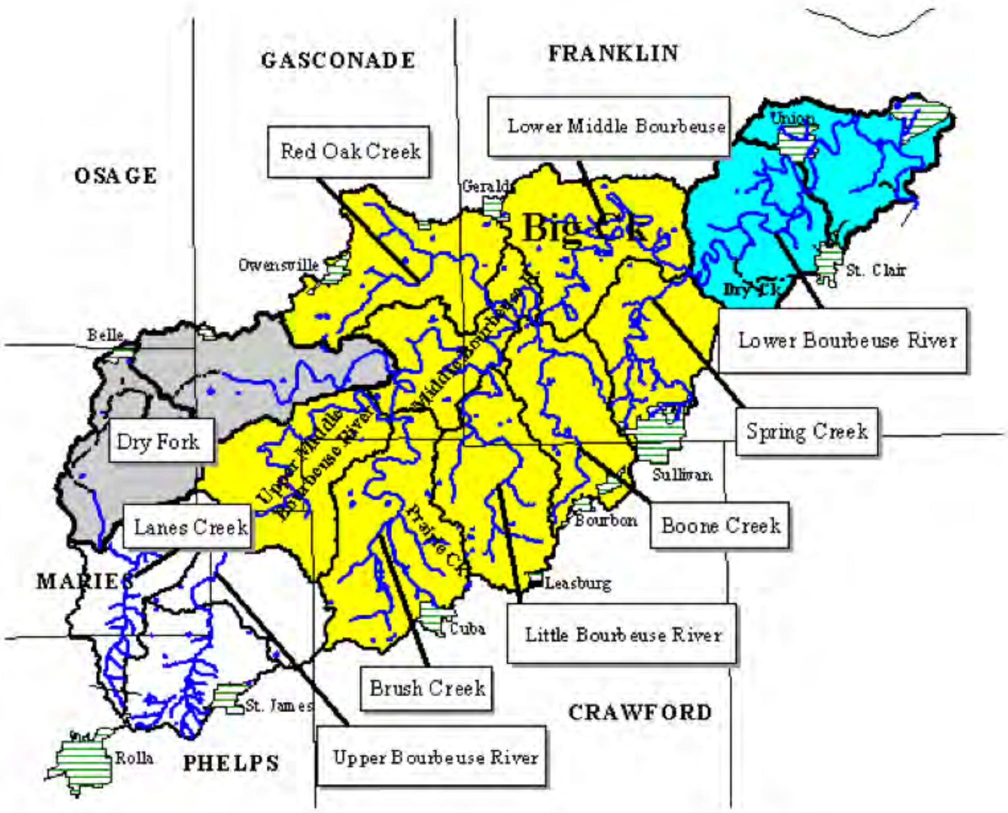



# Bourbeuse River

*Watershed and Inventory Assessment, December 1999*

*Prepared by*

*Todd J. Blanc, George Kromrey, Michael Smith, Andrew Austin, Ron Burke*

*Missouri Department of Conservation, Sullivan, MO*

# Table of Contents

# Executive Summary

The Bourbeuse River watershed is located within the northeastern quarter of the Ozark Highlands. The main stem of the Bourbeuse River winds northeasterly through Phelps, Gasconade, and Franklin counties to join the Meramec River, and its watershed additionally encompasses portions of Maries, Osage, and Crawford counties. The Bourbeuse River is 147 miles from mouth to headwaters, and the lower 132 miles have permanent flow. The Bourbeuse River watershed drains 843 square miles and is composed of a number of smaller watersheds including Spring Creek, Boone Creek, Brush Creek, Red Oak Creek, Dry Fork, Little Bourbeuse River, and the Lower Bourbeuse River. The gradient of the main stem is low compared to other streams of the Ozark Highlands, and gradients of the tributaries are slightly higher in the lower watershed compared to the upper watershed. The Bourbeuse River has fewer springs with smaller discharges than the Meramec River.

Cropland and pasture are the land uses for 45% of the Bourbeuse River watershed. According to 1992 NRCS estimates, approximately 16, 600 acres were cultivated, another 59, 100 acres of farmland were uncultivated, and 140, 900 acres were pasture. These areas are found primarily within stream floodplains. Fifty-one percent of the total land area within the watershed is deciduous forest. Other forest types are evergreen and mixed forest land. Successional areas, such as shrub and brush rangeland, are small in total acreage, reflecting the high grazing rates and hay production in the watershed. Most of the urban-type land use is found in the lower watershed near Union.

Although some exceptions are present and improvement are needed, water quality in the Bourbeuse River watershed is generally good. Sewage treatment plants for St. James, St. Clair, and Cuba have not always met water quality standards for their treated discharge. In general, non-point pollution in the form of sediment from erosion and organic wastes from livestock impair water quality. In particular, organic wastes from livestock contribute to excessive algal production in watershed streams. Contaminant sampling for pesticide bioaccumulation in fish indicates that Bourbeuse fish are safe for human consumption.

Stream habitat conditions within the Bourbeuse River and its tributaries are variable. The main stem has no channelized segments, and old mill dams located near Beaufort and Union provide channel grade controls. A number of tributaries are impounded, with the largest impoundment being Indian Lake (326 acres) in the Brush Creek subwatershed. In many streams, the lack of adequate riparian corridors, excessive nutrient loading, streambank erosion, excessive runoff and erosion, and the effects of extensive instream gravel mining are among the problems observed. Grazing practices along many streams contribute to streambank instability, nutrient loading, and poor riparian corridor conditions.

The Bourbeuse River watershed has a diverse assemblage of 90 fish species collected from 1941 through 1996. In historic fish collections, prior to the 1995-96 collections, fisheries biologists found 81 fish species. In the 1995-96 survey, nine additional fish species were added to the list; these included freshwater drum, highfin carpsucker, fantail darter, chestnut lamprey, smallmouth buffalo, bigmouth buffalo, warmouth, western redfin shiner, and freckled madtom. However, some fish species found in earlier collections were not taken in the 1995-96 collections; these included least brook lamprey, goldeye, red shiner, pallid shiner, bigmouth shiner, suckermouth minnow, bullhead minnow, stippled darter, and orangespotted sunfish. The highfin carpsucker, a state listed species, occurred at several locations within the watershed in the 1995-96 collections.

The Bourbeuse River is home to most of the popular sport fish found in Missouri. The river tends to be turbid, and because of the relatively low gradient, is slower moving than other Ozark streams. Most float anglers fish the Bourbeuse in the spring, before base flows limit their ability to move between access points. Smallmouth bass, largemouth bass, spotted bass, rock bass, channel catfish, flathead catfish, walleye, redhorse and suckers, longear sunfish, bluegill, black crappie, and white crappie are among the most popular species sought by anglers.

A total of 39 mussel species have been collected prior to 1977 in various surveys of the Bourbeuse River and three of its tributaries. Thirty-seven of the 39 species were collected in the 1977-78 survey, but *Cumberlandia monodonta,* spectaclecase mussel (a Missouri species of conservation concern), and *Cyclonaias tuberculata,* purple wartyback, were collected in previous surveys but not in the 1977-78 survey. In a more recent survey of the Bourbeuse River and two of its tributaries during 1994-97, 31 living and five dead species of mussels were collected. Habitat disturbances are the suspected cause of the decline in the number of mussel species present in the Bourbeuse River watershed.

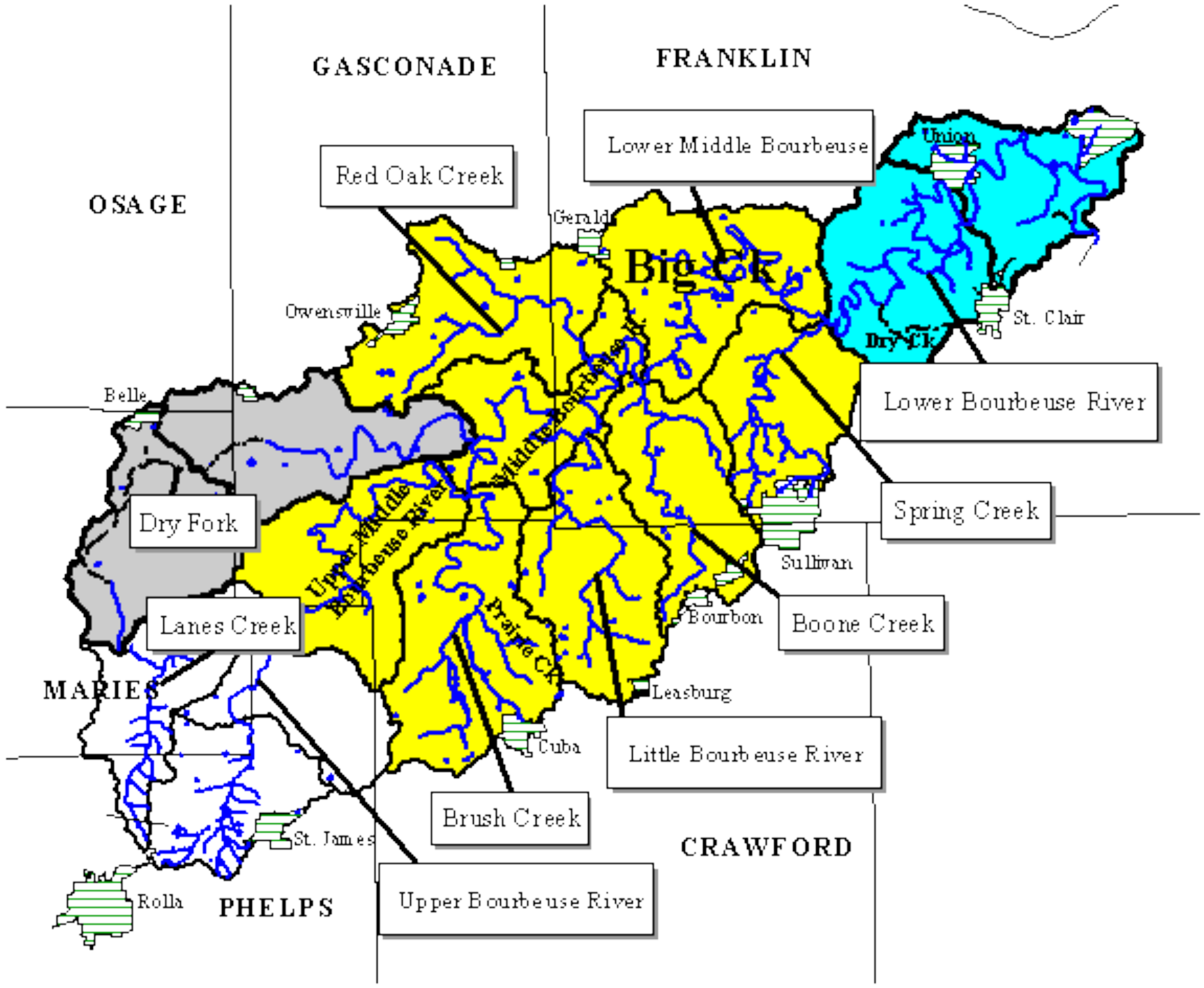
Our major goals for the basin are improved water quality, better riparian and aquatic habitat conditions, the maintenance of diverse and abundant populations of native aquatic organisms and sport fish, and increased public appreciation for the stream resources. Periodic fish population samples will be collected and appropriate habitat surveys will be conducted. Fishing regulations will be adjusted if needed to maintain quality fishing. Cooperative efforts with other resource agencies on water quality, habitat, and watershed management issues will be critical. Enforcement of existing water quality and other stream related regulations and necessary revisions and additions to these regulations will help reduce violations and lead to further water quality improvements. Working with related agencies to promote public awareness and incentive programs and cooperating with citizen groups and landowners will result in improved watershed conditions and better stream quality.

## Location

The Bourbeuse River watershed is found within the northeastern quarter of the Ozark Highlands. As a tributary to the Meramec River, the Bourbeuse River watershed flows northeast through Phelps, Maries, Osage, Crawford, Gasconade, and Franklin counties to join the Meramec River, which joins with the Mississippi River (Figure 1). The watershed is comprised of several small watersheds, including Spring Creek, Boone Creek, Brush Creek, Red Oak Creek, Dry Fork, Little Bourbeuse River, and the Upper, Middle, and Lower Bourbeuse River drainages.

The entire Meramec River watershed, including the Bourbeuse River and the Big River, drains 3, 980 square miles into the Upper Mississippi River watershed (United States Geological Survey 1997). The Bourbeuse River, excluding the Meramec River and the Big River, drains 842.9 square miles (U.S. Department of Agriculture and SCS 1990).

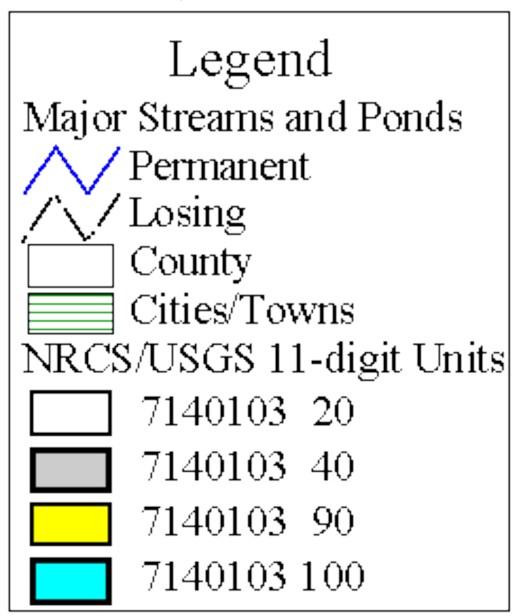
Figure 1. Bourbeuse River watershed base map.





Data source: USGS Topos (streams, towns); NRCS 100K watershed boundaries.

Map Production: Todd Blanc, Missouri Department of Conservation, December 1998



# Geology

## Physiographic Region

The Bourbeuse River watershed lies within the Salem Plateau subdivision of the Ozark Plateau. The majority of the Bourbeuse River is contained within the Ozark Border region. The region is composed of steep-sided hills and deep valleys, separated by gently rolling uplands. Soils are typically thin outside of the lowland areas. In these areas, decomposed bedrock has formed an unconsolidated residual material (see glossary). This residuum allows high rates of groundwater discharge (Vandike 1995).

## Geology

The geology (see map) of the Bourbeuse River valley is similar to the upper Meramec River watershed. The Bourbeuse River watershed, however, possesses a range of surface rocks varying in age from the younger Pennsylvanian to the older Ordovician Period (Missouri Department of Natural Resource (MDNR) 1984, 1996). By comparison, its rocks are younger than the Meramec River watershed, whose rock formations date to the Pre-Cambrian Age. An interesting feature of the Bourbeuse River watershed is the two north trending faults that "sandwich" the newer Pennsylvanian Age formations between the older Ordovician Age formations. The western fault runs parallel to Highway 19, but lies 3-4 miles to its west. The eastern fault runs parallel to I-44 before turning north along Highway 185, intersecting Spring Bluff township, and finally, ending east of Beaufort. The interior of the sandwich contains, from greater to lesser extent, the Pennsylvanian undifferentiated, the Roubidoux Formation, and a collection of Ordovician Formation rock types containing Smithville, Potter and Cotter, Jefferson City Dolomite formations. On either side of the interior are the Roubidoux Formation and Gasconade Dolomite. Stream gradient is not affected by the presence of the fault. Possibly, the fault contributes, along with the Roubidoux Formation and Gasconade Dolomite rock type, to the formation of springs. The largest spring, Kratz Spring, emerges from the Gasconade Formation. Few other springs exist because of the presence of Pennsylvanian age rock and Jefferson City Dolomite that prevent water movement to subsurface levels.

Blue Springs near Bourbon, Missouri has a measured flow of about 4.9 to 7.05 cubic feet per second (CFS). The flow of the spring exceeds that which the surface runoff from the Blue Springs Creek drainage area in the Meramec River watershed can produce; therefore, an independent watershed consultant hypothesized that the spring is receiving groundwater from another watershed (Tryon 1996). Tryon (1996) analyzed static-water well levels, sinks, faults, valley lineaments, and leaky ponds to conclude that a portion of the Boone Creek watershed of the Bourbeuse River watershed is supplying water to Blue Springs.

## Losing Streams

A losing stream is defined as a stream that loses 30 percent or more of its flow into an aquifer within two miles of flow discharge (MDNR 1994; Clean Water Commission Water Quality Standards 10 CSR 20-7.01). Permeable rock type is responsible for the movement of water to subsurface levels. Almost all of the watershed has poorly sustained base flows except Spring Creek below Kratz Spring and Bourbeuse River below Spring Creek.

Knowledge of groundwater sources such as losing streams are important to safeguard water supplies. On some stream systems the MDNR’s Division of Geology and Land Survey has conducted dye tracing to determine a stream's potential to lose to lower aquifers. Recent dye tracing around the Sullivan sewage treatment plant has led to the reclassification of Winsel Creek as a losing stream (Sullivan Independent News, November 15, 1995). Dry Fork has losing sections extending from its headwaters to nearly the confluence with Brush Creek. Two oil-product pipelines, the Continental and Explorer, cross the Dry Fork. Dry Creek in the Lower Bourbeuse River watershed is another losing stream. Finally, an unnamed tributary to Boone Creek is also classified as a losing stream.

## Soil Associations

Within the Bourbeuse River watershed, two soil surveys, the Soil Survey of Franklin County (SCS 1989) and the Soil Resources Inventory of Gasconade County (SCS 1994), are completed and published for use. Osage, Maries, and Phelps counties have surveys completed but not yet available to the public.

Crawford County is presently being surveyed by soil scientists. With some exceptions, the generalized state soil associations found on the general soil map, produced in 1979, combine major soils into associations that adequately describe soils in the Bourbeuse River watershed. The Union-Goss-Gasconade-Peridge and the Hobson-Clarksville-Gasconade general soil associations are contained within the Ozark Border land resource area, and within the Ozarks land resource area, the Hobson-Coulstone-Clarksville, and the Hartville-Ashton-Cedargap-Nolin soil associations. The Hartville-Ashton-Cedargap-Nolin soil association parallels the river and is composed of alluvium. This generalized association adequately describes river bottom soil associations with some exceptions. For example, the Franklin County survey, a more precise survey, describes this area paralleling the river as the Haymond-Pope association; however, the Gasconade County survey in the western portion of the watershed lists the Nolin-Cedargap association as the floodplain soil type. Nolin is also found in the floodplains of other Bourbeuse River tributaries such as the Dry Fork. On SCS aerial photographs, the Nolin, Pope, and Cedargap soil types are often found in river bottoms with Clarksville, Union, Beemont soil types on ridges or near slopes. Many of the other major soil types are found on ridges and side slopes of the river valley. Peridge, mentioned on the 1979 generalized soil association map, was not found in either soil survey.

## Soil Types

The Ozark Border region is a transitional area between the Central Mississippi Valley Wooded Slopes area and the Ozark region. Ridge-tops have a thin mantle of loess caps and subsoils formed in fragipans (Allgood, F. P. and I. D. Persinger 1979). Fragipans are loamy, brittle subsurface horizons, low in porosity and organic matter and low or moderate in clay. This layer appears cemented and restricts roots. Within the Ozark Border region, soil types are dissimilar to the Ozark region, having Union, Gasconade, Goss, and Peridge (Table 1). Union, Hobson, Goss, and Peridge are found on uplands. Union is a silty loam with clay increasing in its sublayers, thus it tends to allow only slow percolation of water. This soil has a relatively high water erosion factor and runoff potential. Hobson is a more brittle loam that has firm clay loam subsurface layers. Both the Union and the Hobson have fragipans in their subsoil at approximately 60 inches. Goss is similar to Hobson, except it has chert in its surface layers and its subsurface layers; in places the subsurface layers reach bedrock. Goss is low in water erosion potential and moderate in runoff potential. Peridge has a silt loam surface soil overlying a moderately permeable silt loam subsoil. As mentioned, the Haymond-Pope association is found quite extensively along the river bottom and is a generally sandy loam.

Within the Ozark region soil types are variable, generally having infertile, stony clay soils in some areas determine a stream's potential to lose to lower aquifers. Recent dye tracing around the Sullivan sewage treatment plant has led to the reclassification of Winsel Creek as a losing stream (Sullivan Independent News, November 15, 1995). Dry Fork has losing sections extending from its headwaters to nearly the confluence with Brush Creek. Two oil-product pipelines, the Continental and Explorer, cross the Dry Fork. Dry Creek in the Lower Bourbeuse River watershed is another losing stream. Finally, an unnamed tributary to Boone Creek is also classified as a losing stream.

## Soil Associations

Within the Bourbeuse River watershed, two soil surveys, the Soil Survey of Franklin County (SCS 1989) and the Soil Resources Inventory of Gasconade County (SCS 1994), are completed and published for use. Osage, Maries, and Phelps counties have surveys completed but not yet available to the public.

Crawford County is presently being surveyed by soil scientists. With some exceptions, the generalized state soil associations found on the general soil map, produced in 1979, combine major soils into associations that adequately describe soils in the Bourbeuse River watershed. The Union-Goss-Gasconade-Peridge and the Hobson-Clarksville-Gasconade general soil associations are contained within the Ozark Border land resource area, and within the Ozarks land resource area, the Hobson-Coulstone-Clarksville, and the Hartville-Ashton-Cedargap-Nolin soil associations. The Hartville-Ashton-Cedargap-Nolin soil association parallels the river and is composed of alluvium. This generalized association adequately describes river bottom soil associations with some exceptions. For example, the Franklin County survey, a more precise survey, describes this area paralleling the river as the Haymond-Pope association; however, the Gasconade County survey in the western portion of the watershed lists the Nolin-Cedargap association as the floodplain soil type. Nolin is also found in the floodplains of other Bourbeuse River tributaries such as the Dry Fork. On SCS aerial photographs, the Nolin, Pope, and Cedargap soil types are often found in river bottoms with Clarksville, Union, Beemont soil types on ridges or near slopes. Many of the other major soil types are found on ridges and side slopes of the river valley. Peridge, mentioned on the 1979 generalized soil association map, was not found in either soil survey.

## Soil Types

The Ozark Border region is a transitional area between the Central Mississippi Valley Wooded Slopes area and the Ozark region. Ridge-tops have a thin mantle of loess caps and subsoils formed in fragipans (Allgood, F. P. and I. D. Persinger 1979). Fragipans are loamy, brittle subsurface horizons, low in porosity and organic matter and low or moderate in clay. This layer appears cemented and restricts roots. Within the Ozark Border region, soil types are dissimilar to the Ozark region, having Union, Gasconade, Goss, and Peridge (Table 1). Union, Hobson, Goss, and Peridge are found on uplands. Union is a silty loam with clay increasing in its sublayers, thus it tends to allow only slow percolation of water. This soil has a relatively high water erosion factor and runoff potential. Hobson is a more brittle loam that has firm clay loam subsurface layers. Both the Union and the Hobson have fragipans in their subsoil at approximately 60 inches. Goss is similar to Hobson, except it has chert in its surface layers and its subsurface layers; in places the subsurface layers reach bedrock. Goss is low in water erosion potential and moderate in runoff potential. Peridge has a silt loam surface soil overlying a moderately permeable silt loam subsoil. As mentioned, the Haymond-Pope association is found quite extensively along the river bottom and is a generally sandy loam.

Within the Ozark region soil types are variable, generally having infertile, stony clay soils in some areas and fertile, loess-capped soils in others (MDNR 1986). Stony cherty soils characterize much of the Ozarks. Clarksville is excessively drained and formed in cherty dolomite and limestone residuum. On the surface the soil is a very cherty silt loam underlain by very cherty, silty clay loam (Allgood, F. P. and I. D. Persinger 1979). Lastly, Coulstone is a deep, somewhat excessively drained soil formed in sandstone and cherty dolomite on side slopes of ridges.

Four soil types are found in the river bottom areas along the Bourbeuse River: Nolin, Hartville, Cedargap, and Ashton. Nolin is a brittle silt loam from its surface layers to its subsurface layers. Hartville series, formed in alluvium, consists of very deep, slightly poorly drained, slowly permeable soils on stream terraces. Cedargap series, formed in cherty alluvium, consists of very deep, well drained soils on small floodplains along streams. Finally, Ashton is a deep, well drained soil formed in silty alluvium on low stream terraces.

## Erosion Potential

In a 1977 National Erosion Inventory estimate, the Soil Conservation Service showed that the soil erosion from cropland in the form of sheet and rill erosion amounted to five tons/acre/year in the Bourbeuse River watershed. Sheet and rill erosion, involving the removal of thin layers of soil from an area by water and creating channels about 30 centimeters in depth, did not exceed allowable limits of 2-5 tons/acre/year on pasture land; however, sheet and rill erosion did reach 18-24 tons/acre on tilled land (Anderson et al. 1980). Twenty tons per year is equivalent to one-eighth inch of soil. For comparison, in forest soils, with many roots to maintain soil integrity, losses in the Bourbeuse River watershed were less than 0.25 tons/acre/year. Gully erosion problems, extreme soil losses causing trenches that exceed 30 centimeters in depth, were rare in the Bourbeuse River watershed.

Major sources of stream sediment are sheet and rill, gully, streambank, and urban erosion. Remarkably, in the Bourbeuse River watershed, these types of erosion comprised 90%, 5%, 3%, and 1% of the sediment in streams, respectively (Anderson et al. 1980). Compared to other watersheds listed by Anderson, 90% sheet and rill erosion was a high percentage. On the other hand, gully erosion, a more severe type of erosion, was low in comparison to other watersheds. In general, lower gully erosion was a characteristic of Ozark streams.

Stream order was determined using a system of classification that was first defined by Horton (1945) and later modified by A.N. Strahler (1952). Strahler called all unbranched tributaries first-order streams; two first-order streams joined to make a second-order stream, and so on downstream to the stream mouth.

MDC East Central Region fishery personnel determined stream mileage and stream order from USGS 1:24, 000 topographic maps for all third-order and greater streams. This information was used to make gradient plots of the higher order streams. The three longest streams, greater than twenty miles in total length, are the Little Bourbeuse River, Brush Creek, and Dry Fork.

The drainage area of hydrologic units in the Bourbeuse River watershed (8-digit) were derived from USGS Hydrologic Units, which identify a hierarchy of land for Soil Conservation Service planning (USDA and SCS 1990). The NRCS has digitized 14-digit and 11-digit boundaries.

Within the four 11-digit boundaries, we combined several 14-digit hydrologic unit boundaries to calculate acreage and square mileage (Table 2). The total watershed area is 540, 318 acres and 842.9 square miles. Lanes Fork, at 5.71% of the 8-digit watershed area, has the smallest percentage area of the watershed, and has the smallest fourth-order stream hydrologic unit. Dry Fork, at 13.8% of the 8-digit watershed area, has the largest fourth-order stream hydrologic unit.

## Gradient Plot

MDC East Central Region fisheries personnel collected elevation and distance data (stream miles) from USGS 7.5 minute topographic maps (usually 20-foot contours). Within each hydrologic unit we constructed gradient plots for all fourth-order or greater streams, and for third-order streams that were at least 2.0 river miles or greater (Appendix A; Figures 1 - 62). Those stream systems with high gradients are Coppedge Creek, Clear Creek, and Lanes Fork, and those with low gradients are Pleasant Valley Creek, Three Mile Creek, and Prairie Creek. Lanes Fork, Dry Fork, Lower Peavine and Upper Peavine creeks have a relatively steady decline in slope from their headwaters to their mouth, but Brush Creek, Little Bourbeuse Creek, Little Bourbeuse River, and Upper Bourbeuse River have a high initial slope and a subsequent more gentle slope.

## Channel Gradient from Regional Geology

Following the Bourbeuse River along its 147 miles, the river intersects two faults and two different rock types. Within the headwaters of the river, which start near Rolla, MO, elevation starts at 1, 140 feet and ends near Union at approximately 500 feet. The major landform in the Bourbeuse River drainage is the Salem Plateau, which tilts north and east. Periodic uplift has elevated older Ordovician rock above younger Pennsylvanian. Gradient and percent slope of tributaries are slightly higher in the lower watershed areas compared to the upper watershed. Composed chiefly of Ordovician rock, the lower watershed has relief intervals that are closer together than in the upper watershed.

Table 1. Soil characteristics of the generalized soil associations (SCS 1979) related to hydrology, water management, erosion, and runoff within the Bourbeuse River watershed (SCS Gasconade County Soil Survey 1994, SCS Franklin County Soil Survey 1989)

| Soil Name | Feature Affects | | Water Erosion Factors[2] | | Water Features | |
|---|---|---|---|---|---|---|
| | Grassed Waterway[1] | Drainage | K2 | T | Hydro-Soil Group[3] | Water Capacity[4] |
| **Hartville** | Erodes easily, percs slowly | Percs slowly, frost action | 0.28-0.43 | 4 | C | 0.1-0.24 |
| **Union** | Erodes easily, shallow root zone | Percs slowly, slope | 0.43-0.43 | 4 | C | 0.11-0.21 |
| **Goss** | Large stones, slope, droughty | Deep to water | 0.10-0.24 | 2 | B | 0.04-0.17 |
| **Peridge** | Erodes easily | Deep to water | 0.37-0.32 | 5 | B | 0.16-0.20 |
| **Ashton** | Erodes easily | Deep to water | 0.43-0.28 | 4 | B[a] | NA |
| **Cedargap** | Large stones | Deep to water | 0.10-.024 | 5 | B[b] | 0.04-0.18 |
| **Nolin** | Erodes easily | Deep to water | 0.43-0.43 | 5 | B[c] | 0.18-0.23 |
| **Hobson** | Erodes easily, droughty | Percs slowly, slope | 0.37-0.37 | 3 | C | 0.01-0.24 |
| **Clarksville** | Large stones, slope, droughty | Deep to water | 0.28-0.28 | 2 | B | 0.05-0.12 |
| **Gasconade** | Large stones, slope, droughty | Deep to water | 0.20-0.20 | 2 | D | 0.05-0.12 |
| **Coulstone** | Droughty, slope | Deep to water | 0.24-0.24 | 3 | B | 0.06-0.09 |
| **Pope** | Erodes easily | Deep to water | 0.28 | 5 | B | 0.10-0.18 |
| **Beemont** | Slope, perks slowly | Deep to water | 0.32-0.24 | 3 | C | 0.14-0.12 |

Table 2. Drainage area of hydrologic units, Bourbeuse River watershed, Missouri (Watersheds in Missouri, USDA and SCS, 1990). The hydrologic unit code - 07140103 - is the prefix to the 11-digit and 14-digit (USDA, SCS) code.

| USDA Code | Major Stream | Max Order | Area (acres) | Area (sq.mi) | % of Basin |
|---|---|---|---|---|---|
| **020-002** | Lanes Fork | 41 | 30846 | 48.12 | 5.71 |
| **020-001, 003** | Upper Bourbeuse River | 5 | 53736 | 83.83 | 9.95 |
| **040-001, 002** | Dry Fork | 4 | 74934 | 116.9 | 13.87 |
| **090-002** | Brush Creek | 5 | 48197 | 75.19 | 8.92 |
| **090-001, 004, 008** | Middle Bourbeuse River | 6 | 113397 | 176.9 | 20.99 |
| **090-005** | Red Oak Creek | 4 | 41270 | 64.38 | 7.64 |
| **090-006** | Boone Creek | 4 | 32721 | 51.04 | 6.06 |
| **090-007** | Spring Creek | 4 | 34227 | 53.39 | 6.33 |
| **100-001, 002** | Lower Bourbeuse River | 6 | 72986 | 113.86 | 13.51 |
| **Total Bourbeuse River basin** | | | 540318 | 842.9 | 100 |

[1]Little Bourbeuse Creek

# Land Use

## Historical and Recent Land Use

Changes in stream morphology have taken place within the Bourbeuse River watershed as well as the entire Ozarks. Written historic observations of early settlers and explorers described fertile bottoms with clear-flowing water. Nevertheless, geologists working in the late 1800s, before significant land use, describe Ozark streams as having large quantities of gravel in streambanks (Jacobson and Primm 1994). Early settlers logged the land and thereafter farmed the bottomland areas and grazed the arid upland areas. Pasture was maintained by burning. Jacobson and Primm (1994) suggested that this practice of grazing and burning effectively removed topsoil and loosened the cherty, gravelly soil that eventually accumulated in streams. Also described in Jacobson and Primm (1994) is the practice of free-range grazing that impacted stream corridors in first and second order streams (valley bottoms) and whose subsequent decline permitted gravel to be released causing pulses of gravel in medium-sized streams.

Corridor vegetation decline was a significant land cover change that reduced streambank stability.

Recent Ozark land-use practices (1960-present) include greatly reduced intentional burning. Cultivated fields and total improved land have decreased over this period (Jacobson and Primm 1994). Grazing has increased in upland areas, and valley bottom lands are still being cleared for pasture. Logging operations on valley slopes and uplands are better managed than during the Timber Boom and Post-timber Boom periods, but upland areas and valley slopes still have a slight increase in annual runoff, storm runoff, and upland sediment yield as compared to pre-settlement conditions (Jacobson and Primm 1994).

The MORAP land use / land cover (LU/LC) spatial data set uses the Missouri Phase II Land Cover Classification Scheme to delineate land uses in the Bourbeuse River watershed (MORAP 1999). Satellite images were obtained from years 1991 to 1993. Phase II relied on an extensive ground truth effort to verify cover classes. Grassland (pasture) and row crops are major portions of the land use, representing 42.54% and 3.74% respectively of the total 8-digit hydrologic unit (HU) acreage (Table 3). Most (53.4%) of the Boone Creek land use is grassland (pasture). These areas are found primarily within the stream floodplains (Figure 2). The largest land use type with 50.77% of the total land area within the watershed is forest and woodland. Most of the urban land uses are found in the Lower Bourbeuse River, Spring Creek, and the Boone Creek 11-digit HU (Figure 2). The old field complexes are rather small in total acreage (0.59% in the entire 8-digit watershed), reflecting the high grazing rates and hay production in the watershed. Brush Creek has the largest percentage old field complex relative to its total acreage.

A comparison of the MORAP Phase II Land Cover with the 1:250, 000 scale GIRAS land use / land cover spatial data set (EPA 1994), which uses the Anderson Level 2 Classification system (Anderson et al. 1976), indicates that some of the categories have the same percentages. The satellite imagery used by the EPA has quadrangles from years 1977 to 1980. More detailed information on scene dates specific to the Bourbeuse River watershed could not be found. In the GIRAS LU/LC data set, cropland and pasture represented 45% of the total watershed acreage. Fifty-one percent (51.22%) of the total land area within the watershed is deciduous forest, representing the largest category. Other forest types are evergreen and mixed forest land with 1.68% and 0.14%, respectively. The combined urban categories of the GIRAS LU/LC are 1.33% (0.73% as residental) of the total watershed acreage. Although it is difficult to draw conclusions, the MORAP Phase II LU/LC spatial data set shows 1.84% as urban land use in the Bourbeuse River watershed (Table 3).

## Population Trends

As the human population grew in size, more land clearing took place. Since 1900 Missouri's population has seen a 64.7 percentage increase (OSEDA 1999). The 1900 population census found Crawford, Franklin, Gasconade, Maries, Osage, and Phelps counties with 12, 959, 30, 581, 12, 298, 9, 616, 14, 096, and 14, 194 people, respectively (Table 4). The largest increase in population since the 1990 census has been in Franklin County (164%). This urban sprawl into Franklin County from St. Louis, which brought with it some development within the vicinity of Union, is mainly outside the Bourbeuse River watershed near the City of Washington. The second largest population size increase since the 1990 census was Phelps County (148%). Portions of the Upper Bourbeuse River lie within a few miles of the City of Rolla. Two counties, Maries and Osage, have experienced slight declines in population size. Recent population size increases from 1990-97 in Crawford County are generally outside the watershed.

The general trend toward rising rural populations is expected to continue until 2010 within Missouri. Counties within the watershed are projected to have as much as 8% increase in population. For perspective, Missouri's population increased by 241, 719 between 1990 and 1996 – a 4.7% increase (OSEDA 1999). The population living inside the city limits of incorporated places increased from 3, 360, 399 to 3, 438, 564 – an increase of 78, 165 (2.3% growth rate). In 1996 about 64% of Missouri's population lived in a town or city. The remaining 36% lived in the open country. Since 1990 the rate of increase in open-country populations has been more rapid than for town populations.

## Farming

The search for productive soils to farm attracted many early settlers to this region. Floodplains are more fertile areas than upland areas, making them desirable for farming. By the early 1800s, the land within the Bourbeuse River watershed was being cleared for crops and the wood was used as timber for home construction, fences, and firewood.

Early settlers removed tree stands by girdling, cutting, and burning to open the landscape to crop and cattle production. Within Franklin and Gasconade counties the principal agricultural crop production in 1880 was barley, buckwheat, Indian corn, oats, rye, and wheat (Goodspeed 1888). Also, since the early 1800s, because the climate favored its production, wine has been produced in Crawford County. In 1850, Franklin and Crawford counties had 42, 674 and 26, 910 acres of improved land, respectively; by 1910, wheat was by far the most widely grown crop on 66, 000 acres. By 1958, Franklin, Crawford, Gasconade, Maries, and Osage counties, had an estimated 111, 424, 81, 545, 46, 155, 31, 143, and 637 acres of cropland (USDA 1966). The most common crop rotation was corn, wheat, and clover, which is a rotation still practiced today in Franklin County (SCS 1989).

One of several grist mills in the region, Noser Mill remains a testimony to the early agricultural production of the Bourbeuse River watershed. Grist mills were important public utilities in the 1800's and a nucleus of frontier communities. Marrying agriculture and industry, these mills were also places to socialize and trade. Today, Noser Mill is a popular fishing spot.

Livestock in the watershed have always been an important aspect of agriculture. A 1850 census recorded substantial numbers of horses, dairy cows, cattle, sheep, and swine (USDA 1966). In the early 1900s, use of land to raise livestock was one of the principal sources of income in the watershed. By 1958, Franklin County had 55, 569 acres of land in pasture (USDA 1966). According to the NRCS 1992 broad land use estimates, approximately 16, 600 acres of Bourbeuse River farmland are cultivated, and another 59, 100 acres of farmland are uncultivated. Farmers are producing mostly hay (Missouri Agricultural Statistics Service (MASS) 1995). In fact, land for hay production and grazing are major components of the agricultural land use in the Bourbeuse River watershed. According to the NRCS 1992 broad land use estimates, 140, 900 acres are pasture. Several of the larger counties within the watershed do not produce sizable amounts of wheat or corn (MASS 1995). Because of this low cash crop production, use of herbicides such as 2, 4-D and Atrazine is generally low.

Comparison of the average farm size and the number of farms by county within the watershed show that the largest county, Franklin, has the smallest farm size and the largest number of farms (OSEDA 1999). According to the USDA Census of Agriculture in 1992 and 1997, Franklin, Crawford, Gasconade, Maries, and Osage counties, had an average farm size of 187 and 182, 297 and 264, 241 and 247, 287 and 280, 271 and 266 acres, respectively. The number of farms for 1992 and 1997 was 1, 586 and 1592, 680 and 691, 816 and 762, 813 and 817, and 1, 171 and 1147, by county respectively.

## Mining

The Mineral Belt of Franklin County (lead, iron, copper) is in townships 40, 41, 42, part of 43 and ranges 1 East to 1 West. Several historical mines are within this vicinity, including Virginia Lead Mines, Mount Hope Mine, and Evans Mines (Goodspeed 1888). Other counties in the watershed had small mining operations upon small deposits. Coal was mined in Gasconade County for a number of years.

Deposits of fire clay and white sand were mined in and around Union in Franklin County. Mineral production is still a high-dollar industry in the Meramec River watershed, where Lead, iron ore, zinc, sand and gravel, crushed stone, clays and shale, limestone, and barite are still being produced. By comparison, only active fire clay pits and in-stream sand and gravel mining are found throughout the Bourbeuse River watershed.

Several mineral mines were active in the 1930-40s. It is doubtful these mines negatively impact stream water quality today, given that the Missouri Department of Natural Resources Water Pollution Program does not currently include these as point or non-point source discharges (MDNR 1984, 1996). Iron ore from the mines (Taylor Iron Mine, Preston Iron Mine, Varrison Iron Mine) in the Brush Creek watershed was likely mined for limonite (iron oxide) and pyrite (iron sulfide) in the 1930-40s.

Numerous fire clay pits are still active today near Owensville and north of Cuba. The Dry Fork subwatershed contains a series of clay pits. Several of the abandoned pits are now very turbid ponds but pose minimal water quality problems (MDNR 1984, 1996). An unnamed tributary of the Bourbeuse River, a tributary of Fenton Creek, and Fenton Creek receive discharge from quarries currently operating within their watersheds (MDNR 1996).

Compared to the Meramec River watershed, the Bourbeuse River watershed does not have a long history of sand and gravel mining. Historical sand and gravel mining was limited to a few small non-commercial excavations for building use. Until recently, the lower watershed area had no history of sand and gravel mining, but the upper watershed in Gasconade and Phelps counties has one or two operations with a 30-40 year history of commercial sand and gravel mining (Smith, Michael, personal communication).

Gravel bars are being mined within the Bourbeuse River, Robinson Creek, Little Bourbeuse River, Big River Creek, and Spring Creek (Table 5). Thirteen COE 404 General Permits, two COE Individual Permits, and one DNR Land Reclamation Permit have been issued for the watershed. Proper mining practices at these sites should include the use of vegetative and waterline buffer zones to reduce mining impacts on streams. There are several unpermitted sites (Smith, Michael, personal communication).

## Logging

The expansive Ozark Plateau had two land-use periods known as the Timber Boom (1880-1920) and the Post-timber Boom (1920-1960) that affected uplands, valley slopes, and valley bottoms. Cutover valley slopes during the Timber Boom were converted to pasture and seasonally burned. From 1880-1920, timber was cut for a variety of uses. Several portable sawmills existed for local use. Because of the limited supply of shortleaf pine, builders used hardwoods for railroad ties, flooring, barrel staves, and fuel. Franklin, Crawford, and Gasconade counties had predominately hardwood species such as scrub oak, white oak, post oak, and red oak in the hills and black walnut, hickory, maple, ash, birch, and sycamore in bottom lands (Goodspeed 1888). By 1880, approximately two thirds of Franklin County was yet to be logged. The Post-timber Boom was a time of economic depression and migration out of the Ozarks. This economic depression was due to reduction in logging and the attractive wages in factories. The Great Depression placed increased pressure on the valley bottoms and uplands for subsistence farming (Jacobson and Primm 1994). Residents in the Ozarks at this time attempted to extract a living from an already impacted land resource, which caused further disturbances to the uplands, valley slopes, and valley bottoms.

## Recreation

Angling and float fishing are popular recreational activities in the Bourbeuse River watershed. Angler catch rate on the Bourbeuse River in fish per hour was higher than the Big River, Huzzah and Courtois creeks but below that of the Lower Middle Meramec River as shown on Table 25, Biotic Section. The catch rate for the lower 147 miles of Bourbeuse River was 0.29 fish/hour compared to 0.44 in the lower 117 miles of the Meramec River (Fleener 1988).
During the mid-1980s, Allan S. Weithman conducted a statewide survey by telephone to estimate angler effort and success in Missouri waters (Weithman 1991). Angler effort in the Bourbeuse River watershed compared favorably to other river systems of equal or larger size over the five year period (Table 6).

## Natural Resources Conservation Service Projects

According to Paul Freeze of the NRCS, no Wetland Reserve Program (WRP) Farm Plans exist within the Bourbeuse River watershed. Clarence Buel (personal communication, NRCS) estimates that the Bourbeuse River watershed has approximately 2, 000 - 2, 500 acres of land in the Conservation Reserve Program (CRP). A total of 5, 618 acres of land for Gasconade and Franklin counties are in CRP (MDC 1998).

## Public Areas

Public land in the watershed is composed of numerous river accesses, a few natural areas, and conservation areas (Figure 3). Long Ridge Conservation Area is found in the Spring Creek watershed and has 1, 816 acres of predominantly upland forest. The area is managed for multiple uses and ecological diversity. Mint Spring Conservation Area is a 36.9 acre tract of land near the Bourbeuse River. Both the Mint Spring Seep Natural Area and the Mint Spring Access are adjacent to this site. The spring on the natural area has created a unique seep forest.

## Stream Access

Nine Missouri Department of Conservation stream accesses to the Bourbeuse River are available for public use (Figure 3). Some distances between accesses are quite long, particularly when coupled with the river's relatively low gradient.

## Corps of Engineers 404 Jurisdiction

The entire Bourbeuse River watershed is under the jurisdiction of the St. Louis District of the U.S. Army Corps of Engineers. Section 404 regulation permitting, inquiries, and violation reports should be directed to the St. Louis Office: 1222 Spruce Street, St. Louis, MO 63103-2833 or call (314) 331-8575.

Figure 2. Bourbeuse River watershed land use / land cover.

Data Originator: MoRAP, June 1999

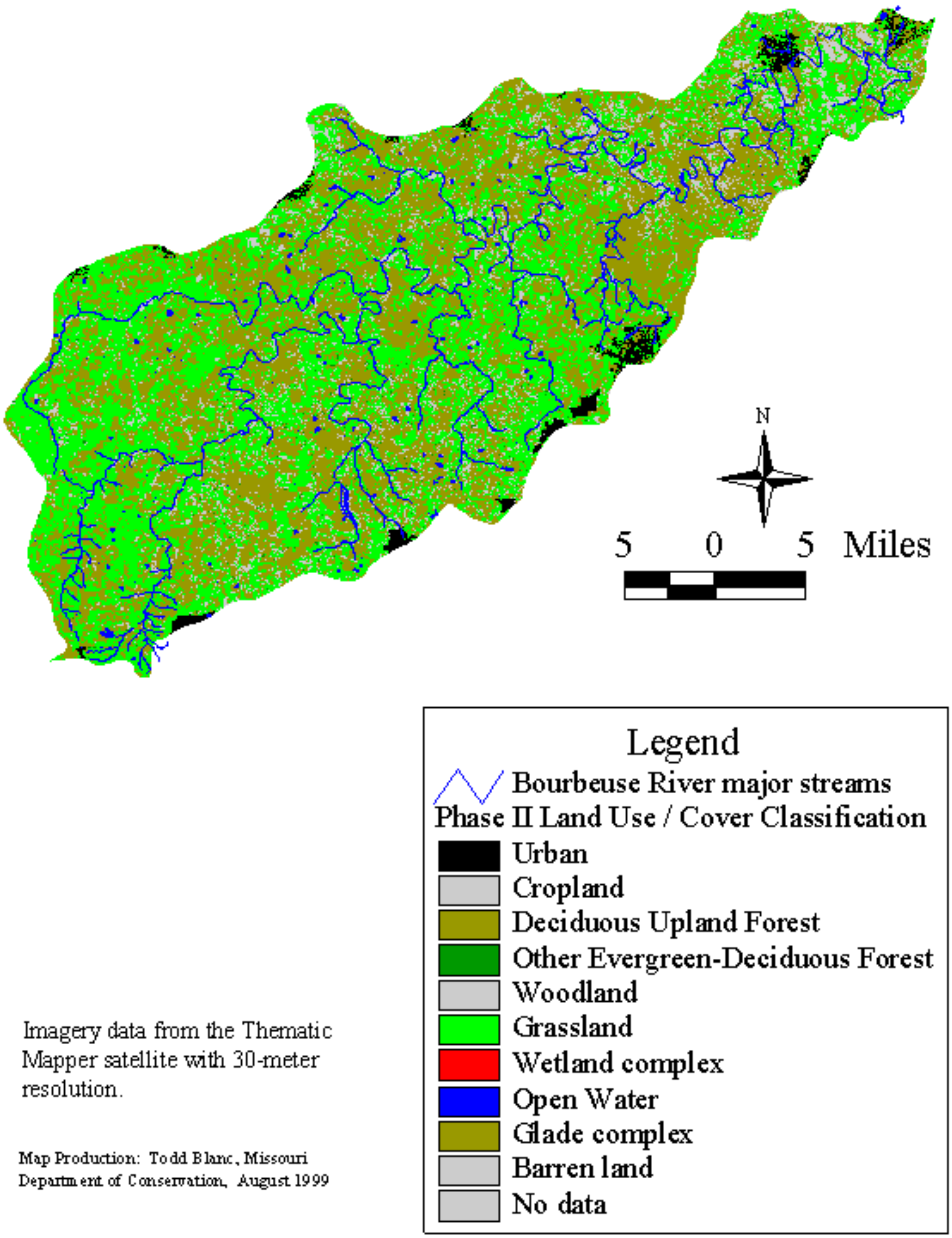


Table 3. Bourbeuse River watershed land use / land cover within each of the 11-digit hydrologic units. Data source: 30-meter resolution Thematic Mapper satellite imagery. Source: MORAP, 1999.

| Land Use /Land Cover | Acreage | Percentage |
|---|---|---|
| **8-digit Hydrologic Unit** | | |
| **Entire Bourbeuse River watershed Urban** | | |
| **Urban** | 9901 | 0.0184 |
| **Row & Close Crown Crops** | 20179 | 0.0376 |
| **Forest & Woodland*** | 272806 | 0.5077 |
| **Young Oldfield Complex** | 3195 | 0.0059 |
| **Grassland** | 228600 | 0.4254 |
| **Open Water** | 2074 | 0.0039 |
| **Barren/Sparsely Vegetated** | 573 | 0.0011 |
| **Total Acreage** | 537328 | 1 |
| **11-digit Hydrologic Units** | | |
| **Lanes Fork** | | |
| **Urban** | 41 | 0.0013 |
| **Row & Close Crown Crops** | 59 | 0.0019 |
| **Forest & Woodland*** | 12438 | 0.3991 |
| **Young Oldfield Complex** | 205 | 0.0066 |
| **Grassland** | 18356 | 0.589 |
| **Open Water** | 65 | 0.0021 |
| **Barren/Sparsely Vegetated** | 0 | 0 |
| **Total Acreage** | 31164 | 1 |
| **Upper Bourbeuse** | | |
| **Urban** | 1091 | 0.021 |
| **Row & Close Crown Crops** | 334 | 0.0064 |
| **Forest & Woodland*** | 25669 | 0.4948 |
| **Young Oldfield Complex** | 243 | 0.0047 |
| **Grassland** | 24282 | 0.4681 |
| **Open Water** | 226 | 0.0044 |
| **Barren/Sparsely Vegetated** | 34 | 0.0007 |
| **Total Acreage** | 51878 | 1 |
| **Brush Creek** | | |
| **Urban** | 928 | 0.0197 |
| **Row & Close Crown Crops** | 648 | 0.0137 |
| **Forest & Woodland*** | 26672 | 0.5654 |
| **Young Oldfield Complex** | 415 | 0.0088 |
| **Grassland** | 18102 | 0.3837 |
| **Open Water** | 369 | 0.0078 |
| **Barren/Sparsely Vegetated** | 42 | 0.0009 |
| **Total Acreage** | 47175 | 1 |
| **Dry Fork** | | |
| **Urban** | 214 | 0.0029 |
| **Row & Close Crown Crops** | 1040 | 0.014 |
| **Forest & Woodland*** | 32925 | 0.4423 |

| Land Use /Land Cover | Acreage | Percentage |
|---|---|---|
| **Young Oldfield Complex** | 674 | 0.0091 |
| **Grassland** | 39291 | 0.5278 |
| **Open Water** | 221 | 0.003 |
| **Barren/Sparsely Vegetated** | 80 | 0.0011 |
| **Total Acreage** | 74447 | 1 |
| **Little Bourbeuse** | | |
| **Urban** | 306 | 0.0081 |
| **Row & Close Crown Crops** | 516 | 0.0136 |
| **Forest & Woodland*** | 19031 | 0.5027 |
| **Young Oldfield Complex** | 328 | 0.0087 |
| **Grassland** | 17590 | 0.4647 |
| **Open Water** | 86 | 0.0023 |
| **Barren/Sparsely Vegetated** | 0 | 0 |
| **Total Acreage** | 37855 | 1 |
| **Red Oak Creek 377** | | |
| **Urban** | | 0.0093 |
| **Row & Close Crown Crops** | 3134 | 0.0777 |
| **Forest & Woodland*** | 21502 | 0.5328 |
| **Young Oldfield Complex** | 237 | 0.0059 |
| **Grassland** | 14917 | 0.3697 |
| **Open Water** | 145 | 0.0036 |
| **Barren/Sparsely Vegetated** | 44 | 0.0011 |
| **Total Acreage** | 40353 | 1 |
| **Boone Creek** | | |
| **Urban** | 1459 | 0.0438 |
| **Row & Close Crown Crops** | 905 | 0.0272 |
| **Forest & Woodland*** | 12787 | 0.3842 |
| **Young Oldfield Complex** | 238 | 0.0072 |
| **Grassland** | 17771 | 0.534 |
| **Open Water** | 88 | 0.0026 |
| **Barren/Sparsely Vegetated** | 35 | 0.0011 |
| **Total Acreage** | 33282 | 1 |
| **Spring Creek** | | |
| **Urban** | 2217 | 0.0647 |
| **Row & Close Crown Crops** | 967 | 0.0282 |
| **Forest & Woodland*** | 20588 | 0.6005 |
| **Young Oldfield Complex** | 101 | 0.0029 |
| **Grassland** | 10334 | 0.3014 |
| **Open Water** | 29 | 0.0008 |
| **Barren/Sparsely Vegetated** | 46 | 0.0013 |
| **Total Acreage** | 34283 | 1 |
| **Middle Bourbeuse River** | | |
| **Urban** | 181 | 0.0016 |
| **Row & Close Crown Crops** | 5705 | 0.0501 |

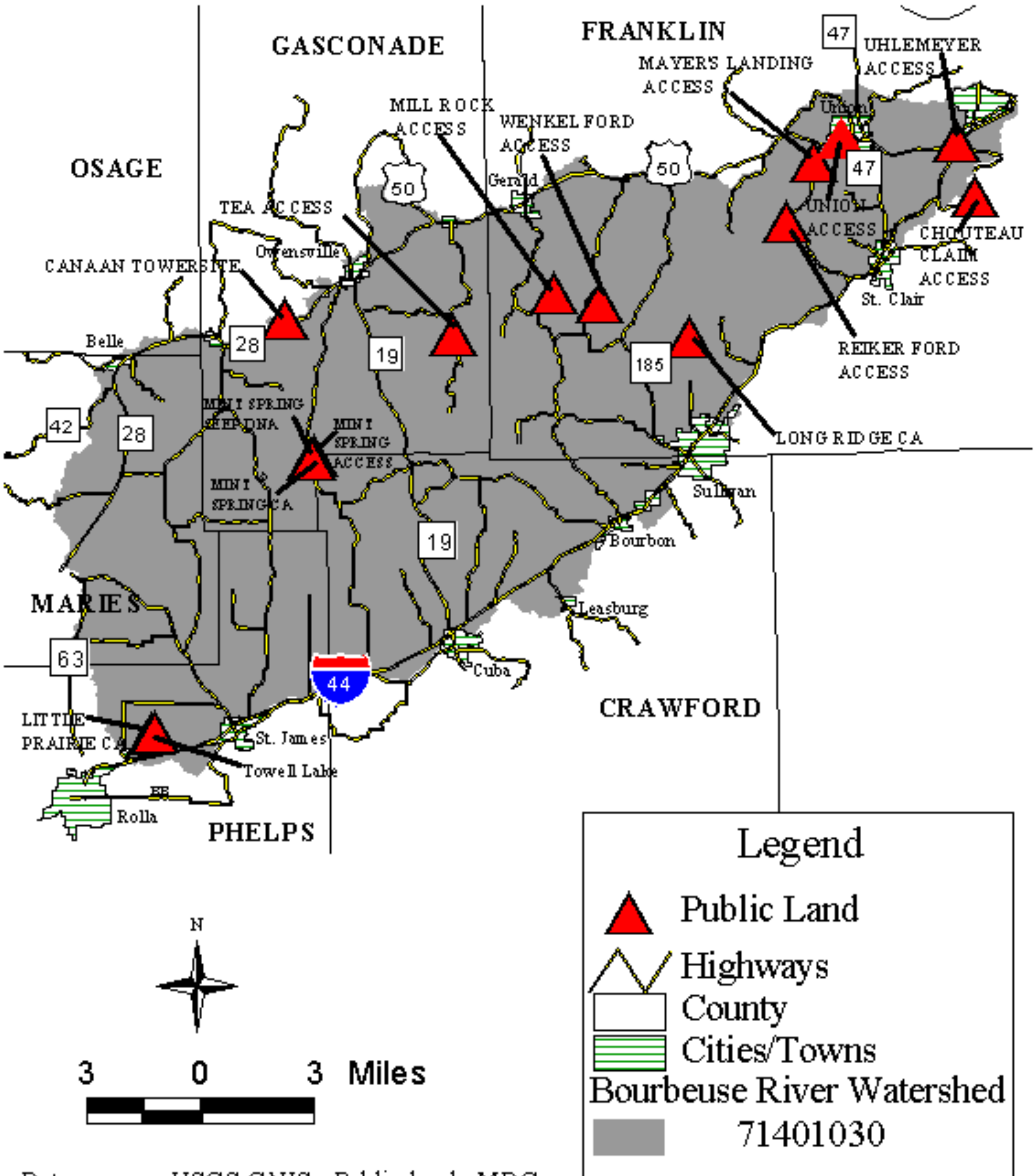
| Land Use /Land Cover | Acreage | Percentage |
|---|---|---|
| **Forest & Woodland*** | 63600 | 0.559 |
| **Young Oldfield Complex** | 689 | 0.0061 |
| **Grassland** | 43079 | 0.3786 |
| **Open Water** | 315 | 0.0028 |
| **Barren/Sparsely Vegetated** | 211 | 0.0019 |
| **Total Acreage** | 113780 | 1 |
| **Lower Bourbeuse River** | | |
| **Urban** | 3087 | 0.0422 |
| **Row & Close Crown Crops** | 6871 | 0.094 |
| **Forest & Woodland*** | 37594 | 0.5142 |
| **Young Oldfield Complex** | 65 | 0.0009 |
| **Grassland** | 24878 | 0.3403 |
| **Open Water** | 530 | 0.0072 |
| **Barren/Sparsely Vegetated** | 81 | 0.0011 |
| **Total Acreage** | 73108 | 1 |

(*including forested wetlands)

Table 4. Population trends in counties within the Bourbeuse River watershed (OSEDA 1999).

| Total Population | Percent Change |
|---|---|
| **Crawford County, Missouri** | |
| **1900 12, 959** | 1900_90 48.0% |
| **1970 14, 828** | 1970_80 23.0% |
| **1980 18, 300** | 1980_90 5.0% |
| **1990 19, 173** | 1990_97 15.0% |
| **1997 22, 011** | |
| **Franklin County, Missouri** | |
| **1900 30, 581** | 1900_90 164.0% |
| **1970 55, 127** | 1970_80 29.0% |
| **1980 71, 233** | 1980_90 13.0% |
| **1990 80, 603** | 1990_97 13.0% |
| **1997 90, 997** | |
| **Gasconade County, Missouri** | |
| **1900 12, 298** | 1900_90 14.0% |
| **1970 11, 878** | 1970_80 11.0% |
| **1980 13, 181** | 1980_90 6.0% |
| **1990 14, 006** | 1990_97 5.0% |
| **1997 14, 763** | |
| **Maries County, Missouri** | |
| **1900 9, 616** | 1900_90 slight decline |
| **1970 6, 851** | 1970_80 10.0% |
| **1980 7, 551** | 1980_90 6.0 % |
| **1990 7, 976** | 1990_97 5.0% |
| **1997 8, 331** | |
| **Osage County, Missouri** | |
| **1900 14, 096** | 1900_90 slight decline |
| **1970 10, 994** | 1970_80 9.0% |
| **1980 12, 014** | 1980_90 0% |
| **1990 12, 018** | 1990_97 4.0% |
| **1997 12, 529** | |
| **Phelps County, Missouri** | |
| **1900 14, 194** | 1900_90 148.0% |
| **1970 29, 567** | 1970_80 14.0% |
| **1980 33, 633** | 1980_90 5.0% |
| **1990 35, 248** | 1990_97 9.0% |
| **1997 38, 464** | |

Figure 3. Public lands in the Bourbeuse River watershed.




Data source: USGS GNIS; Public land--MDC Policy Coordination

Map Production: Todd Blanc, Missouri Department of Conservation, December 1998

Table 5. Sand and gravel permitted sites in the Bourbeuse River watershed (from the East Central Region Stream Environmental Review Database). Permit issue date and expiration date are given.

| Streamname | County | Township-Range-Section | Permit Type | Issue Date | Expiration Date |
|---|---|---|---|---|---|
| **Bourbeuse River** | Phelps | 39N-06W-8SWNWNW | GP | 35129 | 36877 |
| **Robinson Creek** | Phelps | 38N-06W-5SENESE | GP | 35128 | 36877 |
| **Robinson Creek** | Phelps | 38N-06W-5SENESE | GP | 35128 | 36877 |
| **Bourbeuse River** | Phelps | 39N-06W-4 | GP | 35597 | 36877 |
| **Bourbeuse River** | Phelps | 39N-06W-4 | GP | 35597 | 36877 |
| **Little Bourbeuse** | Phelps | 39N-06W-6, Site #1 | GP | 35781 | 36877 |
| **Little Bourbeuse** | Phelps | 39N-06W-6, Site #2 | GP | 35781 | 36877 |
| **Little Bourbeuse** | Phelps | 39N-06W-6, Site #3 | GP | 35781 | 36877 |
| **Little Bourbeuse Creek** | Phelps | 39N-06W-6, Site #4 | GP | 36146 | 36877 |
| **Big River Creek** | Gasconade | 40N-05W-4 | IP | 36228 | 00/00/00 |
| **Big River Creek** | Gasconade | 40N-05W-9 | IP | 36228 | 00/00/00 |
| **Spring Creek** | Phelps | 38N-08W-5 | GP | 35628 | 36877 |
| **Spring Creek** | Phelps | 38N-08W-5 | GP | 35628 | 36877 |
| **Spring Creek** | Phelps | 38N-08W-8 | GP | 35628 | 36877 |
| **Spring Creek** | Phelps | 38N-08W-8 | GP | 35628 | 36877 |
| **Bourbeuse River** | Franklin | 42N-01W-2 | LR | 35403 | 00/00/00 |

GP—COE 404 General Permit; LR—DNR Land Reclamation Permit; IP-Individual Permit.

Table 6. Estimates of days fished per total watershed area in acres on the Bourbeuse River and selected rivers in Missouri (Weithman 1991).

| Location[a] | Year | | | | | |
|---|---|---|---|---|---|---|
| | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
| **Big** | 0.0839 | 0.0247 | 0.0994 | 0.0439 | 0.0505 | 0.0524 |
| **Bourbeuse** | 0.1018 | 0.0496 | 0.0283 | 0.0325 | 0.1209 | 0.0394 |
| **Gasconade** | 0.0491 | 0.0474 | 0.0517 | 0.0381 | 0.063 | 0.0543 |
| **Meramec** | 0.1071 | 0.076 | 0.0684 | 0.0484 | 0.1022 | 0.1153 |
| **St. Francis** | 0.0187 | 0.058 | 0.0779 | 0.0318 | 0.004 | 0.0328 |
| **Total** | 0.3793 | 0.3137 | 0.4036 | 0.2265 | 0.3446 | 0.327 |

[a]The estimates of effort listed for each river or stream include days of fishing on all smaller tributaries in the watershed.

# Hydrology

## Precipitation

The upper watershed areas have slightly more rainfall than the lower basin areas. The average annual rainfall at Union (lower watershed) was 39.63 inches over the period 1961-90 (Owenby and Ezell 1992). At Rolla (upper watershed) the average annual rainfall was 41.09 inches over the period 1961-90.

## USGS Gaging Stations

Bourbeuse River watershed US Geological Survey (USGS) water discharge gage stations collect daily water discharge data, and also house National Weather Service gage-height meters (Figure 4). The following lists gage station location and period of record.

## Permanent and Intermittent Reaches

Several streams in the watershed are losing for many stream miles. Dry Fork has large segments that are considered losing (Figure 1; Location Section). Dry Creek in the Lower Bourbeuse River hydrologic unit loses flow to ground water for a major portion of its length. Recently, portions of Winsel Creek were designated as losing by the Department of Natural Resources.

The USGS defines perennial or permanent streams as those having water 12 months of the year during normal precipitation. Permanent and intermittent stream reaches within the Bourbeuse River watershed were tabulated from Funk (1968) using information derived from 7.5" topographic maps (Table 7). According to Funk, the Bourbeuse River watershed has 163 miles of permanent streams capable of supporting angling.

## Average Annual Discharge

Of the two currently active gages, the volume of water that passes the High Gate gage station, (Figure 5) draining approximately 135 square miles, is less than that which passes the Union gage station, draining approximately 808 square miles. From the period of 1965-97, the annual mean discharge at the High Gate gage station (USGS 1997) was 138 cubic feet per second (CFS). Over the same period, the lowest annual mean was 21.7 CFS and the highest annual mean, 315 CFS. The annual mean at the Union gage station was 681 CFS for water years 1921-97. At this same gage, the highest annual mean was 1, 771 CFS, and the lowest annual mean was 106 CFS.

Water years 1993 and 1954 were the highest and lowest annual average flows on the Bourbeuse River, where the discharges averaged 1, 771 CFS and 106 CFS, respectively. Peak record flow was on December 5, 1982, when flow was 73, 300 CFS. The lowest flow occurred October 10, 1956, when flow was 11 CFS.

## Stream/Hydrologic Characteristics 7-Day Q2, Q10, Q20 Low Flows

The 7-day Q2 low flow is the two-year return period of 7-day low flow. Every two years (Q2) the discharge at the Union gage station has fallen below 32 CFS for seven days, and every ten years the discharge has fallen below 18 CFS for seven days (Table 8). Farther upstream at Spring Bluff, every two years (Q2) the discharge has fallen below 6.8 CFS for seven days, and every ten years the discharge has fallen below 0.9 CFS for seven days.

In general, flows are sustained by adequate precipitation, evaporation, runoff conditions, and ground water supply (sandstone and cavernous carbonate rocks transfer water from highland areas to deep river valleys). The average annual runoff near Union, draining 808 square miles, is 11.9 inches/year (Vandike 1995).

The major difference between the Meramec River and the Bourbeuse River watersheds that affects low flow characteristics is the groundwater contribution to each stream. Numerous springs contribute to the Meramec River, where the Bourbeuse River has fewer springs with smaller discharges. Local geology is the underlying factor. Runoff rates are higher on the Bourbeuse than on the Meramec River (Vandike 1995).

## Flow Duration Curve

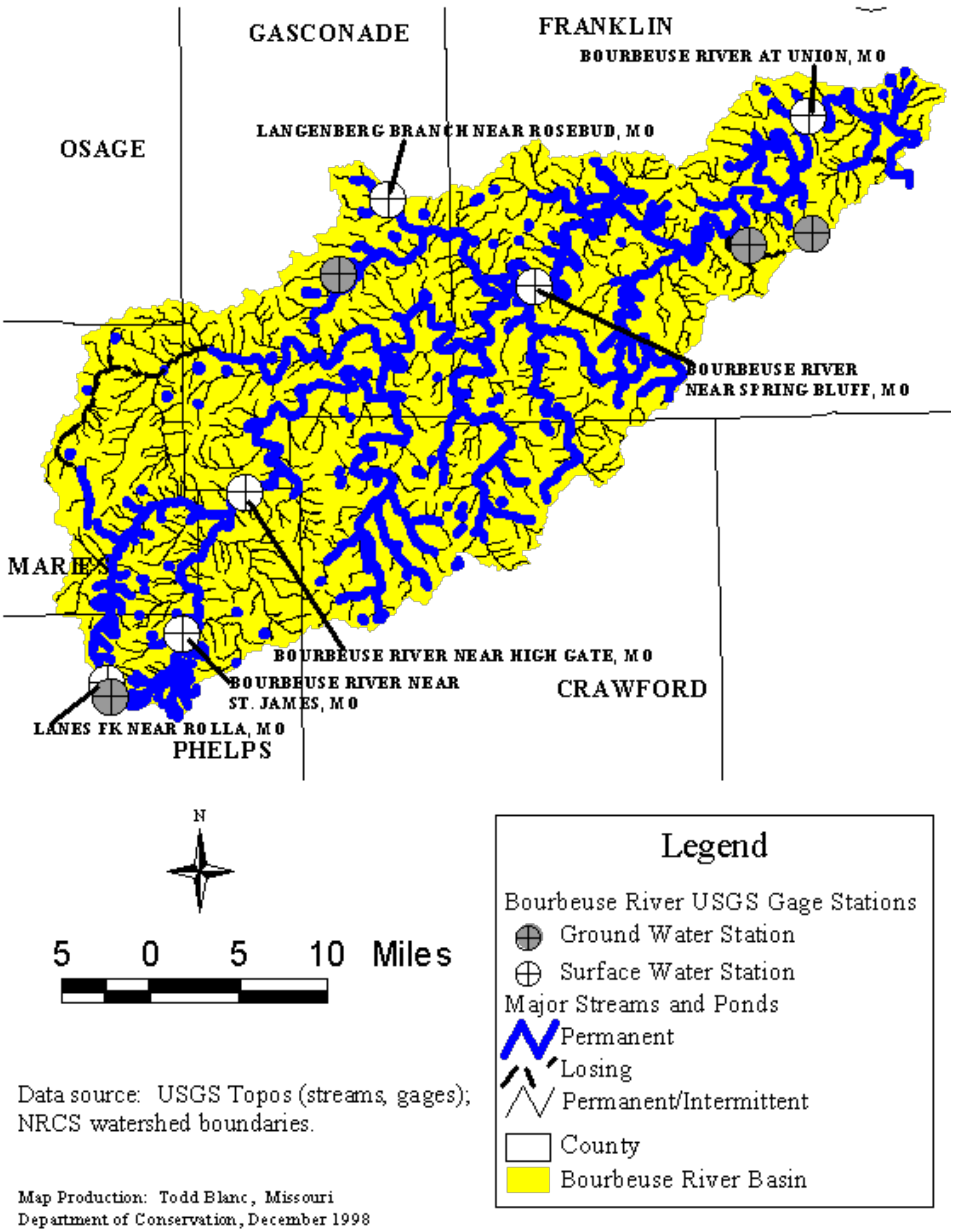
A comparison of the flow-duration curve characteristics of the upper Meramec River and the Bourbeuse River show how groundwater affects these streams (Vandike 1995). At the Steelville gage station on the upper Meramec River, discharge is nearly three times that of the Bourbeuse River. Figure 5 shows the percentage of time that the flow equals or exceeds a given discharge. Represented in the figure in log normal scale, High Gate station discharge is 401 CFS for 6% of the time, 19 CFS for 52% of the time, and 0.35 CFS during 95% of the time.

A small percentage of the time the Bourbeuse River reaches flood stage. The two-year recurrence interval (probability of flood event or 50% of the time) at the Union gage station, the flow could reach 13, 700 CFS (Hauth 1974) and at the 100-year recurrence interval (one percent chance in any given year), 34, 300 CFS.

## Dam and Hydropower Influences

There are no hydroelectric facilities in the Bourbeuse River watershed. A number of small recreational reservoirs are found throughout the watershed. Indian Lake is a 326-acre residential lake found in the Brush Creek hydrologic unit (Figure 1; watershed base map). Towell Lake at Little Prairie Conservation Area is a 100-acre public recreational fishing reservoir. Other small private lakes include Foxboro Lake (25 acres), Tea Lakes (0.5 acres, 5 acres, 0.25 acres, and 25 acres), and Melody Lake (35 acres).

Figure 4. USGS gage stations in the Bourbeuse River watershed.



| Gage Station | Stream | Location | Comment | Period of Record |
|---|---|---|---|---|
| **High Gate, 07015720** | Bourbeuse River | Lat. 38 08' 49", long. 91 34' 50" in T39N, R6W, Sec. SW, NE 4 | located on downstream side of the right bridge pier on State Highway B. | July 1965 - present |
| **Union, 07016500** | Bourbeuse River | Lat. 38 26' 45", long. 90 59' 30" in T43N, R1W Sec. SE 26 | located on the left streambank at the upstream side of the bridge on US Highway 50. Part of the ambient water quality monitoring network. | June 1921 - present |
| **St. James, 07105000** | Bourbeuse River | no longer active | no longer active | 1977-79 & 1948-82 |
| **Rolla, 07015500** | Lanes Fork | no longer active | no longer active | 1952-71 |
| **Rosebud, 07015800** | Langenburg Branch | no longer active | no longer active | 1964-70 |
| **Spring Bluff, 07016000** | Bourbeuse River | no longer active | no longer active | 1966-82 |

Figure 5. Flow duration curve for Bourbeuse River at High Gate, MO.

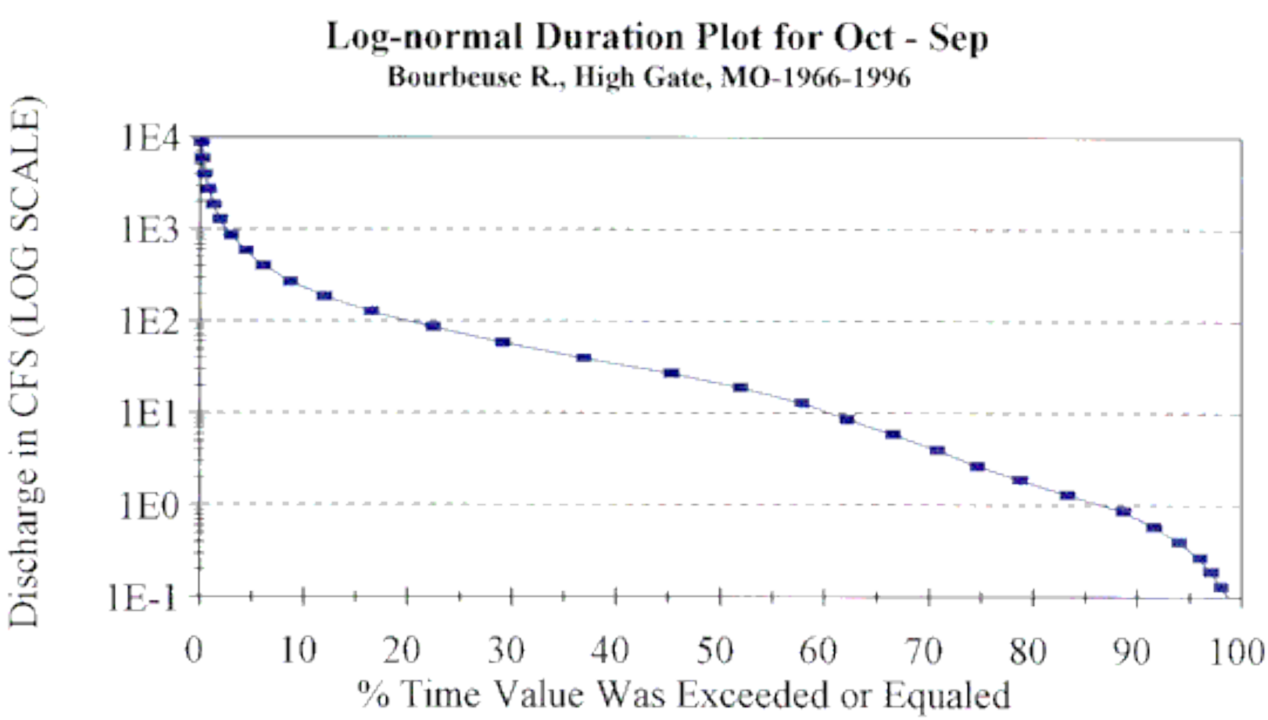


Table 7. Permanence of stream flow (fishable waters) in third-order and larger streams in the Bourbeuse River watershed (Funk 1968). Note: Dry reaches constitute the difference between total length of permanent streams and intermittent pools.

| Stream Name | Order[1] | Permanent Stream[2] | Intermittent Pools[2] | Total Length Miles[3] |
|---|---|---|---|---|
| | | Miles | Miles | |
| **Bourbeuse River** | | 106.5 | 11.5 | 147 |
| **Lower Bourbeuse Hydrologic Unit 100-002, 001** | | | | |
| **Birch Creek (Franklin)** | 3 | 4 | | 7.9 |
| **Voss Creek (Franklin)** | 3 | 0.5 | | 4.4 |
| **Spring, Boone, & Red Oak creeks Hydrologic Unit 090-007, 006, 005** | | | | |
| **Spring Creek (Franklin)** | 4 | 3 | 3.5 | 14.9 |
| **Boone Creek (Crawford)** | 4 | 2.5 | 9.5 | 16.35 |
| **Little Boone Creek (Franklin)** | 3 | | 1.5 | 6.1 |
| **Red Oak Creek (Gasconade-Franklin)** | 4 | 5.5 | 8 | 18.37 |
| **Kriete Creek (Franklin)** | 3 | | 0.5 | 2.7 |
| **Soap Creek (Gasconade)** | 3 | | 0.5 | 6.95 |
| **Little Bourbeuse River & Brush Creek Hydrologic Unit 090-003, 002** | | | | |
| **Little Bourbeuse River (Crawford-Franklin)** | 4 | 11 | 3 | 20.4 |
| **Brush Creek (Crawford-Gasconade)** | 5 | 15.5 | 3 | 24.27 |
| **Prairie Creek (Crawford)** | 4 | 2.5 | 1.5 | 5.72 |
| **McDade Spring Lateral (Crawford)** | 3 | 1 | 1.5 | 4.35 |
| **Dry Fork Hydrologic Unit 040-002, 001** | | | | |
| **Dry Fork (Maries-Gasconade)** | 4 | 11.5 | 13 | 34.33 |
| **Brush Creek (Gasconade)** | 3 | | 1 | 4.5 |
| **Lower Peavine Creek (Maries)** | 3 | | 2 | 6.55 |
| **Upper Peavine Creek (Maries)** | 3 | | 0.5 | 7.7 |

| Stream Name | Order[1] | Permanent Stream[2] Miles | Intermittent Pools[2] Miles | Total Length Miles[3] |
|---|---|---|---|---|
| **Middle Bourbeuse River Hydrologic Unit 090-008, 004, 001** | | | | |
| **Big Creek (Franklin)** | 4 | 3 | 6.9 | |
| **Price Creek (Gasconade)** | 3 | 2 | 6.15 | |
| **Lanes Fork & Upper Bourbeuse River Hydrologic Unit 020-002, 003, 001** | | | | |
| **Lane Fork (Maries-Phelps)** | 3 | | 11.5 | 8.3 |
| **Pin Oak Branch (Maries)** | 3 | | 0.5 | 5.12 |
| **Clear Creek (Phelps)** | 4 | | 2 | 9.85 |

[1]Stream order taken from 7.5" topographic maps.
[2]Taken from Funk 1968.
[3]As determined using hand dividers from 7.5" topographic maps by East Central Regional and St. Louis Regional Fisheries personnel.

Table 8. Estimated magnitude and frequency of annual low flow within period of record listed except where footnoted (MDNR 1996, USGS 1997, Skelton 1970).

| GAGE NO. | STREAM | SITE | PERIOD OF RECORD | DISCHARGE (CFS) | | | 7-DAY LOW FLOW | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Avg | Max | Min | Q2 | Q10 | Q20 |
| **7015000** | nr. St. James | nr. St. James | 1947-81 | 15.8 | | | 0.0[4] | 0 | |
| **7015720** | Bourbeuse | nr. High Gate | 1965-97 | 138 | 315 | 21.7 | 0.1[3] | 0 | |
| **7016000** | Bourbeuse | nr. Spg. Bluff | 1943-81 | | | | 6.8 | 0.9 | 4.0[1] |
| **7016500** | Bourbeuse | @ Union | 1921-97 | 681 | 1771 | 106 | 32[3] | 18 | 27[2] |
| **7015500** | Lanes Fork | nr. Rolla | 1953-72 | | | | 0 | 0 | |

Period of Record - [1]1962-1965, [2]1922-1967, [3](USGS 1994), [4]1947-81

# Water Quality

## Beneficial Use Attainment

All streams classified for beneficial uses within the Bourbeuse River watershed are designated as suitable for warm-water aquatic life protection and fishing, and livestock and wildlife watering. Additionally, 14.5 miles of Brush Creek from the mouth to the dam at Indian Lake are designated as whole body contact and recreation. The Bourbeuse River is classified as a Class P stream, meaning the stream maintains permanent flow even during drought periods, for the first 132.0 miles from the mouth to the headwaters (MDNR 1994). Stream uses for this segment include: irrigation, livestock and wildlife watering, warm-water aquatic life protection and fishing, cool-water fishing, whole-body contact recreation, boating and canoeing, and drinking-water supply. Nine miles of the Bourbeuse River's 147 total miles may cease flow during dry periods; therefore, it is classified as a Class C stream. Stream uses for this segment include: livestock and wildlife watering, warm-water aquatic life protection and fishing, and cool-water fishing. Of the River's 147 total miles, the remaining six miles of the Bourbeuse River are unclassified stream.

## Threats to Beneficial Uses

Non-attainment of whole-body recreational use and drinking-water supply could result from failure of sewage lagoons. The Union waste water treatment lagoon has in the past caused high levels of fecal coliform in receiving waters. In 1996, the Missouri Department of Natural Resources (MDNR) reported no adverse impact from the Union lagoon; however, some filamentous algae was observed (MDNR 1996). Also, the City of Sullivan discharges treated water to Winsel Creek. The City of Sullivan and the MDNR have struggled with the recent designation of portions of Winsel Creek as a losing stream and with the collapse potential of the city's treatment lagoon resting on karst bedrock (Sullivan Independent 1996). Though beneficial uses are being maintained both cases, the potential exists for groundwater contamination that could impair the drinking-water supply from such sources.

Current threats to beneficial uses are excessive discharge from sewage treatment plants (STP), cattle in streams causing water quality problems, and lastly. Several STPs have problems that need to be addressed. Robinson Creek, in the upper Bourbeuse River watershed, receives flow from the St. James STP. In a 1995 survey, the MDNR found sludge, grease, and excessive algae in Robinson Creek (MDNR 1996). Biological oxygen demand (BOD) and nonfilterable residues (NFRs) in receiving waters of waste-water treatment plants should not exceed a monthly average of 30 mg/l and weekly average of 45 mg/l (MDNR 1984). St. Clair waste-water treatment facility (WWTF) was surveyed in March 1996 and had a BOD=30 mg/l and NFRs=128 mg/l (MDNR 1996). The Cuba WWTF discharges into Pleasant Valley Creek – BOD and NFRs are higher than permitted. Excessive use of Bourbeuse River watershed streams for watering cattle may be more of a problem than it is for the Meramec River watershed, given the large amount of pasture in the Bourbeuse River watershed. Lastly, atrazine is an agricultural pesticide used to control weeds and certain grasses. In 1993, the maximum contaminant level for atrazine in public drinking water was established at 0.003 milligrams per liter. Atrazine levels in the Bourbeuse River are much lower than the water quality standard for the maximum contaminant level (Buchanan 1995).

## Water Quality

The MDNR is responsible for regulating water quality in the state of Missouri. Its mission is to ensure that the quality and quantity of the water resources of the state are maintained to support existing and potential beneficial uses. Some aspects of their mission are shared with the Missouri Department of Conservation.

Compared with the Meramec River, the Bourbeuse River has poorly sustained base flows during dry periods except below Spring Creek that is fed by Kratz Spring (MDNR 1984). Also, compared with the Meramec River, the Bourbeuse River is more turbid and prone to algae blooms.

Potential sources of pollutants come from 1) Cuba, affecting Brush Creek, 2) Bland and Belle, affecting Dry Fork, 3) Owensville, affecting Red Oak Creek, 4) Sullivan, affecting Spring Creek, and 5) Union, affecting the lower Bourbeuse River. In 1964, the Missouri Water Pollution Board sampled several of these streams for indicator aquatic invertebrates. Invertebrate species, suggesting good water quality, were found on Brush Creek, Dry Fork, Bourbeuse River near Chouteau Claim, Bourbeuse River near Noser Mill, Bourbeuse River headwaters, and Boone Creek. Red Oak Creek was suspected to be contaminated by heavy metals from a plating plant at Owensville (MDNR 1964). Although indicator algal cultures showed that organic pollution was present at several Bourbeuse River sites that were receiving waste water, water quality was good. In a 1978 survey by the Department of Conservation, the presence of excessive aquatic plant growth indicated that organic pollutants had degraded water quality on several miles of tributaries (Red Oak Creek, Happy Sock Creek, Pin Oak Creek) and main stem reaches (Duchrow 1978).

## Springs

Springs in the Bourbeuse River watershed are not as numerous as the Meramec River watershed. Four sizable springs are on the west side of the fault that runs parallel to Highway 19 (Table 9). Kratz Spring, the largest spring in the watershed, surfaces on the eastern side of the Leasburg fault that intersects Spring Bluff township and ends east of Beaufort. The presence of Pennsylvanian age rock and Jefferson City Dolomite likely prevents water movement to subsurface levels, explaining the lack of springs in the watershed. The Roubidoux and the Gasconade formations are permeable to water. Kratz Spring is found in the Gasconade Formation.

## Chemical Quality of Stream Flow

The Bourbeuse River flows over younger geologic formations than surrounding watersheds, and this characteristic influences its water chemistry. The chemical composition of the Bourbeuse is affected by erosion, surface runoff, and to a lesser degree, municipal and industrial effluents. Erosion and surface runoff are influenced by soil permeability (Table 1).

Selected water quality parameters (USGS 1995) for the Bourbeuse River watershed at the Union USGS gage station (Figure 4) in Franklin County are compared with Missouri State Water Quality 1995 Standards within designated uses I, II, VI, and VII (Table 10). Fluoride levels did not exceed four mg/l as F (USGS 1995). Surface water pH over the thirty-year period from 1964 to 1994 did not fall outside the state standard range of 6.5-9.0. Surveys of stream pH during habitat assessment, however, indicated that pH at some sites was out of state standard range. The pH levels are affected by photosynthesis and fluctuate daily. Nitrogen nitrate (mg/l N) never exceeded the state limit (Table 10). Fecal coliform levels, however, exceeded the whole-body contact limit during part of 1984 and 1996. The sewage treatment plant at Union may contribute to high fecal coliform levels. In 1964, no samples for coliform bacteria from any station had colonies greater than 100 per 100 ml except during periods of high runoff (MDNR 1964). Ammonia is an indicator of organic pollution and elevated pH reveals high concentrations of ammonium ions. The Union gage station had pH and ammonia concentrations (related measures) below toxicity levels. Levels of ammonia-N were less than 0.1 mg/l over the thirty-year period. This station is influenced by surface-water runoff from the urban environment and may not represent average conditions in the watershed.

Citizen groups, such as the Missouri Stream Team, are taking an increasing role in water-quality information collection. Stream Teams collect information mainly on water color, odor, and clarity.

Other information collected includes: temperature, dissolved oxygen, pH, nitrates and ammonia, total dissolved solids (TDS), phosphate, zinc, lead, fecal coliform, and stream flow.

## Fish Kills, Contamination Levels, and Health Advisories

The Conservation Department has investigated reports of fish kills since the late 1940s. Pollution accounts for some fish kills found in Missouri waters, but many are caused by non-regulated conditions. The purpose of fish kill investigations is to detect the causes and to abate and mitigate for the losses to aquatic resources and recreation. Pollution causes are divided into categories as follows: transportation, industrial, municipal, agricultural, miscellaneous, and undetermined causes. Reports of these activities related to pollution and fish kills have been compiled into reports since the 1960s.

Pollution can result in contamination of state waters and aquatic species. To guard against the adverse effects of fish contamination to humans from fish consumption, the State of Missouri releases a health advisory. The Missouri Department of Health has no health advisories for fish in the Bourbeuse River watershed.

## Fish Kills and Pollution Events

Pollution events in the Bourbeuse River watershed have resulted in few fish kills (Table 11). Only one in six of the events caused an immediate loss of fish. Flat Creek in Union lost an estimated 5, 280 fish to an industrial pollutant in May of 1995. The remaining pollution events did not result in an immediate loss in fish. One pollution event was for Rhodamine dye, which is used by the MDNR to determine the path of subsurface water by injecting sinkholes. Two of the six reported pollution events were linked to transportation.

## Contamination Levels

Since the early 1980s, MDC has conducted contaminant surveys on fish and mussels. Statewide fish contaminant sampling was initiated after suspected contaminant problems were discovered by the U.S. EPA. Based on fish sampling and analysis performed by Department of Conservation, the Department of Health issues annual health advisories regarding the safety of eating fish harvested from Missouri streams and impoundments. The 1999 Missouri Department of Health Fish Advisory reports that fish, i.e., catfish, bluegill, crappie, and walleye taken from the Bourbeuse River are safe for human consumption.

From 1980-1983, MDC fishery biologists collected and analyzed mussels and fish from the Bourbeuse River watershed to detect mean heavy metal concentrations (mg/kg) in the soft tissue of freshwater mussels and edible tissue of fish (Table 12). These data show the variation among fish species, especially suckers, having higher concentrations of heavy metals than centrarchid species. Also, mussels accumulate more heavy metals than fish, demonstrating that mussels are useful water quality indicators.

In 1986, the Conservation Department sampled several sites throughout Missouri for chlordane levels in the fillets of game fish. Samples of catfish species and flathead catfish in Indian Lake, an impoundment near Cuba, contained concentrations of chlordane over the U.S. FDA action level of 0.3 mg/kg (McGrath 1988). Chlordane concentrations in catfish species and flathead catfish were 0.478 and 1.238 mg/kg, respectively. Bluegill sunfish and largemouth bass were well below the action level. Catfish species (bottom feeders) have different feeding strategies than centrarchid species (mid-column feeders), explaining the differences in contaminant concentration between species. Carried to streams and lakes by rainfall runoff, chlordane accumulates in the sediments, and a bottom feeder can easily ingest large quantities of sediment during feeding. Also, age and size of fish can influence the bioaccumulation of toxins into the muscle tissue. Many pesticides like chlordane are lipophilic (Burkley, Kellogg, and Shannon 1976). In many studies, pesticide levels were found to vary with fish size, but Burkley et al. (1976) found size is not as important as the factors that vary with fish size, such as fat content and metabolic rate. This fact suggests that season and water temperature may be an important determinant in pesticide contaminant levels. Fish contaminant samples should be collected during periods (early fall) when fat content and metabolic rate are at their highest to assure that contaminant values are at the maximum possible.

During 1994, MDC biologists collected fish contaminant samples from 30 sites in Missouri. Only one sample at Foxboro Lake was taken from the Bourbeuse River watershed (Buchanan 1995). Chlordane levels were in the safe zone for the largemouth bass sampled from this lake in Franklin County.

Statewide, chlordane and lead were the only two toxins that were found in fish in 1994 that exceeded U.S. FDA action levels for human consumption. The World Health Organization's maximum safe level for lead is 0.3 mg/kg.

The 1997 fish contaminant sampling on the Bourbeuse River at Union included 30 fillets of carp, 8 fillets of bass species, and 15 fillets of redhorse species. Chlordane levels were below action levels for all fish sampled (Table 12). Chlordane found within filleted fish composites were 0.045 mg/kg for carp and 0.089 mg/kg for redhorse species. Lead and cadmium levels were below action levels for all fish species sampled.

## Water Use

Water use refers to water used for any purpose (MDNR 1986). All classified streams within the Bourbeuse River watershed are designated as suitable for warm-water aquatic life protection and fishing (AQL), and livestock and wildlife watering (LWW). The warm-water aquatic life protection is an important and complex use. Fish need water and Missourians enjoy fishing. Water provides habitat for fish, and that habitat has various components such as in-stream flows, water depth, cover, and streambed substrates. Habitat for fish is a delicate balance that must be maintained if fish species are not to be lost (see Habitat Section). Reduction in number of fish species can be an indicator of a failing ecosystem.

Endangered aquatic species could be eliminated, should habitat quality become degraded. Livestock water use is defined by the USGS as water used in the production of livestock, such as cattle, poultry, and hogs. No figures are available for the watershed as a whole, but Franklin County uses between 176-225 million gallons per day for livestock water use. One can estimate water use by multiplying the selected livestock populations (U.S. Bureau of the Census) by the coefficients 8.8 gallons per day per animal (G.P.D.) for cattle, 27.4 G.P.D. for milk cows, 0.7 G.P.D. for sheep and lambs, and 2.6 G.P.D. for hogs and pigs (DuCharme and Miller 1996). Livestock represent most of the agricultural production in the Bourbeuse River watershed (MASS 1995).

Brush Creek in Crawford County has, besides the designation for AQL and LWW, a designation for whole-body contact recreation from the mouth to the dam at Indian Lake (MDNR 1994). Designated uses for the Bourbeuse River from the mouth to T39N, 6W, Sec 4 are irrigation, LWW, AQL, cool-water fishery, whole-body contact and recreation, boating and canoeing, and drinking-water supply. This designation covers 132 miles, leaving the remaining nine miles as LWW, AQL, and cool-water fisheries. The Bourbeuse River has no surface-water withdrawals for public drinking water supply (MDNR 1984, 1996). The MDNR has limited data to quantify watershed irrigation water use; however, six percent of the irrigation in Missouri is from surface-water withdrawals (DuCharme and Miller 1996).

## Point Source Pollution

Point source pollution is permitted through the NPDES (National Pollution Discharge Elimination System). Some of the major sewage and water treatment plants with discharge greater than 0.100 MGD in the Bourbeuse River watershed (Table 13) include Belle, Bourbon, Cuba, Gerald, Leasburg, Owensville, St. Clair, St. James, Sullivan, and Union. The ten facilities each affect 1-2 miles of receiving stream reach (MDNR 1984, 1996). Because it lacks proper operation and maintenance, the Cuba Waste Water Facility continues to impact Pleasant Valley Creek with heavy algal growth and sludge—the facility. The Bourbon Waste Water Treatment Facility has similar maladies, affecting receiving waters with sludge, turbidity, and discoloration (MDNR 1996). Overall, major treatment facilities are functioning properly, while periodic surveys are required by Missouri Water Pollution Control Program. The MDNR Water Quality Basin Plan lists 78 non-public waste-water treatment facilities and 17 public treatment facilities in the Bourbeuse River watershed. In the plan, flow rate, receiving location, and EPA river reach code are listed for each facility. The largest listed contributor of a non-public pollution source is Kingsford Products, discharging to the Dry Fork.

Two decades ago, Missouri Department of Conservation biologists noted that portions of the Bourbeuse River and several of its permanent tributaries (Red Oak Creek, Happy Sock Creek, Pin Oak Creek) were influenced by point source pollutants (Duchrow 1978). Excessive plant growth was noted by MDC biologists that indicated nutrient enrichment was the cause. Specific pollution sources were not identified in the 1978 report. Severity of the problems were also omitted; however, Happy Sock and Pin Oak are small tributaries to Bourbeuse River that flow through urbanized areas near Union and I-44.

## Concentrated Animal Feed Operations (CAFOs)

Twelve animal feedlots are found within the Bourbeuse River that require permitting through the Missouri Department of Natural Resources (Table 14). The MDNR's permitting program is voluntary for farm operations with less than 300 animal units. This means that many farms are not in the database. In addition, permitted operations listed in the database may no longer be in operation because MDNR may not have been notified of the change (Scott Tackett, MDNR, personal communication). Several farms in Bourbeuse River watershed have high concentrations of swine, poultry, or cattle adjacent to streams, and during low flow they could impair water quality.

## Non-point Source Pollution

Runoff from farms, forest operations, residential septic tanks, and impervious surfaces in urban areas are considered non-point source pollutants. Annual runoff at the High Gate Gage Station on the Bourbeuse has averaged 13.77 inches from 1965-1996. Union Gage Station annual runoff has averaged 11.39 inches from 1921-1996. The MDNR Bourbeuse River Water Quality Basin Plan (1984, 1996) lists three sites as potential non-point pollution sources. These sites are a hog feeding operation in Maries County, a landfill in Crawford County, and a landfill in Franklin County.

In a report by Duchrow (1978) he noted non-point sources existed near Melody Lake and another several miles upstream from Noser Mill. No specifics were mentioned, but excessive plant growth in the observation could have been cause by agricultural sources.

Agricultural pollution comes in several forms: silt from erosion, chemical fertilizers, pesticides, and organic wastes from livestock. Presently, cultivated cropland represents nearly 4% of the land use in the watershed, and uncultivated cropland represents nearly 13% of the land use. Although this appears to be a small percentage, the majority of the cultivation takes place within the floodplain of streams. The negative impacts of crop cultivation are transmitted directly to the stream, if stream corridor is poor. The good news is that based on contaminant sampling for pesticide bioaccumulation in fish, pesticides are at relatively safe levels for humans. However, organic wastes from livestock continue to contribute to the excessive algal production in watershed streams. For several decades, water quality and nutrient supply has been altered by agricultural activities. Agencies continue to work with farmers to change this condition.

Runoff from farms, forest operations, residential septic tanks, and impervious surfaces in urban areas are considered non-point source pollutants. Annual runoff at the High Gate Gage Station on the Bourbeuse has averaged 13.77 inches from 1965-1996. Union Gage Station annual runoff has averaged 11.39 inches from 1921-1996. The MDNR Bourbeuse River Water Quality Basin Plan (1984, 1996) lists three sites as potential non-point pollution sources. These sites are a hog feeding operation in Maries County, a landfill in Crawford County, and a landfill in Franklin County.

In a report by Duchrow (1978) he noted non-point sources existed near Melody Lake and another several miles upstream from Noser Mill. No specifics were mentioned, but excessive plant growth in the observation could have been cause by agricultural sources.

Agricultural pollution comes in several forms: silt from erosion, chemical fertilizers, pesticides, and organic wastes from livestock. Presently, cultivated cropland represents nearly 4% of the land use in the watershed, and uncultivated cropland represents nearly 13% of the land use. Although this appears to be a small percentage, the majority of the cultivation takes place within the floodplain of streams. The negative impacts of crop cultivation are transmitted directly to the stream, if stream corridor is poor. The good news is that based on contaminant sampling for pesticide bioaccumulation in fish, pesticides are at relatively safe levels for humans. However, organic wastes from livestock continue to contribute to the excessive algal production in watershed streams. For several decades, water quality and nutrient supply has been altered by agricultural activities. Agencies continue to work with farmers to change this condition.

Table 9. Location and discharge of springs into the Bourbeuse River watershed. Rate of flow represents records for dates ranging from 1924-72 (Vineyard and Feder 1982).

| Spring | Nearest Town/County | Twnship-Rge-Sec | Rate of Flow | |
|---|---|---|---|---|
| | | | Cubic feet (CFS) per second | 1000 gallons/day |
| **Kratz** | Stanton/Franklin | 41N-2W-4-SENW | 15.6 42 6.85 | 10100 27, 100 27, 100 |
| **Coon Cave** | Bland/Gasconade | 40N- 6W-14-NWNW | 0.2 | 129 |
| **McDade** | Cuba/Crawford | 39N-5W-16-NENW | 0.8 1.43 0.56 1.19 | 517 924 362 769 |
| **Mint** | Redbird/ Gasconade | 40N-6W-13-NESE | 0.01 0.05 | 6 32 |
| **Rhodes** | Bland/Gasconade | 40N-6W-22-NENW | < 0.01 | < 0.01 |

Table 10. Selected water quality data for the Bourbeuse River Watershed at Lat. 38E25'55", Long. 91E01'11, Union, Franklin County, Hydrologic Unit #07140103, Gage station #07016400 for water years 1964, 1973, 1984, 1996 (USGS 1963-96; MDNR WQ Code of Regulations 10 CSR 20.7).

| Parameter | State Standard of Uses | | | | Water Year | | | |
|---|---|---|---|---|---|---|---|---|
| | I | III | VI | VII | 1964 | 1973 | 1984 | 1996 |
| **Water Temperature (°C)** | 32.2o Max1<br>28.9o Max2 | | | | 0-27E | 0-27.5E | 0.5-27E | 2.0-27.5E |
| **Specific Conductance (us/cm)** | | | | | 165-360 | 131-310 | 76-295 | 152-340 |
| **$O_2$, Dissolved (mg/l)** | 51, 62 | | | | 6-12.9 | 6-10.9 | 4.4-14.2 | 6.7-13.2 |
| **pH** | 3* | | | | 7.2-8.4 | 7.3-8.1 | 7.3-8.0 | 7.3-8.6 |
| **Hardness, Total (mg/l $CaCO_3$)** | | | | | 62-180 | 54-140 | 84-150 | 71-120 |
| **Calcium, Dissolved (mg/l as Ca)** | | | | | 14-36 | 28-Nov | 17-29 | 14-26 |
| **Magnesium, Dissolved (mg/l as Mg)** | | | | | 6.6-23 | 6.4-17 | 19-Nov | 8.8-17 |
| **Fluoride, Dissolved (mg/l as Fl)** | | 4 | | 4 | | 0.1-0.2 | <0.1-0.6 | <0.1-0.1 |
| **Sulfate, Dissolved (mg/l as $SO_4$)** | | 250 | | | 13-28 | 14-21 | 14-24 | 13-20 |
| **Nitrogen, Total Ammonia (mg/l as NH4)** | | | | | | <0.01-0.2 | 0.0-0.1 | 0.0-0.1 |
| **Nitrate-N (mg/l N)** | | 10 | | 10 | | 0.1-0.4 | 0.0-1.0 | <0.02-0.5 |
| **Phosphorus, Total P (mg/l as $PO_4$)** | | | | | | 0.0-0.2 | 0.0-0.4 | <0.02-0.1 |
| **Coliform, Fecal (colonies/100ml)** | | | 200 | | | | 6-1100 | 7-400 |
| **Streptococci, Fecal (colonies/100ml)** | | | | | | | | 1-2000 |
| **Iron Dissolved (mg/l FE)** | | | | | | 50-350 | 15-120 | 20-180 |

I: Protection of aquatic life.
III: Drinking water supply.
VI: Whole-body-contact recreation. VII: Groundwater.
[1]For warm-water fisheries.
[2]For cold-water fisheries.
[3]H2O contaminants should not cause pH to fall out of 6.5-9.0 range.

Table 11. Summary of pollution investigations on streams of the Bourbeuse River Watershed (USGS #07140103) sorted by year within county from 1990 to 1995 (Missouri Department of Conservation Environmental Services and East Central Region files).

| Date | County | Subwatershed | Stream Name | Discharge Substance |
|---|---|---|---|---|
| **34366** | Crawford | 090-007 | Winsel Creek | Rhodamine-WT dye |
| **34537** | Crawford | 090-007 | Winsel Creek | Diesel Fuel, other petroleum |
| **34585** | Crawford | 090-003 | Little Bourbeuse River | Ammonia nitrate, diesel fuel |
| **33630** | Franklin | * | Bourbeuse River, | Gasoline/oil unnamed tributary |
| **33266** | Franklin | * | Bourbeuse River, tributary to | Spices |
| **33266** | Franklin | 100-002 | Flat Creek | Chlorine |

*Not Given

Table 12. Mean heavy metal concentrations (mg/kg) in the soft tissue of freshwater mussels and edible fish tissue in the Bourbeuse River watershed collected by MDC, 1980-83. 1Collected by MDC in 1997.

| Water Body | Location | County | Species | N | Lead | Cadmium |
|---|---|---|---|---|---|---|
| **Bourbeuse River** | Union | Franklin | Pocketbook | 8 | 0.12 | 0.09 |
| **Bourbeuse River** | Reiker Ford Access | Franklin | Northern hog sucker | 10 | 0.04 | <.030 |
| **Bourbeuse River** | Reiker Ford Access | Franklin | Black redhorse | 1 | 0.009 | <.030 |
| **Bourbeuse River** | Reiker Ford Access | Franklin | Smallmouth bass | 6 | 0.004 | |
| **Bourbeuse River** | Reiker Ford Access | Franklin | Longear sunfish | 6 | < .005 | |
| **Bourbeuse River[1]** | Union Access | Franklin | Carp | - | < .010 | 0.0031 |
| **Bourbeuse River[1]** | Union Access | Franklin | Bass species | - | .010 | 0.0015 |
| **Bourbeuse River[1]** | Union Access | Franklin | Redhorse species | - | < .010 | 0.0037 |

FDA and the World Health Organization (WHO) have identified action levels for lead as 0.3 mg/kg, cadmium as not determined, mercury as 1 mg/kg, and PCBs as 1 mg/kg.

Table 13. Major sewage and water treatment plants (flow > 0.100 MGD) in the Bourbeuse River Watershed (MDNR 1996).

| Facility | Flow[1] | Receiving Stream | County | Watershed Code[2] |
|---|---|---|---|---|
| **Belle WWTF** | 0.148 | Klein Branch | Maries | 040-001 |
| **Bourbon WWTF** | 0.125 | Trib. of Boone Creek | Crawford | 090-006 |
| **Cuba Municipal WWF** | 0.52 | Pleasant Valley Creek | Crawford | 090-002 |
| **Gerald E Lagoon** | 0.105 | Big Creek | Franklin | 090-008 |
| **Leasburg WWTF** | 0.064 | Little Bourbeuse River | Crawford | 090-003 |
| **Owensville WWTF** | 0.288 | Trib. of Red Oak Creek | Gasconade | 090-005 |
| **St. Clair WWTF** | 0.657 | Happy Sock Creek | Franklin | 100-001 |
| **St. James STP** | 0.615 | Robinson Creek | Phelps | 020-001 |
| **Sullivan WWTP** | 0.8 | Winsel Creek | Franklin | 090-007 |
| **Union WWTF** | 0.8 | Bourbeuse River | Franklin | 100-002 |

[1]Million gallons per day (MGD)
[2]Hydrologic unit code

Table 14. Location of permitted animal waste facilities within the Bourbouse River watershed as of October 1, 1999 (MDNR 1999). All classified operations are included.

| Operation Type | Amount of Units | Location Twn-Rng-Sec* | County |
|---|---|---|---|
| **A hog operation** | 3, 200 | 41-5W-SENW 30 | Gasconade |
| **A hog operation** | 650 | 41-5W-SWSNE 1 | Gasconade |
| **A hog operation** | 500 | 39-7W-NWSE 4 | Maries |
| **A hog operation** | 4, 000 | 40-08W-NENW 26 | Maries |
| **A hog operation** | 600 | 39-8W-SWSW 24 | Maries |
| **A hog operation** | 3, 200 | 40-7W-NENW 04 | Maries |
| **A hog operation** | 16 | 41-7W-NENE 22 | Maries |
| **A hog operation** | 5, 760 | 39-7W-SNNW 2 | Maries |
| **A hog operation** | 20 | 42-1W-SESE 19 | Franklin |
| **A dairy milking or cow** | 150 | 43-3W-NENE 9 | Franklin |
| **A hog operation** | 20 | 43-1E-SWSW 18 | Franklin |
| **A hog operation** | 24 | 42-2-SWNE 28 | Franklin |

* Section is from smallest to largest

# Habitat Conditions

## Channel Alterations

According to the Missouri Water Atlas (1986), the main stem Bourbeuse River has no channelized segments in its 147 stream miles, nor are any major segments impounded. Some tributaries such as Brush Creek with Indian Lake and the upper Bourbeuse River with Towell Lake (see Hydrology Section, Dam and Hydropower Influences) are impounded. Also, Noser Mill near Highway 185 and Goodes Mill below Highway 50 have dams that behave as grade controls. Similarly, an untold number of bridges and fords on secondary streams can change stream gradient on smaller order tributaries, and in general, alter discharge rates.

## Dredging, Gravel Mining

In-channel mining has the potential to artificially accelerate a stream's natural geomorphic processes by increasing channel slope, channel water velocity, and sedimentation. A stable stream is in dynamic equilibrium. A section of stream gravel removed from a location, resulting in stream disequilibrium, will cause erosion upstream from the nick-point (removal area) and within the nick-point. As the stream seeks new mass-balance equilibrium, a nick-point will eventually erode away and migrate upstream in a process known as "head-cutting" (Patrick et al. 1993). In an effort to control erosion, landowners sometimes resort to "channel reaming, " a process of plowing out a straight and uniform new channel in the stream bed or gravel bar, followed by blocking off the old channel with gravel or debris, and often accompanied by pushing loose gravel against eroded banks. The Bourbeuse River and its tributaries have segments altered by these detrimental activities (see Land Use Section, Mining).

## Unique Habitat

### Natural Features Inventory

The Missouri Natural Features Inventory is completed for Franklin (Kurz 1981), Phelps (Ryan 1992), Gasconade, and Maries (Currier 1991), and Crawford (Ryan 1993) counties. The objective of the MDC statewide Natural Features Inventory was to locate, describe, classify, and rank high quality elements of Missouri's natural habitat. With this knowledge, Missourians protect the state's outstanding features through inclusion to the state natural-areas system by voluntary landowner agreements or by providing informed management decisions in ecologically sensitive areas already in public ownership.

Identifying sites within the Bourbeuse River watershed and adjacent areas involved surveying seven categories:

- natural communities (undisturbe assemblages of plants and animals),
- state-listed species habitats (rare and endangered species),
- habitats of relict species,
- outstanding geologic features,
- areas for nature studies,
- other unique features, and aquatic communities.

The natural community, geologic feature, and aquatic community sites were further classified using the Terrestrial Natural Communities of Missouri (Nelson 1987) and the Geologic Natural Feature Classification System for Missouri (Hebrank 1989). Following the classification, biologists graded sites for their natural quality, and ranked them to provide a means of comparing similar features for their preservation value (Ryan 1993; Currier 1991). Rankings were in three categories: significant, exceptional, or notable (Ryan 1993; Currier 1991). According to Ryan (1993), areas that he defined as significant natural features should receive a form of protection (possible inclusion in the Missouri natural areas system), and areas that he defined as exceptional are not of natural area quality but deserving of some protection. Lastly, notable areas on private land do not merit special management or protection.

Kurz (1981) ranked the potential natural features sites differently. Areas were either special natural features or notable.

In Gasconade County, several upland forest types were identified as rare Dry-Mesic Limestone/Dolomite Forests (T41N, R6W, Sec. 1, 2; T40N, R5W, Sec. 6, 7) near the Mint Spring Area of Gasconade County (Currier 1991). Mint Spring, designated a Missouri Natural Area in 1982, has an acid seep (T40N, R6W, Sec. 13), a forested acid seep (T40N, R6W, Sec. 13), and a mesic bottomland forest with a natural Ozark headwater stream. In Maries County, a 0.5-acre pond swamp (called Ash Pond, T40N, R7W, Sec. 22) has an unusual community association, dominated by green ash, buttonbush, and sedges. An intermittent slough in a young to mature bottomland forest along the Bourbeuse River (T34N, R7W, Sec. 23, 24) was identified as potential wetland. Finally, Gasconade County, besides several other counties, has glades that are worthy of protection. These glades are usually dry south-facing slopes with unique wild flowers and grasses, prickly pear cacti, few trees, and numerous lizards.

Franklin County is the third largest county in the state. Kurz (1981) noted that most of the county has been cleared and plowed or grazed, leaving only the northern- and southern-extreme part of the county having the natural features. Several of the sites visited by Kurz included the areas within the Meramec River watershed. In the Bourbeuse River watershed portion of Franklin County, several small streams such as the large portions of the Little Bourbeuse River were notable natural systems (Kurz 1981). This notable portion of the Little Bourbeuse River began with T41N, R4W, Sec. 26 and extended into Crawford County. In the Crawford County survey, Ryan (1992) noted the unique sandstone and shale geological features of Little Bourbeuse River watershed (T40N, R4W, Sec. 13, 35), near Argo. Large portions of the Bourbeuse River near Strain (T42N, R4W, Sec. 27) thru Noser Mill (T42N, R2W, Sec. 28 thru Sec. 2) to Union (T43N, R1W, Sec. 26) were noted by Kurz as an outstanding example of an Ozark border stream. Kurz (1981), also noted the outstanding example of Kratz Spring (T41N, R2W, Sec. 4).

Both Ryan and Kurz found outstanding upland sandstone/shale capped bluffs.

## Rare & Endangered Species

MDC Natural History inventories documented a total of 43 sites with species of conservation concern within the Bourbeuse River watershed (Table 15). The *Alosa alabamae* (Alabama shad) and the *Carpiodes velifer* (highfin carpsucker) are the only state-listed fish species in the Natural Heritage Database (see Biotic Section for recent MDC collections). The Alabama shad was collected by Dr. Brooks Burr, Southern Illinois University, Carbondale. The mussel species listed in the Natural Heritage Database as critically imperiled (5 or fewer occurrences statewide) were the *Anodontoides ferussacianus* (cylindrical papershell), *Epioblasma triquetra* (snuffbox), *Plethobasus cyphyus* (sheepnose), and *Simpsonaias ambigua* (salamander mussel). Additional information regarding state-listed mussel species can be found in the Biotic Section.

## Improvement Projects

MDC fisheries biologists use cedar tree revetments, corridor reforestation, streambank re-vegetation, willow staking, and rock blankets (rip-rap) as stream bank erosion control treatments. These techniques contribute to improved water quality and fish habitat. Once installed, a project on public land can also serve as a local demonstration site of proper stream management techniques and correction (Fantz et al. 1993). The same is true with private land, although the demonstration site aspect depends on the installation agreement with the landowner, as the landowner retains the right to refuse trespass. In 1994, Conservation Department used a cedar tree revetment to stabilize the 396-foot streambank on the Bourbeuse River at T38N, R7W, S12 (Table 16). Another streambank stabilization project was installed in 1996 on Robinson Creek, a third-order tributary to the Bourbeuse River watershed. That revetment was installed on a 95-foot long eroding streambank that was 4-6 feet in height.

## Stream Habitat Assessment Site Selection

Following Bovee (1982), the methodology for stream habitat assessment site selection of segments, sub-segments, and representative reaches was based on stream order, flow, and stream complexity within the hydrologic units. Fisheries personnel evaluated habitat on all third-order and larger streams (Figure 6). In addition, the site selection procedures, which were similar to those employed for fish community selection, consisted of:

1) constructing gradient plots of potential areas to aid in the selection of sites with various gradients,
2) consulting a topographic map or aerial photos for surrounding land use and access to sites, and
3) viewing video tapes of the watershed areas. Final selection was based on relative differences of the areas, access to the sites, and previously sampled fish community sites. For ease of stream assessment and avoidance of trespass, a ford or a bridge was often near or part of a site. The average length of sites in streams greater than or equal to order 3 was 669 feet. Third- and fourth-order stream sample sites averaged 378 feet in length, and fifth- and six-order stream sample sites averaged 745 feet in length. A sample site or reach consisted of a segment of stream that began with a riffle or pool and ended with a riffle.

## Habitat Evaluation

### Erosional, Corridor, and Land Use Conditions

Soil types, stream corridor, and land use conditions ultimately affect the erosional characteristics of a stream. Silty clays, silty clay loams, and silty loams have a soil erodibility factor of 0.24, 0.37, and 0.43, respectively, representing moderately to highly erodible soils (Table 1; Geology Section, Soil Types).

Soil types in the Ozark Region are similar to the Ozark Border Region (USDA and SCS 1979). The Soil Survey of Franklin County, Missouri (1989) describes the area that parallels the river as the Haymond-Pope soil association that is composed of alluvium with water erodibility factors of 0.28-0.43. Similarly, the Gasconade County survey in the western portion of the watershed lists the Nolin-Cedargap soil association as the floodplain soil type. Likewise, its water erodibility factors range from 0.10 to 0.43.

Soils along the Bourbeuse River are very deep, well drained, silty, loamy alluvium to somewhat fine sandy loam subsurface layers in some areas or gravelly basal deposits in other subsurface layers (SCS 1989). Following Olsen (1983), soils within the habitat assessment sites were categorized with primary soil descriptors such as gravel (G), sand (S), silt (M), clay (C), organic (O), and peat (Pt), and with secondary descriptors such as well graded (W), poorly graded (P), non-plastic fines (M), plastic fines (C), low plastic fines (L), high plasticity (H), and (BR) bedrock (Olsen 1983). The streambank was broken into soil profile inch groups and assigned descriptors based on the soil's characteristics. The most common soil type was clay loam (Figure 7, 8, 9).

Erosion protection comes from a combination of soil type and vegetative characteristics of the stream corridor. Streambank erosion protection was assessed on the left and right streambank within a sample site. Within the entire Bourbeuse River watershed (Figure 10, 11), sampled sites had 36 streambanks that were completely vegetated with no erosion, 39 streambanks – only isolated bare spots, 17 streambanks – about one-half vegetated, 13 streambanks – most of streambank unvegetated, and three streambanks – completely unvegetated. Comparing Bourbeuse River hydrologic units, the sampled sites in the Upper Bourbeuse River hydrologic unit have the best overall streambank protection and the Little Bourbeuse River hydrologic unit, the worst overall streambank protection.

The bottomland trees and riparian vegetation help protect against erosion especially in areas having highly erodible soils. According to the Franklin County Soil Survey in areas that have the Haymond-Pope soil association, 80% of this association has been cleared of trees and used for cropping and pasture. Within the entire Bourbeuse River watershed (Figure 12, 13), sampled sites had 45 corridors that were unbroken and more than one tree in width, 10 corridors—a contiguous row of trees along sample sites, 14 corridors—broken along 50% of the corridor length, 17 corridors—limited, present along portion of sample corridor, and 22 corridors—no corridor. Comparing hydrologic units, the sampled sites in the Lower Bourbeuse River hydrologic unit and the Middle Bourbeuse River hydrologic unit have the best overall riparian corridor width and the Little Bourbeuse River hydrologic unit, the worst overall riparian corridor width. Stream roughness components from vegetation and tree roots within a streambank are vital part of the erosion coverage.

Land use on floodplains in the Bourbeuse River watershed is mainly limited to agricultural uses and forested areas. Corn, soybean, wheat, and hay are grown in abundance. Because floodplains are level, they are often chosen for the production of crops (SCS 1989). Observed land use within sampled sites in the Lower Bourbeuse River hydrologic unit showed the predominant uses were from greatest to least:

1) forested lands with livestock excluded,
2) land with row crop and pasture, and
3) home sites and developed land. The lower watershed areas are more urbanized when compared to the Spring Creek, Boone Creek, Red Oak Creek, and the Little Bourbeuse River hydrologic units that are devoted to cattle production. Within these hydrologic units many floodplain areas that were observed contained hayfields, pasture, old fields, and to a lesser degree, forest. Similarly, the Upper Bourbeuse River hydrologic unit was pasture, hayfield, old field, and lastly, forested areas, from most to least observed. Row cropping consumes a major portion of the land use in the Middle Bourbeuse River hydrologic unit.

## Channel Condition

Channel condition of sampled streams was characterized by evaluating the gravel bar vegetation status. A stable gravel bar contains early succession woody stems. Likewise, an unstable gravel bar has no vegetation or may have annual plants or grasses. Gravel bar stability is a good indicator of overall stream reach stability.

Gravel bars are numerous in the Bourbeuse River watershed. An average of three gravel bars per site of various sizes and with various amounts of vegetation was found within all hydrologic units (HUs).

Within habitat sample reaches of the Lower Bourbeuse River HU, 57%, 26%, and 17% of total gravel bars had early successional or woody stems, grasses and sedges, and no vegetation, respectively (Table 17). Within the Spring, Boone, Red Oak Creek HU are smaller-order tributaries to the Bourbeuse River.

The percentage of the total number of gravel bars within the fourth-order tributaries was 5% early successional or woody stems, 50% grasses and sedges, and 45% no vegetation. Within the Middle Bourbeuse River HU, the sixth-order Bourbeuse River had more stable gravel bars (50% early successional woody stems). Conversely, the smaller-order tributaries generally had more unstable gravel bars with grasses or no vegetation. Combining third to fifth orders within the Middle Bourbeuse River (Table 17), 10 out of the 14 gravel bars had grasses and sedges or no vegetation, compared to four out of 14 gravel bars with early successional or woody stems. The same relationship was noted within the Upper Bourbeuse River HU. Approximately 57% of the gravel bars within fourth-order tributaries had no vegetation. Conversely, the main stem Upper Bourbeuse River (fifth order) had 67% of its gravel bars with early successional or woody stems. Sampled gravel bars within stream orders of the Dry Fork and the Little Bourbeuse River HUs indicated that sample site position within the HU was an important determinant in the presence or absence of vegetation on gravel bars. Of the gravel bars sampled, 57% of those within fourth order segments had no vegetation. Although slightly more stable, the fifth-order sample reaches of the Little Bourbeuse River had 50% of the gravel bars with grasses and sedges and 50% gravel bars with no vegetation.

## Channel Stability

Gravel bars with early successional plants or woody stems are considered more stable than those with grasses or no vegetation. Those gravel bars with little more than grasses or no vegetation are receiving deposition from shifting bed loads from upstream areas and reflect relatively unstable channel conditions. Channel stability, as well as fish habitat, is influenced by a variety of factors such as bed load and gradient. The observation that smaller-order streams have less vegetated gravel bars may suggest that bed load is moving through these streams to the larger-order streams. Stream gradient within the smaller order tributaries is usually higher than larger-order streams. For example, as stream gradient increases upstream from 8-14.5 feet/mile within sample reaches of the Middle Bourbeuse River HU, the number of non-vegetated gravel bars increases. Lower gradient areas are places of gravel deposition and will have both vegetated and non-vegetated gravel bars. For instance, Brush Creek at river mile 8.3 has a gradient of 5.3 feet/mile and several gravel bars with no vegetation and one large bar. A downstream sample site at river mile 5.15 has lower gradient and vegetated gravel bars and few non-vegetated gravel bars. A similar pattern of gravel bars with no vegetation was present in the Dry Fork HU, especially in the losing portion. The sample site at river mile 19.0 had large gravel bars with no vegetation and a gradient of 6.9 feet/mile. The channel is more stable downstream at river mile 8.45 with more large, woody-stem vegetated gravel bars.

## Land Use

Without knowledge of the gravel bar disturbance history, correlating the presence or absence of gravel bar vegetation with land use is somewhat tenuous. However, some evidence of this relationship was suggested in research on the Little Piney River by Jacobson and Primm (1994) and Jacobson and Pugh (1995). According to Jacobson and Primm, prior to European settlement, historic changes in streambed elevations appear to correlate with climatic shifts that suggests a destablization of streams and an influx of gravel. However, research suggests a greater deposition of gravel since European settlement, which is thought to be related to land-use changes after European settlement.

Gravel bars with little or no vegetation may be influenced by land use that affect sheet and rill erosion rates within the watershed (see Geomorphology Section). Changes in the stream channel are influenced by shifting bed load from smaller-order streams. For these reasons, using MoRAP 30-meter resolution TM satellite imagery, an estimate of dominant land use surrounding (generally upstream) the sample sites was determined. From this estimate, a percentage of sites with forest, urban, or woodland and a percentage of sites with cropland or grassland land use for each HU was determined. The land-use combination is based on the similarity of each in hydraulic properties and erosion resistance. The Lower Bourbeuse River HU had 50% of the land use in cropland/grassland and 50% in forest/urban/woodland (Table 17). Compared to other HUs, the Lower Bourbeuse River HU (sixth order) had fewer unstable gravel bars with no vegetation. Other HUs with similar land-use percentages were the Dry Fork HU (fourth order) and the Little Bourbeuse River HU (fifth order). Both of these HUs had unstable gravel bars with grasses or no vegetation. A result which does not necessarily support the relationship between land use and gravel bar stability. The Upper Bourbeuse River HU sample sites appear to have stable gravel bars and more sites with forest/urban/woodland as land use. The observation of streams in the Spring, Boone, and Red Oak creeks hydrologic unit reveals gravel bars with mostly grasses (Table 17). Many sample sites in Boone Creek and Red Oak Creek were characterized by pasture or row cropping as the surrounding land use. 37% of the sampled sites had cropland/grassland as land use, considered a potential source of gravel deposition in streams (Table 17). Showing a good relationship between land use and gravel bar stability, the Middle Bourbeuse River HU had 67% of the land use as forest/urban/woodland and more early successional or woody-stem vegetated gravel bars than gravel bars with grasses or no vegetation. These results indicate that while some sampled sites had stable gravel bars and dominant surrounding land use encouraging good soil stability, other sample sites showed little relationship between surrounding land use and gravel bar stability. The results reinforce the concept that the transport and deposition of bed load in streams is influenced by a complex of factors within a watershed. Factors such as channel pattern (straight, meandering, or braided), channel gradient, land use, land cover, flood events, soil types, etc. affect gravel bars, making the analysis of the cause of their instability or stability quite complex.

## Channel Habitat

McCain et al. (1990) developed a channel habitat classification system based on stream channel morphological features and pool-riffle and step-pool formation. A tally of these features was made to provide an estimate of the habitat diversity represented as a percentage composition of habitat types (Figure 14). A number of the classifications are good descriptors of Ozark streams. The 22 original McCain et al. (1990) classifications and one additional classification, backwater pool associated with gravel bar (BWPG), were used to describe stream channel morphology (Table 18).

McCain et al. (1990) divided habitat types into three categories based on water depth: riffle, run, and pool. Further pool category distinction is based on pool position in the stream (secondary channel, backwater, lateral, and main channel) or the cause of the scour (obstruction, blockage, constriction, or merging flow). Riffle and run are differentiated based on gradient and velocity. Using the river mile and average gradient for the stream segment, we distinguished between low gradient riffle and high gradient riffles.

The low gradient riffle category (LGR) was identified as 22% of the cumulative total types within all sample sites. This was expected because sampling, when possible, included a segment of stream that began with a riffle or pool and ended with a riffle. At times the stream segment sample included two riffles, and possibly, a number of small pools of any given type as described above, separated by a run (7% watershed-wide total) or glide (5% watershed-wide total). Of course, in the smaller-order systems the riffle-pool continuum was closer together; therefore, these segments may have included a pool-riffle-pool-riffle.

During this survey, distinguishing pool types from stream order to stream order improved with experience. Among pool formations, lateral scour was dominant over other pool formations. The lateral scour pool rootwad type was a dominant pool habitat type, accounting for nearly 8% of the habitat types (Figure 14). This numerical dominance illustrates the role of a healthy terrestrial-aquatic interface in shaping streams and providing habitat for fish species. The role channel blockage and obstruction from logs and boulders plays in scour pool development is further illustrated by a relative composition of 4.2% (LSPL) and 4% (LSPB), respectively (Figure 14).

Other pool types were mid-channel pool, backwater pool, secondary channel pool, and the corner pool, channel confluence pool, and pocket water pools. First, the mid-channel pool (6.4% watershed-wide total) was a middle channel scour area with low water velocity that may be a transitional area created by shifting bedload. Along with lateral scour pools, these areas are used during fall and winter low water periods. Second, backwater pools ranged in relative composition from 2.1-5.5% watershed-wide total.

Mostly used by larval fish and juvenile fish, these were out of the main flow and have low current velocities. These habitats were formed during high flow by rootwad (2.1%), boulders (or in some case concrete; 3.6%), logs (3.9%), or gravel (5.5%). Third, secondary channel pool, formed by merging-flow scour, were fairly common with a composition of 5% watershed-wide total. Fourth, corner pools (3% watershed-wide total) were found in many of the 6th-order stream segments of the Bourbeuse River.

Because corner pools are formed by scour and are of large size, they were identified mainly by topographic map. Fifth, the channel confluence pool accounts for 2.1% of the watershed-wide total. Lastly, the pocket water pool was rare in the Bourbeuse River watershed. It accomprised < 1% of the watershed-wide total. This habitat was found at the base of the dam at Noser Mill, where numerous large boulders created small pocket pools from the high flow of the falls.

In addition to the backwater pools, the edgewater areas were important nursery areas for juvenile fish. They typically had emergent vegetation such as waterwillows and are adjacent to riffles or mid-channel pools. Edgewater areas were numerous (8.3% watershed-wide total).

## Channel Alterations

We categorized the human activities in the Bourbeuse River hydrologic units at or near the stream sample sites into 19 categories (Table 19). Most sampling was done where low-water crossing or roads were found; therefore, this alteration was noted at many sites.

Agricultural activities were found at nearly all watershed sample sites. First, livestock had access to streams in five of the seven hydrologic unit sample sites. Seven of the thirteen sample sites in the Little Bourbeuse River hydrologic unit had livestock access to streams, making stream sample sites in this watershed the most heavily used by livestock. The Little Bourbeuse River hydrologic unit had the worst riparian corridor and erosion protection condition as compared to other hydrologic units (see Habitat Evaluation Section, Erosion, Corridor, and Land Use Conditions). Although it is difficult to prove relationships between the livestock access and filamentous algae, most sites with livestock access to streams had abundant or some algae (Table 19). Lastly, concentrated animal farms were within two of the seven watersheds. The Middle Bourbeuse River and the Little Bourbeuse River hydrologic units had one site each with this activity.

The Middle Bourbeuse River and the Little Bourbeuse River hydrologic units have the most need for management based on the observed scarcity of streambank protection and intact riparian corridors. When comparing across hydrologic units, the Upper Bourbeuse River and the Spring, Boone, and Red Oak Creek hydrologic units may have the best overall watershed conditions within or near riparian zones.

Table 15. Sensitive animal species known from the Bourbeuse River watershed (printout of the Missouri Natural Heritage Database 1998).

| Sensitive Animal Species | Federal Status | # of Locations |
|---|---|---|
| **Birds** | | |
| ***Accipter cooperii* (Cooper's hawk)** | | 2 |
| **Fish** | | |
| ***Carpiodes velifer* (Highfin carpsucker)** | | 1 |
| ***Alosa alabamae* (Alabama shad)** | | 1 |
| **Mammals** | | |
| ***Myotis grisescens* (Gray bat)** | E | 2 |
| **Mollusks** | | |
| ***Anodontoides ferussacianus* (Cylindrical papershell)** | | 3 |
| ***Cumberlandia monodonta* (Spectaclecase)** | | 1 |
| ***Alasmidonta marginata* (Elktoe)** | | 1 |
| ***Epioblasma triquetra* (Snuffbox)** | | 16 |
| ***Leptodea leptodon* (Scaleshell)** | | 5 |
| **Plethobasus cyphyus (Sheepnose)** | | 10 |
| ***Simpsonaias ambigua* (Salamander mussel)** | | 1 |

**Federal Status:** E=Endangered

Figure 6. Fish and habitat sample sites in the Bourbeuse River watershed.

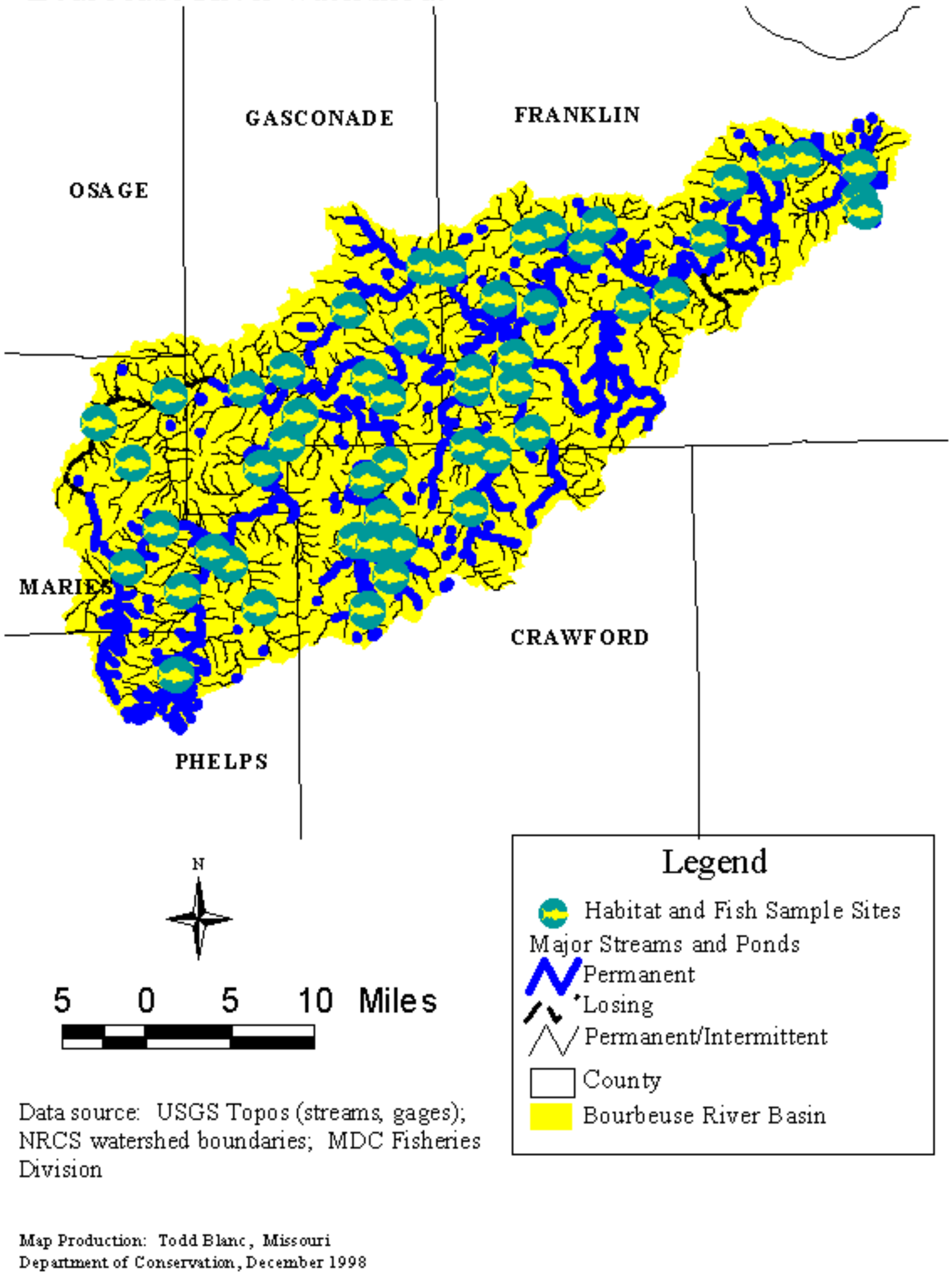


Table 16. Description of stream improvement projects in the Bourbeuse River watershed, Missouri (Missouri Department of Conservation, unpublished data).

| Stream | Technique/Program | County Twn-Rng-Sec | Completion | Comments |
|---|---|---|---|---|
| **BourbeuseRiver** | Cedar Tree Revetment1/ CS3 | Phelps T38N-R7W-Sec12 | 1994 | 396-ft eroding bank, 4-14 ft height. |
| **Robinson Creek** | Cedar Tree Revetment1/ EL2 | Phelps T39N-R6W-Sec25 | 1996 | 95-ft eroding bank, 4-6 ft height |

[1]Anchoring of trees along an eroding bank to control erosion.
[2]EL—Equipment Loan
[3]CS—Costshare

Figure 7. Streambank soil types of the Bourbeuse River watershed habitat assessment sites. Summarized is the percentage (total soil type/total sampled soil layers) X 100] found within sampled streambank soil layers of the shown hydrologic units. Soil layers within the streambank were categorized by starting at the water line of the streambank to the top. See primary and secondary despriptors of the soil type.

Primary soil descriptors are gravel (G), sand (S), silt (M), clay(C), organic (O), and peat (Pt). The secondary descriptors are well graded (W), poorly graded (P), with nonplastic fines (M), with plastic fines (C), or low plastic fines (L), and of high plasticity (H) (Olson 1983). BR—bedrock

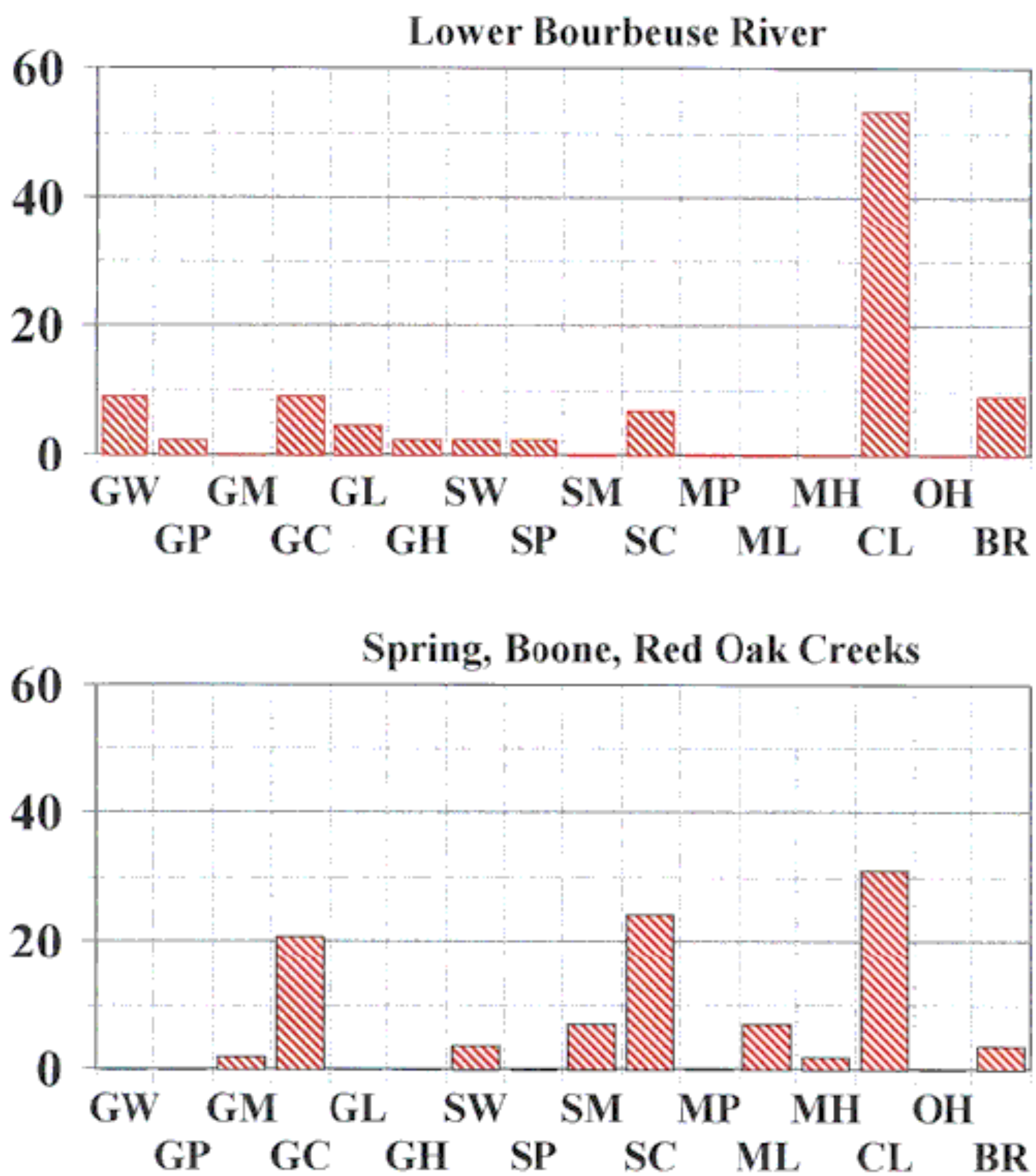
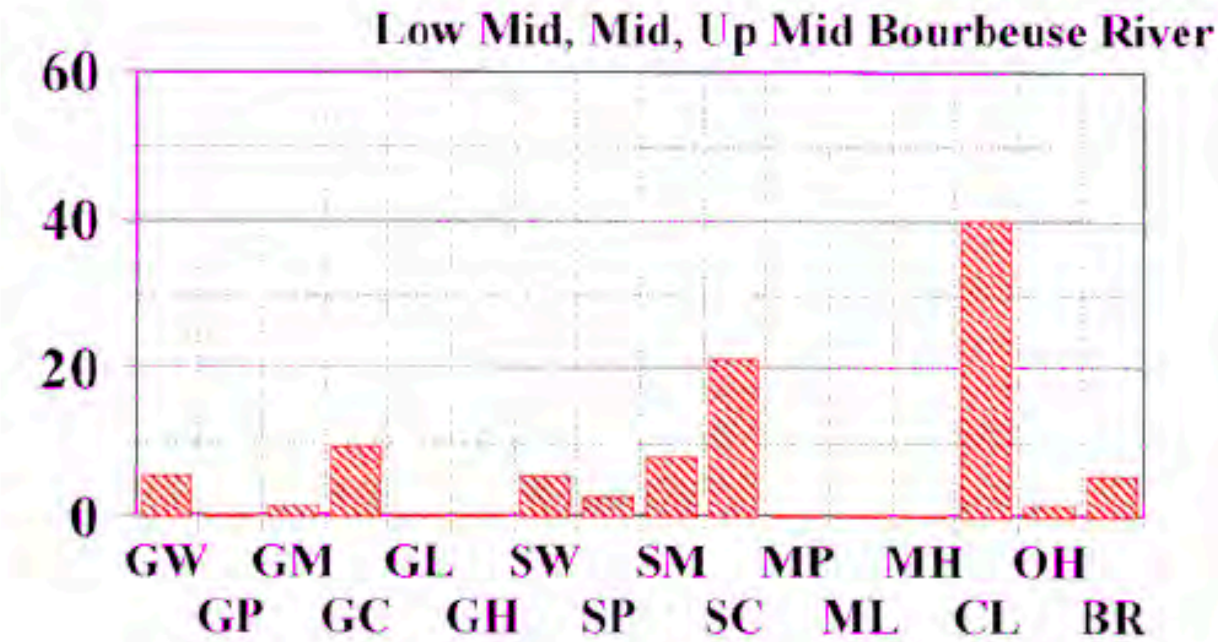


Figure 8. Streambank soil types of the Bourbeuse River watershed habitat assessment sites. Summarized is the percentage (total soil type/total sampled soil layers) X 100] found within sampled streambank soil layers of the shown hydrologic units. Soil layers within the streambank were categorized by starting at the water line of the streambank to the top. See primary and secondary despriptors of the soil type.

Primary soil descriptors are gravel (G), sand (S), silt (M), clay(C), organic (O), and peat (Pt). The secondary descriptors are well graded (W), poorly graded (P), with nonplastic fines (M), with plastic fines (C), or low plastic fines (L), and of high plasticity (H) (Olson 1983). BR—bedrock



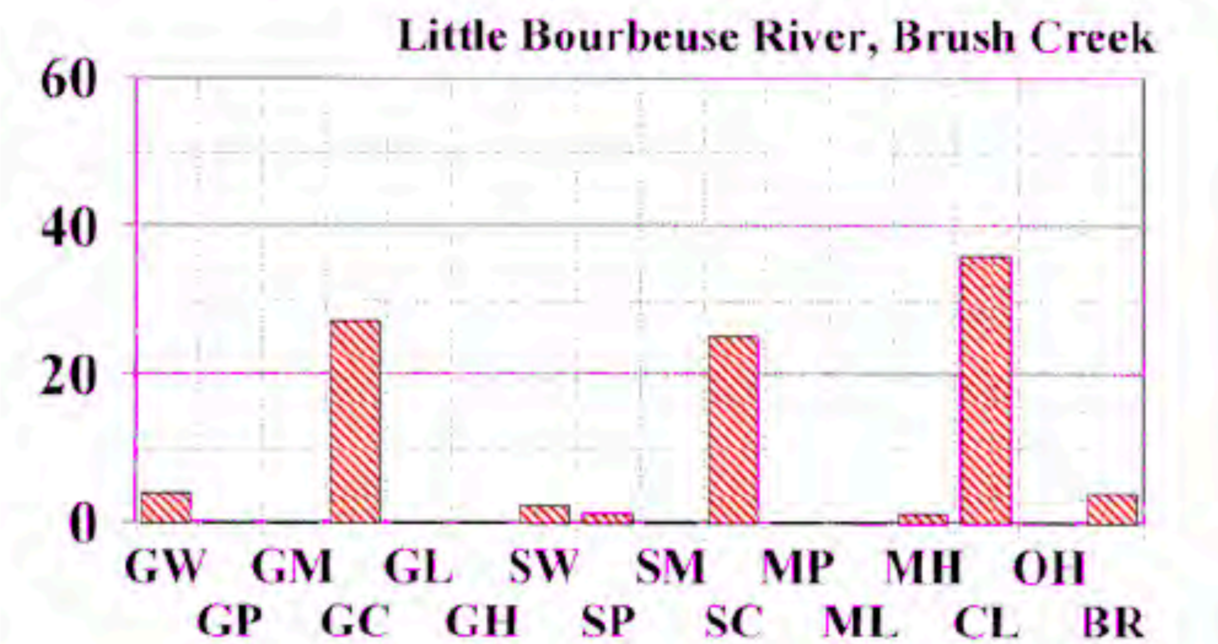
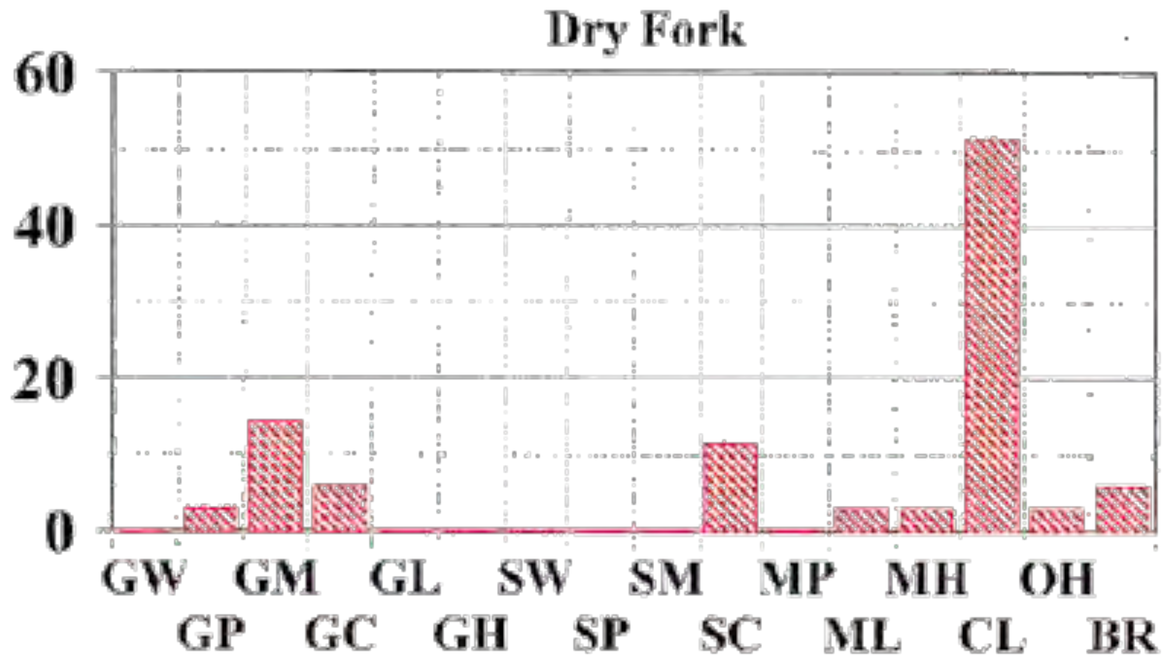



Figure 9. Streambank soil types of the Bourbeuse River watershed habitat assessment sites. Summarized is the percentage (total soil type/total sampled soil layers) X 100] found within sampled streambank soil layers of the shown hydrologic units. Soil layers within the streambank were categorized by starting at the water line of the streambank to the top. See primary and secondary despriptors of the soil type.

Primary soil descriptors are gravel (G), sand (S), silt (M), clay(C), organic (O), and peat (Pt). The secondary descriptors are well graded (W), poorly graded (P), with nonplastic fines (M), with plastic fines (C), or low plastic fines (L), and of high plasticity (H) (Olson 1983). BR—bedrock



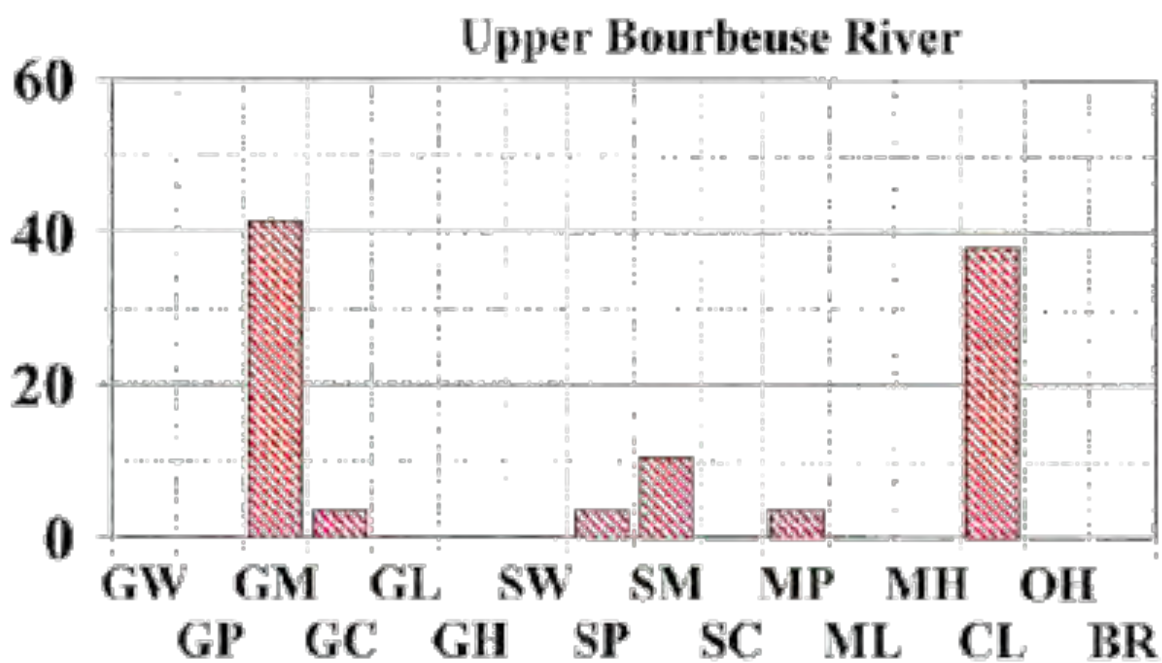



Table 17. Gravel bar vegetation observed on habitat sample sites located in the Bourbeuse River watershed (*hydrologic unit # 07140103-) Missouri, 1997. Values represent stream bar numbers within defined categories. Total # of bars = A + B + C.

| Gravel Bar Vegetation Status Land Use | | | | | | | |
|---|---|---|---|---|---|---|---|
| Stream Order | Total # of Bars[A] | (A) Early successional or woody strems[1] | (B) Grasses and sedges[2] | Large bars[3] | (C) No veg.bars[4] | % of sites with forest, urban, or woodland[5] | % of sites with cropland or grassland land use[5] |
| **LOWER BOURBEUSE HYDROLOGIC UNITS*-100-001, 002** | | | | | | | |
| **6** | 23 | 13 | 6 | 7 | 4 | | |
| | | 57% | 26% | 17% | 17% | 50% | 50% |
| **SPRING, BOONE, RED OAK CREEK HYDROLOGIC UNITS* -090-007, 006, 005** | | | | | | | |
| **3** | 2 | | | 1 | 2 | | |
| | | | | | 100% | | |
| **4** | 20 | 1 | 10 | 10 | 9 | | |
| | | 5% | 50% | | 45% | 63% | 37% |
| **MIDDLE BOURBEUSE HYDROLOGIC UNITS* -090-008, 004, 001** | | | | | | | |
| **3** | 1 | | | | | | |
| | | | 1 | | | | |
| | | | 100% | | | | |
| **4** | 1 | | | 1 | 1 | | |
| | | | | | 100% | | |
| **5** | 12 | 4 | 5 | 5 | 3 | | |
| | | 33% | 42% | | 25% | | |
| **6** | 22 | 11 | 8 | 5 | 4 | | |
| | | 50% | 36% | 18% | 67% | 33% | |
| **LITTLE BOURBEUSE RIVER HYDROLOGIC UNITS* -090-002, 003** | | | | | | | |
| **3** | 3 | | 2 | | 1 | | |
| | | | 67% | | 33% | | |
| **4** | 31 | 10 | 10 | 7 | 11 | | |
| | | 32% | 32% | | 35% | | |
| **5** | 8 | | 4 | | 4 | | |
| | | | 50% | | 50% | 46% | 54% |
| **2** | 3 | | | | 1 | 3 | |
| | | | | | | 100% | |
| **3** | 5 | 1 | | | 1 | 4 | |
| | | 20% | | | | 80% | |
| **4** | 14 | 4 | 2 | 7 | 8 | | |
| | | 29% | 14% | | 57% | 50% | 50% |
| **UPPER BOURBEUSE HYDROLOGIC UNITS* -020-002, 003, 001** | | | | | | | |
| **3** | 2 | 2 | ND | | | | |
| **100%** | | | | | | | |
| **4** | 14 | 4 | 2 | 4 | 8 | | |

| Gravel Bar Vegetation Status Land Use | | | | | | | |
|---|---|---|---|---|---|---|---|
| Stream Order | Total # of Bars[A] | (A) Early successional or woody strems[1] | (B) Grasses and sedges[2] | Large bars[3] | (C) No veg.bars[4] | % of sites with forest, urban, or woodland[5] | % of sites with cropland or grassland land use[5] |
| **29%** | 14% | 57% | | | | | |
| **5** | 6 | 4 | 2 | 2 | | | |
| **67%** | 33% | 57% | 43% | | | | |

[A]Representing all bars in the sample reach (not the row total). 1 Early successional (< 1" diameter stems) to woody (< 1" diameter stems). 2 Number gravel bars with grasses/sedges. 3 Number of large gravel bars out of total number. 4 Bars with no vegetation, easily disturbed. 5 Land use surrounding the site as possible reason for gravel deposition (30-meter resolution TM satellite imagery).

Figure 10. Bourbeuse River watershed streambank erosion protection assessment for sampled sites. summarized by hydrologic units with values representing right and left streambanks.
Covered - Streambank completely covered—no erosion
Bare spots- Streambank has only isolated bare spots
50% covered- About half streambank covered
25% covered- Most of streambank uncovered— little protection
All uncovered-Streambank completely uncovered

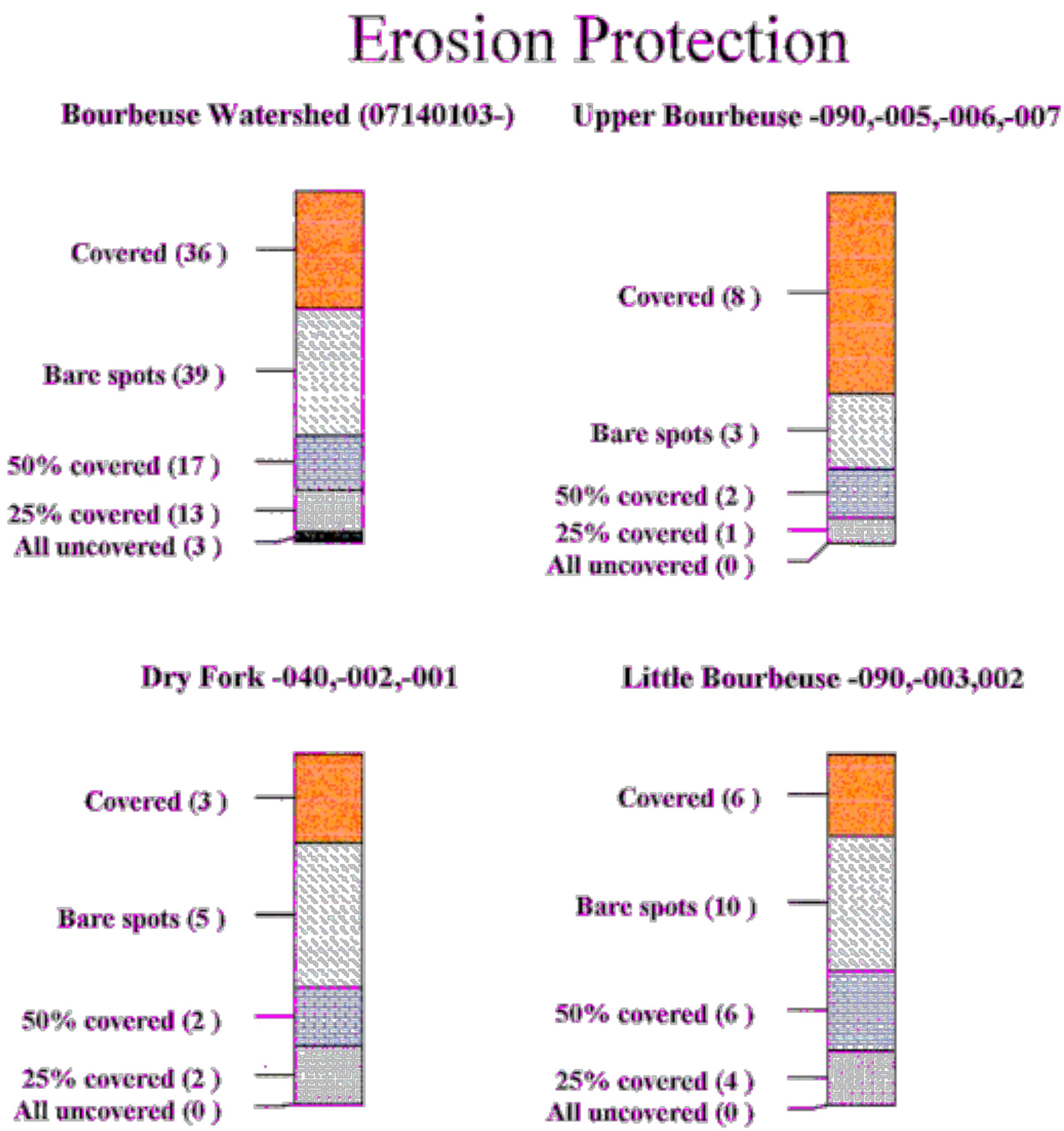


Figure 11. Bourbeuse River watershed streambank erosion protection assessment for sampled sites summarized by hydrologic units with values representing right and left streambanks.
Covered = Streambank completely protected—no erosion
Bare spots = Streambank has only isolated bare spots
50% covered = About half streambank protected
25% covered = Most of streambank uncovered—little protection
All uncovered = Streambank completely unprotected

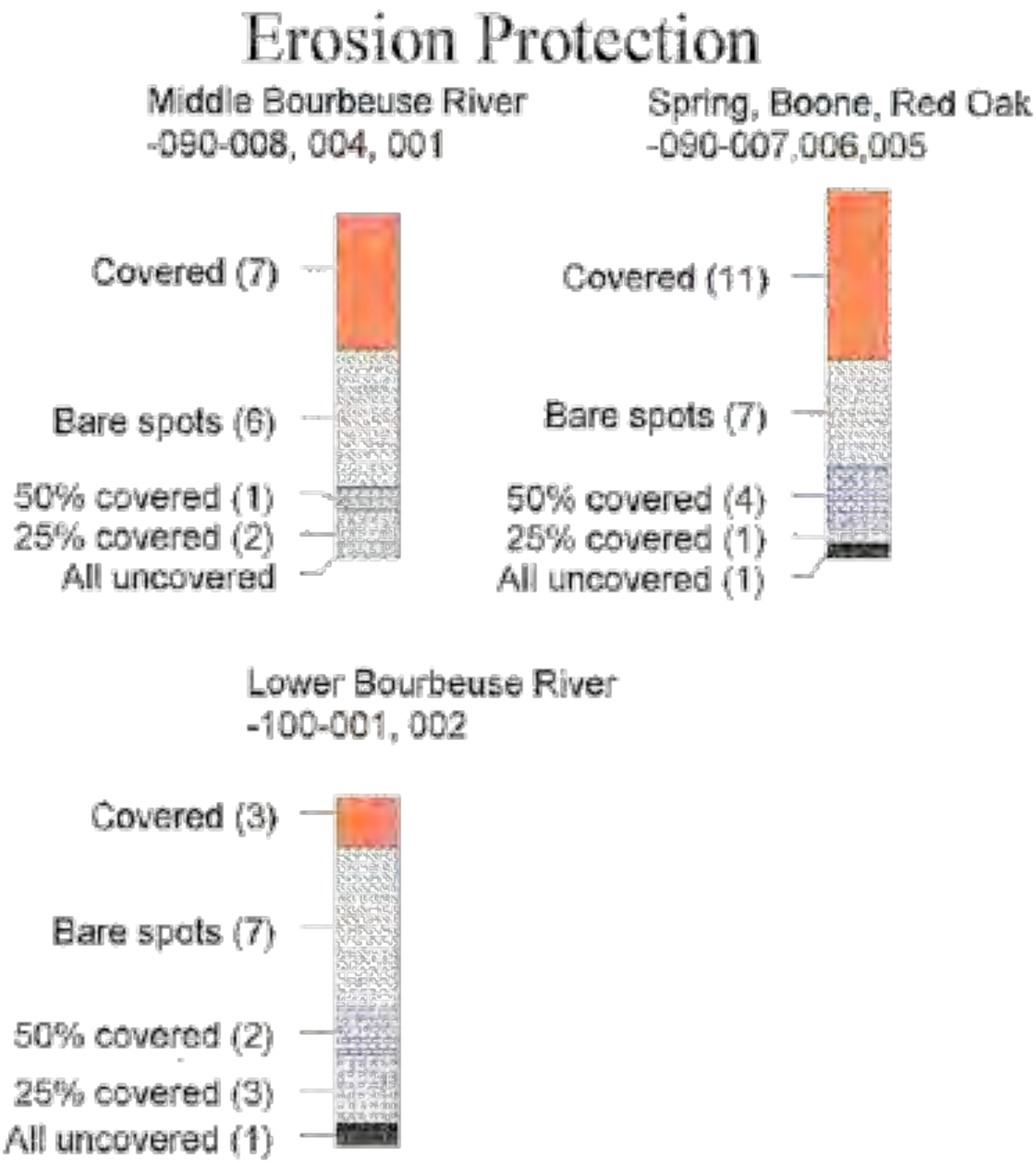


Figure 12. Bourbeuse River watershed riparian corridor width descriptions for sampled sites are summarized by hydrologic units with values representing both right and left corridor segments. >one row = unbroken corridor more than one tree width. One row trees = contiguous row of trees along sample site. 50% present = *broken along 50% of corridor length.
<50% present = limited, present along portion of sample site. Absent = no corridor
(#)—values represent number of corridors sampled—right and left corridor.

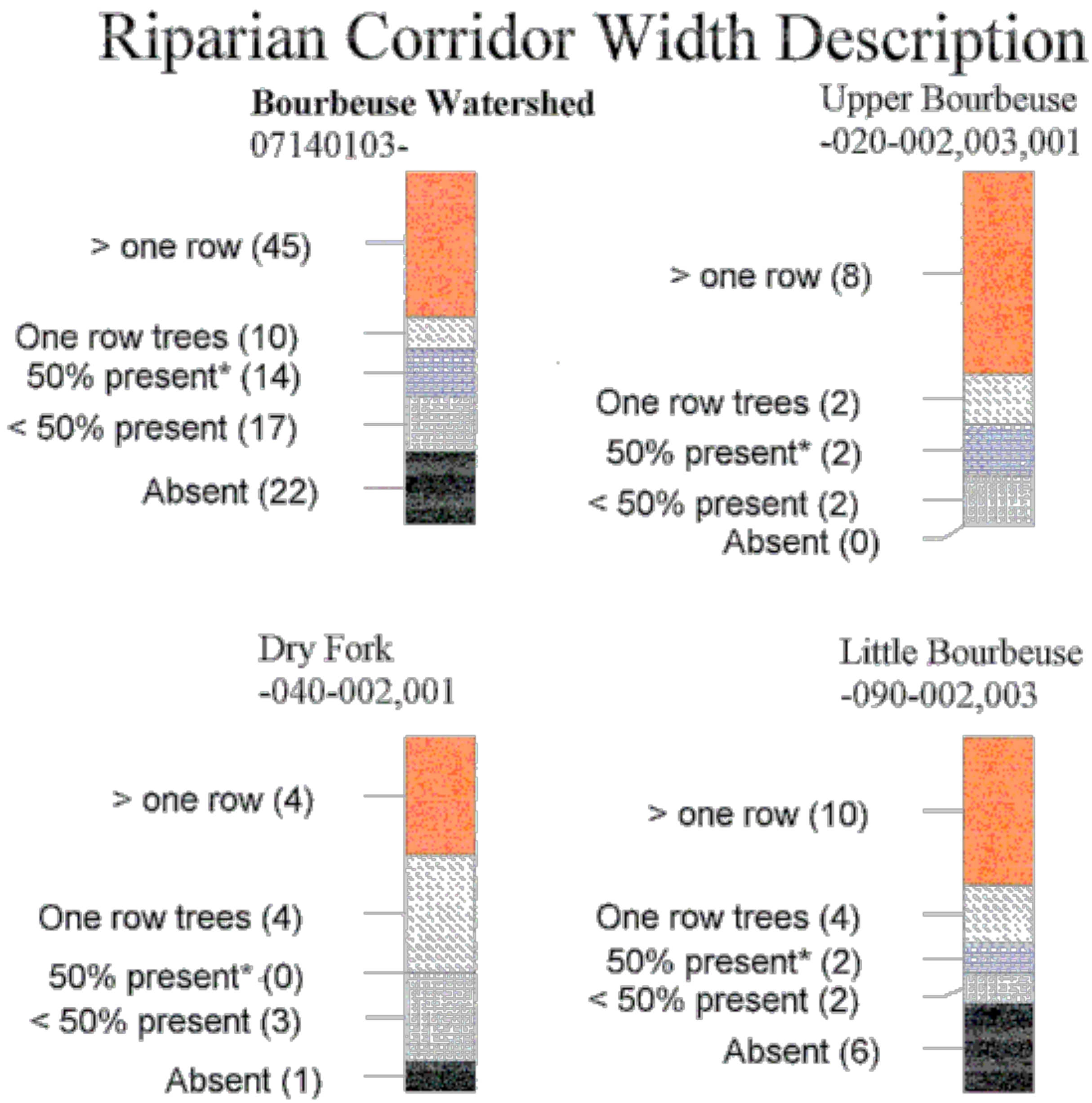


Table 18. List of habitat features and definitions used in the Bourbeuse River watershed habitat assessment based on McCain et al. 1990.

1) **Low Gradient Riffles (LGR) -** shallow reaches with swiftly flowing, turbulent water with some partially exposed substrate. Gradient < 4%, substrate is usually cobble dominated.
2) **High Gradient Riffles (HGR) -** steep reaches of moderately deep, swift, and very turbulent water. Amount of exposed substrate is relatively great. Gradient is > 4%, and substrate is boulder dominated.
3) **Cascade (CAS) -** The steepest riffle habitat, consists of alternating small waterfalls and shallow pools. Substrate is usually bedrock and boulders.
4) **Secondary Channel Pool (SCP) -** pools formed outside the average wetted channel. During summer, these pools will dry up or have very little flow. Mainly associated with gravel bars and may contain sand and silt substrates.
5) **Backwater Pool, Boulder Formed (BWPB) -** found along channel margins and caused by eddies around boulders. These pools are usually shallow and are dominated by fine-grain substrates. Current velocities are quite low.
6) **Backwater Pool, Rootwad Formed (BWPR) -** found along channel margins and caused by eddies around rootwads. These pools are usually shallow and are dominated by fine-grain substrates. Current velocities are quite low.
7) **Backwater Pool, Log Formed (BWPL) -** found along channel margins and caused by eddies around woody debris. These pools are usually shallow and are dominated by fine-grain substrates. Current velocities are quite low.
8) **Backwater Pool, w/ associated gravel bar (BWPG) -** found along channel margins and caused by eddies around gravel bars. These pools are usually shallow and are dominated by fine-grain substrates. Current velocities are quite low.
9) **Trench/Chute (TRC) -** channel cross sections typically U-shaped with bedrock or coarse grained bottom flanked by bedrock walls. Current velocities are swift and the direction of flow is uniform. May be pool-like.
10) **Plunge Pool (PLP) -** found where stream passes over a complete or nearly complete channel obstruction and drops steeply into the streambed below, scouring out a depression, often large and deep. Substrate size is highly variable.
11) **Lateral Scour Pool, Log Formed (LSPL) -** formed by impinging against one streambank or against a partial obstruction of a log or other woody debris. The associated scour is confined to < 60% of wetted channel width.
12) **Lateral Scour Pool, Rootwad Formed (LSPR) -** formed by impinging against rootwads creating a partial channel obstruction. The associated scour is confined to < 60% of wetted channel width.
13) **Lateral Scour Pool, Bedrock Formed (LSPB) -** formed by impinging against bedrock creating a partial channel obstruction. The associated scour is confined to < 60% of wetted channel width.
14) **Lateral Scour Pool, Boulder Formed (LSP) -** formed by impinging against boulders that create a partial channel obstruction. The associated scour is confined to < 60% of wetted channel width.
15) **Dammed Pool (DPL) -** water impounded from a complete or nearly complete channel blockage (debris jams, rock landslides, or beaver dams). Substrate tends toward smaller gravels and sand.
16) **Glides (GLD) -** a wide shallow pool flowing smoothly and gently, with low to moderate velocities and little or no surface turbulence. Substrate usually consists of cobble, gravel and sand.

17) **Run (RUN) -** swiftly flowing reaches with little surface agitation and no major flow obstructions. Often appears as flooded riffles. Typical substrates are gravel, cobble and boulders.
18) **Step Run (SRN) -** a sequence of runs separated by short riffle steps. Substrates are usually cobble and boulder dominated.
19) **Mid-Channel Pool (MCP) -** large pools formed by mid-channel scour. The scour hole encompasses more than 60% of the wetted channel. Water velocity is slow, and the substrate is highly variable.
20) **Edgewater (EGW) -** quiet, shallow, area found along the margins of the stream, typically associated with riffles. Water velocity is low and sometimes lacking. Substrate varies from cobbles to boulders.
21) **Channel Confluence Pool (CCP) -** large pools formed at the confluence of two or more channels. Scour can be due to plunges, lateral obstructions or down scour at the channel intersections. Velocity and turbulence are usually greater than those in other pool types.
22) **Pocket Water (POW) -** a section of swift flowing stream containing numerous boulders or other large obstructions which create eddies or scour holes (pockets) behind the obstructions.
23) **Corner Pool (CRP) -** lateral scour pools formed at a bend in the channel. These pools are common in lowland valley bottoms where streambanks consist of alluvium and lack hard bottoms.

Figure 13. Bourbeuse River watershed 11parian corridor width descriptions for sampled sites are stunmarized by hydrologic units with values representing both rigbt and left corridors segn1ents.

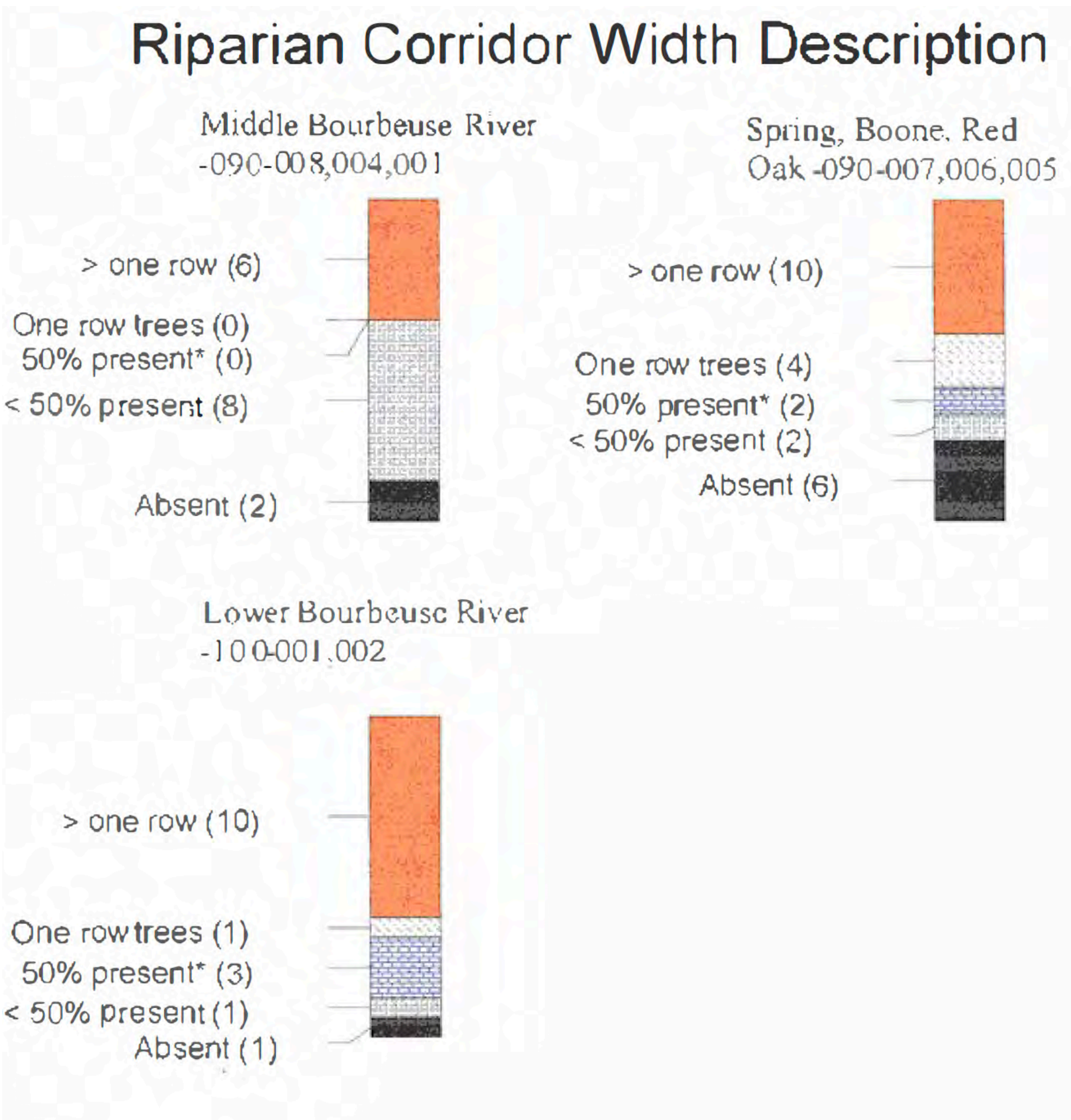
one row = unbroken corridor, more than one tree width. One row trees = contiguous row of trees along sample site.

50% present= *Broken along 50% of corridor len5'1h.

<50% present= limited, present along portion of san1ple site.

Absent= no co, Tidor.

(#)—values represent number of corridors sampled—right and left corridor.



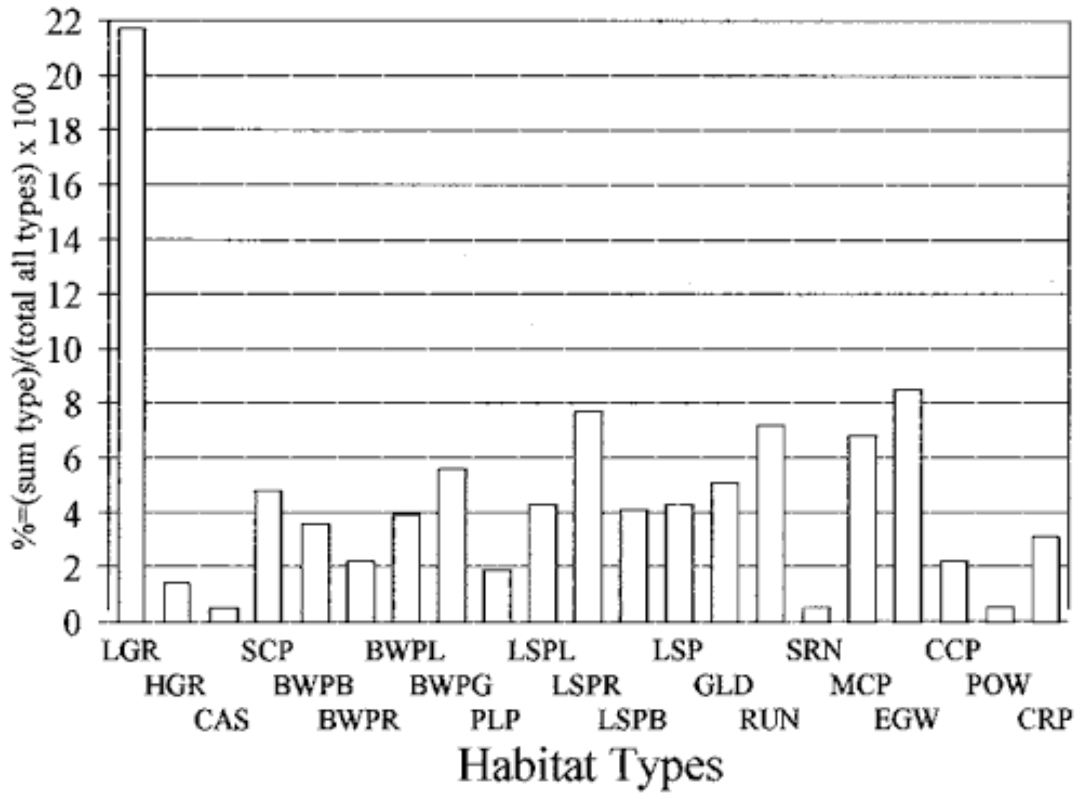



Figure 14. Percentage composition of habitat types based on McCain et al. (1990) in the Bourbeuse River watershed. Acronyms for habitat types are defined in Table 18.

Low Gradient Riffles (**LGR**); High Gradient Riffles (**HGR**); Cascade (**CAS**), Secondary Channel Pool (**SCP**); Backwater Pool, Boulder Formed (**BWPB**); Backwater Pool, Rootwad Formed (**BWPR**); Backwater Pool, Log Formed (**BWPL**); Backwater Pool, w/ associated gravel bar (**BWPG**); Plunge Pool (**PLP**); Lateral Scour Pool, Log Formed (**LSPL**); Lateral Scour Pool, Rootwad Formed (**LSPR**); Lateral Scour Pool, Bedrock Formed (**LSPB**); Lateral Scour Pool, Boulder Formed (**LSP**); Glides (**GLD**); Run (**RUN**); Step Run (**SRN**); Mid-Channel Pool (**MCP**); Edgewater (**EGW**); Channel Confluence Pool (**CCP**); Pocket Water (**POW**); Corner Pool (**CRP**)

Table 19. Human activities at or near the sample site and the presence or absence of aquatic vegetation in the Bourbeuse River watershed (**hydrologic unit (HU) # 07140103-). Activity values are codes defined on the last page.

| Id-# [1] | HU** | Stream Name | Activity[2] 1 2 3 4 5 | | | | | | Aquatic Vegetation[3] |
|---|---|---|---|---|---|---|---|---|---|
| **LOWER BOURBEUSE HYDROLOGIC UNIT**-100-001, 002** | | | | | | | | | |
| **31** | 100 | 2 | Bourbeuse River | 14 | 19 | | | | 1, 2E, 4A |
| **29** | 100 | 2 | Bourbeuse River | 12 | 1, 2S, 4A | | | | 1, 2S, 4A |
| **48** | 100 | 2 | Bourbeuse River | 14 | 1, 4S | | | | 1, 4S |
| **56** | 100 | 2 | Bourbeuse River | 14 | | | | | 1S, 2S |
| **55** | 100 | 2 | Bourbeuse River | 16 | | | | | 1S, 2E, 4E |
| **30** | 100 | 1 | Bourbeuse River | 1 | 14 | | | | 2E, 4E |
| **28** | 100 | 1 | Bourbeuse River | 6 | 14 | | | | 1, 4S |
| **32** | 100 | 1 | Bourbeuse River | 6 | 19 | 16 | | | 1, 2R, 3R, 4A |
| **SPRING, BOONE, RED OAK CREEK HYDROLOGIC UNIT**-090-007, 006, 005** | | | | | | | | | |
| **1** | 90 | 7 | Spring Creek | 6 | 16 | | | | 2E, 4R |
| **50** | 90 | 6 | Boone Creek | 2 | 4 | 7 | 16 | 1 | 2E, 3R, 4R |
| **51** | 90 | 6 | Boone Creek | 6 | 19 | 2 | | | |
| **52** | 90 | 6 | Boone Creek | 1 | 3 | 6 | 7 | 19 | 2R, 4S |
| **4** | 90 | 5 | Red Oak Creek | 6 | 15 | | | | 1A, 2E, 4S |
| **3** | 90 | 5 | Red Oak Creek | 6 | 11 | 16 | 19 | 1 | 2A |
| **2** | 90 | 5 | Red Oak Creek | 1 | 19 | 2S | | | |
| **5** | 90 | 5 | Red Oak Creek | 2 | 15 | | | | 1S, 2A, 4S |
| **MIDDLE BOURBEUSE HYDROLOGIC UNIT** -090-008, 004, 001** | | | | | | | | | |
| **33** | 90 | 8 | Bourbeuse River | 2 | 6 | 9 | 14 | 19 | 1, 2S, 4S |
| **34** | 90 | 8 | Bourbeuse River | 2 | 3 | 14 | | | 124 |
| **43** | 90 | 8 | Bourbeuse River | 19 | | | | | 1, 4S |
| **54** | 90 | 8 | Big Creek | 2 | 6 | 19 | | | 2S, 4R |
| **53** | 90 | 8 | Big Creek | 6 | 19 | | | | 2S, 4S |
| **37** | 90 | 4 | Bourbeuse River | 6 | | | | | 1, 2S, 4A |
| **35** | 90 | 4 | Bourbeuse River | 1 | 6 | 15 | 19 | | 1, 2R, 3R, 4A |
| **46** | 90 | 4 | Bourbeuse River | 6 | 19 | | | | 2S, 4 |
| **42** | 90 | 4 | Bourbeuse River | 6 | 14 | | | | 124 |
| **40** | 90 | 1 | Bourbeuse River | 6 | | | | | 2R, 4S |
| **41** | 90 | 1 | Bourbeuse River | 6 | 19 | | | | 1S, 4S |
| **49** | 90 | 1 | Bourbeuse River | 5 | 6 | | | | 1, 2A, 3R, 4S |
| **LITTLE BOURBEUSE RIVER HYDROLOGIC UNIT**-090-003, 001** | | | | | | | | | |
| **9** | 90 | 3 | Little Bourbeuse River | 1 | 5 | 6 | 9 | | 2A, 4S |
| **8** | 90 | 3 | Little Bourbeuse River | 1 | 6 | 19 | | | 1R, 4A |

| Id-# [1] | HU** | Stream Name | Activity[2] 1 2 3 4 5 | | | | | | Aquatic Vegetation[3] |
|---|---|---|---|---|---|---|---|---|---|
| **6** | 90 | 3 | Little Bourbeuse River | 6 | 7 | 19 | | | 1, 2S, 4A |
| **7** | 90 | 3 | Little Bourbeuse River | 1 | 6 | 19 | | | 1R, 4S |
| **22** | 90 | 2 | Prairie Creek | 6 | 7 | 19 | | | 3E, 4S |
| **23** | 90 | 2 | Praire Creek | 1 | 6 | 19 | | | 2, 4S |
| **20** | 90 | 2 | Pleasant Valley Creek | 6 | 7 | 19 | | | 2S, 3R |
| **21** | 90 | 2 | Pleasant Valley Creek | 1 | 6 | 7 | 19 | | 2S, 4R |
| **24A** | 90 | 2 | Br.Noname/Brush/20. | 1 | 6 | 7 | | | 2S, 4S |
| **26** | 90 | 2 | Brush Creek | 1 | 6 | 19 | | | 4 |
| **27** | 90 | 2 | Brush Creek | 1 | 6 | 7 | | | 4A |
| **24B** | 90 | 2 | Brush Creek | 1 | 6 | 7 | | | 2 |
| **25** | 90 | 2 | Brush Creek | 6 | 19 | | | | 1, 4S |
| **DRY FORK HYDROLOGIC UNIT**-040-002, 001** | | | | | | | | | |
| **13** | 40 | 2 | Dry Fork | 1 | 2 | 4 | 6 | | 2A, 4R |
| **12** | 40 | 2 | Dry Fork | 6 | | | | | 2 |
| **14** | 40 | 2 | Dry Fork | 6 | 14 | 19 | | | 2R, 3R, 4A |
| **16** | 40 | 2 | Dry Fork | 1 | 6 | 7 | 19 | | 2S, 4R |
| **15** | 40 | 2 | Dry Fork | 6 | | | | | 2A |
| **17** | 40 | 1 | Upper Peavine Creek | 1 | 6 | 7 | | | 1S, 2A, 4R |
| **UPPER BOURBEUSE HYDROLOGIC UNIT**-020-002, 003, 001** | | | | | | | | | |
| **19** | 20 | 3 | Clear Creek | 19 | | | | | 2S |
| **18** | 20 | 3 | Clear Creek | 6 | 19 | | | | 4 |
| **39** | 20 | 3 | Bourbeuse River | 6 | 16 | | | | 2S |
| **38** | 20 | 3 | Bourbeuse River | 2 | 19 | | | | 24 |
| **10** | 20 | 2 | Ltl. Bourbeuse Creek | 6 | 7 | 19 | | | 2A, 4S |
| **11** | 20 | 2 | Ltl. Bourbeuse Creek | 3 | 6 | 7 | | | 2A, 4R |
| **36** | 20 | 1 | Bourbeuse River | 6 | 10 | 19 | | | 2A, 4R |

[1]ID# = SITE INDENTIFICATION NUMBER

[2]Activities Code: 3Aquatic vegetation:

1- Streambank stablization 7- Livestock access 13- Human sewage untreated 1- Planktonic algae

2- Gravel mining-past 8- Livestock waste runoff 14- Floodplain development 2- Filamentous algae

3- Gravel mining-current 9- Concentrated animal farm 15- Levee 3- Submergent macrophytes

4- Gravel mining equipment 10- Pipe line crossing 16- Waste (refuse) disposal 4- Emergent macrophytes nearby

5- Channel snagging 11- Streamside clearing 17- Irrigation Aquatic veg. abundance: R-rare,

6- Slab crossing or road 12- Sewage lagoon 18- Industry 19-Other S-some, A-abundant, E-excessive.

# Biotic Community

Selection of subwatershed segments, subsegments, and representative reaches for fish sampling was based on stream order, flow, and stream complexity. Fisheries personnel evaluated the fish community on all third-order or larger streams (Figure 6). In addition, site selection procedures consisted of

1) constructing gradient plots of potential areas to aid in the selection of sites with varying gradients,
2) consulting a topographic map or aerial photos for surrounding land use and access to sites, and
3) viewing video tapes of the watershed areas. Final selection was based on relative differences of the areas and access to the sites. For ease of stream assessment and avoidance of trespass, a ford or a bridge was often near or part of a site.

Fish community collections were made by the Fisheries Research and Fisheries Management sections. A variety of microhabitat types were sampled within a riffle-pool-riffle complex. On occasion, a run was included in the sample site. Depending on the site, biologists worked up or down stream of the ford, bridge, or access point until habitat within the riffle-pool-riffle complex had been sampled.

Fisheries Research Section typically used the drag-seine for pool and run areas and the kick-seine to sample benthic species in riffles. East Central Region Fisheries Management Personnel performed stream sampling of reaches using a backpack electroshocker or a boat boom-electroshocker. Regional Fisheries Staff used electrofishing as the primary sampling method and supplemented some collections with seining.

A total of 90 fish species have been collected by Missouri Department of Conservation fisheries biologists from 1941-96 (Table 20). In historic fish collections, prior to the 1995-96 collections, fisheries biologists found 81 fish species.

In the 1995-96 survey, nine additional fish species were added to the list: freshwater drum, highfin carpsucker, fantail darter, chestnut lamprey, smallmouth buffalo, bigmouth buffalo, warmouth, western redfin shiner, and freckled madtom. However, seven fish species (bolded on Table 20) have not been collected in the watershed since 1963 or 1941. These include the pallid shiner that is considered extirpated from Missouri (Pflieger 1997) and has not been collected since 1941. One state-listed endangered species, the highfin carpsucker *(Carpiodes velifer),* was collected in the 1995-96 collections.

The Bourbeuse River tends to be more turbid and less steep in gradient than other Ozark streams. It is home to most of the popular sport fish found in Missouri. Most float anglers fish the Bourbeuse in the spring, before base flows limit their ability to move between access points. Many anglers fish the river from its banks or fish only the pool along their private property, especially during the low water periods.

The black bass and rock bass populations have been sampled extensively, especially in those reaches below Highway 185. Smallmouth bass densities are relatively high with a good proportion of fish larger than the 12-inch minimum length limit. Eighteen-inch or larger fish can be found in association with cover, deep water, and current. Largemouth bass are also present in every pool. In any given sample, the largest bass would almost always be a largemouth. Found only below Goodes Mill in samples taken during the early 1990s, spotted bass have progressively been sampled farther upstream. Now they can be found all the way up the river to the Noser Mill Dam and will likely continue to expand their range further upstream. Spotted bass body condition has thus far been excellent. Because spotted bass are relatively new to the river system, it is difficult to determine whether they are occupying a niche created by the degradation of habitat or they are displacing one of the other black bass species. Rock bass can be found throughout the watershed, however, they do not represent a significant component of the fish samples except in the lower river near Union.

Channel catfish and flathead catfish have not been targeted for any extensive management evaluations to date. Typically, catfish species were collected while doing other investigations. Good numbers of channel catfish are apparently available, and channel catfish larger than three pounds are fairly common. Moderate fishing pressure occurs for channel catfish using both rod and reel as well as set and trot lines. Flathead catfish are caught by anglers in the lower portions of the Bourbeuse River.

Walleye and sauger are present in the river. Some population investigations have occurred during their spring spawning run. River walleye are difficult to sample due to the effect of temperature and flow on the timing of their spawning. Age and growth analysis from these evaluations indicate a self-sustaining, but low density population, with excellent growth. Local anglers have commented that walleye do not seem to spawn every year below Noser Mill. Sampling done in that reach supports their claim. Most of the walleye sampled during our evaluations were male and exceeded 18 inches total length. Most Bourbeuse River walleye are caught by anglers fishing for other species, especially black bass. Sauger are common below the I-44 Bridge. Almost all sauger caught in the Bourbeuse River were yearlings, indicating that it is an important nursery area to the Meramec River sauger population.

Redhorse and suckers are abundant in the Bourbeuse River. Anglers target them during two seasons of the year. It is popular sport to drift night crawlers in the shoals in March and April. However, the majority of redhorse and suckers are harvested by giggers, especially late in the season when the water clears.

Rainbow trout are found in Kratz Spring Branch and the lower end of Spring Creek in Franklin County. A few trout can be found in the Bourbeuse River below Spring Creek year round. These trout range up and down the river some distance from Spring Creek during the cold weather months. Several small trout were captured in the run below Noser Mill during a March sample. Only trout in the Bourbeuse River are available to most anglers, as trespass rights are strictly controlled along Spring Creek and the Kratz Spring Branch.

Longear sunfish are common throughout the Bourbeuse River, though few grow large enough to harvest. Bluegill are found in the slower portions of the large pools and many exceed seven inches. Black and white crappie occur in the Bourbeuse River, though black crappie are the dominant species. Like rock bass, they are not evenly distributed but are abundant when located, especially in the segment below the Goodes Mill Dam.

A total of 39 species of mussels have been collected in various historic surveys of the Bourbeuse River and three of its tributaries, Brush Creek, Dry Fork, and Little Bourbeuse River (Buchanan 1980). Thirty-seven living mussel species of the 39 species were collected in the 1977 and 1978 survey (Buchanan 1980) of the watershed (Table 21).

*Cumberlandia monodonta* (Missouri species of conservation concern) and *Cyclonaias tuberculata* were collected in previous surveys but only as dead specimens in the 1977 and 1978 survey. In the 1977 and 1978 Bourbeuse River survey, Buchanan noted that the main stem Bourbeuse River had favorable habitat for *naiades* throughout its reach, only a few sites were completely devoid of mussels. The *Lampsilis radiata luteola* was the most abundant (largest % composition) within the Bourbeuse River watershed and all its tributary watersheds (Table 21). It may be found in almost any type of substrate from moderate to slow moving water (Oesch 1995). The *Lampsilis ventricosa* and *Anodonta g. grandis* were well represented in all watersheds.

In a more recent survey in the Bourbeuse River and two of its tributaries, Brush Creek and Dry Fork, 31 living mussel species and five dead mussel species were collected by MDC Fisheries Research from 1994-97 (Table 22). In the 1997 survey 26 sites were assessed, and 18 sites were reassessed to compare to the 1977 and 1978 survey (Roberts and Bruenderman 1999). Five new species, *Lampsilis siliquoidea, Pleurobema sintoxia, Pyganodon grandis grandis,* and *Utterbackia imbecillis,* were discovered in neither the historic surveys nor the 1977 and 1978 survey but were found in the 1997 survey of the Bourbeuse River. *Anodonta imbecillis, Anodonta g. grandis, Simpsonaias ambigua, Amblema p. plicata, Pleurobema coccineum, Plagiola lineolata, Ligumia subrostrata, Lampsilis radiata luteola, Lampsilis ventricosa,* and *Lampsilis reeviana brittsi* were not collected in the 1997 survey but were found in the 1977 and 1978 surveys. *Cyclonaias tuberculata* was collected as a dead specimen in the 1977 and 1978 survey, but in the 1997 survey, researchers discovered live specimens. *Quadrula quadrula* and *Strophitus undulatus* were collected in the historic surveys but not in the 1977 and 1978 survey. Four state-listed species of conservation concern, *Alasmidonta marginata, Epioblasma triquetra, Leptodea leptodon,* and *Plethobasus cyphyus* were discovered in the main stem Bourbeuse River. The two Bourbeuse River tributaries were home to few mussel species, only *Lampsilis siliquoidea, Venustaconcha e. ellipsiformis,* and the *Amblema plicata* were collected.

In the 1997 survey, the most abundant living mussel species in the Bourbeuse River from most to least abundant were *Actinonaias ligamentina carinata, Venustachoncha ellipsiformis ellipsiformis, Pleurobema sintoxia, Quadrula pustulosa*, and *Lampsilis siliquoidea* (Roberts and Bruenderman 1999). As stated above, the most abundant species in the 1977 and 1978 survey was *Lampsilis radiata luteola.* While relative abundance of mussels within the 18 reassessed sites was lower in the 1997 survey than in the 1977 and 1978 survey, mussel abundance within the new survey sites was comparable with abundance within 1977 and 1978 survey sites.

Changes in species composition and abundance in the Bourbeuse River have been attributed to many factors, such as accelerated erosion, water quality degradation, in-stream gravel mining, and channelization. In addition, natural causes of decline, such as disease and drought, impact mussel species composition and abundance. Site selection and sampling methods can also affect estimation of species composition and abundance.

Some notable differences in species were reported in the Bourbeuse River as compared to the Big and Meramec rivers. Buchanan (1980) found that the *Lampsilis radiata luteola,* uncommon in the Big and Meramec rivers, comprised 29.7% of the living mussels collected in the Bourbeuse River. Buchanan also found that the dominant species located in Brush Creek, Dry Fork, and the Little Bourbeuse River were different from those of Courtois Creek, Huzzah Creek, and the Mineral Fork subwatersheds. Nine species *(Lampsilis radiata luteola, Actinonaias ligamentina carinata, Lampsilis ventricosa, Elliptio dilatata, Venustaconcha e. ellipsiformis, Amblema p. plicata, Fusconaia flava*, *Anotonda grandis grandis,* and *Pleurobema coccineum)* comprised 83.3% of the living naiades collected in Bourbeuse River. In the 1997 survey by Roberts and Bruenderman, *Cumberlandia monodonta* comprised a higher portion of individuals in the Meramec River than in the Bourbeuse or Big rivers. *Cumberlandia monodonta, Amblema p. plicata,* and *Megalonaias nervosa* were less common in the Bourbeuse River than in the Big and Meramec rivers, while *Venustachoncha ellipsiformis ellipsiformis* was more common.

Freshwater mussels are declining at an alarming rate throughout North America, and have been for many decades (Bruenderman, personal communication). A combination of factors are responsible for the decline in the Bourbeuse River mussel community since it was last sampled 20 years ago. The shifting unstable stream bottom and the excessive siltation, caused by poor land-use practices are not tolerable to mussels (Bruenderman 1998). Bruenderman believes that the mussel decline has been ongoing and that reproductive failure has gone unnoticed because the remaining adults have created the illusion of healthy conditions.

## Crayfish

During surveys conducted from 1983-86, Fisheries Research collected 5 species of crayfish in the Bourbeuse River watershed. Table 23 contains a summary of the streams surveyed, the number of specimens, and the % composition of species at each survey site. The spothanded crayfish (Orconectes punctimanus) was collected at each of the survey sites throughout the watershed.

Found in association with the spothanded crayfish, the golden crayfish *(Orconectes luteus)* often was more abundant than the spothanded crayfish.

The northern crayfish *(Orconectes virilis),* which is well distributed throughout the state (Pflieger 1996), was found in abundance at a site on Webber Creek in the Lower Bourbeuse River HU. Crayfish species diversity was best at Webber Creek in the Lower Bourbeuse River HU (Table 24). Richness was highest on Brush Creek where there were three species of crayfish, and the number of specimens were fairly even among the three species.

## Benthic Insects and Other Invertebrates

In a 1964 Missouri Department of Natural Resources water quality report, benthic invertebrate sampling provided indication of water quality conditions of the watershed (Table 25). Using biological indicators such as benthic invertebrates, biologists were able to rate the Bourbeuse River watershed stream segments near sampling stations. Pollution intolerant benthic invertebrates are the stonefly, caddisfly, mayfly, and gilled snails. The slightly pollution tolerant forms are the dragonfly and the damselfly nymphs (see list on last page of Table 25). At the Highway B Bridge of the Bourbeuse River in Phelps County, biologists reported fauna representing clean water. One such fauna, the mayfly, *Stenonema tripunctatum,* was found in great numbers. At two Bourbeuse River sites, near Strain and Franklin County Highway H Bridge and the Noser Mill, benthic fauna were and unpolluted conditions (MDNR 1964). Various intolerant forms of invertebrates were found at the Bourbeuse River Union station and Bourbeuse River confluence with the Meramec River station. Altogether, 43 types of organisms at the Union station and 57 types at the confluence station were found (MDNR 1964). Tributaries to the Bourbeuse River such as Brush Creek, Dry Fork, Red Oak Creek, and Boone Creek were sampled for the same pollution indicators. Brush Creek had high production of macroinvertebrates, including sensitive forms of Ephemeroptera, Trichoptera, and to a lesser extent, Plecoptera. In the remaining three tributary sample sites, biologists concluded that the presence of a number of the sensitive organisms in sufficient quantity was a good indication of the high quality of the sampling station. However, a particularly alarming find was the absence of mussels in the Red Oak Creek and Brush Creek sampling stations. Heavy metals from an Owensville plating plant were the likely cause in the Red Oak Creek area (MDNR 1964). No explanation was given for the lack of mussels in the Brush Creek sampling station, although in all cases it is unknown whether any mussels were ever present.

The disappearance of some fish species from the Bourbeuse River watershed is due to several factors, but the largest contributor may be habitat alteration. A locational list of the sensitive species (see Habitat Section, Rare and Endangered Species) within the watershed can be found within the Natural Heritage Database (the database is updated periodically with recent locations and new species). In 1995-96 fish collections, the highfin carpsucker *(Carpiodes velifer),* state-listed species of conservation concern, was collected.

Highfin Carpsucker. The highfin carpsucker is considered rare in Missouri and over the years has become less common (Pflieger 1997). The highfin carpsucker prefers clear water, firm bottoms, and is less tolerant of turbidity and siltation than other carpsuckers. In the 1996 collection, the highfin carpsucker was collected in the Bourbeuse River (T43N, R1E, S27, 34, 35).

Two species, mottled sculpin and silverjaw minnow, that were species of concern prior to 1998 are no longer being monitored by MDC because of improvements in their numbers.

Mottled Sculpin. The mottled sculpin occurs to the exclusion of the Ozark sculpin in the Meramec River subwatersheds (Pflieger 1997). The mottled sculpin favors cold-water habitat and is often found in spring branches. In 1963 and 1995, the mottled sculpin was collected in Spring Creek (T41N, R2W, S4).

Silverjaw Minnow. The silverjaw minnow has a limited distribution in Missouri, and is found in shallow, sandy stretches of clear permanent-flowing streams that are either in the Meramec system or direct tributaries of the Mississippi (Pflieger 1997). Collected in 1963 at Spring Creek (T41N, R2W, S4), the silverjaw minnow was again collected in the 1995 at the same site. In the 1995 collection year, the silverjaw minnow was also found at a site on Big Creek (T42N, R3W, S15).

According to Pflieger (1997), the silverjaw shiner seems to be the ecological counterpart to the bigmouth shiner and replaces this species in the clearer and more stable streams of the Mississippi Valley from Missouri eastward. The bigmouth shiner has not been collected in the Bourbeuse River since 1963 (Table 20).

Pallid Shiner. The pallid shiner has not been collected on the Bourbeuse River since 1941. Pflieger (1997) noted two locations on the Bourbeuse River where the pallid shiner was found. The last collection of this species was in 1957 within the Lower Meramec River subwatershed. It is likely this species is extirpated from Missouri.

A survey conducted from 1981-82 on the lower 147 miles of the Bourbeuse River found that all types of fishing (pole and line, set line, and gigging) made up about 29% of all visits (Fleener 1988). Although the Meramec River watershed saw more total recreational use during its survey period, the Bourbeuse River survey segment had more angler use than the Meramec River watershed. In the survey segment of the Bourbeuse River, pole-and-line fishing was popular, making up 25% of all visits to the area (Fleener 1988).

When compared to the other stream systems in the area, angler catch rate of the Bourbeuse River in fish per hour was second to the Meramec River (Table 26). The angler catch rate for the lower 147 miles of the Bourbeuse River was 0.29 fish/hour compared 0.44 in the lower 117 miles of the Meramec River.

The only recent angler survey conducted for the Bourbeuse River watershed was a phone interview conducted by Weithman in 1991 (see Land Use Section, Recreation). No recent creel surveys have been conducted in the Bourbeuse River watershed.

No commercial harvest of fish or mussels is allowed in the Bourbeuse River watershed (Wildlife Code of Missouri 1999).

The Bourbeuse River was sampled using boom-mounted electrofishing equipment in 1994-1996 to assess the potential for special management of the smallmouth bass population beyond the 12-inch minimum length limit and six bass daily creel limit. River access points divide the river into nine reaches of varying lengths. In 1994, a portion of each reach was electrofished. Table 27 summarizes the 1994 population parameters for each of the black bass species. Electrofishing effort was concentrated on reaches between Noser Mill and Goodes Mill in 1995 (Table 28) and 1996 (Table 29). In 1994, spotted bass were the dominant species in the three samples collected below Goodes Mill (a physical barrier), however, spotted bass were found just below the Noser Mill Dam, the upstream-most sample site in 1995 and 1996. Smallmouth bass PSD ranged from 35.6 - 39.8% for all sample sites combined for the three years sampled. Similarly, RSD-14 ranged from 9.2 - 14.1%, RSD-15 from 5.3 - 8.0%, and RSD-18 from 0.6 - 1.5%. The reach from Reiker Ford Access to Goodes Mill consistently had high smallmouth bass PSD and RSD values. The population parameters for the Bourbeuse River smallmouth bass compare favorably to some other streams (Table30). For example, in 1997 the Big Piney River regulated zone had a PSD of 29.7%, RSD-14 of 8.8%, RSD-15 of 5.8%, and a RSD-18 of 0.2%. Also, the 1973 Courtois Creek PSD was 37%, RSD-14, 8%, and RSD-15, 4%. The fall 1991 Courtois Creek PSD was 39%, RSD-14, 8%, and RSD-15, 6%.

A total of 1, 264 smallmouth bass scales were analyzed during the study (Table 30). Bourbeuse River smallmouth attain 12 inches by age five. Growth rates were variable at older ages with smallmouth reaching 15 inches by age seven or eight and 18 inches by age nine.

A tagging study was initiated in 1995 and repeated in 1996, to identify anglers and determine the harvest rate of smallmouth bass. A tagging study approach was used because multiple access points on private land made a probability creel unworkable and a roving creel was not practical for other reasons. One hundred legal (>12-inch) smallmouth bass were tagged in spring 1995, and 95 legal smallmouth bass were tagged in spring 1996. Fish were tagged in a 34-mile segment bounded by Door Ford and Goodes Mill (Figure 15). Almost one half of these tags were in the reach from Reicker's Ford to Mayer's Landing (4.9 tags/mile). Twenty-eight tags were returned in 1995, and 16 tags were returned in 1996. The Bourbeuse River was above normal water stage and muddy during the spring of 1996, which could account for the difference. Thirty-five different anglers returned tags. Seven anglers caught more than one tagged smallmouth bass, only one of these seven anglers harvested the smallmouth bass they caught. Overall, 7% of the bass tagged in 1995 were harvested, and 8% of the bass tagged in 1996 were harvested.

The Bourbeuse River black bass populations are protected by a 12-inch minimum length limit. In addition, black bass must be released immediately after being caught from March 1 through the Friday before the fourth Saturday in May. All other species are managed by the standard statewide fishing regulations.

Table 20. Fish species collected within the Bourbeuse River watershed. Represented are both Missouri Department of Conservation Fisheries Research Section (Pflieger) and Fisheries Management Section with corresponding collection year. Historic collections – 1941-92. Recent collections – 1993-96. Bolded species names are those not recently collected (in 30-50 years).

| Species Scientific Name | Common Name | Collection Year |
|---|---|---|
| ***Petromyzontidae* (Lampreys)** | | |
| ***Ichthyomyzon castaneus*** | Chestnut lamprey | 1996 |
| ***Ichthyomyzon*** | Larval lamprey | 1995, 96 |
| ***Lampetra aepyptera*** | Least brook lamprey | 1963 |
| ***Lepisosteidae* (Gars)** | | |
| ***Lepisosteus osseus*** | Longnose gar | 1941, 42, 63, 92, 95, 96 |
| ***lupeidae* (Shad)** | | |
| ***Dorosoma cepedianum*** | Gizzard shad | 1963, 96 |
| ***Hiodontidae* (Mooneyes)** | | |
| ***Hiodon alosoides*** | Goldeye | 1963 |
| ***Esocidae* (Pikes)** | | |
| ***Esox americanus*** | Grass pickerel | 1941, 62, 63, 95 |
| ***Cyprinidae* (Minnows)** | | |
| ***Campostoma oligolepis*** | Largescale stoneroller | 1941, 42, 62, 63, 83, 84, 92, 94, 95, 96 |
| ***Campostoma anomalum*** | Central stoneroller | 1941, 42, 61, 62, 63, 83, 84, 92, 94, 95, 96 |
| ***Carassius auratus*** | Goldfish | 1992 |
| ***Cyprinella whipplei*** | Steelcolor shiner | 1941, 42, 62, 63, 84, 92, 94, 95, 96 |
| ***Cyprinella lutrensis*** | Red shiner | 1941 |
| ***Cyprinrlla spiloptera*** | Spotfin shiner | 1941, 42, 62, 63, 84, 92, 94, 96 |
| ***Cyprinus carpio*** | Common carp | 1963, 96 |
| ***Erimystax x-punctatus*** | Gravel chub | 1941, 42, 63, 95, 96 |
| ***Luxilus zonatus*** | Bleeding shiner | 1992, 94, 95, 96 |
| ***Lythrurus u umbratilis*** | Western redfin shiner | 1995, 96 |
| ***Lythrurus u cyanocephalus*** | Eastern redfin shiner | 1941, 42, 62, 63, 84, 92, 94 |
| ***Macrhybopsis storeriana*** | Silver chub | 1992 |
| ***Nocomis biguttatus*** | Hornyhead chub | 1941, 83, 94, 95 |
| ***Notemigonus crysoleucas*** | Golden shiner | 1941, 63, 95 |
| ***Notropis volucellus*** | Mimic shiner | 1941, 63, 95, 96 |
| ***Notropis rubellus*** | Rosyface shiner | 1942, 63, 84, 92, 95, 96 |
| ***Notropis stramineus*** | Sand shiner | 1941, 63, 92, 94, 95, 96 |

| Species Scientific Name | Common Name | Collection Year |
|---|---|---|
| ***Notropis boops*** | Bigeye shiner | 1941, 62, 63, 84, 92, 94, 95, 96 |
| ***Notropis amnis*** | Pallid shiner | 1941 |
| ***Notropis amblops*** | Bigeye chub | 1941, 92, 94, 95, 96 |
| ***Notropis atherinoides*** | Emerald shiner | 1963, 95, 96 |
| ***Notropis dorsalis*** | Bigmouth shiner | 1941, 63 |
| ***Notropis buccatus*** | Silverjaw minnow | 1963, 94, 95 |
| ***Notropis greenei*** | Wedgespot shiner | 1992, 95, 96 |
| ***Cyprinidae* (Minnows)** | | |
| **Phenacobius mirabilis** | Suckermouth minnow | 1941, 42, 63 |
| ***Phoxinus erythrogaster*** | Southern redbelly dace | 1963, 94, 95 |
| ***Pimephales vigilax*** | Bullhead minnow | 1963 |
| ***Pimephales promelas*** | Fathead minnow | 1963, 94 |
| ***Pimephales notatus*** | Bluntnose minnow | 1941, 42, 61, 62, 63, 84, 92, 94, 95, 96 |
| ***Semotilus atromaculatus*** | Creek chub | 1941, 63, 83, 94, 95, 96 |
| ***Catostomidae* (Suckers)** | | |
| ***Carpiodes velifer*** | Highfin carpsucker | 1996 |
| ***Carpiodes cyprinus*** | Quillback | 1963, 96 |
| ***Catostomus commersonni*** | White sucker | 1941, 63, 94, 95 |
| ***Erimyzon oblongus*** | Creek chubsucker | 1941, 62, 63, 83, 92, 95 |
| ***Hypentelium nigricans*** | Northern hog sucker | 1941, 63, 92, 94, 95, 96 |
| ***Ictiobus bubalus*** | Smallmouth buffalo | 1995, 96 |
| ***Ictiobus cyprinellus*** | Bigmouth buffalo | 1996 |
| ***Minytrema melanops*** | Spotted sucker | 1962, 63, 92, 95, 96 |
| ***Moxostoma duquesnei*** | Black redhorse | 1941, 63, 92, 94, 95, 96 |
| ***Moxostoma carinatum*** | River redhorse | 1963, 96 |
| ***Moxostoma erythrurum*** | Golden redhorse | 1941, 62, 63, 92, 94, 95, 96 |
| ***Moxostoma anisurum*** | Silver redhorse | 1941, 63, 92, 94, 96 |
| ***Moxostoma macrolepidotum*** | Shorthead redhorse | 1963, 95, 96 |
| ***Ictaluridae* (Catfishes)** | | |
| ***Ameiurus melas*** | Black bullhead | 1941, 63, 84, 95, 96 |
| ***Ameiurus natalis*** | Yellow bullhead | 1941, 63, 83, 92, 95, 96 |
| ***Ictalurus punctatus*** | Channel catfish | 1942, 63, 95, 96 |
| ***Noturus exilis*** | Slender madtom | 1962, 84, 92, 94, 95, 96 |
| ***Noturus flavus*** | Stonecat | 1963, 95, 96 |
| ***Noturus nocturnus*** | Freckled madtom | 1995, 96 |

| Species Scientific Name | Common Name | Collection Year |
|---|---|---|
| ***Pylodictis olivaris*** | Flathead catfish | 1941, 63, 95, 96 |
| ***Cyprinodontidae* (Killifishes)** | | |
| ***Fundulus olivaceous*** | Blackspotted topminnow | 1992, 94, 95, 96 |
| ***Fundulus catenatus*** | Northern studfish | 1941, 42, 63, 84, 92, 94, 95, 96 |
| ***Fundulus notatus*** | Blackstripe topminnow | 1941, 42, 61, 62, 63, 84, 92, 95, 96 |
| ***Poecilliidae* (Livebearers)** | | |
| ***Gambusia affinis*** | Mosquitofish | 1992, 94, 95, 96 |
| ***Atherinidae* (Silversides)** | | |
| ***Labidesthes sicculus*** | Brook silverside | 1941, 42, 62, 63, 83, 84, 92, 94, 95, 96 |
| ***Cottidae* (Sculpins)** | | |
| ***Cottus carolinae*** | Banded sculpin | 1992, 95 |
| ***Cottus bairdi*** | Mottled sculpin | 1963, 94, 95 |
| ***Centrarchidae* (Basses)** | | |
| ***Ambloplites rupestris*** | Rock bass | 1941, 42, 63, 92, 94, 95, 96 |
| ***Lepomis megalotis*** | Longear sunfish | 1941, 51, 62, 63, 84, 92, 94, 95, 96 |
| ***Lepomis macrochirus x Lepomis megalotis*** | Bluegill x longear sunfish | 1995, 96 |
| ***Lepomis macrochirus*** | Bluegill | 1941, 42, 61, 62, 63, 83, 84, 92, 94, 95, 96 |
| ***Lepomis humilis*** | Orangespotted sunfish | 1941, 42, 63 |
| ***Lepomis gulosus*** | Warmouth | 1995 |
| ***Lepomis cyanellus x Lepomis megalotis*** | Green sunfish x longear sunfish | 1995, 96 |
| ***Lepomis cyanellus x Lepomis macrochirus*** | Green sunfish x bluegill | 1995, 96 |
| ***Lepomis cyanellus*** | Green sunfish | 1941, 42, 61, 62, 63, 83, 92, 95, 96 |
| ***Micropterus salmoides*** | Largemouth bass | 1941, 61, 62, 63, 92, 94, 95, 96 |
| ***Micropterus punctulatus*** | Spotted bass | 1941, 92, 95, 96 |
| ***Micropterus dolomieu*** | Smallmouth bass | 1941, 42, 61, 62, 63, 92, 94, 95, 96 |
| ***Pomoxis anularis*** | White crappie | 1941, 63, 95, 96 |
| ***Pomoxis nigromaculatus*** | Black crappie | 1941, 96 |
| ***Percidaes* (Perches)** | | |
| ***Etheostoma tetrazonum*** | Missouri saddled | 1941, 62, 63, 92, 94, 95, 96 |
| ***Etheostoma s spectabile*** | Northern orangethroat | 1941, 61, 62, 63, 83, 84, 92, 94, 95, 96 |
| ***Etheostoma f lineolatum*** | Striped fantail | 1941, 42, 61, 62, 63, 83, 84, 92, 94, 95, 96 |

| Species Scientific Name | Common Name | Collection Year |
| --- | --- | --- |
| ***Etheostoma blennioides*** | Greenside darter | 1941, 42, 62, 63, 83, 84, 92, 94, 95, 96 |
| ***Etheostoma punctulatum*** | Stippled | 1963, 92 |
| ***Etheostoma nigrum*** | Johnny darter | 1941, 61, 62, 63, 84, 92, 94, 95, 96 |
| ***Etheostoma zonale*** | Banded darter | 1941, 62, 63, 92, 94, 95, 96 |
| ***Etheostoma f flabellare*** | Barred fantail darter | 1995, 96 |
| ***Etheostoma caeruleum*** | Rainbow darter | 1941, 42, 62, 63, 83, 84, 92, 94, 95, 96 |
| ***Percina c caprodes*** | Ohio logperch | 1941, 62, 63, 95, 96 |
| ***Percina phoxocephala*** | Slenderhead darter | 1941, 42, 62, 63, 95, 96 |
| ***Percina c fulvitaenia*** | Ozark logperch | 1984, 92, 94, 95, 96 |
| ***Percina evides*** | Gilt darter | 1942, 63, 95, 96 |
| ***Stizostedion vitreum*** | Walleye | 1963, 1996 |
| ***Sciaenidae* (Drums)** | | |
| ***Aplodinotus grunniens*** | Freshwater drum | 1996 |

Table 21. Numbers and relative abundance of living *naiades* found in the Bourbeuse River watershed (hydrologic unit # 07140103) and some of its major tributaries (Buchanan 1980).

| Species | Bourbeuse River | | Brush Creek | | Dry Fork | | Little Bourbeuse River | |
|---|---|---|---|---|---|---|---|---|
| | No. | % | No. | % | No. | % | No. | % |
| *Actinonaias ligamentina carinata* (Mucket) | 1,074 | 14.7 | - | - | - | - | - | - |
| *Alasmidonta viridis* (Slippershell mussel) | 1 | ** | - | - | - | - | - | - |
| *Alasmidonta* marginata(Elktoe) | 46 | 0.6 | - | - | - | - | - | - |
| *Amblema p. plicata* (Threeridge) | 299 | 4.1 | - | - | - | - | - | - |
| *Anodontoides ferussacianus* (Cylindrical papershell) | - | - | 2 | 0.8 | 1 | 2.8 | - | - |
| *Ellipsaria lineolata* (Butterfly) | 18 | 0.2 | - | - | - | - | - | - |
| *Elliptio dilatate* (Spike) | - | 7.2 | 2 | 0.8 | — | - | - | - |
| *Epioblasma triquetra* (Snuffbox) | 16 | 0.2 | - | - | | - | - | - |
| *Fusconaia flava* (Pig toe) | 288 | 3.9 | - | — | — | - | - | - |
| *Lampsilis teres* (Yellow sandshell) | 1 | ** | - | - | - | - | - | - |
| Lampsilis t. teres (Slough sandshell) | 85 | 1.2 | - | - | | - | - | - |
| Lampsilis cardium (Pocketbook) | 843 | 11.5 | 17 | 6.7 | 2.8 | | 1 | 5.9 |
| *Lampsilis reeviana brits* (Britt's shell) | 22 | 0.3 | - | - | - | — | - | - |
| *Lampsilis siliquoidea* (Fat mucket) | 2,170 | 29.7 | 104 | 40.9 | 17 | 48.6 | 4 | 23.5 |
| *Lasmigona complanata* (White heelsplitter) | 17 | 0.2 | - | - | - | - | - | - |
| *Lasmigona costata* (Fluted shell) | 79 | 1.1 | - | - | - | - | - | - |
| *Leptodea leptodon(*Scale shell) | 1 | ** | - | - | - | - | - | - |
| *Leptodea fragilis* (Fragile papershell) | 66 | 0.9 | - | - | - | - | - | - |
| *Ligumia subrostrata*(Pond mussel) | 24 | 0.3 | 3 | 1.2 | - | - | 5 | 29.4 |

| Species | Bourbeuse River | | Brush Creek | | Dry Fork | | Little Bourbeuse River | |
|---|---|---|---|---|---|---|---|---|
| | No. | % | No. | % | No. | % | No. | % |
| ***Ligumia recta* (Black sandshell)** | 23 | 0.3 | - | - | - | - | - | - |
| ***Megalonaias nervosa* (Washboard)** | 4 | 0.1 | - | - | - | - | - | - |
| ***Obliquaria reflexa* (Three-horned wartyback)** | 6 | 0.1 | - | - | - | - | - | - |
| ***Plethobasus cyphyus* (Bullhead)** | 10 | 0.1 | - | - | - | - | - | - |
| ***Pleurobema sintoxia* (Round pigtoe)** | 241 | 3.3 | - | - | - | | - | - |
| ***Potamilus alatus* (Pink heelsplitter)** | 123 | 1.7 | | - | - | - | - | - |
| ***Potamilus ohiensis* (Fragile heelsplitter)** | 1 | ** | | - | - | - | - | - |
| ***Pyganandon g. grandis* (Giant floater) (Floater) (gai(ss** | 254 | 3.5 | 10 | 3.6 | 14 | 40.0 | 6 | 35.3 |
| ***Quadrula metanevra* (Monkeyface)** | 2 | ** | - | - | - | - | - | - |
| ***Quadrula pustulosa* (Pimpleback)** | 195 | 2.7 | - | - | - | - | - | - |
| ***Simpsonaias ambigua* (Salamander mussel)** | 5 | 0.1 | - | - | - | - | | - |
| ***Strophitus u. undulatus* (Squaw foot)** | 125 | 1.7 | 9 | 3.1 | 1 | 2.8 | - | - |
| ***Toxolasma parvus* (Lilliput mussel)** | 19 | 0.3 | - | - | - | - | | |
| ***Tritogonia verrucose* (Buckhorn)** | 117 | 1.6 | 1 | 0.4 | - | - | - | |
| ***Truncilla donaciformis* (Fawn's foot)** | 5 | 0.1 | - | - | - | - | | - |
| ***Truncilla truncate* (Deertoe)** | 19 | 0.3 | - | - | - | - | - | - |
| ***Utterbackia imbecillis* (Paper pond shell)** | 189 | 2.6 | 3 | 1.2 | | 1 | 5.9 | - |
| ***Venustaconcha e. ellipsiformis* (Ellipse)** | 391 | 5.4 | 104 | 40.9 | 1 | 2.8 | - | - |
| **Total** | 9,470 | | 75 | | 237 | | 265 | - |

** = less than 0.1% of total

Table 22. Living and dead mussel species collected from 1994-97 within streams of the Bourbeuse River watershed (Missouri Department of Conservation Fisheries Research Collection 1997; Roberts and Bruenderman 1997). Notes: 1Former candidate species category 2is no longer federally listed. # = Missouri species of conservation concern. E = endangered. D = represented by dead mussel shell material.

| Stream | Stream Order | Year | Federal Status | D | State Status | Species Scientific Name | Species Common Name |
|---|---|---|---|---|---|---|---|
| **Bourbeuse River** | 6 | 94 | | | | *Venustaconcha ellipsiformis* | Ellipse |
| **Bourbeuse River** | 6 | 95 | | | | *Lasmigona costata* | Fluted shell |
| **Bourbeuse River** | 6 | 95 | | | | *Lampsilis teres* | Yellow sandshell |
| **Bourbeuse River** | 6 | 97 | | | | *Actinonaias ligamentina* | Mucket |
| **Bourbeuse River** | 6 | 97 | C21 | | # | *Alasmidonta marginata* | Elktoe |
| **Brush Creek** | 4 | 97 | | D | | *Amblema plicata* | Threeridge |
| **Bourbeuse River** | 6 | 97 | | | | *Amblema plicata* | Threeridge |
| **Bourbeuse River** | 6 | 97 | | D | | *Arcidens confragosus* | Rock pocketbook |
| **Bourbeuse River** | 6 | 97 | | | | *Cumberlandia monodonta* | Spectacle-case |
| **Bourbeuse River** | 6 | 97 | | | | *Cyclonaias tuberculata* | Purple wartyback |
| **Bourbeuse River** | 6 | 97 | | | | *Ellipsaria lineolata* | Butterfly |
| **Bourbeuse River** | 6 | 97 | | | | *Elliptio dilatata* | Spike |
| **Bourbeuse River** | 6 | 97 | C2 | | # | *Epioblasma triquetra* | Snuffbox |
| **Bourbeuse River** | 6 | 97 | | | | *Fusconaia flava* | Wabash pigtoe |
| **Bourbeuse River** | 6 | 97 | | | | *Lampsilis cardium* | Pocketbook |
| **Brush Creek** | 5 | 97 | | | | *Lampsilis siliquoidea* | Fatmucket |
| **Bourbeuse River** | 6 | 97 | | | | *Lampsilis siliquoidea* | Fatmucket |
| **Dry Fork Creek** | 4 | 97 | | D | | *Lampsilis siliquoidea* | Fatmucket |
| **Bourbeuse River** | 6 | 97 | | | | *Lampsilis teres* | Yellow sandshell |

| Stream | Stream Order | Year | Federal Status | D | State Status | Species Scientific Name | Species Common Name |
|---|---|---|---|---|---|---|---|
| **Bourbeuse River** | 6 | 97 | | | | *Lampsilis teres anodonta* | |
| **Bourbeuse River** | 6 | 97 | | | | *Lasmigona costata* | Fluted shell |
| **Bourbeuse River** | 6 | 97 | | D | | *Lasmigona c. complanata* | White heelsplitter |
| **Bourbeuse River** | 6 | 97 | | | | *Leptodea fragilis* | Fragile papershell |
| **Bourbeuse River** | 6 | 97 | C2 | | # | *Leptodea leptodon* | Scaleshell |
| **Bourbeuse River** | 6 | 97 | | | | *Ligumia recta* | Black sandshell |
| **Bourbeuse River** | 6 | 97 | | | | *Megalonaias nervosa* | Washboard |
| **Bourbeuse River** | 6 | 97 | | | | *Obliquaria reflexa* | Threehorn wartyback |
| **Bourbeuse River** | 6 | 97 | | | | *Pleurobema sintoxia* | Round pigtoe |
| **Bourbeuse River** | 6 | 97 | | | E | *Plethobasus cyphyus* | Sheepnose |
| **Bourbeuse River** | 6 | 97 | | | | *Potamilus alatus* | Pink heelsplitter |
| **Bourbeuse River** | 6 | 97 | | | | *Potamilus ohiensis* | Pink papershell |
| **Bourbeuse River** | 6 | 97 | | | | *Pyganodon grandis grandis* | Giant floater |
| **Bourbeuse River** | 6 | 97 | | | | *Quadrula pustulosa* | Pimpleback |
| **Bourbeuse River** | 6 | 97 | | D | | *Quadrula quadrula* | Mapleleaf |
| **Bourbeuse River** | 6 | 97 | | | | *Strophitus undulatus* | Squawfoot |
| **Bourbeuse River** | 6 | 97 | | | | *Toxolasma parvus* | Lilliput |
| **Bourbeuse River** | 6 | 97 | | | | *Tritogonia verrucosa* | Pistolgrip |
| **Bourbeuse River** | 6 | 97 | | | | *Truncilla donaciformis* | Fawnsfoot |
| **Bourbeuse River** | 6 | 97 | | | | *Truncilla truncata* | Deertoe |
| **Bourbeuse River** | 6 | 97 | | | | *Utterbackia imbecillis* | Paper pondshell |

| Stream | Stream Order | Year | Federal Status | D | State Status | Species Scientific Name | Species Common Name |
|---|---|---|---|---|---|---|---|
| **Bourbeuse River** | 6 | 97 | | | | *Venustaconcha e. ellipsiformis* | Ellipse |
| **Brush Creek** | 4 | 97 | | | | *Venustaconcha e. ellipsiformis* | Ellipse |

Table 23. Location, total specimens, and the site percentage composition of crayfish species within the Bourbeuse River watershed (Missouri Department of Conservation 1995a) 1USGS 14-digit Hydrologic Unit (HU) Code – 07140103

| (HU)[1] | Stream name | Twn | Rng | Sec | Collection Date | Species | Total Speci-mens | % Com-position |
|---|---|---|---|---|---|---|---|---|
| **100-001** | Webber Creek | 42N | 01W | 5 | 03/22/86 | *Orconectes punctimanus* (Spothanded crayfish) | 8 | 36.4 |
| **100-001** | Webber Creek | 42N | 01W | 5 | 03/22/86 | *Orconectes virilis* (Northern crayfish) | 14 | 63.6 |
| **090-002** | Unnamed Creek | 40N | 06W | 1 | 10/10/83 | *Orconectes punctimanus* (Spothanded crayfish) | 17 | 100.0 |
| **090-002** | Brush Creek | 40N | 04W | 18 | 03/27/84 | *Cambarus diogenes* (Devil crayfish) | 3 | 7.3 |
| **090-002** | Brush Creek | 40N | 04W | 18 | 03/27/84 | *Orconectes luteus* (Golden crayfish) | 33 | 80.5 |
| **090-002** | Brush Creek | 40N | 04W | 18 | 03/27/84 | *Orconectes punctimanus* (Spothanded crayfish) | 5 | 12.2 |
| **090-002** | McDade Branch | 39N | 05W | 16 | 10/10/83 | *Orconectes luteus* (Golden crayfish) | 47 | 77.0 |
| **090-002** | McDade Branch | 39N | 05W | 16 | 10/10/83 | *Orconectes punctimanus* (Spothanded crayfish) | 14 | 23.0 |

| (HU)[1] | Stream name | Twn | Rng | Sec | Collection Date | Species | Total Speci-mens | % Com-position |
|---|---|---|---|---|---|---|---|---|
| **090-001** | Living Well Creek | 40N | 06W | 13 | 10/10/83 | *Orconectes punctimanus* (Spothanded crayfish) | 5 | 100.0 |
| **090-001** | Living Well Creek | 40N | 06W | 13 | 09/17/85 | *Orconectes punctimanus* (Spothanded crayfish) | 24 | 100.0 |
| **090-001** | Mint Spring | 40N | 06W | 13 | 10/10/83 | *Orconectes luteus* (Golden crayfish) | 2 | 6.9 |
| **090-001** | Mint Spring | 40N | 06W | 13 | 10/10/83 | *Orconectes punctimanus* (Spothanded crayfish) | 27 | 93.1 |
| **020-001** | Bourbeuse River S5 | 38N | 07W | 12 | 10/19/84 | *Orconectes luteus* (Golden crayfish) | 48 | 76.2 |
| **020-001** | Bourbeuse River S5 | 38N | 07W | 12 | 10/19/84 | *Orconectes punctimanus* (Spothanded crayfish) | 15 | 23.8 |

Table 24. Crayfish species diversity (Shannon) and richness (Margalef) within subwatersheds of the Bourbeuse River watershed (Missouri Department of Conservation 1995a)

| Basin (USGS)[1] | Stream name | Twn | Rng | Sec | Date | Shannon[2] | Margalef[2] |
|---|---|---|---|---|---|---|---|
| **100-001** | Webber Creek | 42N | 01W | 5 | 03/22/86 | 0.655 | 0.324 |
| **090-002** | Unnamed Creek | 40N | 06W | 1 | 10/10/83 | 0 | 0 |
| **090-002** | Brush Creek | 40N | 04W | 18 | 03/27/84 | 0.623 | 0.539 |
| **090-002** | McDade Branch | 39N | 05W | 16 | 10/10/83 | 0.539 | 0.243 |
| **10/10/83** | 0 | 0 | 09/17/85 | 0 | 0 | 10/10/83 | 0.251 |
| **0.297** | 090-001 | Living Well Creek | 40N | 06W | 13 | 06W | 13 |
| **090-001** | Living Well Creek | 40N | 090-001 | Mint Spring | 40N | 06W | 13 |
| **020-001** | Bourbeuse River S5 | 38N | 07W | 12 | 10/19/84 | 0.549 | 0.241 |

[1]USGS Hydrologic Unit Code — 07140103 [2]diversity or richness for the site.

Table 25. Benthic Macroinvertebrate Collections for the Bourbeuse River from 1962-1963 (printout from the Fisheries Research Benthic Collection)

| Order | Species | Stream |
|---|---|---|
| | **Crustacea** | |
| **Amphipoda** | *Hyalella azteca* (Saussure) | Bourbeuse River |
| **Decapoda** | *Orconectes longidigitus* (Faxon) | Bourbeuse River |
| - | *Orconectes marchandi Hobbs* | Bourbeuse River |
| - | - | Brush Creek |
| - | *Dry Fork Bourbeuse River* | - |
| - | *Orconectes virilis* (Hagen) | Red Oak Creek |
| **Megagastropoda** | *Elimia potosiensis plebeius* (Gould) | Bourbeuse River |
| - | *Pleurocera acuta Rafinesque* | Bourbeuse River |
| - | *Pleurocera sp.* | Bourbeuse River |
| - | *Insecta* | - |
| **Coleoptera** | *Berosus sp.* | Bourbeuse River |
| - | - | Red Oak Creek |
| - | *Dineutus sp.* | Bourbeuse River |
| - | - | Brush Creek |
| - | - | Red Oak Creek |
| - | *Dubiraphia bivittata* (LeConte) | Bourbeuse River |
| - | - | Dry Fork Bourbeuse River |
| | *Dytiscus sp.* | Brush Creek |
| - | *Ectopria nervosa* (Melsheimer) | Bourbeuse River |
| - | - | Dry Fork Bourbeuse River |
| - | *Gyrinus sp.* | Bourbeuse River |
| - | *Helichus lithophilus* (Germar) | Boone Creek |
| - | - | Bourbeuse River |
| - | - | Brush Creek |
| - | *Dry Fork Bourbeuse River* | - |
| - | - | Red Oak Creek |
| - | *Macronychus glabratus Say* | Bourbeuse River |
| - | *Microcylloepus pusillus pusillus (LeConte)* | Bourbeuse River |
| - | *Optioservus sandersoni Collier* | Boone Creek |
| - | - | Bourbeuse River |
| - | - | Brush Creek |
| - | *Psephenus herricki* (DeKay) | Boone Creek |
| - | - | Bourbeuse River |
| - | - | Brush Creek |
| - | — | Dry Fork Bourbeuse River |
| - | *Stenelmis sp.* | Boone Creek |
| - | - | Bourbeuse River |
| - | - | Brush Creek |
| - | *Atherix lantha Webb* | Boone Creek |
| - | - | Bourbeuse River |

| Order | Species | Stream |
|---|---|---|
| - | - | Brush Creek |
| - | *Bezzia/Probezzia...* | Boone Creek |
| - | *Bezzia/Probezzia...* | Bourbeuse River |
| - | - | Brush Creek |
| - | - | Red Oak Creek |
| - | *Ceratopogonidae* | Bourbeuse River |
| - | *Chironomidae* | Boone Creek |
| - | - | Bourbeuse River |
| - | - | Brush Creek |
| - | | Dry Fork Bourbeuse River |
| - | - | Red Oak Creek |
| - | *Empididae* | Bourbeuse River |
| - | - | Brush Creek |
| - | *Hemerodromia rogatoris Coquillett* | Bourbeuse River |
| - | *Hexatoma sp.* | Boone Creek |
| - | - | Bourbeuse River |
| - | - | Brush Creek |
| - | - | Dry Fork Bourbeuse River |
| - | - | Red Oak Creek |
| - | - | Bourbeuse River |
| - | *Simuliidae* | Boone Creek |
| - | - | Bourbeuse River |
| - | - | Brush Creek |
| - | - | Dry Fork Bourbeuse River |
| - | - | Red Oak Creek |
| - | *Tabanidae* | Boone Creek |
| - | - | Bourbeuse River |
| - | - | Brush Creek |
| - | - | Dry Fork Bourbeuse River |
| - | - | Red Oak Creek |
| - | *Tipula sp.* | Boone Creek |
| - | - | Bourbeuse River |
| - | - | Brush Creek |
| - | - | Dry Fork Bourbeuse River |
| - | *Tipulidae* | Bourbeuse River |
| **Ephemeroptera** | *Acentrella sp.* | Boone Creek |
| - | - | Bourbeuse River |
| - | - | Brush Creek |
| - | - | Red Oak Creek |
| - | *Anthopotamus sp.* | Boone Creek |
| - | - | Bourbeuse River |
| - | - | Brush Creek |
| - | *Baetidae* | Bourbeuse River |
| - | *Baetidae* | Red Oak Creek |

| Order | Species | Stream |
|---|---|---|
| - | - | Brush Creek |
| - | *Bezzia/Probezzia...* | Boone Creek |
| - | *Bezzia/Probezzia...* | Bourbeuse River |
| - | - | Brush Creek |
| - | - | Red Oak Creek |
| - | *Ceratopogonidae* | Bourbeuse River |
| - | *Chironomidae* | Boone Creek |
| - | - | Bourbeuse River |
| - | - | Brush Creek |
| - | - | Dry Fork Bourbeuse River |
| - | - | Red Oak Creek |
| - | *Empididae* | Bourbeuse River |
| - | - | Brush Creek |
| - | *Hemerodromia rogatoris Coquillett* | Bourbeuse River |
| - | *Hexatoma sp.* | Boone Creek |
| - | - | Bourbeuse River |
| - | - | Brush Creek |
| - | - | Dry Fork Bourbeuse River |
| - | - | Red Oak Creek |
| - | - | Bourbeuse River |
| - | *Simuliidae* | Boone Creek |
| - | - | Bourbeuse River |
| - | - | Brush Creek |
| - | - | Dry Fork Bourbeuse River |
| - | - | Red Oak Creek |
| - | *Tabanidae* | Boone Creek |
| - | | Bourbeuse River |
| - | - | Brush Creek |
| - | - | Dry Fork Bourbeuse River |
| - | - | Red Oak Creek |
| - | *Tipula sp.* | Boone Creek |
| - | - | Bourbeuse River |
| - | - | Brush Creek |
| - | - | Dry Fork Bourbeuse River |
| - | *Tipulidae* | Bourbeuse River |
| **Ephemeroptera** | *Acentrella sp.* | Boone Creek |
| - | - | Bourbeuse River |
| - | - | Brush Creek |
| - | - | Red Oak Creek |
| - | *Anthopotamus sp.* | Boone Creek |
| - | - | Bourbeuse River |
| - | - | Brush Creek |
| - | *Baetidae* | Bourbeuse River |
| - | *Baetidae* | Red Oak Creek |

| Order | Species | Stream |
| --- | --- | --- |
| **-** | - | Bourbeuse River |
| **-** | - | Brush Creek |
| **-** | - | Dry Fork Bourbeuse River |
| **-** | *Stenonema bednariki McCafferty* | Bourbeuse River |
| **-** | - | Brush Creek |
| **-** | - | Dry Fork Bourbeuse River |
| **-** | *Stenonema femoratum* (Say) | Boone Creek |
| **-** | - | Bourbeuse River |
| **-** | - | Brush Creek |
| **-** | - | Brush Creek |
| **-** | - | Dry Fork Bourbeuse River |
| **-** | *Stenonema mediopunctatum* (McDunnough) | Boone Creek |
| **-** | - | Bourbeuse River |
| **-** | - | Red Oak Creek |
| **-** | - | Brush Creek |
| **-** | - | Dry Fork Bourbeuse River |
| **-** | *Stenonema pulchellum* (Walsh) | Boone Creek |
| **-** | - | Bourbeuse River |
| **-** | - | Brush Creek |
| **-** | - | Dry Fork Bourbeuse River |
| **-** | *Stenonema terminatum* (Walsh) | Bourbeuse River |
| **-** | - | Brush Creek |
| **-** | *Tricorythodes sp.* | Boone Creek |
| **-** | - | Bourbeuse River |
| **-** | - | Brush Creek |
| **-** | - | Dry Fork Bourbeuse River |
| **Lepidoptera** | *Petrophila sp.* | Brush Creek |
| **Megaloptera** | *Corydalus cornutus* (Linnaeus) | Bourbeuse River |
| **-** | - | Brush Creek |
| **-** | - | Dry Fork Bourbeuse River |
| **-** | *Sialis sp.* | Bourbeuse River |
| **-** | - | Brush Creek |
| **Odonata** | - | Dry Fork Bourbeuse River |
| **-** | - | Red Oak Creek |
| **-** | *Argia moesta* (Hagen) | Boone Creek |
| **-** | - | Bourbeuse River |
| **-** | - | Brush Creek |
| **-** | - | Dry Fork Bourbeuse River |
| **-** | - | Red Oak Creek |
| **-** | *Dromogomphus sp.* | Bourbeuse River |
| **-** | *Dromogomphus spinosus Selys* | Boone Creek |
| **-** | - | Bourbeuse River |
| **-** | *Gomphidae* | Boone Creek |

| Order | Species | Stream |
|---|---|---|
| **-** | - | Bourbeuse River |
| **-** | — | Brush Creek |
| **-** | *Hetaerina americana* (Fabricius) | Boone Creek |
| **-** | - | Bourbeuse River |
| **-** | - | Brush Creek |
| **-** | *Macromia sp.* | Bourbeuse River |
| **-** | *Ophiogomphus rupinsulensis* (Walsh) | Bourbeuse River |
| **-** | - | Brush Creek |
| **-** | - | Dry Fork Bourbeuse River |
| **-** | *Ophiogomphus sp.* | Boone Creek |
| **-** | *Progomphus obscurus* (Rambur) | Boone Creek |
| **-** | - | Bourbeuse River |
| **-** | *Stylogomphus albistylus* (Hagen) | Brush Creek |
| **-** | *unidentified anisoptera* | Dry Fork Bourbeuse River |
| **Plecoptera** | *Acroneuria sp.* | Bourbeuse River |
| **-** | - | Brush Creek |
| **-** | - | Red Oak Creek |
| **-** | *Agnetina capitata* (Pictet) | Bourbeuse River |
| **-** | - | Dry Fork Bourbeuse River |
| **-** | *Allocapnia sp.* | Boone Creek |
| **-** | - | Bourbeuse River |
| | | Brush Creek |
| **-** | *Allocapnia sp.* | Dry Fork Bourbeuse River |
| **-** | - | Red Oak Creek |
| **-** | *Allocapnia vivipara* (Claassen) | Red Oak Creek |
| **-** | *Amphinemura delosa* (Ricker) | Boone Creek |
| **-** | - | Bourbeuse River |
| **-** | - | Brush Creek |
| **-** | - | Red Oak Creek |
| **-** | *Hydroperla crosbyi* (Needham & Claassen) | Boone Creek |
| **-** | - | Bourbeuse River |
| **-** | - | Brush Creek |
| **-** | - | Dry Fork Bourbeuse River |
| **-** | - | Red Oak Creek |
| **-** | *Hydroperla sp.* | Bourbeuse River |
| **-** | - | Red Oak Creek |
| **-** | *Isoperla bilineata* (Say) | Boone Creek |
| **-** | - | Bourbeuse River |
| **-** | - | Brush Creek |
| **-** | *Isoperla mohri Frison* | Bourbeuse River |
| **-** | - | Red Oak Creek |
| **-** | *Isoperla nana* (Walsh) | Red Oak Creek |
| **-** | *Neoperla clymene* (Newman) | Bourbeuse River |

| Order | Species | Stream |
|---|---|---|
| **-** | - | Dry Fork Bourbeuse River |
| **-** | *Perlesta placida* (Hagen) | Boone Creek |
| **-** | - | Bourbeuse River |
| **-** | - | Brush Creek |
| **-** | *Perlidae* | Dry Fork Bourbeuse River |
| **-** | - | Red Oak Creek |
| **-** | *Perlinella drymo* (Newman) | Bourbeuse River |
| **-** | *Strophopteryx fasciata* (Burmeister) | Boone Creek |
| **-** | - | Bourbeuse River |
| **-** | - | Brush Creek |
| **-** | - | Dry Fork Bourbeuse River |
| **-** | *Taeniopteryx metequi* (Ricker & Ross) | Bourbeuse River |
| **-** | *Taeniopteryx sp.* | Bourbeuse River |
| **-** | - | Brush Creek |
| **-** | - | Dry Fork Bourbeuse River |
| **-Trichoptera** | *Agraylea multipunctata curtis* | Bourbeuse River |
| **-** | *Ceraclea flavus* (Banks) | Bourbeuse River |
| **-** | *Cheumatopsyche sp.* | Boone Creek |
| **-** | - | Bourbeuse River |
| **-** | - | Brush Creek |
| **-** | *Cheumatopsyche sp.* | Dry Fork Bourbeuse River |
| **-** | - | Red Oak Creek |
| **-** | *agen* | Boone Creek |
| **Chimarra aterrima h -** | *Chimarra obscura* (walker) | Boone Creek |
| **-** | - | Bourbeuse River |
| **-** | - | Brush Creek |
| **-** | - | Dry Fork Bourbeuse River |
| **-** | - | Red Oak Creek |
| **-** | *Helicopsyche borealis* (Hagen) | Bourbeuse River |
| **-** | *Hydropsyche cuanis ross* | Bourbeuse River |
| **-** | *Hydropsyche frisoni ross* | Bourbeuse River |
| **-** | *Hydroptilidae* | Bourbeuse River |
| **-** | *Oecetis avara* (Banks) | Bourbeuse River |
| **-** | *Oecetis inconspicua* (Walker) | Bourbeuse River |
| **-** | *Polycentropus sp.* | Brush Creek |
| **-** | *Pycnopsyche sp.* | Boone Creek |
| **-** | - | Bourbeuse River |
| **-** | - | Brush Creek |
| **-** | *Wormaldia moesta* (Banks) | Boone Creek |
| | ***Tricladida*** | |
| **-** | *Planariidae* | Bourbeuse River |
| **-** | - | Brush Creek |
| **-** | - | Dry Fork Bourbeuse River |

| Order | Species | Stream |
|---|---|---|
| - | - | Red Oak Creek |
| | ***Veneroida*** | |
| - | *Sphaeriidae* | Boone Creek |
| - | - | Bourbeuse River |
| - | - | Brush Creek |
| - | - | Dry Fork Bourbeuse River |
| | ***Miscellaneous Groups*** | |
| **Lymnophila** | *Ferrissaia fragilis* (Tryon) | Bourbeuse River |
| - | - | Brush Creek |
| — | *Dry Fork Bourbeuse River* | |
| - | *Lymnaea (Stagnicola) sp.* | Bourbeuse River |
| - | *Lymnaeidae* | Dry Fork Bourbeuse River |
| - | *Physidae* | Boone Creek |
| - | - | Bourbeuse River |
| - | - | Brush Creek |
| - | - | Dry Fork Bourbeuse River |
| - | *Planorbidae* | Bourbeuse River |
| - | *Hirudinea* | Boone Creek |
| - | *Nemata* | Bourbeuse River |
| - | *Oligochaeta* | Boone Creek |
| - | - | Bourbeuse River |
| | - | Brush Creek |
| - | - | Dry Fork Bourbeuse River |
| - | - | Red Oak Creek |

Table 26. Angler total hours fished and average catch rates of the Bourbeuse River and other streams in the area (Fleener 1988).

| Stream Name | Total Fish | Total Hours | Fish/Hour |
|---|---|---|---|
| **Upper Meramec River, Lower 13 miles Huzzah Creek, and Lower 15 miles Courtois Creek** | 15,499 | 86,390 | 0.18 |
| **Lower 141 miles Big River and Lower 5 miles Mineral Fork** | 13,916 | 75,130 | 0.19 |
| **Lower 147 miles Bourbeuse River** | 23,508 | 80,380 | 0.29 |
| **Lower 117 miles Meramec River** | 89525 | 202,880 | 0.44 |

Table 27. Bourbeuse River 1994 Smallmouth Bass population parameters (%).

| | Goodes Mill to the Mouth (%) | Union to Goodes Mill (%) | Mayer's to Union (%) | Reiker to Mayer's (%) | Noser Mill to Reiker (%) | Peter's Ford to Noser Mill (%) | Mill Rock to Wenkel Ford (%) |
|---|---|---|---|---|---|---|---|
| **Smallmouth** | | | | | | | |
| **PSD[1]** | 9.1 | 61.8 | 48.3 | 28.6 | 20.8 | 62.5 | 50.0 |
| **RSD[2]-12** | 9.1 | 49.1 | 33.3 | 20.8 | 16.7 | 50.0 | 25.0 |
| **RSD-14** | 9.1 | 29.1 | 16.7 | 6.5 | 10.4 | 18.8 | 12.5 |
| **RSD-15** | 9.1 | 18.2 | 6.7 | 3.9 | 8.3 | 12.5 | 6.3 |
| **RSD-16** | 9.1 | 12.7 | 5.0 | 2.6 | 6.3 | 0.0 | 0.0 |
| **RSD-17** | 9.1 | 9.1 | 3.3 | 0.0 | 4.2 | 0.0 | 0.0 |
| **RSD-18** | 0.0 | 0.0 | 1.7 | 0.0 | 2.1 | 0.0 | 0.0 |
| **Largemouth** | | | | | | | |
| **PSD** | 66.7 | 50.0 | 50.0 | 83.3 | 72.7 | 38.5 | 66.7 |
| **RSD-14** | 33.3 | 0.0 | 50.0 | 50.0 | 18.2 | 30.0 | 33.3 |
| **RSD-15** | 26.7 | 0.0 | 50.0 | 50.0 | 9.1 | 15.4 | 33.3 |
| **RSD-16** | 20.0 | 0.0 | 16.7 | 33.3 | 0.0 | 15.4 | 33.3 |
| **RSD-17** | 13.3 | 0.0 | 16.7 | 16.7 | 0.0 | 7.7 | 33.3 |
| **RSD-18** | 6.7 | 0.0 | 0.0 | 16.7 | 0.0 | 0.0 | 33.3 |
| **Spotted bass** | | | | | | | |
| **PSD** | 30.7 | 69.2 | 0.0 | 50.0 | 100.0 | 0.0 | 0.0 |
| **RSD-12** | 20.5 | 7.7 | 0.0 | 50.0 | 100.0 | 0.0 | 0.0 |
| **RSD-14** | 4.5 | 7.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **RSD-15** | 1.1 | 7.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0 |
| **RSD-16** | 0.0 | 7.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Smallmouth** | 9.6 | 78.6 | 90.9 | 90.6 | 80.0 | 55.2 | 84.2 |
| **Largemouth** | 13.2 | 2.9 | 9.1 | 7.1 | 18.3 | 44.8 | 15.8 |
| **Spotted** | 77.2 | 18.6 | 0.0 | 2.4 | 1.7 | 0.0 | 0.0 |

% composition stock[3]

| | Above Mill Rock (%) | Above Mint Spring (%) | All Combined (%) |
|---|---|---|---|
| **Smallmouth** | | | |
| **PSD** | 14.3 | 0.0 | 37.7 |
| **RSD-12** | 10.7 | 0.0 | 27.8 |
| **RSD-14** | 7.1 | 0.0 | 14.1 |
| **RSD-15** | 0.0 | 0.0 | 8.0 |
| **RSD-16** | 0.0 | 0.0 | 5.1 |
| **RSD-17** | 0.0 | 0.0 | 3.2 |
| **RSD-18** | 0.0 | 0.0 | 0.6 |
| **Largemouth** | | | |
| **PSD** | 42.9 | 12.5 | 53.5 |
| **RSD-14** | 14.3 | 0.0 | 26.8 |
| **RSD-15** | 14.3 | 0.0 | 21.1 |
| **RSD-16** | 14.3 | 0.0 | 14.1 |
| **RSD-17** | 14.3 | 0.0 | 9.9 |
| **RSD-18** | 0.0 | 0.0 | 4.2 |
| **Spotted Bass** | | | |
| **PSD** | 0.0 | 0.0 | 36.5 |
| **RSD-12** | 0.0 | 0.0 | 20.2 |
| **RSD-14** | 0.0 | 0.0 | 4.8 |
| **RSD-15** | 0.0 | 0.0 | 1.9 |
| **RSD-16** | 0.0 | 0.0 | 1.0 |
| **Smallmouth** | 80.0 | 20.0 | 64.1 |
| **Largemouth** | 20.0 | 80.0 | 14.5 |
| **Spotted Bass** | 0.0 | 0.0 | 21.3 |

[1]Equation: PSD or Proportional Stock Density = (quality size fish)/(stock size fish of 7-8")
[2]Equation: RSD or Relative Stock Density = (quality equal to 12, 14 inches, etc)/ stock size)
[3]Equation: % Composition Stock = percentage of total stock size fish that are smallmouth, largemouth, or spotted bass.

Table 28. Bourbeuse River 1995 Smallmouth Bass population parameters (%).

| | Union to Goodes Mill | Mayer's to Union | Reiker to Mayer's | Noser Mill to Reiker | All Combined |
|---|---|---|---|---|---|
| **Smallmouth** | | | | | |
| **PSD[1]** | 37.5 | 30.8 | 40.8 | 32.1 | 36.5 |
| **RSD[2]-12** | 27.8 | 18.3 | 26.7 | 22.6 | 24.1 |
| **RSD-14** | 15.3 | 8.3 | 9.4 | 7.5 | 9.9 |
| **RSD-15** | 12.5 | 2.5 | 5.2 | 5.7 | 5.7 |
| **RSD-16** | 8.3 | 1.7 | 3.7 | 5.7 | 4.1 |
| **RSD-17** | 1.4 | 0.8 | 1.6 | 5.7 | 1.8 |
| **RSD-18** | 1.4 | 0.0 | 1.0 | 3.8 | 1.1 |
| **Largemouth** | | | | | |
| **PSD** | 8.3 | 50.0 | 52.6 | 60.0 | 45.5 |
| **RSD-14** | 8.3 | 40.0 | 36.8 | 33.3 | 31.8 |
| **RSD-15** | 8.3 | 35.0 | 26.3 | 20.0 | 24.2 |
| **RSD-16** | 8.3 | 25.0 | 21.1 | 0.0 | 15.2 |
| **RSD-17** | 8.3 | 15.0 | 10.5 | 0.0 | 9.1 |
| **RSD-18** | 8.3 | 10.0 | 10.5 | 0.0 | 7.6 |
| **Spotted Bass** | | | | | |
| **PSD** | 47.6 | 46.4 | 0.0 | 75.0 | 0.0 |
| **RSD-12** | 33.3 | 32.1 | 0.0 | 50.0 | 0.0 |
| **RSD-14** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **RSD-15** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **RSD-16** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **RSD-17** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **RSD-18** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **% composition stock[3]** | | | | | |
| **Smallmouth** | 68.6 | 83.9 | 89.3 | 77.9 | 82.3 |
| **Largemouth** | 11.4 | 14.0 | 8.9 | 22.1 | 12.5 |
| **Spotted Bass** | 20.0 | 2.1 | 1.9 | 0.0 | 5.3 |

[1]Equation: PSD or Proportional Stock Density = (quality size fish)/(stock size fish of 7-8")
[2]Equation: RSD or Relative Stock Density = (quality equal to 12, 14 inches, etc)/ stock size)
[3]Equation: % Composition Stock = percentage of total stock size fish that are smallmouth, largemouth, or spotted bass.

Table 29. Bourbeuse River 1996 Smallmouth Bass population parameters (%).

| | Union to Goodes Mill (%) | Mayer's to Union (%) | Reickers to Mayer's (%) | Noser Mill to Reickers (%) | All Combined (%) |
|---|---|---|---|---|---|
| **Smallmouth** | | | | | |
| **PSD[1]** | 45.6 | 46.1 | 35.3 | 20.0 | 35.6 |
| **RSD[2]-12** | 27.9 | 33.7 | 25.3 | 8.0 | 23.6 |
| **RSD-14** | 17.6 | 15.7 | 8.1 | 4.0 | 10.0 |
| **RSD-15** | 14.7 | 13.5 | 5.9 | 1.0 | 7.5 |
| **RSD-16** | 13.2 | 10.1 | 3.6 | 1.0 | 5.6 |
| **RSD-17** | 5.9 | 6.7 | 2.7 | 0.0 | 3.3 |
| **RSD-18** | 1.5 | 6.7 | 0.0 | 0.0 | 1.5 |
| **Largemouth** | | | | | |
| **PSD** | 37.5 | 50.0 | 60.0 | 61.5 | 54.1 |
| **RSD-14** | 25.0 | 20.0 | 40.0 | 15.4 | 26.2 |
| **RSD-15** | 25.0 | 20.0 | 20.0 | 7.7 | 18.0 |
| **RSD-16** | 25.0 | 15.0 | 20.0 | 0.0 | 14.8 |
| **RSD-17** | 25.0 | 10.0 | 20.0 | 0.0 | 13.1 |
| **RSD-18** | 12.5 | 5.0 | 10.0 | 0.0 | 6.6 |
| **Spotted Bass** | | | | | |
| **PSD** | 28.6 | 42.9 | 29.2 | 33.3 | 31.1 |
| **RSD-12** | 19.0 | 14.3 | 16.7 | 33.3 | 19.7 |
| **RSD-14** | 4.8 | 0.0 | 8.3 | 11.1 | 6.6 |
| **RSD-15** | 0.0 | 0.0 | 0.0 | 11.1 | 1.6 |
| **RSD-16** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **RSD-17** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **RSD-18** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **% composition stock[3]** | | | | | |
| **Smallmouth** | 70.1 | 76.7 | 83.4 | 82.0 | 79.7 |
| **Largemouth** | 8.2 | 17.2 | 7.5 | 10.7 | 10.2 |
| **Spotted Bass** | 21.6 | 6.0 | 9.1 | 7.4 | 10.2 |

[1]Equation: PSD or Proportional Stock Density = (quality size fish)/(stock size fish of 7-8")
[2]Equation: RSD or Relative Stock Density = (quality equal to 12, 14 inches, etc)/ stock size)
[3]Equation: % Composition Stock = percentage of total stock size fish that are smallmouth, largemouth, or spotted bass.

Table 30. A summary comparison of the Bourbeuse River smallmouth bass parameters with Courtois Creek and selected Smallmouth Bass Management Areas.

| | Bourbeuse 1994 | Bourbeuse 1995 | Bourbeuse 1996 |
|---|---|---|---|
| **PSD[1]** | 38 | 40 | 36 |
| **RSD[2]-12** | 28 | 26 | 24 |
| **RSD-14** | 14 | 9 | 10 |
| **RSD-15** | 8 | 5 | 8 |
| **RSD-18** | 0.6 | 1.4 | 1.5 |

1Equation: PSD or Proportional Stock Density = (quality size fish)/(stock size fish of 7-8")
2Equation: RSD or Relative Stock Density = (quality equal to 12, 14 inches, etc)/(stock size)

| | Courtois 1973 | Courtois 1991 | Big Piney 1997 | Meramec 1996 | Big 1996 |
|---|---|---|---|---|---|
| **PSD[1]** | 37 | 39 | 30 | 32 | 33 |
| **RSD[2]-12** | 25 | 23 | 20 | 23 | 26 |
| **RSD-14** | 8 | 8 | 9 | - | - |
| **RSD-15** | 4 | 6 | 6 | 6 | 14 |
| **RSD-18** | 0.2 | 0.2 | 0.2 | 0.5 | 5 |

1Equation: PSD or Proportional Stock Density = (quality size fish)/(stock size fish of 7-8")
2Equation: RSD or Relative Stock Density = (quality equal to 12, 14 inches, etc)/(stock size)

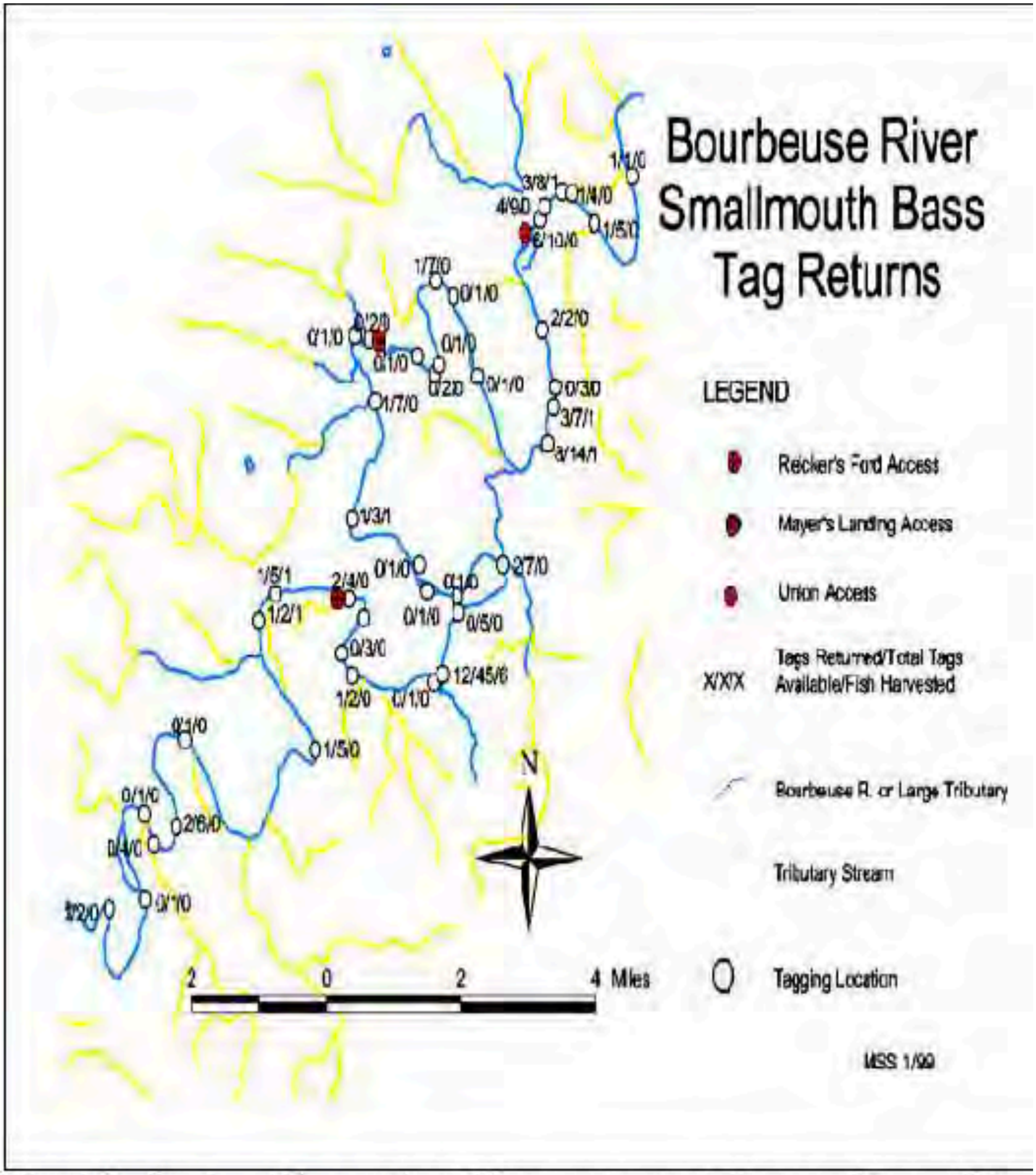



Figure 15. Bourbeuse River smallmouth bass tag returns, total tags available, and fish harvested.

# Management Problems and Opportunities

The following goals, objectives, and strategies help outline approaches, partners, and programs to assist citizens and agency personnel in conserving the aquatic resources of the Bourbeuse River watershed.

## GOAL I: Maintain and improve water quality in the Bourbeuse River watershed so all streams are capable of supporting healthy native aquatic communities.

**Status:** Water quality in the Bourbeuse River watershed is generally good, with some exceptions, and room for improvement. Sewage treatment plants for St. James, St. Clair, and Cuba have not always met water quality standards for their treated discharge. In general, non-point pollution in the form of sediment from erosion and organic wastes from livestock impairs water quality. In particular, organic wastes from livestock contribute to excessive algal production in watershed streams. Contaminant sampling for pesticide bioaccumulation in fish indicates that Bourbeuse River fish are safe for human consumption.

### Objective 1.1: Streams within the watershed will meet state standards for water quality.

Strategy: Enforcement of existing water quality regulations and necessary revisions to these regulations will help reduce violations. Water quality problems must also be addressed through public awareness efforts and by encouraging good land use in riparian areas. The citizen activism present in the watershed through STREAM TEAMs and a variety of related organizations should be encouraged. Working with related agencies to promote public awareness and incentive programs, cooperating with citizen groups involved with water quality issues in the watershed, and helping to enforce water quality laws will be among the most efficient ways to achieve this objective.

- Enhance people's awareness of 1) water quality problems affecting aquatic biota, 2) viable solutions to these problems, and 3) their role in implementing these solutions. Media contacts, personal contacts, special events, and literature development and distribution can be used to reach people throughout the watershed.
- Review Section 404, NPDES, and other permits and either recommend denial or appropriate mitigation for those which are harmful to aquatic resources. Related activities will include cooperating with other state and federal agencies to investigate pollution events and fish kills, assisting with the enforcement of existing water quality, mining, landfill, and dam safety laws, and recommending appropriate measures to protect and enhance aquatic communities.
- Work with the Missouri Department of Health and MDNR to reduce contaminant levels in fish by collecting fish for contaminant analysis, advising the fishing public about fish tissue contaminant levels, and identifying and eliminating sources of contamination.
- Work with MDNR and the Missouri Department of Health to monitor water quality, improve water quality, and ensure compliance with discharge permits. With training, volunteer groups, such as STREAM TEAMs, can assist with water quality monitoring and improvement. These volunteer groups are strong advocates for good water quality throughout the watershed. Further development of STREAM TEAMs should be encouraged. Related monitoring efforts, such as MDC's newly developing Resource and Assessment Monitoring Program which will track aquatic biota and habitat trends statewide, should also be encouraged and directed to strategic locations.

## GOAL II. Improve riparian and aquatic habitat conditions in the Bourbeuse River watershed to meet the needs of native aquatic species.

**Status:** Stream habitat conditions within the Bourbeuse River and its tributaries are variable. The main stem has no channelized segments, and old mill dams located near Beaufort and Union provide channel grade control. A number of tributaries are impounded, with the largest impoundment being Indian Hills Lake (326 acres) in the Brush Creek hydrologic unit. In many streams the lack of adequate riparian corridors, excessive nutrient loading, streambank erosion, excessive runoff and erosion, and the effects of extensive instream gravel mining are among the problems observed. Grazing practices along many streams contribute to streambank instability, nutrient loading, and poor riparian corridor conditions. The Middle Bourbeuse and the Little Bourbeuse hydrologic units have the most need for improved watershed management based on the observed scarcity of streambank protection and intact riparian corridor.

### Objective 2.1: Riparian landowners should be helped to understand the importance of good stream stewardship and where to obtain technical assistance for sound stream habitat improvement and good watershed management.

**Strategy:** Advertising and promoting stream programs, installing and maintaining demonstration projects, and providing educational opportunities to landowners will make them more aware of the reasons and techniques for protecting streams. Emphasizing economic advantages of stream improvements will encourage more landowners to participate.

- Work with MDC's Education Division to develop stream management related materials and present related courses for elementary and secondary school teachers.
- Establish and maintain stream management demonstration sites.
- Promote good stream stewardship through landowner workshops and stream demonstration site tours.

### Objective 2.2: Maintain, expand, and restore riparian corridors, enhance watershed management, improve instream habitat, and reduce streambank erosion throughout the watershed.

**Strategy:** High quality aquatic habitat is the critical factor in maintaining and improving natural stream communities. Stream habitat conditions will be improved by cooperating with and providing technical assistance to private landowners, working with other local, state, and federal agencies to manage stream frontages on their properties, and installing stream improvement and habitat enhancement projects on MDC lands within the watershed. Monitoring habitat conditions and using regulatory avenues to reduce impacts from development projects should also help to identify problems and minimize impacts on the stream resource.

- Ensure that all MDC areas are examples of good stream and watershed management by including appropriate recommendations and prescriptions in area plans, implementing these practices in a timely manner, and monitoring these practices throughout their life. These practices will include, but may not be limited to, riparian corridor re-establishment, riparian corridor management, and maintaining soil erosion levels at "T" (soil replacement level) or lower.
- Provide technical recommendations to all landowners that request assistance and who are willing to reestablish and maintain an adequate riparian corridor.
- Work with NRCS and SWCD boards to help them address watershed management concerns with their programs.

- Improve landowner stewardship of streams by promoting and implementing cost share programs that include streambank stabilization, alternative watering provisions, and establishment and maintenance of quality riparian corridors within hydrologic units cooperatively selected by MDC, NRCS, and the SWCD boards.
- Assist the US Army Corps of Engineers in their Section 404 regulatory activities, especially those pertaining to gravel mining and bridge replacements. Assistance shall be in the form of reporting unauthorized activity as well as participating in pre-application meetings and commenting as requested on 404 permit applications. Utilize contacts with landowners, contractors, developers, and municipal and county officials as opportunities to educate people about how to obtain gravel and control construction site erosion in ways that minimize damage to stream systems.

## GOAL III: Maintain diverse and abundant populations of native aquatic orgnaisms while accommodating angler demands for quality fishing.

**Status:** The Bourbeuse River watershed has a diverse assemblage of 90 fish species collected from 1941 through 1996. In historic fish collections, prior to the 1995-96 collections, fisheries biologists found 81 fish species. In the 1995-96 survey, nine additional fish species were added to the list; these included freshwater drum, highfin carpsucker, barred fantail darter, chestnut lamprey, smallmouth buffalo, bigmouth buffalo, warmouth, western redfin shiner, and freckled madtom. However, some fish species found in earlier collections were not taken in the 1995-96 collections; these included least brook lamprey, goldeye, red shiner, pallid shiner, bigmouth shiner, suckermouth minnow, bullhead minnow, stippled darter, and orangespotted sunfish. The highfin carpsucker, state listed species, occurred at several locations within the watershed in the 1995-96 collections.

The Bourbeuse River is home to most of the popular sport fish found in Missouri. The river tends to be turbid, and because of the relatively low gradient, is slower moving than other Ozark streams. Most float anglers fish the Bourbeuse in the spring, before base flows limit their ability to move between access points. Smallmouth bass, largemouth bass, spotted bass, rock bass, channel catfish, flathead catfish, walleye, redhorse and suckers, longear sunfish, bluegill, black crappie, and white crappie are among the most popular species sought by anglers.

A total of 39 mussel species have been collected prior to 1977 in various surveys of the Bourbeuse River and three of its tributaries. Thirty-seven of the 39 species were collected in the 1977-78 survey, but *Cumberlandia monodonta* (a Missouri species of conservation concern) and *Cyclonaias tuberculata* were collected in previous surveys but not in the 1977-78 survey. In a more recent survey of the Bourbeuse River and two of its tributaries during 1995-97, 31 living and five dead species of mussels were collected. Habitat disturbances are the suspected cause of the decline in the number of mussel species present in the Bourbeuse River watershed.

### Objective 3.1: Evaluate, maintain, and where feasible, improve sport fish populations, with primary emphasis on smallmouth bass, largemouth bass, spotted bass and rock bass.

**Strategy:** Assess the quality of populations of sport fishing management emphasis species and take steps to maintain or improve their populations through public education, regulations, habitat improvement, and other methods.

### Objective 3.2: Maintain populations of native non-game fishes and aquatic invertebrates at or above present levels throughout the watershed.

**Strategy:** Assess the status of fish and invertebrate communities through systematic, periodic sampling. Techniques to maintain or improve non-game fish or invertebrate communities will depend on the community in decline and the causative agent.

- Develop standard sampling techniques for assessing fish and invertebrate communities, including the use of indicator species, and implement a monitoring program to track trends in species diversity and abundance.
- Maintain aquatic biodiversity and protect or enhance fish and invertebrate species diversity and abundance using regulations, stocking, habitat improvement, and related techniques.

## GOAL IV. Improve the public's appreciation for stream resources in the Bourbeuse River watershed.

**Status:** Streams in the watershed are used extensively for fishing, and some floating, motor boating, and other recreational activities occur as well. Nine MDC stream access sites are located in the watershed.

The public's understanding of the biological, social, and economic importance of streams in the Bourbeuse River watershed may be above average as evidenced by the defeat of the Meramec Dam proposal by referendum in 1978. The proposal included plans for damming the Bourbeuse River near Union. While landowner participation in Streams for the Future programs has been limited, public participation in the STREAM TEAM program has been good.

### Objective 4.1: Increase the general public's awareness of stream recreational opportunities, local stream resources, and good watershed and stream management practices.

**Strategy:** The public will be made aware of stream related recreational opportunities and issues through media outlets, fair exhibits, and MDC publications. Increased appreciation of stream resources should follow enhanced public awareness and education. More concern about the quality of water and habitat within the watershed's streams should follow, and greater citizen involvement and advocacy in related environmental issues should result. Newspaper articles, presentations, and special events highlighting streams should help foster this awareness.

- Working with MDC's Education Division, use streams for aquatic education programs. Identify stream locations appropriate for educational field trips near participating schools.
- Provide a stream resource emphasis at public events such as the Washington Town and Country Fair and other local fairs.
- Promote the formation of STREAM TEAMs and STREAM TEAM associations within the watershed.

# Bourbeuse River Angler Guide

Bourbeuse River game fish commonly sought by anglers are smallmouth bass, largemouth bass, channel catfish, flathead catfish, rock bass, and panfish. A cool-water fish, the walleye, is also found in the river in reaches below the dam at Noser Mill.

Black bass, which include smallmouth bass, largemouth bass, and the spotted bass, have been extensively studied in the river especially in reaches below Highway 185 (Noser Mill). The daily limit for black bass in streams is six. Smallmouth bass are common with a good portion of fish greater than 12 inches, the minimum length for the harvest of black bass.

Large smallmouth bass prefer deep water with some current, in particular next to cover such as boulders, logs, or bedrock. Smallmouth bass prefer temperatures from 60E F to no more than 80E F. This species feeds optimally at 70-75E F.

## Smallmouth Bass Fishing Tips

Smallmouth bass can be caught on a variety of artificial lures such as spinner baits, jig and plastic grub combinations, crankbaits, and plastic worms. The Bourbeuse tends to be cloudy, so lures that are easily seen should be selected. Live bait such as crayfish, earthworms, minnows, and insect larvae is often very productive.

Largemouth bass are a sporting alternative to smallmouth bass. Largemouth bass are often the largest bass species present in the Bourbeuse River in most pools greater than 3 feet in depth. Also, spotted bass have become increasingly common in theBourbeuse in recent years. Largemouth bass and spotted bass can tolerate slightly warmer temperatures and turbidity than smallmouth bass.

## Largemouth Bass Fishing Tips

Largemouth bass prefer more woody habitats, sluggish weedy backwater areas, and slightly warmer waters. They can be caught on baits similar to those used for smallmouth bass. Spotted bass tend to prefer the main channel zone, but angling techniques effective for smallmouth and largemouth bass also work on spotted bass.

Channel catfish weighing three-plus pounds are a fairly common catch. Bourbeuse River catfish anglers pursue both channel and flathead catfish, but channel catfish are the most sought-after fish. Moderate fishing pressure does occur for both speciesusing pole and line as well as trotlines and limb lines.

## Catfish Fishing Tips

Channel catfish are bottom feeders. Look for them in habitat containing current, deep pools, and cover such as downed trees. Your bait should be on or near bottom to attract attention. Although fish will take live bait such as minnows, frogs, earthworms, or sunfish, they are attracted to anything with strong scent such as rotting meat or bloody chicken livers.

There are a number of effective prepared baits on the market. Fishing trotlines, limb lines, and bank lines at night are the most popular methods of angling for channel catfish. A trotline consists of a stout line stretched for several yards into the stream with short lines or "stagings" tied every 3 feet for baited hooks. A swivel is used on the short line to prevent fish from tangling the line. Weighted ends of the main line are lowered to the depths wanted. Unlike the channel catfish, flathead catfish prefer live bait or freshly killed baits. Use large minnows, goldfish, green sunfish, or bullheads. In the Bourbeuse River, catfish can be taken throughout the year. Daily limit is ten (10) channel catfish and five (5) flathead catfish. There is no length limit on catfish species taken from the Bourbeuse River.

Redhorse and suckers are very abundant in Ozark streams. For every 100 pounds of fish in a stream, more than 50 pounds are suckers. Suckers may be taken by a variety of fishing methods including pole and line, gigging, snaring, snagging, and grabbing.

## Sucker Fishing Tips

Now limited to a cooler part of the year, gigging has long been an Ozark tradition. Nongame fish may be taken by the gig method in the Bourbeuse River between sunrise and midnight from September 15 to January 31. While the majority of suckers are taken by giggers in the fall and winter, other fishing methods can be used. From March 15 to May 15, anglers are permitted to snag or snare suckers and redhorse shoaling on riffles. To catch suckers and redhorse all year, anglers use small hooks baited with mussels (clams) or nightcrawlers that are drifted into riffles. If suckers and redhorse are taken by pole and line, the daily limit is 50 in aggregate. If they are taken by gigging, snagging, snaring, or grabbing, the daily limit is 20 in the aggregate.

Walleye and sauger have been caught by anglers, however most are caught by those fishing for other species, especially black bass. While population sampling during walleye spring spawning, biologists routinely capture walleye exceeding 18 inches total length. Although walleye growth is exceptional, population density is low. Walleye can be found in deep pools during the day and feeding in the shallow margins of the river at night. From February 20 to April 14, walleye and sauger may be taken and possessed from 0630-1830 CST. Sauger are more abundant and can be caught below the Missouri Department of Conservation Uhlemeyer Public Access at the I-44 Bridge.

## Walleye/Sauger Fishing Tips

Walleye and sauger can be caught on similar baits. Having a preference for live baits, walleye will strike minnows, earthworms, and leeches. Fishing crankbaits and deep-running plugs in deep pools is an effective summer strategy. Because walleye are active at night, try baits that reflect the available light and produce some sound. Spring fishing strategies should include fishing bridge abutments and rock piles that are walleye and sauger magnets. Jigs and minnow combinations can also be trolled in large pool areas with bridge abutments.

Rock bass, a favorite for the frying pan, can be fished with similar gear and techniques as the smallmouth bass. Fisheries Biologist Mike Smith says, "Rock bass can be found throughout the basin. However, they do not represent a significant component of our fish samples, except in the lower river especially near Union." Rock bass, regionally known as goggle eye, earn their name from their preference for rocky areas along a streambank that has some current. The rock bass has no size limit and has a daily limit of fifteen.

Other panfish include the longear sunfish, bluegill, black crappie, and white crappie. Panfish are plentiful and are often accessible from the streambank. Tiny jigs with a grub attached work well for longear sunfish and bluegill (see table below for other lures). A float rig is often the most effective method of fishing for panfish. Suspend your bait by float about half the depth of the water you are fishing. Move your rig periodically until you find fish.

Baits to Use

| Species | Baits | Lures |
|---|---|---|
| **Catfish species** | worms, minnows, crawfish, stinkbaits, cheese, liver | occasionally on jigging spoons or crankbaits |
| **Black bass species** | crayfish, minnows, worms | jigs, spinnerbaits, crankbaits, artificial worms |
| **Walleye** | minnows, leeches, nightcrawlers | jigs, crankbaits, jigging spoons |
| **Panfish and Rock bass** | worms, grubs, leeches, small minnows, crickets, grasshoppers | tiny jigs, in-line spinner, small spoons, small spinner bait |

# Literature Cited


Allgood, F. P. and I. D. Persinger. 1979. *Missouri general soil map and soil association descriptions.* For the U.S. Department of Agriculture, Soil Conservation Service in cooperation with Missouri Agricultural Experiment Station. U.S. Department of Agriculture, Columbia, Missouri.

Anderson, James R., Ernest E. Hardy, John T. Roach, and Richard E. Witmer. 1976. *A land use and land cover classification system for use with remote sensor data.* Reston, Virginia, US Geological Survey Professional Paper 964.

Anderson, C. L. 1980. *Best management practices for erosion and sediment control.* University of Missouri-Columbia and Missouri Department of Natural Resources. Manual 17.

Bovee, K. D. 1982. *A guide to stream habitat analyses using the instream flow incremental methodology*. Instream Flow Information Paper. No. 12. Fish and Wildlife Service. FWS/OBS-82/26.

Buel, Clarence. Natural Resource Conservation Service (NRCS), personal telephone communication, February 1996.

Buchanan, A. C. 1980. *Mussels (Naiades) of the Meramec River basin, Missouri.* Missouri Department of Conservation, Columbia, Missouri.

Buchanan, A. 1995. *Atrazine in Missouri waters.* Unpublished memorandum. Missouri Department of Conservation, Columbia, Missouri.

– 1995. *Contaminant levels in Missouri fish: 1994.* Missouri Department of Conservation, Columbia, Missouri.

– 1998. *Contaminant levels in Missouri fish: 1997.* Printout from the Missouri Department of Conservation, Fisheries Research Division, Columbia, MO..

Bulkley, R.V., R.L. Kellogg, and L.R. Shannon. 1976. *Size-related factors associated with Dieldrin concentrations in muscle tissue of channel catfish, Ictalurus punctatus.* Transactions of the American Fisheries Society. 105(2):301-07.

Bruenderman, S. 1998. *Bourbeuse River Mussel Decline.* Letter to Ms. Goudy address mussel decline. Missouri Department of Conservation.

CARES (Center for Agricultural, Resource and Environmental Systems) 1997a. *Geology of the Meramec River Basin.* Originator: CARES, MDNR; Scale: 1:24, 000. Based on basin series used in the Missouri Water Atlas 1986. http://www.cares.missouri.edu/cwic/mowater/geology7.html

CARES (Center for Agricultural, Resource and Environmental Systems) 1997b. *Soils of the Meramec River Basin.* Originator: CARES, MDNR; Scale: 1:24, 000. Based on basin series used in the Missouri Water Atlas 1986. http://www.cares.missouri.edu/cwic/mowater/statsgo7.html

Craig, R.F. 1987. *Soil mechanics.* Van Nostrand Reinhold Co. Ltd. Wokingham, Berkshire, England.

Crunkilton, R. L. and Czarnezki, J. M. 1981. *Missouri pollution and fish kill investigations 1980.* Missouri Department of Conservation, Fish and Wildlife Research Center, Columbia, Missouri.

Crunkilton, R. L. and Czarnezki, J. M. 1982. *Missouri pollution, fish kill, and water quality research investigations 1981.* Missouri Department of Conservation, Fish and Wildlife Research Center, Columbia, Missouri.

Currier, M. P. 1991. *Missouri natural feature inventory: Camden, Cole Cooper, Gasconade, Maries, Moniteau, Morgan, and Osage counties.* Natural History Division, Missouri Department of Conservation, Jefferson City, MO.

Ducharme, C. B. and Miller, T. M. 1996. *Missouri state water plan series—Volume IV, Water use in Missouri,* Missouri Department of Natural Resources, Division of Geology and Land Survey, Water Resources Report Number 48, 150p.

Duchrow, R. M. 1978. *An inventory of point and non-point water pollution sources in Missouri with notes regarding their impact upon fish and other aquatic resources.* 208 Water Quality Report. Missouri Department of Conservation, Columbia, Missouri.

— 1991. *Missouri pollution and fish kill investigations 1990.* Missouri Department of Conservation, Columbia, Missouri

— 1992. *Missouri pollution and fish kill investigations 1991.* Missouri Department of Conservation, Columbia, Missouri.

— 1993. *Missouri pollution and fish kill investigations 1992.* Missouri Department of Conservation, Columbia, Missouri.

— 1994. *Missouri pollution and fish kill investigations 1993.* Missouri Department of Conservation, Columbia, Missouri.

— 1996. *Missouri pollution and fish kill investigations 1994.* Missouri Department of Conservation, Columbia, Missouri.

EPA. 1994. *1:250, 000 scale quadrangles of landuse/landcover GIRAS spatial data in the conterminous United States.* Environmental Protection Agency's (EPA) Office of Information Resources Management (OIRM).

EPA Surf Your Watershed 1999. *Bourbeuse River USGS Cataloging Unit: 07140103: Environmental Profile.* http://www.epa.gov/surf2/hucs/07140103/ Date of access: December 6, 1999.

Fantz, J. R., D. M. Lobb, M. P. Matheney, B. L. Todd, W. M. Turner, and R. E. Wehnes. 1993. *A status report of stream projects installed in Missouri from 1987 to 1992.* Missouri Department of Conservation, Jefferson City, Missouri.

Fleener, G. G. 1988. *Recreational use survey of Big, Bourbeuse, and Meramec rivers.* Final Report, Dingel-Johnson Project F-1-R-37, Study S-26. Missouri Department of Conservation, Columbia, Missouri.

Freeze, Paul. Natural Resources Conservation Service, Union Missouri, personal communication, August 1997.

Funk, J. L. 1968. *Missouri's fishing streams. D-J series No. 5.* Missouri Department of Conservation. Jefferson City, Missouri.

Goodspeed Publishing Company*. 1888. History of Franklin, Crawford, Dent, Washington, Gasconade, and Jefferson counties, Missouri*. Reprinted in 1970 by Ram Free Press, Cape Girardeau, Missouri. 1, 131 pp, illus.

Hauth, L. D. 1974. *Technique for estimating the magnitude and frequency of Missouri floods.* U.S. Geological Survey, Rolla, Missouri.

Hebrank, A. W. 1989. *Geologic natural features classification system for Missouri.* Natural Areas Journal 9(2): 106-116.

Hansen, M. H. 1991. *Timber resources of Missouri's riverborder.* Resource Bulletin NC-118. USDA Forest Service, St. Paul, Minnesota.

Jacobson, R. B. and A. T. Primm. 1994. *Historical land-use changes and potential effects of stream disturbance in the Ozark Plateaus, Missouri.* U.S. Geological Survey Open-File Report 94-333. U.S. Geological Survey, Rolla, Missouri.

Jacobson, Robert B. and Aaron L. Pugh. 1995. *Riparian-vegetation controls on the spatial pattern of stream-channel instability, Little Piney Creek, Missouri.* United States Geological Survey Water-Supply paper 2494, Denver, Co.

Kurz, D. R. 1981. *Missouri natural features inventory: Franklin, Jefferson, St. Louis, and Washington counties.* Missouri Department of Conservation, Jefferson City, Missouri.

McCain, M., et al. 1990. *Stream habitat classification and inventory procedures for northern California.* US Department of Agriculture. Forest Service. Pacific Southwest Region. US Government Printing Office: 1990-786-951.

McGrath, K. E. 1988. *Contaminant levels in Missouri Fish — 1986.* Missouri Department of Conservation, Columbia, Missouri.

Missouri Agricultural Statistics Service (MASS). 1995. *Missouri farm facts.* Missouri Agricultural Statistics Service, Columbia, Missouri.

Missouri Department of Conservation. 1978. *An inventory of point and non-point water pollution sources in Missouri with notes regarding their impact upon fish and other aquatic life.* Missouri Department of Conservation, Jefferson City, Missouri.

Missouri Department of Conservation. 1995a. *Pflieger's fish and crayfish collections.* Missouri Department of Conservation Fisheries Research Section, Columbia, Missouri.

— 1995b. *Missouri benthos collections.* Missouri Department of Conservation Fisheries Research Section, Columbia, Missouri.

— 1997. *Missouri watershed protection practice.* 1997 management guidelines for maintaining forested watersheds to protect streams. Missouri Department of Conservation, Jefferson City, Missouri.

— 1998. *East Central Region Resource Inventory.* July 1998. Missouri Department of Conservation Policy Coordination Division, Jefferson City, MO.

— 1999. *Sensitive species and high-quality natural communities known from the Bourbeuse River basin.* Printout of the Missouri Natural Heritage Database, Missouri Department of Conservation, Jefferson City, Missouri.

Missouri Natural Heritage Database. 1999. *Missouri species of conservation concern checklist.* June 1999. Missouri Department of Conservation, Jefferson City, Missouri. 30 pp.

Missouri Department of Conservation Fisheries Research Collection. 1997. *Naiade GIS database.* Missouri Department of Conservation Fisheries Research. Missouri Department of Conservation, Columbia, Missouri.

Missouri Department of Health. 1995. *Missouri Department of Health 1995 fish consumption advisory.* Missouri Department of Health, Bureau of Environmental Epidermiology, Jefferson City, MO.

Missouri Department of Natural Resources (MDNR). 1964. *Water Quality of Big, Bourbeuse, Meramec River Basins.* MDNR, Missouri Water Pollution Board, Jefferson City, Missouri.

Missouri Department of Natural Resources. 1984, 1996. *Missouri water quality basin plans.* Volume 5. Meramec, Whitewater and Castor River, Mississippi R., Joachim, Plattin, Establishment, Clinque Hommes and Apple creeks. Missouri Department of Natural Resources, Jefferson City, Missouri.

— 1986. *Missouri water atlas.* Missouri Department of Natural Resources, Jefferson City, Missouri

— 1994. *Rules of Department of Natural Resources Division 20 - Clean Water Commission chapter 7 - Water Quality.* 10 CSR 20-7.010. Code of State Regulations, Office of Secretary of State, Jefferson City, Missouri.

— 1996. *Active permits: Operation and construction permits for animal waste facilities for classes of operation.* Print out from the Division of Water Pollution Control, February 16, 1996.

Natural Resources Conservation Service. 1995. *1992 broad land use estimates for the Bourbeuse River basin.* Natural Resources Inventory database, U.S. Department of the Interior, Columbia, Missouri.

Nelson, P. W. 1987. *The terrestrial natural communities of Missouri.* Missouri Department of Natural Resources, Jefferson City, Missouri.

Oesch, R. D. 1995. *Missouri Naiades: A guide to the mussels of Missouri.* Missouri Department of Conservation, Jefferson City, Missouri.

Missouri University Extension, Office of Social and Economic Development (OSEDA) 1999. *USDC, Bureau of the Census, Census of Agriculture.* Accessed September 1998. Map series and social economic data from: http://www.oseda.missouri.edu/ Last viewed 12-9-99.

OSEDA. 1999. USDC, *Bureau of the Census, Census of Agriculture.* Accessed August 1999. County population information from: http://www.oseda.missouri.edu/counties/97aghilites Last viewed 12-9-99.

Olsen, G.W. 1983. *Soils and the environment.* Chapman and Hall: New York.

Owenby, J. R. and D. S. Ezell. 1992. *Monthly station normals of temperature, precipitation, and heating and cooling degree days 1961-90 Missouri, Climatography of the United States No. 81,* Asheville, North Carolina.

Patrick, D. M., S. T. Ross, and P. D. Hartfield. 1993. *Fluvial geomorphic considerations in the management and stewardship of fluvial ecosystems.* Riparian ecosystems in the humid U.S.: Functions, values and management. Sheraton Colony Square, Atlanta, Georgia.

Pflieger, W. L. 1997. *The fishes of Missouri.* Missouri Department of Conservation, Jefferson City, Missouri.

Pflieger, W. L. 1996. *The crayfishes of Missouri.* Missouri Department of Conservation, Jefferson City, Missouri.

Roberts, Andrew and Sue Bruenderman. 1999. *A qualitative reassessment of freshwater mussels in the Meramec River basin. Missouri Department of Conservation, Columbia Missouri.* Prepared for the US Fish and Wildlife Service. October 1999.

Ryan, J. 1993. *Missouri natural features inventory: Crawford, Dent, and Reynold counties.* Missouri Department of Conservation, Jefferson City, Missouri.

Ryan, J. 1992. *Missouri natural features inventory: Phelps, Pulaski, and Laclede counties.* Missouri Department of Conservation, Jefferson City, Missouri.

Soil Conservation Service (SCS). 1989. *Soil survey of Franklin County, Missouri.* United States Department of Agriculture, Columbia, Missouri.

SCS. 1994. *Soil survey of Gasconade County, Missouri.* United States Department of Agriculture, Columbia, Missouri.

Skelton, J. 1970. *Base-flow recession characteristics and seasonal low-flow frequency characteristics for Missouri streams.* Missouri Geological Survey and Water Resources, Water Report 25. Missouri Geological Survey, Rolla, Missouri, 43pp.

Smith, Michael, *Missouri Department of Conservation, personal communication, August 1999.*

Sullivan Independent News. 1995. *Investigation holds fate of city's treatment plant.* Sullivan Independent News. November 15, 1995. Vol. 29, No. 25.

Tackett, Scott. *Missouri Department of Natural Resources, personal communications, September 1999.*

Tryon, C. P. 1996. *Hydrogeologic-Reconnaissance investigations of the Blue Springs Creek watershed and nearby area near Bourbon, Missouri.* Prepared for Meramec Basin Chapter, Trout Unlimited.

U.S. Department of Agriculture (USDA). 1966. *Meramec River basin report.* Publication #5. U.S. Department of Agriculture, Soil Conservation Service, Economic Research Service, Forest Service, State of Missouri, Jefferson City, Missouri.

USDA and SCS. 1990. *Hydrological unit maps of Missouri counties.* United States Department of Agriculture and Soil Conservation Service, Columbia, Missouri.

United States Geological Survey (USGS). 1995. *Water resources data, Missouri, Water Year 1994.* USGS Water-Data Report MO-95-1. USGS, Rolla, Missouri.

United States Geological Survey (USGS). 1997. *Water resources data, Missouri, Water Year 1996.* USGS Water-Data Report MO-96-1. USGS, Rolla, Missouri.

USGS. 1998. *Water resources data, Missouri, Water Year 1996.* USGS Water-Data Report MO-96-1. USGS, Rolla, Missouri.

Vandike, J. E. 1995. *Surface water resources of Missouri. Missouri state water plan series.* Volume 1. Missouri Department of Natural Resources, Geology and Land Survey, Rolla, Missouri.

Weithman, Stephen A. 1987. *Missouri fish kill and water pollution investigations 1986.* Missouri Department of Conservation, Columbia, Missouri.

Weithman, A. S. 1991. *Recreational use and economic value of Missouri fisheries.* Dingell-Johnson Project F-1-R-40. Missouri Department of Conservation, Jefferson City, Missouri.

Wildlife Code of Missouri. 1999. *Rules of the Conservation Commission.* Issued March 1, 1999. Missouri Department of Conservation. Administrative Office, PO Box 180, Jefferson City, MO 65102.

# Glossary

**Alluvial soil:** Soil deposits resulting directly or indirectly from the sediment transport of streams, deposited in river beds, flood plains, and lakes.
**Aquifer:** An underground layer of porous, water-bearing rock, gravel, or sand.
**Benthic:** Bottom-dwelling; describes organisms which reside in or on any substrate.
**Benthic macroinvertebrate:** Bottom-dwelling (benthic) animals without backbones (invertebrate) that are visible with the naked eye (macro).
**Biota:** The animal and plant life of a region.
**Biocriteria monitoring:** The use of organisms to assess or monitor environmental conditions.
**Channelization:** The mechanical alteration of a stream which includes straightening or dredging of the existing channel, or creating a new channel to which the stream is diverted.
**Concentrated animal feeding operation (CAFO):** Large livestock (ie. cattle, chickens, turkeys, or hogs) production facilities that are considered a point source pollution, larger operations are regulated by the MDNR. Most CAFOs confine animals in large enclosed buildings, or feedlots and store liquid waste in closed lagoons or pits, or store dry manure in sheds. In many cases manure, both wet and dry, is broadcast overland.
**Confining rock layer:** A geologic layer through which water cannot easily move.
**Chert:** Hard sedimentary rock composed of microcrystalline quartz, usually light in color, common in the Springfield Plateau in gravel deposits. Resistance to chemical decay enables it to survive rough treatment from streams and other erosive forces.
**Cubic feet per second (cfs):** A measure of the amount of water (cubic feet) traveling past a known point for a given amount of time (one second), used to determine discharge.
**Discharge:** Volume of water flowing in a given stream at a given place and within a given period of time, usually expressed as cubic feet per second.
**Disjunct:** Separated or disjoined populations of organisms. Populations are said to be disjunct when they are geographically isolated from their main range.
**Dissolved oxygen:** The concentration of oxygen dissolved in water, expressed in milligrams per liter or as percent.
**Dolomite:** A magnesium rich, carbonate, sedimentary rock consisting mainly (more than 50% by weight) of the mineral dolomite ($CaMg(CO_3)_2$).
**Endangered:** In danger of becoming extinct.
**Endemic:** Found only in, or limited to, a particular geographic region or locality.
**Environmental Protection Agency (EPA):** A Federal organization, housed under the Executive branch, charged with protecting human health and safeguarding the natural environment — air, water, and land — upon which life depends.
**Epilimnion:** The upper layer of water in a lake that is characterized by a temperature gradient of less than $1^{o}$ Celsius per meter of depth.
**Eutrophication:** The nutrient (nitrogen and phosphorus) enrichment of an aquatic ecosystem that promotes biological productivity.
**Extirpated:** Exterminated on a local basis, political or geographic portion of the range.
**Faunal:** The animals of a specified region or time.
**Fecal coliform:** A type of bacterium occurring in the guts of mammals. The degree of its presence in a lake or stream is used as an index of contamination from human or livestock waste.
**Flow duration curve:** A graphic representation of the number of times given quantities of flow are equaled or exceeded during a certain period of record.

**Fragipans**: A natural subsurface soil horizon seemingly cemented when dry, but when moist showing moderate to weak brittleness, usually low in organic matter, and very slow to permeate water.
**Gage stations:** The site on a stream or lake where hydrologic data is collected.
**Gradient plots:** A graph representing the gradient of a specified reach of stream. Elevation is represented on the Y-axis and length of channel is represented on the X- axis.
**Hydropeaking:** Rapid and frequent fluctuations in flow resulting from power generation by a hydroelectric dam's need to meet peak electrical demands.
**Hydrologic unit (HUC):** A subdivision of watersheds, generally 40, 000-50, 000 acres or less, created by the USGS. Hydrologic units do not represent true subwatersheds.
**Hypolimnion:** The region of a body of water that extends from the thermocline to the bottom and is essentially removed from major surface influences during periods of thermal stratification.
**Incised:** Deep, well defined channel with narrow width to depth ration, and limited or no lateral movement. Often newly formed, and as a result of rapid down-cutting in the substrate
**Intermittent stream:** One that has intervals of flow interspersed with intervals of no flow. A stream that ceases to flow for a time.
**Karst topography:** An area of limestone formations marked by sinkholes, caves, springs, and underground streams.
**Loess:** Loamy soils deposited by wind, often quite erodible.
**Low flow:** The lowest discharge recorded over a specified period of time.
**Missouri Department of Conservation (MDC):** Missouri agency charged with: protecting and managing the fish, forest, and wildlife resources of the state; serving the public and facilitating their participation in resource management activities; and providing opportunity for all citizens to use, enjoy, and learn about fish, forest, and wildlife resources.
**Missouri Department of Natural Resources (MDNR):** Missouri agency charged with preserving and protecting the state's natural, cultural, and energy resources and inspiring their enjoyment and responsible use for present and future generations.
**Mean monthly flow:** Arithmetic mean of the individual daily mean discharge of a stream for the given month.
**Mean sea level (MSL):** A measure of the surface of the Earth, usually represented in feet above mean sea level. MSL for conservation pool at Pomme de Terre Lake is 839 ft. MSL and Truman Lake conservation pool is 706 ft. MSL.
**Necktonic:** Organisms that live in the open water areas (mid and upper) of waterbodies and streams.
**Non-point source:** Source of pollution in which wastes are not released at a specific, identifiable point, but from numerous points that are spread out and difficult to identify and control, as compared to point sources.
**National Pollution Discharge Elimination System (NPDES):** Permits required under The Federal Clean Water Act authorizing point source discharges into waters of the United States in an effort to protect public health and the nation's waters.
**Nutrification:** Increased inputs, viewed as a pollutant, such as phosphorous or nitrogen, that fuel abnormally high organic growth in aquatic systems.
**Optimal flow:** Flow regime designed to maximize fishery potential.
**Perennial streams:** Streams fed continuously by a shallow water table an flowing year-round.

**pH :** Numeric value that describes the intensity of the acid or basic (alkaline) conditions of a solution. The pH scale is from 0 to 14, with the neutral point at 7.0. Values lower than 7 indicate the presence of acids and greater than 7.0 the presence of alkalis (bases).
**Point source:** Source of pollution that involves discharge of wastes from an identifiable point, such as a smokestack or sewage treatment plant.
**Recurrence interval:** The inverse probability that a certain flow will occur. It represents a mean time interval based on the distribution of flows over a period of record. A 2-year recurrence interval means that the flow event is expected, on average, once every two years.
**Residuum:** Unconsolidated and partially weathered mineral materials accumulated by disintegration of consolidated rock in place.
**Riparian:** Pertaining to, situated, or dwelling on the margin of a river or other body of water.
**Riparian corridor:** The parcel of land that includes the channel and an adjoining strip of the floodplain, generally considered to be 100 feet on each side of the channel.
**7-day $Q^{10:}$: Lowest** 7-day flow that occurs an average of every ten years.
**7-day $Q^{2}$:** Lowest 7-day flow that occurs an average of every two years.
**Solum:** The upper and most weathered portion of the soil profile.
**Special Area Land Treatment project (SALT):** Small, state funded watershed programs overseen by MDNR and administered by local Soil and Water Conservation Districts. Salt projects are implemented in an attempt to slow or stop soil erosion.
**Stream Habitat Annotation Device (SHAD):** Qualitative method of describing stream corridor and instream habitat using a set of selected parameters and descriptors.
**Stream gradient:** The change of a stream in vertical elevation per unit of horizontal distance.
**Stream order:** A hierarchical ordering of streams based on the degree of branching. A first order stream is an unbranched or unforked stream. Two first order streams flow together to make a second order stream; two second order streams combine to make a third order stream. Stream order is often determined from 7.5 minute topographic maps.
**Substrate:** The mineral and/or organic material forming the bottom of a waterway or waterbody.
**Thermocline:** The plane or surface of maximum rate of decrease of temperature with respect to depth in a waterbody.
**Threatened:** A species likely to become endangered within the foreseeable future if certain conditions continue to deteriorate.
**United States Army Corps of Engineers (USCOE) and now (USACE):** Federal agency under control of the Army, responsible for certain regulation of water courses, some dams, wetlands, and flood control projects.
**United States Geological Survey (USGS):** Federal agency charged with providing reliable information to: describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect the quality of life.
**Watershed:** The total land area that water runs over or under when draining to a stream, river, pond, or lake.
**Waste water treatment facility (WWTF):** Facilities that store and process municipal sewage, before release. These facilities are under the regulation of the Missouri Department of Natural Resources.