Lake St. Louis and Peruque Creek Watershed-Based Plan Warren and St. Charles Counties

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Project Vision, Goal, and Objectives

The vision for this 9-element watershed-based plan (WBP) is to restore water quality in Lake St. Louis to conditions that meet applicable state water quality standards, and to provide water quality improvement in Peruque Creek as it relates to water quality impairments in that stream.

The Missouri Department of Natural Resources is developing this WBP in cooperation with the Peruque Creek Watershed Alliance and in conjunction with the development of a Total Maximum Daily Load (TMDL) report to address the chlorophyll-a (Chl-a) impairment in Lake St. Louis (water body ID 7054). This impairment is the result of excessive sediment and nutrients entering the lake from the surrounding landscape and from Peruque Creek, which is the primary source of flow to the lake. The goals of this WBP are to restore the aquatic life designated use assigned to Lake St. Louis, and to ensure continued protection of the use once water quality criteria are met. Although primarily focused on restoring water quality in Lake St. Louis, an additional goal of this plan is the improvement of water quality in Peruque Creek as it relates to an aquatic life use impairments in that stream due to low aquatic diversity and low dissolved oxygen conditions likely resulting also from excess sediment and nutrient inputs. Implementation of best management practices (BMPs) to restore water quality in Lake St. Louis is expected to also provide water quality improvements, and potentially restore water quality, in Peruque Creek. Specific objectives are:

- Achieve necessary nonpoint source phosphorus, nitrogen, and sediment load reductions to meet the applicable Chl-a criteria in Lake St. Louis through implementation of BMPs.
- Reduce excess sedimentation and the potential for harmful algal blooms in Lake St. Louis.
- Protect aquatic life designated uses in the Lake St. Louis watershed.
- Reduce excess sedimentation, which contributes to nutrient, biological, and low dissolved oxygen impairments in the Lake St. Louis watershed.

Executive Summary

Lake St. Louis (water body ID 7054) is located in eastern central Missouri. Peruque Creek, the primary tributary to Lake St. Louis, originates in Warren County, runs east into St. Charles County, eventually reaching the impoundment of Lake St. Louis in central St. Charles County. Restoration actions and pollutant load reductions presented in this WBP are driven by the Lake St. Louis chlorophyll-a (Chl-a) 303(d) impairment listing by targeting nutrients and sediment. Additionally, a 10-mile segment of Peruque Creek (water body ID 218) is impaired for low dissolved oxygen and poor aquatic life conditions. This plan specifically targets restoration and load reductions to address the Lake St. Louis Chl-a impairment, however these actions are expected to also improve and potentially restore water quality in Peruque Creek. Implementing actions in this WBP to achieve the stated total nitrogen (TN), total phosphorus (TP), and total suspended solids (TSS)[1] load reductions for Lake St. Louis will address the impairment and attain water quality standards. This WBP addresses the entire Lake St. Louis watershed including areas that drain to the impaired portions of Peruque Creek. The WBP also provides a continuing framework for the department and the Peruque Creek Watershed Alliance to work with landowners, communities, and organizations in the watershed to voluntarily implement BMPs and provides opportunities for eligible entities to apply for Clean Water Act Section 319 funding to support such implementation.

Element A: Causes and Sources of Pollution

Pollutant loading to Lake St. Louis comes from a combination of point and nonpoint sources including wastewater treatment facilities, agricultural runoff, urban development, leaky septic systems, atmospheric deposition, and natural background conditions. A TMDL report is being developed to address the Chl-a impairment in Lake St. Louis by establishing the maximum pollutant loading that Lake St. Louis can take in while still meeting and maintaining applicable water quality standards. The TMDL allocates are portion of that loading to point sources and necessary reductions to achieve that allocation will be implemented through the department's Missouri State Operating Permit Program. The TMDL also assigns a pollutant load allocation not nonpoint sources that when met in conjunction with point source goals, will result in attainment of water quality standards. Implementation of pollutant load reduction targets for nonpoint sources is expected to primarily occur through implementation of this WBP. Major sources of nonpoint source pollution in the Lake St. Louis watershed are runoff from areas with agricultural land uses as well as from expanding development and rapid urbanization occurring in the watershed. In some of these areas, those major sources also contribute to or exasperate streambank erosion that may also contribute excess sediment or phosphorus. Causes and sources of pollution are further discussed in Sections 4 and 5. Section 5 also provides estimates of loading from those major land use sources. The significance of specific pollutant contributions from streambank erosion will be determined on a case-by-case basis as it relates to the primary areas of concern in the watershed. A conservative estimate of streambank erosion is assumed in achieving pollutant reduction targets based on modeling outputs and best professional judgment.

[1] For purposes of this plan, TSS serves as measure for suspended sediment consistent with the Lake St. Louis TMDL.

Areas and sources to be addressed by BMPs are presented in Section 8 and supplemented with additional locational information in Appendix A.

Element B: Expected Load Reductions

Pollutant load reduction targets assigned in this WBP are consistent with meeting the nonpoint source load allocations established in the draft TMDL developed by the department to address the Chl-a impairment in Lake St. Louis. To address eutrophication in Lake St. Louis, the department developed TN, TP, and TSS load allocations using a HAWQS/SWAT watershed model and a BATHTUB lake model to connect nutrient levels to resultant Chl-a levels. Final nutrient targets are consistent with numeric nutrient criteria for lakes established in Missouri's Water Quality Standards regulations (10 CSR 20-7.031)

Table ES-1 below presents estimates of current pollutant loading from the watershed that is causing the impairment in Lake St. Louis, the amount of load reduction needed to restore the lake, the estimated load reduction expected after 5 years of BMP implementation, and the final load reduction achieved at the end of this 35-year planning period. It is expected by the conclusion of the 35-year implementation period prescribed in this WBP that water quality standards in Lake St. Louis will be attained. Actual determination of attainment will be completed by the department through biennial reporting requirements established by sections 303(d) and 305(b) of the federal Clean Water Act. Expected load reductions are further discussed in Sections 7 and 8.

Table ES - 1. Pollutant loading and reduction goals for the Lake St. Louis watershed

Pollutant	Current loading causing impairment	Load reduction needed to meet water quality standards	Load reduced by BMPs every 5 years	Final loading at end of plan
TSS (tons/yr)	7,092	6,657	951	435
TN (lbs/yr)	256,373	135,335	19,333	121,038
TP (lbs/yr)	36,595	35,677	2,654	18,575

Notes:

- Five-year values serve as milestones for evaluating progress towards overall plan progress and load reduction achievement.to determine if implementation efforts need to be adjusted.
- Based on the plan's given implementation rate TP targets are projected to not be fully met at the end of the established planning period. Due to conservative assumptions and margins of safety incorporated into TMDL targets, along with additional point source reductions occurring separately from this plan, and unquantified phosphorus reductions tied to overall sediment reductions, it is expected that the load reductions achieved through the implementation of this 35-year plan will result in attainment of the Chl-a water quality criterion.

Element C: Proposed Management Measures

Types of BMPs, as well as the amount of area needing to be treated by those BMPs, to achieve the targeted load reductions specified in Element E were modeled using the U.S. Environmental Protection Agency's (EPA) Pollutant Load Estimate Tool (PLET). Table ES-2 presents summaries of suggested BMPs and implementation rates appropriate for each targeted land use (urban, row crop, pastureland).

For structural BMPs, the level of implementation shown in Table ES-2 should be repeated every 5 years throughout the 35-year planning period. Once installed and maintained, structural BMPs continue to provide pollutant reductions beyond the initial year of implementation. For this reason, to achieve this plan's targeted pollutant reduction the BMPs and acres treated in any previous 5-year period should be maintained. Although not included in the schedule provided in this plan, structural BMPs reaching end-of-life should be replaced as appropriate.

Four of the suggested BMPs, prescribed grazing, conservation tillage, cover crops, and contour farming, are management BMPs and must occur on an annual basis to achieve specified pollutant load reduction targets. The acres associated with these management BMPs are not additive to previous years' reductions. Although scheduled to be implemented annually throughout the 35-year period of this plan, and 5-year load reduction benchmarks are based on implementing these practices annually, to meet water quality standards in Lake St. Louis the load reductions achieved by the implementation of these practices and acreages just need to be met by the final year of this plan and then carried forward each year into the future. Even so, the 5-year benchmarks set a goal for maximizing pollutant reductions over the planning period. Management measures are further discussed in Section 8. In all cases, other BMPs not specifically identified in this plan may be considered and implemented provided those alternative BMPs address the sources and pollutants identified in this plan with consideration also given to overall planning objectives and targets.

Table ES - 2. Suggested BMPs and Area Served per Land Use Type

Pastureland BMPs	**Grass Buffer**	**Forest Buffer**	**Critical Area Planting**	**Heavy Use Protection**	**Streambank Stabilization w/fencing**	**Prescribed Grazing**	**Exclusion Fencing**
Five-year Implementation goal (acres)	14.25	14.25	14.25	7.25	7.25	400 managed annually	28.5
25-year Final Implementation goal (acres)	100	100	100	50	50	400 managed annually	200

Cropland BMPs	**Cover Crops**	**Conservation Tillage**	**Grass Buffer**	**Forest Buffer**	**Land Retirement**	**Contour Farming**
Five-year Implementation goal (acres)	300 planted annually	300 managed annually	7.25	3.5	3.5	300 managed annually
25-year Final Implementation goal (acres)	300 planted annually	300 managed annually	50	25	25	300 managed annually

Urban BMPs	**Urban Wetlands (restoration/design)**	**Extended Stormwater Retention**
Five-year Implementation goal (acres)	125	125
25-year Final Implementation goal (acres)	875	875

Notes:

- Structural BMPs provides annual load reductions during the lifetime of the BMP. Due to this compounding load reduction, acreages are pro-rated over the 35-year implementation period. BMPs implemented and acres treated in any 5-year period should be maintained (or reinstalled at end-of-life) in conjunction with new BMP implementation.
- Management BMPs (i.e., contour farming, conservation tillage, cover crops, and prescribed grazing) provide a single year of pollutant reduction and therefore require practices to be implemented over the given acreages annually.
- To maintain targeted pollutant loading at the end of the 35-year plan, final BMPs and acres treated should continue to be maintained on an annual basis, or equivalent load reductions provided by additional BMPs should be provided.
- For simplicity, acreages presented at 5-year intervals are rounded to the nearest quarter acre. Modeled reductions showing attainment of water quality standards are based on the final total acreages.

Element D: Technical, Financial, and Regulatory Assistance Needs

Technical resources and financial assistance can be sourced from a variety of local, state, federal agencies, non-profit organizations, or local interest groups (non-governmental organizations). Private businesses, companies, and organizations located within the watershed may also provide technical and financial support to improve local water quality conditions. Although the Peruque Creek Watershed Alliance will be the primary implementer of this plan, the alliance is not a legal entity capable of providing financial assistance directly. However, individual partners and entities of the alliance may provide such financial capabilities. Financial resources are further discussed in Sections 8 and 9, including tables listing common BMP cost (Table 15), five-year BMP implementation cost estimates (Table 16), technical, financial, and regulatory resources (Table 17).

Element E: Information and Education

The Peruque Creek Watershed Alliance is a local watershed group made up of local municipal partners, private businesses, local stream team volunteers, home owner associations, citizens living in the watershed, and others. This group has and will continue to initiate and provide support of this WBP, as well as strive to provide implementation consistent with the goals of this plan. During the development of this WBP, this grassroots organization has already begun outreach activities, providing public planning, and informational meetings to bring awareness to water quality issues in the Lake St. Louis watershed. It is expected that such efforts will continue as the WBP is implemented. Additionally, the department's 319 Nonpoint Source Unit will continue to provide additional technical support and, through a Watershed Coordinator, engage other potential partners in the watershed with the goal of implementing this plan. Outreach efforts will encourage public participation in the planning and implementation process. Education efforts will serve to inform the public of the function and purpose of this WBP, the expected outcomes, and future planning through an adaptive implementation process. Examples of possible outreach and education activities include watershed and lake tours, volunteer water quality sampling, water quality education events, and public meetings. Future events will be scheduled throughout the implementation schedule and be integrated into future watershed implementation activities. Specific education and outreach efforts anticipated to be implemented during the period of this plan are outlined in Section 10.

Elements F and G: Implementation Schedule, Measurable Milestones, and Project Outcomes

This WBP includes a 35-year implementation schedule using a recommended suite of BMPs to achieve the targeted pollutant loading targets that will make progress towards the restoration of water quality in Lake St. Louis (Table ES-3). Implementation of practices in areas draining to Peruque Creek are expected to address aquatic life use impairments in that stream as well, although specific pollutant reduction targets have not been developed at this time.

Acreages treated by BMPs are presented at a five-year interval to coincide with the WBP evaluation and milestone review period. Modeled load reduction estimates are generated annually, not accounting for compounding reductions for the extended life of structural BMPs (i.e., buffers or flow control structures). To account for these compounding reductions, structural BMPs implementation rates are pro-rated over the 35-year period. Management BMPs (i.e., cover crops or grazing rotation) require annual implementation at the suggested acres. Based on modeled outputs, continued implementation of these management BMPs on the same fields and acreages annually will be consistent with the goals of the plan.

As WBPs are written to be adaptive, alternative BMPs or combinations of BMPs may be implemented provided they address the pollutants and sources consistent with this plan, as well as give consideration to overall pollutant reduction targets and goals. Feedback from local stakeholders, property owners, or watershed groups should be considered in establishing alternative BMPs. Milestones and implementation schedules will be reviewed and updated as needed at five-year intervals. Initial evaluation results will help decide if future implementation rates need adjusting to achieve load reduction and water quality goals. Evaluation criteria are further discussed below in Element H: Evaluation Criteria (Table ES-4). The implementation schedule is further discussed in Section 11, and milestones are further discussed in Section 12.

Table ES-3. BMP Implementation Schedule and Acres Served by Land Use Type

Pastureland BMPs	Grass Buffer	Forest Buffer	Critical Area Planting	Heavy Use Protection	Stream bank Stabilization w/fencing	Prescribed Grazing	Exclusion Fencing
Years 1 - 5	14.25	14.25	14.25	7.25	7.25	400 managed annually	28.5
Years 6 - 10	+14.25	+14.25	+14.25	+7.25	+7.25		+28.5
Years 11 - 15	+14.25	+14.25	+14.25	+7.25	+7.25		+28.5
Years 15 - 20	+14.25	+14.25	+14.25	+7.25	+7.25		+28.5
Years 21 - 25	+14.25	+14.25	+14.25	+7.25	+7.25		+28.5
Years 26 - 30	+14.25	+14.25	+14.25	+7.25	+7.25		+28.5
Years 31 - 35	+14.25	+14.25	+14.25	+7.25	+7.25		+28.5
35-years Final Implementation (acres)	100	100	100	50	50	400	200

Cropland BMPs	Cover Crops	Conservation Tillage	Grass Buffer	Forest Buffer	Land Retirement	Contour Farming
Years 1 - 5	300	300	7.25	3.5	3.5	300

Years 6 - 10	planted annually	managed annually	+7.25	+3.5	+3.5	managed annually
Years 11 - 15			+7.25	+3.5	+3.5	
Years 16 - 20			+7.25	+3.5	+3.5	
Years 21 - 25			+7.25	+3.5	+3.5	
Years 26 - 30			+7.25	+3.5	+3.5	
Years 31 - 35			+7.25	+3.5	+3.5	
35-years Final Implementation (acres)	300	300	50	25	25	300

Urban BMPs	**Urban Wetlands (restoration/design)**	**Extended Stormwater Retention**
Years 1 - 5	125	125
Years 6 - 10	+125	+125
Years 11 – 15	+125	+125
Years 16 – 20	+125	+125
Years 21 – 25	+125	+125
Years 26 - 30	+125	+125
Years 31 - 35	+125	+125
35-years Final Implementation (acres)	875	875

Notes:

- For simplicity, acreages are rounded to the nearest quarter acre
- Structural BMPs provides annual load reductions during the lifetime of the BMP. Due to this compounding load reduction, acreages are pro-rated over the 35-year implementation period. BMPs implemented and acres treated in any 5-year period should be maintained (or reinstalled at end-of-life) in conjunction with new BMP implementation.
- Management BMPs (i.e., contour farming, conservation tillage, cover crops, and prescribed grazing) provide a single year of pollutant reduction and therefore require practices to be implemented over the given acreages annually.
- To maintain targeted pollutant loading at the end of the 35-year plan, final BMPs and acres treated should continue to be maintained on an annual basis, or equivalent load reductions provided by additional BMPs should be provided.

Element H: Evaluation Criteria

BMPs have been identified that will reduce TP, TN, and TSS to Lake St. Louis and Peruque Creek. To assess the performance of the BMPs, and overall progress implementing this WBP, lake and stream concentrations of TSS, TP, and TN, as well as Chl-a in Lake St. Louis should be periodically measured. As implementation occurs pollutant load reductions are expected, and water quality data can show progress towards targeted milestones. Using this information, decisions can be made about any needs for changes to BMP selection or schedules for implementation.

Missouri's Water Quality Standards regulations provide nutrient screening thresholds for TN (843 ug/L) and TP (49 ug/L) that serve as the overall water quality targets for Lake St. Louis as measured at the dam. Nutrient load reductions from the watershed to the lake are based on these values and serve as the primary criteria to evaluate whether implementation is making progress

towards water quality attainment. To reduce nutrient loading via sediment particle transport, TSS reductions are also targeted in this WBP. An ecoregional TSS target of 18 mg/L serves as the numeric water quality target for which sediment load reductions are based. Because this target is based on the lower quartile of ecoregional data, it is a conservative estimate reflective of minimally impacted conditions. Achieving 18 mg/L of TSS in Peruque Creek is expected to also be consistent with concentrations necessary for achieving water quality standards in that water body as well.

Implementation of BMPs following the schedule presented in Element F and G will result in incremental progress towards meeting these water quality goals. For this reason, water quality values are provided in Table ES-4 to measure progress. Estimates of both the expected pollutant loading and associated pollutant concentrations are provided for each 5-year milestone period. Measuring water quality samples and comparing them to the target concentrations presented in Table ES-4 will provide an indication that the expected loading is being achieved. Evaluation criteria are further discussed in Section 12.

Table ES-4. Lake St. Louis Evaluation Criteria at 5-year Milestones

Pollutant	Loading Target	Target (year 5)	Target (year 10)	Target (year 15)	Target (year 20)	Target (year 25)	Target (Year 30)	Target (Year 35)
TSS (tons/yr)	435	6,141	5,190	4,239	3,288	2,337	1,386	≤ 435
TN (lbs/yr)	121,038	237,040	217,707	198,374	179,041	159,708	140,375	≤ 121,038
TP (lbs/yr)	918	33,941	31,287	28,633	25,979	23,325	20,671	18,575
Pollutant	**Water Quality Target[1]**	**Target (year 5)**	**Target (year 10)**	**Target (year15)**	**Target (year 20)**	**Target (year 25)**	**Target (Year 30)**	**Target (Year 35)**
TSS (mg/L)	18	120.43	101.78	83.13	64.48	45.83	27.18	≤ 18.00
TN (mg/L)	0.84	2.32	2.13	1.95	1.76	1.57	1.38	≤ 0.84
TP (mg/L)	0.049	0.33	0.31	0.28	0.25	0.23	0.20	0.18

Notes:

- Nutrient targets are based on the concentrations necessary to achieve Missouri's lake nutrient criterion of 18 mg/L of Chl-a in the Plains Ecoregion. TSS target is based on the 25th percentile of all available TSS sampling data in the same ecoregion where Lake St. Louis is located. Target concentrations were calculated from pollutant loading estimates using a weighted annual mean flow rate for the watershed.
- Because models are based on annual averages, concentration targets are based on median flow conditions in Peruque Creek calculated from daily mean flows used during TMDL development (51.8 cubic feet per second). These estimated concentrations provide a means for evaluating BMPs and overall implementation progress. Determination of actual water quality attainment will be completed by the department through its biennial water quality assessment and reporting consistent with sections 305(b) and 303(d) of the Clean Water Act.

Element I: Monitoring

Periodic monitoring of water quality in the Lake St. Louis watershed provides data for comparison to values presented in Element H to evaluate implementation progress and BMP effectiveness. This information will be useful for assessing evaluation and adjusting, if necessary, implementation timelines, and BMP adoption. Water quality data collected separately from the

purposes of this plan may also be used to evaluate and inform implementation activities. Any monitoring completed by the department would typically occur within reasonable timeframe following approval of TMDLs, completion of facility upgrades and permit compliance schedules, as well as implementation of watershed BMPs. Determination of water quality attainment will be completed by the department and may include evaluation of quality assured data collected by universities, municipalities, private companies, and volunteer groups implementing this plan.

Although not typically quality assured for assessment purposes, certain volunteer data can be useful for estimating BMP effectiveness and general progress towards meeting implementation goals. This screening level data may also be used to identify when more comprehensive quality assured data may be needed. Monitoring is further discussed in Section 13.

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1. Introduction

Lake St. Louis, which is an impoundment of Peruque Creek, is impaired for exceedances of Missouri's lake numeric nutrient criteria in the Plains Ecoregion. Portions of Peruque Creek are also impacted by excess nutrients and are impaired by low dissolved oxygen (DO) conditions, low aquatic macroinvertebrate diversity, and habitat indices scoring.

To restore water quality in Lake St. Louis and improve water quality in Peruque Creek, existing pollutant loading to these water bodies exceeds levels established by Missouri water quality standards and must be reduced. Through a watershed approach, establishing pollutant load reduction targets for nutrients contributing to algae growth, such as total nitrogen (TN), total phosphorus (TP), will address exceedances of numeric nutrient criteria in Lake St. Louis. An additional total suspended solids (TSS) target is also included as sediment contributes plant nutrients, particularly phosphorus, and excess sedimentation may reduce habitat for aquatic life. The use of TSS as a surrogate for sediment, is to make use of the best existing available data and is a parameter commonly measured. TSS includes both organic and inorganic solids. It is the inorganic portion of TSS that contributes to in-stream sedimentation and habitat concerns. Inorganic sediment originates from overland runoff, stream bank, and landscape erosion.

Although this plan is specifically intended to address pollutant loading from nonpoint sources, in order to derive pollutant load reduction targets that will achieve water quality standards, all potential loading sources in the watershed are considered. Water quality standards are the basis for establishing targets for load reductions, while water body and watershed models are used to identify required load reductions to meet those targets. Implementation of pollutant reductions from point sources will be carried out by the Missouri Department of Natural Resources (department) through the Missouri State Operating Permit Program. Missouri state operating permits ensure discharges from point sources are limited to conditions that meet water quality standards and do not contribute to water quality impairments. Achieving point source loading targets in conjunction with nonpoint source loading targets will result in attainment of Missouri Water Quality Standards.

The U.S. Environmental Protection Agency (EPA) has established guidelines for watershed-based plans to be implemented using Clean Water Act section 319 grant funds. Such plans should include EPA's "nine minimum elements." The following are EPA's "nine minimum elements" required for a successful watershed-based plan:

A. Identification of the causes or sources of the targeted pollutant in the watershed (Watershed Description, Defining the Problem, Source Inventory and Assessment);
B. Quantification of existing loads and reductions necessary to meet water quality targets and applicable water quality standards (Applicable Water Quality Standards, Source Inventory and Assessment, Establishing Watershed Loading Capacity);
C. Identification of planned nonpoint source management practices to reduce pollutant loading (Established Watershed Loading Capacity, Load Allocations and Reductions, Best Management Practices);
D. Measures to implement technical and financial resources watershed planning and management practice installation (Technical and Financial Assistance);
E. Measures to provide educational and public outreach opportunities during the watershed plan development and implementation (Education and Outreach);

F. A clearly defined implementation schedule with expected initiation and completion dates (Implementation Schedule);
G. Identification of milestones for the implementation of the watershed plan (Milestones);
H. Establish evaluation methods to determine the load reduction effectiveness (Evaluation of Load Reductions);
I. Measures to establish future watershed monitoring to determine best management practice effectiveness and if water quality conditions are improving (Monitoring).

These elements will serve as a foundation for the Lake St. Louis watershed-based plan, with the goal of producing sufficient load reductions within the watershed to restore water quality. Previous watershed management planning initiated in 2005 (CDM, 2005) provided insight for the development of the nine elements established in this plan, any short comings or missing requirements of previous planning efforts are addressed in this document.

In Missouri, watershed-based plans (WBP) are expected to be reviewed and revised as necessary every five years. This WBP incorporates the best data and information available at the time of this writing to inform watershed planning. New data and information that become available in the future will be considered and incorporated as appropriate during WBP review periods. This adaptive approach will inform future implementation actions based on the effectiveness of the actions taken to restore water quality in the watershed.

In addition to this WBP, the department is researching and developing total maximum daily loads (TMDLs) for the impaired waters to meet the requirements of Section 303(d) of the Clean Water Act. Modeling completed as part of TMDL development was used for providing water quality and pollutant load reduction targets in this WBP. Should adjustments be made to final TMDL, then future updates to this WBP will be completed to ensure consistency with the approved TMDL targets.

2. Watershed Description

Lake St. Louis, water body identification number (WBID) 7054, and the lake's primary tributary Peruque Creek WBIDs 217 and 218 are located in central eastern Missouri, approximately 2 miles south of Wentzville. Located within the Peruque-Piasa sub-basin, the lake and stream are cataloged by the U.S. Geological Survey (USGS) within the 8-digit hydrologic unit code (HUC) 07110009. Within the Peruque-Piasa sub-basin, the lake is located within the Headwaters Peruque Creek subwatershed, which is cataloged by the USGS as the 12-digit HUC 071100090101.

Lake St. Louis is formed by an impoundment of Peruque Creek. Low DO conditions and low aquatic macroinvertebrate diversity have been documented on a 10.9 mile segment of Peruque Creek (WBID 218). The impaired segment runs eastward from just south of Archer Road to just east of Highway Z, with the drainage area for the impaired segment being approximately 38 square miles. Peruque Creek flows east from Warren County to St. Charles County, through the municipalities of Foristell, Wentzville, and Lake Saint Louis.

The surface area of Lake St. Louis is 444 acres and has a contributing watershed area of approximately 57 square miles. The watershed includes the drainage (watershed) areas

contributing to both WBID 217 and 218 of Peruque Creek. The Lake St. Louis watershed is a mix of primarily agricultural and developed land uses, with rapidly increasing urbanization. The lake itself is located within the boundaries of the Lake Saint Louis municipality and is managed by a private homeowner's lake association. The Lake St. Louis watershed is displayed in Figure 1.

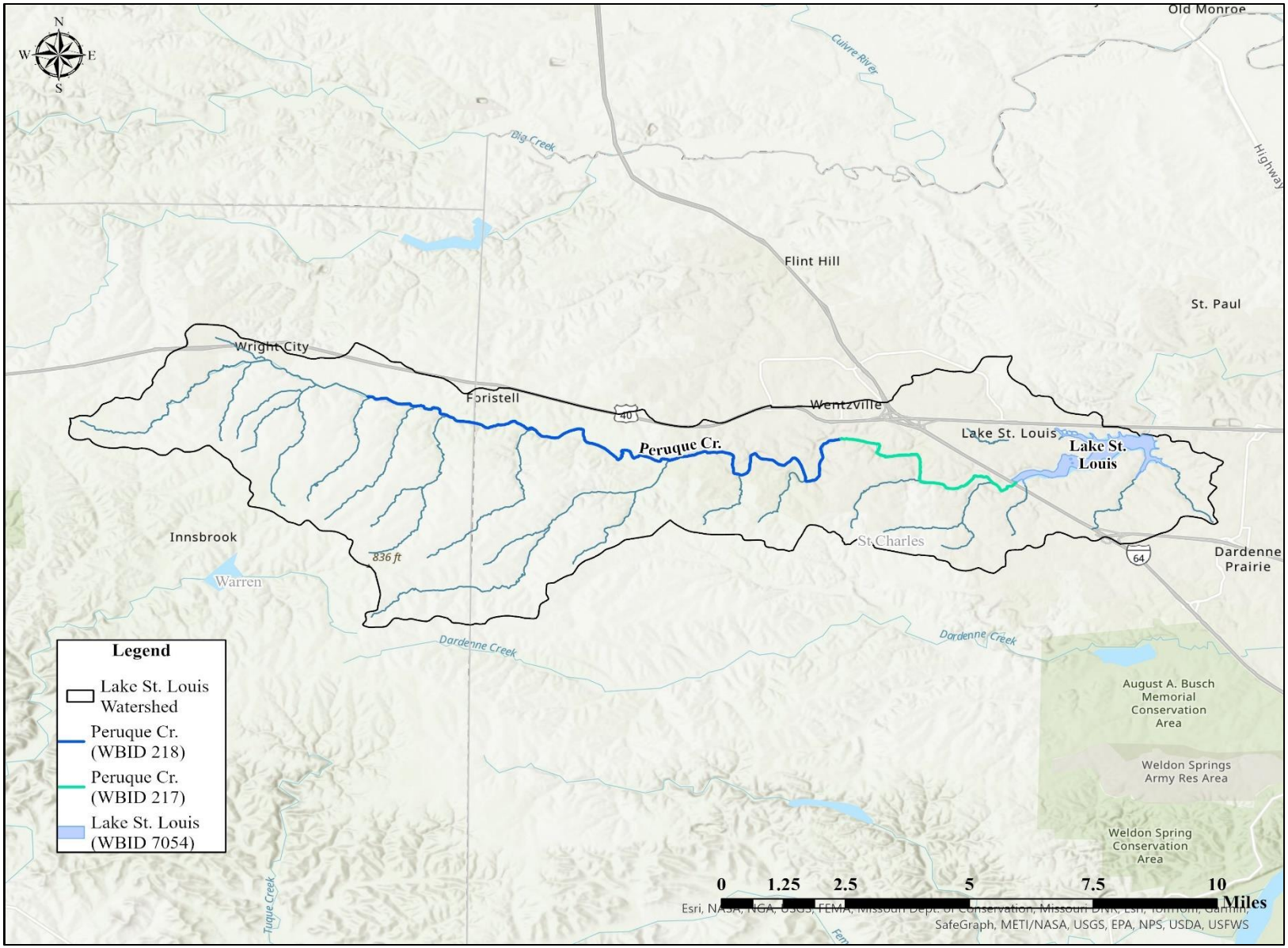

Figure 1. View of the Lake St. Louis and Peruque Creek watershed

2.1 Geology, Physiography, and Soils

The Lake St. Louis watershed is located within the southern portion of the Central Plain's Cuivre/Salt ecological drainage unit (EDU), which covers portions of central and northeastern Missouri (MoRAP 2005). Ecological drainage units are groups of watersheds that have similar biota, geography, and climate characteristics (USGS 2009). Within the Cuivre/Salt EDU, the watershed is in the River Hills EPA Level IV ecoregion. Ecoregions are areas with similar ecosystems and environmental resources and are designed to serve as a spatial framework for the research, assessment, management, and monitoring of ecosystems and ecosystem components. By recognizing spatial differences in ecosystems, ecoregions stratify the environment by its probable response to disturbance (Bryce et al. 1999). Ecoregions are further defined in Missouri's Water Quality Standards regulations at 10 CSR 20-7.031(1)(H).

Topography in the River Hills area within the Interior River Valley and Hills ecoregion varies from flat to moderately hilly. This region is located along the Missouri and Mississippi Rivers, which represents the transition zone between the northern loess and till covered plains and southern dissected forested slopes of the Ozark Highlands. Ridges and valleys in this ecoregion can have thick mantles of soil, while slopes can be steep at times with rock outcroppings present (Chapman et al. 2002).

Soils in the watershed are varied and can be categorized into hydrologic soil groups based on similar runoff potentials. Each hydrologic soil group indicates the rate at which water enters the soil profile under conditions of a bare, thoroughly wetted soil surface (NRCS 2009). This infiltration rate determines the amount of precipitation that flows over land to water bodies as direct runoff. These hydrologic soil groups serve as an indicator of where runoff carrying pollutants may come from.

Hydrologic Soil Groups are categorized from A to D. Hydrologic Soil Group A soils have the highest rate of infiltration and the lowest runoff potential. Therefore, these areas are less likely to contribute sediment and nutrients through runoff. Group D soils have the lowest rate of infiltration and highest runoff potential. For these reasons, these areas are more likely to contribute sediment and nutrients through runoff. Many wet soils fall into dual soil groups (e.g., Group C/D) due to the presence of a seasonal high-water table that results in saturation to the soil surface. Dual hydrologic soil groups account for this condition by providing both the drained and undrained condition of the soil.[2]

It should be noted that soil runoff potential is only one factor that contributes to the amount of runoff in a watershed. Impervious surfaces, vegetative cover, slope, rainfall intensity, and land use can also significantly influence the potential for runoff regardless of the underlying soil. Additionally, in some areas of the watershed, sediment and nutrient inputs may occur as a result of streambank erosion and not necessarily due to overland runoff.

Table 1 provides a summary of the hydrologic soil groups in watershed. Figure 2 is a map showing the distribution of these groups. Due to urbanization, soils in a significant portion of the watershed have not been rated. Where soils have been rated there is a high percentage of Group

[2] For the purpose of hydrologic soil group, adequately drained means that the seasonal high water table is kept at least 24 inches (60 centimeters) below the surface in a soil where it would be higher in a natural state (NRCS 2009).

D soils where runoff is likely. These areas may be a major contributor of sediment and nutrients to Peruque Creek and eventually to Lake St. Louis.

Table 1. Hydrologic soil groups in the watershed (NRCS 2020)

Hydrologic Soil Groups	Area in the Watershed	
	Square miles	Percent
Group B	2.36	4.14%
Group B/D	1.87	3.28%
Group C	7.06	12.39%
Group C/D	0.95	1.66%
Group D	35.51	62.30%
Not Rated	9.25	16.23%
Total	57.00	100.00%

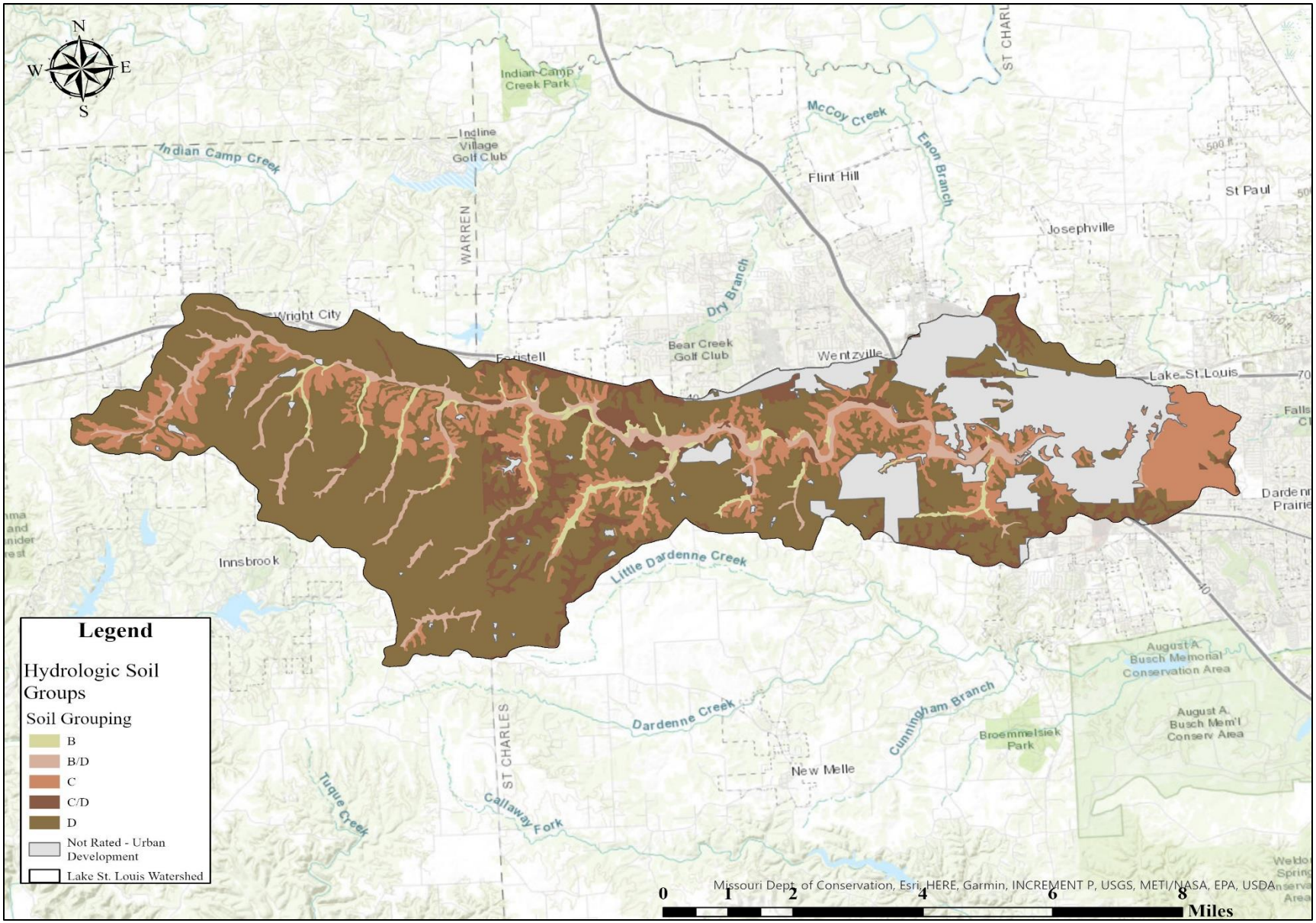

Figure 2. Hydrologic soil groups in the Lake St. Louis and Peruque Creek watershed

2.2 Climate

The most recent climate data from a weather station nearest to the Lake St. Louis watershed were measured at the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information (NCEI) Weldon Springs Weather Station (USC00238805). Climate normals were developed based on temperature and precipitation data collected at that station between 1991 and 2020 (NOAA-NCEI 2020). Table 2 displays the 30-year monthly climate normals from the Weldon Springs Weather Station for precipitation and temperature. Figure 3 is a graphical display of the data. Between 2001 and 2020, annual precipitation at the Weldon Springs weather station ranged from a minimum 34.9 inches to a maximum 62.8 inches. Periods of significant rainfall may contribute more nutrients and sediment through stormwater runoff. This information may inform management measures taken to implement this plan.

Table 2. 30-year monthly climate normals at the Weldon Springs weather station

Month	Precipitation Average	Minimum Temperature	Maximum Temperature
	inches	ºF	ºF
January	2.61	21.2	39.3
February	2.43	24.4	44.8
March	3.74	33.3	55.2
April	4.70	43.8	67.0
May	5.09	54.2	75.7
June	4.72	63.3	83.7
July	3.92	67.3	87.5
August	3.58	65.4	86.7
September	3.50	57.0	79.8
October	3.37	45.6	68.3
November	3.69	34.9	55.4
December	3.07	25.9	44.0
	Total	**Average**	**Average**
	44.42	44.7	65.6

Although precipitation amounts have been found to correlate with erosion rates at the local level (Mishra et al. 2019), rainfall intensity is more indicative of soil erosion potential than the quantity of precipitation alone. Rainfall intensity is the amount of rain that falls over time. Compared with moderate rainfall, heavy rainfall and storm rainfall are more likely to cause erosion (Meng et al. 2021). High rainfall intensity occurs when a large amount of rain falls in a short time. Climate warming models predict increases in the intensity of rainfall, especially convective rainfall, which produces short and local heavy rainfall (Martel et al. 2021).

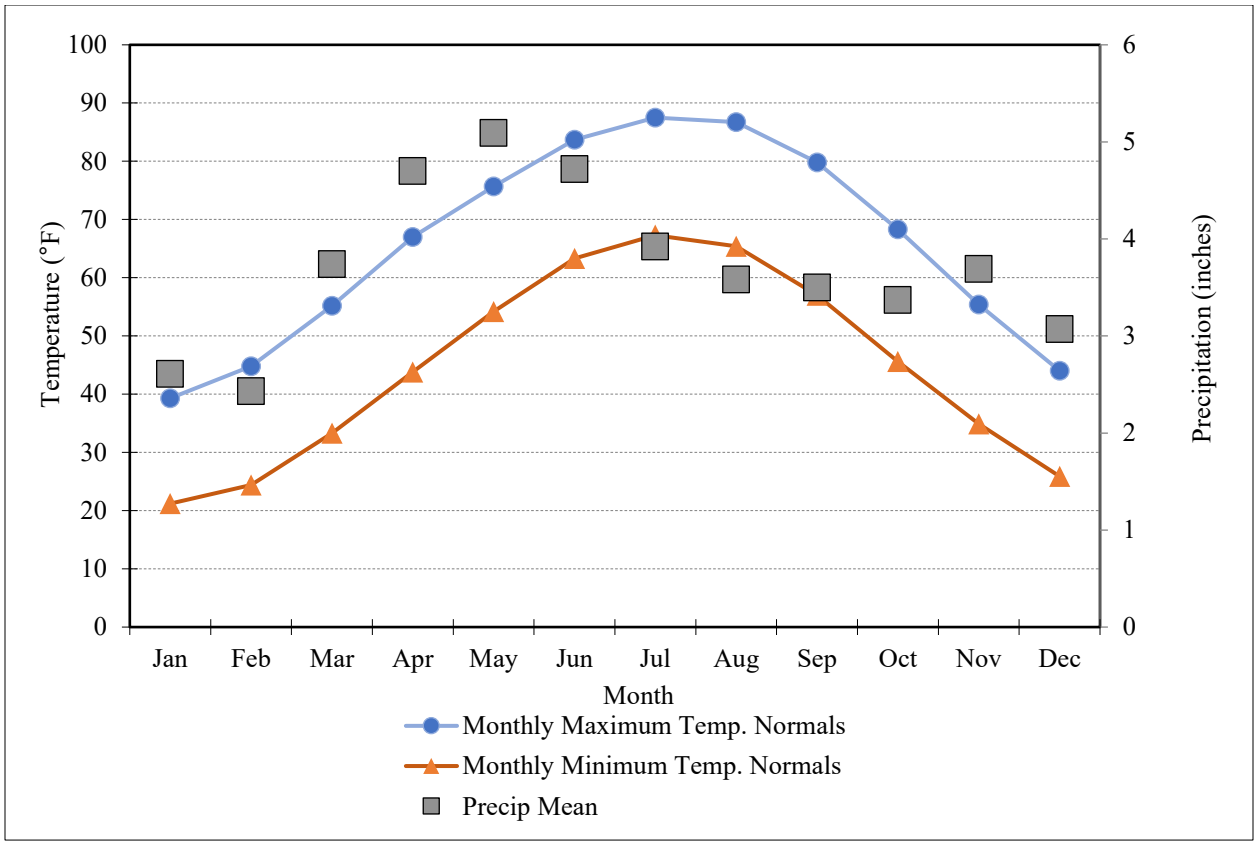

Figure 3. Monthly climate normals – Weldon Springs, MO

2.3 Population

State and county population estimates are available from the U.S. Census Bureau's 2020 census and can be localized using census block data (U.S. Census Bureau 2020). Population estimates for the watershed were derived using geographic information system (GIS) software by overlaying the watershed boundary over a map of census blocks. Wherever the centroid of a census block falls within the watershed boundary, the entire population of the census block is included in the total. If the centroid of the census block is outside the boundary, the population of the entire block is excluded.

As shown in Table 3, the watershed experienced substantial population growth between 2000 and 2020, primarily within urban areas with slight decreases occurring for the rural population. This general shift from rural to urban population is likely associated with observed urban expansion and increases in impervious surfaces. Such expansion is expected to continue throughout the period of this plan. The population distribution in the watershed is displayed on Figure 4.

Table 3. Population estimates for the Lake St. Louis and Peruque Creek watershed

Municipal			Rural			Total		
2000	2010	2020	2000	2010	2020	2000	2010	2020
17,423	34,993	41,790	4,439	5,530	2,826	21,862	40,523	44,616

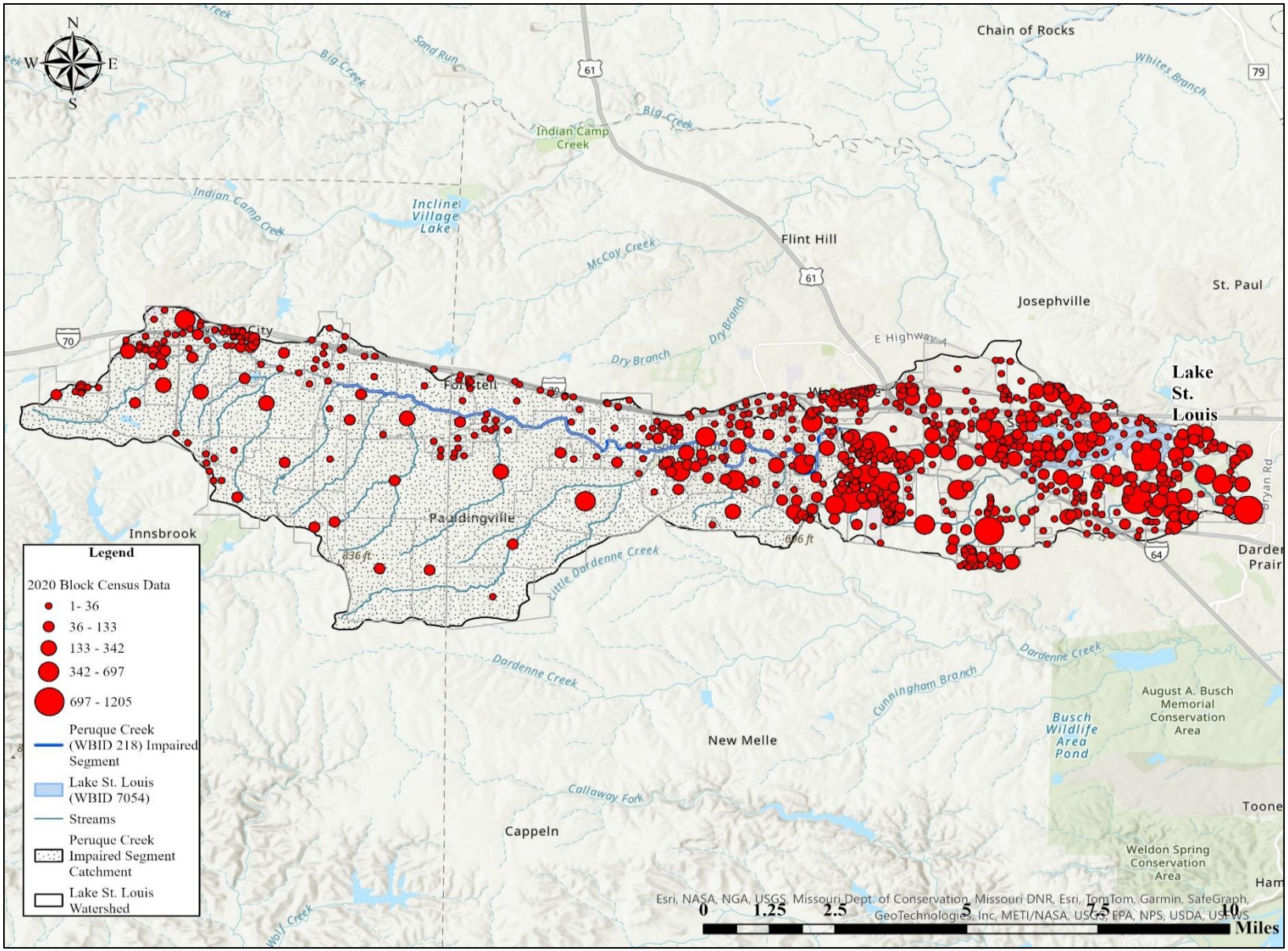

Figure 4. 2020 census block and population in the Lake St. Louis and Peruque Creek watershed

2.4 Land Use

A land use analysis was completed using the 2019 National Land Cover Database (NLCD) published by the Multi-Resolution Land Characteristics Consortium (MRLC 2022). Land use types in the Lake St. Louis watershed are summarized in Table 4 and displayed on Figure 5. Areas used for agricultural purposes, such as pasture and cropland, together account for more than 37% of the watershed, primarily in the upper watershed draining to the impaired segment of Peruque Creek. Developed areas where impervious surfaces are common account for 30% of the watershed and are primarily located in the lower watershed adjacent to Lake St. Louis, but are rapidly expanding to the upper watershed. The amount of imperviousness associated with development in the watershed is substantial. Stream degradation associated with imperviousness has been shown to first occur at about 10% imperviousness and will increase in severity as imperviousness increases (Arnold & Gibbons 1996; Schueler 1994). Runoff from both developed and agricultural areas are expected to be the primary source of nonpoint source pollution contributing to the impairments of Lake St. Louis and Peruque Creek.

Table 4. Land use in the watershed

Land Use Type	Area Square miles	Percent
Developed, High Intensity	1.53	2.70%
Developed, Medium Intensity	5.57	9.80%
Developed, Low Intensity	6.18	10.90%
Developed, Open Space	4.17	7.40%
Cultivated Crops	10.47	18.50%
Barren Land	0.08	0.10%
Hay/Pasture	10.81	19.20%
Forest	16.09	28.40%
Wetlands	0.33	0.60%
Shrub and Herbaceous	0.14	0.20%
Open Water	1.23	2.20%
Total	56.60	100.00%

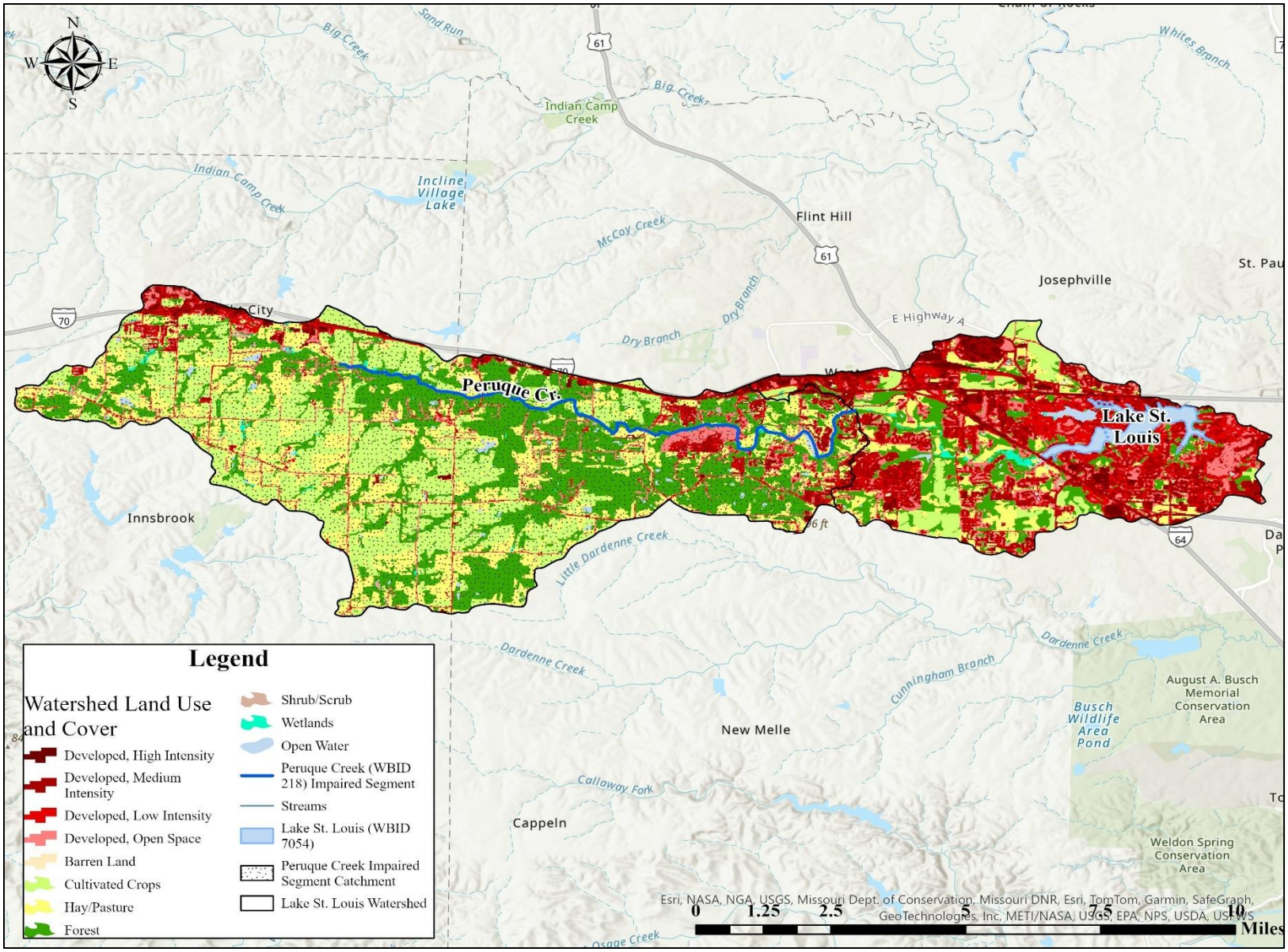

Figure 5. Land use in the Lake St. Louis and Peruque Creek watershed

3. Applicable Water Quality Standards

For water quality restoration, it is critical to identify the maximum pollutant load a water body can take in and still meet and maintain water quality standards. Under the federal Clean Water Act, every state must adopt water quality standards to protect, maintain, and improve the quality of the nation's surface waters (U.S. Code Title 33, Chapter 26, Subchapter III). Water quality standards include designated uses that specify the water quality goals of a particular water body and water quality criteria that establish specific conditions that protect those uses.

3.1 Designated Uses

Missouri's Water Quality Standards at 10 CSR 20-7.031(1)(F) define designated uses that are assigned to individual water bodies in accordance with 10 CSR 20-7.031(2) and are listed in 10 CSR 20-7.031, Table G (Lakes) and Table H (Streams). Missouri's Water Quality Standards designate the following uses to Lake St. Louis and Peruque Creek:

- Warm water habitat (aquatic life)
- Human health protection
- Whole body contact recreation category A (Lake St. Louis)
- Whole body contact recreation category B (Peruque Creek)
- Secondary contact recreation
- Irrigation
- Livestock and wildlife protection

The warm water habitat (aquatic life) designated use of Lake St. Louis is impaired due to frequent exceedances of Missouri's lake nutrient criteria. Excess nutrients and sedimentation contribute to these conditions. Low DO conditions and low macroinvertebrate diversity are causes for the impairment of warm water habitat (aquatic life) designated use in Peruque Creek WBID 218. These conditions also result from excess sediment and nutrient loading.

3.2 Water Quality Criteria

Water quality criteria represent a level of water quality that supports and protects particular designated uses. Water quality criteria can be expressed as specific numeric criteria or as general narrative statements. Missouri 10 CSR 20-7.031(4) and (5) establish General Criteria applicable to all waters of the state at all times and Specific Criteria applicable to waters contained in 10 CSR 20-7.031 Tables G (Lakes) and H (Streams). Available data and field observations note water quality violations of general criteria associated with sediment loading, as well as specific criteria violations associated with stream DO and lake nutrient criteria as described below.

Missouri's Water Quality Standards include statewide numeric nutrient criteria for lakes that are waters of the state and have an area of at least 10 acres during normal pool condition (10 CSR 20-7.031(5)(N)1.C(II)2.). Due to differences in watershed topography, soils, and geology, applicable nutrient criteria for lakes and reservoirs is determined by which ecoregion the lake's watershed is primarily located within (10 CSR 20-7.031(5)(N)1.B.). Missouri's criteria use Chl-a as a proxy for algal biomass, which responds to nutrient inputs, particularly TN and TP. Increased nutrient inputs from various sources such as agricultural runoff, wastewater, and fertilizers can stimulate algae growth and lead to higher Chl-a concentrations. For this reason,

Missouri's nutrient criteria for lakes include Nutrient Screening Thresholds for TN, TP, and Chl-a, and a Chl-a Response Impairment Threshold (10 CSR 20-7.031 Tables L and M).

All TP, TN, and Chl-a concentrations must be calculated as the geometric mean of a minimum of four representative samples per year for one year for purposes of comparison to lake ecoregion criteria thresholds. All samples must be collected from the lake surface, near the outflow of the lake, and during the period May 1 - September 30 (10 CSR 20-7.031(5)(N)4.). Lakes with water quality that exceed Response Impairment Thresholds are deemed impaired for excess nutrients (10 CSR 20-7.031(5)(N)5.). Lakes are also deemed impaired for excess nutrients if Nutrient Screening Thresholds are exceeded and any of the Response Assessment Endpoints are documented in the same year (10 CSR 20-7.031(5)(N)6.). The Response Assessment Endpoints are:

A. Occurrence of eutrophication-related mortality or morbidity events for fish and other aquatic organisms;
B. Epilimnetic excursions from DO or pH criteria;
C. Cyanobacteria counts in excess of 100,000 cells per milliliter (cells/mL);
D. Observed shifts in aquatic diversity attributed to eutrophication; and
E. Excessive levels of mineral turbidity that consistently limit algal productivity during the period of May 1 - September 30.

Lake St. Louis is located in the Plains lake ecoregion and are subject to the criteria displayed in Table 5. Pollutant loading targets and pollutant reduction targets presented in this WBP are based on achieving these criteria in Lake St. Louis.

Table 5. Plains lake ecoregional nutrient criteria

Chl-a Response Impairment Threshold (µg/L)	Nutrient Screening Thresholds (µg/L)		
	TP	TN	Chl-a
30	49	843	18

Additional water quality impairments in the watershed include Peruque Creek WBID 218. The stream's impairment is associated with violations of Missouri's minimum DO criterion for warm water habitat, and low macroinvertebrate diversity. Low DO can result for a variety of physical and chemical reasons but is often associated with excess nutrients. Excess nutrients contribute to plant and algae growth that, although produce oxygen during the day, can use more oxygen at night or can die-off and cause sudden oxygen loss due to microbial decay. Loss of habitat can contribute to low macroinvertebrate diversity, which can be caused, in part, by excess sedimentation. Excess sediment also can contribute nutrients that bind to the soil particles. For warm water habitats, Table A1 of 10 CSR 20-7.031 specifies a minimum criterion of 5.0 mg/L of DO. Excessive sediment deposition that results in bottom deposits that harm aquatic life, or otherwise prevent the full maintenance of designated uses, are violations of Missouri's general criteria specified at 10 CSR 20-7.031(4)(A) and (C). As previously stated, excess sediments also transport nutrients that can contribute to increases of Chl-a and contribute to the impairment of Lake St. Louis.

4. **Defining the Problem**

Lake St. Louis WBID 7054 is identified as impaired on Missouri's approved 2022 List of Impaired Waters and was initially listed in 2020 due to exceedances of the Chl-a Response Impairment Threshold coupled with exceedances of the Nutrient Screening Thresholds for TN and TP during the period of May 1 - September 30. Summer geometric mean lake data from 2016-2020 are displayed in Table 6. As shown, lake water samples exceeded the Plains ecoregion TP Screening Threshold of 49 micrograms per liter (µg/L) in all years, while also exhibiting elevated sediment and shallow Secchi depths in most years.

Nutrients, such as nitrogen and phosphorous, contribute to algae growth which is measured as Chl-a. High nutrient and Chl-a concentrations indicate excessive nutrient loading as the cause of impairment to the aquatic life designated use in Lake St. Louis. Primary management concerns in the Cuivre/Salt EDU include soil erosion, excessive sedimentation, excessive nutrient loads, and elevated water temperatures (MoRAP 2005). Soils associated with the Loess Flats and Till Plains area within the Central Irregular Plains ecoregion are inherently fertile, but use can be limited due to severe erosion when appropriate management practices are not in place (Chapman et al. 2002). Natural Resources Conservation Service (NRCS) data indicate soils in the Lake St. Louis watershed have predominately silt loam (NRCS 2022). Fine soils tend to stay suspended in water during and after runoff and erosion events. These factors can contribute to excessive mineral turbidity and sedimentation in Lake St. Louis.

Table 6. 2016-2020 Water quality at Lake St. Louis dam*

	Geometric Mean (µg/L)			Secchi Depth (m)	Mean TSS (mg/L)
May-September	**TP**	**TN**	**Chl-a**		
2017	*82.00*	*864.00*	*22.42*	0.61	*14.81*
2018	*73.00*	731.00	**31.37**	0.81	4.20
2019	*81.00*	*868.00*	**34.95**	0.66	6.06
2020	*78.00*	*874.00*	*27.82*	0.74	5.64
***Bold** values represent Response Impairment Threshold exceedances and *italicized* values represent Nutrient Screening Threshold exceedances.					

Generally, nitrogen not taken up by plants moves through watershed soils in nitrate form, potentially reaching storm sewers, ditches, grass waterways, or field tiling, then eventually streams and lakes. Excessive nitrogen loading can lead to increased primary production (i.e., algal growth), resulting in elevated Chl-a concentrations in the receiving water body. Resulting algal blooms from nitrogen loading can lead to elevated oxygen demands, ultimately leading to low DO conditions in the water body, which can adversely impact aquatic life. Freshwater algal blooms themselves can pose health concerns when harmful forms of algae or cyanobacteria are present, such as certain cyanobacteria (blue-green algae) which can create dangerous cyanotoxins (Microcystin, Cylindrospermopsin, Anatoxin-a, Saxitoxin). These toxins can be harmful to humans, livestock, and pets. It is important to note that not all cyanobacteria produce cyanotoxins, typically toxins are found when *Mirocystis* are the predominant cyanobacteria present in a harmful algal bloom.

Excessive sediment loading adversely impacts aquatic life and fisheries, source water for drinking supplies, and recreational uses (USEPA 1999). The Lake St. Louis watershed suffers from sedimentation contributing to excessive mineral turbidity, and watercolor concerns. Fine sediment particles often transport other pollutants such as nutrients. Reducing sediment erosion and overland runoff can improve aquatic habitat, improve water clarity (reduced turbidity), and reduce overall nutrient loading to the lake.

Peruque Creek WBID 218 is on the 2022 Missouri 303(d) list of impaired waters for "Aquatic Macroinvertebrate Bioassessments" and general criteria violations, which are attributed to nonpoint sources of pollution. Past impairment concerns also pointed to "fish bioassessments" as a cause for concern, due to data showing less diversity than fish communities in similar sized streams (MoDNR 2015). The upper Peruque Creek is in a progressively urbanizing watershed. This urbanization can make the stream susceptible to land and hydrologic disturbance that results in in-stream sedimentation, which adversely affects aquatic macroinvertebrate habitat substrate (Li & Wang 2009). Such rapid develop removes vegetation and disturbs soils contributing to erosion from runoff. Destabilization of streambanks may also occur. Erosion from existing agricultural areas in the watershed also contribute sediment. Excess sedimentation can smother or reduce fish spawning areas that may contribute to lower community diversity. Additionally, sediment contributes increased nutrient loads that can lead to low DO issues by contributing to excess algae growth.

5. Source Inventory and Assessment (Element A)

The following source inventory and assessment identifies and characterizes known, suspected, and potential sources of nutrients (TN and TP) and sediment loading to Lake St. Louis. Specific sources are identified and quantified to the extent that information is available. Although general sources identified in this plan are not expected to change, individual sources within the broader defined categories may be identified throughout the implementation of this plan on a case-by-case basis and addressed with consideration given to the expected potential pollutant load reductions contributing to the impairment and the overall restoration and load reduction goals established in this plan. Sources identified in this plan are consistent with those identified in the draft TMDL for Lake St. Louis.

5.1 Point Sources

Point sources are defined by Section 644.016(16) of the Missouri Clean Water Law and are regulated pursuant to the Clean Water Act's National Pollutant Discharge Elimination System through the Missouri State Operating Permit program.[3] A point source is defined as "any discernible, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. Point source does not include agricultural storm water discharges and return flows from irrigated agriculture." Based on this definition, point sources include domestic wastewater treatment facilities, industrial and commercial facilities, concentrated animal feeding operations

[3] The Missouri State Operating Permit program is Missouri's program for administering the federal National Pollutant Discharge Elimination System (NPDES). Generally, the Clean Water Act requires all point sources that discharge pollutants to waters of the United States to obtain an NPDES permit. Issued and proposed operating permits are available online at dnr.mo.gov/water/business-industry-other-entities/permits-certification-engineering-fees/wastewater.

(CAFOs), municipal separate storm sewer systems (MS4s), and certain stormwater discharges from industrial areas and construction sites. Illicit straight pipe discharges are also point sources but are illegal. Pollutant loading from point sources is typically most evident during low-flow conditions when stormwater influences are lower or nonexistent. Compliance with specified permit limits and conditions will result in loading that does not violate water quality standards or contribute to water quality impairments. Permit limits are required by federal regulations to be consistent with available wasteload allocations established by an approved TMDL.

Land disturbance and construction activities occurring in the watershed may serve as potential source of sediment loading. Land disturbance activities include clearing, grubbing, excavating, grading, filling and other activities that result in the destruction of the root zone or land disturbance activity that is reasonably certain to cause pollution to waters of the state. Land disturbance permits are required for construction disturbance activities of one or more acres or construction activities that disturb less than one acre when part of a larger common plan of development or sale that will disturb a cumulative total of one or more acres over the life of the project. However, those areas that are not required to be permitted are considered nonpoint sources.

Permit conditions often establish BMP requirements to address water quality impacts and may require the development of a Storm Water Pollution Prevention Plan (SWPPP). When permit conditions are met and maintained these sites should not contribute significant TSS loading. Additionally, these sites can have long term pollution controls integrated into the new construction activities and planning. Unpermitted land disturbance and construction activities greater than one acre may be considered unlawful and should be reported to the Missouri Department of Natural Resources St. Louis Regional Office at 314-416-2960 or 800-361-4827. Figure 6 displays active land disturbance permits in the Lake St. Louis watershed as of November 2024.

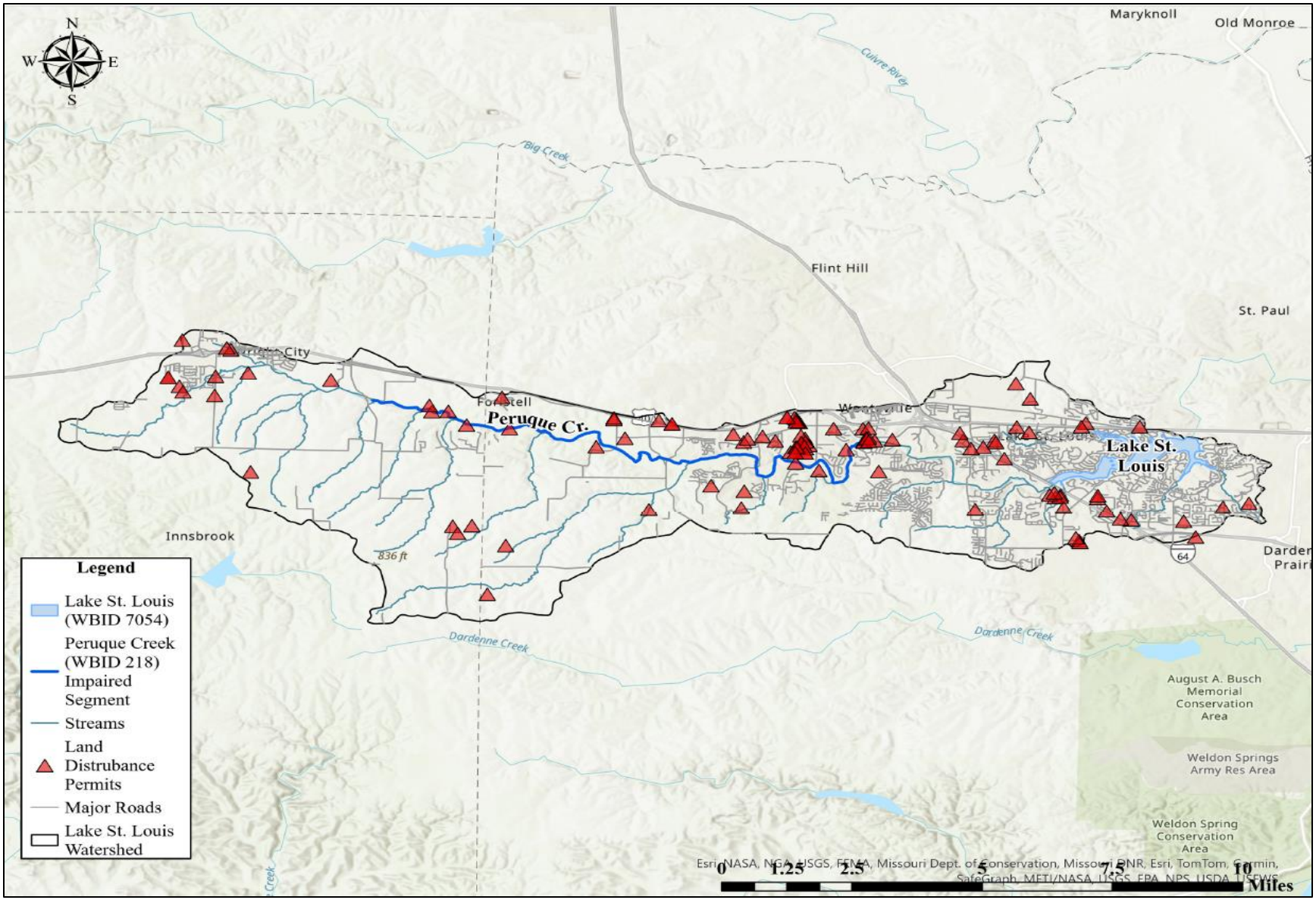

Figure 6. Land disturbance permits located across the Lake St. Louis and Peruque Creek Watershed

Illicit straight pipe discharges of domestic wastewater are potential sources of nutrients and sediment. These types of sewage discharges bypass treatment systems, such as septic tanks or sanitary sewers, and discharge directly to a stream or an adjacent land area (Brown & Pitt 2004). Illicit straight pipe discharges are illegal and are not authorized by the federal Clean Water Act or the Missouri Clean Water Law. At present, there are no data about the presence or number of illicit straight pipe discharges in the Lake St. Louis watershed. For this reason, it is unknown if any straight pipe discharges exist and, if they do, to what significance they contribute to surface water impairments in the watershed. Due to the illegal nature of these discharges, any illicit straight pipe discharges must be eliminated. Communities having a regulated MS4 are required to address illicit straight pipe discharges as a condition of their permit.

5.2 Nonpoint Sources

Nonpoint sources are diffuse sources with no discernible, confined, or discrete conveyance, and include all categories of pollutant discharge that do not meet the definition of a point source. Nonpoint sources are not regulated by the federal Clean Water Act and are exempt from department permit requirements by state regulation at 10 CSR 20-6.010(1)(B)1. Nonpoint source pollutants are typically transported by stormwater runoff, which is minor or negligible during dry weather conditions. Nonpoint sources in the Lake St. Louis watershed primarily include runoff from agricultural lands, urban areas, and areas of new construction associated with increased urban development. Table 7 summarizes estimated pollutant loading by major land use types in the Lake St. Louis watershed.

Table 7. Estimated pollutant loading by major land use categories in the watershed[4]

Land Use	TN Load (lb/year)	TP Load (lb/year)	Sediment Load (ton/year)
Urban	83,665	12,966	1,923
Cropland	53,526	10,797	3,228
Pastureland	60,596	6,234	1,703
Forest	48,856	4,467	239

In addition to major land use types, other nonpoint sources are also present in the watershed. Onsite wastewater treatment (septic) systems can contribute nutrients when not operating correctly or properly maintained and are present within the watershed. Atmospheric deposition of nitrogen and phosphorus can also contribute to nutrient loading in lakes and may be a component of stormwater runoff. Internal loading of phosphorus already within Lake St. Louis from past phosphorus deposition can also contribute to Chl-a exceedances. And streams with little to no riparian buffer are most susceptible to erosion, including stream bank erosion, and are potential contributors of nonpoint source pollution.

5.2.1 Agricultural Lands

Croplands, pasturelands, and low-density animal feeding operations that do not meet the definition of being CAFOs are potential nonpoint sources of nutrients and sediment in the watershed. Nutrients can be transported in runoff from areas where fertilizers or animal manure

[4] Loading estimates based on land use do not account for all nonpoint source loading in the watershed, such as loading from septic tanks. As a result, these values might be slightly lower than the overall loading estimates.

are applied, and areas where livestock are present. Runoff can result from precipitation or irrigation. Soil and Water Conservation Districts located in each county provide funding and guidance for the development of nutrient management plans for private lands. Areas where nutrient management plans guide fertilizer and manure applications, and where BMPs are used to reduce soil erosion, contribute less nutrients to surface waters than unmanaged areas. Although grazing areas are typically well vegetated, livestock tend to congregate near feeding and watering areas, which can create barren areas that are susceptible to erosion (Sutton 1990). Additionally, livestock that are not excluded from streams will deposit manure, and thus nutrients, directly into the waterway. Riparian areas where livestock are not excluded, may also disturb stream banks, cause soil compaction, and thereby contribute to sediment erosion.

Areas of hay and pasture, which can be used for livestock grazing, are common in the watershed. Although the exact type and number of livestock present in the watershed are unknown, livestock numbers can be estimated using EPA's Pollutant Load Estimation Tool (PLET). Estimates of livestock population from PLET are based on the U.S. Department of Agriculture's 2012 Census of Agriculture (Tetra Tech & USEPA 2024). Livestock data from PLET within the watershed is outlined in Table 8.

Table 8. Estimation of livestock in the Watershed

Cattle	Swine	Sheep	Horse	Chicken	Turkey	Duck
1055	3270	38	98	248	8	3

5.2.2 Urban Development and Watershed Land Use Changes

Land use in the Lake St. Louis watershed has changed over time and continues to change as development increases in the watershed. Impervious surfaces increase as a result of development, resulting in greater runoff intensities, volumes, and increased sedimentation. Table 9 provides a summary of land use changes in the Lake St. Louis watershed from 2011 to 2019. The greatest changes in land use were observed in forest and medium intensity developed areas, with medium intensity development increasing by 1,439 acres (3.97% increase) and forest decreasing by approximately 1,055 acres (2.78% decrease). It is also worth noting the decrease in wetland acreage, which decreased by approximately 368 acres between 2011 and 2019 (0.44% decrease). Wetlands can provide sediment and nutrient load reductions among other ecosystem services.

Table 9. 2011 to 2019 Summary of Land use change in the Watershed

LAND COVER	Acreage Increase or Decrease	Percentage of Watershed 2011	Percentage of Watershed 2019	Percent increase or decrease
Barren Land	34.94	0.05%	0.15%	0.10%
Developed, High Intensity	413.61	1.57%	2.71%	1.14%
Developed, Low Intensity	-288.73	11.69%	10.89%	-0.80%
Developed, Medium Intensity	1,439.35	5.87%	9.84%	3.97%
Developed, Open Space	-499.27	8.74%	7.37%	-1.38%
Forest	-1,005.42	31.21%	28.44%	-2.78%
Cultivated Crops	96.29	18.23%	18.49%	0.27%
Hay/Pasture	36.00	18.17%	18.27%	0.10%

Shrub/Scrub	-98.09	1.36%	1.09%	-0.27%
Wetlands	-157.87	1.02%	0.58%	-0.44%
Open Water	29.19	2.09%	2.17%	0.08%

5.2.3 Onsite Wastewater Treatment Systems

Onsite wastewater treatment systems treat and disperse domestic wastewater on the property where it is generated. When properly designed and maintained, these systems perform well and should not contribute substantial amounts of nutrients to surface waters. However, when these systems fail hydraulically (surface breakouts) or hydrogeologically (inadequate soil filtration) there can be adverse effects to surface water quality (Horsley & Witten 1996). The Missouri Department of Health and Senior Services or local administrative authorities (commonly the local health department) have jurisdiction over onsite wastewater treatment systems with a design or actual flow of 3,000 gallons per day or less. Municipalities or counties may impose more stringent or additional requirements than those required by the state. The Missouri Department of Health and Senior Services estimates that approximately 25% of homes in Missouri utilize onsite wastewater treatment systems, particularly in rural areas where public sewer systems are not available (DHSS 2018). Failing onsite wastewater treatment systems can contribute nutrients to nearby streams under wet or dry weather conditions directly or through surface runoff and groundwater flows.

The exact number of onsite wastewater treatment systems in the watershed is unknown. EPA's online input data server for the PLET provides estimates of septic system numbers by 12-digit HUC watersheds based on 1992 and 1998 data from the National Environmental Service Center (USEPA 2014b).[5] The PLET input server estimates that there may be approximately 1,758 septic systems in the watershed. Over time as urbanization expands and availability of sewer system connections become available, the total number of septic systems is expected to decrease. However, areas experiencing rapid development may see a period of increased installation of onsite systems until sewer system expansion occurs.

Septic systems can fail due to age and poor maintenance. A study by the Electric Power Research Institute (EPRI 2000) estimates septic system failure rates are 30-50% statewide. Newer septic systems are less likely to fail in the short term, but proper maintenance should be completed for successful long-term operation. In general, the greater the distance an onsite system is located from a surface water, the less likely it is to cause contamination (MU Extension 2023).

5.2.4 Atmospheric Deposition

Sources of atmospheric phosphorus include dust from soils, ash from volcanos, combustion of oil and coal, and emissions from phosphate manufacturing (Tipping et al. 2014). Data on phosphorus deposition from the atmosphere are limited compared to that of nitrogen. Based on 2017 data used for Missouri's Nutrient Loss Reduction Strategy Baselines Report (MoDNR 2023), atmospheric phosphorus may account for 1.4% to 14.2% of annual phosphorus loading into Lake St. Louis.

[5] The National Environmental Services Center is located at West Virginia University and maintains a clearinghouse for information related to, among other things, onsite wastewater treatment systems. Available URL: www.nesc.wvu.edu/

Wet deposition (via precipitation) of atmospheric inorganic nitrogen (ammonium (NH_4^+), nitrite (NO_2^-), and nitrate (NO_3^-) is a substantial source of nitrogen. Volatilization of fertilizer and manure may account for over 60% of total emissions. Other sources of nitrogen include coal-fired power plants, fertilizer manufacturers, and vehicle emissions. Particulate nitrogen can remain in the air for 7-10 days, enabling it to move a good distance from the area of origin (Le Roy et al. 2021). Data on nitrogen deposition from the atmosphere into Lake St. Louis was obtained from the University of Wisconsin's National Atmospheric Deposition Program for Missouri Site 43 (MO043) (University of Wisconsin 2023). Based on that data, atmospheric nitrogen may account for approximately 30% of annual loading into the Lake St. Louis watershed in any given year.

5.2.5 Internal Loading

Phosphorus is widely considered the primary contributor to potentially harmful cyanobacteria blooms in lakes (Schindler 1977). Internal loading of phosphorus occurs when phosphorus bound to lake sediment is released into the lake water. The unbinding of phosphorus from sediment occurs when lakes are stratified due to substantially different temperatures in the deep water and at the surface. Missouri lakes typically stratify in the summer. During stratification a thermal barrier (thermocline) forms isolating deep water and preventing oxygen replenishment from the atmosphere. When DO is low, the chemical bonds between phosphorus and metal particles in the sediment, such as iron, aluminum, and manganese, weaken and dissolved phosphorus is released into the lake water. Upon release, the phosphorus is sequestered below the thermocline where there is minimal light available. Once the surface and deep-water temperatures equalize, the lake mixes vertically and the phosphorus is available at the water surface where sufficient light enables growth of algae and cyanobacteria.

Limited available profile data collected from Lake St. Louis during summer months presents the thermocline at approximately 3.5-4.0 meters deep, below which, oxygen concentrations steadily declined from approximately 6 mg/L to <0.10 mg/L over the remaining 1.5-2.0 meters (Jones 2023). Natural mitigation of internal phosphorus loading can be achieved by reducing sediment loading from the watershed. Once sediment loading from the watershed is reduced, over time, phosphorus dissolved out of lake sediment may wash out of the lake. Removal of sediments from the lake through dredging can also help reduce overall phosphorus loads in the lake. However, without the addition of overall sediment loading contributions from the watershed, any benefits obtained through dredging will be temporary.

5.2.6 Riparian Corridor Conditions

Riparian corridor conditions have a strong influence on instream water quality. Wooded riparian buffers are a vital functional component of stream ecosystems and are instrumental in the attenuation of pollutants in runoff. Land cover within 100 feet of streams in the Lake St. Louis watershed is presented in Table 10. Agricultural areas (hay or pasture land) constitute 1.86% of the riparian corridors of streams in the watershed. These areas may be susceptible to soil compaction and erosion from livestock if not prevented from accessing waterways. Phosphorus loading is highest from agricultural areas (Allafta et al. 2020). Streambanks and floodplains that lack woody vegetation are the most susceptible to erosion and allow nitrogen, phosphorus, and sediment to enter streams with very minimal interception. Establishing woody or vegetated

riparian corridors in areas most susceptible to erosion will reduce the amount of sediment and phosphorus transported to Peruque Creek and Lake St. Louis. Impervious surfaces, such as roads and pavement, prevent the infiltration of stormwater and can contribute to pollutant loading in riparian areas where development is common. Even residential lawns that are frequently mowed or less permeable than natural native grasses and can contribute nutrients directly to water ways from pet wastes or fertilizers.

Table 10. Land use in riparian corridors in the watershed

Land Use Type	Area of Riparian Corridor Land Use	
	Acres	Percent
Developed (Roads and Residences)	77.35	54.11%
Barren Land	0.29	0.20%
Hay or Pasture	2.66	1.86%
Forest	20.7	14.48%
Open Water	41.94	29.34%
Total:	142.94	100.00%

6. Establishing Watershed Water Quality Targets

The amount of a pollutant a water body can take in without exceeding an applicable water quality criterion is called the loading capacity. Calculating a water body's loading capacity (LC) is important for identifying water quality restoration targets. The LC is derived from the numeric water quality criterion for each pollutant or an appropriate surrogate when no numeric criterion is applicable. Calculation of the LC is a requirement of a TMDL and was completed by the department during development of a draft TMDL for Lake St. Louis. The calculated LCs for the pollutants of concern provide the overall water quality restoration targets for this WBP. Once the TMDL is formally established and approved by EPA, this plan should be reviewed and updated if necessary to ensure consistency with the final TMDL document.

Through the TMDL development process, the department assigns a portion of the loading capacity to point sources as a wasteload allocation (WLA) and to nonpoint sources as a load allocation (LA). A reserve capacity (RC) is also calculated and is a portion of the total loading capacity that is held for future growth and loading in the watershed. Wasteload allocations and load allocations serve as pollutant loading targets for the watershed and will result in water quality standards being met when achieved.

Once the pollutant allocations are allotted the amount of pollutant reductions can be determined. Point source contributors will be assigned permit limits targeting the pollutant of concern to ensure compliance with water quality standards. Nonpoint source load reductions are dependent on voluntary watershed management actions, including the action specified in this plan. The equation for calculating the load capacity is as follows:

$$LC = \sum WLA + \sum LA + MOS + RC$$

A margin of safety (MOS) is included in the department's modeling and calculations to account for uncertainties in scientific and technical understanding of water quality in natural systems. A

MOS is a requirement for TMDLs. Practices established in this watershed plan will target the nonpoint source loading contributions assigned to the load allocation. Established load allocations will be referenced to quantify numeric load reduction targets. These reductions will be accomplished through the implementation of BMPs, watershed planning actions, and educational outreach opportunities. Dredging activities may provide temporary load reductions by addressing internal loading, consistent with the goals of this plan. However, BMPs addressing overland runoff, or in some cases streambank stabilization, will provide long lasting water quality improvement.

7. Load Reductions (Element B)

By referencing Plains Ecoregion Lake Criteria screening threshold values TN and TP reductions were developed by using a combined watershed (SWAT) and lake (BATHTUB) modeling approach. These models were calibrated to long-term annual mean watershed data, data from Lake St. Louis, and other already existing calibrated model data (Jones & Knowlton 1993). The resulting reductions will be integrated into BMP design throughout the implementation of the plan. To address sediment, TSS loading targets were developed using an ecoregional concentration of 18 mg/L TSS and flow values generated from watershed and lake models. The TSS target set for Lake St. Louis is based on the 25th percentile of all USGS data collected within the same ecoregion as Peruque Creek and Lake St. Louis. The 25th percentile, in this case 18 mg/L, means that 25% of the data is lower or equal to this value and 75% of the data is higher. For this reason, use of the 25th percentile provides a conservative target that best represents reference conditions for which aquatic life are not expected to be negatively impacted. Appendix C contains supplemental plan data and Table C 1 provides site information for the ecoregional TSS data complied to develop the reduction target.

With the Lake St. Louis watershed flow regime established (SWAT model) and target TN, TP, and TSS concentrations identified, allowable loading that achieves water quality standards can be calculated. From that information the necessary load reductions are determined. Table 11 presents estimates of current pollutant loading from the watershed that is causing the impairment in Lake St. Louis, the amount of load reduction needed to restore the lake, the estimated load reduction expected after 5 years of BMP implementation, and the final load reduction achieved at the end of this 35-year planning period. It is expected by the conclusion of the 35-year implementation schedule presented in Section 11 of this WBP that water quality in Lake St. Louis will be restored to conditions that meet Missouri water quality standards.

Table 11. Pollutant loading and reduction goals for the Lake St. Louis watershed

Pollutant	Current loading causing impairment	Load reduction needed to meet water quality standards	Load reduced by BMPs every 5 years	Final loading at end of plan
TSS (tons/yr)	7,092	6,657	951	435
TN (lbs/yr)	256,373	135,335	19,333	121,038
TP (lbs/yr)	36,595	35,677	2,654	18,575

Notes:
- Five-year values serve as milestones for evaluating progress towards overall plan progress and load reduction achievement.to determine if implementation efforts need to be adjusted.
- Based on the plan's given implementation rate TP targets are projected to not be fully met at the end of the established planning period. Due to conservative assumptions and margins of safety incorporated into TMDL

targets, along with additional point source reductions occurring separately from this plan, and unquantified phosphorus reductions tied to overall sediment reductions, it is expected that the load reductions achieved through the implementation of this 35-year plan will result in attainment of the Chl-a water quality criterion.

8. Best Management Practices (Element C)

Measures to reduce sediment and nutrient loading from nonpoint sources are necessary to improve water quality conditions in Peruque Creek and restore water quality in Lake St. Louis. Conservation practices such as stream bank stabilization, flow control structures, and buffer strip management, which are commonly referred to as BMPs, can reduce pollutant loads to adjacent waterbodies and improve downstream water quality conditions. BMPs implemented in the Lake St. Louis watershed should address the nonpoint sources identified in Section 5 to reduce the pollutant loading by various land use types presented in Table 7. There are a variety of BMPs which can be implemented in agricultural, urban, and stream channel settings to address excessive sediment loss and control nutrient loading within a watershed. In Appendix C, Table C 2 provides a list of BMP categories recently evaluated by the United States Army Corps of Engineers (ACOE) and the EPA for performance and efficiency (ACOE & EPA, 2020). Several of the BMPs listed can be implemented in the Lake St. Louis watershed to reduce nonpoint source sediment and nutrient loading from a variety of sources. Specific BMPs to address the pollutant reduction goals of this WBP are presented below in Table 12. Selected BMPs to attain water quality targets are based on efficiency rates from PLET modeling presented in Appendix B. Although specific BMPs are prescribed in this plan to meet loading reduction goals, other BMPs can be considered and may be selected based upon mode of action, the pollutants addressed, and the overall pollutant load reduction goals specified in this plan. Additional BMPs acceptable for implementing this plan in urban and agricultural areas are available in Appendix 5 of the Missouri Nonpoint Source Management Plan.

Table 12. Suggested BMPs and Area Served per Land Use Type

Pastureland BMPs	Grass Buffer	Forest Buffer	Critical Area Planting	Heavy Use Protection	Streambank Stabilization w/fencing	Prescribed Grazing	Exclusion Fencing
Five-year Implementation goal (acres)	14.25	14.25	14.25	7.25	7.25	400 managed annually	28.5
25-year Final Implementation goal (acres)	100	100	100	50	50	400 managed annually	200

Cropland BMPs	Cover Crops	Conservation Tillage	Grass Buffer	Forest Buffer	Land Retirement	Contour Farming
Five-year Implementation goal (acres)	300 planted annually	300 managed annually	7.25	3.5	3.5	300 managed annually
25-year Final Implementation goal (acres)	300 planted annually	300 managed annually	50	25	25	300 managed annually

Urban BMPs	Urban Wetlands (restoration/design)	Extended Stormwater Retention
Five-year Implementation goal (acres)	125	125
25-year Final Implementation goal	875	875

(acres)		

Notes:

- Structural BMPs provides annual load reductions during the lifetime of the BMP. Due to this compounding load reduction, acreages are pro-rated over the 35-year implementation period. BMPs implemented and acres treated in any 5-year period should be maintained (or reinstalled at end-of-life) in conjunction with new BMP implementation.
- Management BMPs (i.e., contour farming, conservation tillage, cover crops, and prescribed grazing) provide a single year of pollutant reduction and therefore require practices to be implemented over the given acreages annually.
- To maintain targeted pollutant loading at the end of the 35-year plan, final BMPs and acres treated should continue to be maintained on an annual basis, or equivalent load reductions provided by additional BMPs should be provided.
- For simplicity, acreages presented at 5-year intervals are rounded to the nearest quarter acre. Modeled reductions showing attainment of water quality standards are based on the final total acreages.

While the suggested BMPs are effective at reducing nutrient and sediment loading entering Peruque Creek and Lake St. Louis, the placement of these practices at critical locations within the watershed will have the greatest load reduction potential and is prioritized in this plan. Focusing BMP implementation in priority locations will increase the return on investment of BMP costs and will provide the greatest opportunity to improve water quality (Naisargi & Mitteslet 2017).

For this WBP, a four-tier approach is applied based on contributing land use types and factors influencing pollutant loading from the sources in the watershed discussed in Section 5. These tiers, presented in Table 13 below, identify general to more critical areas for BMP implementation and provide a means of prioritizing implementation. Implementation in lower numbered tiers (i.e., 1 and 2) should be considered before implementing practices in higher-numbered tiers (i.e., 3 or 4). Additional discussion about these tiers follows the table. Locations of critical areas prioritized for implementation are found in the map in Figure 7 following the discussion. It should be noted that due to the rapid expansion of development in the watershed, areas currently identified for agricultural BMPs may instead require BMPs more commonly identified as urban BMPs. For this reason land use analysis during each 5-year review is recommended.

Table 13. Critical Areas and Prioritization for BMP Implementation

Priority	Tier	Qualifying Factors	Example BMP Actions
Lowest	4	Targeted watershed land use types for load reductions: Row crop, pasturelands, and urban development	Broad scale watershed BMP implementation such as cover crop planting and promotion, nutrient application management planning (urban and agriculture), stormwater controls (urban and agriculture), land retirement (conservation lands)
Lower	3	Target specific watershed land use activities - ***active*** row crop and pastureland areas, areas of ***increasing*** urban development. Areas of active land disturbance and locations which optimize watershed stormwater controls should be prioritized.	Field to edge-of-field BMPs should be utilized at this scale. Engineered grass waterways, terracing, and buffer strips are examples. Both urban and agricultural stormwater BMPs should target site to catchment size stormwater runoff flows, trying to retain the greatest amount of nutrients and sediment as possible. Watershed scale stormwater BMP examples include retention basins and ponds, engineered wetlands, and sediment retention

			measures (structural). Examples of site scale BMPs include bio-swales, planted grass-ways and buffers, and scaled stormwater retention controls.
Higher	2	***100-ft stream buffer*** areas which are classified as urban, row crop, pastureland or barren lands uses, targeting ***active*** use development	Targeted land use types within a 100-ft buffer of watershed streams with active or planned land disturbance are priority, BMPs should target controlling direct stormwater discharges to the waterways. Implementation actions can include engineered streambank stabilization if appropriate. Other relevant BMPs are buffer planting and restoration (hydraulic connectivity), wetland design and restoration, cattle exclusion and managed grazing, and engineered stormwater controls. Properly placed and engineered stormwater controls will typically provide the greatest nutrient and sediment load reductions.
Highest	1	***100-ft stream buffer*** areas classified as urban, row crop, pastureland or barren lands uses and have high run-off potential soils (e.g., Group D and C/D), targeting ***active*** land use development	With high runoff potential, and considering sources discussed, these areas should take top priority when initially planning BMP implementation. Restoring vegetation to maintain ground cover is critical to control overland flow. Restoring and maintaining buffer conditions will likely be initial actions at these locations, with stormwater controls and bank stabilization efforts to follow. Cattle exclusion and reducing, restricting, or eliminating land disturbance and development within a proposed buffer area would significantly improve buffer and stream conditions.

Source assessment analysis completed in Section 5 identified areas of development and agricultural land use types as being likely significant contributors of pollutants causing impairments in the Lake St. Louis watershed. For this reason, urban and agricultural land coverage types should be considered the most general tier of prioritization for implementation in the Lake St. Louis watershed (Tier 4). Specific areas of urban and agriculture having tributaries carrying pollutant loads into the impaired water bodies or that are immediately adjacent to the lake and contribute loading directly are identified in Figure 7 and represent the Tier 4 – General Priority area for implementation. All other tiers are confined to within this general priority area. To refine prioritization of implementation, active row crop or pastureland and developed urban (Tier 3) areas should be targeted for BMP implementation. Active agricultural areas are prevalent in the western portion of watershed and have tributaries flowing north to Peruque Creek, while the eastern portion of the watershed has significant urban development growth contributing loading to Lake St. Louis. The next tier to consider are stream corridors or the riparian zone (Tier 2). These areas should be targeted within the described criteria above, focusing on restoring these areas in agricultural and urban land uses. Reinforcing and stabilizing streambanks may be warranted in this area, This prevents direct loading of sediment and nutrients to watershed streams, which ultimately flow to the lake. Tier 1 priority areas were delineated within the buffer area using land use and hydrologic soil groups having the greatest potential for runoff (Groups D and C/D). Figure 7 also presents buffer areas which meet the previously described criteria, additional detailed figures are provided in Appendix A. Ground truthing, or stream surveys should be conducted to confirm streambank and riparian conditions prior to initiating BMP implementation.

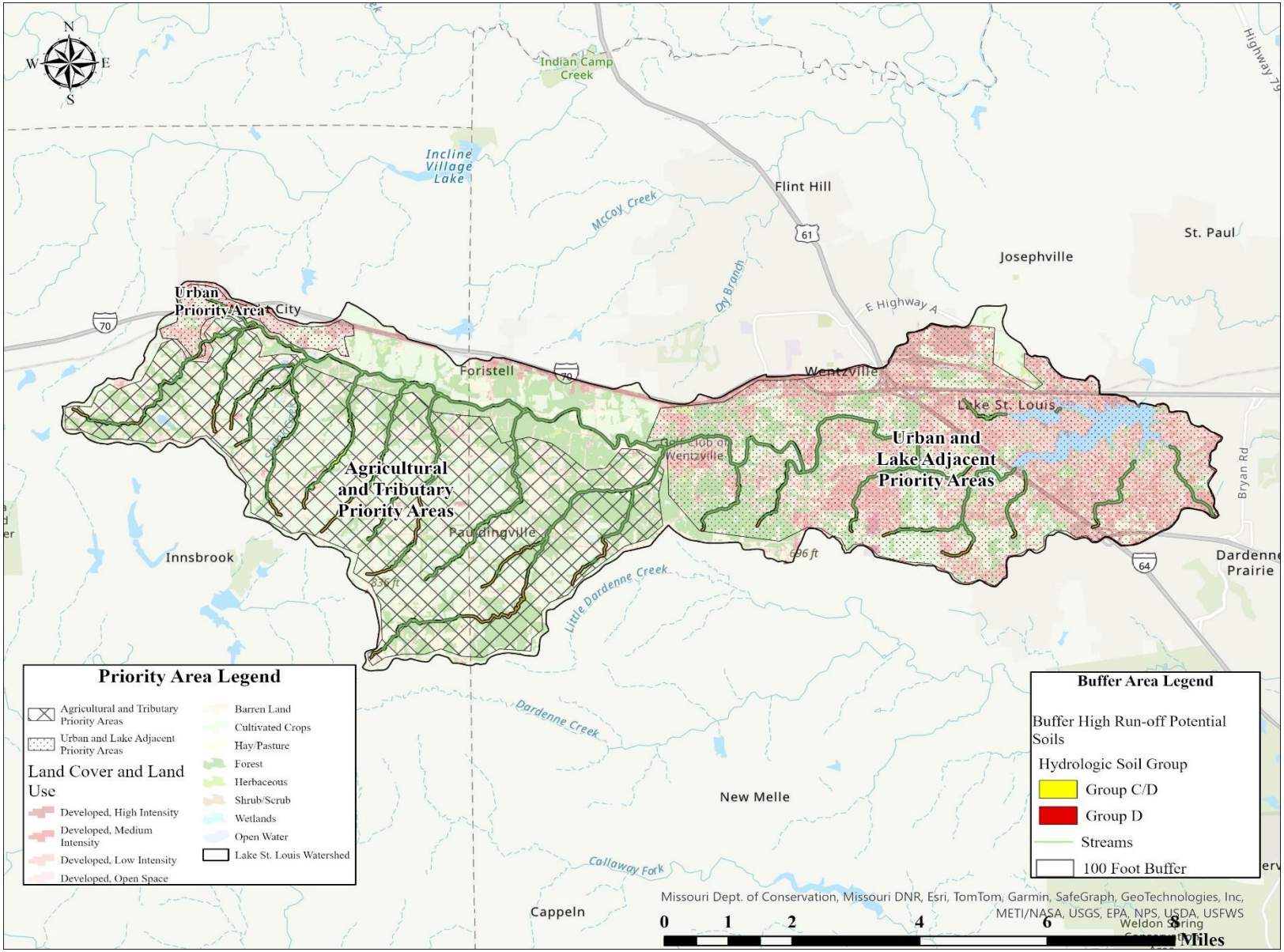

Figure 7. Critical areas for tiered-prioritization of BMP implementation.

9. Technical and Financial Assistance (Element D)

Implementation cost vary between BMP type, with cost generally increasing with the amount of acreage or liner feet the practice treats. While the design, construction, and maintenance cost of structural BMPs are project specific. Table 14 provides average cost per unit for example BMPs recently implemented in other Missouri watersheds. Table 15 presents projected BMP implementation cost estimates for this plan approximated by referencing the cost data in Table 14. A 2.4% inflation rate was applied to the costs for each 5-year planning period. Actual costs may be higher or lower depending upon actual yearly inflation rate variability. Although exact costs are unknown, it is expected that costs will generally increase over the period of this plan.

These cost estimates serve as reference for project planning purposes and reflect implementation necessary to achieve water quality standards in Lake St. Louis. Lake ecosystems are multifaceted and dynamic ecosystems, which poses challenges when developing load reductions rates and cost. As implementation occurs, costs estimates may need to be reevaluated. Annual BMP implementation cost will likely vary throughout the implementation of this WBP. Each project implemented will vary in size, scope, and ultimately cost, but should always aim for efficiency and maximum pollutant load reductions. Note cost associated with BMP implementation may have a one-time initial cost associated with installation and a prescribed lifetime, such as grass waterways, while other practices may have annual cost associated with implementation, such as cover crop applications.

Table 14. BMP Cost Estimates from Select Missouri HUC-8 Watersheds

BMP Type	Average Unit Cost	Unit
Access Control (Use Exclusion)	$567.51	$/acre
Cover Crop	$32.26	$/acre
Critical Area Planting	$1,624.26	$/acre
Diversion	$3.73	$/ft
Drainage Water Management	$445.67	$/acre
Fence	$46.90	$/acre
Field Border	$864.05	$/acre
Filter Strip	$5.68	$/cubic yard
Forage and biomass planting	$160.67	$/acre
Grade Stabilization Structure	$3.08	$/cubic yard
Grassed Waterway	$6,808.26	$/acre
Livestock Pipeline	$118.13	$/acre
Prescribed Grazing	$79.60	$/acre
Stream Exclusion Fencing	$3.70	$/ft
Streambank & Shoreline Protection	$63.76	$/ft
Terrace	$4.33	$/ft
Livestock Waste Storage Facility	$499.85	$/animal unit
Water & Sediment Control Basin	$5.74	$/cubic yard
Water Well	$86.31	$/acre
Well Decommissioning	$400.00	$/unit

Notes:
Average cost values are generated from project contract years 2018-2022 from the North Fabius (07110002), North Fork Salt (07110005), Upper Mississippi-Cape Girardeau (07140105), Spring (11070207), and Sac (10290106) HUC-8 watersheds.

Table 15. Estimated BMP Implementation Costs for Lake St. Louis Watershed

BMP Category	Annual Cost (years 0-5)	Annual Cost (years 5-10)	Annual Cost (years 10-15)	Annual Cost (years 15-20)	Annual Cost (year 20-25)	Totals
Grass Buffer	$17,281.00	$17,626.62	$17,979.15	$18,338.74	$18,705.51	$89,931.02
Forest Buffer	$17,281.00	$17,626.62	$17,979.15	$18,338.74	$18,705.51	$89,931.02
Cover Crops	$48,390.00	$49,357.80	$50,344.96	$51,351.86	$52,378.89	$251,823.50
Critical Area Planting	$32,485.20	$33,134.90	$33,797.60	$34,473.55	$35,163.03	$169,054.29
Stream Bank Stabilization	$133,896.00	$136,573.92	$139,305.40	$142,091.51	$144,933.34	$696,800.16
Exclusion Fencing, Heavy Use Exclusion,	$22,700.40	$23,154.41	$23,617.50	$24,089.85	$24.571.64	$118,133.79
Conservation Tillage, Contour Farming, Prescribed Grazing	$398,000.00	$405,960.00	$414,079.20	$422,360.78	$430,808.00	$2,071,207.98
Land Retirement	$25,000.00	$25,500.00	$26,010.00	$26,530.20	$27,060.80	$130,101.00
Designed Wetland and restoration	$1,750,000.00	$1,785,000.00	$1,820,700.00	$1,857,114.00	$1,894,256.28	$9,107,070.28
Extended Retention	$77,992.25	$79,552.10	$81,143.14	$82,766.00	$84,421.32	$405,874.80
Totals	$2,523,025.85	$2,573,486.37	$2,624,956.09	$2,677,455.22	$2,731,004.32	$13,129,927.85

Notes:
- Values after the initial 5-year implementation period incorporate a 2.4% inflation rate.
- Some cost estimates are based on similar practices or a combination of similar practices and may not reflect exact costs estimated in Table 15

Technical resources and financial assistance can be sourced from a variety of local, state, and federal agencies, non-for-profit agencies, or local interest groups (non-governmental organization). Private businesses, companies, and organizations located within the watershed may also have interest in providing technical and financial support to improve local water quality conditions. Although the Peruque Creek Watershed Alliance will be the primary implementer of this plan, the alliance is not a legal entity capable of providing financial assistance directly. However, individual partners and entities of the alliance may provide such financial capabilities.

Clean Water Act section 319 grants may be provided by Missouri Department of Natural Resources for eligible projects implementing this plan. Additional in-kind funding will be necessary to meet the application requirements of federal 319 grant funding, examples of in-kind

funding include monetary matches, material donations, and volunteer hours. Table 16 provides examples of agencies which can provide technical and financial assistance for implementation in the watershed. To inquire about eligibility and availability of Section 319 funding, please contact modnr.npsprogram@dnr.mo.gov.

Table 16. Agency Roles and Funding Options

Agency and Roles	Funding Options
US Department of Agriculture, Natural Resources Conservation Service https://www.nrcs.usda.gov/wps/portal/nrcs/site/mo/home/	
Financial assistance and incentives to implement voluntary BMPs	Environmental Quality Incentives Program (EQIP) Regional Conservation Partnership Program (RCPP) Conservation Stewardship Program (CSP) Agricultural Conservation Easement Program (ACEP)
US Department of Agriculture's Farm Service Agency (FSA) https://www.fsa.usda.gov/	
Administers a program called the Continuous Sign-up Conservation Reserve Program (CCRP) that provides farmers with rental payments on land set-aside for conservation buffers for a period of 10 to15 years. Cost-share payments are also made available to help farmers with the financial burden of establishing the buffers.	Continuous Sign-up Conservation Reserve Program (CCRP)
Missouri Department of Natural Resources https://dnr.mo.gov/	
Water Protection Program https://dnr.mo.gov/water/hows-water Implements federal Clean Water Act regulations including: enforcing National Pollutant Discharge Elimination System (NPDES) regulations through point source facility operating permits, establishing Water Quality Standards, identifying impaired water bodies, and developing TMDLs.	Free volunteer water quality monitoring training and tools

Agency and Roles	Funding Options
Financial Assistance Center dnr.mo.gov/water/business-industry-other-entities/financial-opportunities/financial-assistance-center Provides technical guidance for publicly owned treatment works and administers low-interest long-term loans to assist with technology and capacity upgrades. The Clean Water State Revolving Fund provides subsidized loans to municipalities, counties, public sewer districts, and political subdivisions for wastewater infrastructure projects. Loans may be paired with grant funds for qualifying communities. Eligible projects include new construction or improvement of existing facilities. Information on the department's grant policy is available online at dnr.mo.gov/water/business-industry-other-entities/financial-opportunities.	Clean Water State Revolving Fund
Soil and Water Conservation Program dnr.mo.gov/env/swcp/ The Soil and Water Conservation Program (SWCP) provides financial incentives to landowners to implement practices that help prevent soil erosion and protect water quality. The program offers cost-share practices through its county conservation districts. Landowners may receive up to 75% reimbursement of the estimated cost of a practice through the program. The primary funding for cost-share practices from the Soil and Water Conservation Program comes from the one-tenth-of-one percent Parks, Soils, and Water Sales Tax.	SWCP cost-share
Section 319 Nonpoint Source Program dnr.mo.gov/water/what-were-doing/nonpoint-source-pollution-section-319 ▪ Provides assistance with the development of watershed-based plans and administers Section 319 subgrants for plan development and implementation.	Section 319 subgrants
Missouri Department of Conservation mdc.mo.gov/community-conservation/community-conservation-funding-opportunities/.	
Offers a number of grant and cost-share options including Community Conservation Grant and Land Conservation Partnership Grant. Provides outreach, education, and technical guidance for stream and watershed management issues. Maintains Missouri Conservation lands.	Community Conservation Grant and Land Conservation Partnership Grant Free volunteer water quality monitoring training and tools

Agency and Roles	Funding Options
Missouri Agricultural and Small Business Development Authority agriculture.mo.gov/abd/financial/awloanprg.php	
Offers an Animal Waste Treatment System Loan Program in cooperation with the Clean Water State Revolving Fund. Animal Waste Treatment Loans Program may finance eligible animal waste treatment systems for independent livestock and poultry producers with operations of less than 1,000 animal units. Eligible costs include storage structures, land, dedicated equipment, flush systems, composters, and more.	Clean Water State Revolving Fund
University of Missouri Extension https://extension2.missouri.edu/	
Provides guidance for farm management including crop resilience, pond health, and livestock care.	Free information and assistance
County Soil and Water Conservation Districts https://mosoilandwater.land/	
Provides guidance and assistance with the development of nutrient management plans and procurement of funding from the state cost-share program.	Free information and assistance with grant applications
Online Databases of Additional Funding Sources	
▪ Wichita State University, Environmental Finance Center (EFC) Missouri Healthy Watershed Funding Search Tool https://www.wichita.edu/academics/fairmount_college_of_liberal_arts_and_sciences/hugowall/efc/news/meramec-funding-sources-landing-page.php ▪ Catalog of Federal Funding https://www.epa.gov/waterdata/catalog-federal-funding ▪ EPA Nonpoint Source Funding Opportunities http://water.epa.gov/polwaste/nps/funding.cfmGrants.gov http://www.grants.gov	

10. Education and Outreach (Element E)

Outreach efforts should be designed to encourage public participation in implementing the goals of this watershed-based plan. Education efforts serve to inform the public of the watershed-based plan, its purpose, goals, and expected outcomes. Efforts should be made to identify and engage landowners and appropriate stakeholders who are willing to support the implementation goals of this WBP. Building strong working relationships with landowners and stakeholders will allow for ease of implementation (i.e., land access and easement development) and support the overall success of achieving the goals specified in this WBP. Installation of demonstration projects can provide opportunities for combining both implementation of BMPs with educational and outreach opportunities and should be considered.

To support education and outreach efforts, the department has participated in public meetings with interested groups and individuals wanting to reduce pollutant loading in the watershed. The department additionally provided public notification of the development of this plan and made

the plan publicly available for review and comment for a 45-day period in conjunction with draft TMDL development. The department has also attended meetings hosted by the Peruque Creek Watershed Alliance who meet regularly to discuss ways to address nonpoint source pollution in the Lake St. Louis and Peruque Creek watersheds.

The Peruque Creek Watershed Alliance is a local watershed group made up of local municipal partners, private businesses, local stream teams, homeowner associations, citizens living in the watershed, and others. This group will initiate and provide support of this WBP. During the development of this WBP, this grassroots organization has already begun outreach activities, providing public planning, and informational meetings to bring awareness to water quality issues in the watershed. It is expected that such efforts will continue as the WBP is implemented. Additionally, the department's 319 Nonpoint Source Unit will continue to provide additional technical support and, through its Watershed Coordinator, engage other potential partners in the watershed with the goal of implementing this plan. Outreach efforts will encourage public participation in the planning and implementation process.

Another important aspect of education and outreach efforts is determining the effectiveness of the programs developed. Program metrics and goals which track progress should be established which are easily tracked. Examples of potential metrics and goals include, but are not limited to, the number of program participants, number of planned events, event attendance, survey response counts, number of training events, the number of participants trained, amount of literature distributed, and the number of electronic newsletters emailed. It is important to identify how (spreadsheet or database), who (volunteers, contractor, agency personnel), and when (on-line registration, mail delivery, on-site registration) education and outreach data metrics are collected. Similarly, establishing the frequency of metric collection and public reporting should be a defined goal. Finally, it should be determined how the results and information will be shared with the target audiences (websites, electronic notification, newsletters, local and regional publications).

Examples of initial outreach and education activities initiated since 2024 and completed during the development of this watershed-based plan include watershed and lake tours, volunteer water quality sampling, and both agency and watershed group led outreach events or public meetings. Future outreach events to implement the goals of this plan are outlined on the following page in Table 17. This 5-year strategy is intended to be implemented every five years over the course of this management plan, and be updated and evaluated as needed. Applicable Alliance member outreach and education BMPs may be counted to reach these goals as long as it includes target audiences in the Peruque Creek and Lake St. Louis watershed, as well as includes target pollutants as outlined in this plan. The department intends to provide supplemental outreach efforts during the public notice and comment period associated with the development of the Lake St. Louis TMDL. The department also has a statewide watershed coordinator to help facilitate additional outreach opportunities in these watersheds in the future.

Table 17. Five-Year Education and Outreach Plan

Outreach Task	Target Audience*	Target Goal(s)	Tracking	5-Year Cost**	Schedule
Develop and maintain Alliance website	General public	Develop and maintain a web page with up-to-date information	Track website traffic metrics such as unique visitors or page views to gauge public engagement.	$1,300	Ongoing
Direct mail informational materials that may include information about topics such as cost-share programs and water quality BMP, workshops and regional, state or federal programs	Streamside, Agricultural and/or large landowners	Develop and mail postcards, informational materials, brochures or similar	Track the number of individuals who sign up for programs, join mailing lists, or respond to surveys.	$6,000	Biennial
Alliance members and partner organizations link to the Alliance website or include information about Alliance activities and efforts on their websites or social media	General public	Encourage Alliance members and partner organizations to include a link to the Alliance website on their website or social media.	Track Monitor the number of partners sharing content	$0	Ongoing
Promote, host, or develop educational meetings, seminars, or trainings.	General public, Streamside, Agricultural and/or large landowners, urban resident, homeowner, local business owners	Event shall address ways attendees can minimize or avoid adverse stormwater impacts or practices to improve the quality of stormwater runoff. A minimum of two events will be held, hosted or promoted annually.	Track attendance and distributed education materials. Attendance shall be used to gauge interest in the topic. Hosting organization may choose to do a questionnaire or follow-up survey and track responses. These responses will be used to gauge understanding and interest.	$15,000	Annual

Targeted education campaign (email, social media or in-person)	General public, Streamside, Agricultural and/or large landowners, urban resident, homeowner, local business owners	Develop and disperse/share education material or messaging	Track a metric to track interest based on activity such as: number of education material distributed, number of social media followers or number of email addresses contacted	$6,000	Biennial
Install and maintain outreach educational signage such as stream signs, watershed signs, water quality BMP informational signage, etc.	General public	Signs shall be installed based on priority and funding availability. Maintenance shall be completed by partner organizations where applicable	Track number of installed signs annually and total number and type of signs and topics covered. Some signs may include QR code to the Alliance website.	$10,000	Ongoing
Speaker series	Alliance members, specific target audience such as urban or agricultural landowners or general public	Host or promote a regional speaker series	Track topics covered, educational materials distributed and attendance to gauge interest.	$8,000	Biennial
Host or promote volunteer opportunities such as water quality monitoring, tree plantings, etc.	General public, Alliance members	Host or promote at least one volunteer opportunity annually.	Track number of volunteers and number of hours the event occurred.	$8,000	Annual
Provide watershed update to one or more municipal or other governing body board, council or committee	Municipal or governing body boards, councils, committees	Provide at least one watershed update annually.	Track the number of updates provided and the governing bodies reached.	$2,500	Annual
Alliance members attend conference, trainings, seminars, etc.	Alliance members	Two Alliance members attend relevant conferences, trainings, or seminars annually and share back learned information.	Track the number of Alliance members who attended training and relevant topics covered.	$10,000	Annual
Publish Alliance or partner newsletter articles	Agricultural, large landowners, residential property owners, business owners or other target stakeholders	Develop and distribute an article in a newsletter (or similar publication) twice a year.	Track the number of newsletters distributed and/or the number of subscribers.	$30,000	Biannual

Hold Alliance or committee meetings	Alliance members, committee members	Hold regular Alliance or committee meetings to discuss watershed plan implementation.	Track meeting dates, attendance, and meeting minutes. The Alliance may elect to conduct an annual survey and track responses. These responses will be used to gauge understanding and interest of Alliance members.	$2,500	Quarterly or as needed
Develop an engagement plan	General public	Develop an Alliance engagement plan to help coordinate efforts and get target goals	Track process on engagement plan	$1,500	Ongoing

* All listed target audiences are in the watershed. Example: general public means the general public within the watershed.
** Costs listed represent the estimated in-kind value of the activities and partner contributions required to execute this plan, rather than direct expenditure by the Alliance. This does not include staff time.

11. Implementation Schedule (Element F)

As presented in Section 7, nutrient and sediment loading reduction targets have been developed to restore the lake to conditions that meet water quality standards. In Section 8, specific types of BMPs for particular land uses are identified that will reduce nutrient and sediment loading and make progress towards the reduction targets. Below, Table 17 uses the information from the previously presented information and outlines a 35-year schedule for implementation. At the end of the 35-year implementation schedule, TSS and TN reduction targets are expected to be fully achieved while TP reduction targets may not be fully realized. Although TP targets may not be fully achieved by the end of the planning period, it should be noted that TMDL targets include multiple margins of safety and conservative assumptions required to meet the requirements of the Clean Water Act and applicable federal regulations. Due to these conservative assumptions, and continued pollutant reduction that will be required from point sources, as well as unquantified nutrient reductions achieved from achieving the specified sediment target, it is expected that Chl-a values in Lake St. Louis will meet applicable water quality stanadards with the specified levels of implementation.

For structural BMPs, the level of implementation shown in Table 17 should be repeated every 5 years throughout the 35-year planning period. Once installed and maintained, structural BMPs continue to provide pollutant reductions beyond the initial year of implementation. For this reason, to achieve this plan's targeted pollutant reduction the BMPs and acres treated in any previous 5-year period should be maintained. Structural BMPs reaching end-of-life should likewise be replaced. Four of the suggested BMPs, prescribed grazing, conservation tillage, cover crops, and contour farming, are management BMPs and must occur on an annual basis. The acres associated with these management BMPs are not cumulative.

Table 18. BMP Implementation Schedule by Land Use with Number of Acres Treated

Pastureland BMPs	Grass Buffer	Forest Buffer	Critical Area Planting	Heavy Use Protection	Stream bank Stabilization w/fencing	Prescribed Grazing	Exclusion Fencing
Years 1 - 5	14.25	14.25	14.25	7.25	7.25	400 managed annually	28.5
Years 6 - 10	+14.25	+14.25	+14.25	+7.25	+7.25		+28.5
Years 11 - 15	+14.25	+14.25	+14.25	+7.25	+7.25		+28.5
Years 15 - 20	+14.25	+14.25	+14.25	+7.25	+7.25		+28.5
Years 21 - 25	+14.25	+14.25	+14.25	+7.25	+7.25		+28.5
Years 26 - 30	+14.25	+14.25	+14.25	+7.25	+7.25		+28.5
Years 31 - 35	+14.25	+14.25	+14.25	+7.25	+7.25		+28.5
35-years Final Implementation (acres)	100	100	100	50	50	400	200

Cropland BMPs	Cover Crops	Conservation Tillage	Grass Buffer	Forest Buffer	Land Retirement	Contour Farming
Years 1 - 5	300 planted annually	300 managed annually	7.25	3.5	3.5	300 managed annually
Years 6 - 10			+7.25	+3.5	+3.5	
Years 11 - 15			+7.25	+3.5	+3.5	
Years 16 - 20			+7.25	+3.5	+3.5	

Years 21 - 25			+7.25	+3.5	+3.5	
Years 26 - 30			+7.25	+3.5	+3.5	
Years 31 - 35			+7.25	+3.5	+3.5	
35-years Final Implementation (acres)	300	300	50	25	25	300

Urban BMPs	**Urban Wetlands (restoration/design)**	**Extended Stormwater Retention**
Years 1 - 5	125	125
Years 6 - 10	+125	+125
Years 11 – 15	+125	+125
Years 16 – 20	+125	+125
Years 21 – 25	+125	+125
Years 26 - 30	+125	+125
Years 31 - 35	+125	+125
35-years Final Implementation (acres)	875	875

Notes:

- For simplicity, acreages are rounded to the nearest quarter acre
- Structural BMPs provides annual load reductions during the lifetime of the BMP. Due to this compounding load reduction, acreages are pro-rated over the 35-year implementation period. BMPs implemented and acres treated in any 5-year period should be maintained (or reinstalled at end-of-life) in conjunction with new BMP implementation.
- Management BMPs (i.e., contour farming, conservation tillage, cover crops, and prescribed grazing) provide a single year of pollutant reduction and therefore require practices to be implemented over the given acreages annually.
- To maintain targeted pollutant loading at the end of the 35-year plan, final BMPs and acres treated should continue to be maintained on an annual basis, or equivalent load reductions provided by additional BMPs should be provided.

12. Milestones (Element G) and Evaluation Criteria (Element H)

Milestones provide measurable benchmarks to evaluate the progress of implementing the plan. The previous section provides, through specified numbers of acres treated, a level of BMP implementation expected to be achieved after every five-years of implementation These five-year values serve as a measurable goal for evaluating implementation progress. In addition to the implementation of BMPs, the amount of pollutant reduction achieved from those practices every five years serves as another measurable goal. Quantitively determining the amount of pollutant reduction occurring from BMP installations across the watershed will determine if water quality conditions are improving or if water quality standards are being attained. Nutrient screening thresholds for the Plains ecoregion (18 µg/L Chl-a, 843 µg/L TN, 49 µg/L TP) and an ecoregional TSS concentration of 18 mg/L serve as the final water quality targets for Lake St. Louis. Using these targets and modeled watershed flow data, annual pollutant loading rates after achieving the benchmark load reduction targets in Table 19 were calculated. Then from these loading rates, corresponding pollutant concentrations were estimated. These concentrations, applicable to water quality in Lake St. Louis, are presented in Table 18 and serve as milestones and comparable targets for evaluation purposes.

Table 19. Loading Milestones and Evaluation Criteria

Pollutant	Loading Target	Target (year 5)	Target (year 10)	Target (year 15)	Target (year 20)	Target (year 25)	Target (Year 30)	Target (Year 35)
TSS (tons/yr)	435	6,141	5,190	4,239	3,288	2,337	1,386	≤ 435
TN (lbs/yr)	121,038	237,040	217,707	198,374	179,041	159,708	140,375	≤ 121,038
TP (lbs/yr)	918	33,941	31,287	28,633	25,979	23,325	20,671	18,575
Pollutant	**Water Quality Target[1]**	**Target (year 5)**	**Target (year 10)**	**Target (year15)**	**Target (year 20)**	**Target (year 25)**	**Target (Year 30)**	**Target (Year 35)**
TSS (mg/L)	18	120.43	101.78	83.13	64.48	45.83	27.18	≤ 18.00
TN (mg/L)	0.84	2.32	2.13	1.95	1.76	1.57	1.38	≤ 0.84
TP (mg/L)	0.049	0.33	0.31	0.28	0.25	0.23	0.20	0.18

Notes:

- Nutrient targets are based on the concentrations necessary to achieve Missouri's lake nutrient criterion of 18 mg/L of Chl-a in the Plains Ecoregion. TSS target is based on the 25th percentile of all available TSS sampling data in the same ecoregion where Lake St. Louis is located. Target concentrations were calculated from pollutant loading estimates using a weighted annual mean flow rate for the watershed.
- Because models are based on annual averages, concentration targets are based on median flow conditions in Peruque Creek calculated from daily mean flows used during TMDL development (51.8 cubic feet per second). These estimated concentrations provide a means for evaluating BMPs and overall implementation progress. Determination of actual water quality attainment will be completed by the department through its biennial water quality assessment and reporting consistent with sections 305(b) and 303(d) of the Clean Water Act.

13. Monitoring (Element I)

Water quality monitoring may be conducted by public entities, private companies, and research institutions for a variety of reasons, and may include both regulatory and non-regulatory interest. On a biennial basis, the department will evaluate all readily available and quality assured data following the procedures established in Missouri's Listing Methodology.[6] Ultimate determinations of continued impairment or water quality attainment, will be completed by the department on even-numbered consistent with Clean Water Act requirements for Section 303(d) and 305(b) reporting. Pre-implementation monitoring is being conducted in advance of this plan by the Peruque Creek Watershed Alliance in cooperation with Missouri State University's Ozarks Environmental and Water Resources Institute (OEWRI).

To determine if the goals of the plan are being achieved monitoring is likely most appropriate and applicable after BMP implementation to identify progress towards meeting the established pollutant reduction goals established in Sections 7 and 8, as well as to estimate BMP effectiveness. Load reduction goals should be considered when monitoring associated with BMP implementation is planned and should be evaluated at a minimum 5-year increments. Sampling planning and development for BMP monitoring can be completed concurrently with BMP planning and design, but monitoring should not be conducted until a year after BMP installation. Scheduled milestones and evaluation criteria in Section 12 provide water quality targets for

[6] Available online at https://dnr.mo.gov/water/what-were-doing/water-planning/quality-standards-impaired-waters-total-maximum-daily-loads/impaired-waters

evaluating progress at five-year intervals following the established BMP implementation schedule in Section 11.

Data collected from such monitoring may also be used to adjust BMP selection, location, and number as appropriate to ensure progress towards the ultimate restoration goal of this plan are maintained. Volunteer-level monitoring is often less costly and can provide general information regarding BMP effectiveness and water quality improvement. More extensive quality assured monitoring may be more appropriate following substantial implementation of BMPs typically following the timelines and milestones established in this plan. Additional implementation monitoring at more frequent intervals may be appropriate when specific consideration is given to expected pollutant loading and overall expected load reductions achieved.

It should also be noted the TSS and nutrient load reduction targets to restore water quality in Lake St. Louis are based on modeled estimates because observed water quality data is limited in the watershed. For this reason, continuous flow data collection, or paired flow and parameter monitoring, as well any equipment needs to support such monitoring, can aid the implementation goals of this plan by providing site-specific data for which to calculate actual load reductions achieved during known flow conditions. This information can then provide adjustment to BMP activities (i.e., number, types, and locations) to known reduction needs to ensure progress towards attainment of water quality goals are being achieved.

The department may periodically supplement such monitoring with its own, dependent upon available resources, need, weather conditions, and other statewide priority monitoring. In general, the department will not conduct monitoring until an appropriate time after which implementation actions have occurred. However, the department will continue to evaluate all other readily available and quality assured data.

The development of a QAPP is often applied and typically required for sample planning, and analysis type of projects (USEPA, 2002). QAPPs define the goals of the monitoring efforts, helping the project produce successful returns. QAPPs often include details such as the identification of sampling parameters (TSS, DO, nutrients, flow, biological assessment, etc.), sampling locations (upstream, downstream, outfall, weir) sampling type (grab, auto-sampler, depth integrated), sampling event type (baseline, routine, storm event), collecting entity or agency, sampling frequency and duration (seasonality, storm events, discreet sampling, continuous sampling), laboratory quality assurance and quality control documentation, and contracted technical and laboratory support qualifications. Creating a concise and complete QAPP will ensure quality data results that will confidently reflect the performance of implemented BMPs. Often QAPPs are considered ‘living documents” and can be updated if necessary to address changes to the watershed plan and implementation process. Monitoring data will reflect the effectiveness of the watershed plan and ultimately demonstrate pollutant loading reductions occurring across the Lake St. Louis watershed. Therefore, QAPP development is critical to the overall success of the WBP and should be initiated and reviewed by the department prior to any data collection efforts. Additional USEPA QAPP development guidance can be found at: https://www.epa.gov/quality/guidance-quality-assurance-project-plans-epa-qag-5.

Watershed groups or interested public may participate in the Missouri Stream Team and Volunteer Water Quality Monitoring programs, to collect general water quality indicator data, such as macroinvertebrate sampling, cobble embeddedness, and transparency that may provide general indication of water quality improvement or decline. Such information may be used to inform when and where more robust monitoring may be beneficial and can generally provide an indicator of BMP effectiveness. More information about these voluntary programs is available at https://mostreamteam.org/.

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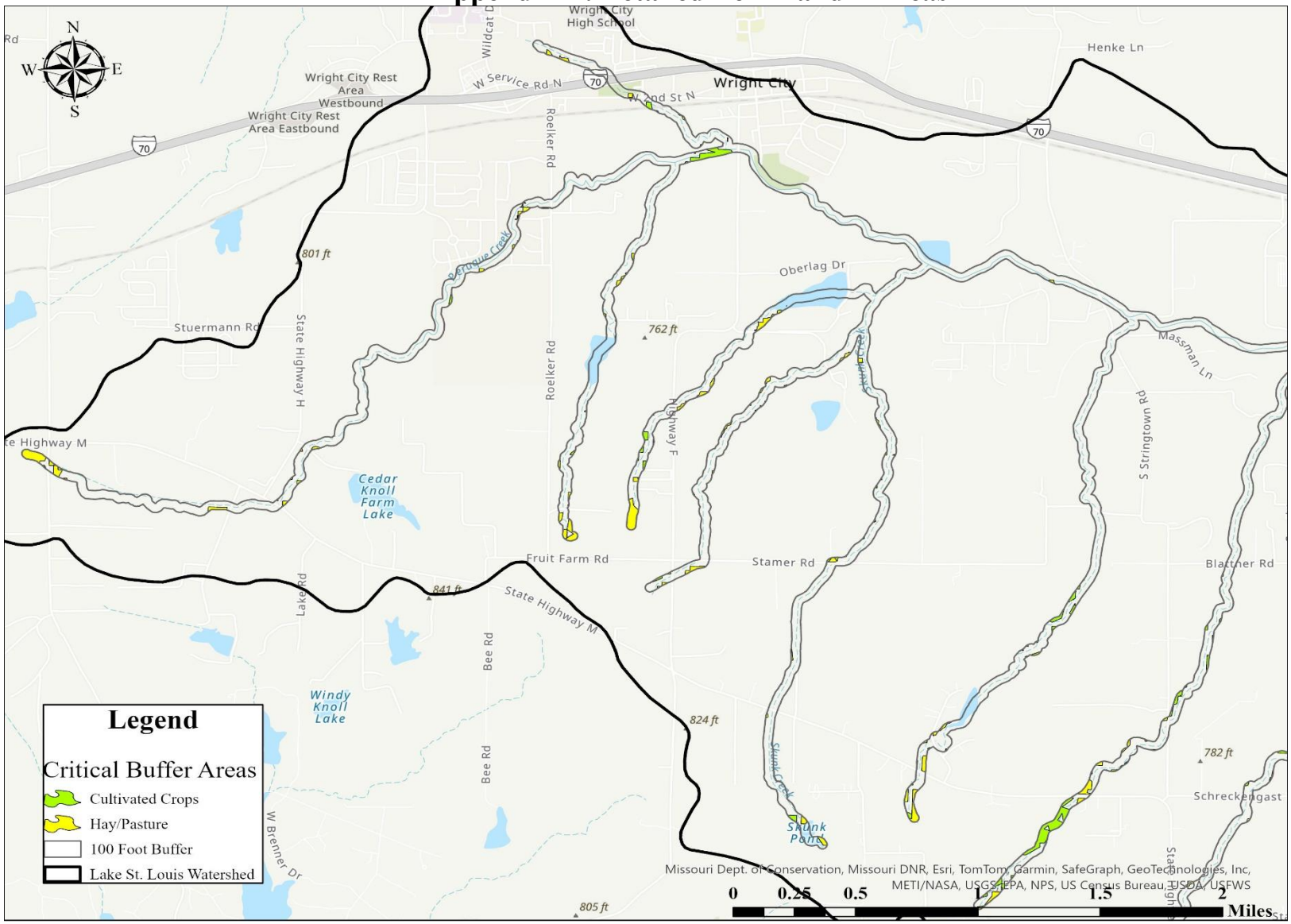
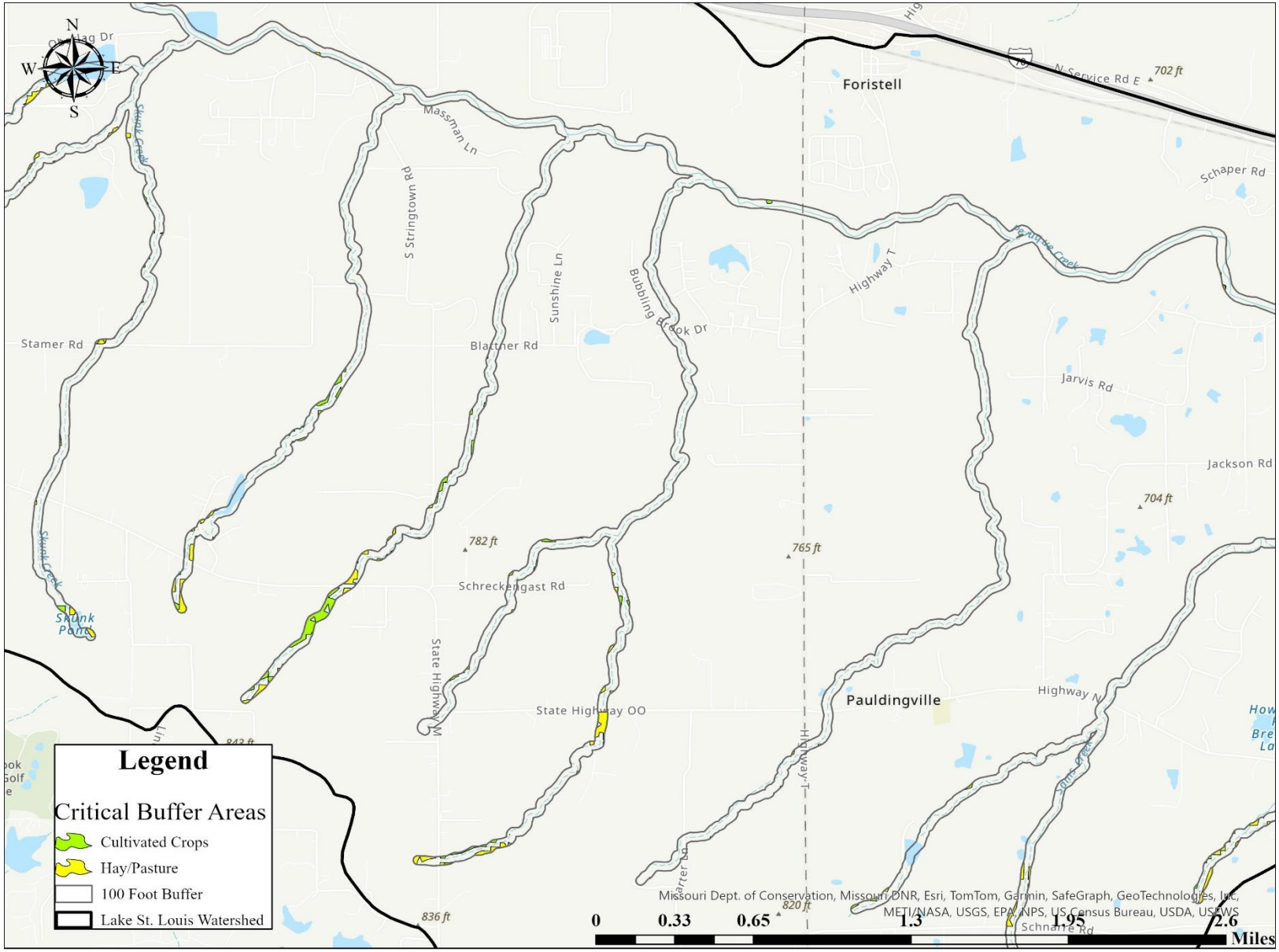
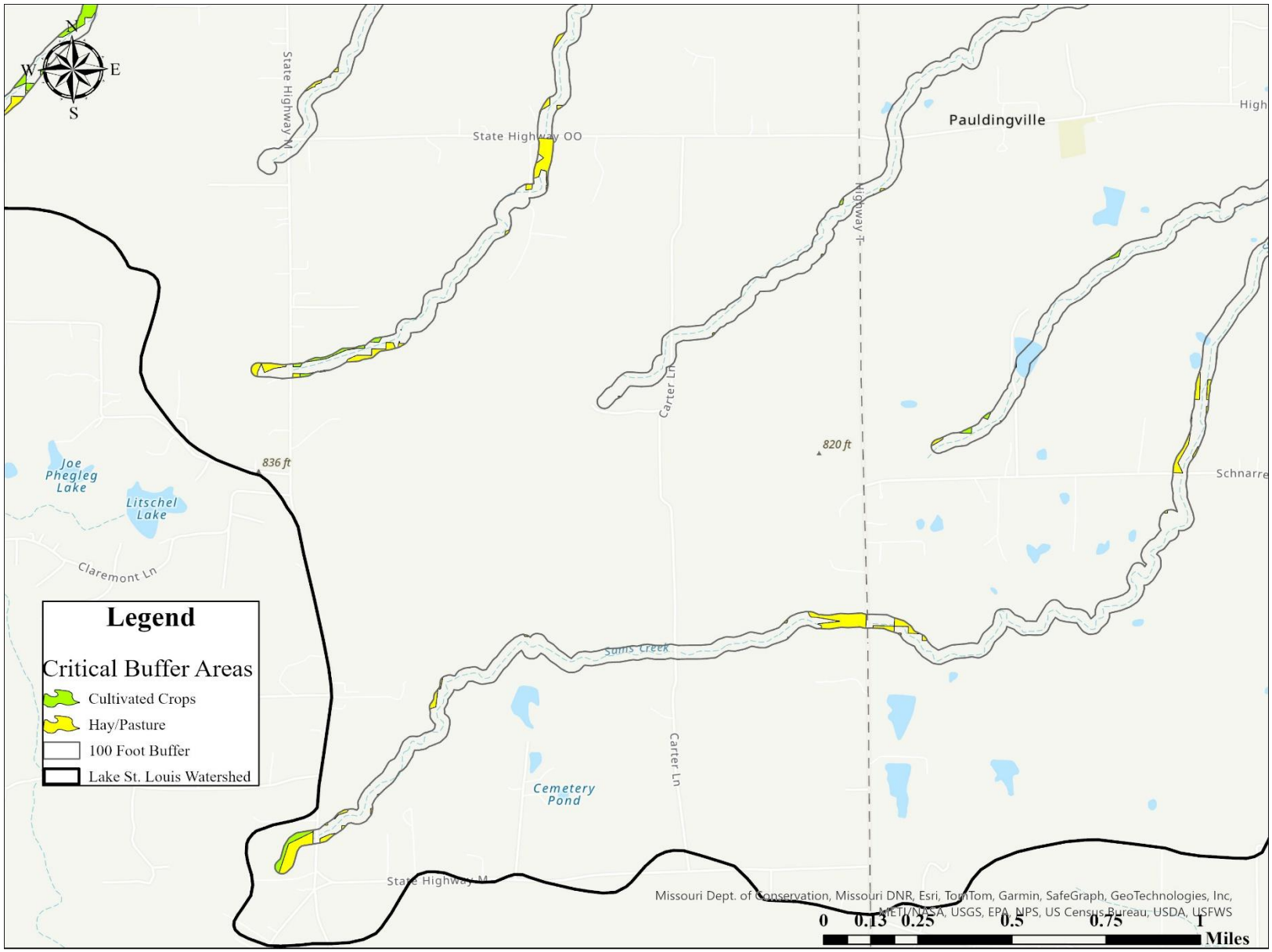
Appendix A. Detailed Teir 1 and 2 Areas



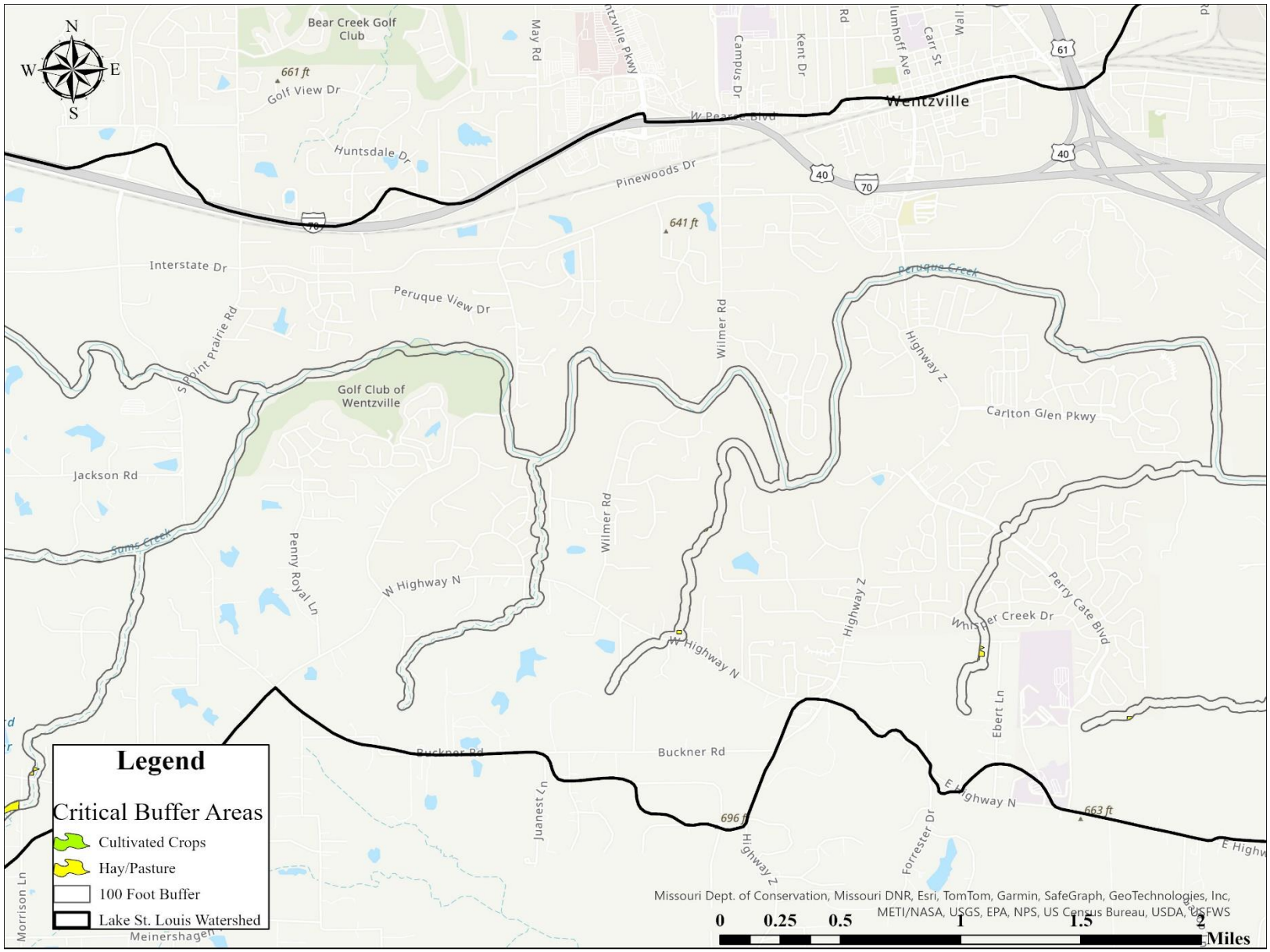
Appendix Figure 1. Western Watershed - Wright City Area



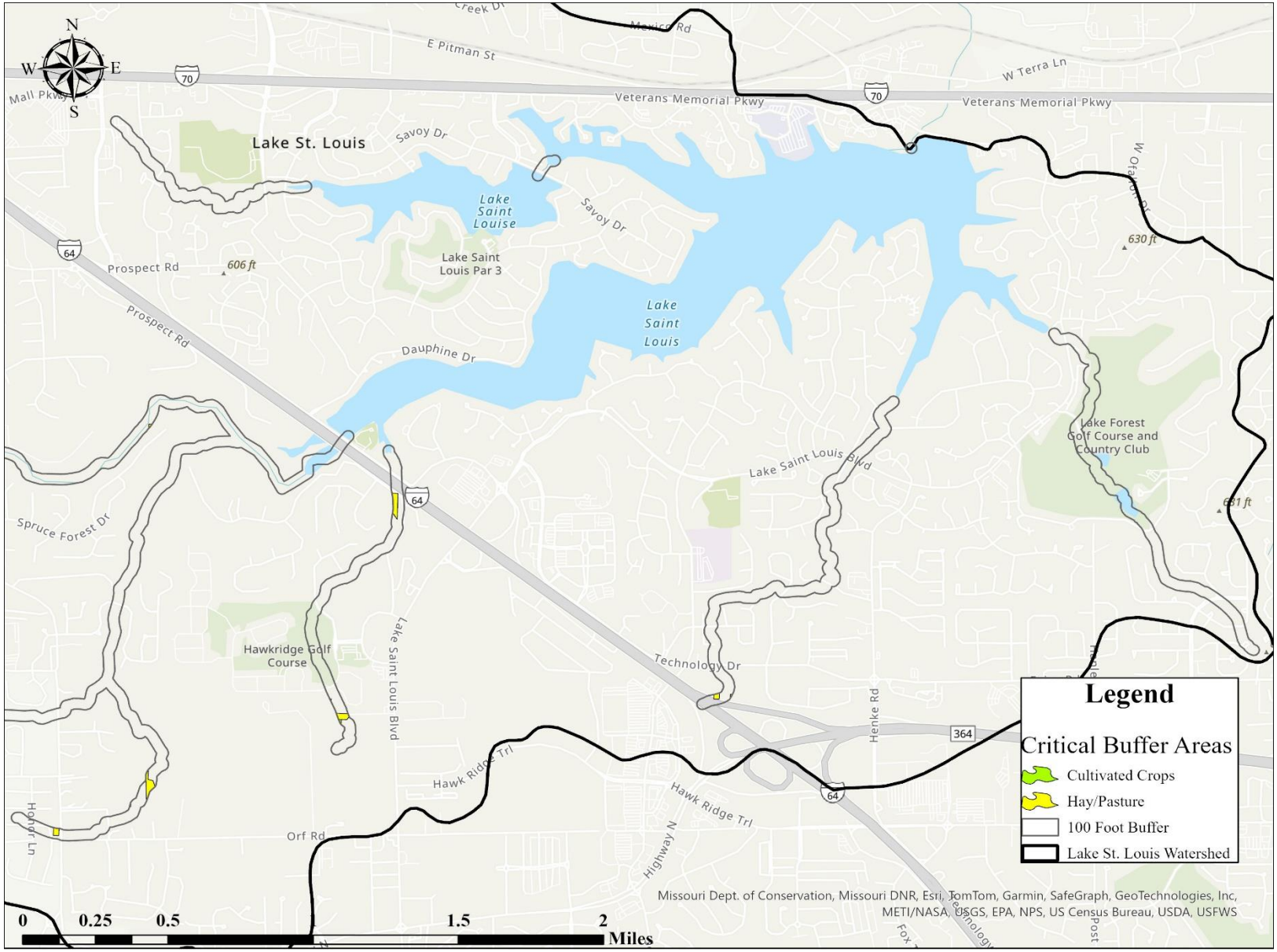
Appendix Figure 2. Western Watershed – Foristell and Pauldingville Area



Appendix Figure 3. Western Watershed – Skunk Creek Headwaters



Appendix Figure 4. Central Watershed



Appendix Figure 5. Eastern Watershed – Lake St. Louis Area

Appendix B. PLET Individual BMP Efficiency Values

Land use Type	BMP Name	N	P	Sediment
Cropland	Bioreactor	0.45		
Cropland	Buffer - Forest (100ft wide)	0.49	0.47	0.6
Cropland	Buffer - Grass (35ft wide)	0.34	0.44	0.53
Cropland	Conservation Tillage 1 (30-59% Residue)	0.07	0.36	0.46
Cropland	Conservation Tillage 2 (equal or more than 60% Residue)	0.13	0.69	0.79
Cropland	Contour Farming	0.34	0.46	0.41
Cropland	Controlled Drainage	0.39	0.35	—
Cropland	Cover Crop 1 (Group A Commodity) (High Till only for Sediment)	0.0078	—	—
Cropland	Cover Crop 2 (Group A Traditional Normal Planting Time) (High Till only for TP and Sediment)	0.2	0.07	0.1
Cropland	Cover Crop 3 (Group A Traditional Early Planting Time) (High Till only for TP and Sediment)	0.2	0.15	0.2
Cropland	Land Retirement	0.9	0.81	0.95
Cropland	Nutrient Management 1 (Determined Rate)	0.15	0.45	—
Cropland	Nutrient Management 2 (Determined Rate Plus Additional Considerations)	0.22	0.56	—
Cropland	Streambank Stabilization and Fencing	0.75	0.75	0.75
Cropland	Terrace	0.27	0.31	0.41
Cropland	Two-Stage Ditch	0.12	0.28	—
Feedlots	Diversion	0.45	0.7	—
Feedlots	Filter strip	—	0.85	—
Feedlots	Runoff Mgmt System	—	0.83	—
Feedlots	Solids Separation Basin	0.35	0.31	—
Feedlots	Solids Separation Basin w/Infilt Bed	—	0.8	—
Feedlots	Terrace	0.55	0.85	—
Feedlots	Waste Mgmt System	0.8	0.9	—
Feedlots	Waste Storage Facility	0.65	0.6	—
Forest	Road dry seeding	—	—	0.41
Forest	Road grass and legume seeding	—	—	0.71
Forest	Road hydro mulch	—	—	0.41
Forest	Road straw mulch	—	—	0.41
Forest	Road tree planting	—	—	0.5
Forest	Site preparation/hydro mulch/seed/fertilizer	—	—	0.71
Forest	Site preparation/hydro mulch/seed/fertilizer/transplants	—	—	0.69
Forest	Site preparation/steep slope seeder/transplant	—	—	0.81
Forest	Site preparation/straw/crimp seed/fertilizer/transplant	—	—	0.95
Forest	Site preparation/straw/crimp/net	—	—	0.93

Forest	Site preparation/straw/net/seed/fertilizer/transplant	—	—	0.83
Forest	Site preparation/straw/polymer/seed/fertilizer/transplant	—	—	0.86
Pastureland	30m Buffer with Optimal Grazing	0.16	0.65	—
Pastureland	Alternative Water Supply	0.18	0.13	0.2
Pastureland	Critical Area Planting	0.18	0.2	0.42
Pastureland	Forest Buffer (minimum 35 feet wide)	0.45	0.4	0.53
Pastureland	Grass Buffer (minimum 35 feet wide)	0.87	0.89	0.65
Pastureland	Grazing Land Management (rotational grazing with fenced areas)	0.43	0.26	—
Pastureland	Heavy Use Area Protection	0.18	0.19	0.33
Pastureland	Litter Storage and Management	0.14	0.14	0
Pastureland	Livestock Exclusion Fencing	0.2	0.43	0.64
Pastureland	Multiple Practices	0.25	0.2	0.22
Pastureland	Pasture and Hayland Planting (also called Forage Planting)	0.18	0.15	—
Pastureland	Prescribed Grazing	0.41	0.23	0.33
Pastureland	Streambank Protection w/o Fencing	0.15	0.22	0.58
Pastureland	Streambank Stabilization and Fencing	0.75	0.75	0.75
Pastureland	Use Exclusion	0.43	0.08	0.51
Pastureland	Winter Feeding Facility	0.35	0.4	0.4
Urban	Alum Treatment	0.6	0.9	0.95
Urban	Bioretention facility	0.63	0.8	—
Urban	Concrete Grid Pavement	0.9	0.9	0.9
Urban	Dry Detention	0.3	0.26	0.58
Urban	Extended Wet Detention	0.55	0.69	0.86
Urban	Filter Strip-Agricultural	0.53	0.61	0.65
Urban	Grass Swales	0.1	0.25	0.65
Urban	Infiltration Basin	0.6	0.65	0.75
Urban	Infiltration Devices		0.83	0.94
Urban	Infiltration Trench	0.55	0.6	0.75
Urban	LID*/Cistern	—	—	—
Urban	LID*/Cistern+Rain Barrel	—	—	—
Urban	LID*/Rain Barrel	—	—	—
Urban	LID/Bioretention	0.43	0.81	
Urban	LID/Dry Well	0.5	0.5	0.9
Urban	LID/Filter/Buffer Strip	0.3	0.3	0.6
Urban	LID/Infiltration Swale	0.5	0.65	0.9
Urban	LID/Infiltration Trench	0.5	0.5	0.9
Urban	LID/Vegetated Swale	0.08	0.18	0.48
Urban	LID/Wet Swale	0.4	0.2	0.8
Urban	Oil/Grit Separator	0.05	0.05	0.15

Urban	Porous Pavement	0.85	0.65	0.9
Urban	Sand Filter/Infiltration Basin	0.35	0.5	0.8
Urban	Sand Filters	—	0.38	0.83
Urban	Settling Basin	—	0.52	0.82
Urban	Vegetated Filter Strips	0.4	0.45	0.73
Urban	WQ Inlet w/Sand Filter	0.35	—	0.8
Urban	WQ Inlets	0.2	0.09	0.37
Urban	Weekly Street Sweeping	—	0.06	0.16
Urban	Wet Pond	0.35	0.45	0.6
Urban	Wetland Detention	0.2	0.44	0.78

Appendix C. Supplemental Data

Table C 1. Interior River and Hills Level 3 Ecoregion Sites used to develop TSS target for Lake St. Louis

Stream Site Name	Waterbody ID Number (WBID)	Number of Samples	Collecting Agency
South Fork. Salt River @Santa Fe	141	94	USGS
Cuivre River @Old Monroe	151	240	USGS
Cuivre River near Troy	152	206	USGS
Cowmire Creek near Hwy I-270	1604	40	USGS
Caulk's Creek @Chesterfield	1701	12	USGS
Bonhomme Creek @Hwy CC	1701	42	USGS
Creve Coeur Creek @Hwy 340	1703	65	USGS
Fee Fee Creek @McKelvey Rd.	1704	48	USGS
Coldwater Creek @Jamestown Rd.	1706	62	USGS
Watkins Creek @Fry Lane	1708	43	USGS
Maline Creek @Bellefontaine Rd.	1709	72	USGS
River des Peres @St. Louis	1710	34	USGS
Gravois Creek @Green Park Rd, Mehlville	1713	43	USGS
South Fork. Saline Creek @ Hwy T	1769	66	USGS
Peruque Creek 7.6 mi. DS of O'Fallon North STP	215	256	USGS
Dardenne Creek @ Hwy B	219	265	USGS
Dardenne Creek 1.8 mi. DS of Spencer Cr.	219	12	USGS
Dardenne Creek @ Salt River Rd.	221	19	USGS
Spencer Creek 0.1 mi. US of Mouth	224	12	USGS
Bobs Creek @Hwy 79	32	15	USGS
Des Moines River @ St. Francisville, MO.	36	704	USGS
Fox River near Wayland, MO.	38	111	USGS
Black Creek near Brentwood	3825	7	USGS
Deer Creek @Big Bend Blvd	3826	22	USGS
River des Peres @Heman Park	3972	64	USGS
Deer Creek @ LaDue	4078	23	USGS
Engelholm Creek near Wellston	4110	42	USGS
Cedar Cr. 25 miles below Manacle Cr., nr Ashland	737	37	USGS
Lamine River near Pilot Grove	847	222	USGS
Salt River near New London, MO.	91	501	USGS

Table C 2. Common categories of structural Best Management Practices implemented to address nonpoint source loading concerns[7]

BMP Category	Identifier Code	Description
Detention Basin	DB	Dry extended detention grass-lined and concrete lined basins which empty after storm events.
Retention Basin	RP	Surface wet pond, generally maintains a permanent pool, can include additional underground storage capacity.
Wetland Basin	WB	Similar to the retention basin, maintaining permanent pool, also maintains at least 50% coverage of emergent wetland vegetation.
Wetland Channel	WC	Saturated channel with wetland vegetation and slow water residency time.
Grass Swale	BS	Shallow, vegetated channel, termed bioswale or vegetated swale commonly.
Grass Strip	BI	Designated vegetated areas designed to intercept lateral sheet flows from adjacent impervious surface areas, also termed buffer strips or vegetated buffers.
Bioretention Basin	BR	Shallow, vegetated basins with a various plantings and filtration media, with underdrainage often included.
Media Filter System	MF	Filter bed typically filled with sand, gravel, or granular media.
High Rate Biofiltration	HRBF	System designed for high flow rate filtration, typically used to support treatment plants.
High-Rate Media Filtration	HRMF	System designed for high flow rate filtration, media consist of inert and sportive materials and configurations (e.g. membrane filters, up flow filters, vertical bed filters, cartridge filters).
Hydraulic Separation Devices	HDS	Engineered system which uses gravitational settling using baffles, screens, and swirl concentrators.
Oil/Grit Separators and Baffle Boxes	OGS	Engineered systems such as oil/water separators and baffle chambers which remove coarse solids and floatables.
Permeable Friction Course Overlays	PF	Course overlay designed to increase surface friction of impervious surfaces which slows and reduces sheet flow velocities.
Porous Pavements and Surfaces	PP	Engineered surface systems which allow for precipitation infiltration, examples include porous

[7] This BMP table was developed directly from the ACOE and EPA International Stormwater BMP Database 2020 Summary Statistics report; https://bmpdatabase.org/performance-summary-reports.

		asphalt and concrete, brick and pavers, other permeable surfaces designed to replace pavement.