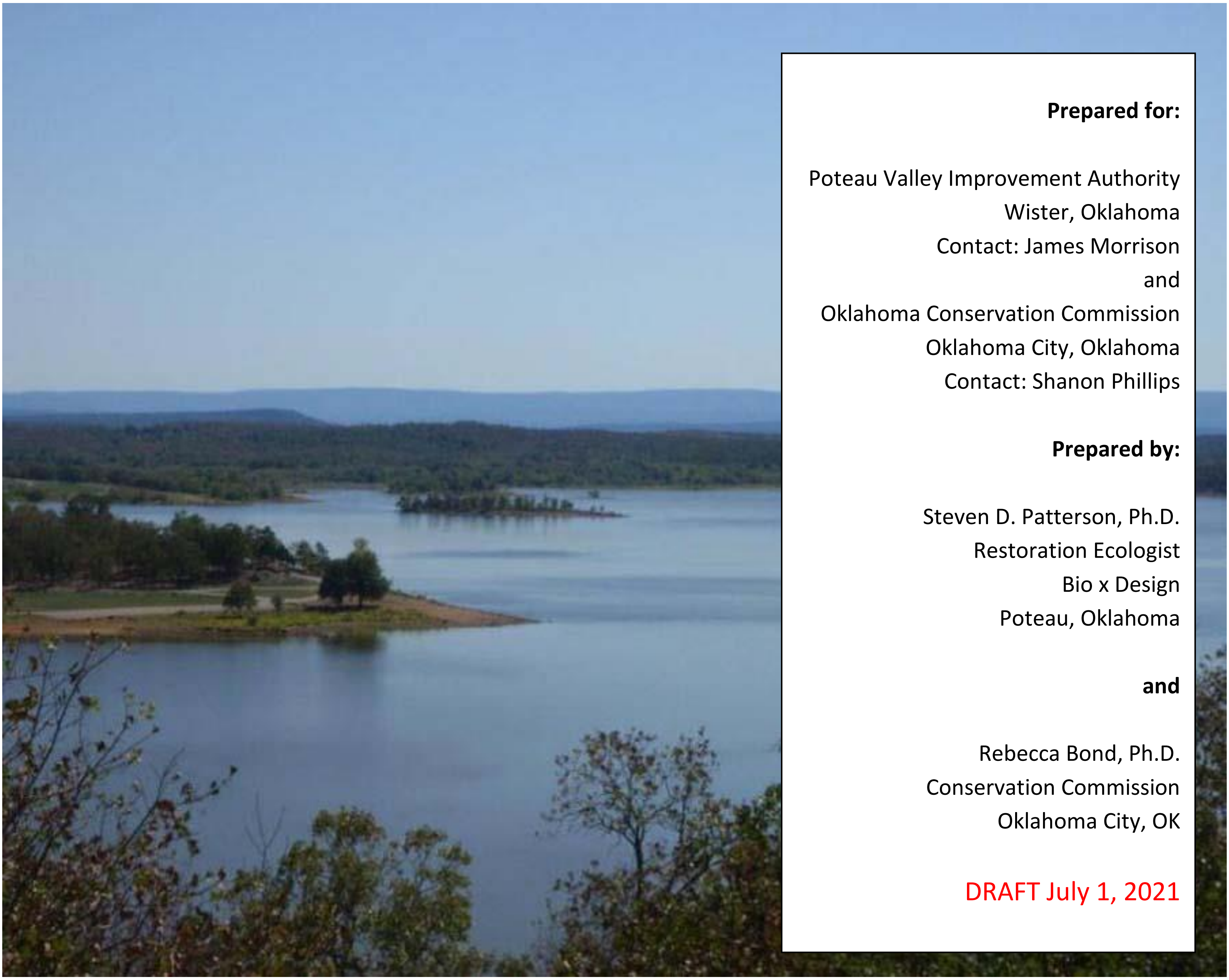
LAKE WISTER WATERSHED PLAN

A Nine-Element Watershed Based Plan



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CHAPTER 1: INTRODUCTION

This watershed based plan has been prepared to guide efforts to improve water quality in Lake Wister, Oklahoma. The plan has been drafted following US EPA recommendations for nine-element watershed based planning.

Lake Wister

Figure 1: Lake Wister aerial view (Photo: Google Earth, imagery date 2009)

Lake Wister is a 25.4 km^2 (6,288-acre) flood control, water supply, and recreation reservoir in LeFlore County in eastern Oklahoma (Figure 1). The focus area for this watershed planning effort is the Oklahoma portion of the Lake Wister watershed. Wister is a bistate watershed--approximately 60% of the Lake Wister watershed is in Oklahoma; the remaining 40% is in Arkansas, upstream of the Oklahoma portion. A separate watershed planning effort for the Arkansas portion of the Poteau River watershed is also underway. Although the Arkansas effort is completely separate from Oklahoma's watershed planning, individuals involved in both states are committed to sharing data and collaborating where possible.

Lake Wister is on the Oklahoma 303(d) list of impaired water bodies (ODEQ, 2018), identified as impaired for its beneficial uses of *Public and Private Water Supply*, *Fish and Wildlife Propagation, Fish Consumption*, and *Aesthetics*. Causes of impairment include excess chlorophyl-*a*, turbidity, pH, phosphorus, and mercury (see Chapter 3).

The Poteau Valley Improvement Authority (PVIA) is a State of Oklahoma-chartered trust founded in 1969 that produces potable water for drinking, commercial, and industrial uses for most of LeFlore County, Oklahoma (Figure 2) and portions of adjacent counties. PVIA treats water from Lake Wister and distributes it to sixteen cities and rural water districts. The quality of the water in Lake Wister directly affects the cost and difficulty of water treatment and therefore the ability of PVIA to supply safe, affordable drinking water to its customers.

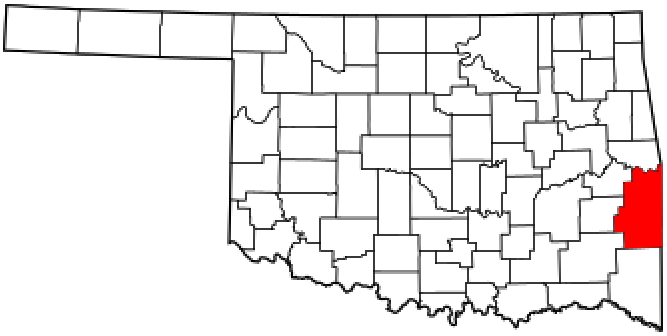


Figure 2: LeFlore County location in eastern Oklahoma

The benefits of high-quality water in Lake Wister accrue to a broad community of users--fishermen, boaters, recreationists, and other water users--and not only to PVIA customers. PVIA has, nevertheless, taken the lead in efforts to protect and restore water quality in the lake. In October 2019 PVIA completed and submitted to the Oklahoma Department of Environmental Quality a lake-modeling report that made recommendations for the promulgation of Total Maximum Daily Loads (TMDLs) for the lake (Scott and Patterson, 2019). The establishment of TMDLs has paved to the way to begin to focus on implementation of projects necessary to achieve the load reductions that will restore water quality in the lake. The purpose of a watershed based plan is to identify the actions desirable and necessary to achieving water quality restoration. PVIA and the Oklahoma Conservation Commission are collaborating in the development of this watershed based plan. A watershed based plan establishes a framework for protecting and improving water quality in a watershed.

Watershed Planning Process

Actions envisioned in this watershed based plan are voluntary, non-regulatory, and ultimately require stakeholder collaboration to be successful in addressing the reduction of nonpoint source pollutants. An effective watershed approach requires the integration of a variety of scientific and descriptive information on a range of topics from land use to climate, from hydrology, drainage, and topography to vegetation (USEPA, 2012). A watershed based plan does not ascribe legal obligations; rather it is a general blueprint for a comprehensive, watershed-wide water quality restoration program.

Per US EPA recommendations, a watershed based plan consists of nine key elements (USEPA, 2008):

1. Identification of the causes and sources of NPS water pollution that will need to be controlled
2. An estimation of load reductions expected from the management measures used to achieve water quality goals
3. A description of the management measures that will need to be implemented to achieve pollution load reductions
4. Technical and funding needs to support the implementation and maintenance of restoration measures
5. A description of public outreach method(s) that will be used to engage and maintain public and governmental involvement including local, state, federal, and tribal governments
6. A schedule for implementation of needed restoration measures and identification of appropriate lead agencies to oversee implementation, maintenance, monitoring, and evaluation
7. A description of interim, measurable milestones for the actions to be taken and desired water quality goals and outcomes
8. Criteria that can be used to determine whether load reductions are being achieved over time and substantial progress is being made toward achieving water quality standards
9. A description of monitoring and evaluation activities needed to further define problems and/or assess progress towards achieving water quality goals

State of Oklahoma Water Quality Standards

Oklahoma's Water Quality Standards (WQS) were adopted by the State Oklahoma in accordance with the federal Clean Water Act, applicable federal regulations, and state pollution control and administrative procedure statutes. WQS serve a dual role:

- They establish water quality benchmarks
- They provide the basis for the development of water quality pollution control programs, including discharge permits, which dictate specific treatment levels required of municipal and industrial wastewater dischargers

Water Quality Standards consist of three main components:

1) designation of beneficial uses,
2) water quality criteria to protect the designated uses, and
3) antidegradation policies.

Establishment of beneficial uses, water quality monitoring, and beneficial use assessment comprise the core of water quality standards implementation. Oklahoma's water quality standards include the following beneficial uses:

- Public and private water supply,
- Fish and wildlife propagation,
- Agriculture,
- Primary body contact recreation (such as swimming),
- Secondary body contact recreation (such as boating or fishing),
- Navigation,
- Aesthetics.

Physical, chemical, and biological data on Oklahoma's rivers, streams, and lakes are obtained primarily through field sampling. Beneficial use support is assessed by comparing data to narrative and numerical criteria specified in the WQS. The overarching purpose of WQS and assessment of beneficial uses is to protect the quality of the state's water resources.

Impairments of Concern

The targets of concern in this watershed plan are total phosphorus and total suspended solids, as identified in the proposed TMDLs for Lake Wister (Scott and Patterson, 2019).

2019 Total Maximum Daily Loads for Lake Wister

In October 2019 PVIA completed and submitted to the Oklahoma Department of Environmental Quality a lake-modeling report that made recommendations for the promulgation of Total Maximum Daily Loads (TMDLs) for the lake (Scott and Patterson, 2019)

Water quality modeling simulations indicated that a 78% reduction in the average total phosphorus (TP) load delivered to the lake will be required for the lake to meet the criterion of 10 µg/L of chlorophyll-*a* (chl-*a).* Model simulations also indicate that a 71% reduction in the average total suspended solids (TSS) load delivered to the lake will be required for no more than 10% of samples to exceed the turbidity criterion of 25 NTU.

The establishment of TMDLs for Lake Wister for phosphorus and sediment set the target loads for these constituents to support the designated beneficial uses for Lake Wister. The next step towards improving water quality is to establish a plan for how to achieve the required load reductions. That is the purpose of this document, a watershed based plan for the Lake Wister watershed, drafted in keeping with US EPA recommendations for nine-element watershed based planning.

CHAPTER 2: PROJECT AREA BACKGROUND

Geographic Location of Project Area

Figure 3: Lake Wister Dam

Lake Wister is located in LeFlore County in eastern Oklahoma. The lake was formed in 1949 by the completion of a dam on the Poteau River by the United States (US) Army Corps of Engineers (Figure 3). The Poteau River begins east of the town of Waldron in western Arkansas and the river flows west to Lake Wister. Leaving the lake, the Poteau River flows north to its confluence with the Arkansas River at Fort Smith, Arkansas. The Poteau River watershed (HUC 11110105) covers some 4,890 km^2 (1,888 mi^2) in Arkansas and Oklahoma (Figure 4).

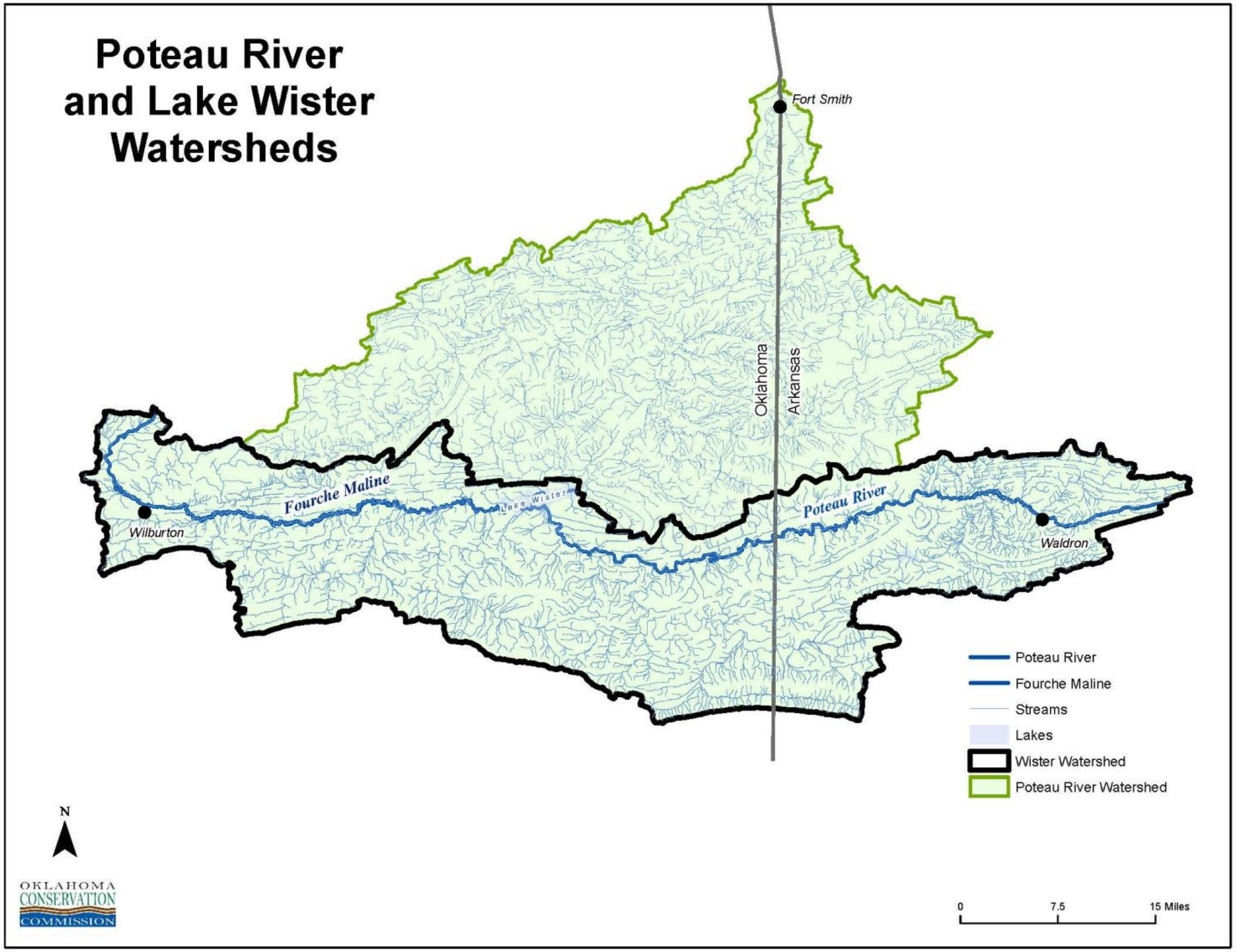


Figure 4: Poteau River and Lake Wister watersheds

The Lake Wister watershed, with an area of 2,572 km^2 (993 mi^2 or 635,520 acres) encompasses just over half of the Poteau River watershed area. The Oklahoma Lake Wister watershed is located in LeFlore and Latimer counties. Lake Wister and the Oklahoma portion of its watershed are located within the Choctaw Nation of Oklahoma.

Climate of Project Area

Climate in the Lake Wister watershed area is temperate, with a mean annual temperature of 60.3^0 F. On average, temperatures 90^0 F or higher occur 60 days per year, while days where the highest temperature is less than 32^0 F occur three days per year. The total average annual precipitation in LeFlore County is 49.9 inches. The average growing season is 211 days (Oklahoma Climatological Survey, 2017).

Ecological context

Lake Wister is located in the Arkansas Valley ecoregion, #37 on the US EPA's Level III and Level IV Ecoregions map (USEPA, 2013) (Figure 5). Lake Wister lies just north of the Winding Stair Mountains, the northernmost range of the Ouachita Mountains (Ecoregion #36) in Oklahoma. The Poteau River begins in the Ouachita Mountains, but quickly descends into the Arkansas Valley. Some tributaries to the Poteau River also rise in the Ouachita Mountains before descending into the Arkansas Valley. The second major stream entering Lake Wister is the Fourche Maline (the "bad or evil fork"). The Fourche Maline rises on the slopes of the San Bois Mountains above the town of Wilburton, Oklahoma, and then like the Poteau, quickly descends into the lowlands at the foot of the hills. The Fourche Maline is located almost entirely within the Arkansas Valley ecoregion. The Fourche flows east to Lake Wister. Lake Wister was constructed just downstream of the former confluence of the Fourche Maline with the Poteau.

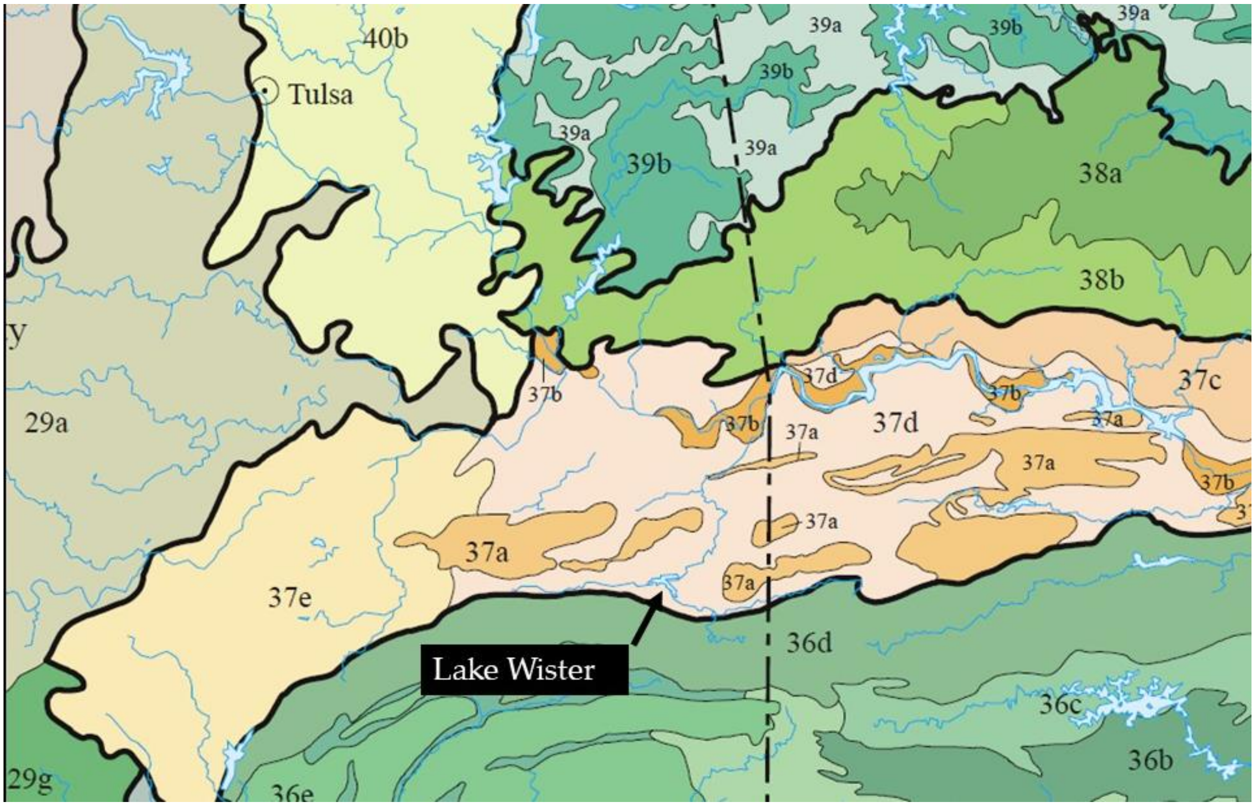


Figure 5: US EPA Level IV Ecoregions for the project area (USEPA, 2013)

Despite a long history of human use and degradation, streams in the Poteau River watershed remain ecologically rich. The Poteau River supports 35 species freshwater mussels (Vaughn & Spooner 2004), which is over 60% of the 55 species known for the entirety of the State of Oklahoma. Oklahoma Conservation Commission fish sampling in the Fourche Maline indicates that fish diversity and biological integrity supported by the Fourche Maline are among the highest in the state (OCC 2017).

The Arkansas Valley ecoregion is essentially the same area as the geological region known as the Arkoma Basin. The Arkoma Basin was created as the sinking front wave of the Ouachita Mountains as they were being pushed up from the south by plate tectonics. Landforms within the Arkoma Basin are an irregular series of ridges and valleys. Today the ridges are mostly forested and the valleys most pasture. Much of the pasture areas were formerly tallgrass prairie, and a few remnant patches of prairie remain, maintained by annual hay mowing.

All exposed rocks in the Lake Wister watershed are sedimentary in origin, and primarily consist of marine shales interbedded with sandstone and coal (Lindsay et al. 1974). The weathering of these shales produces clay particles that dominate in the lowland streams of the watershed, leading to high turbidities following storm events. This geology also contributes to the fact that even streams relatively unimpacted by human activities have considerably lower dissolved oxygen levels in the Arkansas Valley than adjacent ecoregions, and, hence, support different biological communities (USEPA, 2013).

Topographically, LeFlore County ranges from nearly level flood plains along major creeks and rivers to steep mountainous areas. The Poteau River watershed drains most of LeFlore County, north of the Winding Stair Mountains. (The southernmost portion of the county drains to the Kiamichi River and thence to the Red River.) The lowest point in the county is along the Arkansas River and is about 128 m (420 ft) above sea level. Elevation of the valley areas ranges from 142 m (465 ft) in the north end of the county to 280 m (920 ft) in the south end of the county. The ridges and mountains range in elevation from 213 m (700 ft) to nearly 732 m (2,400 ft) (USDA 1983).

Latimer County lies primarily within Arkansas Valley ecoregion. The topography ranges from level on the flood plains of Gaines Creek and Fourche Maline Creek to steep in the San Bois Mountains. The general slope is to the south and east. Most of the eastern part of Latimer County is drained by the Fouche Maline. The average elevation is approximately 366 m (1200 ft) and the lowest point in the county (155 m or 510 ft) is on the Latimer-LeFlore County line where the Fourche Maline leaves the county (USDA, 1981).

The Neff-Kenn-Ceda soil association is found along the floodplains of the Poteau River, Fourche Maline Creek, and other streams in the basin. These loamy floodplain soils are nearly level to gently sloping, and moderately well-drained to well-drained. They have loamy subsoils, with cobbly and loamy underlying layers. The south side of Lake Wister is dominated by the Stigler-Shermore-Wister association. These are deep, nearly level to sloping moderately well-drained loamy soils that consists of loamy or clayey subsoil. This soil is found over colluvium and shale on uplands (USDA, 1983).

Historical Description of Project Area

The waterways of the Poteau River watershed have been of major importance for human occupation for thousands of years. One period of high numbers of people occupying the area was from around 1500 BCE (Before Current Era = BC) to around 900 CE (Current Era = AD). This encompasses regional archaeological phases known as the Wister and the Fourche Maline (Shingleton, 2014, Galm, n.d., Vehik, n.d.) This was a time abundant human occupation with people making significant use of stream and wetland habitats for subsistence. Dark, accretional midden mounds are (or were) a common feature along the Fourche Maline and the Poteau River in the Lake Wister area (Vehik, n.d.). Freshwater mussel shells are abundant in many of these middens and date to between 3,500 and 1,000 BP (White, 1977). Hundreds of archaeological sites have been found around Lake Wister that date to this time period. In 1975, most of the floodpool of Lake Wister was placed on the National Register of Historic Sites as the *Lake Wister Archaeological District* (SHPO, 2021).

Figure 6: Canoe paddler on engraved shell (replica). (Photo: Spiro Mounds Archaeological Center, LeFlore County, Oklahoma)

Beginning around 900 CE, following the Fourche Maline Phase, the Mississippian-era city of Spiro was constructed near the floodplain of the Arkansas River about 9 miles upstream on the Arkansas River from where the Poteau River enters the Arkansas. Spiro was one of the largest cities in North America in pre-European times, with a population in the city itself of some 10,000 people at its peak (Singleton and Reilly, 2020). Spiro was connected to most of the rest of North America via a vast trade and tribute network. Items found at Spiro include colored flint from New Mexico, copper from the Great Lakes, conch shells from the Gulf Coast, and mica from the Carolinas (Singleton and Reilly, 2020). Much of that transportation took place via dugout canoes rivers and streams (Hartmann, 1996) as depicted on the artwork in Figure 6.

Many changes have occurred to aquatic systems over the last 200 years. Bridges were constructed, stream channels straightened, and wetlands drained. We have no specific information to quantify the extent of local wetland drainage. But, by our best estimate wetlands at the beginning of European occupation occupied some 6.4% of the area of Oklahoma (Dahl, 1990). By 1980 that had been reduced to 2.1% (Dahl, 1990). Since wetlands were more common in eastern than western Oklahoma, and, given the abundance of oxbow lakes in the Poteau River bottomlands, it is reasonable to suppose that the loss of wetlands in the Wister watershed equaled or exceeded the statewide average.

The completion of Lake Wister dam in 1949 by the US Army Corps of Engineers for flood control purposes dramatically changed Poteau River hydrology and ecology and ushered in a new era of water infrastructure in the region. Most of LeFlore County north of the Winding Stair Mountains now relies on Lake Wister to supply water for domestic, business, and industrial uses.

Watershed and Lake Hydrology

The Poteau River watershed is a USGS HUC 8 (Hydrologic Unit Code - 11110105) watershed, a subwatershed of the Arkansas River watershed. Within the Oklahoma portion of the Lake Wister watershed there are 26 HUC 12-scale subwatersheds that range in size from 42 to 125 km^2 (10,300 to 30,800 acres) (Figure 7). The Oklahoma Nonpoint Source Management Program Plan recognizes these smaller scale watershed areas to be an appropriate scale for watershed restoration action--for planning, implementation, and effectiveness monitoring (OCC, 2019). In support of this approach, OCC and PVIA sponsored approximately three years of baseflow water quality monitoring at the HUC 12 scale across the Oklahoma portion of the Lake Wister watershed (see Chapter 3 for more on this sampling effort).

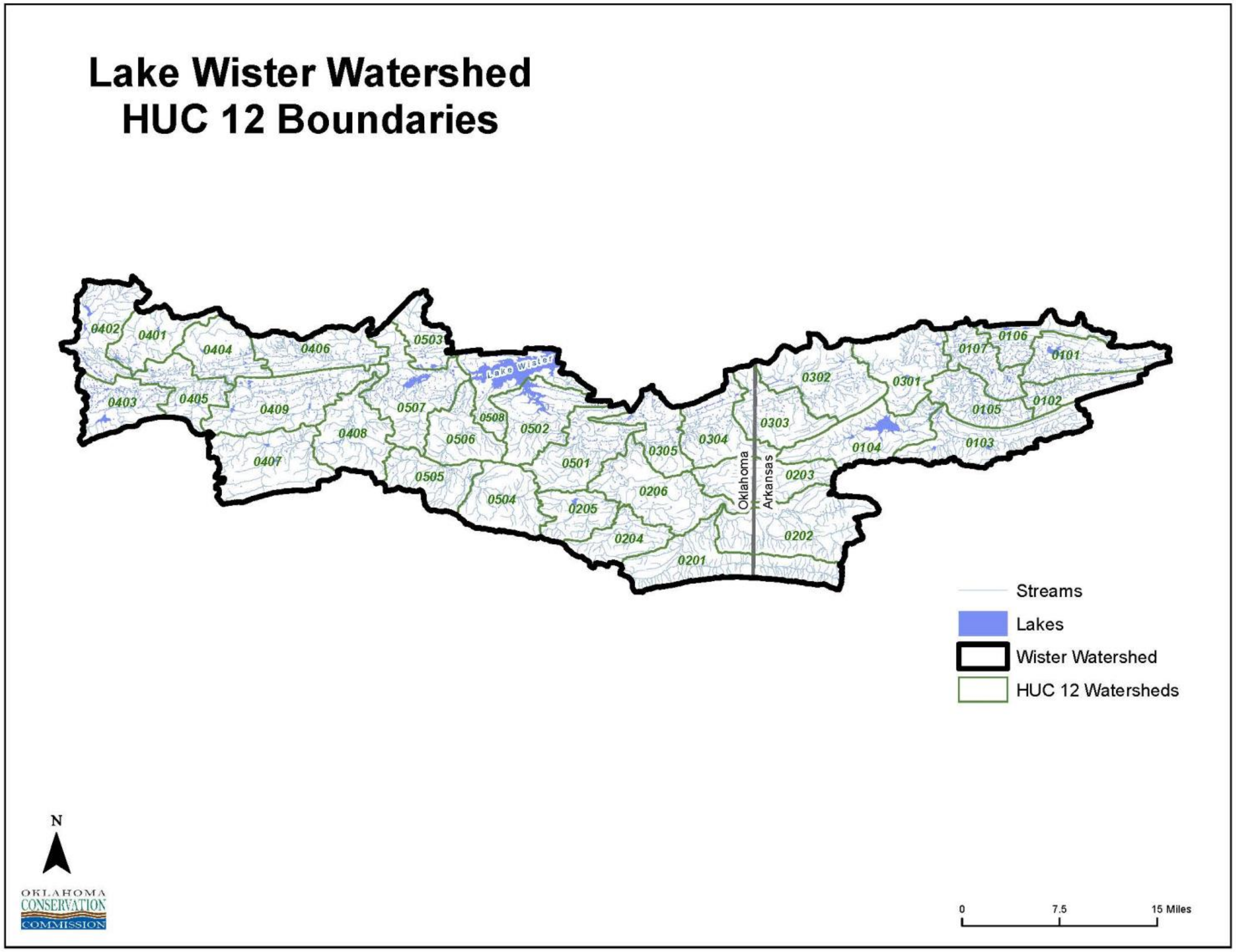


Figure 7: Lake Wister watershed HUC 12 boundaries

At its conservation pool elevation of 145.7 m (478 ft), Lake Wister has an average depth of 2.4 m (8 ft) resulting in storage of approximately 6.23 x 10^7 m^3 water (50, 529 acre-feet) (OWRB, 2011). The surface area of the lake can increase by almost four times at maximum flood pool (Figure 8), resulting in a potential cumulative storage of 4.81 x 10^8 m^3 (390,215 acre-feet) of water (USACE, 2021).

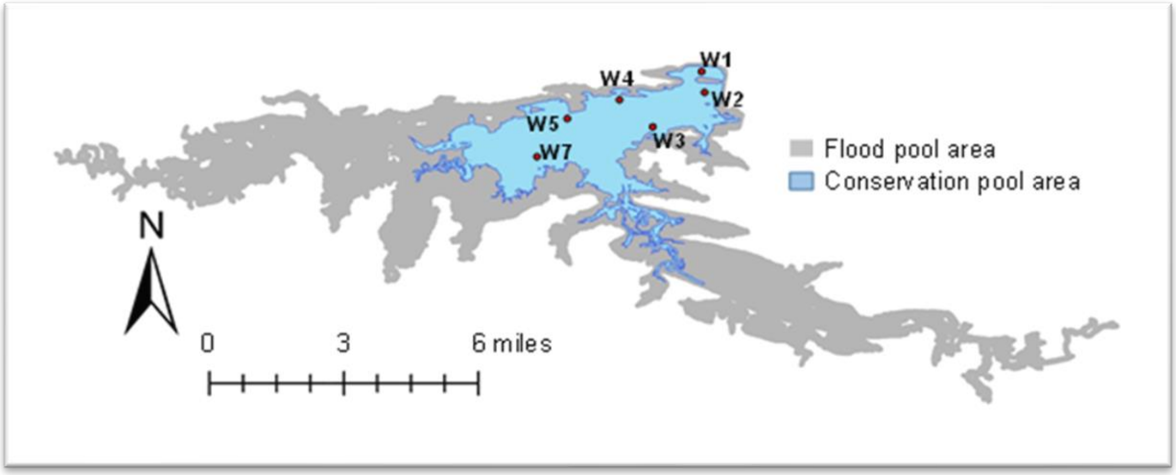


Figure 8: Lake Wister and its flood pool. Gray area represents flood pool of the lake and blue represents the conservation pool. Lake monitoring stations are also shown (W1-W7).

The ratio of watershed area to lake area provides an indication of the likelihood of water quality issues in a lake or reservoir. For instance, very clear, low nutrient Lake Tahoe has a ratio of less than 3:1. On the other hand, Lake Wister's watershed area to lake area ratio is approximately 100:1. Lake Wister receives water from approximately 2,572 km^2 (993 mi^2) (USACE, 2021) and the lake surface area is just under6,400 acres. A watershed area to lake area ratio of 100:1 means that for every surface acre of the lake, runoff from 100 acres of land enters the lake; consequently, Lake Wister must process a high quantity of runoff relative to its size.

Land Use in the Watershed

The primary land uses and land cover across the Oklahoma Lake Wister watershed are forest (72%), agriculture (19%), and urban (4%) (Austin et al, 2018a) (Figure 9). The Ouachita National Forest comprises 234,326 acres of the Wister watershed (OWRB 1996); approximately 111,600 acres of this is in the Oklahoma portion. The 19% agriculture is composed almost entirely grassland and pasture; there is very little cropland. The category Urban as used here includes small amounts of barren, developed-open space, and low, medium, and high intensity development.

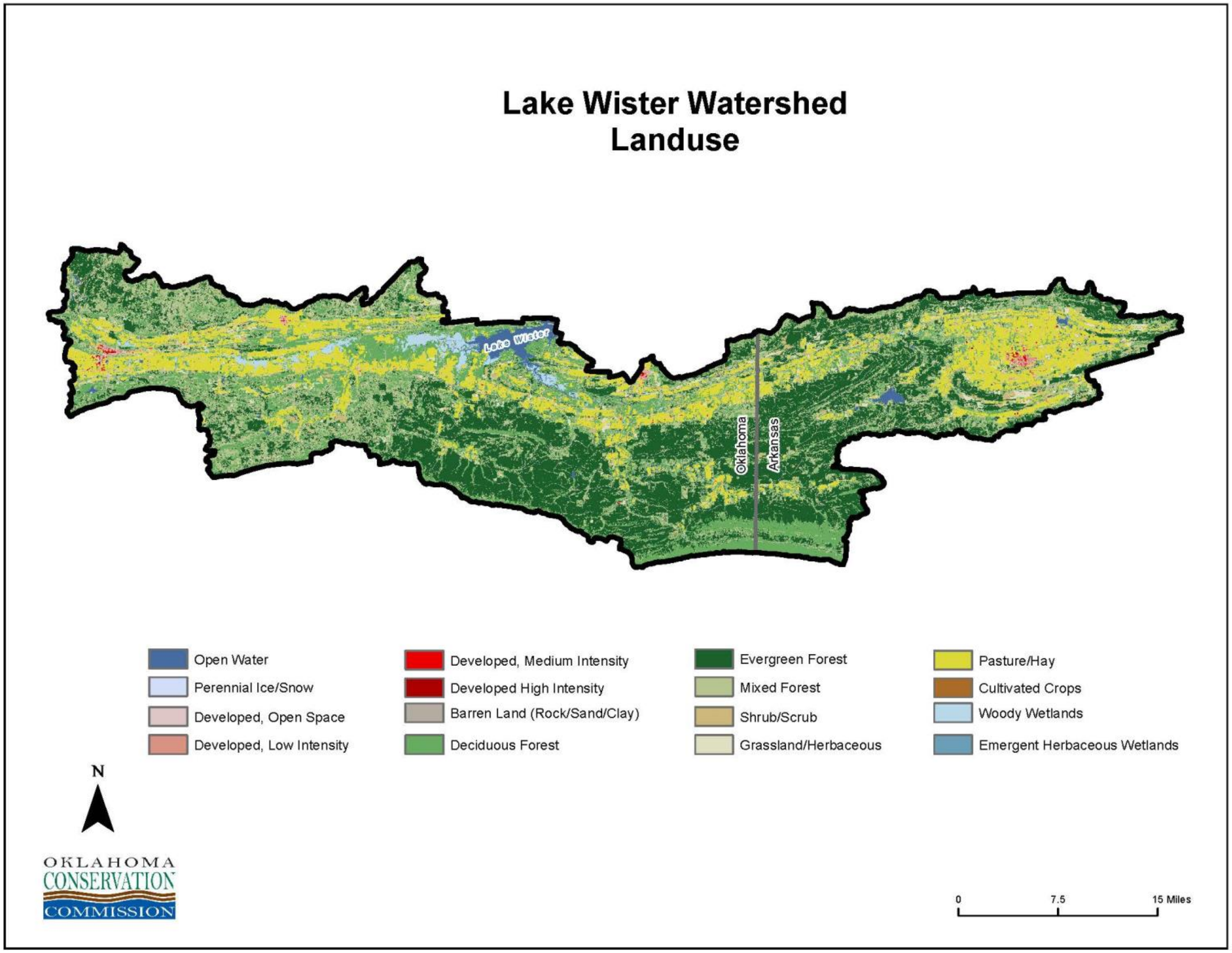


Figure 9: Lake Wister watershed landuse

Poultry and beef production are the main agricultural endeavors in the Lake Wister watershed, and the two activities are frequently related. A primary method of disposal of chicken litter has been application to pastures to improve grass production for cattle (see Chapter 3). In 2019, there were 47,000 head of beef cattle reported for LeFlore County and 17,000 for Latimer (NASS & ODAFF, 2019). The 2019 NASS & ODAFF report withholds poultry numbers for LeFlore County. As of June 2017, there were 142 farms, with 435 poultry houses, and a licensed bird capacity of 12,522,939 birds (not all houses are full at any one time) reported for LeFlore County; three farms, nine houses, and a 212,100 bird capacity were reported for Latimer County (ODAFF, 2017). In 2009, there were 451 poultry houses in the Lake Wister watershed—220 in Oklahoma and 231 in Arkansas (PVIA, 2009; based on a Google Earth aerial photo analysis). The number of houses may have declined since that time, though not necessarily the number of chickens produced, as some producers have gone out of business, but new poultry houses being constructed are significantly larger (J. Britton, pers. com.).

History of Water Quality Degradation

Lake Wister was created in 1949. So far as is known, the first water quality sampling in the lake took place about 25 years later in 1974 as part of a nationwide lake assessment project by the recently created US EPA (USEPA, 1977). Those samples indicate that Lake Wister would have met today's Oklahoma chlorophyll-*a* standard for drinking water supplies of 10 ug/l. The lake was sampled quarterly in two locations. The highest chlorophyll-*a* measurement was 8 ug/l; the average of all samples was 5 ug/l.

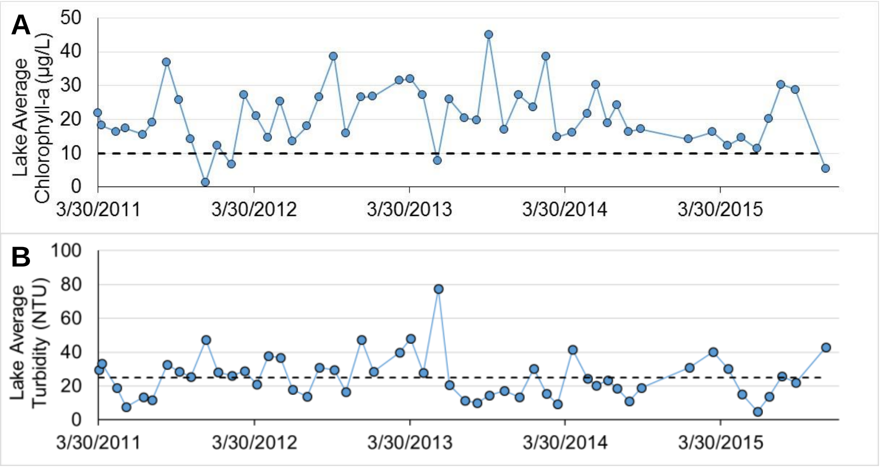


Figure 10: Whole lake average A) chl-*a* concentrations and B) turbidity from the five PVIA monitoring locations on Lake Wister from 2011-2015 (Scott and Patterson, 2019)

In the 45-plus years since that time, water quality in the lake has degraded significantly. The five-year average (2011-2015) for chlorophyll-*a*, analyzed for the TMDL report, was 20 ug/l, four times the 1974 level (Scott and Patterson, 2019). Both point source and nonpoint sources contributed to this decline.

By the early 1990s, water quality degradation in Lake Wister had become particularly noticeable and began to increase drinking water treatment costs and cause more frequent taste and odor problems in the finished water. A Federal Clean Water Act 314 Phase I Diagnostic-Feasibility Study documented problems in the reservoir, including low dissolved oxygen, excessive suspended solids, and nutrient pollution from the watershed (OWRB, 1996).

Since 1998, Lake Wister and stream segments in the watershed have been on Oklahoma's 303(d) list of impaired waters. A significant algae bloom in 1998, and additional blooms in 2003 and 2005, brought problems in the lake into public awareness (Figure 11). In 2006, Lake Wister was designated as a nutrient-limited watershed (NLW) and a chlorophyll-*a* criterion of 10 µg/L at a depth of 0.5 m below the surface was established (OAC 785:45-5-10(7)) (OWRB 2015). Also in 2006, Oklahoma State University completed watershed modelling that indicated pastureland was the dominant source of total phosphorus and sediment in the lake (Storm, White and Busteed, 2006).

Figure 11: 1998 algae bloom at Lake Wister

Since 2007 a significant portion of poultry litter produced in the watershed has been sold outside of the watershed (See Chapter 3, below). The apparent reduction in chicken litter application to watershed soils since around 2007 has contributed to an improvement in lake water quality. The 1998-2005 heavy blooms have not recurred in the lake since 2005.

However, in spite this apparent movement towards improvement and extensive research that has improved understanding of lake processes, Lake Wister continues to be impaired for sediment, total phosphorus, and chlorophyll-*a*. In 2019, Scott and Patterson completed a lake modeling effort and made recommendations for total maximum daily loads (TMDLs) for Lake Wister. The TMDL is currently under review by the Oklahoma Department of Environmental Quality.

CHAPTER 3: IDENTIFICATION OF CAUSES AND SOURCES OF IMPAIRMENTS

Causes of Impairments

Four designated beneficial uses for Lake Wister are currently listed as non-supported, as seen below in Table 1:

Table 1: Beneficial uses that are not supported and causes of impairment

Beneficial Uses that are Not Supported	Cause of Impairment
Public and Private Water Supply	Chlorophyll-*a*
Fish and Wildlife Propagation-Warm Water Aquatic Community (WWAC) Subcategory	Turbidity, pH
Aesthetics	Total Phosphorus
Fish Consumption	Mercury

(ODEQ, 2018)

Among the causes of these impairments, the chlorophyll-*a*, total phosphorus, and turbidity impairments are interrelated. Chlorophyll-*a* is measured as a way to estimate the amount of phytoplankton (that is, algae and cyanobacteria) in the lake. According to the lake model, total phosphorus is the primary driver of the chlorophyll-*a* impairment. As a result, the total phosphorus impairment and the chlorophyll-*a* impairment have the same sources.

Turbidity is caused by suspended materials in the water column. Those materials may be either mineral (i.e., sediment) or organic. To reduce turbidity, the quantity of these suspended solids must be reduced.

Phytoplankton biomass tends to increase as phosphorus increases and decrease as turbidity increases. Phytoplankton also contributes an organic component to turbidity. Increased turbidity tends to result in decreased chlorophyll-*a* because phytoplankton biomass is limited by the reduced light penetration into the water column. Turbidity and total phosphorus may also be positively correlated because phosphorus tends to attach to sediment particles.

Other Impairments and Potential Impairments

pH. This WBP does not address the pH or mercury impairments. Low pH in southeastern Oklahoma streams is widely considered by state biologists and water quality scientists to be the result of naturally acidic soils and low buffering capacity in waterbodies of the region rather than a true water quality impairment (cf. OWRB, 2009). Geology in the region is dominated by shale and sandstone with very little limestone to provide any buffering. The species richness and diversity of the fauna in southeast Oklahoma streams, particularly with regard to fishes, supports the general consensus that a relatively high pH is a natural condition, and not the result of a pollutant.

Mercury. The mercury impairment is categorized as a 5C impairment, which means that additional data should be collected prior to completing a TMDL. The mercury impairment is likely due to atmospheric deposition, but not enough data are available to definitively identify sources of impairments, required load reductions or best management practices necessary to achieve required load reductions (Wright, 2019).

Nitrogen. There is an increasing emphasis on nitrogen as a co-limiting nutrient in aquatic systems (Elser et al., 1990; Elser et al., 2007). Although there may be periods of the year when nitrogen is the limiting nutrient in Lake Wister, the results of the model used to develop TMDL recommendations for Lake Wister indicate that reducing nitrogen (either alone or in combination with total phosphorus) would have little effect on long-term chlorophyll-*a* values, beyond the effect expected from the reduction of total phosphorus alone. Therefore, nutrient reduction efforts in this WBP focus on phosphorus.

Dissolved Oxygen. Lake Wister is not listed for Dissolved Oxygen (DO) in the most recent Integrated Report (ODEQ, 2018). It has, however, been listed in some previous assessments, as, for example, in the 2006 Integrated Report (ODEQ). Low DO is a problem at the lake and is related to the total phosphorus and chlorophyll-*a* impairments.

High nutrients fuel algae and cyanobacterial growth in the lake, when these organisms die and fall to the bottom their subsequent decomposition leads to oxygen depletion when the lake is stratified. Lake Wister is considered a polymictic lake, that is, the lake mixes irregularly, and often more than once per year.

In some years, stratification is strong and low DO conditions persist throughout the summer, often from April through September. In other years, weaker stratification or strong storms may mix the lake one or more times during the summer. When the lake mixes, it allows oxygenated water to reach the bottom of the lake and temporarily improve DO conditions throughout the water column. Generally, stratification and low DO conditions begin to set up again very quickly once the storm or other mixing event is over. Therefore, the DO conditions in the lake at any point in time are strongly linked to how recently the lake has mixed, and mixing events occur at irregular and unpredictable times.

The Oklahoma Water Quality Standards consider low dissolved oxygen in relation to maintaining fish and wildlife habitat. Low DO also impacts water quality in ways that directly affect drinking water treatment. Water plant personnel must respond quickly when low oxygen water reaches plant intake pipes in order to ensure continued delivery of clean, safe drinking water. Under low DO conditions iron, manganese, and hydrogen sulfide may be released and their removal during water treatment may cause problems for plant operation. If not addressed promptly, problems can cascade in the distribution system. Therefore, improvement in DO conditions in the lake is important for fish and wildlife and water supply. It is anticipated that improvement in DO conditions in the lake will occur as nutrient supply to the lake is reduced.

Identification of Sources

2019 TMDL

The TMDL for Lake Wister (Scott and Patterson, 2019) identifies overgrazed pastures, unpaved roads, eroding streambanks, and lake shoreline erosion as likely sources of suspended solids in watershed streams and the lake, and therefore to the turbidity impairment. Because phosphorus is often attached to soil particles, these eroding soils also contribute to the total phosphorus impairment.

Beyond eroding soils, other sources of total phosphorus include point source contributions from wastewater treatment plants (WWTPs) and animal waste (primarily poultry and beef production). Cumulatively, WWTPs in the Wister watershed contribute approximately 8% of the total phosphorus load (Scott and Patterson, 2019).

Animal waste may runoff directly from cattle operations and from areas where chicken litter is spread to fertilize pasture. Phosphorous from land-applied poultry litter and cattle waste also enters the soil and attaches to soil particles. Soil erosion from pastures therefore carries phosphorous into watershed streams and Lake Wister.

The long history of chicken litter application to watershed soils has created one of the major sources of phosphorus in streams and the lake. Litter application started more than two decades before records began to be kept in 2001. Between 2001 and 2017 over 14.5 million pounds of phosphorus were applied to LeFlore County pasture soils via poultry litter (Table 2). Since 2017 the State of Oklahoma no longer compiles or releases chicken litter production and application records (Rice, 2021).

Table 2: Poultry litter produced and applied, LeFlore County, OK (OCC 2002-2015 and ODAFF 2017).

Year	Poultry Litter Produced (Tons)	Poultry Litter Applied (Tons)	Phosphorus Applied* (Pounds)	Phosphorus Applied (kg)
2001	58,469	57,278	1,718,340	781,064
2002	37,592	36,990	1,109,700	504,409
2003	31,998	32,207	966,210	439,186
2004	38,295	36,314	1,089,420	495,191
2005	46,714	42,419	1,272,570	578,441
2006	49,552	36,575	1,097,250	498,750
2007	46,512	53,824	1,614,720	733,964
2008	40,001	30,382	911,460	414,300
2009	45,270	32,025	960,750	436,705
2010	36,492	26,780	803,400	365,182
2011	34,030	23,714	711,420	323,373
2012	36,696	21,589	647,670	294,395
2013	78,767	9,596	287,880	130,855
2014	28,459	13,928	417,840	189,927
2015	45,244	16,150	484,500	220,227
2016	50,738	9,766	292,980	133,173
2017	35,045	6,359	190,770	86,714
Totals	**740,874**	**485,896**	**14,576,880**	**6,625,855**

*Phosphorous calculated at 1.5% by weight

The TMDL report (Scott and Patterson, 2019) likewise identifies beef and poultry production and pasture management (particularly the application of poultry litter to pastures) as important nonpoint sources of total phosphorus and sediment. The long history of chicken litter application to Wister watershed soils is the likely cause of the results seen in the SWAT modeling (cf. 2006 SWAT Model, below).

Unpaved roads and eroding ditches can be sources of sediment erosion, and efforts to address these will be a part of watershed restoration actions. In the Lake Wister watershed, most of the erosion resulting from unpaved roads occurs in forested areas. Much of the forestland in the watershed is under federal (Ouachita National Forest) which has its own erosion control and watershed protection regulations. The Oklahoma Department of Agriculture, Food and Forestry (ODAFF) Forestry Division works with private forest landowners in the watershed and they have their own set of BMPs to minimize soil erosion from harvest activities including road building. These conclusions suggest that BMPs which address pasture management and the maintenance of unpaved roads should be prioritized.

2018 Integrated Report

The 2018 Integrated Report (ODEQ 2018) does not identify sources of any of the impairments for Lake Wister. Each impairment is coded as 140 which means "source code unknown."

2019 Oklahoma Lakes Report

The 2019 Oklahoma Lakes Report: Beneficial Use Monitoring Program (OWRB, 2019) includes 2015 and 2016 monitoring data for Lake Wister. Turbidity, pH and chlorophyll-*a* are identified as causes of impairment. The report does not attempt to document sources of impairment.

2006 SWAT Model

A SWAT model was completed for Lake Wister in 2006 (Storm, White and Busteed, 2006). The results indicated that while pastureland accounted for only 15% of the land area in the basin at that time, 90% of total phosphorus load and 85% of the sediment load originated from pastureland.

Oklahoma HUC 12 Subwatershed Monitoring

A water quality monitoring effort focused on the HUC 12-scale subwatersheds in the Oklahoma Lake Wister watershed was conducted from July 2016 through May 2019 by the University of Arkansas, under the direction of PVIA and OCC (Austin et al, 2018a; Austin et al, 2019a). Baseflow stream sampling was conducted monthly near the outflows of 21 of the 26 Oklahoma Lake Wister HUC 12 subwatersheds (Table 3) (Refer to Figure 7 in Chapter 2 for map). The purpose of this sampling effort was to develop information to assist in prioritization of subwatersheds for BMP implementation, and, to provide a baseline against which to measure improvements in the future. (In addition to the two project reports cited above, this work is also described in three published reports (Austin et al, 2018b; Austin et al, 2018c; and Austin et al, 2019b)).

Table 3: HUC 12 watersheds in the Oklahoma portion of the Lake Wister watershed

HUC 12 Number	Last 4 digits	HUC12 Watershed Name	Austin Sample Site #	Watershed Area (km2)	Watershed Area (mi2)
HUC10 - 11110100502: Black Fork Poteau River					
111101050201	0201	Big Creek	11	117.7	45.4
111101050202	0202	Upper Black Fork	10	124.5	48.1
111101050203	0203	Haws Creek	12	73.5	28.4
111101050204	0204	Shawnee Creek	13	50.2	19.4
111101050205	0205	Cedar Creek	26	49.8	19.2
111101050206	0206	Lower Black Fork	14	100.4	38.8
HUC10 - 11110100503: Upper Poteau River			15		0.0
111101050303	0303	Cane Creek		70.4	27.2
111101050304	0304	Sugar Creek	1	71.3	27.5
111101050305	0305	Hontubby Creek	2	55.5	21.4
HUC10 - 11110100504: Fourche Maline			3		0.0
111101050401	0401	Cunneo Creek-Fourche Maline		55.5	21.4
111101050402	0402	Coon Creek-Fourche Maline	25	74.4	28.7
111101050403	0403	Bandy Creek	24	61.6	23.8
111101050404	0404	Little Fourche Maline	23	61.8	23.9
111101050405	0405	Clear Creek-Fourche Maline	21	56.1	21.7
111101050406	0406	Red Oak Creek	22	73.2	28.3
111101050407	0407	Upper Long Creek	20	103.8	40.1
		Long Creek tributary - extra site	17		0.0
111101050408	0408	Lower Long Creek	18	78.2	30.2
111101050409	0409	Pigeon Creek-Fourche Maline	16	110.5	42.7

HUC 12 Number	Last 4 digits	HUC12 Watershed Name	Austin Sample Site #	Watershed Area (km2)	Watershed Area (mi2)
HUC10 - 11110100505: Middle Poteau River			19		0.0
111101050501	0501	Coal Creek - Poteau River		83.0	32.0
111101050502	0502	Upper Holson Creek		77.7	30.0
		Conser Creek	4		
			8		
111101050503	0503	Coal Creek - Fourche Maline	9	41.6	16.1
111101050504	0504	Middle Holson Creek	5	73.0	28.2
111101050505	0505	Lower Holson Creek	6	59.1	22.8
111101050506	0506	Cedar Creek - Fourche Maline	7	59.5	23.0
111101050507	0507	Baker Branch-Fourche Maline		97.6	37.7
111101050508	0508	Wister Lake Dam		75.5	29.2

Geometric means of total phosphorus concentrations in monthly samples in subwatershed streams ranged from 0.010 mg/L to 0.247 mg/L. Total suspended solids geometric means ranged from 1.2 mg/L to 30.7 mg/L (Austin et al, 2019a).

Causes and Sources in the Arkansas Portion of the Watershed

As previously noted, the Lake Wister watershed is a bistate system. While this watershed based plan is focused on the Oklahoma component of the watershed, it is important to recognize that a significant portion of the Lake Wister watershed (ca. 40%) lies upstream in Arkansas.

The State of Arkansas has considered the Poteau River watershed within its borders as a priority watershed for many years. The Poteau River continues to be prioritized in the most recent Arkansas Annual Report (ADADNR, 2021).

2005 ADEQ TMDL

In 2005, Arkansas promulgated a TMDL for total phosphorus, as well as for zinc and copper, for a reach of the Poteau River in Arkansas (AR_11110105_031). A total phosphorous TMDL remains in place for this reach as a Category 4a waterbody—Impaired with a TMDL—in the most recent Arkansas Integrated Report (AEE, 2018).

The impaired reach is approximately 22 miles upstream of the Arkansas-Oklahoma state line. The total phosphorus TMDL developed was 47.73 lb./day, approximately equally apportioned between point sources and nonpoint (22.73 and 20.23 lb./day, respectively) (FTN, 2005). Based on this TMDL, phosphorous discharge limits were established for the City of Waldron WWTP and for the Tyson Foods Inc. Waldron Facility of 1.0 mg/l and 1.5 mg/l, respectively (FTN, 2005). An instream numeric criterion of 0.1 mg/L for total phosphorus was used to establish the TMDL. As in the Oklahoma portion of the watershed, cattle and poultry production were identified as important nonpoint sources of total phosphorus in the watershed. In the Integrated Report, the source of contamination is reported as *Industrial Point Source* (AEE 2018).

2018 Poteau River Monitoring and Assessment Report

A range of water quality sampling efforts were conducted in the Arkansas Poteau River watershed between January 2017 and May 2018 (GBMac, 2018). The primary objective was to collect physio-chemical data from the major drainages in the Arkansas portion of the Poteau River watershed, quantify loadings of nutrients and sediment, and delineate possible sources of impairments. This assessment concluded that the City of Waldron WWTP and the Tyson Foods facility in Waldron are point sources of nutrients and turbidity. Possible nonpoint sources of nutrients and turbidity identified varied between stream segments but included cattle land runoff, poultry runoff, mining site runoff, compromised riparian buffers, streambank erosion and urban runoff from Waldron. The results of this assessment will be used to develop a nine-element watershed management plan for the Poteau River in Arkansas with completion scheduled for December 2022 (ADADNR, 2021).

Conclusions of Data Analysis from Prior Studies and Recent Monitoring Efforts

PVIA has conducted monthly monitoring of Lake Wister continuously from March 2011 to the present, and the USGS has sampled the inflows to the lake on the Poteau River and the Fourche Maline since late 2010. The USGS summarized their methods and the results of their first three years of monitoring in a report (Buck, 2014). More information regarding lake monitoring protocols may be found in Patterson (2015).

The results of these sampling efforts from 2011 to 2015 were the basis on which the lake modeling and TMDL recommendations were developed. Monitoring results are summarized in the modeling report (Scott and Patterson, 2019). Data collected since 2015 (not included in the TMDL report) continue to support the conclusion that Lake Wister is impaired for turbidity, total phosphorus, and chlorophyll-*a*.

CHAPTER 4: TARGET LOADS FOR TOTAL PHOSPHORUS AND TOTAL SUSPENDED SOLIDS

Recommended TMDLs for phosphorous and suspended solids were developed using ELCOM-CAEDYM, a three-dimensional hydrodynamic and water quality model that simulates thermal stratification, mixing, horizontal and lateral hydraulic variation and water quality dynamics in lakes and reservoirs (Scott and Patterson, 2019). The model was calibrated and validated with five years of stream and lake data collected by the US Geological Service (stream inflows to the lake) and Bio x Design and PVIA (in-lake sampling). Please see Scott and Patterson (2019) for detailed descriptions of model development, calibration, validation, and results.

Applicable Thresholds and Criteria

The applicable threshold for total phosphorus and criteria for chlorophyll-*a* and turbidity are listed in Table 4:

Table 4: Beneficial uses and applicable criterion or threshold for assessment of use support

Designated Beneficial Use	Criterion or Threshold	Citation in OWQS
Public and Private Water Supply	Average chlorophyll-*a* concentration of no more than 10 µg/L 0.5 m below the surface	OAC 785:45-5-10(7)
Fish and Wildlife Propagation-Warm Water Aquatic Community (WWAC) Subcategory	No more than 10% of the measurements exceed a turbidity of 25 NTU	OAC 785:45-5-12(7)(A)(ii)
Aesthetics	Free of objectionable floating mater, suspended materials, and color.	OAC 785:45-5-19

Lake Wister is listed for chlorophyll-*a* because its average chlorophyll-*a* measurement exceeds the chlorophyll-*a* criterion of 10 µg/L established for Lake Wister and other designated lakes (OAC 785:45-5-10(7)) (OWRB 2015).

Lake Wister is listed for turbidity in accordance with OAC 785:45-5-12(7)(A)(ii). Turbidity is a measure of relative water clarity rather than a pollutant concentration, and so does not lend itself to the calculation of loads or load reductions. Total suspended solids (TSS) is used as a surrogate for turbidity.

The criteria for the Aesthetics beneficial use is a narrative standard (OAC 785:45-5-19) (OWRB 2015):

> (a) To be aesthetically enjoyable, the surface waters of the state must be free from floating materials and suspended substances that produce objectionable color and turbidity.
>
> (b) The water must also be free from noxious odors and tastes, from materials that settle to form objectionable deposits, and discharges that produce undesirable effects or are a nuisance to aquatic life.
>
> (c) The following criteria apply to protect this use: *Color*. Surface waters of the state shall be virtually free from all coloring materials which produce an aesthetically unpleasant appearance. [A second criteria is also listed that applies only to Scenic Rivers and therefore, not to Lake Wister.]

The Lake Wister watershed is also considered a "nutrient-limited watershed" (OAC 785:45-5-29(11)) (OWRB 2015). In Oklahoma, a "nutrient-limited watershed" is the watershed of a waterbody with a designated beneficial use which is adversely affected by excess nutrients as determined by Carlson's Trophic State Index (using chlorophyll-*a*) of 62 or greater (OAC 785:45-1-2) (OWRB 2015).

Existing and Target Loads

Data collected between 2011 and 2015 indicate an average chlorophyll-*a* concentration of 20.8 ± 11.1 µg/L, approximately twice the Oklahoma Water Quality Standards criterion. During the same period, 43% of the turbidity measurements were above the criterion. The average turbidity of samples above the criterion was 39.2 NTU.

Lake modeling simulations indicate that a 78% reduction in the average total phosphorus (TP) load delivered to the lake will be required for the lake to meet the water quality standard. Simulations indicate that a 71% reduction in the average total suspended solids (TSS) load delivered to the lake will be required to meet the Oklahoma water quality standard (Scott and Patterson, 2019).

Estimated current loads, recommended TMDLs, margins of safety, and annual and daily target loads are shown in Table 5:

Table 5: Target load recommendations to meet water quality standards in Lake Wister (Scott and Patterson, 2019)

Pollutant	**Average Load** 2011-2015 (kg/yr)	**TMDL** (Annual Basis) (kg/yr)	**10% Margin of Safety** (kg/yr)	**Target Annual Load** (kg/yr)	**Target Daily Load** (kg/yr)
Total Phosphorus	221,787	48,793	4,879	43,914	120
Total Suspended Solids	142,560,053	41,342,415	4,134,242	37,208,174	101,940

Recommended Waste Load and Load Allocations

The total phosphorous and total suspended solid loads are primarily from nonpoint sources (Table 6), as discussed in Chapter 3. The recommended waste load allocation of total phosphorus for point sources is based on implementing a 1 mg/L total phosphorus discharge limit for all Oklahoma dischargers in the watershed.

Table 6: Target load and waste load recommendations to meet water quality standards in Lake Wister (Scott and Patterson, 2019)

	Total Phosphorus TMDL (kg/day)	**% Total Phosphorus TMDL**	**Total Suspended Solids TMDL** (kg/day)	**% TSS Total Load**
Waste Load Allocation	9.6	8.0	94.1	0.0009
Load Allocation	110.4	92.0	101,845.9	99.9991
Total	120.0	100.0	101,845.9	100.0

CHAPTER 5: MANAGEMENT MEASURES AND LOAD REDUCTIONS

Water quality modeling simulations developed for Lake Wister indicate that a 78% reduction in the average total phosphorus (TP) load delivered to the lake will be required for the lake to meet the Oklahoma Water Quality Standard of 10 µg/L of chlorophyll-*a* (chl-*a)* (Table 7). Model simulations further indicate that a 71% reduction in the average total suspended solids (TSS) load delivered to the lake will be required for the lake to meet the Oklahoma Water Quality Standard of no more than 10% of samples exceeding 25 NTU turbidity (Table 7).

Table 7: Required load reductions to meet water quality standards

Pollutant	**Average Annual Load** (kg/yr)	**Load Allocation** (kg/yr)	**Margin of Safety** (kg/yr)	**Target Annual Load Reduction** (kg/yr)	**Annual Load Reduction of 1%** (kg/yr)	**Annual Load Reduction of 2%** (kg/yr)
Total Phosphorus	221,787	48,793	4,879	177,873	1,779	3,557
Total Suspended Solids	142,560,053	41,342,415	4,134,242	105,351,879	1,053,519	2,107,038

Timeframe. These load reduction goals set a high bar. Achieving the necessary load reductions to achieve full support of beneficial uses for Lake Wister will not be achieved overnight. Rather, recognizing that it took many decades for water quality conditions in the lake to deteriorate to current conditions, we also recognize that it will likely take several decades to reverse degradation and achieve water quality standards.

However, lake modeling results also show that incremental improvements will benefit the lake. The lake model showed that the average chl-*a* concentration in the lake decreased by 0.12 µg/L for every 1% decrease in the external TP load and the long-term average turbidity decreased by 0.2 NTU in the lake for every 1% decrease in external sediment load (Scott and Patterson, 2019). Table 6 shows what the quantities of one percent and two percent load reductions are for both total phosphorus and total suspended sediment.A phosphorus load reduction averaging 2% per year would result in meeting water quality standards in 40 years. To improve Lake Wister, every little bit will help.

For example, the results of an early nutrient reduction effort in the Lake Wister watershed in the late 1990s was assessed through a SWAT model (Storm, White and Busteed, 2006). One successful reduction strategy was pond construction. It was estimated that construction of 134 ponds resulted in a reduction of total phosphorus to Lake Wister of approximately 1.8% (Storm, White and Busteed, 2006).

There are other relatively straightforward actions capable of achieving a 2% reduction (see discussion below). These achievable reduction strategies will be targeted in early years of the watershed restoration effort. In the future, new ideas or new technologies may be discovered that will allow reductions beyond current typical BMPs.

Internal Loading. Modelling results detailed in the TMDL report indicate addressing the internal phosphorus loads the lake could contribute significantly to achieving water quality standards. A reduction of internal loading by 90% would be equivalent to an approximately 20% reduction in external load. This would be equivalent to 10 years of an annual 2% reduction, and reduce the time required to 30 years.

Point sources. Permitted point source dischargers in the Lake Wister watershed contributed an average 5,831 kg TP per year during the lake modeling period. This represented approximately 2.6% of the average TP load to Lake Wister for the 5-year lake modeling period. If all Oklahoma dischargers adopted and achieved a 1 mg/L TP discharge limit, the TP load to Lake Wister would decrease by an average of 2,338 kg/yr, slightly more than 1% of the current total phosphorus load to the lake. As noted, a 1% reduction in the total phosphorus load will result in a decrease in the long-term average chlorophyll-*a* concentrations in the lake of 0.12 µg/ (Scott and Patterson, 2019). This reduction would therefore achieve one-half of one year's annual two percent per year target.

Spatial priorities. The implementation of management measures in the watershed will be informed by the results of the HUC 12 monitoring discussed in Chapter 3. It is anticipated that initial programs will be implemented in a few HUC 12 scale watersheds. The HUC 12 monitoring data will provide a baseline against which to assess results. Successful activities will then be expanded as appropriate to additional subwatersheds.

Domains of Watershed Actions

It is useful to consider six domains as conceptual organizing principles for BMP implementation and other actions in the Wister watershed:

1. Chicken Litter Management

- Reduce applications of chicken litter to watershed soils
  - sell chicken litter outside of the watershed
  - support this movement out via tax subsidies
  - improve tracking and transparency

    - know with assurance how much litter is being applied and where
- Reduce available phosphorus in watershed soils
    - apply water treatment residuals (WTR) where appropriate
- Improve soil testing
    - implement a watershed-wide soil testing program to better define soil phosphorus levels
    - identify areas that could potentially benefit from chicken litter applications (rather than already having an excess)
    - if required, modify regulations to reduce allowable litter application rates
- Research and identify alternative chicken raising methods (e.g., pastured chickens) that reduce litter accumulations
- Combine this with improved soil health and pasture management practices to reduce nutrient and sediment movement from fields

2. Soil Health and Pasture Management

- Reduce soil erosion from cattle pastures, especially those with history of chicken litter application
    - increase grass cover year-round to reduce soil erosion and movement of nutrients and sediments from fields
    - research, demonstrate and promote potential economic benefits of improved soils and grasses

3. Field Buffers

- Grass buffers at edge of field
- Native prairie grass buffers
    - provide additional benefits beyond filtering capacity
    - reduced width required compared to other grasses because native plants are better at reducing nutrient and sediment movement

4. Ponds and wetlands

- Capture and transform nutrients and sediments leaving fields before they reach streams
- Where appropriate, increase beaver population in the watershed to create ponds and wetlands and trap nutrients and sediments

5. Streams, Stream Banks, and Riparian Buffers

- Exclude cattle from streams
  - fencing, alternative water sources, etc.
- River cane buffers at pasture edge of riparian buffers
  - 10 feet (3.3 m)
  - where appropriate - not appropriate everywhere
- Riparian buffers
  - protect existing riparian buffers
  - add trees and width to existing buffers where necessary and possible
  - develop conservation easements to protect existing buffers
  - educate producers about the ways riparian buffers help reduce the cost of producing drinking water
  - seek funds to oversee management of riparian buffers

6. Unpaved Roads and Ditches

- Reduce erosion from unpaved roads and roadside ditches in the watershed
  - Hold workshops for decision makers on importance of reducing erosion and practices that can do so
  - Hold workshops for county road maintenance crews and supervisors on BMPs and maintenance practices that can reduce erosion
  - Implement demonstration projects of BMPs and practices

Typical Applicable BMPs

Table 8 lists a set of typical BMPs applicable to reducing phosphorus and sediment loads, their load reduction efficiencies, and NRCS codes. Note that implementation of many of these BMPs will address both nutrients and sediment.

Table 8: Typical BMPs to reduce phosphorus and sediment pollution from pasture (OCC, 2021)

Landuse	BMP	Load Reduction Efficiencies			NRCS code	Ref	Treatment area (acres)*
		N	P	Sediment			
Pastureland	alternative water supply	0.25	0.3	0.4	516, 642, 614, 533	1	contributing area or 40 acres default
Pastureland	Critical Area Planting	0.3	0.3	0.75	342	1	actual acreage implemented
Pastureland	Cross Fencing with grazing management	0.24	0.3	0.09	382	3	actual field acreage or linear ft/330*40 acres
Pastureland	Heavy Use Area	0.2	0.2	0.4	561	3	actual acreage implemented
Pastureland	Waste Storage, management	0.52	0.58	ND	313, 317, 633	1	assume 40 affected acres per unit
Pastureland	Pasture-Hayland Planting/Range Seeding	0.66	0.67	0.59	512, 550	1	actual acreage implemented
Pastureland	Pond	0.82	0.72	0.77	378	1	contributing area or 40 acres default
Pastureland	Precision Intensive Rotational/Prescribed Grazing	0.09	0.24	0.3	528		actual acreage implemented
Pastureland	Riparian area establishment/management/exclusion	0.75	0.75	0.83	472, 390, 391, 612, 516, 642, 614, 533	1	contributing area or 13 acres/acre BMP implemented (eastern OK)
Pastureland	Streambank stabilization and protection	0.75	0.75	0.75		2	actual linear feet implemented
Pastureland	Winter Feeding Facility	0.35	0.4	0.4	313		assume 40 affected acres per WFF unit

[1] Miller, et al. 2012.
[2] Waidler, et al. 2009.
[3] Comittee on the Evaluation of Chesapeake Bay Program Implementation for Nutrient Reduction to Improve Water Quality. 2011.
*Default areas used in STEPL for single instance of practice implementation when treatment area is unknown, OCC. 2021.

STEPL Model Calculations

A suite of potential load reduction estimates was calculated using the STEPL 4.4 Spreadsheet Model for 10 Watersheds (USEPA, 2020). The *Spreadsheet Tool for Estimating Pollutant Load* (STEPL) employs simple algorithms to calculate:

- nutrient and sediment loads from different land uses, and
- the load reductions that would result from the implementation of various best management practices (BMPs).

For the following calculations, the model was populated with HUC 12 data from the EPA Input Data Server. Data from the Input Data Server can be downloaded from the same webpage. The model is available for download at https://www.epa.gov/nps/spreadsheet-tool-estimating-pollutant-loads-stepl#doc.

The STEPL model was run for each of the four HUC 10 watersheds (Black Fork, Poteau River, Fourche Maline and Middle Poteau River) in the Oklahoma portion of the Wister watershed. Output from model runs is included as Appendix II.

Prior studies (cf. Chapter 3) have concluded that nonpoint sources of sediment and phosphorus originate primarily from pastureland. As a result, we evaluated the likely effectiveness of pastureland best management practices (BMPs) in STEPL. We did not evaluate the effectiveness of cropland or urban BMPs as these represent very minor sources in the Lake Wister watershed.

We also did not evaluate the effectiveness of forestland BMPs. As discussed earlier (Chapter 3), while forestland is the predominant land use in the watershed, it is not considered to be the main driver of nutrient pollution to the lake.

The load reduction estimates in the tables below were calculated using default STEP-L values for load reductions. After many years of working with the STEP-L model, implementing BMPs, and tracking actual improvements in water quality, the Oklahoma Conservation Commission has determined that STEP-L underestimates load reductions for some BMPs under local conditions. As a result, they have developed adjustments to the STEP-L calculations that they think better capture local results (some of those adjustments are noted in Table 7, above). For the purposes of this WBP, we used default values. In the design phase of specific future implementation projects, OCC adjusted treatment values will likely be incorporated into project design and implementation.

Tables 9 and 10 provide the STEP-L estimated annual load reductions for both phosphorus and sediment when a given BMP is applied to five percent and twenty percent of watershed acreage, respectively. A full suite of calculations from 5% to 40% are provided in Appendix II.

Table 9: Annual load reduction estimates for total phosphorus and sediment if the specified BMPs are applied in five percent of the watershed

	Annual Load Reduction Estimates for each HUC 10 Watershed								Total Annual Load Reduction Estimates	
	Black Fork		Poteau River		Fourche Maline		Middle Poteau		Oklahoma Portion of Lake Wister Watershed	
BMP	**Phosphorus** (kg/yr)	**Sediment** (kg/yr)	**Phosphorus** (kg/yr)	**Sediment** (kg/yr)	**Phosphorus** (kg/yr)	**Sediment** (kg/yr)	**Phosphorus** (kg/yr)	**Sediment** (kg/yr)	**Phosphorus** (kg/yr)	**Sediment** (kg/yr)
Streambank Stabilization and Fencing	107	26,426	202	81,420	524	150,239	1	517	834	258,602
Grass Buffer (minimum 35 feet wide)	107	22,834	198	70,352	520	129,809	1	454	826	223,449
30 m Buffer with Optimal Grazing	79	ND	132	ND	375	ND	1	ND	587	ND
Livestock Exclusion Fencing	50	21,845	103	67,313	251	124,203	1	426	405	213,787
Forest Buffer (minimum 35 feet)	60	18,779	116	57,869	296	106,776	1	372	473	183,796
Use Exclusion	18	20,756	47	63,947	96	117,988	0	408	161	203,099
Winter Feeding Facility	57	14,098	108	43,427	279	80,132	1	281	445	137,938
Streambank Protection without Fencing	39	20,267	83	62,423	197	115,185	1	399	320	198,274

Table 10: Annual load reduction estimates for total phosphorus and sediment if the specified BMPs are applied in 20 percent of the watershed

	Annual Load Reduction Estimates for each HUC 10 Watershed								**Total Annual Load Reduction Estimates**	
	Black Fork		**Poteau River**		**Fourche Maline**		**Middle Poteau**		**Oklahoma Portion of Lake Wister Watershed**	
BMP	**Phosphorus** (kg/yr)	**Sediment** (kg/yr)	**Phosphorus** (kg/yr)	**Sediment** (kg/yr)	**Phosphorus** (kg/yr)	**Sediment** (kg/yr)	**Phosphorus** (kg/yr)	**Sediment** (kg/yr)	**Phosphorus** (kg/yr)	**Sediment** (kg/yr)
Streambank Stabilization and Fencing	427	105,723	807	325,698	2,095	600,974	5	2,077	3,334	1,034,472
Grass Buffer (minimum 35 feet wide)	425	91,344	793	281,400	2,082	519,236	5	1,796	3,305	893,776
30 m Buffer with Optimal Grazing	315	ND	528	ND	1,502	ND	3	ND	2,348	ND
Livestock Exclusion Fencing	200	87,398	412	269,243	1,005	496,802	3	1,724	1,620	855,167
Forest Buffer (minimum 35 feet)	239	75,133	466	231,459	1,183	427,094	3	1,479	1,891	735,165
Use Exclusion	70	83,025	190	255,781	383	471,963	1	1,633	644	812,402
Winter Feeding Facility	228	56,382	430	173,708	1,117	320,518	3	1,107	1,778	551,715
Streambank Protection without Fencing	156	81,057	807	249,703	790	460,741	2	1,597	1,755	793,098

According to STEPL model output, the five most effective BMPs to reduce total phosphorus loading (listed in order from most to least effective) are:

1. Streambank Stabilization and Fencing
2. Grass Buffer (minimum 35 feet wide)
3. 30 m Buffer with Optimal Grazing
4. Forest Buffer (minimum 35 feet wide)
5. Winter Feeding Facility

The five BMPs found to be most effective in reducing sediment loading (listed in order from most to least effective) are:

1. Streambank Stabilization and Fencing
2. Grass Buffer (minimum 35 feet wide)
3. Livestock Exclusion Fencing
4. Use Exclusion
5. Streambank Protection without Fencing

In practice BMPs are often be planned and implemented together. For example, a common scenario could be:

> *Pastureland, Streambank Stabilization w/Fencing* would be planned along with *Pastureland, Livestock Exclusion Fencing* and *Pastureland, Prescribed Grazing*. Frequently, this would also require addressing *Pastureland, Alternative Water Supply*.

Another scenario might be:

> *Pastureland, Prescribed Grazing* in combination with *Pastureland, Pasture and Hayland Planting* (also called Forage Planting); these may also require *Pastureland, Alternative Water Supply*.

Because grass buffers effectively reduce both pollutants and are less expensive to implement than streambank stabilization and fencing (a BMP that also effectively treats both pollutants), these would make an appropriate target for emphasis in the first few years of the project. Other BMPs that require more human management but less infrastructure (prescribed grazing and grazing land management, for example) may also be emphasized, even those these are not the most effective BMPs to reduce phosphorus and sediment.

Comparing the potential for load reduction shown in Tables 8 and 9 with the one and two percent load reduction requirements estimated above in Table 6, it becomes evident that significant load reductions to Lake Wister, particularly of sediment, will be challenging.

National Water Quality Success Stories

An analysis of national water quality improvement success stories from 2005 to 2021 (USEPA, 2021) lends further credence to the challenges of planning for large reductions in nutrients and sediments from nonpoint sources in large watersheds. “Success Stories” are waterbodies or segments of waterbodies that have been removed from the 303(d) list for one or more pollutants. It is important to note that nonpoint source pollution control is usually, but not always the primary driver in a delisting. The current database has some 560 entries. We sorted for waterbodies with a watershed size between 535,000 and 735,000 acres—that is, a size range that brackets the Lake Wister watershed (ca. 640,000 acres).

No lakes or reservoirs in the Wister watershed size range were found in the database with a successful delisting for reductions in phosphorus or sediment. There were eight success stories with watershed sizes similar to Lake Wister’s. These were all for stream segments. These eight watersheds were sorted for those delisted for a pollutant related to phosphorus or sediment (i.e., nutrients, phosphorus, chorophyll-a, DO/organic enrichment, turbidity, sediment/siltation, and TSS). Five waterbodies were returned that have been delisted for a nutrient or sediment cause. Of these five stream segments, four were delisted for pollutants related to sediment and one was delisted for nutrients. The cost for delisting varied from $1,370,918 to $5,065, 000.

Both the STEP-L results and the analysis of success stories emphasize the challenges in making the large nonpoint source reductions that will be required to return Lake Wister to a state that meets Oklahoma water quality standards. However, as discussed earlier, lake modeling results indicate that every incremental reduction in sediment or phosphorus load to Lake Wister results in a corresponding improvement in lake condition. Therefore, setting and meeting annual small (e.g., 2%) goals, and working consistently over the long term is a recipe for action that can lead to success.

CHAPTER 6: OUTREACH PROGRAM

The nutrient and sediment pollution degrading Lake Wister is derived primarily from nonpoint sources. Actions to address these pollutants will be largely voluntary and non-regulatory, therefore an ongoing education and outreach process will be key to efforts to improve water quality in the watershed and lake. A major component of watershed restoration actions will be to develop and implement a targeted education program that highlights the relationship between soil health and water quality and teaches landowners and other stakeholders practices that build soil health and protect waterways.

While PVIA regularly conducts various educational activities, as a small water treatment authority, they do not have the financial resources or staff to develop and sustain a comprehensive education program of the scale that will be required. The education program described below will be implemented by OCC with support from PVIA.

Wister Watershed Alliance. PVIA intends to apply for funding to support the creation of a nonprofit watershed association—a Wister Watershed Alliance—that would take the lead in watershed improvement activities. Funding will be sought to hire a Watershed Coordinator who would coordinate and manage the outreach process.

Education and outreach activities will be required that address four primary sources of supply of excess nutrients to watershed streams and the lake:

- Poultry litter management, including moving litter out of the watershed
- Soil erosion and leaching of nutrients from watershed pastures
- Streambank erosion
- Soil erosion from unpaved roads and ditches

PVIA's Current Outreach Program

PVIA conducts several types of outreach and educational activities for residents of LeFlore County and the Wister watershed, including:

- Water plant tours—inform those who use the water about the process that is used to clean it and make it safe, and about issues and challenges that PVIA faces in producing clean, safe drinking water. Tours are given to school classes that request a tour, to several classes from Carl Albert State College, and to LeFlore County Leadership, a program designed to inform future leaders about important aspects of the regional economy.

- Visits to the lake and discussions of PVIA source water protection activities—these frequently are paired with plant tours.
- LeFlore County Ag Days—PVIA has a booth and distributes educational materials to producers and their families regarding water supply, treatment, and watershed activities.
- PVIA maintains a website with information on lake and watershed activities.
- Outreach through speaking at local service organization meetings
- Public meetings and watershed symposia—on an irregular basis and as needed, PVIA has organized and held meeting to inform stakeholders about important activities at the lake and in the watershed.
- Source water protection workdays—when appropriate PVIA has held educational activities where school children and employees of local organization have assisted in lake and watershed activities, for example constructing floating wetland for the lake (Figure 12).

It is anticipated that these activities will continue and be expanded as part of watershed restoration action.

Figure 12: PVIA educational outreach event involving floating wetlands

Outreach Program for Agricultural Producers

The outreach program described in this section will be implemented by OCC's Blue Thumb and Soil Health Programs with support from PVIA. Blue Thumb supports a network of citizen scientists who monitor local streams. Blue Thumb also provides education and outreach about reducing nonpoint source pollution statewide. In addition to providing education and outreach, the Soil Health Program works individually with agricultural producers to improve soil health and protect water quality on Oklahoma rangeland and farmland.

The initial education program will span two years and may be repeated as needed. During the first year, Soil Health and Blue Thumb will host a Full Circle Citizenship (FCC) Training in the watershed. This training will be by invitation with an effort to include a diverse group of stakeholders and community leaders. The training will last a half-day or a full day and will involve a trip to a local stream and/or a demonstration farm. The training will include a combination of lectures and hands-on experiences. Topics that will be covered include stream ecology, the ways poor soil health impact local water quality, and actions landowners can take to improve soil health and protect local waterways. The goal of Full Circle Citizenship trainings is to bring watershed community leaders together to explore the interface between soil health and water quality. An additional goal of the Lake Wister Full Circle Citizenship Training will be to form a core group of leaders who will assist in moving forward soil health education in the watershed.

Figure 13: Blue Thumb Volunteer Coordinator, Cheryl Cheadle, teaches students about stream ecology

Within six months of the FCC training, the Soil Health Program will hold a general soil health training. This training will be larger, and attendants of FCC will be asked to invite other producers in the watershed. The general soil health training will occur at the farm or ranch of a producer in the watershed who is willing to implement BMPs and serve as a demonstration site for the duration of the project (two years). The Soil Health Program currently has relationships with producers in the watershed who may be willing to serve in this capacity. The general soil health training will include modules on plant identification, the WORMS app (a soil health data collection app), a demonstration of the rainfall simulator, and an exploration of BMPs that reduce the delivery of nutrients and sediment. Soil health data will be collected at the demonstration farm prior to the implementation of BMPs.

Within six months of the Full Circle Citizenship training, Blue Thumb will also hold a volunteer training event in the watershed. Volunteer trainings are two-day events during which participants receive 16 hours of training. The first day focuses on stream ecology (Figure 13) and the second day focuses on the nuts and bolts of collecting stream data. The purpose of the trainings is to prepare new volunteers to begin monitoring in the watershed. Historically, Blue Thumb volunteers collected data at nine sites in the watershed, but there are currently no active volunteers collecting data in the watershed. The goal of these trainings will be to recruit one or more volunteers to resume data collection on watershed streams.

During the second year of the project, producers who completed the general soil health training will be offered a private consultation with an OCC or NRCS soil health expert. During these consultations, the soil health expert will visit the producer’s operation and discuss practices that could be implemented to restore soil health, protect water quality and provide an economic benefit to the producer.

During the second year of the project, Blue Thumb staff will support new volunteers in the watershed. This may include hosting educational events, offering Mini-Academies for Monitoring or Mini-Academies for Education and being available to answer volunteer questions.

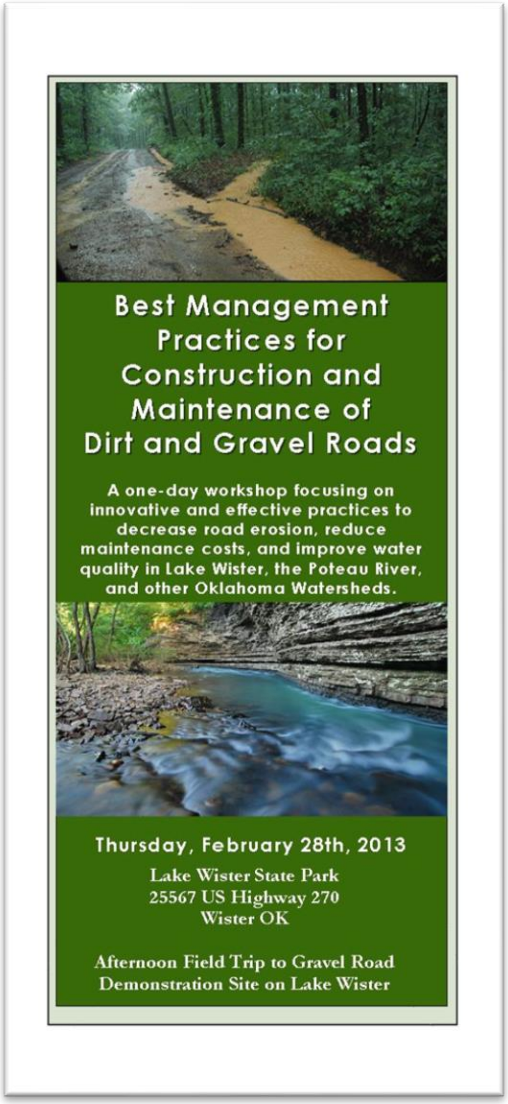
The second year of the project will conclude with a follow-up training at the demonstration site. During the follow-up training, participants will collect soil health data, discuss implemented BMPs and lessons learned. This will provide the opportunity for other producers to share their experience with soil health practices and brainstorm solutions to common obstacles.

If needed, the two-year education and outreach program may be repeated with a new demonstration farm and a new group of volunteers.

Cowboy Botany. A complementary educational program conducted by OCC and directed at improving grassland management are known as Cowboy Botany workshops. These may vary from a half day to a full day of discussion of plants. In a full day, basic botany principles are discussed in a classroom setting and then the rest of the day spent at a local producer's field, with identification of plant species and plant communities as the focus. Options for grazing and land management practices that can encourage healthy ecosystems are discussed.

Outreach Program for Road Crews

Because unpaved roads may be a significant source of sediment in the watershed, the education program will also provide training for employees who maintain unpaved county roads. PVIA and OCC have held such trainings in the past in the Poteau River watershed (see Figure 14), and these efforts would be expanded and continued. The training will likely be provided by a contractor and will focus on maintenance BMPs that reduce the delivery of sediment from unpaved roads and ditches to streams. This may be a one- or two-day training and may be repeated annually or as needed.



Best Management Practices for Construction and Maintenance of Dirt and Gravel Roads

A one-day workshop focusing on innovative and effective practices to decrease road erosion, reduce maintenance costs, and improve water quality in Lake Wister, the Poteau River, and other Oklahoma Watersheds.

Thursday, February 28th, 2013
Lake Wister State Park
25567 US Highway 270
Wister OK

Afternoon Field Trip to Gravel Road
Demonstration Site on Lake Wister

Figure 14: Flyer for 2013 training about the maintenance of unpaved roads

CHAPTER 7: TECHNICAL AND FINANCIAL ASSISTANCE

The necessary technical assistance is available through PVIA contractors, the OCC Soil Health Program, OCC contractors, the Poteau NRCS office, the LeFlore and Latimer County Conservation Districts, and the Oklahoma Blue Thumb Program.

It is impossible to accurately estimate necessary financial assistance because landowners have not been recruited and specific BMPs have not been selected for implementation. The following list includes the five most effective BMPs to treat phosphorus **and/or** sediment according to the output from STEP-L:

Phosphorus and sediment:

1. Streambank Stabilization and Fencing
2. Grass Buffer (minimum 35 ft wide)

Phosphorus:

3. 30 m Buffer with Optimal Grazing
4. Forest Buffer (minimum 35 ft wide)
5. Winter Feeding Facility

Sediment:

6. Livestock Exclusion Fencing
7. Use Exclusion
8. Streambank Protection without Fencing

Cost estimates for these practices shown in Table 11, below, These estimates are taken from Section I, State Payment Rates and Methods, Oklahoma Payment Schedules, Practice Scenarios (https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/financial/?cid=nrcseprd1328258). Each Practice Scenario includes a Scenario Typical Size, Scenario Total Cost, and Scenario Cost/Unit. (Note that default STEP-L BMPs do not always align exactly with NRCS Conservation Practice designations. We have used the most similar categories available in Table 11.

Table 11: Cost estimates for conservation practices (NRCS, 2021)

Practice Identified in STEP-L	NRCS Practice	Average Scenario Cost/Unit	Average Scenario Cost
Streambank Stabilization and Fencing	382-Fence*, Steep, Rocky **PLUS** 580-Streambank and Shoreline Protection, Shaping	$14.12/ft (Plus cost for fencing)	$14,122.96 (Plus cost for fencing)
	382-Fence, Steep, Rocky **PLUS** 580-Streambank and Shoreline Protection, Bioengineered	$48.66/ft (Plus cost for fencing)	$48,656.42 (Plus cost for fencing)
	382-Fence, Steep, Rocky **PLUS** 580-Streambank and Shoreline Protection, Structural	$101.32/yd^3 of riprap (Plus cost for fencing)	$168,907.35 (Plus cost for fencing)
Grass Buffer (minimum 35 ft wide)	386-Field Border, Native Species	$155.44/acre	$155.44
	386-Field Border, Pollinator	$502.89/acre	$502.89
	393-Filter Strip, Native Species	$229.55/acre	$229.55
30 m Buffer with Optimal Grazing	386 or 393 **PLUS** 528-Prescribed Grazing, Standard	$9.90/acre (Plus cost for grass buffer)	$4,951.90 (Plus cost for grass buffer)
	386 or 393 **PLUS** 528-Prescribed Grazing, Intensive	$16.77/acre (Plus cost for grass buffer)	$8,384.42 (Plus cost for grass buffer)
Forest Buffer (minimum 35 ft wide)	391-Riparian Forest Buffer, Plant Using Direct Seeding	$236.02/acre	$2,360.18
	391-Riparian Forest Buffer, Plant Using Cuttings	$273.99/acre	$821.98
	391-Riparian Forest Buffer, Planting Bareroot Hardwood Seedlings	$1.06/seedling	$844.96
Winter Feeding Facility	Not listed as a 2021 reimbursable NRCS practice in Oklahoma	Not listed as a 2021 reimbursable NRCS practice in Oklahoma	Not listed as a 2021 reimbursable NRCS practice in Oklahoma
Livestock Exclusion Fencing	382-Fence, Steep, Rocky	$3.11/ft	$8,220.32
Use Exclusion	Not listed as a 2021 reimbursable NRCS practice in Oklahoma	Not listed as a 2021 reimbursable NRCS practice in Oklahoma	Not listed as a 2021 reimbursable NRCS practice in Oklahoma
Streambank Protection without Fencing	580-Streambank and Shoreline Protection, Shaping	$14.12/ft	$14,122.96
	580-Streambank and Shoreline Protection, Bioengineered	$48.66/ft	$48,656.42
	580-Streambank and Shoreline Protection, Structural	$101.32/ yd^3 of riprap	$168,907.35

Although ponds are not a default pastureland BMP option in STEP-L 4.4, according to the *Minnesota Stormwater Manual* (MPCA, 2016), the average removal efficiency for stormwater ponds is 50% for total phosphorus and 84% for TSS. Stormwater ponds may be functionally most similar to sediment basins (NRCS Practice 350) or water and sediment control basins (NRCS Practice 638), depending on design specifications. Water and sediment control basins are less likely to be implemented by ranchers than ponds or sediment basins because water and sediment control basins are not designed to create a permanent pool of water and therefore may not be useful for livestock watering.

For the purposes of this document, we have assumed that the removal efficiencies for ponds (NRCS Practice 378) are similar to those of sediment basins (NRCS Practice 350). The Oklahoma Practice Scenarios Fiscal Year 2021 cites an average cost of \$1.94/yd^3 of material excavated and a typical scenario cost of \$2,912.84 for a sediment basin. The Practice Scenarios also describe eight scenarios for ponds (NRCS Practice 378). The average cost for pond construction varies from \$4.49-\$8.65/yd^3 of embankment, for an average scenario cost of \$11,230.34-\$34,592.32.

Other practices likely to be implemented in the watershed but not among the five most effective BMPs to treat total phosphorus or sediment, include prescribed grazing (NRCS Practice 528), grazing management plans (NRCS Practice 110), soil health management plans (NRCS Practice 116) and pasture and hay planting (NRCS Practice 512). Please see Table 12 for associated costs.

Table 12: Other practices likely to be implemented in the watershed, but not among the five most effective BMPs in STEP-L calculations

Practice Identified in STEP-L	NRCS Practice	Average Scenario Cost/Unit	Average Scenario Cost
Prescribed Grazing	528-Prescribed Grazing, Standard	\$9.90/acre	\$4,951.90
	528-Prescribed Grazing, Intensive	\$16.77/acre	\$8,384.42
	110-Grazing Management Plans, Less Than or Equal to 100 acres	\$2,350.80/plan	\$2,350.80
	110-Grazing Management Plans, 101-500 acres	\$3,134.40/plan	\$3,134.40
	116-Soil Health Management Plan, Crops and Livestock	\$4,014.50/plan	\$4,014.50
Pasture and Hayland Planting	512-Forage and Biomass Planting, Native Perennial Grass	\$208.92/acre	\$8,356.69

Based on the information in Tables 11 and 12, here is a possible scenario for Years 1-5 of the program:

1. Install grass buffers that treat 100 acres of pasture at an average of \$503 per acre (\$50,300)
2. Complete 1,000 feet of bioengineered streambank stabilization and fencing at an average cost of \$49 per foot (\$49,000)

3. Build 10 ponds at an average cost of $11,230 per pond ($112,300)
4. Develop 20 grazing management plans for farms less than or equal to 100 acres at an average cost of $2,351 per plan ($47,020)
5. Develop five soil heath management plans at an average cost of $4,015 per plan ($20,076)
6. Hire a watershed coordinator ($50,000/year)

Estimated cost per year: **$328,696**

Estimated cost over five years: **$1,643,480**

CHAPTER 8: IMPLEMENTATION SCHEDULE AND MEASURABLE MILESTONES

Table 13: Implementation schedule and measurable milestones

Timeframe	Project Actions	Responsible Agency	Outcome
August 2021	Blue Thumb Training in Poteau	OCC	Increased community understanding of NPS pollution prevention
Fall 2021	Submit WBP to EPA for acceptance	OCC/PVIA	EPA-accepted WBP
Fall 2021	Approval of TMDL	ODEQ	Approved TMDL
Fall 2021	Recruit volunteers to monitor two sites in the watershed	OCC	Collect additional data prior to, during and after BMP implementation to track changes in water quality
Early 2022	Apply for a Bureau of Reclamation Cooperative Watershed Management Program Phase 1 grant to hire a watershed coordinator	PVIA/OCC	Obtain funding to hire a watershed coordinator
Spring 2022	Full Circle Citizenship Training	OCC	Build partnerships between stakeholders; connect with producers
Fall 2022	General Soil Health Training	OCC	Connect with producers; increase knowledge of the connections between soil health and water quality
Winter 2022	If funding is obtained, hire a watershed coordinator	PVIA	Build internal capacity for PVIA to eventually assume responsibility for long-term watershed education program
Spring/Summer 2023	Private consultations with producers interested in implementing BMPs	OCC and NRCS	Recruit producers to implement practices that will improve water quality in tributaries to Lake Wister; recruit two producers to serve as demonstration sites
Spring/Summer 2023	Recruit members to serve on the Wister Watershed Alliance	PVIA	Establish a watershed alliance to provide input on implementation of WBP and to assist with community education

Timeframe	Project Actions	Responsible Agency	Outcome
Fall 2023	Host watershed symposium	PVIA	Educate community, producers and water resource professionals about Lake Wister's water quality impairments and potential solutions
Winter 2023	Host a training for road management crews	PVIA	Reduce the amount of sediment that reaches Lake Wister through improved management of unpaved roads
2024-2026	Implement BMPs to improve water quality	Private producers, NRCS, OCC	Reduce the amount of sediment and total phosphorus that reaches Lake Wister
2024-2026	Annual field days at demonstration sites	Private producers, NRCS, OCC	Showcase soil health improvements as the result of BMP implementation; recruit new producers to implement BMPs
Present and ongoing	Continue monitoring Lake Wister	PVIA	Monitor for improvements in water quality
2026	Revise WBP	PVIA, OCC	Revised WBP that incorporates new data and lessons learned during the first five years of the project

CHAPTER 9: EVALUATION CRITERIA AND MONITORING PLAN

The goal of watershed planning is to describe a path forward to improved water quality in Lake Wister. What actions can we take to reduce the supply of total phosphorus and sediment (total suspended solids) to Lake Wister and eventually achieve full support of beneficial uses?

Total Maximum Daily Loads (TMDLs) for both phosphorus and sediment have been developed for the lake; the required load reductions are very large. On the other hand, lake modeling efforts also show that incremental improvement is beneficial. For every 1% reduction in total phosphorus or sediment, there is a corresponding decrease in average chlorophyll-*a* or turbidity. Therefore, this plan envisions a steady incremental improvement over many years.

How will we track these improvements? A set of evaluation criteria and monitoring activities will allow assessment of progress.

Evaluation Criteria

The following evaluation criteria have been developed to track and assess progress toward project objectives.

- Overall Watershed Based Plan Performance
    - Are planned and preferred management measures being implemented as intended?
- Overall load reduction
    - Quantitatively, what is the impact of implemented management measures? Have these efforts reduced phosphorus or sediment entering Lake Wister?
- Management Measure Performance
    - Was a particular management measure or other activity implemented as intended?
    - How did it perform? What was the percent efficiency and effectiveness?
    - How does this performance compare to expectations for load reduction for the practice?
    - (If applicable) What was the performance of a management measure relative to other measures? How does it compare in terms of efficiency and economy?

Monitoring Program Goals and Objectives

Monitoring will proceed, as appropriate, in three areas: lake and load monitoring, HUC 12 scale monitoring, and project specific monitoring. Each type of monitoring has its own purpose and objectives, as described below.

Lake and Load Monitoring

Improvements in water quality are likely to be detected first in small tributaries, then in major tributaries, and finally in the lake. It will likely take decades to detect water quality improvements in the lake. PVIA has conducted a regular monthly lake monitoring program since early 2011. The data from this monitoring was used to develop the TMDLs for the lake, and will be the ultimate demonstration of success. We look forward to seeing demonstrated long-term average chlorophyll-*a* and turbidity reductions in the lake. PVIA intends to continue this monitoring throughout the course of implementation of this WBP and into the foreseeable future.

Since lake 2010, PVIA has contracted with the US Geological Survey to conduct regular water quality monitoring of water entering Lake Wister from its two primary sources. PVIA intends to continue to support this monitoring throughout the course of implementation of this WBP and into the foreseeable future.

HUC 12 Scale Monitoring

In cooperation with the Oklahoma Conservation Commission and the University of Arkansas, PVIA supported 2-plus years of HUC 12 scale water quality monitoring in the Oklahoma portion of the Lake Wister watershed. Implementation of watershed improvement activities is anticipated to occur primarily in HUC 12 scale subwatersheds. As appropriate for any given implementation project or program, water quality monitoring at the outlet of the subwatershed will be sampled, and those results may be compared to previously collected baseline data, and any changes identified.

Project Specific Monitoring

For any given specific project, monitoring will be implemented as appropriate. This could involve, for instance, edge of field monitoring, or downstream from created ponds or wetlands, or downstream from bank restoration.

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APPENDIX I

Initial Next Steps

Specifically, what do we intend to do next?

Soil Health - Continue ongoing current efforts to implement:

- Soil health demonstration projects on 1-2 demonstration farms in the Wister watershed, including
    - Rotational grazing
    - Field buffers, including native prairie plant buffers, and river cane buffers
- Soil health field days, including
    - Field days to observe farms where soil health practices have already been implemented
    - "Cowboy botany" (plant identification workshops)

Unpaved Roads and Ditches - Continue ongoing current efforts to implement:

- Assessment of soil erosion potential from unpaved roads in one or more HUC 12s
- One or more specific demonstration projects of improved road maintenance practice

Small Ponds and Wetlands - Continue ongoing current efforts to:

- Develop a small ponds and wetland pilot project in one or more HUC 12s

Watershed Organization - Seek grants and other support to:

- Organize and create a formal, nonprofit Wister Watershed Alliance
- Hire a Watershed Coordinator for a minimum of a two-year term, to help oversee development of the watershed restoration program

Financial Support – Continue efforts to identify sources of funding to support watershed restoration activities

APPENDIX II

Table A II-1: Annual load reduction estimates for total phosphorus and sediment if the specified BMP is applied in **five percent** of the watershed

	Annual Load Reduction Estimates for each HUC 10 Watershed								**Total Annual Load Reduction Estimates**	
	Black Fork		**Poteau River**		**Fourche Maline**		**Middle Poteau**		**Oklahoma Portion of Lake Wister Watershed**	
BMP	**Phosphorus (kg/yr)**	**Sediment (kg/yr)**	**Phosphorus (kg/yr)**	**Sediment (kg/yr)**	**Phosphorus (kg/yr)**	**Sediment (kg/yr)**	**Phosphorus (kg/yr)**	**Sediment (kg/yr)**	**Phosphorus (kg/yr)**	**Sediment (kg/yr)**
Streambank Stabilization and Fencing	107	26,426	202	81,420	524	150,239	1	517	834	258,602
Grass Buffer (minimum 35 feet wide)	107	22,834	198	70,352	520	129,809	1	454	826	223,449
30 m Buffer with Optimal Grazing	79	ND	132	ND	375	ND	1	ND	587	ND
Livestock Exclusion Fencing	50	21,845	103	67,313	251	124,203	1	426	405	213,787
Forest Buffer (minimum 35 feet)	60	18,779	116	57,869	296	106,776	1	372	473	183,796
Use Exclusion	18	20,756	47	63,947	96	117,988	0	408	161	203,099
Winter Feeding Facility	57	14,098	108	43,427	279	80,132	1	281	445	137,938
Streambank Protection without Fencing	39	20,267	83	62,423	197	115,185	1	399	320	198,274

Table A II-2: Annual load reduction estimates for total phosphorus and sediment if the specified BMP is applied in **ten percent** of the watershed

	Annual Load Reduction Estimates for each HUC 10 Watershed								**Total Annual Load Reduction Estimates**	
	Black Fork		**Poteau River**		**Fourche Maline**		**Middle Poteau**		**Oklahoma Portion of Lake Wister Watershed**	
BMP	**Phosphorus (kg/yr)**	**Sediment (kg/yr)**	**Phosphorus (kg/yr)**	**Sediment (kg/yr)**	**Phosphorus (kg/yr)**	**Sediment (kg/yr)**	**Phosphorus (kg/yr)**	**Sediment (kg/yr)**	**Phosphorus (kg/yr)**	**Sediment (kg/yr)**
Streambank Stabilization and Fencing	213	52,862	403	162,849	1,048	300,487	2	1,043	1,666	517,241
Grass Buffer (minimum 35 feet wide)	213	45,668	396	140,704	1,041	259,618	2	898	1,652	446,888
30 m Buffer with Optimal Grazing	157	ND	264	ND	751	ND	2	ND	1,174	ND
Livestock Exclusion Fencing	100	43,699	206	134,617	503	248,405	1	862	810	427,553
Forest Buffer (minimum 35 feet)	120	37,566	233	115,730	592	213,542	1	735	946	367,573
Use Exclusion	35	41,513	95	127,886	191	235,977	1	816	322	406,192
Winter Feeding Facility	114	28,195	215	86,854	559	160,263	1	553	889	275,865
Streambank Protection without Fencing	78	40,524	166	124,847	395	230,371	1	798	640	396,540

Table A II-3: Annual load reduction estimates for total phosphorus and sediment if the specified BMP is applied in **15 Percent** of the watershed

	Annual Load Reduction Estimates for each HUC 10 Watershed								**Total Annual Load Reduction Estimates**	
	Black Fork		**Poteau River**		**Fourche Maline**		**Middle Poteau**		**Oklahoma Portion of Lake Wister Watershed**	
BMP	**Phosphorus (kg/yr)**	**Sediment (kg/yr)**	**Phosphorus (kg/yr)**	**Sediment (kg/yr)**	**Phosphorus (kg/yr)**	**Sediment (kg/yr)**	**Phosphorus (kg/yr)**	**Sediment (kg/yr)**	**Phosphorus (kg/yr)**	**Sediment (kg/yr)**
Streambank Stabilization and Fencing	320	79,288	605	244,269	1,571	450,726	4	1,560	2,500	775,843
Grass Buffer (minimum 35 feet wide)	319	68,511	594	211,048	1,561	389,427	4	1,352	2,478	670,338
30 m Buffer with Optimal Grazing	236	ND	396	ND	1,126	ND	2	ND	1,760	ND
Livestock Exclusion Fencing	150	65,544	309	201,930	754	372,599	2	1,288	1,215	641,180
Forest Buffer (minimum 35 feet)	179	56,345	349	173,599	887	320,318	2	1,107	1,417	551,369
Use Exclusion	53	62,269	142	191,833	287	353,975	1	1,225	483	609,302
Winter Feeding Facility	171	42,293	323	130,281	838	240,386	2	835	1,334	413,795
Streambank Protection without Fencing	117	60,790	249	187,279	592	345,556	2	1,197	960	594,822

Table A II-4: Annual load reduction estimates for total phosphorus and sediment if the specified BMP is applied in **20 Percent** of the watershed

	Annual Load Reduction Estimates for each HUC 10 Watershed								**Total Annual Load Reduction Estimates**	
	Black Fork		**Poteau River**		**Fourche Maline**		**Middle Poteau**		**Oklahoma Portion of Lake Wister Watershed**	
BMP	**Phosphorus (kg/yr)**	**Sediment (kg/yr)**	**Phosphorus (kg/yr)**	**Sediment (kg/yr)**	**Phosphorus (kg/yr)**	**Sediment (kg/yr)**	**Phosphorus (kg/yr)**	**Sediment (kg/yr)**	**Phosphorus (kg/yr)**	**Sediment (kg/yr)**
Streambank Stabilization and Fencing	427	105,723	807	325,698	2,095	600,974	5	2,077	3,334	1,034,472
Grass Buffer (minimum 35 feet wide)	425	91,344	793	281,400	2,082	519,236	5	1,796	3,305	893,776
30 m Buffer with Optimal Grazing	315	ND	528	ND	1,502	ND	3	ND	2,348	ND
Livestock Exclusion Fencing	200	87,398	412	269,243	1,005	496,802	3	1,724	1,620	855,167
Forest Buffer (minimum 35 feet)	239	75,133	466	231,459	1,183	427,094	3	1,479	1,891	735,165
Use Exclusion	70	83,025	190	255,781	383	471,963	1	1,633	644	812,402
Winter Feeding Facility	228	56,382	430	173,708	1,117	320,518	3	1,107	1,778	551,715
Streambank Protection without Fencing	156	81,057	807	249,703	790	460,741	2	1,597	1,755	793,098

Table A II-5: Annual load reduction estimates for total phosphorus and sediment if the specified BMP is applied in **30 Percent** of the watershed

	Annual Load Reduction Estimates for each HUC 10 Watershed								**Total Annual Load Reduction Estimates**	
	Black Fork		**Poteau River**		**Fourche Maline**		**Middle Poteau**		**Oklahoma Portion of Lake Wister Watershed**	
BMP	**Phosphorus (kg/yr)**	**Sediment (kg/yr)**	**Phosphorus (kg/yr)**	**Sediment (kg/yr)**	**Phosphorus (kg/yr)**	**Sediment (kg/yr)**	**Phosphorus (kg/yr)**	**Sediment (kg/yr)**	**Phosphorus (kg/yr)**	**Sediment (kg/yr)**
Streambank Stabilization and Fencing	640	158,585	1,210	488,546	3,143	901,452	7	3,121	5,000	1,551,704
Grass Buffer (minimum 35 feet wide)	638	137,012	1,189	422,104	3,122	778,855	7	2,694	4,956	1,340,665
30 m Buffer with Optimal Grazing	472	ND	792	ND	2,253	ND	5	ND	3,522	ND
Livestock Exclusion Fencing	301	131,097	617	403,861	1,508	745,207	4	2,576	2,430	1,282,741
Forest Buffer (minimum 35 feet)	359	112,700	699	347,189	1,775	640,636	4	2,214	2,837	1,102,739
Use Exclusion	106	124,538	285	383,667	574	707,940	2	2,449	967	1,218,594
Winter Feeding Facility	341	84,577	646	260,562	1,676	480,781	4	1,660	2,667	827,580
Streambank Protection without Fencing	301	121,581	498	374,549	1,185	691,112	3	2,395	1,987	1,189,637

Table A II-6: Annual load reduction estimates for total phosphorus and sediment if the specified BMP is applied in **40 Percent** of the watershed

	Annual Load Reduction Estimates for each HUC 10 Watershed								Total Annual Load Reduction Estimates	
	Black Fork		Poteau River		Fourche Maline		Middle Poteau		Oklahoma Portion of Lake Wister Watershed	
BMP	Phosphorus (kg/yr)	Sediment (kg/yr)	Phosphorus (kg/yr)	Sediment (kg/yr)	Phosphorus (kg/yr)	Sediment (kg/yr)	Phosphorus (kg/yr)	Sediment (kg/yr)	Phosphorus (kg/yr)	Sediment (kg/yr)
Streambank Stabilization and Fencing	853	211,447	1,614	651,395	4,190	1,201,938	10	4,164	6,667	2,068,944
Grass Buffer (minimum 35 feet wide)	851	182,688	1,585	562,799	4,163	1,038,473	10	3,592	6,609	1,787,552
30 m Buffer with Optimal Grazing	629	ND	1,056	ND	3,004	ND	6	ND	4,695	ND
Livestock Exclusion Fencing	401	174,796	823	538,487	2,010	993,603	5	3,438	3,239	1,710,324
Forest Buffer (minimum 35 feet)	478	150,266	932	462,927	2,366	854,178	6	2,957	3,782	1,470,328
Use Exclusion	141	166,051	380	511,562	765	943,926	2	3,266	1,288	1,624,805
Winter Feeding Facility	455	112,772	861	347,407	2,234	641,035	5	2,223	3,555	1,103,437
Streambank Protection without Fencing	312	162,105	663	499,405	1,580	921,491	4	3,193	2,559	1,586,194