit provides information to watershed organizations, municipalities, and other interested parties who promote green business efforts to encourage homeowners to install rain barrels, and provide water quality improvements to streams within their communities. The toolkit includes details on the development of social marketing outreach to local residents, lessons learned and a summary of project accomplishments. Appendices include communication scripts for weathercasters, a detailed list of project partners, partnerships, and photos and screenshots of the messages used. The New Urban Waters Outreach Toolkit can be found at
http://water.epa.gov/scitech/swguidance/standards/training.cfm

7. Conclusions and Recommendations

Table 9 provides a list of prioritized locations in the Bear Branch watershed for BMPs by stream segment. The BMP, stream mile, estimated quantities and costs, potential benefits, and rankings are shown in the table. The rankings are based on the severity of the problem, ability to correct the problem, and access to each site. All are ranked from high (5) to low (1). The best projects are those with 5 in both columns. The quantity and cost estimates are rough orders of magnitude for planning purposes.

The existing Bear Branch Watershed has been adversely impacted due to channelization, loss of riparian vegetation, nutrient loading, and infrastructure impediments. Watershed management goals to improve water quality, restore channel functionality and stability, and enhance aquatic habitat and restore riparian buffer function are attainable. Identifying non-point source pollutants such as sedimentation and nutrient loadings by excluding livestock from the channel and riparian corridor, elimination of accelerated bank erosion problems, re-establishment of in-stream habitat, and enhancement of riparian zone with native plantings would serve to improve overall stream health. As these identified impairments are addressed through practices and measures discussed in this plan, the goal of removing Bear Branch from TDEC's 303(d) list of Impaired Waters becomes attainable.

Table 9 - Recommended BMPs by Stream Segment

No.	Reach	Location	Quantity	Unit Cost	Cost $1000	Benefit	Ranking	Notes
1	**Macedonia Dr to East Northfield Blvd**	35.877836/-86.367454						
	Wetland Protection - Above Northfield	Mile 3.8 - 3.7	2.6 acres	varied	113	5	5	Maximum Benefit - wetland protection
	Channel Reconstruction	Mile 4.0 - 3.8	1,000'	$100/200/lf	100-200	2	3	Insufficient land for reconstruction
	Riparian Forest Buffer	Mile 4.0 - 3.8	1,000'	$20/lf	20	3	4	Beneficial for stream habitat
	Trash/Debris Removal	Mile 4.0 - 3.7	1,600'	$1/lf	1.6	4	4	Reduces downstream impacts
2	**East Northfield Blvd to Dejarnette Lane**	35.877836/-86.364223						
	Bioengineering	Mile 3.5 - 3.4, 3.1-2.8	400'/790'	$20/lf	23.8	4	3	Adjacent to Apts, Shagbark Trail
	Wetland Protection - Above Dejarnette	Mile 3.5-3.2, 2.8-2.6	25.4 acres	varied	1,000	5	4	Max Benefit - two wetland sites
	Channel Reconstruction	Mile 2.8 - 2.6	1,000'	$100/200/lf	100-200	3	2	Undefined channel above Dejarnette
	Riparian Forest Buffer	Mile 2.8 - 2.6	1,000'	$20/lf	20	3	3	Homeowners altered riparian areas
	Trash/Debris Removal	Mile 3.7 - 2.6	5300'	$1/lf	10	3	3	Adjacent development
3	**Dejarnette Lane to Osborne Lane**	35.895598/-86.357938						
	Bioengineering	Mile 2.6 - 2.0	3,200'	$20/lf	64	3	3	Little defined riparian area
	Wetland Protection - Above Osborne	Mile 2.2 - 2.0	17.2 acres	varied	180	4	4	Protect wetland below dam
	Channel Reconstruction	Mile 2.5 - 2.2	1,600'	$100/200/lf	160-320	4	3	Dam removal/channel meandering
	Riparian Forest Buffer	Mile 2.6 - 2.2	2,100'	$20/lf	42	4	3	Establish riparian over stream length
4	**Osborne Lane to Compton Road**	35.914169/-86.360261						
	Bioengineering	Mile 1.6-1.5, 1.4-1.2	500', 1,000'	$20/lf	30	3	3	Bioengineer stream segments
	Wetland Protection - Above Compton	Mile 1.6-1.4	6.3 acres	varied	63	5	5	Max Benefit - wetland site
	Channel Reconstruction	Mile 1.5 - 1.3	1,000'	$100/200/lf	100-200	3	3	Channel straightened Mile 1.5-1.3
	Riparian Forest Buffer	Mile 1.6 - 1.3	1,600'	$20/lf	32	4	3	Riparian absent in two locations
	Trash/Debris Removal	Mile 1.6 - 1.2	2,100'	$1/lf	4	4	4	Debris dam, fencing across stream
5	**Compton Road to E Fork Stones River**	35.913265/-86.362739						
	Bioengineering	Mile 1.6 -1.5, 0.5-0.2	1,000', 1,600'	$20/lf	52	4	3	Bioengineering on Lufkin/Ayers
	Wetland Protection - E Fork Stones River	Mile 1.6-1.5, 0.6-0.5	1.6 acres	varied	12	4	3	Lufkin and Ayers Springs
	Riparian Forest Buffer	Mile 1.6 -1.5, 0.5 -0.2	500', 1,600'	$20/lf	42	3	3	Riparian absent in two locations
	Livestock Exclusion	Mile 1.6 - 1.0	3,200'	$51/lf	16	5	4	Establish fencing and watering areas
6	**Dry Branch to Bear Branch Confluence**	35.908786/-86.371271						
	Bioengineering	Mile 1.7 - 1.0	3,700'	$20/lf	74	3	3	Above Dejarnette and Osborne
	Wetland Protection - Dry Branch	Mile 1.7 - 0.0	53 acres	varied	424	5	4	Max Benefit - three wetland sites
	Riparian Forest Buffer	Mile 1.7 - 1.0	3,700'	$20/lf	74	3	3	Homeowners altered riparian areas
	Livestock Exclusion	Mile 0.3 - 0.0	1,600'	$5/lf	8	3	3	Minimal livestock access
	Ranking - based on severity/correctability/accessibility of sites - 1 (Low) - 5 (High)							

Appendices

Appendix A

Bear Branch Watershed Characterization

Physiography

The Bear Branch watershed lies within the Inner Nashville Basin (71i) which is characterized as less hilly and lower in elevation than the Outer Nashville Basin. Outcrops of the Ordovician-age limestone are common, and generally shallow soils are redder and lower in phosphorus than those of the Outer Nashville Basin. Streams are lower gradient than surrounding regions, often flowing over large expanses of limestone bedrock. The most characteristic hardwoods within the Inner Nashville Basin are a maple-oak-hickory-ash association. The limestone cedar glades of Tennessee, a unique mixed grassland/forest/cedar glades vegetation type with many endemic species, are located primarily on the limestone Inner Nashville Basin. The more xeric, open characteristics and shallow soils of the cedar glades also result in a distinct distribution of amphibian and reptile species (Stones River TMDL for E. Coli – Stones River Watershed, TDEC, June 2012).

Land surface elevations range from approximately 620 feet in the headwaters upstream of East Northfield Boulevard to 540 feet at Compton Road. The average land slope for this watershed is about 0.015-foot elevation drop per linear foot. The Bear Branch stream channel, typical for most small streams in the area, is poorly formed and heavily vegetated in some places. Large sections of Bear Branch have few or no trees along the stream bank and less than ten percent of the watershed is forested. This condition has not changed in nearly 45 years. The average slope of Bear Branch is about 0.0042 foot per foot (USDA Soil Survey 1977).

Soils

Table 1 displays the five predominant soils within Bear Branch watershed. Soils tend to be thin with numerous bedrock exposures. The Bear Branch streambed has exposed bedrock at several locations which often coincides with sinks and springs in the watershed. (NRCS, 2012.)

Table 1 - Bear Branch Watershed, Predominant Soils

Map Unit Name	Symbol	Est Acreage	% Watershed
Cumberland silt loam, 2-5% slope	CuB	748	17.5
Gladeville-Rock outcrop-Talbott Association	GRC	269	6.3
Arrington silt loam	Ar	245	5.7
Cumberland silt loam, 0-2% slope	CuA	225	5.3
Lomond silt loam, 2-5% slope	LoB	214	5.0

NRCS Web Soil Survey, 2012

Geology

Rutherford County lies within the Nashville's Central Basin, and is made up of Ordovician age sedimentary formations of the Stones River Group. Stones River Group formations within the

Bear Branch watershed include the Ridley, Pierce, Murfreesboro, and Lebanon limestone formations. Bedrock geology has a profound effect on the stream as evidenced by numerous sinks, springs, and other subsurface karst features. Many springs are located along the stream including Ayers, Lufkin, Bear Branch, Major Overflow, and other unnamed springs. The streams also lose flow through karst Ridley limestone exposures, only to have it re-emerge where water flow is in contact with the Pierce limestone, which is exposed primarily north of Compton Road. (East Fork Stones River Watershed, Visual Stream Assessment, MWSD, 2011).

Land Use

The Bear Branch watershed is 4,100 acres with about 15 % (630 acres) of the lower portion within Rutherford County's boundaries. The remaining 85% (3,470 acres) lies within the City of Murfreesboro. Past land uses have predominantly been agricultural, but residential development is increasing. The majority of lands within Rutherford County remain in agricultural use, while an estimated 62% of lands within the City of Murfreesboro have been developed into single and multi-resident residential areas. Murfreesboro Regional Airport is located along the upper reach of Dry Branch and encompasses approximately 225 acres. Between 2000-2009, Rutherford County led the state with an estimated 41% population growth. The City of Murfreesboro has experienced similar population growth within the last decade, and has an estimated 2011 population of over 111,000 residents. Portions of the MTSU campus are located south of Bear Branch. Middle Tennessee State University (MTSU) is the most populous state university with nearly 23,000 students enrolled in 2012. Continued growth in the watershed will likely place additional stressors on the stream (U.S. Census Quikfacts, 2011). See Table 2 below for land use distribution acreage for the watershed.

Aquatic resource threats for the Stones River watershed, include altered hydrologic regimes, altered in-stream physical habitat conditions, altered near-stream (buffer) habitat conditions, sedimentation, nutrient loading, thermal alteration, toxins and other contaminants, incompatible agricultural practices, urbanization, wastewater management practices, water management practices, and invasive species. Between 2002-2007, farmlands decreased approximately 13 %. Urbanization continues to impact this area, and in the last 10 years, an increase in population of 23% has been experienced, with a projected 27% increase in the next 10 years. Historic aquatic resource losses include dredging, excavation, channel widening, or straightening, bank sloping/stabilization, channel relocation, water diversion and withdrawals, dams/weirs/dikes/levee construction, flooding/excavation/filling of wetlands, road and utility crossings, and structural fill. According to the 2008 303 (d) report, only 23.2% of streams and rivers are classified as "fully supporting" while 5.8% are classified as "not supporting" their intended purposes. Those classified as "not supporting" has increased by nearly 10% during the time between 2006-2008 reporting periods, and increased by roughly the same amount between 2008-2010 reporting periods. (TSMP, 2010). Table 2 below describes land use distribution of impaired subwatersheds for Bear Branch-Dry Branch Watersheds.

Table 2 - Bear Branch, Land Use Distribution

Land Use	Acreage	%
Unclassified	0	0
Open Water	0	0
Developed Open Space	189	10.5
Low Intensity Development	588	32.6
Medium Intensity Development	128	7.1
High Intensity Development	6	0.33
Bare Rock	0	0
Deciduous Forest	49	2.7
Evergreen Forest	55	3.1
Mixed Forest	19	1.1
Shrub/Scrub	39	2.2
Pasture/Hay	629	34.9
Grassland-Herbaceous	4	0.21
Row Crops	95	5.3
Woody Wetlands	443	1.6
Emergent Herbaceous Wetlands	0	0
Subtotal – Urban	912	50.6
Subtotal - Agricultural	725	40.2
Subtotal - Forest	166	9.2
Total	**1802**	**100**

Source: TMDL, Stones River Watershed, Bear Branch Drainage Area, Subwatershed 0105, 2012.

<u>Impervious Surface</u>

Impervious surfaces are mainly artificial structures such as pavements (roads, sidewalks, driveways, parking lots) that cover the ground surface and prevent stormwater infiltration. Surfaces such as asphalt, concrete, brick, stone, and rooftops create an impenetrable surface for stormwater, and can cause stormwater to quickly run off into nearby streams and rivers. Impervious surfaces can adversely impact air resources by collectively increasing solar heat exchanges between the air and ground surface, and often creating heat islands within highly developed urban areas (Wikipedia, 2012).

Figure 11 - Bear Branch, East Northfield Boulevard to Dejarnette Lane impervious surfaces

The total area covered by impervious surfaces is expressed in the percentages of the total land area, and is estimated below in Table 3 for each of the Bear Branch stream segments.

Table 3 – Estimated Impervious Surfaces, Percentages for Bear Branch Watershed

Bear Branch Stream Segment	Impervious Surfaces %
Macedonia Drive – East Northfield Boulevard	39.6 %
East Northfield Boulevard – Dejarnette Lane	30.1 %
Dejarnette Lane – Osborne Lane	21.4 %
Osborne Lane – Compton Road	19.8 %
Compton Road – East Fork Stones River	8.9 %
Dry Branch – Bear Branch Confluence	26.2 %

Murfreesboro Water and Sewer Department, 2012.

Sanitary Sewer Wastewater Collection

Sanitary sewer and wastewater collection information including the number of municipal sewer hookups within the watershed, and also wastewater by-pass history from 2004-present are shown on Tables 4 and 5.

Table 4 – Municipal Sewer Hookups, Bear Branch Watershed

Murfreesboro Water and Sewer – Municipal Hookups	Number
Government	2
Residential (includes metered apartments/townhomes)	3,628
Commercial	26
Churches	4
Schools (includes Middle Tennessee State University)	4
Apartments /Laundries	33
Veterans Administration Hospital	2
Mobile Homes	4
Consolidated Utility District (CUD) Residential	41

Murfreesboro Water and Sewer Department, 2012.

Infrequent and unintentional wastewater releases within the watershed serve to degrade water quality conditions, impact aquatic resources, and detract from aesthetic and natural resources within the watershed. Murfreesboro Water and Sewer Department has rehabilitated 4 mains and 96 manholes along approximately 8,915 feet of sewer line facilities within Bear Branch watershed. The completion of recent upgrades to the City of Murfreesboro's wastewater facilities within the watershed has significantly reduced issues pertaining to potential wastewater by-passes (See Table 4).

Table 5 – Wastewater Bypass Locations Bear Branch Watershed – 2004 - 2012

Wastewater Bypass Location	Number/Date
Pump Station 14 Overflow	1
Pump Station 26 Overflows	5
Pump Station 27 Overflows	11
Pump Station 32 Overflows	5
Manhole 065Q010A – issue due to line blockage, and flow entered ditch	3/5/09
Manhole 065H002F – infiltration/inundation-related flow entered Bear Branch	11/30/10

MWSD, 2012.

On-Site Septic Systems

Another potential source of high nutrients within Bear Branch Watershed is failing septic tanks. There are approximately 216 septic tanks within Bear Branch Watershed, although it is uncertain where within each stream segment they are located (Rutherford County Groundwater Protection, 2012). Failing septic systems can cause elevated levels of E. coli, and manifests by signs such as spongy ground underneath failing systems, dense vegetative growth, ground depressions, and objectionable odors.

Threatened and Endangered Species

According to the US Fish and Wildlife Service, federally threatened and endangered species within the Bear Branch watershed include the species listed in Table 5 below.

Table 5 - USFWS Listed Federally Threatened and Endangered Species, Rutherford County, Tennessee

Species	Scientific Name	Category	Protection Status
Tan riffleshell	*Epioblasma florentina walkeri*	Mollusc	E
Braun’s rock cress	*Arabis perstellata*	Flowering Plant	E
Gutherie’s ground-plum	*Atragalus bibullatus*	Flowering Plant	E
Leafy prairie-clover	*Dalea foliosa*	Flowering Plant	E
Gray bat	*Myotis grisescens*	Mammal	E
Indiana bat	*Myotis sodalis*	Mammal	E

USFWS, IPaC, Natural Resources of Concern, 2012.

Rare Species

Table 4 contains information from TDEC Division of Natural Heritage (DNH) that indicates state-listed threatened, endangered, rare, special concern, and deemed in need of management species that may exist within the Bear Branch watershed. See Table 6. One state endangered species, the Blackfoot quillwort (*Isoetes melanopoda*) has previously been identified within the Bear Branch watershed. (APSU, 2008.)

Table 6 - TDEC DNH Rare Species, Bear Branch-Dry Branch Watershed

Common Name	Scientific Name	Category	Protection Status
Rabbitsfoot	*Quadrula cylindrical cylindrica*	Mollusc	R
Wavy-leaf Purple Coneflower	*Echinacea simulata*	Flowering Plant	T
Limestone Flameflower	*Phemeranthus calcaricus*	Flowering Plant	S
Blackfoot Quillwort	*Isoetes melanopoda*	Fern/Fern Ally	E
Slender Blazingstar	*Liatris cylindracea*	Flowering Plant	T
Evolvulus	*Evolulus nuttallianus*	Flowering Plant	S
Allegheny Woodrat	*Neotoma magister*	Mammal	D
Tennessee Milkvetch	*Astragalus tennesseenis*	Flowering Plant	S
Low Nutrush	*Scleria verticillata*	Flowering Plant	S
Stones River Bladderpod	*Paysonia stonensis*	Flowering Plant	E
Tennessee Cave Salamander	*Gyrinophilus palleucus*	Amphibian	T
Fen Indian-plantain	*Arnoglossum plantagineum*	Flowering Plant	T
Missouri Primrose	*Oenothera macrocarpa*	Flowering Plant	T
Pope's sand parsley	*Ammoselinum popei*	Flowering Plant	T
Limestone Blue Star	*Amsonia tabernaemontana*	Flowering Plant	S
White Prairie-clover	*Dalea candida*	Flowering Plant	S
Bewick's Wren	*Thryomanes bewickii*	Bird	E
Yellow Sunnybell	*Schoenolirion croceum*	Flowering Plant	T
Southern Cavefish	*Typhlichthys subterraneus*	Fish	D
Bedrock Shiner	*Notropis rupestris*	Fish	D
Gray Bat	*Myotis grisescens*	Mammal	E
Tennessee Coneflower	*Echinacea tennesseensis*	Flowering Plant	E
Duck River Bladderpod	*Paysonia densipila*	Flowering Plant	T
Carolina Anemone	*Anemone caroliniana*	Flowering Plant	E
Barn Owl	*Tyto alba*	Bird	D
Leafy Prairie-clover	*Dalea foliosa*	Flowering Plant	E
Glade-cress	*Leavenworthia exigua*	Flowering Plant	S

Common Name	**Scientific Name**	**Category**	**Protection Status**
Wolf Spike-rush	*Eleocharis wolfii*	Flowering Plant	E
Salamander Mussel	*Simpsonaias ambigua*	Mollusc	R
Pyne’s Ground-plum	*Astragalus bibullatus*	Flowering Plant	E
Boykin’s Milkwort	*Polygala boykinii*	Flowering Plant	T
Pale Umbrella-wort	*Mirabilis albida*	Flowering Plant	T
Hairy Fimbristylis	*Fimbrisylis puberula*	Flowering Plant	T
Naked-stem Sunflower	*Helianthus occidentalis*	Flowering Plant	S
Thicket Parsley	*Perideridia americana*	Flowering Plant	E
Northern Dropseed	*Sporobolus heterolepis*	Flowering Plant	T
Smallscale Darter	*Etheostoma microlepidum*	Fish	D
Rosyface Shiner	*Notropos rubellus*	Fish	D

TDEC, Division of Natural Heritage, Rare Species by Watershed

R= Rare, not listed; T=Threatened, S=Special Concern; D=Deemed in Need of Management; E=Endangered

<u>Climate Change</u>

Potential climate change impacts should be considered a part of any long-range planning goals. Climate change can cause higher ambient temperatures that could affect terrestrial vegetation and stream water regime flow. Weather patterns are likely to cause stronger storms of increased frequency and flood duration. Drought conditions could also be more persistent which would adversely affect vegetation and stream flow. Heat-related illnesses and disease would increase, and economic losses from increased environmental stressors would be of concern. (The Nature Conservancy, 2012.)

Bear Branch Stream Parameters and Chemical Results

Name: Bear Branch Location: Hwy 269 (Compton Road Waterbody ID: TN05130203023 Station ID: BEAR000.8RU Lat/Long: 35.90694, - 86.3611 Ecoregion: 71i County: Rutherford Site ID: WSP30-4

Activity ID Field Sample	Date	Field pH	Field Cond	Field DO	Field Temp	Field Turb	Field Flow	E. coli	Fecal coliform	Sus Res	Total Hard	NH3	NO2_3	TKN	TN*	TP	TOC	Comment
	7/20/2006																	Dry
N06090628005	9/26/2006	7.85	440	6.22	22.68	2.9	0.75	980	1400	5	212	0.015	0.14	0.62	0.76	0.005	5.6	
N06100718005	10/10/2006	7.86	516	9.18	17.57	5.05	1.33	56	45	5	224	0.015	0.43	0.075	0.51	0.02	2.8	
	11/30/2006																	Dry
	12/19/2006																	Dry
N07011031006	1/22/2007	7.52	447	14.32	11.03	8.51	5.98	461	430	5	237	0.015	1.1	0.075	1.18	0.005	1.4	
	2/15/2007																	No Flow
N07031160006	3/6/2007	7.97	498	13.93	13.51	2.05	3.95	30	32	5	130	0.015	1.4	0.075	1.48	0.0035	0.92	
	4/11/2007																	
	5/1/2007																	No Flow
	6/26/2007																	No Flow
	8/24/2007																	Dry

Min =	7.52	440	6.22	11.03	2.05	0.75	30	32	5	130	0.015	0.14	0.075	0.51	0.0035	0.92

Max =	7.97	516	14.32	22.68	8.51	5.98	980	1400	5	237	0.015	1.4	0.62	1.48	0.02	5.6
Avg =	7.8	475	10.91	16.20	4.63	3.00	382	477	5	201	0.015	0.77	0.21	0.98	0.009	2.68

Field pH = pH (standard units)	Field Cond = Conductivity (umhos/cm)	Field DO = Dissolved Oxygen (mg/L)	Field Temp = Temperature (^{O}C)	Field Turbid = Turbidity(NTU)
Field Flow = Flow (cfs)	Escherichia coli = *E. coli*	Fecal coliform = *Fecal coliform*	Sus Res = suspended residue (TSS)	Total Hard = Total Hardness (mg/L)
NH3 = unionized Ammonia (mg/L)	NO2_3 = nitrate & nitrite (mg/L)	TKN = Total Kjeldahl nitrogen (mg/L)	TN = Total Nitrogen = (NO2_3 + TKN	TP = Total Phosphorus (mg/L)
TOC = Total Organic Carbon (mg/L)	Min = Minimum	Max= Maximum	Avg=Average	

Macroinvertebrate Results for Bear Branch Stream Assessment

Table 7 - Macroinvertebrate results for Bear Branch stream assessments

Taxa		**1 Ayers Spring**	**2 Dry 1.1**	**0 Dry 1.1**	**-5 Dry 1.1**	**3 Lufkin Spring**	**4 Bear 0.6**	**5 Bear 0.8**	**-2 Bear 0.8**	**6 Bear 3.5**
Ephemeroptera										
	Baetidae		C	C	A		C			
	Heptageniidae				C					
Plecoptera										
	Perlidae (intolerant)			R						
	Perlodidae (intolerant)			R/C					R	
Trichoptera										
	Hydropsychidae		R	R	C		R			R
	Philopotamidae (intolerant)				R					
	Rhyacophilidae (intolerant)			R	R					
Oligochaeta									R/C	
Amphipoda				A	A	A			R	C
Decapoda - Cambaridae			R	R	R					R
Isopoda - Asellidae			A	D	D	C	C		C	
Odonata										
	Aeshnidae						R			

Taxa		1 Ayers Spring	2 Dry 1.1	0 Dry 1.1	-5 Dry 1.1	3 Lufkin Spring	4 Bear 0.6	5 Bear 0.8	-2 Bear 0.8	6 Bear 3.5
	Corduliidae				R					
Zygoptera										
	Coenagrionidae	R			C	R	R			C
	Calopterygidae		R		A					C
Coleoptera										
	Elmidae	R	A		A			R		R
	Dysticidae			R						
	Psephenidae (intolerant)		C		C		R			
	Haliplidae			R/C	R					R
Hemiptera					R					
Diptera										R
	Ceratopogonidae			R						
	Chironomidae - red			R		R				
	Chironomidae – Non-red		R	A	A	R	C	R	D	R
	Simuliidae			C						
	Tipulidae		R							R
Mollusca										
	Planorbidae		R							
	Pleuroceridae				C	R	R			C
	Physidae	R				R				
	Spaheriidae					R				
Total Taxa		3	10	14	17	8	8	2	5	11
Fish		Observed		Observed		Observed			Observed	
	Ethostoma crossopterum		Observed				Observed			
	Gambusia						Observed			Observed
	Cottus carolinae									Observed
	Micropterus salmoides									Observed

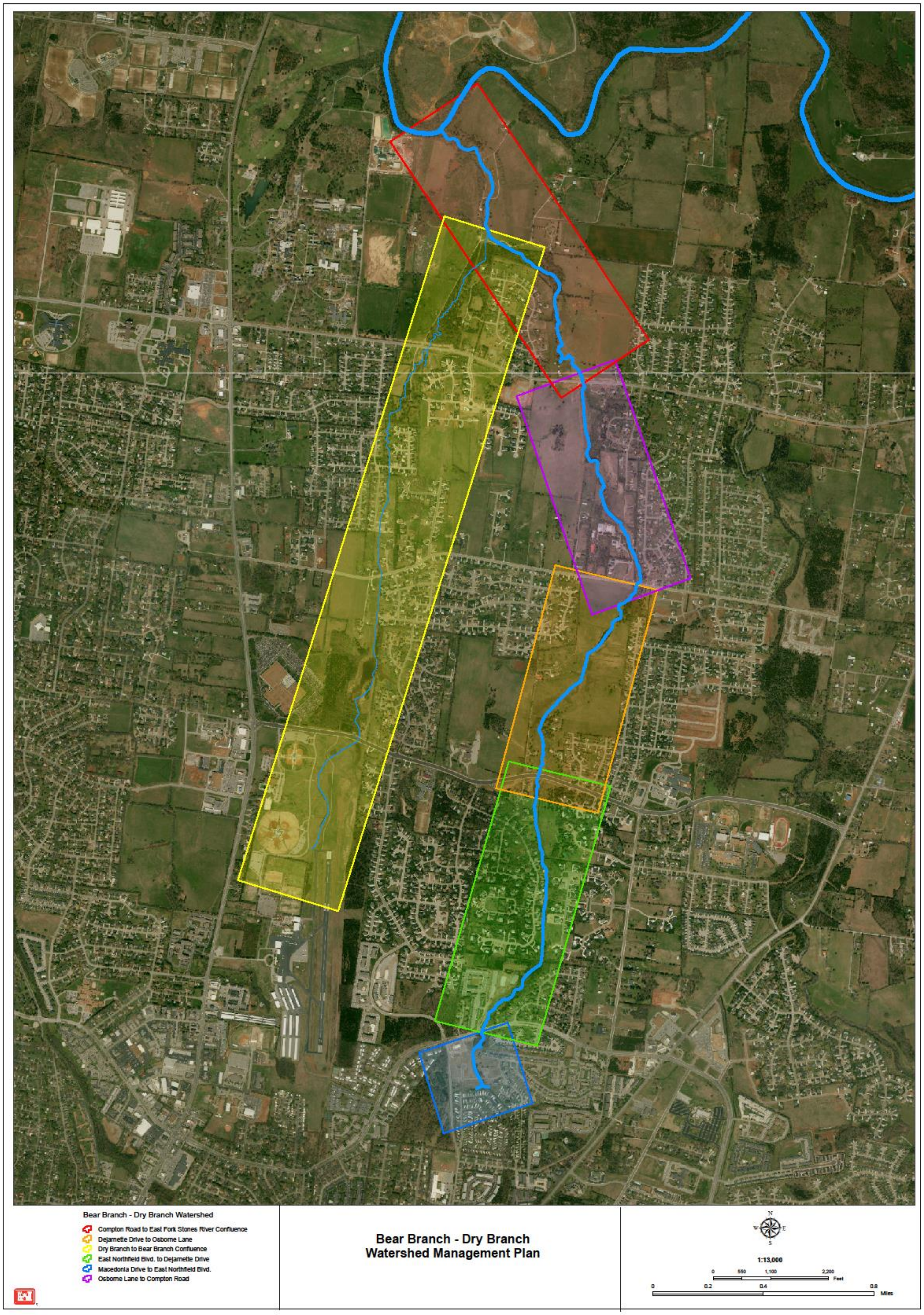
1 Ayers Spring upstream Dry Branch 000.4 mile	3 Lufkin Spring upstream Bear Branch 000.5 mile
2 Dry001.1 mile (2012 survey data)	4 Bear Branch 000.6 mile
+ 2-02 Dry001.1 mile (2002 State data)	5 Bear000.8 mile
+ 2-07 Dry001.1 mile (2007 State data)	+ 5-07 Bear000.8 mile (2002 State data)
Observed = Fish observed	6 Bear Branch 003.6 mile

R = Rare **C = Common** **A = Abundant** **D = Dominant**

Samples Collected: 1- 6 on Sept. 25, 2012; 2-02 on Apr. 10, 2002; 2-07on Feb. 10, 2002, and 5-07 Apr. 10, 2007

Appendix B

Watershed Maps


Bear Branch - Dry Branch Watershed
Compton Road to East Fork Stones River Confluence
Dejarnette Drive to Osborne Lane
Dry Branch to Bear Branch Confluence
East Northfield Blvd. to Dejarnette Drive
Macedonia Drive to East Northfield Blvd.
Osborne Lane to Compton Road
Bear Branch - Dry Branch
Watershed Management Plan
N
W
E
S
1:13,000
0 550 1,100 2,200 Feet
0 0.2 0.4 0.8 Miles

Macedonia Drive to East Northfield Blvd.

- STREAM
- WWC
- POTENTIAL WETLAND AREA

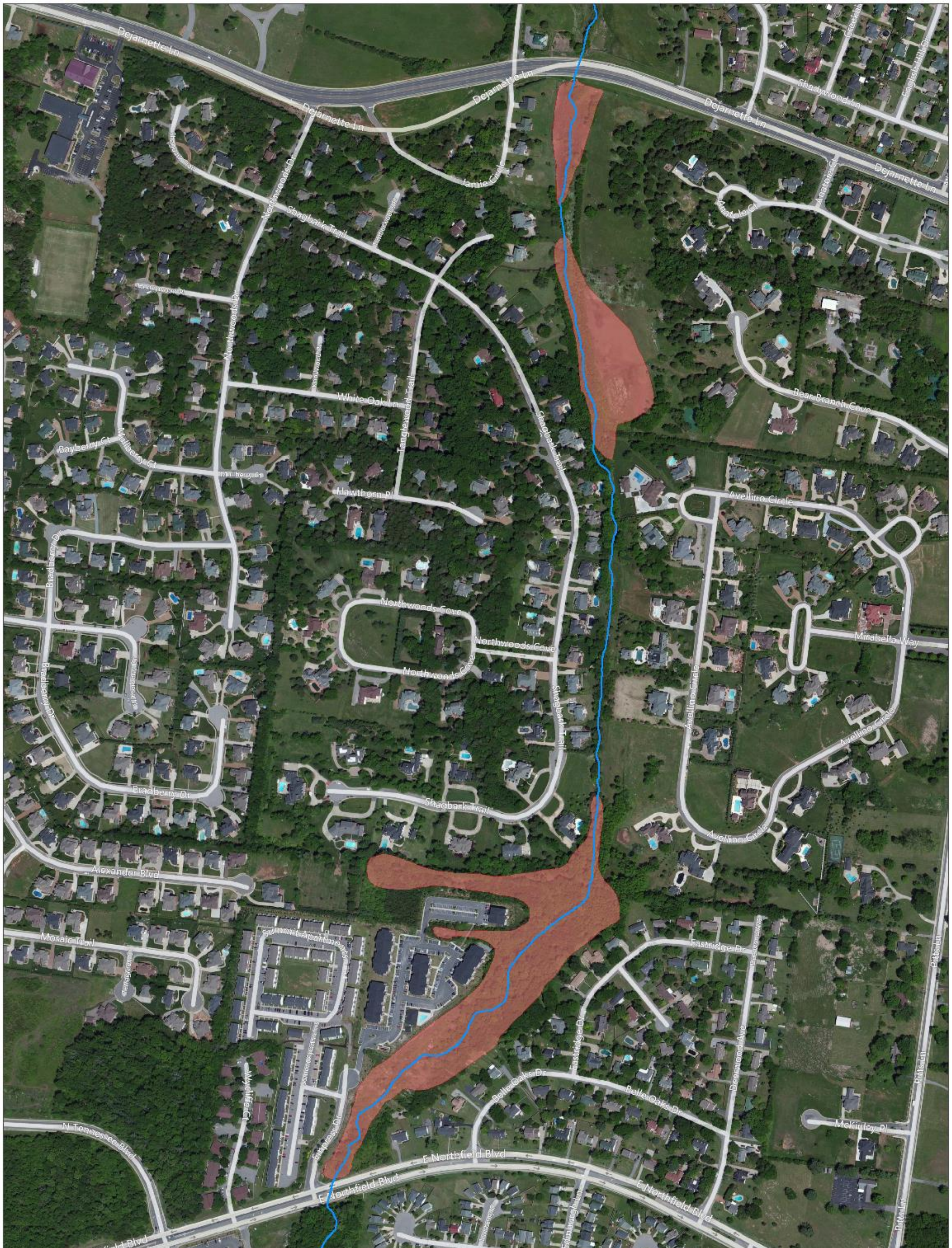
Bear Branch - Dry Branch
Watershed Management Plan

N W E S

1:851

0 35 70 140 Feet

0 0.0125 0.025 0.05 Miles



East Northfield Blvd. to Dejarnette Drive

- STREAM
- WWC
- POTENTIAL WETLAND AREA

Bear Branch - Dry Branch
Watershed Management Plan

N
W E
S

1:3,085

0 130 260 520 Feet

0 0.05 0.1 0.2 Miles

Dejarnette Drive to Osborne Lane

- STREAM
- WWC
- POTENTIAL WETLAND AREA

Bear Branch - Dry Branch
Watershed Management Plan

N
W E
S

1:2,966

0 125 250 500 Feet

0 0.05 0.1 0.2 Miles

Osborne Lane to Compton Road

STREAM

WWC

POTENTIAL WETLAND AREA

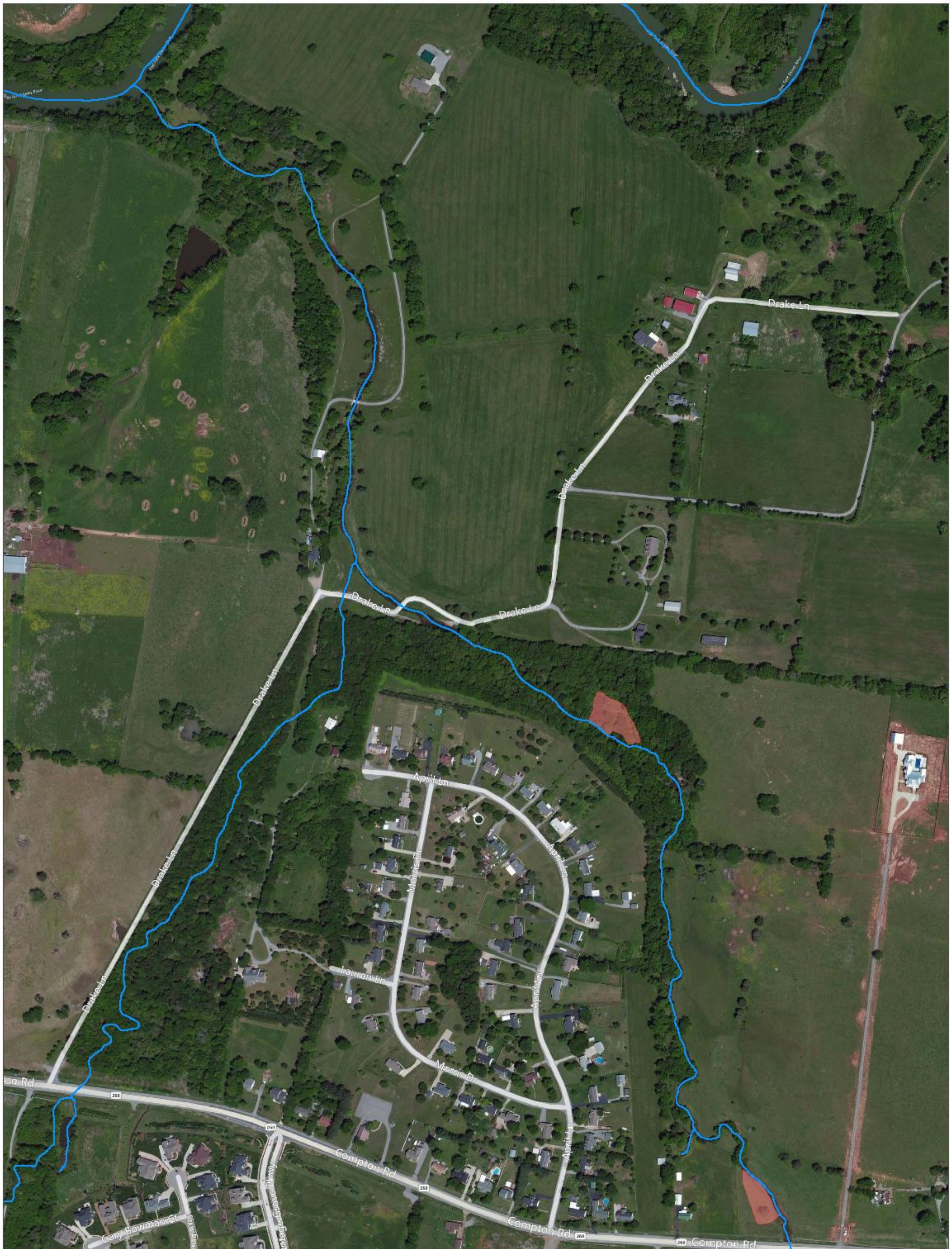
Bear Branch - Dry Branch
Watershed Management Plan

N W E S

1:2,321

0 100 200 400 Feet

0 0.04 0.08 0.16 Miles



Compton Road to East Fork Stones River Confluence

- STREAM
- WWC
- POTENTIAL WETLAND AREA

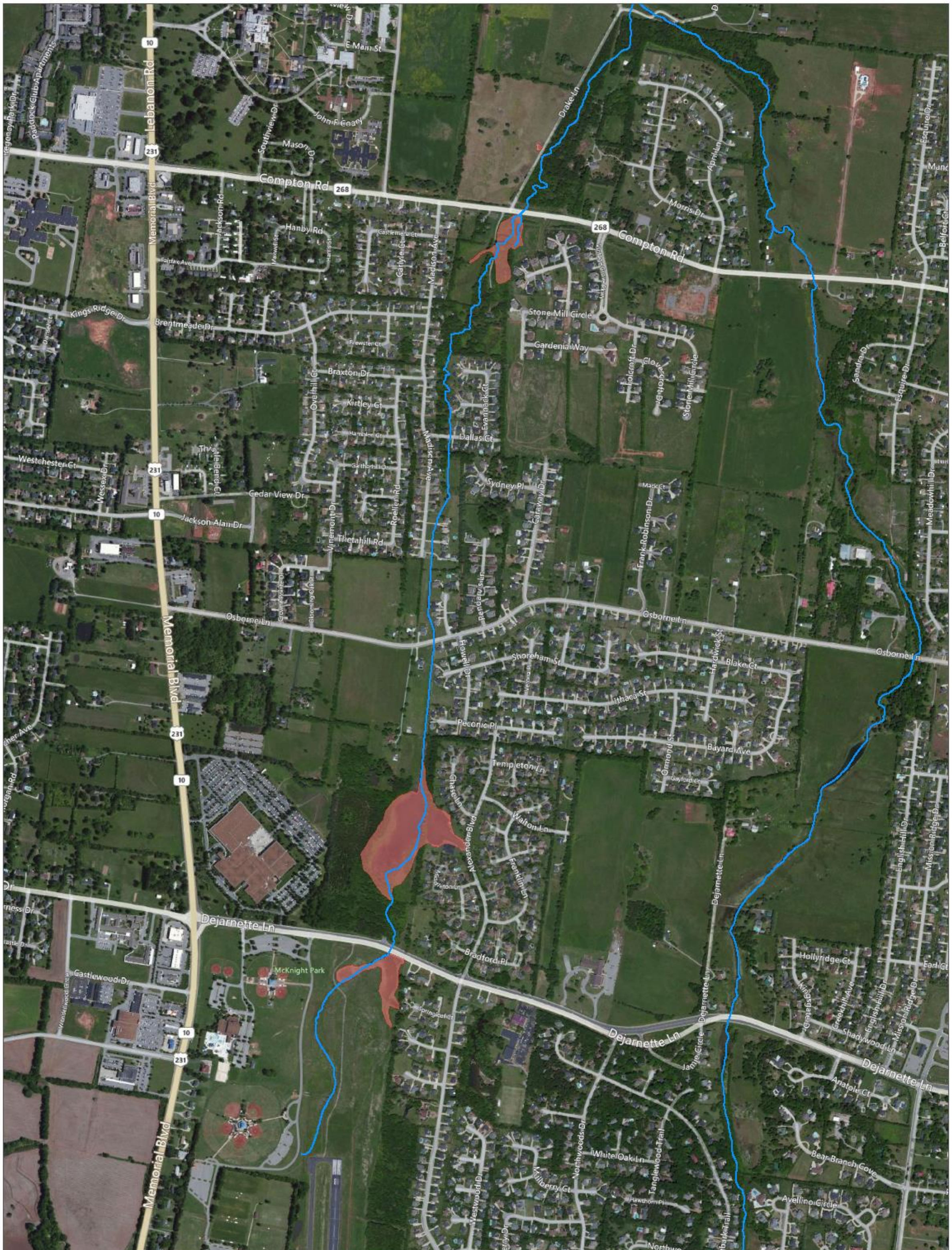
Bear Branch - Dry Branch
Watershed Management Plan

N W E S

1:2,960

0 125 250 500 Feet

0 0.05 0.1 0.2 Miles



Dry Branch to Bear Branch Confluence

- STREAM
- WWC
- POTENTIAL WETLAND AREA

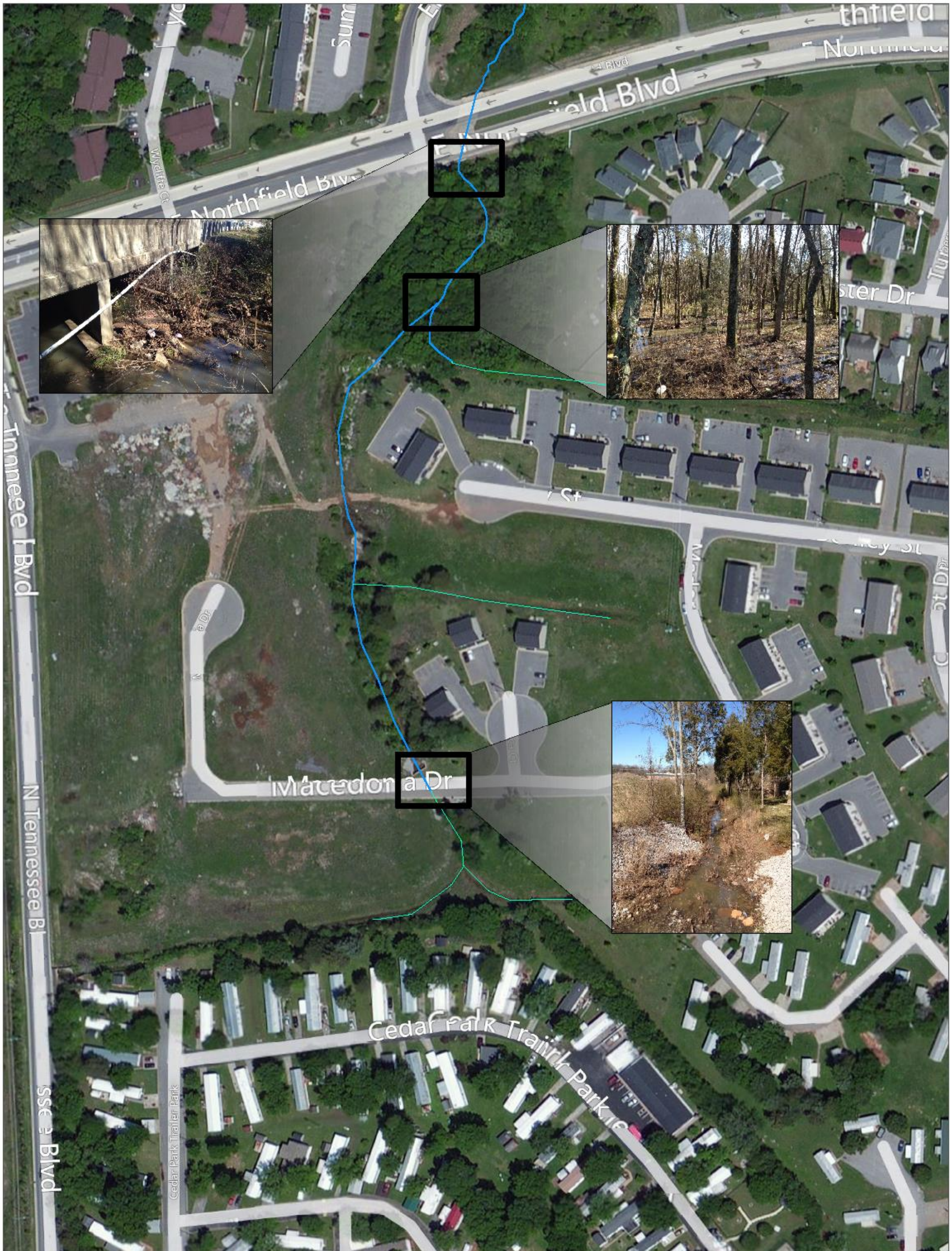
Bear Branch - Dry Branch
Watershed Management Plan

N W E S

1:7,274

0 305 610 1,220 Feet

0 0.125 0.25 0.5 Miles



Macedonia Drive to East Northfield Blvd.

- STREAM
- WWC

Bear Branch - Dry Branch Watershed Management Plan

1:1,000

0 40 80 160 Feet

0 0.015 0.03 0.06 Miles

East Northfield Blvd. to Dejarnette Drive

- STREAM
- WWC

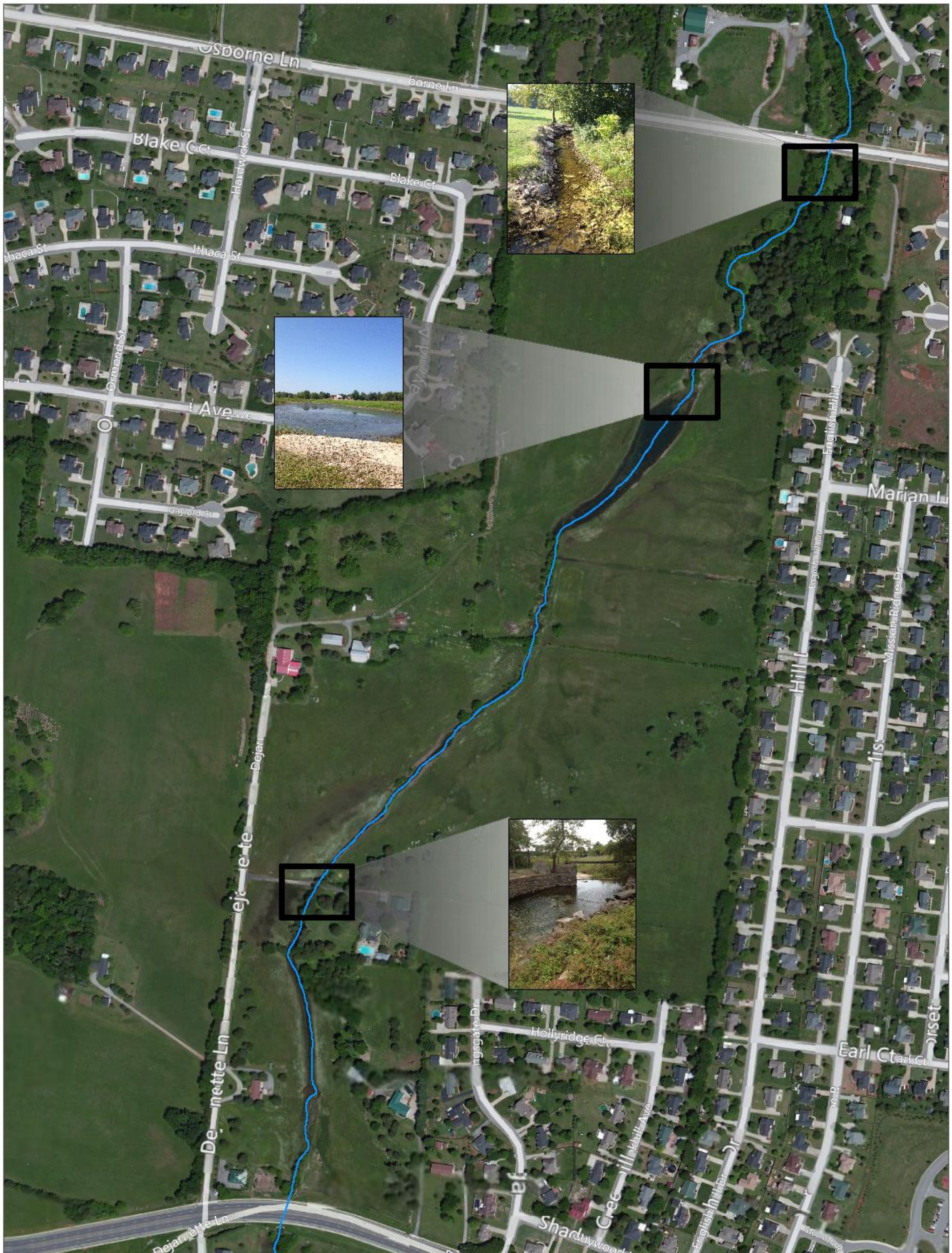
Bear Branch - Dry Branch
Watershed Management Plan

N W E S

1:3,401

0 145 290 580 Feet

0 0.05 0.1 0.2 Miles



Dejarnette Drive to Osborne Lane

- STREAM
- WWC

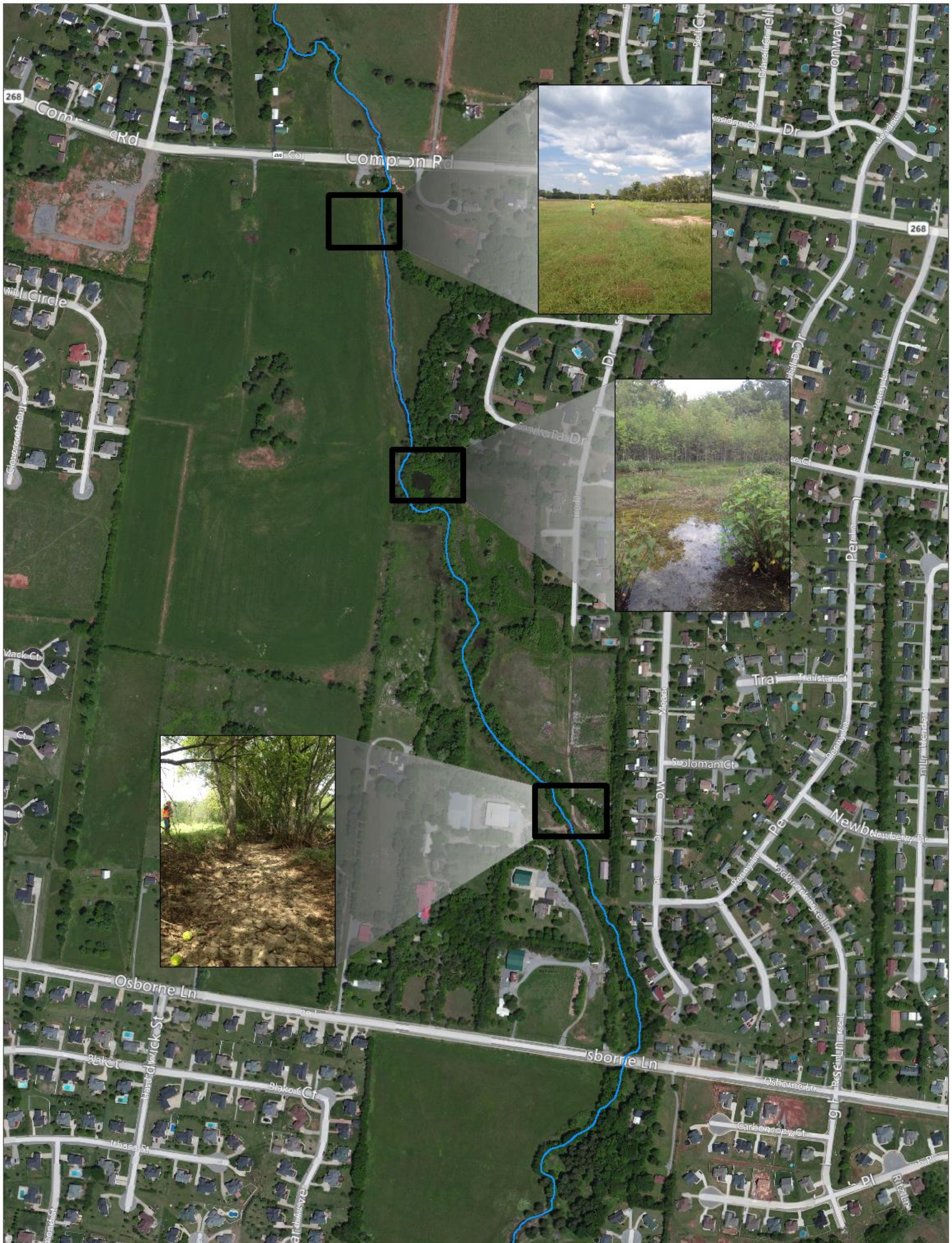
Bear Branch - Dry Branch
Watershed Management Plan

N
W E
S

1:2,455

0 100 200 400 Feet

0 0.035 0.07 0.14 Miles



Osborne Lane to Compton Road

STREAM

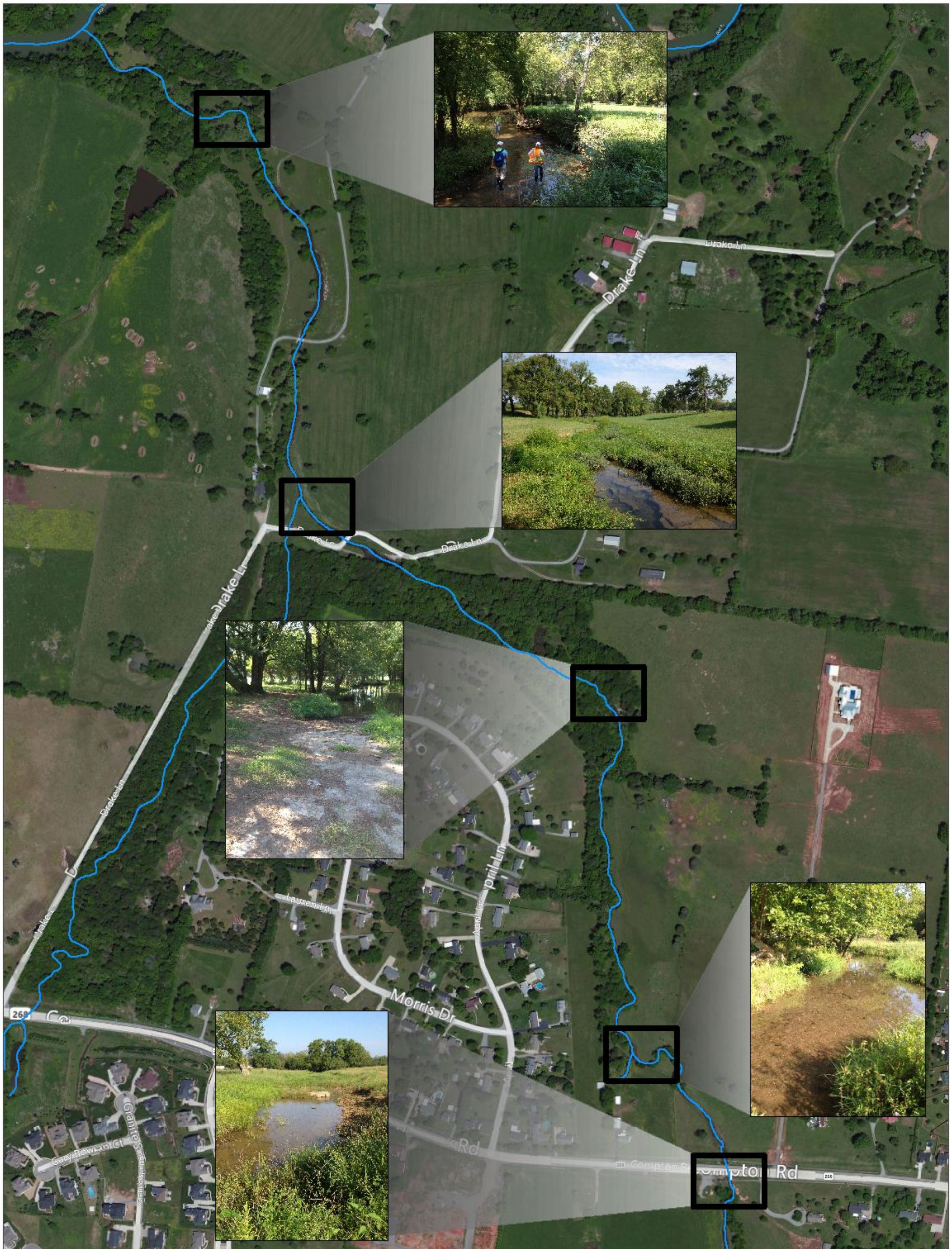
WWC

Bear Branch - Dry Branch
Watershed Management Plan

1:3,047

0 125 250 500 Feet

0 0.045 0.09 0.18 Miles



Compton Road to East Fork Stones River Confluence

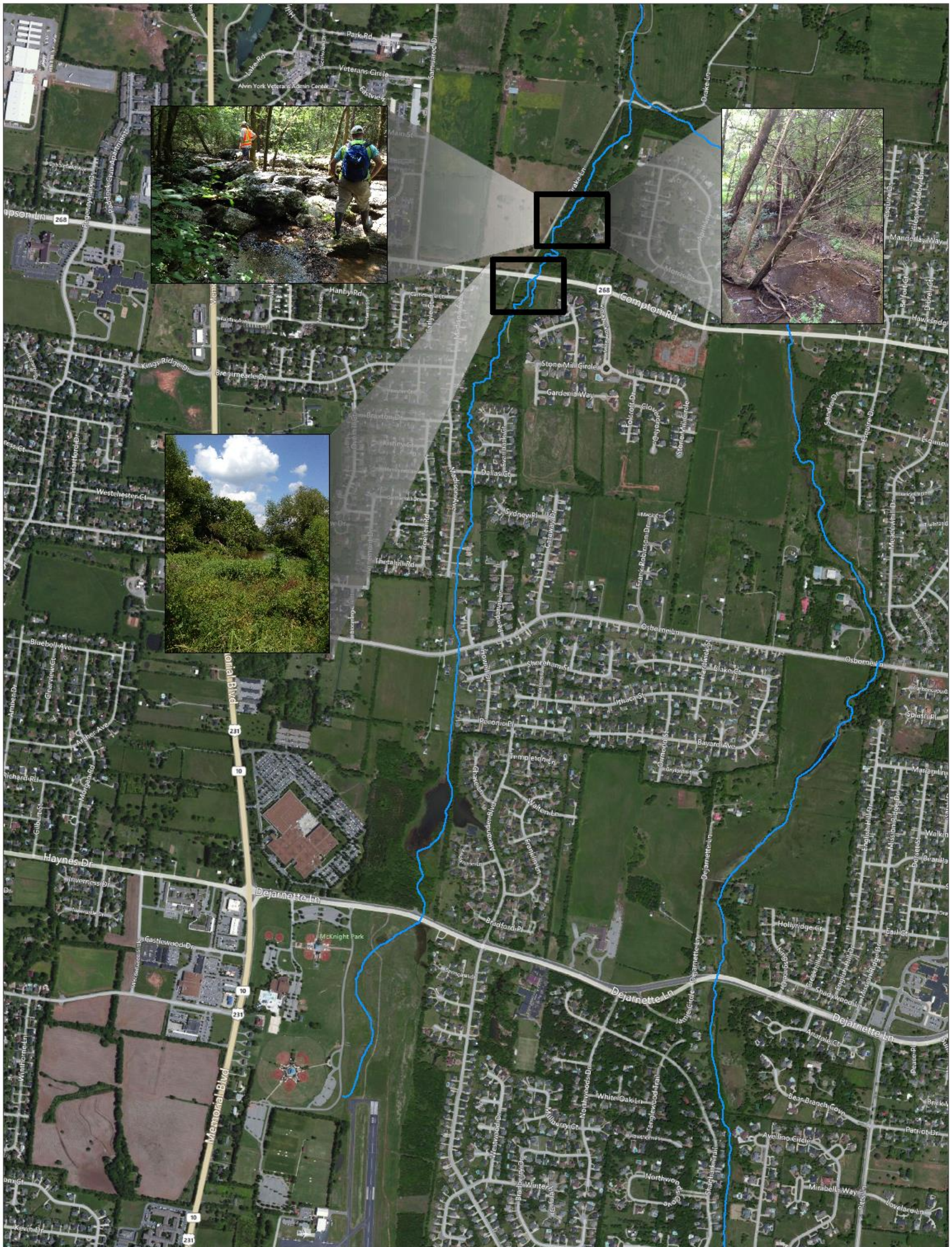
- STREAM
- WWC

Bear Branch - Dry Branch
Watershed Management Plan

1:3,022

0 125 250 500 Feet

0 0.045 0.09 0.18 Miles



Dry Branch to Bear Branch Confluence

STREAM

WWC

Bear Branch - Dry Branch
Watershed Management Plan

N W E S

1:8,329

0 350 700 1,400 Feet

0 0.125 0.25 0.5 Miles

Appendix C - Proposed Best Management Practices

Proposed Best Management Practices

It is apparent that the aquatic macroinvertebrate communities in Bear Branch are impaired. Agricultural areas, cities, and counties can best monitor the effectiveness of a specific BMP and when to use it under various stream flow conditions (high, medium, low flows and dry conditions). This relationship between stream flows and appropriate BMP facilitates understanding the relationship between water quality and BMPs for different flow regimes. Problems with water quality under low flows generally indicate that the water quality impact comes from point sources such as illicit discharges or failing septic tanks because they have continuous flow even without rainfall. Problems with water quality under high flow conditions generally indicate non-point sources such as sediment or high nutrients from animal waste or fertilizers that may be impacting water quality. This is why it is important to use the appropriate BMP under varying stream flow conditions (EPA, 2007, and Nieber, 2009). Flow conditions and the appropriate BMP are noted below.

7.a City of Murfreesboro and Rutherford County

1. Public Education/Outreach

Educate the public about the use of pervious pavement, rain gardens and barrels, lawn fertilizers, and pesticides and water conservation and pet waste management and disposal. Recycling programs minimize the amount of trash entering the stream. Encourage programs like adopt-a-stream, stream clean-ups, riparian plantings, and watershed/community groups. Use volunteers to monitor the stream. Their use encourages public participation and provides the public opportunities to address stream bank erosion, trash dumps, water quality, and the benefits of a healthy riparian area in their own backyards. MWSD has conducted riparian plantings at Garrison Creek to show the importance of riparian areas in stabilizing stream banks and improving backyard aesthetics. Involve the public in storm water management. Train them to recognize illicit discharges and failing septic tanks.

2. Laws & Ordinances (Construction, low impact development, zoning, etc.)

Through zoning, encourage low impact development. Enforce storm water BMPs such as silt fencing, mulching, sediment ponds, berms and swales, and construction entrances to public roadways. These BMPs are most effective during storm events with high to mid-range flows. Post development structural BMPs such as wide grass buffers adjacent roads are effective in filtering pollutants from the road during large rain events. BMPs for bank protection are most effective during high flow events because during this hydrologic condition, high stream volume and velocity erodes unprotected banks causing sediment to be released into the stream that results in large stream deposits that fill in the stream channel.

3. Elimination of Illicit Discharges

During low flows and dry periods identify and eliminating illicit discharges. This is best conducted during low flow and dry conditions when illicit discharges are easy to recognize because they continue to run during these hydrologic conditions.

4. Sanitary Sewer Overflows (SSOs) Repair/Abatement

Dye test or use infrared studies to find leaking sewer lines. Place upgrades, replacements, and improvements on a time basis instead of waiting to repair equipment when it fails. MWSD has performed dye testing, which is best carried out during low flow conditions. Target combined sewer overflows, if present, for sewer and storm water separation to prevent flooding the sewer system. Use tunnels to direct uncontaminated storm water to streams, detain storm water in storage basins, and treat sediment contaminated storm water in treatment basins. These BMPs are most effective during medium and high flow conditions.

5. Septic Tank Inspection/Repair

Use infrared surveys to find and repair failing septic tanks. This is best conducted during low flows and dry conditions when failing septic tank field lines continue to flow. Educate septic tank owners to pump and inspect septic tanks and lines at least every 5 years to ensure they are functioning properly.

6. Storm Drain Identification

Provide protective filtering collars and buffers around sinks and storm water lawn drains to slow and filter the water before it enters into the ground water. Identify storm ditches entering a stream and calculate water quantity to determine storm water volume to manage storm water so as not to swamp Bear Branch and cause flooding to downstream areas. Storm water flow can be best identified during storm events when water flows can be followed to discharge point.

7. Establish Riparian Buffer Zones

Riparian buffers are most effective during high flows. Attempt to maintain a 25-ft buffer along streams. When acquiring a right-of-way for new sewer lines, try to acquire a 25-ft right-of-way from the stream edge for a riparian zone. Install sewer lines into the land side edge of the buffer zones as tree roots can enter into sewer lines and damage the lines. Even a 10-ft tree buffer adjacent the stream would provide shade, take up nutrients, and stabilize the stream channel and bank.

8. Bank Protection

Use bioengineering where possible to minimize maintenance costs. Harden banks where necessary to reduce erosive forces of high velocity flows.

9. Structural BMPs

Retention and detention ponds, constructed wetlands, and filtration systems minimize pollutants (sediment, and nutrients) from entering a stream. Wetlands act as filters for overland flow and provide storage areas for flood waters. Detention ponds to hold storm water so as not to swamp Bear Branch and cause localized flooding. Excess storm water into small streams results in flashier flows at high flows and drier streams at low flows. Small streams like Bear Branch cannot handle excessive storm water volume. It may be helpful to look for storm water storage outside the stream so storm water can be detained and drained at a regulated rate to prevent downstream flooding.

10. Protection

Protect remaining wooded areas, stream buffers, and wetlands using zoning ordinances. This BMP is most cost effective because there would be no installation costs. This BMP would provide valuable protect to state and federally and state listed species that may inhabit these areas. These areas can become park and environmental education sites.

11. Watershed Assessment Training and Partnerships

Strengthen watershed assessment programs through training from the state to ensure macroinvertebrate and chemical sampling data is valid and can be used by the state to support the finding made by the city or the county. Work with other agencies such as the state agriculture, forestry, and non-point source departments to acquire BMPs training and funding. Additional partnerships can be developed with the Natural Resources Conservation Service (NRCS) to help provide BMP assistance and funding for the farming community.

7.b Agricultural Areas

1. Manure/Fertilizer Management

Management of these nutrients is most effective during medium stream flows when overland flows could wash these nutrients into a stream. Minimizing field application and avoiding rain events when spreading manure or fertilizer over fields would allow upland vegetation time to absorb the nutrients and minimize washing them into the stream.

2. Establish Riparian Buffer Zones

Maintaining a riparian buffer would filter nutrients and sediment during storm events and overland flow and would reduce their concentration before they enter a stream. Riparian buffers are most effective during high flows. Leave a buffer where the field is not hayed to the edge of the stream. Allow grasses and forbs to grow up next to the stream. Even a 10 foot buffer is better than none.

3. Erosion Control Measures

Contour farming, conservation tillage, and maintaining a riparian buffer are measures that would filter and reduce the velocity of overland flows. These would reduce erosion by minimizing the formation of rills across the land. BMPs are most effective during high flow events because during this hydrologic condition, high stream volume and velocity erodes unprotected banks causing sediment to be released into the stream. Large sediment deposits can fill in the stream channel.

4. Limit Stream Access to Livestock

Fencing livestock out of streams would reduce nutrient input into the stream. Bank erosion would be reduced since animals often create multiple entry points into a stream that destabilize the stream bank. Providing limited stream access would concentrate watering to only one small area along a stream. Alternate watering sources, such as solar pumps would be another alternative to keeping livestock out of the stream. This BMP is most effective during mid-range, low flows and dry conditions since nutrients concentrate in the stream.

5. Water Flow Management

Slowing overland water flow allows storm water to sheet flow through a riparian buffer and allow time to filter out contaminants (waste, fertilizers, and sediment). Berms and swales would allow storm water to collect at one end of a field and allow infiltration and prevent the run-off from entering the stream.

Appendix D

List of Preparers and References

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References

A Water Quality Study in Rutherford County, Tennessee: Student Group Project, MTSU and TDEC WPC, James/Ogden/DiVincenzo, 2006.

Bear Branch Flood Study Area, City of Murfreesboro, Tennessee, Murfreesboro GIS Department, 2012.

Bear Branch, Murfreesboro, Tennessee, Stream Assessment Surveys and Habitat Assessment Field Data, TDEC, Water Pollution Control, 2002, 2007.

Bear Branch Watershed, Web Soil Survey, Natural Resources Conservation Service, 2012.

City of Murfreesboro, *Water Quality Protection Areas,* Ordinance 06-O-27, Stormwater Management, February, 2007.

City of Murfreesboro Water and Sewer Department, GIS Department, 2012.

City-Data.com, Murfreesboro, Tennessee, 2012. http://www.city-data.com/city/Tennessee.html

Cleland, Bruce, *Back to Basics – Using Hydrology to Develop Solutions*. Minnesota PAC Technical Workshop, St. Paul, MN, February 14, 2006.

Cross Creeks Conservation Plan, Climate Change, USFWS, April 2009.

Draft Tennessee Stream Mitigation Program In-Lieu Fee Instrument, Tennessee Stream Mitigation Program, 2010. http://www.lrn.usace.army.mil/cof/notices/TSMP%20Draft%20Instrument%20Reduced%20Size.pdf

Ecosystem Restoration Management Measures, Institute for Water Resources, 2012.

Environmental Protection Agency, *STEPL Model – Spreadsheet Tool for Estimating Pollutant Load, Handbook for Developing Watershed Plans to Restore and Protect our Waters*, March 2008. http://it.tetratech-ffx.com/stepl

Environmental Protection Agency, Western Ecology Division. Ecoregions of North America. http://www.epa.gov/wed/pages/ecoregions/na_eco.htm accessed 3JAN13.

Engineer Circular (EC) 1105-2-411 – Planning Watershed Plans, 15 January 2012.

Final Year 2010 303 (d) List, TDEC, Division of Water Pollution Control, 2010.
Handbook for Developing Watershed Plans to Restore and Protect Our Waters, EPA, March 2012. http://www.tn.gov/environment/wpc/publications/pdf/2010_303d_final.pdf

Murfreesboro Stormwater Program, 2011. *East Fork Stones River Watershed, Visual Stream Assessment, Stream Characterization Study (Macro Invertebrate, Groundwater, pH, Temperature, Conductivity, Dissolved Oxygen, and E-coli Spring Sampling)*. 124 pp.

Murfreesboro Sewer and Water Department (MSWD), Storm Water Assessment, Bear Branch sediment:
http://www.youtube.com/watch?v=OAyUNAXib3k&list=PLABA74A29095DB2D4&index=59
Accessed November 27, 2012

National Wetlands Inventory, USFWS, 2011.

Nieber, John L. 2009. *Load Duration Curve Analysis, BBE 5533, Fall 2009*. 29 pp.

Nitrogen and Water, USGS Water Science School, 2012.
http://ga.water.usgs.gov/edu/nitrogen.html

Rutherford County, Tennessee - GIS Information Department, 2012.
http://maps.rutherfordcountytn.gov/Rutherford/

Stage 1 TMDL for Low DO and Nutrients in the Stones River Watershed (HUC 05120203) - Cannon, Davidson, Rutherford, and Wilson Counties, Tennessee
http://tn.gov/environment/wpc/tmdl/approvedtmdl/StonesNutr.pdf

Tennessee Department of Agriculture, Water Quality Grants, Nonpoint Pollution Control, 2012. http://www.TN.gov/agriculture/water/nps.html

Tennessee Department of Environment and Conservation, Natural Heritage Inventory Program, Tennessee 2012 Rare and Endangered Species, http://www.tn.gov/environment/na/nhp.shtml

Tennessee Department of Environment and Conservation, Division of Water Resources – Stones River Watershed Guide – Bear Branch Subwatershed 05130203050, 2012. http://www.tn.gov/environment/watersheds/one/stones/

Tennessee Department of Environment and Conservation. 2001. "Development of Regionally-Based Numeric Interpretations of Tennessee's Narrative Biological Integrity Criterion." 136 pp

Tennessee Department of Environment and Conservation. 2007. Chapter 1200-4-4 Use Classification for Surface Waters. 34pp.

Tennessee Department of Environment and Conservation, Division of Water Pollution Control. May 12, 2008. *Stage 1, Total Maximum Daily Load (TMDL) for Low Dissolved Oxygen & Nutrients in the Stones River Watershed (HUC 05130203), Cannon, Davidson, Rutherford, & Wilson Counties, Tennessee, Final*. 125pp.

Tennessee Department of Environment and Conservation, Division of Water Pollution Control. June 19, 2012b. *Proposed Total Maximum Daily Load (TMDL) for E. Coli in the Stones River Watershed (HUC 05130203) Bedford, Cannon, Coffee, Davidson, Rutherford, Williamson, and Wilson Counties, Tennessee.* 175 pp.

Tennessee Department of Environment and Conservation, Division of Water Pollution Control. 2011. *Quality System Standard Operating Procedure for Macroinvertebrate Stream Surveys. 214 pp.*

Tennessee Department of Environment and Conservation. 2011. Chapter 1200-04-03 General Water Quality Criteria. 43pp.

Tennessee Department of Environment and Conservation. 2012. Proposed Final Year 2012 303(d) List. 189pp.

The Nature Conservancy, Global Warming and Climate Change, 2012. http://www.nature.org/ourinitiatives/urgentissues/global-warming-climate-change/threats-impacts/index.htm

TMDL for E. Coli in the Stones River Watershed (HUC 05120203) – Bedford, Cannon, Davidson, Rutherford, Williamson, and Wilson Counties, Tennessee, June 2012 http://tn.gov/environment/wpc/tmdl/approvedtmdl/stones_river_ecoli.pdf

TMDL for Siltation and Habitat Alteration in the Stones River Watershed (HUC 050130203) – Cannon, Davidson, Rutherford, and Wilson Counties, July 2002 http://tn.gov/environment/wpc/tmdl/approvedtmdl/StonesSed04.pdf

U.S. Army Corps of Engineers, Institute of Water Resources, Management Measures Digital Library, Ecosystem Restoration. http://www.iwr.usace.army.mil/docs/MMDL/ECO/index.asp

U.S. Geological Survey. 2012. StreamStats – a web-based program to calculate stream flows in Tennessee at: http://water.usgs.gov/osw/streamstats/tennessee.html. Accessed November 27, 2012.

United States Congress. 2000. *Federal Water Pollution Control Act As Amended Through P.L. 109-308.* 33 U.S.C. 1251 et. seq. Washington D.C.

U.S. Census Quikfacts, 2012

United States Environmental Protection Agency. 2007. *An Approach for Using Load Duration Curves in the Development of TMDLs*. EPA 841-B-07-006.

U. S. Environmental Protection Agency, Handbook for Developing Watershed Plans to Restore and Protect Our Waters, Office of Water, Nonpoint Source Control Branch, March 2008. http://water.epa.gov/polwaste/nps/handbook_index.cfm

U.S. Environmental Protection Agency, Urban Waters Outreach Toolkit, 2012. http://water.epa.gov/scitech/swguidance/standards/upload/anacostiatoolkit.pdf

U.S. Fish and Wildlife Service, Information, Planning, and Conservation (IPAC) System, Natural Resources of Concern, Bear Branch, Murfreesboro, Tennessee http://ecos.fws.gov/ipac/

Wildflowers and Ferns of Kentucky. University Press of Kentucky. Thomas G. Barnes @ USDA-NRCS PLANTS Database / Barnes, T.G., and S.W. Francis. 2004.

Wikipedia, *Impervious Surfaces and Stormwater Runoff*, 2012.

No.	Stream Segment	Location	Quantity	Unit Cost	Cost	Benefit	Rank	Notes
1	**Macedonia Drive to East Northfield Blvd**	35.877836/-86.367454			**$1,000**			
	Wetland Protection - Above Northfield	Mile 3.8 - 3.7	2.6 acres	varied	113	5	5	Maximum Benefit - wetland protection
	Channel Reconstruction	Mile 4.0 - 3.8	1,000'	$100-200/lf	100-200	2	3	Insufficient land for reconstruction
	Riparian Forest Buffer	Mile 4.0 - 3.8	1,000'	$20/lf	20	3	4	Beneficial for stream habitat
	Trash/Debris Removal	Mile 4.0 - 3.7	1,600'	$1/lf	1.6	4	4	Reduces downstream impacts
2	**East Northfield Blvd to Dejarnette Lane**	35.877836/-86.364223						
	Bioengineering	Mile 3.5 - 3.4, 3.1-2.8	400'/790'	$20/lf	23.8	4	3	Adjacent to Apts, Shagbark Trail
	Wetland Protection - Above Dejarnette	Mile 3.5-3.2, 2.8-2.6	25.4 acres	varied	1,000	5	4	Max Benefit - two wetland sites
	Channel Reconstruction	Mile 2.8 - 2.6	1,000'	$100-200/lf	100-200	3	2	Undefined channel above Dejarnette
	Riparian Forest Buffer	Mile 2.8 - 2.6	1,000'	$20/lf	20	3	3	Homeowners altered riparian areas
	Trash/Debris Removal	Mile 3.7 - 2.6	5300'	$1/lf	10	3	3	Adjacent development
3	**Dejarnette Lane to Osborne Lane**	35.895598/-86.357938						
	Bioengineering	Mile 2.6 - 2.0	3,200'	$20/lf	64	3	3	Little defined riparian area
	Wetland Protection - Above Osborne	Mile 2.2 - 2.0	17.2 acres	varied	180	4	4	Protect wetland below dam
	Channel Reconstruction	Mile 2.5 - 2.2	1,600'	$100-200/lf	160-320	4	3	Dam removal/channel meandering
	Riparian Forest Buffer	Mile 2.6 - 2.2	2,100'	$20/lf	42	4	3	Establish riparian over stream length
4	**Osborne Lane to Compton Road**	35.914169/-86.360261						
	Bioengineering	Mile 1.6-1.5, 1.4-1.2	500-1,000'	$20/lf	30	3	3	Bioengineer stream segments
	Wetland Protection - Above Compton	Mile 1.6-1.4	6.3 acres	varied	63	5	5	Max Benefit - wetland site
	Channel Reconstruction	Mile 1.5 - 1.3	1,000'	$100-200/lf	100-200	3	3	Channel straightened Mile 1.5-1.3
	Riparian Forest Buffer	Mile 1.6 - 1.3	1,600'	$20/lf	32	4	3	Riparian absent in two locations
	Trash/Debris Removal	Mile 1.6 - 1.2	2,100'	$1/lf	4	4	4	Debris dam, fencing across stream
5	**Compton Road to E Fork Stones River**	35.913265/-86.362739						
	Bioengineering	Mile 1.6 -1.5, 0.5-0.2	1,000-1,600'	$20/lf	52	4	3	Bioengineering on Lufkin/Ayers
	Wetland Protection - E Fork Stones River	Mile 1.6-1.5, 0.6-0.5	1.6 acres	varied	12	4	3	Lufkin and Ayers Springs
	Riparian Forest Buffer	Mile 1.6 -1.5, 0.5 -0.2	500', 1,600'	$20/lf	42	3	3	Riparian absent in two locations
	Livestock Exclusion	Mile 1.6 - 1.0	3,200'	$5/lf	16	5	4	Establish fencing and watering areas
6	**Dry Branch to Bear Branch Confluence**	35.908786/-86.371271						
	Bioengineering	Mile 1.7 - 1.0	3,700'	$20/lf	74	3	3	Above Dejarnette and Osborne
	Wetland Protection - Dry Branch	Mile 1.7 - 0.0	53 acres	varied	424	5	4	Max Benefit - three wetland sites
	Riparian Forest Buffer	Mile 1.7 - 1.0	3,700'	$20/lf	74	3	3	Homeowners altered riparian areas
	Livestock Exclusion	Mile 0.3 - 0.0	1,600'	$5/lf	8	3	3	Minimal livestock access
	Ranking - based on severity/correctability/accessibility of sites - 1 (Low) - 5 (High)							