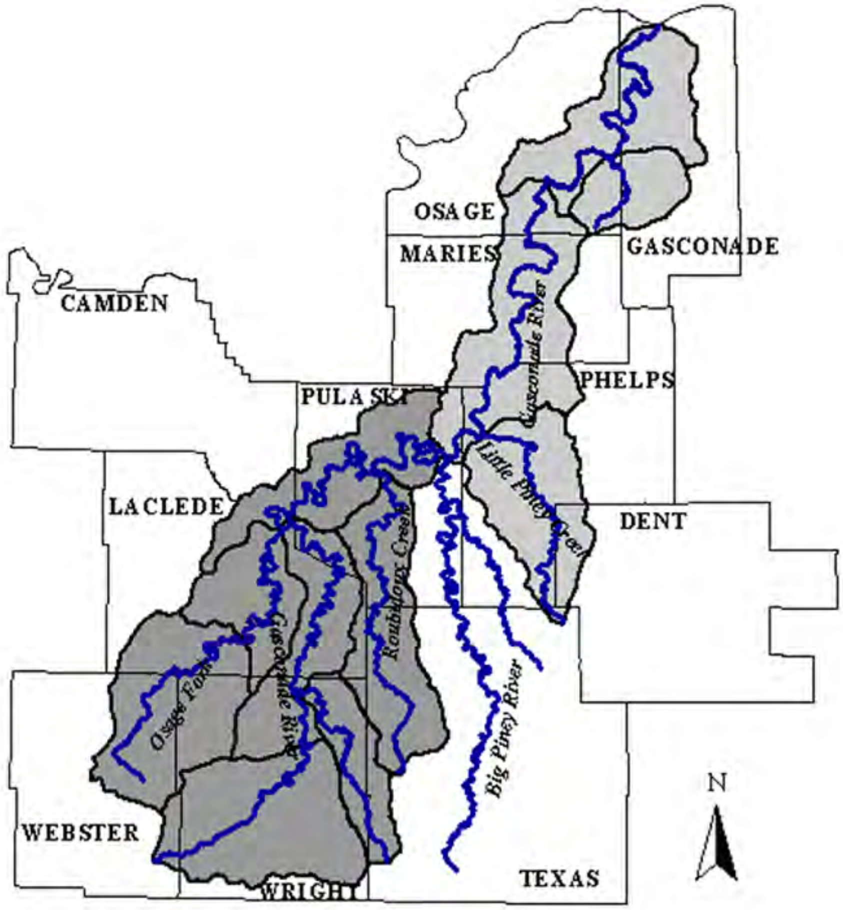



# Gasconade River

*Watershed and Inventory Assessment, May 2001*
*Prepared by*
*Todd J. Blanc, Fisheries Biologist, George Kromrey, Michael Smith*
*Missouri Department of Conservation Sullivan, Missouri*

# Table of Contents

# Executive Summary

The Gasconade River watershed is located within the Ozark Plateau of the Interior Ozark Highlands. The river meanders north to northeast through Webster, Texas, Laclede, Pulaski, Dent, Maries, Osage, Phelps, and Gasconade counties to join the Missouri River. The Gasconade River is 271 miles long from mouth to headwaters with 263 miles having permanent flow. The Upper and Lower Gasconade River watersheds drain 2,806 square miles. The Upper Gasconade River watershed has an average gradient of 27.6 feet/mile, and the Lower Gasconade River watershed has an average of 3.9 feet/mile. A number of springs within the middle Gasconade River portions are due to the karst geology of the Roubidoux and Gasconade Dolomite Formation and losing stream segments. The karst topography causes losing portions in the Osage Fork, Roubidoux, North Cobb, Little Piney, Spring, and Mill creeks, and Gasconade River. The entire Gasconade River watershed is reported to have 76 springs and the largest concentration of big springs in the state.

As a whole, the Gasconade River watershed is rural with low population density and high farmland density. The most populated areas are Pulaski and Phelps counties, which are experiencing land development from growth surrounding Fort Leonard Wood and the City of Rolla. Lower watershed areas of Maries, Osage, and Gasconade counties have low population density. The Upper and Lower Gasconade River watersheds have 49% and 33%, respectively, grassland and cropland as land use. A general trend in the rural Gasconade River watershed toward increased cattle numbers per pastured acre has continued to the present. Forest comprises approximately 46% of the land cover within the Upper Gasconade River watershed and 66% within the Lower Gasconade River watershed. Forests are in good health and have sustainable forest production. Forest land is largely under private ownership with federally-owned forest having the second largest holdings, followed by state-owned lands having a smaller percentage. Public land is 12% or 221,040 acres within the entire watershed. To provide water-based recreational opportunities, 23 public stream accesses have been developed in the watershed. Gasconade River watershed annual precipitation ranges from 40.35 to 42.67 inches with an annual mean of 41.66 inches. This precipitation and the local geology provides good base flow conditions and lower variability in stream flow throughout major portions of the watershed. Average runoff had greater extremes from the late 1970s to the present than during the 1960s to the late 1970s.

The Gasconade River watershed's designated stream uses, assigned by the Missouri Department of Natural Resources (MDNR) are warmwater aquatic life protection and fishing, and livestock and wildlife watering. Threats to beneficial uses in the Gasconade River watershed are point and non-point sources of pollutants. The number of point pollution sources and flow from point pollution sources is low. In fact, improvements have been made to point source discharges through monitoring by the MDNR and sewage treatment upgrades. Also, the Gasconade River has recovered well from the December 1988 oil spill that released hundreds of thousands of gallons of crude oil into the main stem Gasconade River from a broken pipeline near Vienna. On the contrary, non-point source pollution remains a difficult challenge.

Numerous MDNR Soil and Water Program Special Area Land Treatment projects in the Upper Gasconade River HU, and portions of the Upper Osage Fork HU are addressing nutrient problems that have cattle manure as their sources. Sand and gravel mining in sensitive areas can and has affected fisheries, especially sensitive cool- and cold-water fisheries. Other potential non-point pollution sources are two landfills in Wright and Phelps counties. Runoff from farms, mining operations, construction sites, forest operations, residential septics, and impervious surface in urbanized areas create a complex resource management challenge.

The Upper Gasconade River watershed was poorly forested along major segments of its tributaries and main stem compared to the Lower Gasconade River watershed. Thirty-eight percent of the major stream segments within the Upper Gasconade River watershed and 46% of the major segments of the Lower Gasconade River watershed had forested corridors. Results of the corridor quality ratio used to assess stream segments indicated that the Lower Gasconade River watershed had more stream segments rated as good (81%) than the Upper Gasconade River watershed (64%). Based on the land use/land cover GIS analysis, priority management should be given to those hydrologic units that were rated relatively low on the objective rating scale. The Lower Gasconade River HU was rated as poor due to the lack of forested stream corridor. In addition, the Lower Roubidoux Creek HU, should be given priority management attention because of its sensitive springs, growing human population, and urbanization.

Of the total wetland acreage within the Upper Gasconade River watershed, 0.9% met the nursery wetland criteria and within the Lower Gasconade River watershed another 0.6% met the criteria. The Upper Gasconade River watershed had more temporary and temporary-semi-permanent pools than the Lower Gasconade River watershed. High stream density in the Upper Gasconade River watershed is attributed to the difference. Large expanses of pool/riffle complex habitat can be found in the Upper Gasconade River, especially in the Middle Gasconade River HU. Gravel bars are more prominent in the Middle Gasconade River HU due to slower water velocities, lower gradient, and stream disturbances.

The Gasconade River watershed has a diverse assemblage of 103 fish species collected from 1900 to 1999. These species are distributed among 49 genera and 21 families of fish ranging from the ancient Petromyzontidae (lampreys) to the more modern *Percidae* (perches) and *Sciaenidae* (drums). Despite the high number of fish species in the Gasconade River watershed, 9 species are listed on the Missouri Species of Conservation Concern Checklist of June 2000 as critically imperiled, imperiled, or rare.

The crystal darter *(Crystallaria asprella)* is classified as a state endangered species, and the bluestripe darter *(Percina cymatotaenia)* is state imperiled species.

A total of 46 mussel species were collected from Little Piney Creek, Roubidoux Creek, Osage Fork, and the main stem Gasconade River. The dominant genera were *Lampsilis* (6 species), *Quadrula* (3 species), and *Fuconaia* (2 species). These species were distributed among 27 different genera. The pocketbook mussel *(Lampsilis cardium)* was the most widely distributed mussel in the watershed.

Species that are much less abundant include the state-listed endangered mussel species, the elephant ear *(Elliptio crassidens),* ebonyshell *(Fusconaia ebena),* and the pink mucket *(Lampsilis abrupta).* The pink mucket is also classified as federally endangered.

Seven species of crayfish have been collected in the Gasconade River watershed and three genera encompass the seven species. *Orconectes* was the dominant genus and comprised over 99% of the crayfish composition. Devil crayfish *(Cambarus diogenes)* were collected in Roubidoux Creek, and digger crayfish *(Fallicambarus fodiens)* were collected in the lower Gasconade River. The rare Salem cave crayfish *(Cambarus hubrichti)* is located in some caves of the watershed.

Anglers have numerous sport fishing opportunities as the Gasconade River changes character from an Ozark headwater stream system to a large river system. According to the Missouri Department of Health, all game fish are safe to eat in the Gasconade River watershed. Studies on the Osage Fork of the Gasconade River revealed that numbers of black basses and rock bass of regulation size were in good supply. An Osage Fork Smallmouth Bass Special Management Area (SMBSMA) was created in 2000. An Osage Fork Special Management Area has been established for rock bass beginning in March 2001. In 2001 on Little Piney Creek, a Wild Trout Management Area (WTMA) was formed and a Trout Management Area (TMA) was relocated. The Lane Spring TMA was discontinued due to the creation of the WTMA. Portions of Mill Creek and Roubidoux Creek also support trout fisheries.

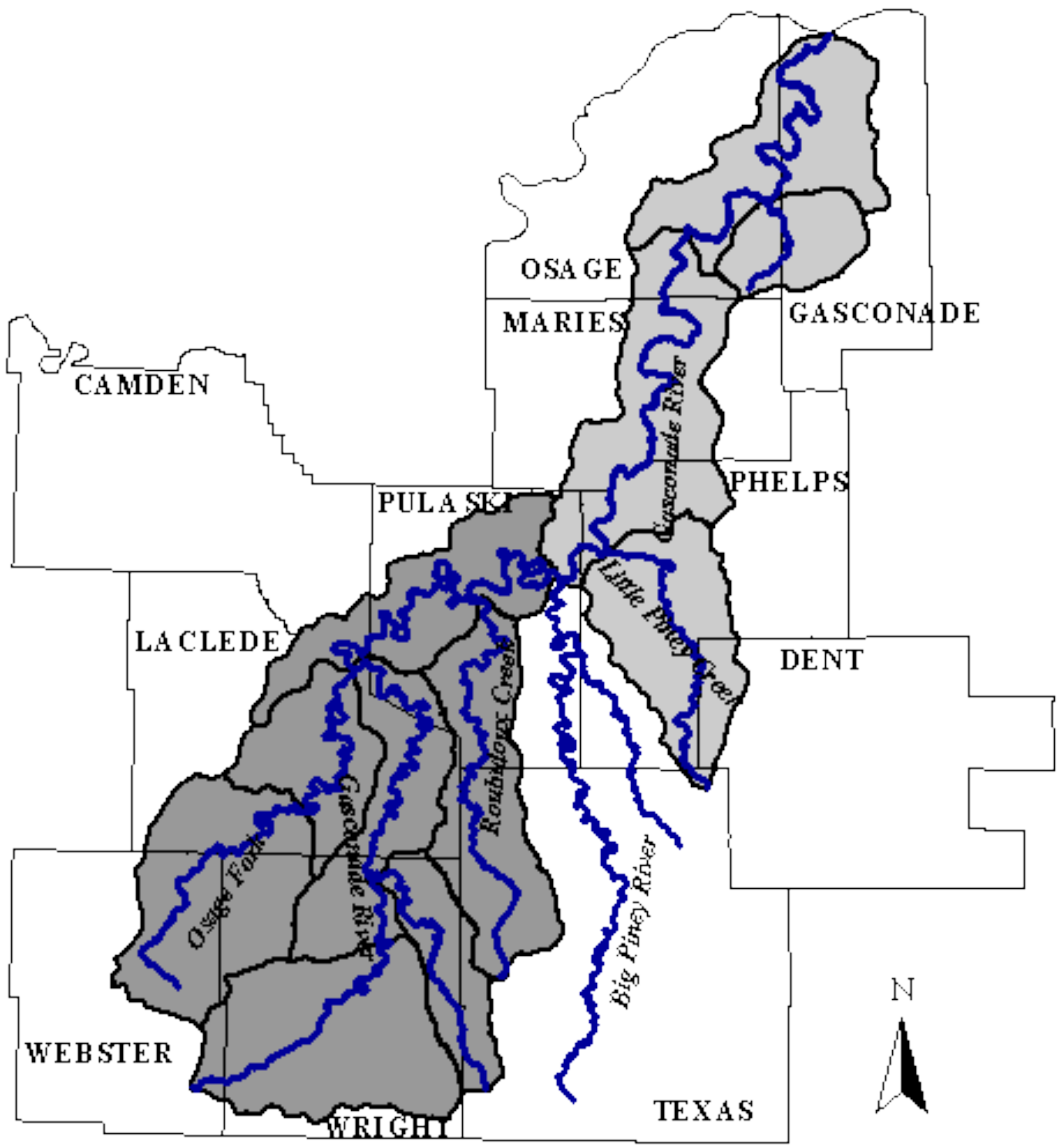
The major goals for the basin are improved water quality, better riparian and aquatic habitat conditions, the maintenance of diverse and abundant populations of native aquatic organisms and sport fish, and increased public appreciation for the stream resources. Periodic fish population samples will be 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 and cooperating with citizen groups and landowners to promote public awareness and landowner incentive programs will result in improved watershed conditions and better stream quality, diverse and abundant population of native aquatic organisms, and wonderful angling opportunities.

## Location

Flowing northeast to join with the Missouri River, the 8-digit Upper and Lower Gasconade River Hydrologic Units (HU) lie in the South Central portion of Missouri. The United States Geological Survey (USGS) 8-digit Upper and Lower Hydrologic Unit Code (HUC) #10290201 and HUC #10290203 are subdivisions of the Gasconade River watershed. These boundaries were adapted for water resources and soil conservation planning and inventory purposes by the USGS and the Natural Resources Conservation Service. The larger 8-digit hydrologic units are further subdivided to smaller 11-digit hydrologic units, representing tributaries to the Gasconade River watershed. Throughout this document the 8-digit Upper and Lower Gasconade River HUs will be called watersheds (although they are actually not complete watersheds) rather than HUs to eliminate confusion with similarly-named 11-digit HUs. These watersheds are drained by the Gasconade River and its tributaries except for the Big Piney River. While it is not part of this inventory and assessment, the Big Piney River flows into the Gasconade River and is part of the Gasconade River's natural drainage.

As the river meanders across the landscape, it travels through Webster, Wright, Texas, Laclede, Pulaski, Phelps, Dent, Maries, Osage, and Gasconade counties (Figure 1). The combined watersheds have a total surface area of approximately 2,806 square miles, which drain a wide upper watershed area of Webster and Wright counties and a more narrow lower watershed. A predominantly rural watershed, a significant portion of the upper watershed lies within the Mark Twain National Forest and Fort Leonard Wood U.S. Army Military Reservation. The Lower Gasconade River watershed has slightly less forest land, more pasture land, and more rural farm communities. A significant portion of the watershed's population is within the upper watershed area, particularly near Interstate 44.

**Figure 1. Gasconade River Watershed -- Base Map**




**Legend**

Gasconade River Major Segments

County Boundaries

Gasconade Watershed

Upper Gasconade River Watershed (HUC # 10290201)

Lower Gasconade River Watershed (HUC # 10290203)

Data source: USGS 7.5 " Streams, USGS Hydrologic Unit Boundaries.

Map Production: Todd J. Blanc, Missouri Department of Conservation, March 1999.

# Geology

## Physiographic Region

The entire state of Missouri has three of the major physiographic provinces of the United States: The Central Lowlands, the Interior Highlands, and the Coastal Plains. The Gasconade River watershed lies within the Ozark Plateau of the Interior Highlands. Further subdivision of the Ozark Plateau places the watershed within the Salem Plateau whose elevation is between 1000 - 1400 feet above mean sea level.

## Geology

Surface geologic formations are composed of dolomite and sandstone of the Ordovician Age. All geologic formations in the watershed are part of the Canadian Series (MDNR 1979). Tributary streams and the main stem Gasconade River cut through a member of the Gunter Sandstone, the Gasconade Formation. This formation has many springs that contribute to the base flow of the main stem Gasconade River. As one moves out of the floodplain toward the uplands, the Gasconade Formation is replaced by the Roubidoux Formation that contains sandstone and cherty dolomite. Farther upland, within the headwaters of the Gasconade River are a composite of Smithville Formation, Powell, Cotter, and Jefferson City dolomites. Rocks in these formations tend to be more weathered with cracks, joints, and solution openings.

## 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 Clean Water Commission Water Quality Standards 10 CSR 20-7.01, 1994). Permeable rock type is responsible for the movement of water to subsurface levels. Most of the watershed has well sustained base flows. The karst topography causes losing portions in the Osage Fork, Roubidoux, North Cobb, Little Piney, Spring, and Mill creeks, and Gasconade River (MDNR 1986).

Approximately 33 miles of the central portion of the Gasconade River comprises the longest losing segment in the watershed (Table 1). The Roubidoux, Corn, and Little Piney creeks have 16, 12.5, and 12 miles of losing stream, respectively. These subwatersheds are more densely populated with springs than other subwatersheds.

## Soil Associations

The collective pattern of soils with their associated relief and drainage makes the Gasconade River watershed a unique natural landscape. The general soils map (Figure 2) is useful for planning on a large scale; more detailed maps can be found in NRCS county soil surveys for small scale planning, such as farm or field management or project site selection.

The Gasconade Watershed traverses three land resource areas: Deep Loess Hills, Ozarks, and Ozark Border. The Deep Loess Hills is found mostly in the northwestern part of the state. Some of the soil deposits are found on ridgetops and broad uplands, but the thickest deposits of loess are found along river bluffs with decreasing thickness away from the bluffs. The Gasconade River has one association, Menfro-Winfield-Haymond, in this resource area along the Missouri River. The Ozarks Land Resource Area is found in the southern part of the state. Soils of this resource area cover a broader soil category and greater number of associations. Not only were soils formed in alluvium along narrow bottomland areas, but most soil formations were under forest vegetation with an occasional tall grassy open area or glade area. Ozark Border soils are located in the southeastern part of Missouri. This area was formed under the same conditions as the Ozarks. The bottomland areas tend to have gravelly alluvium soils rather than cherty alluvium soils. Both the Ozarks and the Ozark Border areas have fragipans that tend to restrict plant root growth.

## Soil Types

The soil associations in the Gasconade River watershed have several major soil types. These soil types determine soil uses and the distribution of vegetation types.

The Clarksville series consists of those soils found in level to steep terrain, steep-side slopes and narrow ridges, that has good drainage. Formed in a residuum cherty dolomite, the surface soils are a dark grayish-brown cherty dolomite. Deeper layers are a paler to reddish silt loam and increase in clay content. Because of Clarksville's hazard for draughtiness, thus low moisture holding capacity, most of this series is forested.

The Lebanon series are moderately well drained soils on level or sloping areas. Soil is silty in its upper layers and cherty fragipan in lower layers. The surface layers are dark grayish-brown silt loam and at a depth of about 24 inches is the fragipan. Clay content increases below 31 inches creating a strong-brown silty clay. Most of the soils are in pasture and some hardwood areas remain.

Formed in cherty colluvium, the Viraton series consists of well drained soils with cherty fragipan. They are sloping to moderately steep. Surface layers are brown cherty silt loam. A cherty silty clay loam exists to 18 inches and a thick fragipan follows. Below the 18-inch fragipan is a yellowish-red silt loam. Like the Lebanon series low moisture holding capacity creates drought conditions. Idle areas and pasture make up most of this series.

Found in floodplains, the Haymond series is very deep and well drained silt loam. Surface layers are dark grayish brown silt loam. Deeper layers vary only slightly in color. Flooded during brief periods, these soils are cultivated for corn, soybeans, and wheat, and some small areas are wooded.

## Erosion Potential

The Soil Conservation Service (now known as the Natural Resources Conservation Service (NRCS)) in a 1977 National Erosion Inventory estimated that the soil loss from sheet erosion amounts to 2.7 tons/acres/year in the Gasconade River watershed (Anderson 1980). In the same survey, 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, in the Gasconade River watershed did not exceed allowable limits of 2.5 - 5 tons/acre/year on pasture land; however, sheet and rill erosion did reach 18 - 24 tons/acre/year on tilled land (Anderson 1980). Twenty tons per year is equivalent to one-eighth of an inch of soil. For comparison, in forest soils, with many roots to maintain soil integrity, losses in the Gasconade River watershed are 0.25 - 0.5 tons/acre/year. Gully erosion problems, extreme soil losses causing trenches that exceed 30 centimeters in depth, are moderate in the Gasconade River watershed. Actual sediment reaching streams is low (0.8 tons/acre/year) in comparison to other watersheds in the state.

## Watershed Area

The drainage of the Gasconade Watershed excluding the Big Piney River covers 1,797,130 acres or 2806.9 square miles (Table 2). The watershed is approximately 130 miles long. Considerably wider at the upper reaches, 50 miles wide, the watershed narrows north of the 38E latitude to approximately 10 miles in width (Vandike 1995). The major tributaries such as Third Creek, Roubidoux River, Little Piney Creek, Upper Osage Fork, and Lower Osage Fork have drainage areas of 64,910, 181,220, 190,720, 214,960, and 109,440 square miles, respectively.

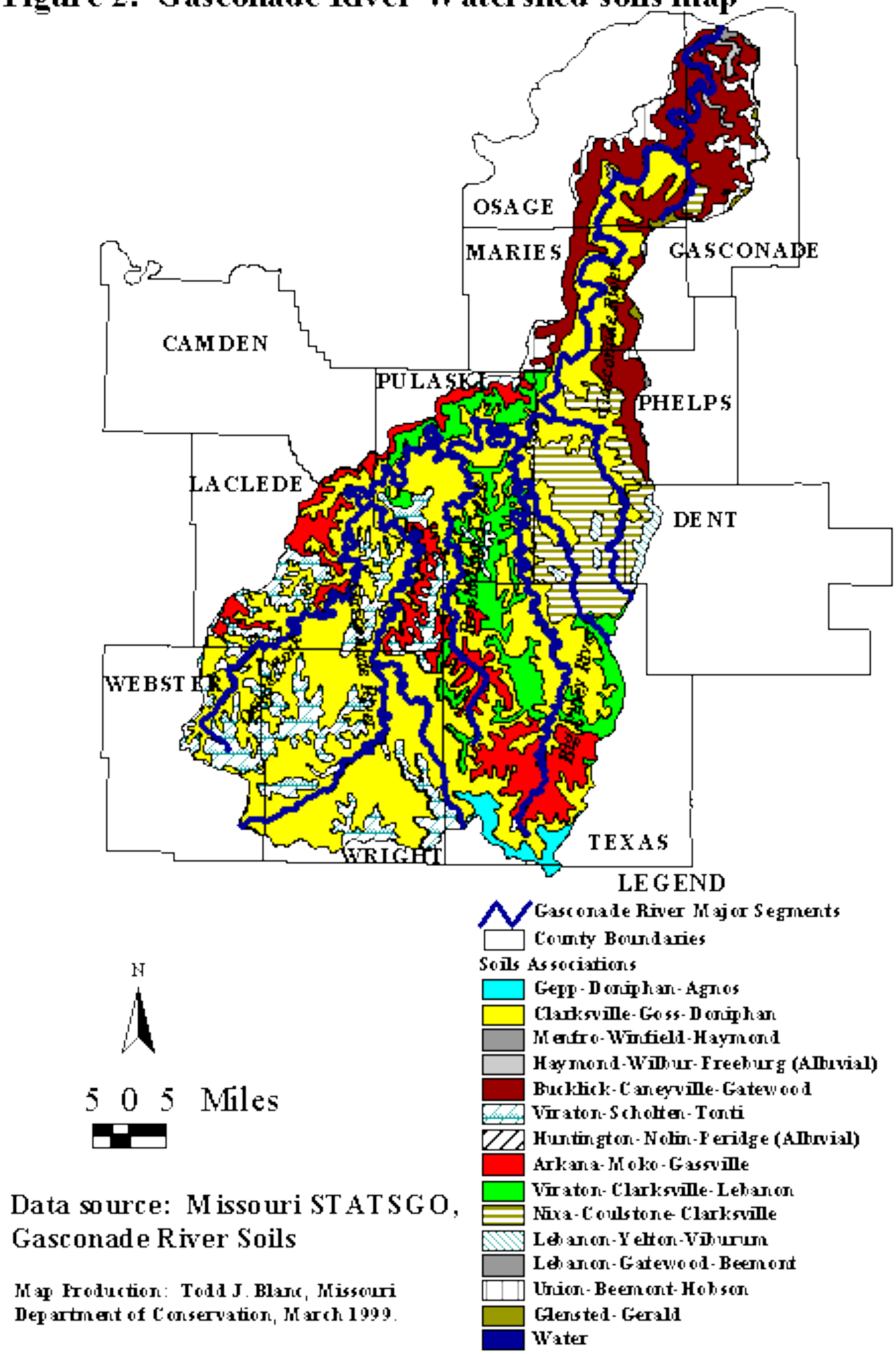
## Stream Order

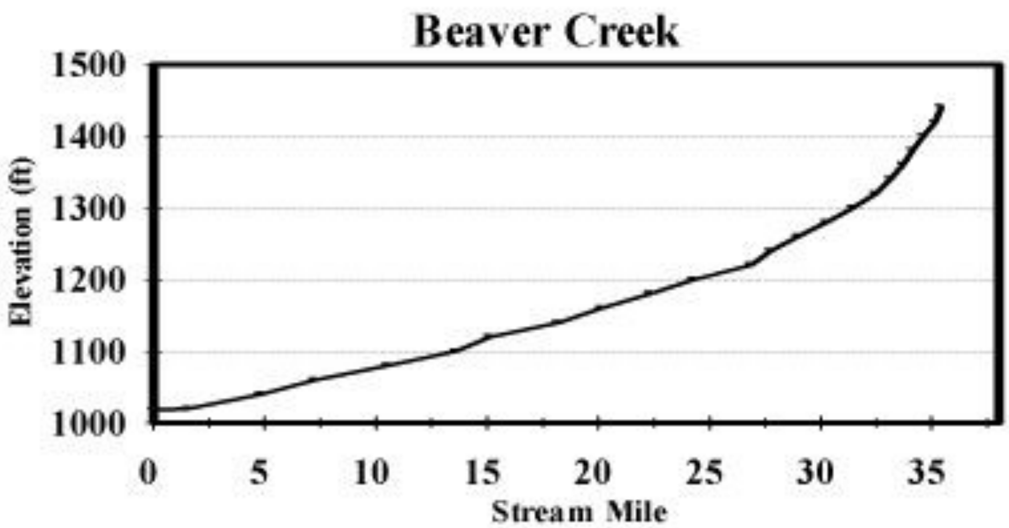
Stream order was determined using a system of classification that was first defined by Horton (1945) and later modified by A. N. Strahler (1952). Strahler called all unbranched tributaries first-order streams; two first-order streams join to make a second-order stream, and so on downstream to the stream mouth. MDC East Central Region Fisheries personnel determined stream gradient and stream order (Table 7) from United States Geological Survey (USGS) 1:24,000-scale topographic maps (Table 3) for all third-order and greater streams within the Lower Gasconade River watershed (HUC # 10290203) and all fourth-order and greater streams within the Upper Gasconade River watershed (HUC # 10290201).

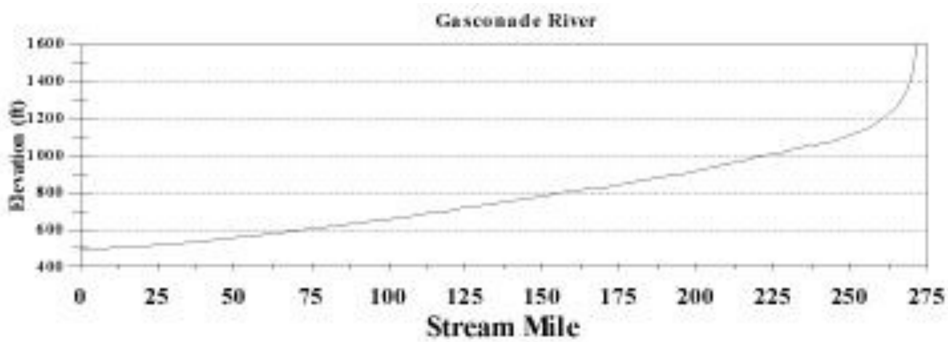
## Stream Gradient

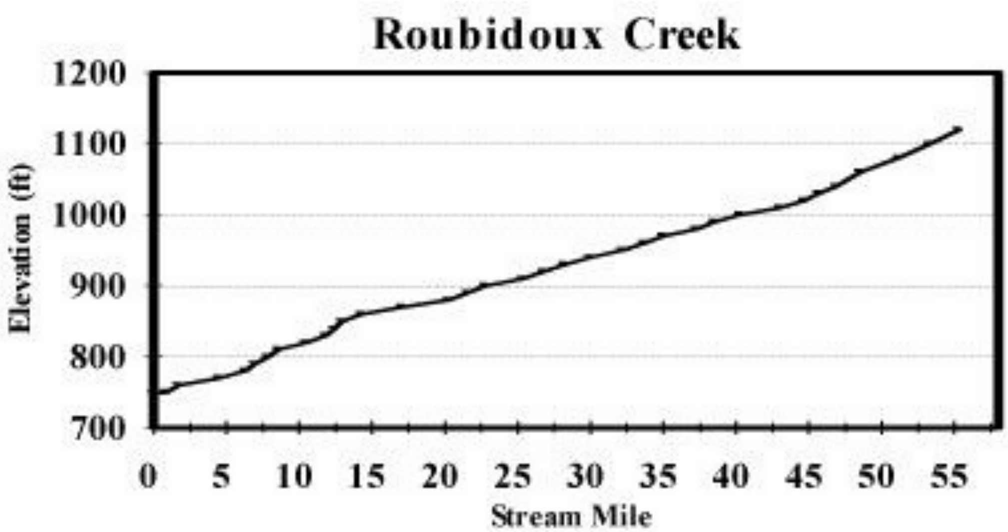
East Central Region Missouri Department of Conservation biologists collected elevation and distance data from USGS 7.5 minute topographic maps (usually 20-feet contours). Gradient by stream order and watershed were tabulated, measuring the vertical drop over a given distance for the number of streams that were fourth-order or greater. When comparing stream gradient between stream systems, the average value provides a useful means of summarizing this type of continuous data. Average gradient for the Upper Gasconade River watershed is 27.6 feet/mile, and the average gradient for the Lower Gasconade River watershed is 3.9 feet/mile. The last mile of the upper Gasconade River more than doubles in gradient from 101.1 feet/mile to 218.9 feet/mile. Little Piney Creek has an average gradient of 46.8 feet/mile. Roubidoux Creek has an average gradient of 6.9 feet/mile from its mouth to the confluence with the East Fork and West Fork Roubidoux Creek, which have average gradients of 60.1 and 58.1 feet/mile, respectively. The Osage Fork and Beaver Creek have gradients that average 25.7 and 20.1 feet/mile.
Gradient plots are useful for understanding channel steepness in relation to geology. The relief of the land influences drainage, runoff, and other factors such as erosion. The gradient of the river decreases downstream, so the overall profile is a hyperbolic curve that decreases in gradient downstream (Figure 3). Within a watershed, gradient plots for all fourth-order or greater streams were created. A plot of the entire Gasconade River and its major tributaries shows relatively moderate gradient (Figure 3).

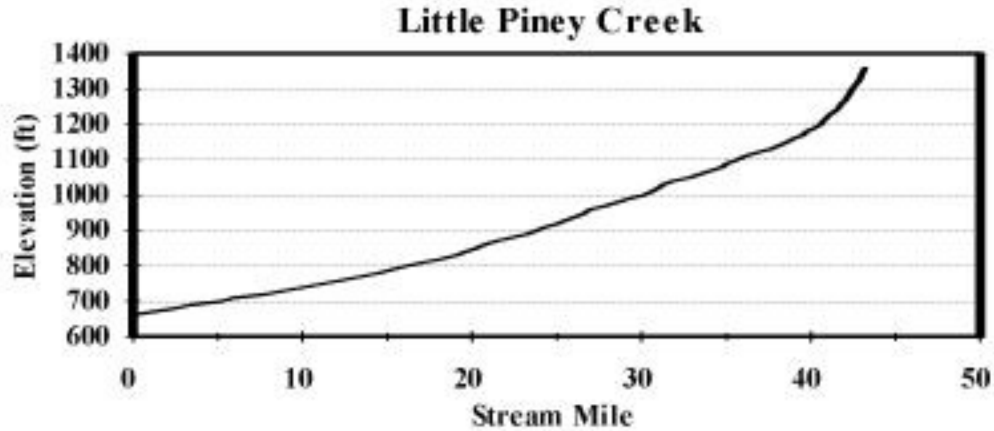
**Figure 2. Gasconade River Watershed soils map**

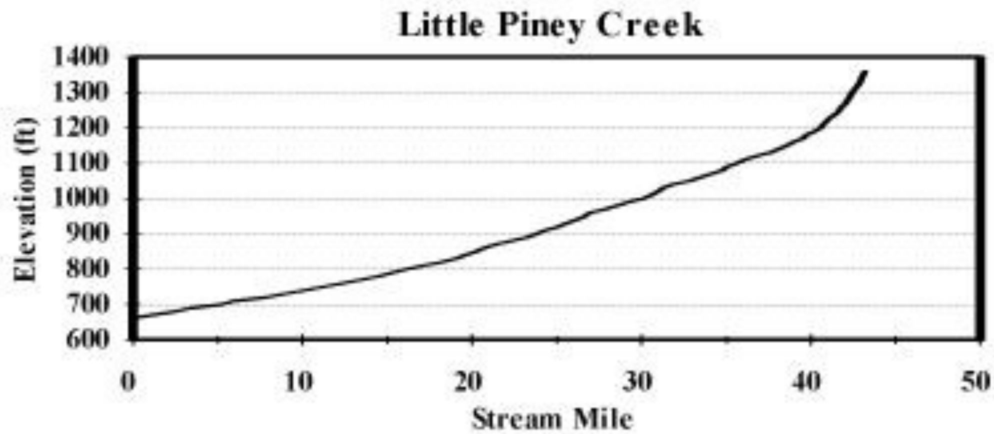



Beaver Creek
1500
1400
1300
1200
1100
1000
Elevation (ft)
0
5
10
15
20
25
30
35
Stream Mile


Gasconade River
1600
1400
1200
1000
800
600
400
Elevation (ft)
0
25
50
75
100
125
150
175
200
225
250
275
Stream Mile


Roubidoux Creek
1200
1100
1000
900
800
700
Elevation (ft)
0
5
10
15
20
25
30
35
40
45
50
55
Stream Mile




Gradient of selected tributaries to Gasconade River.

Table 1. Gasconade River watershed losing stream reaches sorted by county. Listed streams are over 5.0 miles in length. Compiled by the MDNR Division of Geology and Land Survey 1992.

| Stream Name | County | Length of Segment | Legal Start | Legal End |
|---|---|---|---|---|
| **Finn Creek** | Dent | 5.0 | SE NE NE 6 35N 7W | SW NW SE 4 35N 8W |
| **Horse Creek** | Dent | 5.0 | NE NE SW 32 35N 7W | SW SW NE 22 35N 8W |
| **Gasconade River** | Laclede | 33.7 | NW NW NE 11 35N 14W | SE SE NW 15 36N 12W |
| **Mill Creek** | Laclede | 4.0 | SW SW SW 9 34N 15W | SE NE SW 1 34N 15W |
| **North Cobb Creek** | Laclede | 7.3 | NE NW NE 18 34N 15W | NE SW NE 2 33N 15W |
| **Osage Fork** | Laclede | 6.0 | NE NW SW 7 32N 15W | NE NW NW 33 33N 15W |
| **Corn Creek** | Phelps | 12.5 | SW SE NE 2 34N 9W | NE NE SE 35 36N 9W |
| **Little Piney Creek** | Phelps | 12.0 | SE SW SE 6 34N 8W | SW NW SE 4 35N 8W |
| **Roubidoux Creek** | Pulaski | 16.0 | SW NW SW 3 34N 12W | NW NE SW 8 36N 12W |
| **Collie Hollow** | Pulaski | 8.2 | NW SE NE 24 35N 13W | SE NW SE 17 36N |
| **Smith Branch** | Pulaski | 9 | SW SE NE 8 34N 11W | NW SE SW 7 35N 11W |
| **Stiens Creek** | Wright | 8.8 | SW SW SW 22 31N 15W | NW NE NE 22 32N 15W |
| **Elk Creek** | Wright | 5.0 | SW NE NW 8 31N 14W | NW SE NE 26 32N 14W |

Table 2. Drainage area of major watersheds, Gasconade River watershed, Missouri (Watersheds in Missouri, USDA, NRCS, 1990). The hydrologic unit (HU) code - 10290201 and 10290203 - is the prefix to the 11-digit HU (USGS, NRCS) code.

| USGS Code | Watershed | Max. Order | Area (acres) | Area (sq. mi) | % of watershed |
|---|---|---|---|---|---|
| **01-010** | Upper Gasconade River | 5 | 232,320 | 362.8 | 12.9 |
| **01-020** | Beaver Creek | 5 | 85,120 | 132.9 | 4.7 |
| **01-030** | Upper Osage Fork | 5 | 214,960 | 335.7 | 12.0 |
| **01-040** | Lower Osage Fork | 5 | 109,440 | 170.9 | 6.1 |
| **01-050** | Upper Gasconade River Tributaries | 6 | 150,400 | 234.9 | 8.4 |
| **01-060** | Roubidoux River | 5 | 181,220 | 283.1 | 10.1 |
| **01-070** | Middle Gasconade River | 6 | 155,520 | 242.9 | 8.7 |
| **03-010** | Little Piney Creek | 5 | 190,720 | 297.9 | 10.6 |
| **03-020** | Lower Gasconade River | 7 | 221,430 | 345.9 | 12.3 |
| **03-030** | Third Creek | 5 | 64,910 | 101.4 | 3.6 |
| **03-040** | Lower Gasconade River Hills | 7 | 191,090 | 298.5 | 10.6 |
| **Total Gasconade River watershed** | | | 1,797,130 | 2806.9 | |

Table 3. Gasconade River watershed (except Big Piney River) streams and the corresponding topographic maps that each stream flows through.

| Stream Name | Topo Map |
|---|---|
| **Gasconade River** | Gasconade, Morrison, Fredericksburg, Pershing, Goerlisch Ridge, Cooper Hill, Linn, Summerfield, Paydown, Vienna, Nagogami Lodge, Newburg and Dixon |
| **HUC1 # 10290203-040** | |
| **First Cr.** | Gasconade, Pershing, Swiss |
| **-Brushy Fr.** | Gasconade, Pershing |
| **-Unnamed Cr.** | Gasconade, Pershing, Swiss, Hermann |
| **—Unnamed Cr.** | Swiss |
| **Unnamed Cr.** | Fredericksburg |
| **Richland Cr.** | Fredericksburg, Pershing |
| **Unnamed Cr.** | Pershing |
| **Second Cr.** | Pershing, Goerlisch Ridge, Rosebud |
| **-Puncheon Cr.** | Pershing, Swiss |
| **—Unnamed Cr.** | Pershing, Swiss |
| **-Schulte Cr.** | Goerlisch Ridge, Rosebud |
| **Unnamed Cr.** | Fredericksburg |
| **Pin Oak Cr.** | Cooper Hill, Goerlisch Ridge |
| **Hope Cr.** | Fredericksburg |
| **Unnamed Cr.** | Fredericksburg |
| **Contrary Cr.** | Cooper Hill, Fredericksburg, Luystown |
| **Deer Slough** | Cooper Hill, Linn |
| **Pointers Cr.** | Cooper Hill, Linn |
| **-North Fork** | Linn |
| **Owens Cr.** | Cooper Hill, Linn |
| **Indian Cr.** | Linn, Summerfield |
| **Swan Cr.** | Linn, Westphalia East |
| **-Lake Ditch** | Linn, Westphalia East |
| **—Graveyard Br.** | Linn, Westphalia East |
| **HUC # 10290203-030** | |
| **Third Cr.** | Cooper Hill, Goelisch Ridge, Rosebud, Owensville East |
| **-Little Third Cr.** | Cooper Hill, Belle |
| **-Crider Cr.** | Cooper Hill, Belle |
| **—Old Bland Cr.** | Belle, Owensville West |
| **—Unnamed Cr.** | Belle |
| **-Hunke Cr.** | Goerlisch Ridge |
| **-Cedar Branch** | Goerlisch Ridge, Owensville West, Owensville East |
| **—Unnamed Cr.** | Goerlisch Ridge, Owensville West |
| **-Brushy Branch** | Goerlisch Ridge, Rosebud |
| **-Unnamed Cr.** | Goerlisch Ridge, Rosebud |

| Stream Name | Topo Map |
|---|---|
| **Mistaken Cr.** | Cooper Hill, Belle, Summerfield |
| **HUC # 10290203-020** | |
| **Brush Cr.** | Linn, Westphalia East |
| **-Unnamed Cr.** | Linn, Summerfield, Freeburg |
| **-Buchler Cr.** | Westphalia East, Freeburg |
| **—Bexten Br.** | Westphalia East |
| **Unnamed Cr.** | Summerfield |
| **Buck Elk Cr.** | Summerfield, Belle |
| **Reichel Cr.** | Summerfield, Freeburg |
| **Unnamed Cr. (Steuber Hol.)** | Summerfield, Freeburg |
| **Whalen Cr.** | Summerfield, Freeburg |
| **Unnamed Cr.** | Summerfield, Paydown |
| **Hatchee Cr.** | Summerfield, Belle |
| **Mill Cr.** | Paydown |
| **-Unnamed Cr.** | Paydown |
| **Long Cr.** | Paydown |
| **Boardman Cr.** | Paydown, Vienna, Freeburg |
| **Crumb Cr.** | Vienna |
| **Indian Cr.** | Vienna |
| **Irish Cr.** | Vienna |
| **Cedar Cr.** | Paydown |
| **Spring Cr.** | Vienna, Paydown, Vichy, Rolla, Dillon |
| **-Little Spring Cr.** | Vichy, Paydown |
| **-Rocky Br.** | Vichy |
| **-Mill Cr.** | Vichy |
| **-Unnamed Cr.** | Vichy |
| **-Unnamed Cr.** | Vichy, Rolla |
| **Jim Cr.** | Vienna, Nagogami Lodge |
| **Sweetwater Cr.** | Nagogami Lodge |
| **Dry Cr.** | Nagogami Lodge, Big Bend |
| **-Montague Cr.** | Nagogami Lodge, Big Bend |
| **-Doyle Cr.** | Nagogami Lodge |
| **-Unnamed Cr.** | Nagogami Lodge, Big Bend |
| **Gaines Ford Br.** | Nagogami Lodge, Vichy |
| **Unnamed Cr. (Bloom Hol.)** | Nagogami Lodge, Vichy |
| **Camp Cr.** | Nagogami Lodge, Vichy, Rolla |
| **-Mill Cr.** | Nagogami Lodge, Newburg, Rolla |
| **Tick Cr.** | Nagogami Lodge, Newburg, Rolla |
| **Unnamed Cr. (Clifty Hol.)** | Nagogami Lodge, Big Bend |
| **-Little Clifty Cr.** | Nagogami Lodge, Big Bend |
| **-Unnamed Cr.** | Big Bend |
| **Duncan Cr.** | Newburg, Dixon, Big Bend |
| **-Unnamed Cr. (Dobbs Hol.)** | Newburg, Nagogami Lodge, Big Bend |
| **Mill Cr.** | Dixon |

| Stream Name | Topo Map |
|---|---|
| **HUC # 10290203-010** | |
| **Little Piney Cr.** | Newburg, Rolla, Kaintuck Hollow, Yancy Mills, Edgar Springs, Maples |
| **-Unnamed Cr. (Tater Hol.-Smith Hol.)** | Newburg, Dixon, Devil’s Elbow |
| **-Mill Cr.** | Newburg, Kaintuck Hollow, Flat |
| **—Unnamed Cr. (Kaintuck Hol.)** | Kaintuck Hollow |
| **—Unnamed Cr. (Hardester Hol.)** | Kaintuck Hollow, Devil’s Elbow |
| **—Unnamed Cr. (Deep Hol.)** | Kaintuck Hollow |
| **-Unnamed Cr.** | Newburg |
| **-Beaver Cr.** | Rolla, Yancy Mills |
| **—Little Beaver Cr.** | Rolla |
| **—Iron Ore Cr.** | Rolla, Yancy Mills |
| **-Corn Cr.** | Yancy Mills, Kaintuck Hollow, Flat, Edgar Springs |
| **-Kitchens Br.** | Yancy Mills, Edgar Springs |
| **-Finn Br.** | Yancy Mills, Lecoma |
| **-Horse Cr.** | Edgar Springs, Anutt |
| **—Bean Cr.** | Edgar Springs, Anutt |
| **—Unnamed Cr.** | Edgar Springs, Anutt |
| **-Jackson Br.** | Edgar Springs |
| **-Black Oak Cr.** | Edgar Springs |
| **-Everywhere Br.** | Edgar Springs |
| **-Sample Cr.** | Edgar Springs, Maples |
| **-Unnamed Cr.** | Maples |
| **-Unnamed Cr.** | Maples |
| **-Unnamed Cr.** | Maples |
| **Unnamed Cr. (Prewett Hol.)** | Dixon |
| **HUC # 10290201-060** | |
| **Roubidoux Creek** | Waynesville, Bloodland |
| **-unnamed, trib. to Roubidoux., Sec.24** | Waynesville |
| **-unnamed, trib. to Roubidoux, Sec. 24** | Waynesville |
| **—unnamed, trib. to unnamed, Sec. 35** | Waynesville |
| **-Burchard Hollow** | Waynesville |
| **-Ballard Hollow** | Waynesville |
| **-Smith Hollow** | Waynesville, Bloodland |
| **—unnamed cr., trib. to Smith Hollow, Sec 32** | Bloodland |
| **-York Hollow** | Waynesville, Ozarks Springs |
| **-Elliot Hollow** | Bloodland, Brownfield |
| **-Killman Hollow** | Bloodland |
| **-Hurd Hollow** | Bloodland |
| **-unnamed cr., trib. to Roubidoux, Sec. 3** | Bloodland, Brownfield |

| Stream Name | Topo Map |
|---|---|
| **-unnamed cr., trib. to Roubidoux, Sec. 14** | Bloodland, Roby |
| **-Muskgrave Hollow** | Bloodland, Roby |
| **—unnamed cr., trib. to Muskgrave Hollow** | Bloodland, Roby |
| **-unnamed cr., trib. to Roubidoux Cr.** | Roby |
| **-Rock Creek** | Roby, Roubidoux |
| **—Baker Branch** | Roby |
| **—unnamed cr., trib. to Rock** | Roby |
| **—unnamed cr., trib. to Rock** | Roby |
| **-Prairie Creek** | Roby, Winnipeg, Manes |
| **-unnamed Cr., trib. to Roubidoux** | Roby |
| **-Dolittle Creek** | Roby, Roubidoux, Winnipeg |
| **-Mill Creek** | Roubidoux, Manes |
| **-Coghill Hollow** | Roubidoux |
| **-Burkhart Branch** | Roubidoux |
| **-Wolf Branch** | Roubidoux |
| **West Fork Roubidoux Creek** | Roubidoux, Huggins |
| **-unnamed cr., trib. to W. Fork Roubidoux Cr.** | Roubidoux, Huggins |
| **-unnamed cr., trib. to W. Fork Roubidoux Cr.** | Roubidoux, Huggins |
| **East Fork Roubidoux Creek** | Roubidoux, Success, Bucyrus |
| **-Carr Branch** | Roubidoux, Success |
| **-unnamed cr., trib. to E. Fork Roubidoux Cr.** | Success |
| **HUC # 10290201-070** | |
| **Weeks Creek** | Devil's Elbow |
| **Jones Creek** | Dixon, Hancock |
| **Clemens Creek** | Hancock |
| **Bell Creek** | Hancock |
| **-Sewell Creek** | Hancock |
| **-Middle Creek** | Hancock |
| **unnamed, trib. to Gasco. R., Sec. 5** | Hancock |
| **Grills Hollow** | Waynesville |
| **Sawmill Creek** | Waynesville |
| **Tower Hollow** | Waynesville |
| **Collie Hollow** | Ozarks Springs, Brownfield |
| **-unnamed cr., trib. to Collie Hollow** | Ozarks Springs |
| **Crumley Br.** | Crocker |
| **Snake Creek** | Ozark Springs, Crocker |
| **unnamed cr., trib. to Gasco. R., Sec. 35** | Ozark Springs |
| **Laquey Hollow** | Ozark Springs, Brownfield |
| **-unnamed cr., trib. to Laquey Hollow** | Ozark Springs, Richland |

| Stream Name | Topo Map |
| --- | --- |
| **-unnamed cr., trib. to Laquery Hollow** | Ozark Springs |
| **-unnamed cr., trib. to Laquery Hollow** | Ozark Springs |
| **unnamed cr., trib. to Gasco. R., Sec. 14** | Waynesville |
| **Duck Creek** | Richland |
| **Bear Creek** | Stoutland, Richland, Oakland |
| **-Sandy Creek** | Richland, Stoutland |
| **-unnamed cr., trib. to Bear Cr.** | Stoutland, Oakland |
| **-Spud Hollow** | Stoutland, Oakland |
| **unnamed cr., trib. to Gasco. R., Sec. 16** | Richland |
| **HUC # 10290201-050** | |
| **Prairie Creek** | Drynob, Brownfield |
| **Bell Branch** | Drynob, Brownfield |
| **Core Creek** | Drynob, Brownfield |
| **unnamed cr., trib. to Gasco. R., Sec 1** | Brownfield |
| **unnamed cr., trib. to Gasco. R., Sec 1** | Brownfield |
| **Cantrel Hollow** | Brownfield |
| **unnamed cr., trib. to Gasco. R., Sec 14** | Brownfield |
| **unnamed cr., trib. to Gasco. R., Sec 22** | Brownfield |
| **Nelson Creek** | Brownfield, Winnipeg |
| **-unnamed cr., trib. to Nelson Br., Sec. 30** | Winnipeg |
| **unnamed cr., trib. to Gasco. R., Sec. 34** | Winnipeg, Drew |
| **Kuhn Creek** | Winnipeg |
| **Mill Creek** | Winnipeg |
| **-unnamed cr., trib. to Mill Ck., Sec. 24** | Winnipeg |
| **Big Sleepy Hollow** | Winnipeg, Drew |
| **Burnt Cabin Hollow** | Winnipeg, Drew |
| **Pine Creek** | Winnipeg, Manes |
| **Norris Creek** | Winnipeg, Manes |
| **unnamed cr., trib. to Gasco. R., Sec. 30** | Drew |
| **Elk Creek** | Competition, Fuson |
| **-unnamed cr., trib. to Elk Cr., Sec. 25** | Competition |
| **-unnamed cr., trib. to Gasco. R., Sec. 8** | Competition, Grovespring |
| **-Scotts Branch** | Competition, Grovespring, Hartville |
| **unnamed cr., trib. to Gasco. R., Sec. 6** | Drew |
| **unnamed cr., trib. to Gasco. R., Sec. 7** | Competition, Manes |
| **Crooked Creek** | Fuson, Hartville |
| **Dry Creek** | Fuson, Dawson |
| **Greene Hollow** | Fuson, Dawson |
| **Garner Hollow** | Fuson |
| **HUC # 10290201-040** | |
| **Osage Fork, trib. to Gasco. R.** | Drynob, Oakland, Drew, Russ, Grovespring |
| **-Murrel Hollow** | Drynob |
| **-Similin Creek** | Drynob |

| Stream Name | Topo Map |
| --- | --- |
| **-Mill Creek** | Drynob, Oakland |
| **—unnamed cr., trib. to Mill Cr., Sec. 1** | Oakland |
| **—unnamed cr., trib. to Mill Cr., Sec. 1** | Oakland |
| **—Morgan Hollow** | Oakland |
| **—Abbott Hollow** | Oakland |
| **-North Cobb Creek** | Drynob, Drew, Russ, Brush Creek, Oakland, Lebanon |
| **—Bee Branch** | Oakland, Drew, Russ |
| **—unnamed cr., trib. to N. Cobb Cr., Sec 34** | Russ |
| **—unnamed cr., trib. to N. Cobb Cr., Sec 27** | Russ, Oakland |
| **—South Fork North Cobb Creek** | Oakland, Russ, Brush Creek |
| **—unnamed cr., trib. to N. Cobb Cr., Sec 30** | Oakland, Lebanon |
| **-Core Creek** | Drynob, Drew |
| **-Walker Hollow** | Drynob, Drew |
| **-Little Cobb Creek** | Drew |
| **-Cobb Creek** | Drew, Grovespring |
| **HUC # 10290201-030** | |
| **-Stein Creek** | Russ, Grovespring, Hartville |
| **—Barn River** | Russ, Grovespring |
| **—unnamed cr., trib. to Stein Cr., Sec 22** | Grovespring, Hartville |
| **-Sharpe Hollow** | Russ |
| **-Brush Creek** | Russ, Brush Creek |
| **—Hyde Creek** | Rader, Duncan, Hartville |
| **—unnamed cr., trib. to Cantell Cr., Sec. 18** | Duncan, High Prairie |
| **—Wildcat Hollow** | Brush Creek |
| **—unnamed cr., trib. to Brush Cr., Sec. 26** | Brush Creek |
| **—Selvage Creek** | Brush Creek |
| **-unnamed cr., trib. to Brush Cr., Sec 32** | Brush Creek |
| **-unnamed cr., trib. to Osage Fk., Sec. 6** | Russ, Brush Creek |
| **-Parks Creek** | Russ, Grovespring, Rader, Hartville |
| **—Rocky Hollow** | Rader |
| **—Buttrom Creek** | Grovespring, Rader, Duncan |
| **—unnamed cr., trib. to Brush Cr., Sec. 30** | Grovespring, Rader, Duncan |
| **-unnamed cr., trib. to Osage Cr., Sec. 15** | Rader, Lebanon |
| **-Panther Creek** | Rader, Niangua |
| **—Salem Springs Creek** | Niangua, Phillipsburg |

| Stream Name | Topo Map |
|---|---|
| **—-unn'd cr., trib. to Salem Springs Cr., Sec. 11** | Phillipsburg |
| **-Myers Branch** | Rader |
| **-Little Bowen Creek** | Niangua |
| **-Bowen Creek** | Niangua |
| **-Cantell Creek** | Niangua, Rader, Duncan, Mansfield NW |
| **-Hannah Creek** | High Prairie, Mansfield |
| **-unnamed cr., trib. to Osage Cr., Sec. 17** | High Prairie |
| **HUC # 10290201-020** | |
| **Beaver Creek** | Competition, Manes, Dawson, Mountain Grove North, Cabool |
| **-Moore Hollow** | Manes |
| **-Flanery Branch** | Manes |
| **-unnamed cr., trib. to Beaver Cr., Sec 24** | Manes |
| **-Hattie Hollow** | Dawson |
| **-North Fork Beaver Creek** | Dawson, Huggins |
| **—Sycamore Creek** | Dawson, Huggins |
| **-Williams Branch** | Mountain Grove North, Cabool NW |
| **-Hillhouse Hollow** | Competition, Fuson |
| **HUC # 10290201-010** | |
| **Whetstone Creek** | Fuson, Owens, Mountain Grove North, Mountain Grove South |
| **-Dove Creek** | Fuson, Dawson, Mountain Grove North |
| **—Prairie Hollow** | Dawson |
| **-unnamed cr., trib. to Whetstone Cr., Sec. 16** | Mountain Grove North |
| **-East Whetstone Creek** | Mountain Grove North |
| **—Drake Creek** | Mountain Grove North |
| **-unnamed cr., trib. to Whetstone Cr., Sec 28** | Mountain Grove North, Owens, Norwood |
| **Coon Creek** | Fuson, Hartville |
| **Clark Creek** | Fuson, Owens, Norwood |
| **-Carter Branch** | Owens |
| **-unnamed cr., trib. to Clark Cr., Sec. 25** | Owens |
| **Indian Creek** | Fuson, Hartville |
| **-Brush Creek** | Fuson, Hartville |
| **Evening Shade Branch** | Fuson, Owens |
| **Woods Fork** | Fuson, Hartville, Mansfield NE, Duncan, Mansfield NW |
| **-Prairie Branch** | Mansfield NE, Hartville |
| **-Little Creek** | Hartville |

| Stream Name | Topo Map |
|---|---|
| **-Bowman Creek** | Hartville, Duncan |
| **Campbell Branch** | Mansfield NE, Owens |
| **Quillen Branch** | Owens |
| **Gasconade River (Lick Fork)** | |
| **-Wolf Creek** | Mansfield NE, Mansfield |
| **—Long Hollow** | Mansfield NE, Owens |
| **—Spence Creek** | Mansfield NE, Mansfield |
| **—Fry Branch** | Mansfield NE, Mansfield, Norwood |
| **-Buck Hollow** | Mansfield NE, Mansfield NW |
| **-Baker Creek** | Mansfield NE, Mansfield NW, Cedar Gap |
| **-Rippee Hollow** | Mansfield NW |
| **—unnamed cr., trib. to Rippee Creek, Sec 4** | Mansfield NW |
| **-unnamed cr., trib. to Gasco. R. (Lick), Sec 27** | Mansfield NW |

[1]Hydrologic Unit Code

# Land Use

## Historical and Recent Land Use

### General

The earliest settlers to the general region were Native Americans. Within some portions of the watershed, the exact tribes were the Mound Builders (Goodspeed 1889). Mounds can be still found in Pulaski County. Other tribes that frequented the area on hunting excursions were Kickapoo, Osage, and Delaware.

Early American settlers to the upper watershed region migrated from Kentucky and Tennessee near 1834, although Texas County saw Americans as early as 1826 (Goodspeed 1889). Many of these early migrants were attracted to the abundant game (deer, elk, bear, and turkey). Once US lands in the region were proclaimed open for sale, immigration to the area increased in the 1840s. The St. Louis and San Francisco Rail Road increased settlement in 1870 and also brought further communication with Springfield and St. Louis.

Since this time, some streams have been adversely affected by land-use practices. Erosion, siltation, nutrient, and pesticide pollution are the result of Ozark practices such as forest clearing, uncontrolled burning, uncontrolled livestock grazing, poor farming, and unregulated gravel mining. 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.

### Population

Historical county population size in Gasconade, Laclede, Maries, Osage, Pulaski, Phelps, Texas, Webster, and Wright counties of the Gasconade River watershed took a sharp increase after the land sales of the 1840s. By the 1890s the populations of many Ozark counties of Missouri were quite large, reaching as high as 50,000 individuals within the general area, although only Texas County within the Gasconade River watershed exceeded 19,500 individuals at that time (Figure 4). Communities forged existence along the Gasconade River and its tributaries. In fact, the Gasconade County Seat was on the Gasconade River in several locations but was moved to Hermann after being swamped by the flooding river at each previous location (Ohunan 1983).

Recent county population size in the Gasconade River watershed was last estimated during the 1990 US Census (Figure 4). The most populated areas were Pulaski and Phelps counties, which constituted the middle portion of the watershed, containing all the major springs. The presence of the military base Fort Leonard Wood and a growing City of Rolla explained the comparatively larger population size in Pulaski and Phelps counties. The least populated areas were the lower watershed areas, represented by Maries, Osage, and Gasconade counties. Camden County was included in Figure 4 because it borders the watershed boundaries.

An analysis was done on the human population density of the 14-digit Hydrologic Unit (HU) (Figure 5). As demonstrated, the highest human density of any HU was the Roubidoux Creek HU #10290201-050, bolstered by the presence of Fort Leonard Wood Military Base. However, a summarized Missouri Department of Transportation's (MoDOT) lettered-highway dataset (other road types such as the county roads, Gasconade, Laclede, Maries, Osage, Pulaski, Phelps, Texas, Webster, and Wright, were not included in this summary and would add considerably to the totals) indicates that the road density and number of stream road crossing in the Roubidoux Creek were comparatively low. Population densities, road densities, and number of stream road crossings do not correlate. For example, the Lower Osage Creek HU and the Middle Gasconade River HU had human population densities ranging between 33.2 - 46.1 individuals per square mile. Interstate 44 travels through northern Pulaski County and northeastern Laclede County or the Lower Osage Creek and Middle Gasconade River HU, which explains the high road density values in Figure 5. Given the higher stream density (not represented) in the upper watershed, the number of stream road crossings is accurately represented. Stream disturbance and degradation is apparent in these watersheds (See subsections' Grazing and Natural Resource Conservation Service Projects).

Demographic trend information, Gasconade, Laclede, Maries, Osage, Pulaski, Phelps, Texas, Webster, and Wright, in each county within the watershed indicates moderate human population growth from 1990-97 and a potential increase in population outside incorporated areas, i.e., towns and cities. When increases in populations are one-half to two-thirds the incorporated populations increase, this trend may be substantial and could indicate population movement to rural areas. Since 1990 the rate of increase in open-country populations has been more rapid than in town populations (OESDA 1999).

## Farming

By the 1890s, a typical farm was a production mixture of beef, hogs, sheep, fruit, and other products. Farmers were producing a considerable amount of grain in the form of wheat and corn, mainly to feed their livestock.

From 1850 to the present, farm production of hogs, pigs, and sheep has dwindled, but the number of cattle on farms has increased steadily (MASS 1997). While crop agricultural industries have declined, the land has been converted to pasture to accommodate a growing beef industry. Milk cow production reached a peak in 1950-60s, but all counties in the Gasconade River watershed varied in declined rate from slightly to moderately in number of head with the exception of Wright and Webster counties, which have seen moderate increases.

In 1899, cropland used for the production of wheat, corn, and hay produced more bushels than in recent years (MASS 1997). At that time, wheat production ranged from 426,000 bushels in Gasconade County and to 57,000 bushels in Pulaski County. Cropland production of corn was highest in 1899 and 1909 within Laclede County (837,000 bushels) and lowest in Wright County (505,000 bushels). Unlike corn production, which was more affected by changes in yield per acre with the advent of fertilizer in the 1950s and overall consumer demand, as the cattle production rose, production of hay increased. Texas County, aptly named after the State of Texas with its high cattle production, harvested a whopping 131,500 tons of hay in 1996.

Fruit and tomato production had its day in the southern counties of the Gasconade River watershed. As early as the 1890s, Webster County, Missouri led the nation in the production of apples (SCS 1990). The apple industry shriveled in the 1930s as a result of economic factors. Blossoming in the 1930s, the production of tomatoes for the canning industry became an important part of the rural economy. Several large-scale tomato canning factories reduced production due to 1) a poor market, 2) competition with a growing dairy industry, and 3) the added expense of meeting stricter government regulations (SCS 1990).

Cropland yields per acre have substantially increased since the 1950s when the petroleum industry introduced fertilizers. County use of fertilizer on cropland increased 50 to 85% from the 1950s. One side effect of fertilizer application is the nutrient enrichment of streams from cropland runoff. Today, conservation management practices help reduce dependence on chemical fertilizers. Several counties, Gasconade, Laclede, Maries, Osage, Pulaski, Phelps, Texas, Webster, and Wright, within the MDC East Central Region and the Gasconade River watershed have improved farmland though the use of conservation practices. Precision agriculture and use of remote sensing have helped maintain good yields and lessen the soil erosion and nonpoint source pollutants.

| Herbicide | Chemical family | Mechanism of action |
|---|---|---|
| Atrazine | triazine | Photosynthetic inhibitor |
| Cyanazine | triazine | Photosynthetic inhibitor |
| Metribuzin | triazine | Photosynthetic inhibitor |
| Simazine | triazine | Photosynthetic inhibitor |
| Alachlor | chloroacetamide | Growth inhibitor |

Herbicides, like Atrazine, enter surface water by runoff or through atmospheric deposition or groundwater. Atrazine, Cyanzine, Metribuzin, and Simazine are herbicides in the triazines chemical (see below) and are applied only by certified applicators.

In groundwater tests for herbicides Atrazine, Tebuuthiuron, and p,p'-DDE by USGS indicate that there are detectable amounts of these herbicides in the Fort Leonard Wood portion of the Big Piney River watershed and no detectable amounts in the Roubidoux Creek watershed (Imes et al. 1996). The USGS/Missouri Department of Natural Resources Fixed Station Co-op Monitoring Program found at Jerome 0.0 ug/l, 0.0 ug/l, and 0.02 ug/l of Atrazine in November 1992, April 1994, and June 1996, respectively. Also, tested at the same time and location with no detectable quantities were the herbicides' Cyanazine, Metribuzin, Alachlor, or Simazine. As part of the Ozark NAWQA Study, Woods Fork was tested at Hartville in 1994 and 1995 for Atrazine, Alachlor, Cyanzine, Metribuzin, and Simazine (USGS 1994-95).

The State of Missouri Unified Watershed Assessment Final Report identified the Upper Gasconade watershed as having high total animal unit density.

## Grazing

Demand for additional livestock forage generated more land clearing for pasture. Cropland acres expansion, riparian area clearing, and increased pressure on pasture land from cattle grazing, induced greater releases of gravel into streams. Missouri livestock production (livestock numbers) has grown to a rank of number 2 in the nation (MASS 1997).

Jacobson and Primm (1994) demonstrated a trend in the rural Ozarks toward increased populations of cattle and increased grazing density. Increased grazing density translates into greater populations of cattle per unit area. Within the Gasconade River watershed, the number of cattle per pastured acre shows a general climb from census year 1920-1992 (Figure 6). This trend has the potential to precipitate stream-channel disturbance from increased runoff and sediment supply. Nearly all counties have higher numbers of cattle per acre during the 1940s than during any census year. Also, from 1960-92, populations of cattle have increased yet total improved land in farms has decreased. In fact, by the 1960s livestock open range grazing was essentially halted, allowing landowners to improve grazing management and reduce woodland pasturing as demonstrated by a reduction in total acres in woodland pasture (MASS 1997).

Nationwide, Missouri is the second to Texas in production of cattle with 4.45 million head produced in 1997 (MASS 1997). For counties within the Gasconade River watershed, cattle numbers per pastured acre have steadily increased from the 1920s where counties were between 0.25-0.5 cattle per acre (Figure 6). Today, cattle numbers per acre are roughly 0.6-0.8 in most of these counties. Those counties with the highest density and good cattle growing conditions are Webster, Maries, and Wright. Good cattle growing conditions can be attributed to appropriate soil types for growing pasture grasses and summers and winters that are not too harsh.

Cattle watering in Missouri is frequently accomplished using a stream or pond. In fact, a state standard designated use of many permanent streams is livestock watering. However, if cattle stocking rates along a riparian stream corridor are too high, the stream could develop poor pool areas, wide and shallow channels, and more sediment and gravel in the channel. Help could come in the form of fencing cattle from the stream.

For example, a segment of a 3rd-order unnamed tributary to the Gasconade River within the Lower Gasconade River watershed developed the above mentioned symptoms of cattle overgrazing: poor pool areas, wide and shallow channel, poor riparian corridor, and gravel choking the channel. This tributary (Osage County (T44N R7W S24) received several different treatments to heal an eroded streambank on a farmer's land (Table 19; Habitat Section). In 1994, a cedar tree revetment was used to stabilize the streambank. Cattle were subsequently fenced out of the stream, and willow stakes were placed on the streambank (Rob Pullium, personal communication). Today, the streambank is healing with willows more than six feet tall, and the stream has scour pools that support fish.

Alternative (off-stream) watering sources offer an alternative to stream cattle watering. The Alternative Watering Sources for Planned Grazing Systems is designed to provide funds for stream-side landowners who are implementing a planned grazing system practice with the Soil and Water Conservation Program. Researchers in Virginia have found that alternative watering sources, such as spring-fed watering troughs, are utilized 93% of the time, as compared to the time spent drinking from a stream (Sheffield et al. 1996). Use of the stream area by cattle was reduced by 58% when an off-stream water source was made available. Associated benefits from the reduced stream use were the reduction in streambank erosion and fecal bacteria.

## Mining

Zinc and lead were discovered in the southern portions of Texas, Webster, and Wright counties in the mid-1800s (Goodspeed 1889). Mining activity was well underway by the 1880s in the Berry Diggings (Section 1, Township 28, Range 16), Lead Hill Zinc Mines (Section 25, Township 28, Range 16), Panther Creek Mines, and Cabool Mining Company (1887). The Berry Diggings became the Ozark Mining Company in May 1885, following which several family farms were purchased: the Berry farm, Baker farm, and McMullen farm. This general area is in the vicinity of the Baker Creek watershed, a tributary to Rippee Creek. A zinc blend, disseminated with some flint and siliceous lime-rock and a little galena, distinguished the deposit. Large quantities of lead were taken from the Panther Creek Mines.

Finally, the Cabool Mining Company removed zinc from headwaters of the Gasconade River watershed.

The Missouri Department of Natural Resource's (MDNR) Inventory of Mine Occurrences and Prospects (IMOP) Database lists past producers of zinc, iron, lead, clay, and limestone (MDNR 1999b). Many of these ores were extracted from the surface with manual labor. Extracting both zinc and lead, the Brunet Diggings and the Lead Hill Diggings were found in the Roubidoux Creek watershed. Not heavily mined, zinc was extracted by one past producer within the Upper

Osage Creek and five past producers of zinc within the Upper Gasconade River Tributaries HU. Lead was heavily sought after in Wright County and within the Upper Gasconade River Tributaries HU. The ore was mainly extracted from the surface but of the 20 sites found in the watershed three sites were underground, the deepest being 70 feet. Its effects on the groundwater and surface water are unknown. As mentioned above, iron has been mined since the mid-1800s. The most heavily mined watersheds were the Lower Gasconade River HU and the Little Piney Creek HU. Both the Childress Mine and the Licking Mine were underground extraction sites. Past clay and limestone pits are peppered throughout the entire watershed, in particular the Lower Gasconade River HU, the Lower Gasconade River Hills HU, and the Third Creek HU. Present mining activity is not as pronounced in the Gasconade River watershed. In this watershed prospected ores were iron, lead, zinc, bituminous coal, clay, and limestone (MDNR 1999a). Some developed deposits of iron ore can be found in the Little Piney Creek HU, but none of these are actively mined. The present effects of the past mining sites on the stream ecosystem are not known. Some of these iron ore and lead extraction sites are rather small in acreage.

While often having a more pronounced effect on the landscape, many of the past clay and limestone pits are still visible on the landscape. The only active clay mine in the watershed is in the lower Gasconade River. Boethemeyer Clay Mine discharges to a tributary of Second Creek (MDNR 1997). The remaining surface mining sites in the watershed are limestone extraction. These sites are scattered throughout the watershed, but the largest concentration can be found in the lower watershed. The upper watershed areas have three limestone quarries, totaling 69 acres (MDNR 1999a).

### Sand and Gravel Operations

In the Sand and Gravel Resources of Missouri (1918), Dake describes "Second Sandstone" rock outcrops found near Whetstone, Clark, Lick Fork, Elk, and Beaver creeks. Some of the rock was found near the St. Louis and San Francisco Railroad crossing and past quarried bluffs in the vicinity of Mansfield, Missouri. Other sandstone deposits were reported along the Gasconade River, Mill and Bear creeks, but were of little commercial value.

Dake (1918) reports that the most important source of sand and gravel for construction was from Missouri streams. Ozark streams during 1913 produced approximately 20% of the State's sand and gravel. The Gasconade River watershed was not a major producer of sand and gravel as the Meramec River, although the Little Piney River had operations in Phelps County. Freeman, J. H. and the Pillman Bros. mined several gravel and sand bars derived from the Roubidoux Sandstone Formation. The limited market for this region, chiefly St. James and Springfield at that time, reduced the operations within this watershed.

Prior to 1991 sand and gravel mining was generally unregulated. In 1991, legislation gave regulatory authority to governmental agencies to require that sand and gravel miners follow stream channel mining guidelines of gravel bars and floodplains. The Army Corps of Engineers (COE) and the Missouri Department of Natural Resources (MDNR) issue permits for the mining of stream sand and gravel.

During portions of the 1990s, the COE has been involved in sand and gravel mining in areas that were not navigable waters of the US because of a federal court ruling known as the Tullock Rule. In general, the Tullock Rule stated that incidental dripping or "fall back" from the sand and gravel dragline bucket constituted a discharge, which required a GP-34M 404 permit for sand and gravel mining that is below the stream's water line. This means that pre-Tullock and post-Tullock laws allowed mining within flowing water or below the stream's water line. This rule was subsequently over-turned by the US Supreme Court in COE vs The American Mining Association.

For instream operations, mining permits contain a Stream Protection Plan as required by the Permit and Performance Requirements for Industrial Mineral Open Pit and In-Stream Sand and Gravel Operations, Chapter 10 Code of State Regulations 40-10.020 (2)(D)3 (MDNR 1994c). The basic language of the regulation, outlined in Chapter 10 Code of State Regulations 40-10.020 (2)(D)4, requires the operator to describe "measures that will be taken to minimize impacts on the stream environment..... confining active mining to gravel bars rather than in flowing water, and restricting damage to stream banks or bank vegetation....."(MDNR 1994c). Enforcing the Stream Protection Plan requires proving that an action taken by an instream sand and gravel operator has violated his Stream Protection Plan and that such a violation will incur a reclamation liability such as streambank damage due to head cutting.

Present regulations may not adequately protect stream resources and thwart losses of fisheries productivity, biodiversity, recreational potential, streamside land, public infrastructure (roads, bridges, and utilities), and real estate value (Roell 1999). A prescription for stream gravel mining should be developed to continue a viable sand and gravel extraction industry. The Army Corps of Engineers and the Missouri government recognize the economic benefits of sand and gravel extraction; nevertheless, the need for alternatives that would lower risks of upstream headcutting, sedimentation, and environmental effects of operational conditions such as release of petroleum products and species of conservation concern is important (Roell 1999).

Sand and gravel operations remain a presence in both the upper and lower 8-digit watersheds, especially prevalent in the lower watershed. Since the initiation of the East Central Region Stream Environmental Review Database in 1996, Missouri Department of Conservation has tracked 90 sand and gravel extraction permitted sites in the Lower Gasconade watershed (MDC 1999), many of which are alternatively active and inactive as mining depletes the mineral resources and the occasional high flows replenish them. Sand and gravel mining appears to be new to the upper watershed, however, given the low number of permitted operators per watershed area and the few historic observations of sand and gravel mining (COE 1999, MDNR 1999).

Using the Army Corps of Engineer’s Regulatory Analysis Management System database, which encompasses the entire watershed, we found a range of 1-25 permits per HU and a mean of 11.6 ±7.8 permits per HU (COE 1999). A density of sand and gravel site permits for 11-digit HUs was determined for the period of February 1992 - February 1999 (Figure 7). The 8-digit Lower Gasconade River watershed with its more than 500,000 acres of land had high densities of permits ranging from 0.05-0.075 permits/square mile. Lower densities of permitted sand and gravel sites ranging from 0.008-0.075 permits/square mile were found in the 8-digit Upper Gasconade River watershed with its more than one million acres. Beaver Creek HU was heavily mined for its relatively small size.

## Logging

Forests in the area have been burned, grazed, and over harvested. Pre-settlement vegetation was diverse and consisted of oak-hickory woodlands, scattered prairie grasslands on gently rolling uplands, bottomland hardwoods on most alluvial plains, oak savanna and barrens on upland sites, and oak-pine forests (East Central RCT 1998). Particularly damaging to stream water quality, logging has impacted bottomland forests and old-growth forests. Unlike today, forest practices in the past did not respect small order stream riparian zones. Steep topography and poor soils creates slow regeneration, thus explaining the present condition of the forests in the watershed.

In order to improve the quality of wood products in Missouri, Missouri Department of Conservation began fire suppression in the 1940s (East Central RCT 1998). The end result was fewer wildfires and improved quality and quantity of wood products.

As early as the mid-1800s forests in the Gasconade River valley were being harvested. In fact, in 1889 Goodspeed reported that the lumber trade was a booming industry in Texas County. Once the forests were cleared and roads were built, the period of commodity transport on the Big Piney and the Gasconade rivers came to an end in the late 1920s. Before significant road construction, railroad ties were floated to railroad crossings or yards then shipped to mills where the final products were produced. Concern over the effects of tie transport on stream fish populations led to state regulations near the turn of the century. Still earlier, the T. J. Moss Tie Company began delaying their tie drives on the Black River until June 1 to reduce impacts on the spawning fish populations (MDC 1995).

The forests in Missouri are in good health. Missouri’s Eastern Ozarks, with 67% of the State's forest land, offers a wide variety of the major forest types: Black-scarlet oak, white oak, post-blackjack oak, and maple-beech (USDA Forest Service 1999). Forest products produced annually exceed $3.3 billion. There are more than 2,600 forest product-related firms employing more than 33,000 people with a total payroll of about $500 million per year. In 1994, 709 million board feet were cut, 90% of the total was oak (USDA 1998).

According to the 1989 survey of Timber Resources of Missouri’s Northwest Ozarks (comprising Maries, Phelps, Pulaski, Laclede counties and nine other counties west of the Gasconade River watershed), conducted by the USDA Forest Service, 2.2 million acres of harvestable forest were reported, which is up nearly 13% over the 1.9 million acres reported in 1972 (Smith 1990). Recent 1989 forest survey information estimates approximately 2.91 billion board feet of sawtimber and 1.15 billion cubic feet of growing stock in the Northwest Ozarks. Annual growth totaled 80.7 million board feet of sawlogs in 1988, and annual growth of growing stock totaled 29.9 million cubic feet. Estimated removals in 1989 were 9.0 million cubic feet of sawtimber, or about 30% of the annual growth.

Based on these estimates, the forests in the Gasconade River watershed have sustainable forest production. The largest percentage of the forest land in the watershed is privately owned, the next largest percentage is owned by federal agencies (USFS, US Army), and a smaller percentage by state governments.

## Recent Land Use/Land Cover

Recent land use and land cover is best obtained from satellite imagery. Using the Thematic Mapper satellite digital image (Figure 8a & 8b), land-cover class names were developed from the Missouri Land Cover Classification Scheme (1997) by MORAP. Several spectral classes were collapsed into generalized land-cover categories (MORAP 1997). In the Gasconade River watershed, each generalized land-cover category acreage was determined for the Hydrologic Unit Code (HUC). Within the Upper Gasconade River watershed (HUC # 10290201) the land cover categories were quantified to have 46% deciduous and mixed forest, 42% grassland, 6.5% cropland, and 4.9% urban (Table 4). In contrast, the Lower Gasconade River watershed (HUC # 10290203) had 65.5% deciduous and mixed forest, 26.1% grassland, 7% cropland, and 0.9% urban.

## Recreation

Nationwide growth in water-based recreation has steadily grown over the last 15 years. Knowledge of the recreational use types and patterns in the Gasconade River watershed can be used to manage for multiple uses, especially as annual river recreation benefits are $2.6 million (MDC 1991b).

A comprehensive recreational use survey on the Gasconade River was conducted from 1977-78 by George Fleener. The results of this study were compared to a study conducted in Summer 1989 by MDC Fisheries Research to determine recreational use losses caused by the Shell pipeline oil spill of December 24, 1988. Recreational use at six Department of Conservation access sites, comparing 1989 and 1977/78 use visits of 30 recreational use types, indicates no significant statistical difference between 1977/78 and 1989 estimates in five of the six access sites (MDC 1991b). There was a 14% decline in total use hours from 1977/78 to 1989 with larger declines in some activity categories (MDC 1991b). In the 1977 survey, angling, boating, MDC camping, and swimming were the top four activities from greatest to least recreational use. In 1989, fishing, once again, was the most popular activity accounting for nearly 50,000 hours of recreation. Sightseeing and nature study were the second most popular, which was not a popular category in 1977. Camping trips in the summer of 1989 were the least popular of the four categories and dropped somewhat over 1977 estimates. Overall, despite declines in some recreational activities, results of the 1989 public use survey showed that the river use was little affected by the Shell pipeline oil spill.

Personal interviews from the 1989 survey illuminated the demographics of the recreationist, the primary recreational uses, and trends in recreational use. The characteristic Gasconade River user is male, age 25-44, and a vast majority of the users are of local origin from five counties along the river. Two-thirds of the recreational uses are spent fishing or camping. Trends in use indicate increasing use after 1977 then a decline in 1986 and 1987.

In a telephone survey to estimate angler effort and success in Missouri waters, the Gasconade River was among the third highest in days fished within three of the six years listed (Weithman 1991). It also was the largest watershed listed. When angler effort was calculated based on angler effort per watershed area (Table 5), the Gasconade River was slightly less fished than more urban watersheds such as the Meramec and the Bourbeuse rivers.

### Natural Resources Soil Conservation Projects

Six Special Area Land Treatment (SALT) watersheds are found in the Gasconade River watershed (CARES 1999c). Although some of the lower watershed's SALTs are no longer active, particularly numerous are the SALT projects in the Upper Gasconade River watershed. Nutrient problems have plagued these areas for several years, the source of the problem being cattle manure.

### Public Areas

The entire Gasconade River watershed, with an expansive land area of 1,797,130 acres or 2,806.9 square miles (see Table 2, Geomorphology Section), has approximately 12% or 221,040 acres in public land ownership (Table 6). Ninety-five percent of the public land in the watershed is owned by the US Forest Service, 4.9% is owned by the state (MDC), and less than 1% by nonpublic entities (Figure 9).

Approximately, 1,322 acres of state and private land are located in the Big Piney River watershed.

### Stream Frontage

The miles of stream frontage on public land were analyzed within ArcView GIS. Using the digitized 1:100,000-scale stream network and the public lands layer (Figure 9), a determination of whose stream segments intersecting the public lands polygons was compiled. A rough estimate of 1,070 miles of stream was found on public land. In most cases both sides of the stream were on public land, which increased the mileage to 2,140. Most of these streams were within the Mark Twain National Forest. A more detailed estimate within individual public land parcels was not possible given the limitation of the 1:100,000-scale stream network.

### Stream Access

A total of 23 stream access areas in the Upper and Lower Gasconade River (Figure 9) provide numerous opportunities for water-based recreation. Three public land improvement projects are to be completed in FY2001 within the Upper and Lower Gasconade River watersheds, and two of the projects are to improve stream access (EC RCT 1998). MDC Design and Development Division will fund the Jermone Access ramp repairs (Ryck 1998). Cooper Hill Conservation Area and Roubidoux Island Access will have development of an entrance road, parking lot, concrete boat ramp, and associated facilities. Cooper Hill CA fronts Third Creek in addition to the Gasconade River. This section of the Gasconade River has an excellent fishery and limited access. This site fills a high priority need identified in the Stream Area Program Strategic Plan (1994).

### Corps of Engineers 404 Jurisdiction

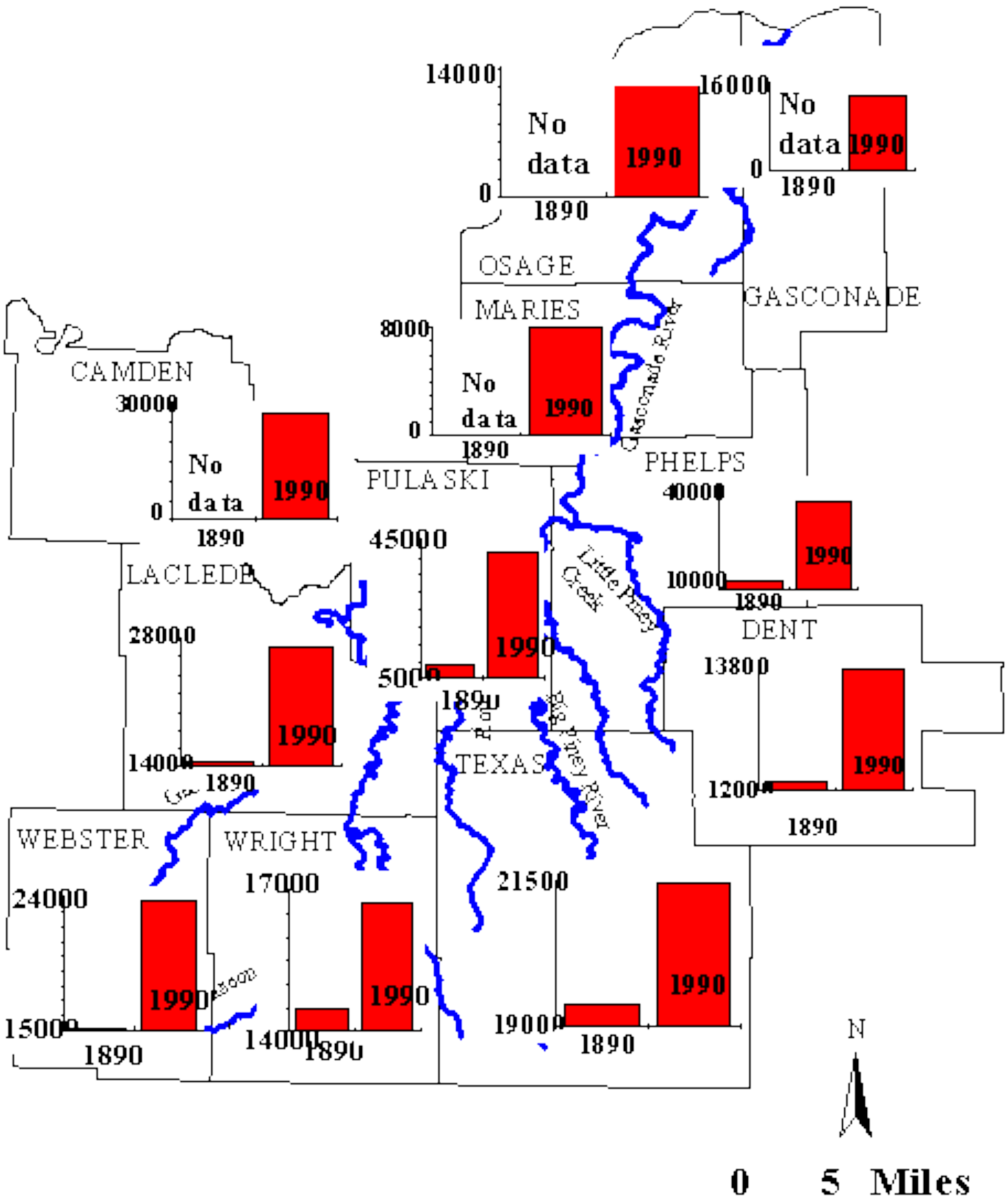
The entire Gasconade River watershed is under the jurisdiction of the Kansas City District of the U.S. Army Corps of Engineers.
Section 404 regulation permitting, inquiries, and violation reports for the Lower Gasconade River watershed should be directed to the Missouri State Regulatory Office:

- 221 Bolivar Street, #103, Jefferson City, MO 65101; Phone: 573-634-4788.

For the Upper Gasconade River watershed, Section 404 regulation permitting, inquiries, and violation reports should be directed to the Truman Satellite Office:

- Route 2, Box 29-C, Warsaw, MO 65355; Phone: 660-438-6697.

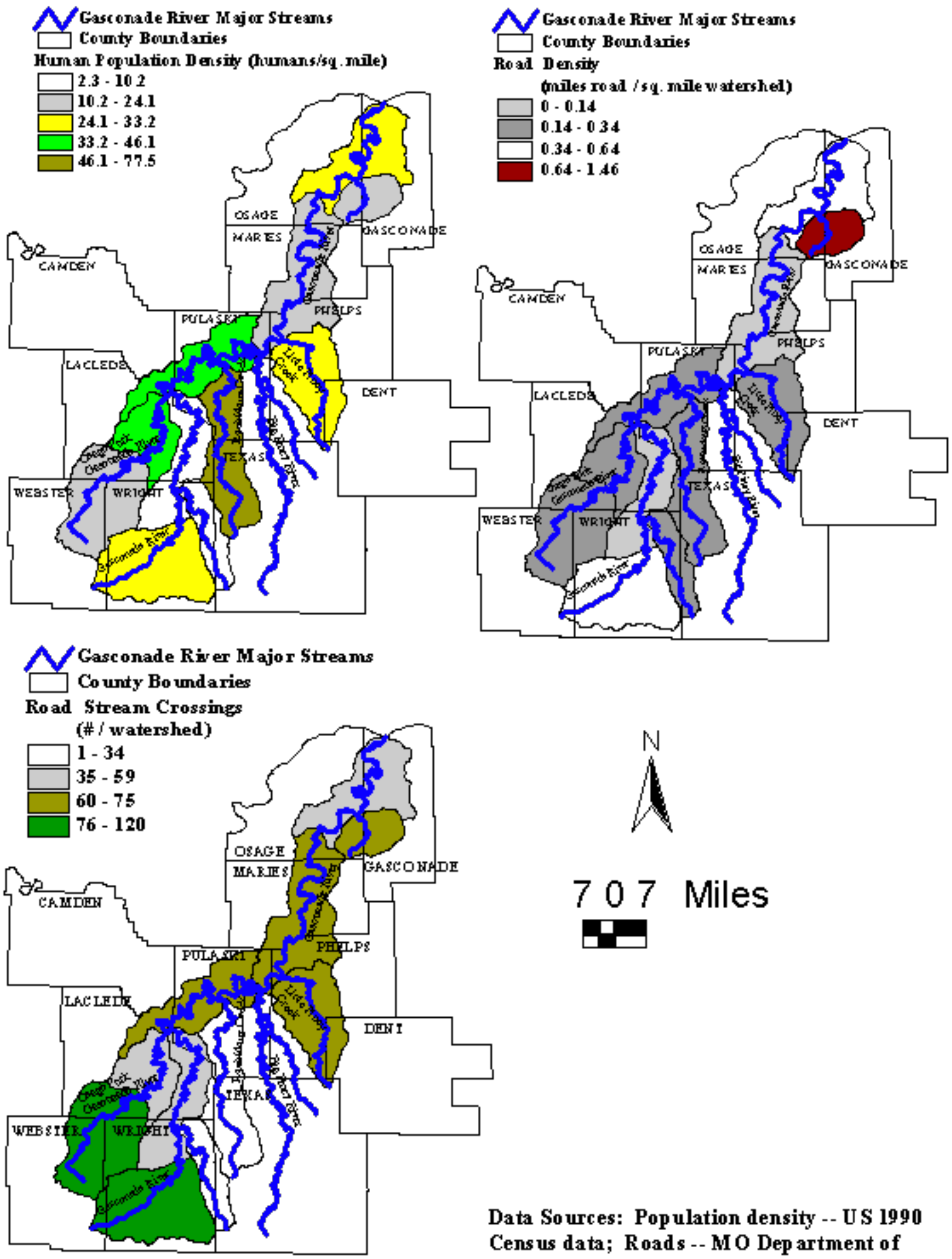
**Figure 4. 100-Year county population change in the Gasconade River Watershed**




Data Sources: USGS Topos (streams);
Population data from 1990 US Census and A Resminiscent History of the Ozark Region (1956).

Map created by Todd J. Blanc, 2/99

## Figure 5. Gasconade population and road density analysis




**Data Sources: Population density -- US 1990 Census data; Roads -- MO Department of ransportation; Streams-- USGS Topos**

Map Production: Todd J. Blanc 3/99

# Number of Cattle per Pastured Acre
# Gasconade River Watershed Counties

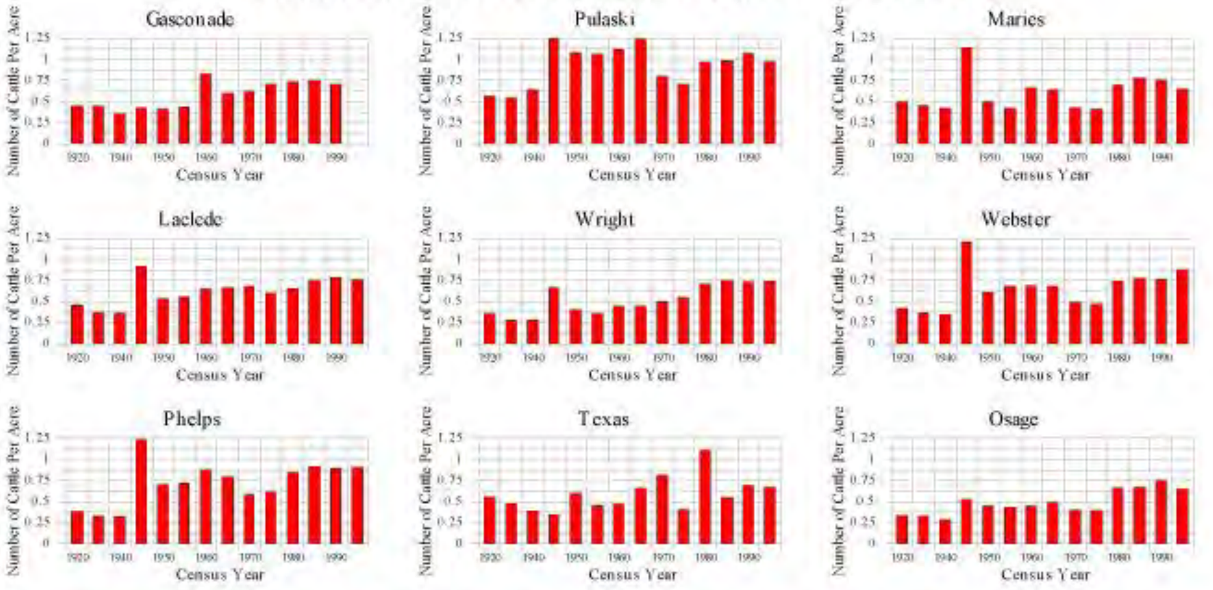


**Figure 7. Density of sand and gravel site permits in the Gasconade River Watershed**

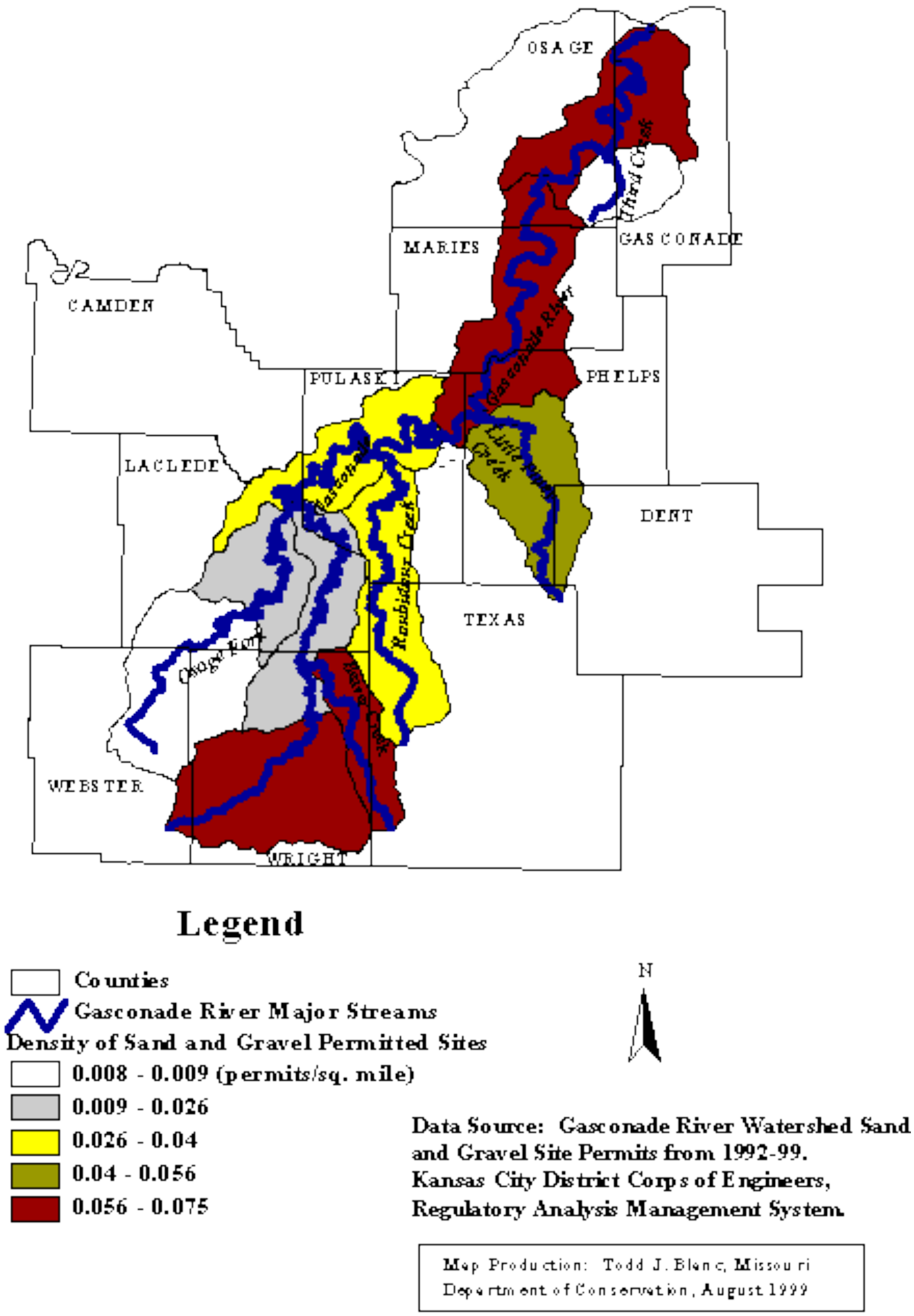
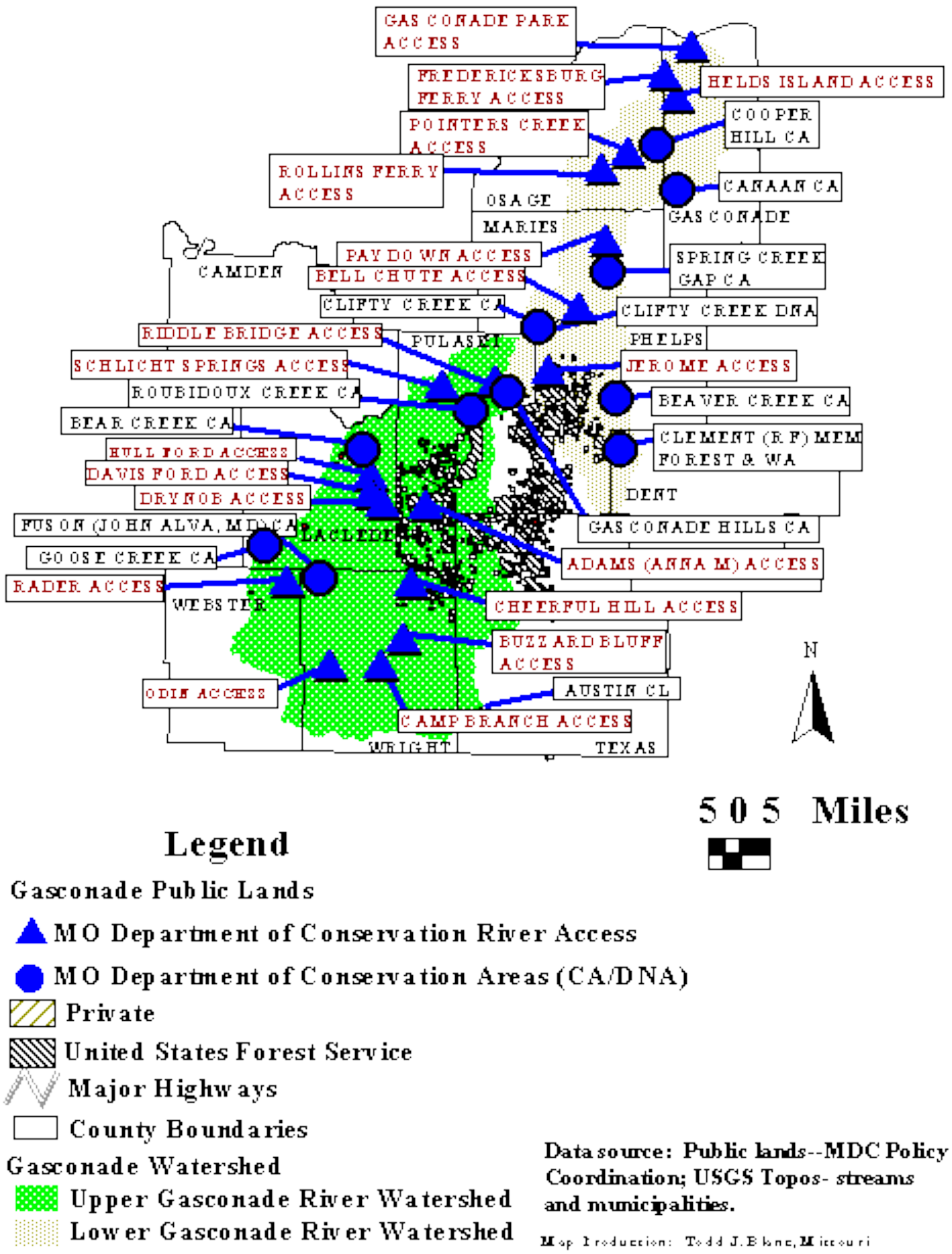


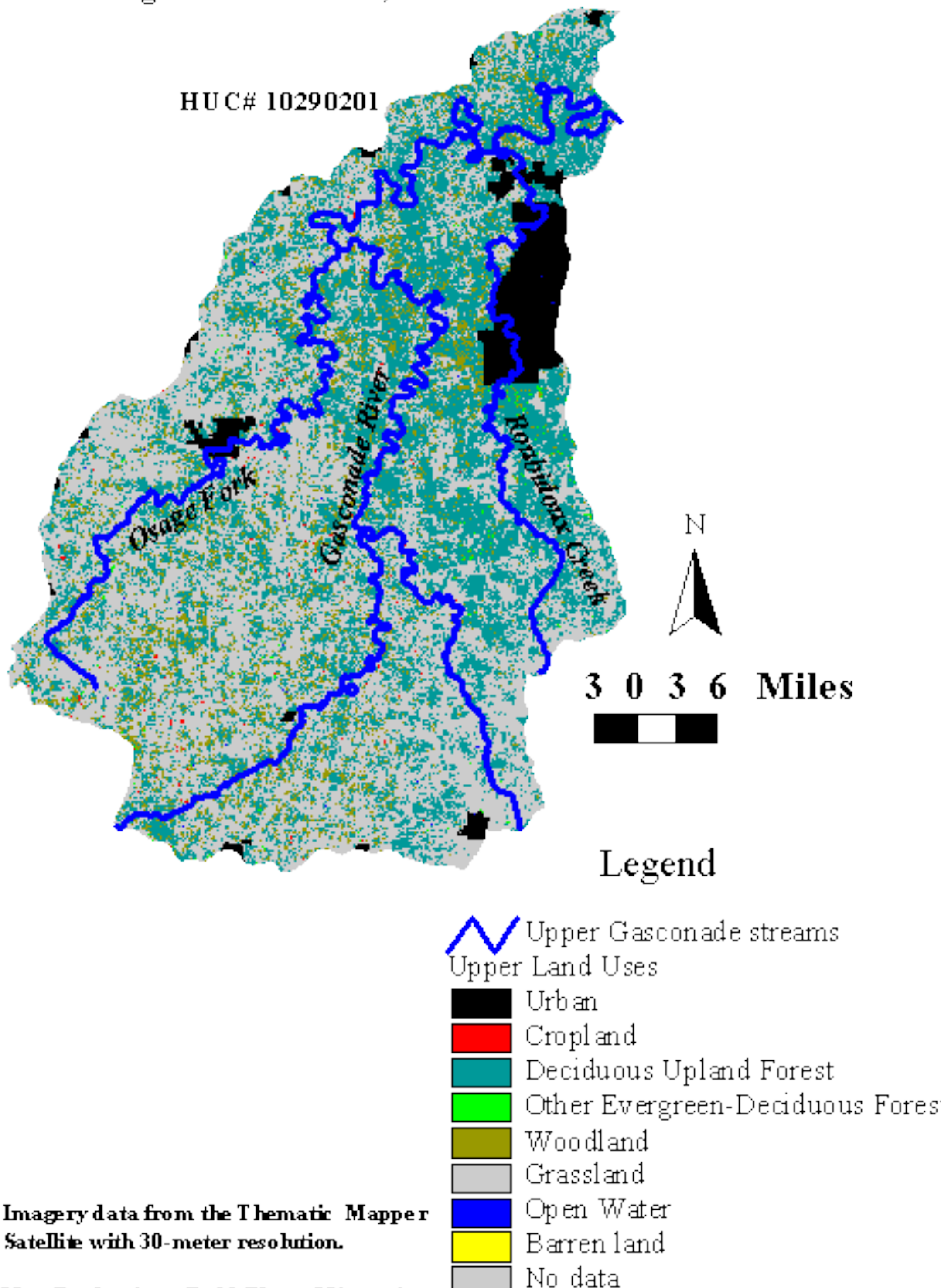
**Figure 9. Public lands in the Gasconade River Watershed**




Data source: Public lands--MDC Policy Coordination; USGS Topos- *streams* and municipalities.

Map Production: Todd J. Blanc, Missouri Department of Conservation, March 1999.

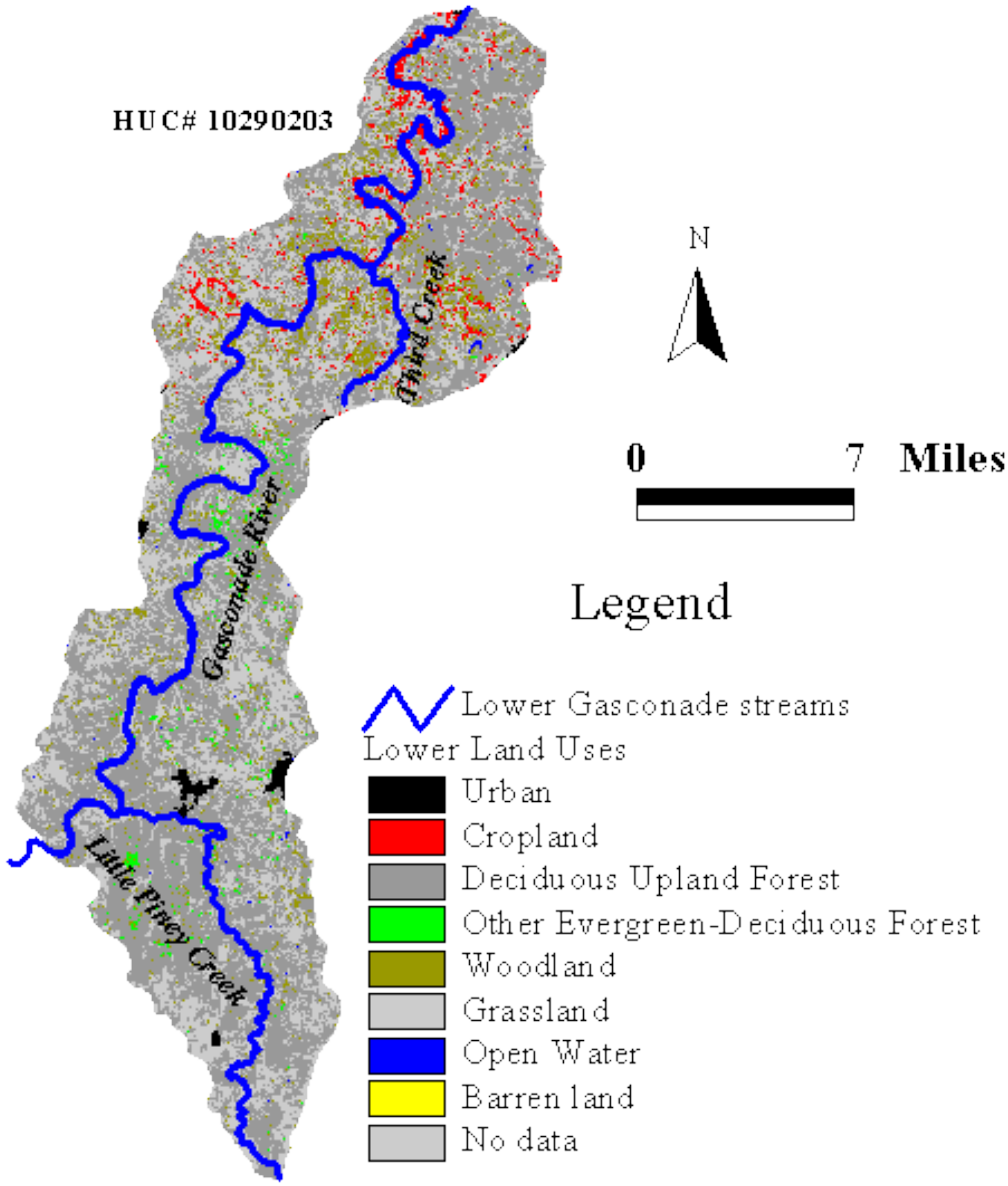
Figure 8a. Upper Gasconade River watershed land use/land cover
Data Originator: MoRAP, June 1999




Imagery data from the Thematic Mapper Satellite with 30-meter resolution.

Map Production: Todd Blanc, Missouri Department of Conservation, August 1999

**Figure 8b. Lower Gasconade River watershed land use/ and cover Data Originator: MoRAP, June 1999**




**Imagery data from the Thematic Mapper Satellite with 30-meter resolution.**

**Map Production: Todd Blanc, Missouri Department of Conservation, August 1999**

Table 4. MORAP Phase I Land Cover acreage for the Upper and Lower Gasconade River watershed. Several other watersheds are listed for comparison to the watersheds in this inventory. Percentage tree cover, grassland, and cropland are also listed.

| H.U.C. | Deciduous | Mixed | Grass | Crop | Urban | Water | Total Average |
|---|---|---|---|---|---|---|---|
| **10290201[1]** | 472,543 | 54,729 | 485,041 | 75,040 | 55,805 | 2,831 | 1,145,989 |
| **Percentages:** | | % Tree = 46.0 | % Grass = 42.0 | % Crop = 6.5 | % = 4.9 | % = 0.3 | |
| **10290202[2]** | 231,065 | 66,839 | 132,137 | 19,786 | 31,375 | 1,131 | 482,333 |
| **Percentages:** | | % Tree = 61.8 | % Grass = 27.0 | % = 0.2 | % Crop = 4.1 | % = 6.9 | |
| **10290203[3]** | 355,323 | 78,351 | 173,716 | 46,767 | 5,934 | 3,660 | 663,751 |
| **Percentages:** | | % Tree = 65.5 | % Grass = 26.1 | % Crop = 7.0 | % = 0.9 | % = 0.5 | |
| **7140102[4]** | 891,160 | 63,151 | 285,304 | 61,164 | 70,690 | 6,198 | 1,377,667 |
| **Percentages:** | | % Tree = 69.8 | % Grass = 20.7 | % Crop = 4.4 | % = 5.1 | % = 0.5 | |
| **10290111[5]** | 272,064 | 87,790 | 213,683 | 93,663 | 9,351 | 6,535 | 683,086 |
| **Percentages:** | | % Tree = 52.8 | % Grass = 31.2 | % Crop = 13.7 | % = 1.4 | % = 0.9 | |
| **10290102[6]** | 43,696 | 1,387 | 128,698 | 122,990 | 5,162 | 7,092 | 309,025 |
| **Percentages:** | | % Tree = 14.6 | % Grass = 41.6 | % Crop = 39.8 | % = 1.7 | % = 2.3 | |
| **7140103[7]** | 250,207 | 24,570 | 180,400 | 65,156 | 14,662 | 2,330 | |
| **Percentages:** | | % Tree = 51.3 | % Grass = 33.5 | % Crop = 12.1 | % = 2.7 | % = 0.4 | 537,325 |
| **7140104[8]** | 341,303 | 66,908 | 156,822 | 32,991 | 15,377 | 4,377 | 617,778 |
| **Percentages:** | | % Tree = 66.1 | % Grass = 25.3 | % Crop = 5.1 | % = 2.5 | % = 0.7 | |

[1]-Upper Gasconade; [2]- Big Piney River; [3]- Lower Gasconade; [4]- Meramec River;[5]-Lower Osage River; [6]- Maries River; [7]- Bourbeuse River; [8]- Big River

Table 5. Estimates of days fished per total watershed area in acres on the Gasconade 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.

Table 6. Public land ownership (MDC, MoRAP 1997) and acreage within the Gasconade River watershed including Big Piney River watershed **(Bolded).**

| Name | Acres | Owner |
|---|---|---|
| **United States Forest Service** | 209,828.82 | United States Forest Service |
| **Adams (Anna M) Access** | 16.43 | MO Dept. of Conservation (MDC)a |
| **Allen (Wilbur) Mem CA1** | 375.57 | MDC |
| **Austin Community Lake** | 56.06 | MDC |
| **Baptist Camp Access** | 7.41 | MDC |
| **Bear Creek CA** | 758.01 | MDC |
| **Beaver Creek CA** | 147.35 | MDC |
| **Bell Chute Access** | 8.10 | MDC |
| **Boesl (L A) Outdoor Education Area** | 8.81 | MDC |
| **Boiling Spring Access** | 11.18 | MDC |
| **Bray (Marguerite) CA** | 129.10 | MDC |
| **Buzzard Bluff Access** | 82.08 | MDC |
| **Cabool Towersite** | 17.43 | MDC |
| **Camp Branch Access** | 21.03 | MDC |
| **Canaan CA** | 1,397.50 | MDC |
| **Canaan Towersite** | 3.15 | MDC |
| **Cheerful Hill Access** | 55.97 | MDC |
| **Clement (R F) Mem Forest & WA** | 512.98 | MDC |
| **Clifty Creek CA** | 255.39 | MDC |
| **Clifty Creek DNA2** | 253.70 | Private |
| **Cooper Hill CA** | 247.40 | MDC |
| **Davis Ford Access** | 17.02 | MDC |
| **Dixon Towersite** | 43.78 | MDC |
| **Dog's Bluff Access** | 4.59 | MDC |
| **Dripping Springs DNA** | 9.14 | Private |
| **Dripping Springs NA3** | 2.07 | MDC |
| **Drynob Access** | 15.51 | MDC |
| **Eck (Peter A) CA** | 113.65 | MDC |
| **Eck Memorial DNA** | 270.59 | MDC |
| **Fredericksburg Ferry Access** | 6.03 | MDC |
| **Ft Leonard Wood Towersite** | 63.79 | MDC |
| **Fuson (John Alva, Md) CA** | 1,270.67 | MDC |
| **Gasconade District Head Quarters** | 4.14 | MDC |
| **Gasconade Park Access** | 1.86 | MDC |
| **Gasconade Hills CA** | 362.73 | MDC |
| **Goose Creek CA** | 365.99 | MDC |
| **Great Spirit Cave CA** | 13.26 | MDC |
| **Hazelgreen Access** | 0.61 | MDC |

| Name | Acres | Owner |
|---|---|---|
| **Helds Island Access** | 10.58 | MDC |
| **Horseshoe Bend DNA** | 95.26 | Private |
| **Horseshoe Bend NA** | 223.12 | MDC |
| **Houston Forestry Office** | 1.86 | MDC |
| **Hull Ford Access** | 11.80 | MDC |
| **Houston Towersite** | 20.21 | MDC |
| **Jerome Access** | 9.57 | MDC |
| **Lebanon Forestry Office** | 10.21 | MDC |
| **Lebanon Towersite** | 3.37 | MDC |
| **Lenox Towersite** | 6.02 | MDC |
| **Mason Bridge Access** | 9.26 | MDC |
| **Mineral Springs Access** | 6.58 | MDC |
| **Niangua CA** | 137.93 | MDC |
| **Odin Access** | 131.25 | MDC |
| **Paydown Access** | 6.41 | MDC |
| **Pilot Knob Towersite** | 4.14 | MDC |
| **Osage Fork CA** | 282.44 | MDC |
| **Piney River Narrows DNA** | 249.10 | Private |
| **Piney River Narrows NA** | 17.98 | MDC |
| **Pointers Creek Access** | 18.05 | MDC |
| **Quercus Flatwoods DNA** | 52.02 | MDC |
| **Rader Access** | 65.45 | MDC |
| **Riddle Bridge Access** | 7.58 | MDC |
| **Rollins Ferry Access** | 20.19 | MDC |
| **Ross Access** | 2.70 | MDC |
| **Roubidoux Creek CA** | 289.50 | MDC |
| **Ryden Cave CA** | 29.20 | MDC |
| **Schlicht Springs Access** | 13.18 | MDC |
| **Spring Creek Gap CA** | 1,797.10 | MDC |
| **Simmons Ford Access** | 3.28 | MDC |
| **Spring Creek Gap Glades DNA** | 42.24 | MDC |
| **White (George O) SF4 Nursery** | 702.16 | MDC |
| **inholding** | 1.92 | Private |
| **Total public land acreage** | 221,040.58 | |

[1]Conservation Area, [2]Designated Natural Area, [3]Natural Area, [4]State Forest. Missouri Department of Conservation (MDC)[a]

# Hydrology

## Precipitation

At this latitude precipitation in the form of rain or snow is affected by temperature, which has an annual mean of 42E F. Rain has the effect of quickly recharging groundwater and surface water, where snow melt has a gradual effect on surface water hydrology. The average annual precipitation at Hermann, MO (lower watershed), Rolla, MO (east middle watershed), Jerome (middle watershed) Lebanon (west middle watershed), Houston (upper watershed), Marshfield (upper watershed) was 40.35, 41.09, 41.76, 41.37, 42.70, 42.67, respectively, inches over the period 1961-90 (Owenby and Ezell 1992). The arithmetic watershed precipitation mean is 41.66 inches.

US Geological Survey (USGS) water discharge gage stations are shown on Figure 10. These stations collect daily water discharge data, and some stations house National Weather Service gage-height meters. The following is a list of the location and period of record of the gage stations.

| Gage Station | Stream | Location | Comment |
|---|---|---|---|
| **06932000** | Little Piney Creek | located on the left bank at downstream side of bridge on State Highway P and T at Newburg, and 2 miles upstream from Mill Creek. | Lat. 37E54' 35", long. 91E 54' 12" in SW 1/4 SE 1/4 sec. 22, T37N, R9W |
| **06933500** | Gasconade River | Lat. 37E55' 47", long. 91E 58' 38" in NE 1/4 NE 1/4 SE 1/4 sec. 13, T37N, R10W | located on the left bank at Jerome, MO, 0.5 miles downstream from Little Piney Creek, and at river mile 107. |
| **06934000** | Gasconade River | Lat. 38E23' 20", long. 91E49' 15" in SE 1/4 sec. 16, T41N, R8W | located downstream side of State Highway 89 Bridge, 100 feet downstream from Brush Creek slough, 800 feet upstream from Swan Creek, and 4 miles east of Rich Fountain. |
| **06928440 (water quality)** | Roubidoux Creek | at Waynesville | 1993present |
| **06927800** | Osage Fork, Gasconade River at Drynob | no longer active | 1962-81 |
| **06928200** | Laquey Branch near Hazelgreen | no longer active | 1958-72 |

| Gage Station | Stream | Location | Comment |
|---|---|---|---|
| **06928500** | Gasconade River near Waynesville | no longer active | 1914-71 |
| **06928000** | Gasconade River near Hazlegreen | no longer active | 1928-71 |

Numerous inactive surface water-quality stations are listed in the Water Resources Data of Missouri (United States Geological Survey 1998).

Using information derived from 7.5" topographic maps by Funk (1968), permanent and intermittent stream reaches within the Gasconade River watershed were tabulated (Table 7). The USGS defines perennial or permanent streams as those having water 12 months of the year during normal precipitation. According to Funk (1968), out of 271 total stream miles, the main stem Gasconade River watershed has 263 permanent stream miles capable of supporting angling. Third Creek, Roubidoux Creek, and Little Piney Creek have several miles of intermittent pools. Roubidoux Creek has several miles of losing stream segments, giving this stream approximately 25 miles of intermittent pools.

With increasing precipitation, monthly mean stream discharge rates climb in the late fall to early winter, followed by a March to May increase. Averaged over the 75-year period of record of the Gasconade River, April has the largest mean discharge rate of 4,682 CFS (Figure 11). It was this same month that the maximum mean discharge rate of 20,450 CFS was set in 1945. June was also a month of high discharge, having a maximum mean discharge of 18,500 CFS. The decay portion of the monthly mean discharge is known as the summer recession. At this time the 7-day low flows are recorded as discussed below. Groundwater storage is the major supply for river flow during the summer recession.

Over the period of record of 75 years, the annual mean discharge, averaged over the 12 months, was 2,663 CFS. The highest recorded annual mean discharge, set in the flood year of 1985, was 6,491 CFS, and the lowest mean discharge, 544 CFS, was recorded in 1954.

Although many factors affected surface runoff in the Gasconade River, an obvious major contributor was precipitation patterns. From smaller to larger catchment, annual surface runoff was 11.22, 12.94, and 13.3 inches over the period of record at the Newburg, Jerome, and Rich Fountain gages, representing an approximate drainage area of 199, 2,840, and 3,180 mi2, respectively. The average annual precipitation for the years 1961-90 was approximately 41 inches/year (Owenby and Ezell 1992).

A 3-year moving average of precipitation (inches) at Jerome, Missouri over the 1960-96 period of record provided a method of smoothing the data to help in pattern recognition. Precipitation for the 1960-96 period of record indicated that the winter seasons and growing seasons (April to November), as defined by the SCS Wright County Soil Survey, had year to year cyclic patterns (Figure 12). Overall, linear regression of winter season precipitation and the growing season precipitation over this period revealed a slight decline in winter season precipitation but no growing season precipitation change. No data were collected for certain years. For example, the USGS surface runoff data in Figure 13 was missing the 1985 precipitation peak, a flood event. Figure 13 depicts the seasonal relationship of precipitation and surface runoff and the importance of vegetation to lessen the quantity of surface precipitation runoff. The beginning of the growing season has elevated rainfall and runoff. With the growth of vegetation, surface runoff declined only to raise with water uptake reduction by plants and the resistance to over-land water flow in late fall.

The linear regression lines provided a baseline to compare average year-to-year precipitation and runoff patterns (Figure 12 and 14). During the 1960s to the early 1980s, average precipitation intensified in the growing season and declined during the winter season. A pattern that appears normal. On the contrary, a pattern of increasing precipitation in the 1970s during the winter season (Figure 12) directly influenced the high surface runoff during this period (Figure 14). This winter pattern could be detrimental to soil integrity as soil erosion is influenced by surface runoff rates. While winter precipitation showed a general decline, linear regression of mean surface runoff is increasing steadily.

Several changes were evident from the 3-year moving average of both winter and growing season runoff.

1) Average runoff had greater extremes from late 1970s to the present than during the 1960s to the late 1970s.
2) Low winter season average runoff that was evident in the 1960s did not compare to low winter season average runoff in the 1980 and 1990s.
3) Low growing season precipitation in the late 1980s did not produce the same low growing season runoff that occurred the late 1960s (ranging between an average of 1.4 and 5.25 inches), which during the 1960's had nearly twice the winter and growing season precipitation.
4) Dry growing seasons of the 1980s to the 1990s may have been responsible for the elevated runoff in the winter seasons (Figure 14). For the 1960 - 1996 period, winter season precipitation was the lowest recorded in 1990, but winter season runoff in 1990 remained higher (Figure 14; mean of 8.6 inches) than any period during the 1960s to 1970s. In contrast, the dry growing season years of the mid 1960s (Figure 12) had lower winter season runoff (Figure 14; mean range of 1.4 and 5.25 inches), although the winter season precipitation was higher than previous years. Based on the evident changes in runoff, landscape factors other than precipitation in the 2,840 mi2 catchment area, represented at the Jerome, Missouri Gage Station, are influencing surface runoff.

Over time, with no precipitation runoff to recharge the streams, discharge rate declined at a curvilinear rate. Base flow is defined as the dry-weather discharge of the stream, which is different from the low flow of the stream that may include some surface runoff. For the period of record 1924-67 at the Jerome gage station (middle watershed), the minimum measured flow (one day value) was 254 CFS (Table 8). In addition, the minimum annual mean was 544 CFS. After ten days of no rain, the base flow receded from 600 CFS to 485 CFS, decreasing to 335 CFS after 40 days. Within the upper watershed, Osage Fork at Drynob had the lowest measured flow of 12 CFS. Beginning at 38 CFS, flow declined to 28 CFS after ten days and reached 11 CFS after a dry period of 40 days (Table 8).

The low flow characteristics of the perennial stream are influenced by the local geology of the watershed, primarily its soil retention and groundwater storage. Over a 20-year period, the lowest recorded 7-day Q20 (20 year) stream flow for the Gasconade River at the Jerome gage station was 299 CFS. Over a two-year period (Q2), the discharge at the Jerome gage station (middle watershed) fell to 470 CFS for seven days, and every ten years (Q10), discharge fell to 320 CFS for seven days (Table 9). Flow conditions inflate as water reaches the lower watershed at Rich Fountain, where the 7- day Q2 fell to 520 CFS and the 7-day Q10, fell to 330 CFS.

Good flow conditions are evidenced by the slope index (SI) of 1.57. Large SI values represent poor water supply and instability from year to year. In comparison, the Castor River and the Meramec River have SI values of 2.1.

At the Jerome USGS gage station discharge data has been collected for 75 years. Figure 15 shows the percentage of time that the flow equaled or exceeded a given discharge. Represented in the figure as log normal scale, Jerome gage station discharge exceeds 8,933 CFS for 5% of the time, 1,274 CFS for 50% of the time, and 448 CFS for 95% of the time. The gage is in the middle of the watershed and represents a large catchment. Flow conditions are good and discharge does not increase as quickly as other streams in Missouri.

At the Jerome gage station of the Gasconade River, the flow duration curve 90:10 ratio of the discharge value exceeded 90% of the time to the value exceeded 10% of the time is 520.4 CFS; 5,571.6 CFS or 1 to 10.7. Compared to the Meramec River, the 90:10 ratio for the Sullivan gage station, and the Eureka gage station was 271.0 CFS; 2,412.2 CFS or 1 to 8.90, and 520.7 CFS; 6,761.8 CFS or 1 to 12.97, respectively. These values suggest, as mentioned above, a lower variability in flow as compared to the Cuivre River that has a high 90:10 ratio of 1 to 218.

As published in Hauth (1974) the magnitude and the frequency of flooding was estimated for most Missouri streams. Hauth developed his mathematical technique for estimating the frequency of floods using 152 gage sites within Missouri's watersheds. Streams having a drainage area ranging from 0.1 to 14,000 mi2 were included in the Hauth (1974) report. The estimated magnitude of floods for gages within the Gasconade River watershed is shown in Table 10. The 100-year flood event of the Jerome gage station would result in a discharge rate of 123,000 CFS. In addition, the probability of a flood happening in a given year is 1%. The decline in the discharge rate at Rich Fountain further upstream from Jerome gage station is due to the change in drainage area and gradient. Hauth (1974) developed equations to estimate the magnitude and frequency of flooding at ungaged sites. The basic regression model has coefficients that are specific to the frequency of flood years.

Dam influences on stream hydrology include cold or warm spillway discharge (depending on the spillway construction) and a gradient control effect. Fords or bridge crossing can act as gradient control and can affect fish passage. A large number of stream crossings exist in the upper watershed area (see Land Use Section, Population). Within the Upper Gasconade River watershed USGS Hydrologic Unit Code (HUC) # 10290201, an estimated total of 83 lakes exist with an estimated total of 1197.6 acres. The Lower Gasconade River watershed, HUC # 10290203, contains approximately 35 lakes, totaling 787.9 acres (EPA Surf Your Watershed 1999).

While ponds continue to be built in the watershed, in the 1984 MDNR Water Quality Basin Plan only three lakes are listed as greater than 50 acres. These lakes are Lake Northwoods in Gasconade County, Peaceful Valley Lake in Gasconade County, and Brays Lake in Phelps County, which are 120, 170 and 162 acres, respectively, (MDNR 1984).

Information on impoundments can be found in the Fish and Wildlife Service National Wetlands Inventory (Cowardin, L. M. et al. 1979). These Palustrine wetlands are coded with the modifier impounded/diked (h) or excavated (x). PUBFh, PUBFx, PUBGh, PUBGhx, PUBHh, and PUBHx are some of the attributes (See Habitat Section).

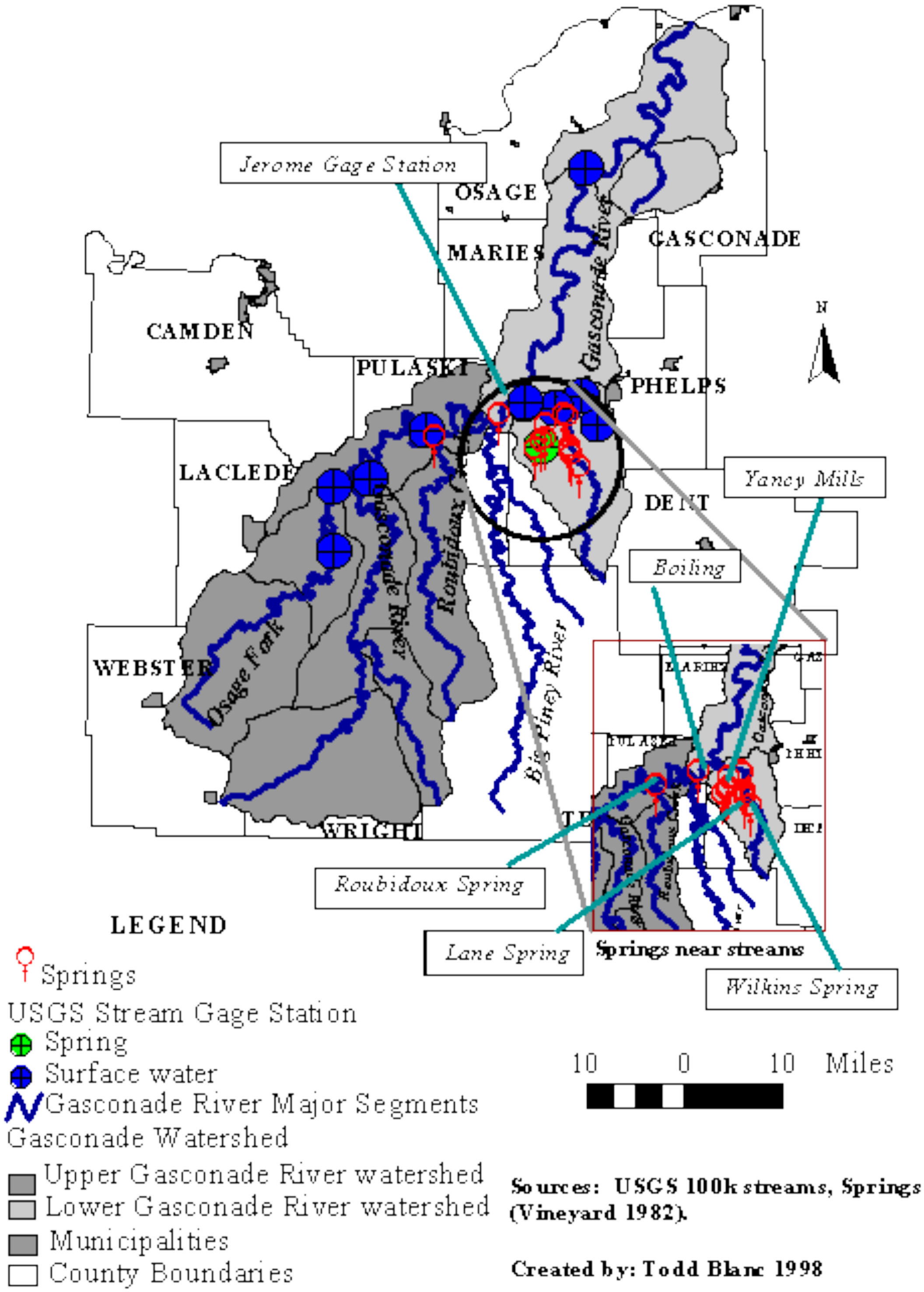
## Cold Water Stream and Losing Segments

Because the Gasconade River watershed has a large concentration of springs, many areas have stream segments where water temperature is colder than the adjoining segments. Losing stream segments, springs, cold water stream segments have a unique relation due to the watershed's karst topography. Losing stream segments lose water flow to groundwater, only to contribute to a spring's discharge in some cases. Through unique hydrologic mechanisms, springs can contribute to a stream's flow thus creating cold water segments. The Upper and Lower 8-digit Gasconade River watersheds have several cold water segments that have been identified by MDC Fisheries Research (Figure 16 and 17). The Upper Gasconade River watershed has a segment near the mouth of Roubidoux Creek (Figure 16). The Lower Gasconade River watershed has three unique cold water segments in the Little Piney Creek Hydrologic Unit because of spring-rich topography (Figure 17). Little Piney Creek and Mill Creek have cold water segments for more than five miles. Mill Spring Creek is a small spring creek tributary to the Gasconade River.

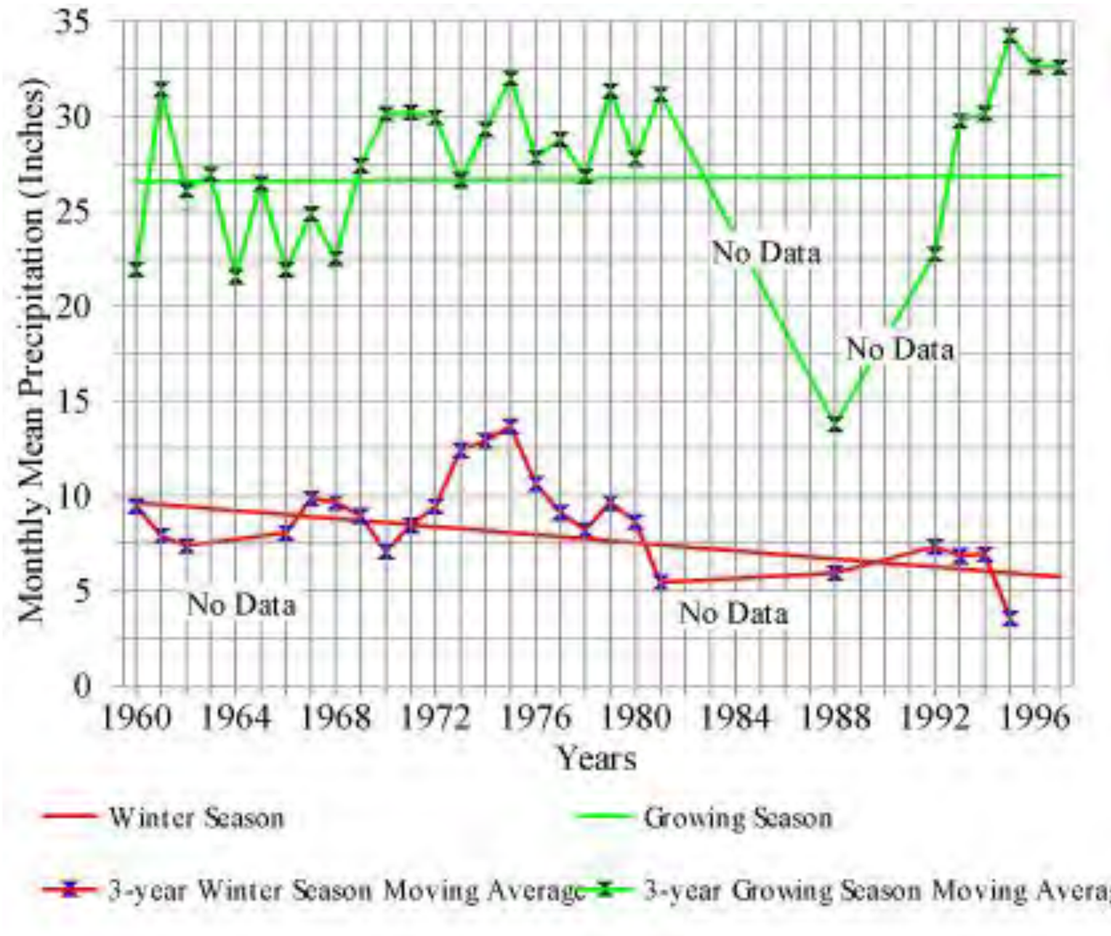
## General Hydrologic Data

For more information on the hydrology of the Gasconade River watershed visit the USGS Water Resources site (HU # 10290201 or HU # 10290203).

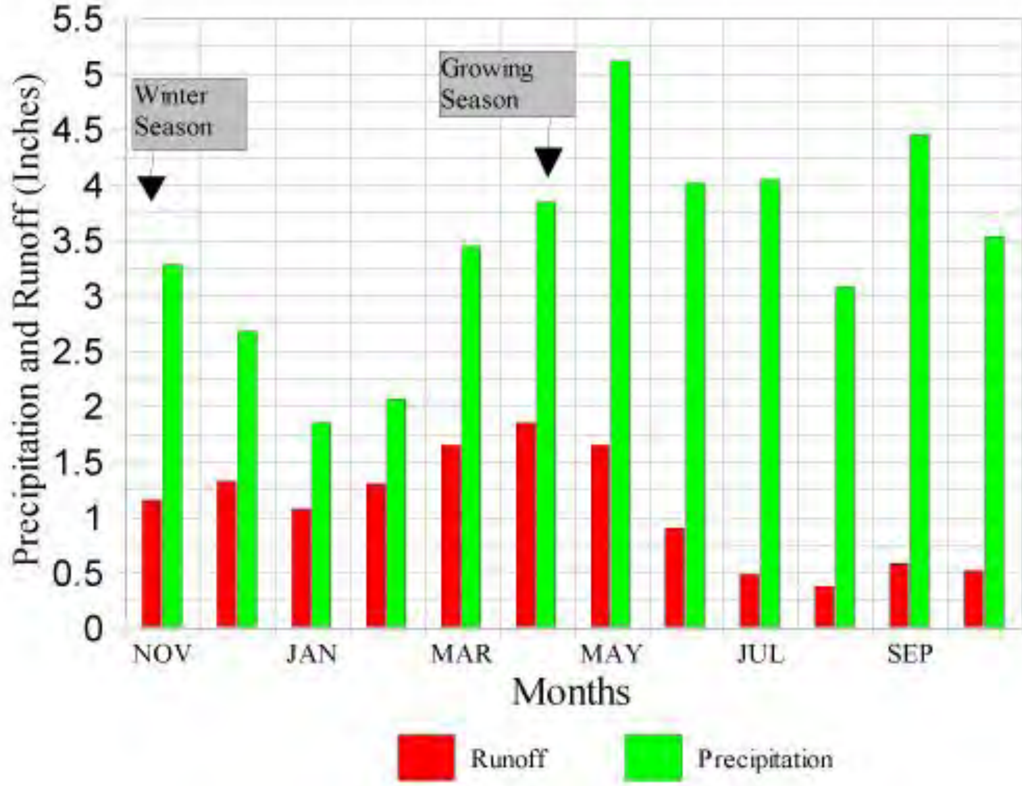
Figure 10. Gasconade River Watershed USGS gage station (historic and recent) and springs.



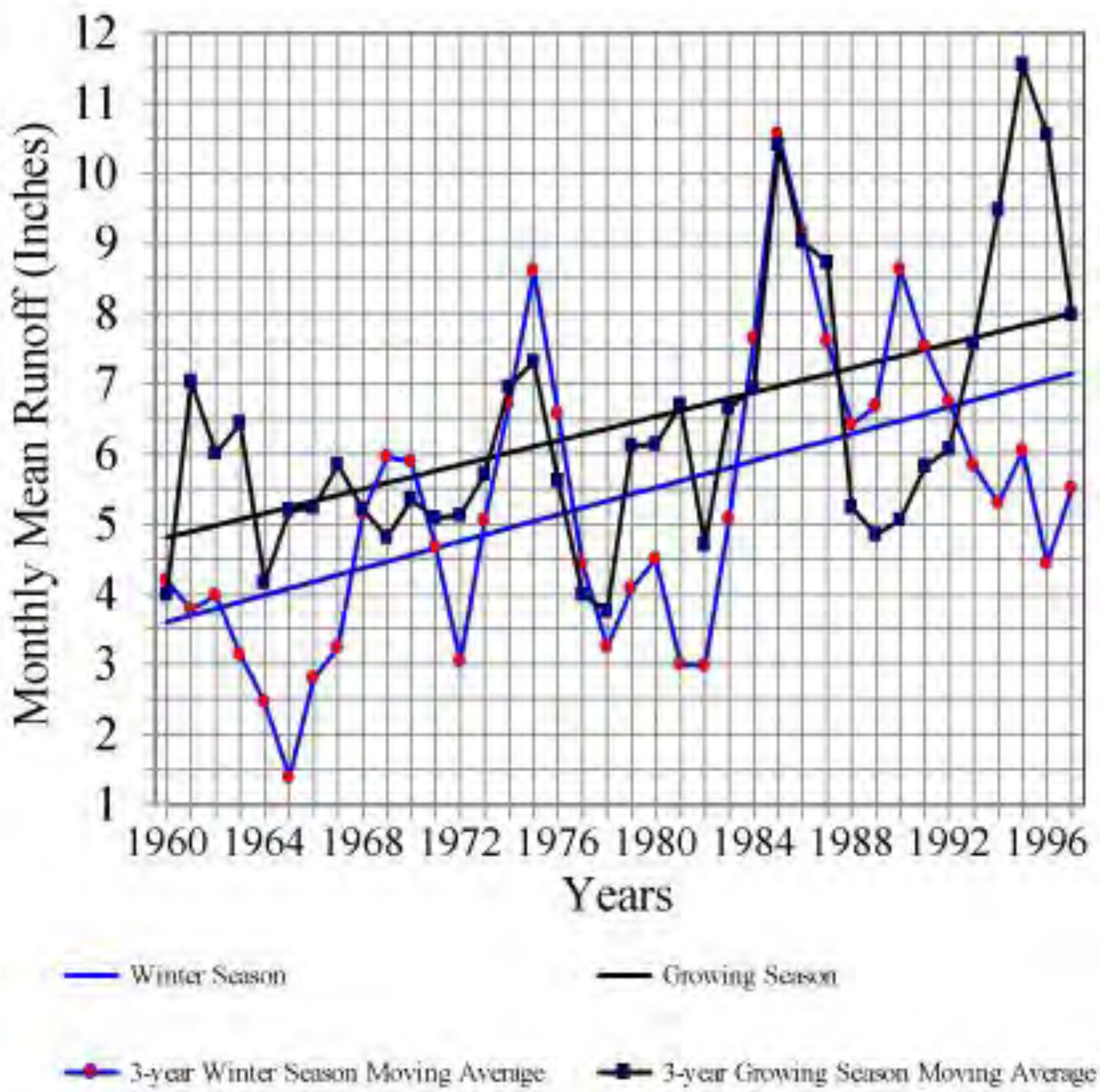
Winter season and growing season (April-November) precipitation linear regression lines and 3-year winter season and growing season moving average.



Monthly mean precipitation and runoff versus years from 1960-70. Bar chart of winter and growing season is shown.



Monthly mean runoff versus years from 1960-97 measured at the Jerome gage station of the Gasconade River watershed.



Gasconade River low flow duration plot for the years 1905-98.

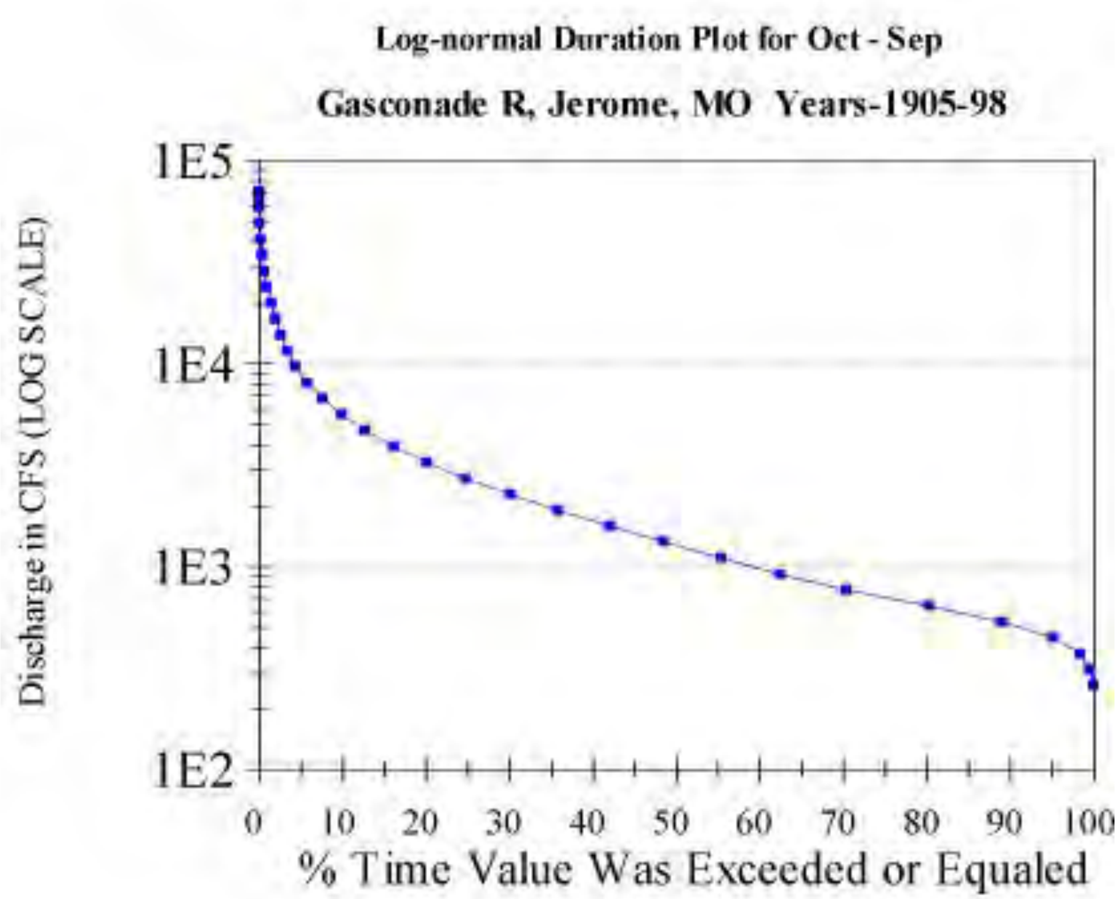


**Figure 16. Coldwater and losing stream segments within the Upper Gasconade River watershed.**

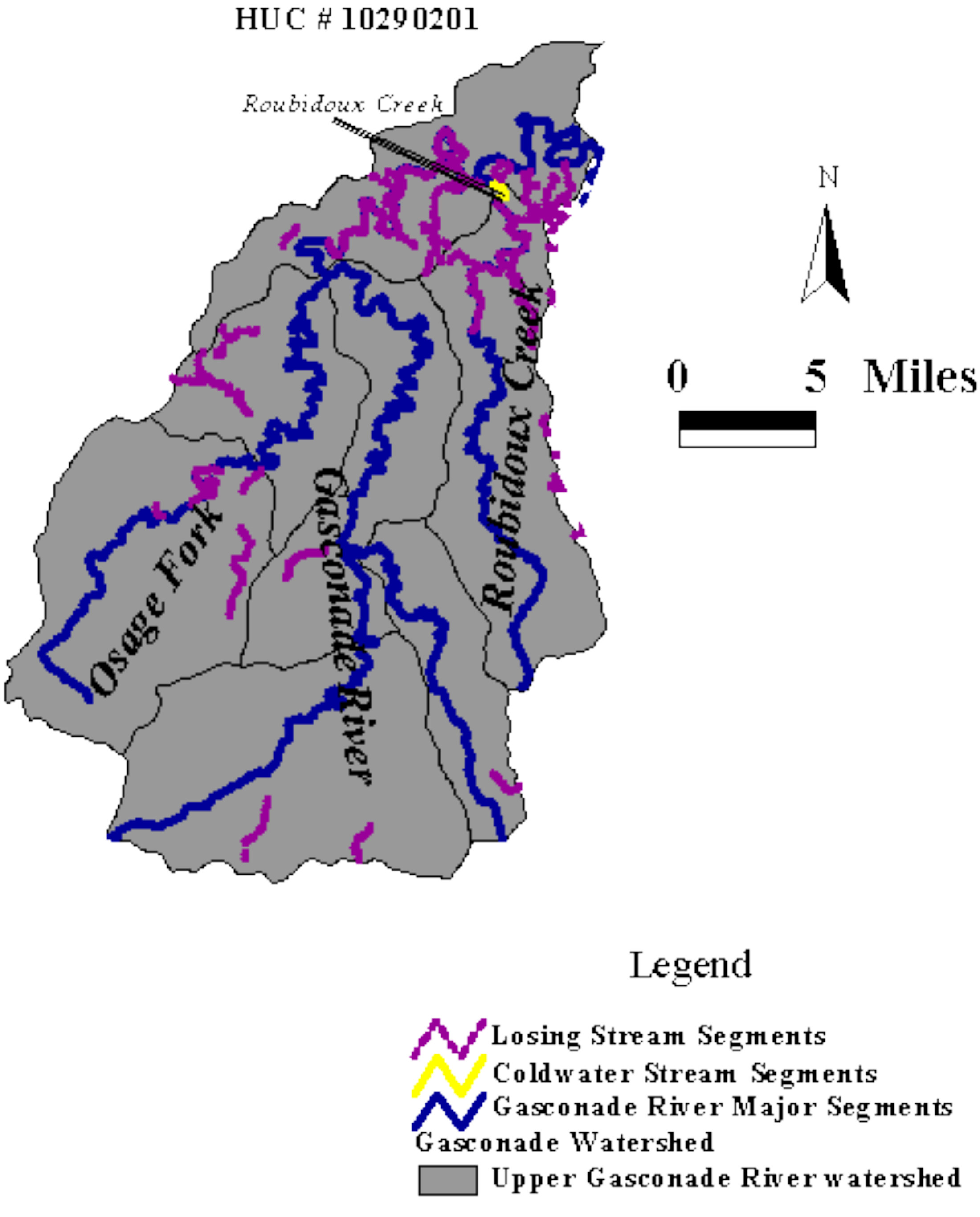


**Figure 17. Coldwater and losing stream segments within the Lower Gasconade River watershed.**

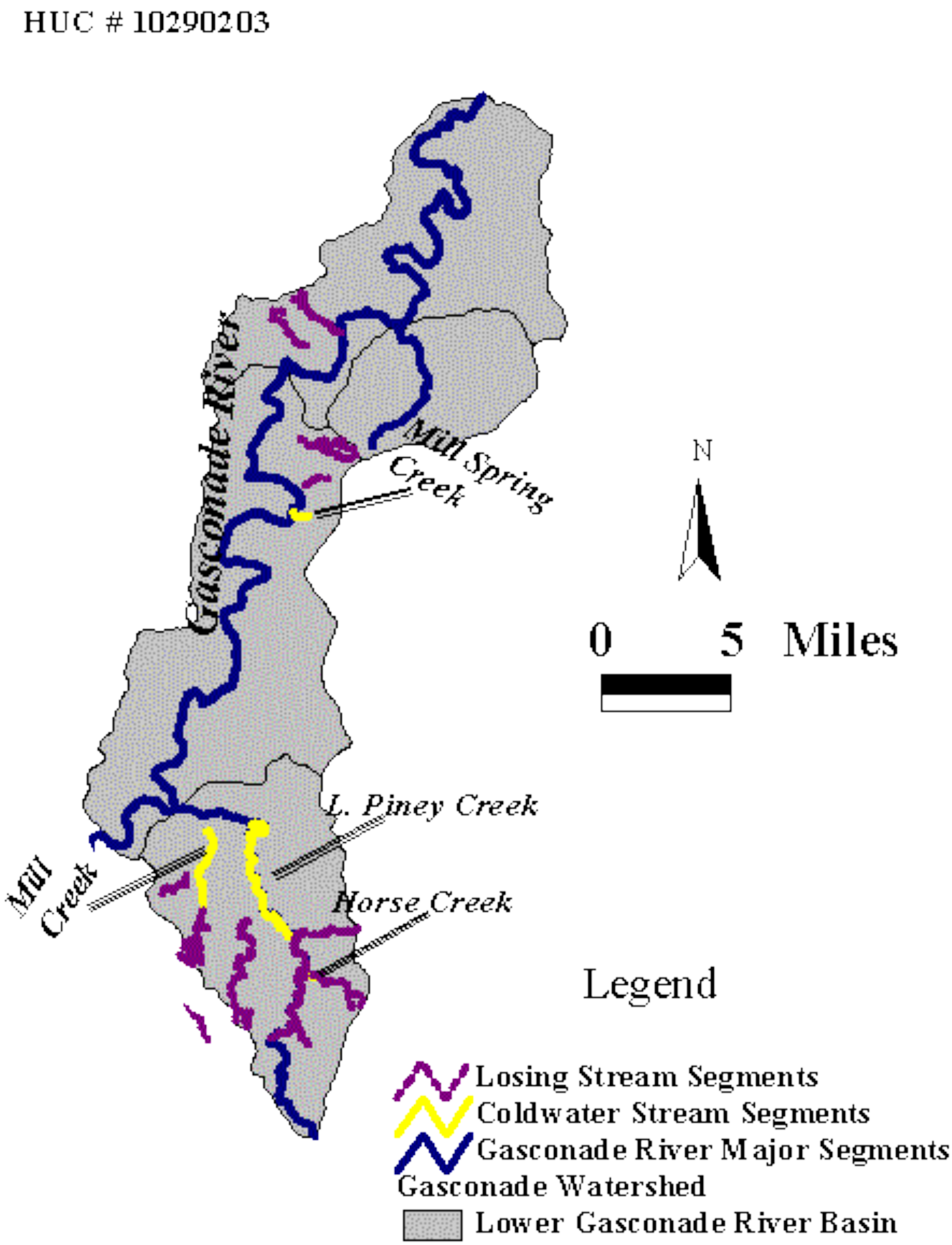


Table 7. Permanence of stream flow (fishable waters) in third-order and larger streams in the Gasconade River watershed (Funk 1968).

| Stream Name | Order[1] | Permanent Stream[2] Miles | Intermittent Pools[2] Miles | Total Length Miles[3] |
|---|---|---|---|---|
| **Gasconade River** | 263 | 2 | 271 | |
| **Lower Gasconade River Hills HU Code #10290203-040** | | | | |
| **First Creek (Gasconade County)** | 4 | 1 | 10 | 14.5 |
| **Brushy Fork Creek (Gasconade)** | 3 | 0.5 | 2.3 | |
| **Unnamed creek (Gasconade)** | 4 | 2 | 5.3 | |
| **Richland Creek (Gasconade)** | 3 | 0.5 | 6.4 | |
| **Second Creek (Gasconade)** | 5 | 6.5 | 6 | 14.7 |
| **Puncheon Creek (Gasconade)** | 4 | 4 | 7.8 | |
| **Unnamed Creek (Osage-Gasconade)** | 3 | 1 | 2.8 | |
| **Pin Oak Creek (Gasconade)** | 3 | 1 | 1.5 | 7.1 |
| **Contrary Creek (Osage)** | 3 | 1.5 | 4 | 9.2 |
| **Third Creek HU Code # 10290203-030** | | | | |
| **Third Creek** | 5 | 3.5 | 5.5 | 14.4 |
| **Little Third Creek** | 3 | 3.5 | 10.7 | |
| **Crider Creek** | 4 | 5 | 1.5 | 10.4 |
| **Old Bland Creek** | 3 | 3 | 5.3 | |
| **Cedar Branch** | 4 | 2 | 9.5 | |
| **Brushy Creek** | 3 | 1 | 5 | |
| **Mistaken Creek** | 3 | 6 | 1.5 | 9.7 |
| **Lower Gasconade River HU Code # 10290203-020** | | | | |
| **Brush Creek (Osage)** | 4 | 2.5 | 2.5 | 6.6 |
| **Unnamed Creek (Osage)** | 3 | 1 | 5.0 | |
| **Buehler Creek (Osage)** | 4 | 1.5 | 3.5 | |
| **Spring Creek (Phelps-Maries)** | 4 | 5 | 1 | 19.2 |

| Stream Name | Order[1] | Permanent Stream[2] Miles | Intermittent Pools[2] Miles | Total Length Miles[3] |
|---|---|---|---|---|
| **Dry Creek (Maries)** | 4 | 1.5 | 1.5 | 9.7 |
| **Camp Creek (Phelps)** | 4 | 2 | 7.4 | |
| **Little Piney Creek HU Code # 10290203-010** | | | | |
| **Little Piney Creek (Texas-Phelps)** | 5 | 19 | 4.5 | 43.2 |
| **Mill Creek (Phelps)** | 4 | 9.5 | 15.2 | |
| **Beaver Creek (Phelps)** | 4 | 3.5 | 10.0 | |
| **Little Beaver Creek (Phelps)** | 3 | 3.5 | 5.4 | |
| **Unnamed Creek (Phelps)** | 1.5 | | | |
| **Unnamed Creek (Phelps)** | .5 | | | |
| **Roubidoux Creek HU Code # 10290201-060** | | | | |
| **Roubidoux Creek (Texas-Pulaski)** | 5 | 23.5 | 25.5 | |
| **East Fork Roubidoux (Texas)** | 5 | 4.5 | | |
| **Middle Gasconade River HU Code # 10290201-070** | | | | |
| **Bear Creek (Laclede-Pulaski)** | 4 | 12 | | |
| **Lower Osage Creek HU Code # 10290201-040** | | | | |
| **Osage Fork (Webster-Laclede)** | 5 | 69.5 | 80.1 | |
| **Unnamed Creek (Laclede)** | 3 | 6 | - | |
| **Cobb Creek (Laclede)** | 1 | 1.5 | 14.1 | |
| **Brush Creek (Laclede)** | 4 | 2 | 11.1 | |
| **Parks Creek (Laclede-Webster)** | 4 | 3 | 2 | 14.7 |
| **Panther Creek (Laclede-Webster)** | 4 | 2.5 | 1.5 | - |
| **Centre Creek (Webster)** | 4 | 7 | 5.5 | - |
| **Hyde Creek (Webster)** | 3 | 4 | - | |

| Stream Name | Order[1] | Permanent Stream[2] Miles | Intermittent Pools[2] Miles | Total Length Miles[3] |
|---|---|---|---|---|
| **Upper Gasconade River HU Code # 10290201** | | | | |
| **Mill Creek (Laclede)** | 4 | 2 | 7.7 | |
| **Elk Creek (Wright)** | 4 | 5 | 1.5 | 14.9 |
| **Beaver Creek HU Code # 10290201-020** | | | | |
| **Beaver Creek (Texas-Wright)** | 5 | 26.5 | 5 | 35.4 |
| **North Fork Beaver Creek (Wright)** | 4 | 1.5 | 4.9 | |
| **Upper Gasconade River HU Code # 10290201-010** | | | | |
| **Whetstone Creek (Wright)** | 5 | 11.5 | 3.5 | 20.3 |
| **Clark Creek (Wright)** | 4 | 1 | 12.3 | |

[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 Region Fisheries personnel.

Table 8. Base-flow (cfs) recession characteristics. The average rate of decrease of stream runoff during periods of no precipitation. Recession data from the period of May through October (Skelton 1970).

| GAGE NO. STREAM, SITE | PERIOD OF RECORD | MINIMUM MEASURED FLOW | TIME, IN DAYS | | | | |
|---|---|---|---|---|---|---|---|
| | | | 0 | 10 | 20 | 30 | 40 |
| **6-9277 Gasconade River, Nebo** | 1942, 1944-47, 1952, 1962-64, 1967 | 26 A B | 45 45 | 32 23 | 22 13 | 16 - | — |
| **6-9277.5 Osage Fork, Orla** | 1953, 1962-65, 1967 | 17 A B | 34 34 | 26 20 | 19 12 | 15 - | 11 - |
| **6-9278 Osage Fork, Drynob** | 1942, 1944-47, 1952, 1953, 1956, 1962-67 | 12 A B | 38 38 | 28 21 | 20 12 | 15 - | 11 - |
| **6-9280 Gasconade River, Hazelgree n** | 1930-67 | 18 A B | 100 100 | 68 46 | 45 23 | 31 - | 21 - |
| **6-9284.5 Roubidoux Creek, Waynesvill e** | 1942-43, 1945-47, 1952, 1062-65, 1967 | 3.9 A B | 22 - | 9.0 - | 4.0 - | 2.2 - | — |
| **6-9285 Gasconade River, Waynesvill e** | 1915-67 | 44 A B | 200 200 | 120 84 | 82 49 | 60 - | 48 - |
| **6-9301 Spring Creek, Spring Creek** | 1953, 1961-65, 1967 | 12 A B | 28 28 | 21 18 | 17 12 | 14 - | — |
| **6-9309 Little Piney Creek, Yancy Mills** | 1953, 1962-65, 1967 | 0.2 A B | 12 12 | 3.0 1.0 | 0.8 0.2 | 0.2 - | — |
| **6-9317 Beaver Creek, Newburg** | 1961-65, 1967 | 1.8 A B | 4.0 4.0 | 2.5 1.8 | 1.6 1.1 | 1.2 - | — |
| **6-9333 Mill Creek, Newburg** | 1955-57, 1961-65, 1967 | 5.6 A B | 8.0 8.0 | 6.0 5.0 | 5.0 4.0 | 4.2 - | — |
| **6-9320 Little** | 1929-67 | 24 A B | 50 50 | 37 31 | 30 23 | 25 - | — |

| GAGE NO. STREAM, SITE | PERIOD OF RECORD | MINIMUM MEASURED FLOW | TIME, IN DAYS | | | | |
|---|---|---|---|---|---|---|---|
| | | | 0 | 10 | 20 | 30 | 40 |
| **Piney Creek, Newburg** | | | | | | | |
| **6-9335 Gasconade River, Jerome** | 1924-67 | 254 A B | 600 600 | 485 415 | 420 325 | 335 255 | 370 275 |
| **6-9340 Gasconade River, Rich Fountain** | 1923-59 | 275 A B | 650 650 | 550 485 | 480 390 | 425 335 | 380 300 |

Row A = average recession rate; Row B = maximum recession rate (used during long periods of extremely hot summer weather when evapotranspiration rates are excessive).

Table 9. Annual mean discharge and estimated magnitude and frequency of annual low flow. Period of record is listed except where footnoted (MDNR 1996, USGS 1998).

| GAGE NO. STREAM | SITE | PERIOD OF RECORD | DISCHARGE (CFS) | | | 7-DAY LOW FLOW | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Annual Mean | Maximum Annual Mean | Minimum Annual Mean | Q2 | Q10 | Slope Index (Q2/Q20) | |
| **06932000 Little Piney Creek** | Newburg, MO. | 1929-98 | 165 | 391 | 47 | 41[1] | 25[1] | Q20 | |
| **06933500 Gasconade River** | 1903-06, 1923-98 | Jerome, MO. | 2663 | 6491 | 544 | 470[2] | 320[2] | 299[3] | 1.57 |
| **06934000 Gasconade River** | 1921-59, 1986-98 | Rich Fountain | 3112 | 6560 | 629 | 520[4] | 330[4] | | |
| **Roubidoux Creek** | Ft. Wood | 1964-71 | 4.5 | 1.5 | | | | | |
| **Beaver Creek** | nr. Rolla | 1949-54 | 5900 | 0.3 | 0.1 | | | | |
| **06927800 Osage Fork** | Dry Nob | 1962-81 | 38800 | 7.2 | 27 | 15 | | | |

Period of Record (USGS) -[1]1928-1991, [2]1923-91, [3]1905-98, [4]1959-91

Table 10. Flood frequency data from stream gaging stations in the Gasconade River basin (Hauth 1974).

| GAGE NO. STREAM SITE | BASIN AREA ($MI^2$) | SLOPE (FT/MI) | MAGNITUDE OF FLOOD IN CFS FOR YEARS | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 2 | 5 | 10 | 25 | 50 | 100 |
| **06928000 Gasconade River, Hazelgreen** | 1,250 | 3.97 | 23,600 | 44,800 | 60,400 | 80,900 | 96,200 | 111,000 |
| **06928500 Gasconade River, Waynesville** | 1,680 | 3.18 | 23,400 | 41,200 | 53,600 | 69,200 | 80,700 | 91,800 |
| **06931000 Beaver Creek, Rolla** | 13.7 | 39.5 | 1,920 | 3,110 | 3,890 | 4,850 | 5,530 | |
| **06931500 Little Beaver Creek, Rolla** | 6.41 | 65.6 | 1,240 | 2,340 | 2,430 | 5,280 | 6,060 | 6,800 |
| **06932000 Little Piney Creek, Newburg** | 200 | 14.0 | 6,760 | 13,400 | 18,200 | 25,100 | 30,300 | 35,400 |
| **06933500 Gasconade River, Jerome** | 2,840 | 3.01 | 31700 | 55500 | 72000 | 92800 | 108000 | 123000 |
| **06934000 Gasconade River, Rich Fountain** | 3,180 | 2.68 | 29400 | 48100 | 60400 | 75600 | 86400 | 96700 |

# Water Quality

## Beneficial Use Attainment

All classified streams within the Gasconade River watershed are designated as warm-water aquatic life protection and fishing, and livestock and wildlife watering (MDNR 1994). Additional designations are assigned to individual streams and to tributaries of the main stem Gasconade River. The main stem Gasconade River, approximately 271.0 miles from the mouth to headwaters in Wright County, is classified with aquatic life protection and fishing (AQL), livestock and wildlife watering (LWW), cool water fishery (CWF), whole body contact recreation (WBC), boating and canoeing (BTC), and drinking water supply (DWS). Little Piney Creek has all of the same uses as the main stem Gasconade River except drinking water (DWS) for six miles of stream in Phelps County. In addition, the Little Piney Creek has a cold-water fishery (CWF) designated use for approximately 20 discontinuous miles in Phelps County. Another major tributary, Roubidoux Creek, has all of the same uses as the main stem Gasconade River except drinking water (DWS) for 38 miles of stream from Phelps to Texas counties. An additional four miles of stream in the Roubidoux Creek main stem are designated for cold-water sport fishery (CWF) uses. Spring Creek is also designated as a cold-water sport fishery (CWF) for 6.5 miles from the mouth. Lastly, Mill Creek in Phelps County has a cold-water sport fishery for five miles to Yelton Spring.

There are a number of municipal sewage discharges to receiving streams in the watershed that have the potential to affect designated uses. Several discharges that have been identified by the Missouri Department of Natural Resources have the potential to impact water quality during low flow conditions. The City of Mountain Grove's Waste Water Treatment Facility, City of Waynesville Waste Water Treatment Facility, Newburg Waste Water Treatment Plant, Niangua Municipal Waste Water Treatment Facility, and Rolla-Vichy Road Waste Water Treatment Plant and Rolla SW Waste Treatment (see Point Source Pollution subsection) have the potential to threaten aquatic life and fishing designation with municipal treated sewage for several miles downstream of the respective receiving stream (MDNR 1984, 1997).

Other threats to beneficial uses are point and non-point source pollutants. Although water quality in the area is good, activities at the Fort Leonard Wood Army complex have the potential to affect Roubidoux Creek with non-point source pollution. This same general area has numerous small sewage treatment facilities that have been earmarked by the Missouri Department of Natural Resources as a threat to local groundwater between Fort Leonard Wood and the Gasconade River. Numerous SALT projects in the Upper Gasconade River watershed are addressing nutrient problems that have plagued these areas for several years, the source of the problem being cattle manure (see Land Use Section). Finally, sand and gravel mining in sensitive watersheds has the potential to impact fish spawning areas and the cool- and cold-water fisheries (see Land Use Section, Mining).

## Outstanding State Water Resources

Sensitive areas as defined by the MDNR State Water Quality Standards include watersheds that are state outstanding water resources. Little Piney Creek, for 25 miles from the mouth to Section 21, Township 35N, Range 8W, has been designated an Outstanding State Water Resource in Missouri.

In the Missouri Unified Watershed Assessment Final Report, September 28, 1998, the Missouri Watershed Assessment Steering Committee, composed of the University of Missouri and federal and state government agencies, identified watersheds that did not meet clean water and other natural resource goals. Each United States Department of Interior Geological Survey (USGS) 8-digit Hydrologic Unit (HU) was prioritized using a numerical ranking system (Final Missouri Unified Watershed Assessment Map). Each HU was scored based on 21 data criteria, selected because the importance and data availability.

According to this assessment, Category I watersheds are in need of protection because of water bodies on the 303(d) list or degraded aquatic system conditions, and category II watersheds have no 303(d) pollutant discharges and have neither moderate nor severe biological impairment nor loss of wetlands.

The Lower Gasconade River watershed (HU# 10290203) is considered a Category II watershed; therefore, it is low priority for future watershed restoration efforts. On the other hand, the Upper Gasconade River watershed (HU# 10290201) is a Category I watershed. In a water quality priority ranking system (zero points as the lowest and 227 points as the highest ranking watershed), the upper watershed scores 115 points for the long-term watershed restoration schedule, although the Upper Gasconade River watershed did not score high enough for immediate restoration.

Springs make important contributions to the river flow and are sources of cold and cool water refuge to fish. Spring water chemistry in the Gasconade River watershed is calcium magnesium bicarbonate, which is derived from the local dolomitic geology (Vineyard 1982). Hardness ranges, depending on the spring and geology, from 135 to 300 mg/l as calcium carbonate.

The Gasconade River watershed, including the Big Piney River, has 76 reported springs (Vineyard 1982). Several springs in the watershed remain undocumented. According to Vineyard (1982), the Gasconade River watershed has one of the largest concentrations of big springs in the state. Most significant springs are found in the middle and narrow portion of the watershed (Figure 7). The dolomite formations in the area are conducive to the formation of springs.

A major concentration of springs is found in the Little Piney Creek watershed (Figure 10). Yancy Mills Spring (Table 11) and Piney Spring yield about 1.9 and 3.2 million gallons per day (mgd), respectively, and are major suppliers to cold-water stream segments (shown on Figure 16 & 17 of the Habitat Section). These stream segments were assessed by MDC Fisheries Research for their potential to support rainbow trout populations. These segments were selected based on their ability to produce thermal refuge to trout during low flow periods.

Several other stream segments receive cold water from springs. Roubidoux Spring discharges approximately 37.7 mgd of cold water to Roubidoux Creek (Table 11). Mill Creek has a number of springs in its watershed. The largest spring in Mill Creek's watershed is Wilkins Spring, which discharges approximately 3.7 mgd (Figure 10). Several smaller springs include Mill Creek Camp Spring and Ousley Creek Spring.

Dye-trace techniques are used to provide evidence of hydraulic connectivity between groundwater recharge areas and groundwater discharge points, such as springs. The Big Piney River, Roubidoux Creek, Gasconade River, and several of their tributaries were the perennial stream detection locations. Historically, the losing portion of Roubidoux Creek was identified as the groundwater recharge area for Roubidoux Spring. In the July 6, 1995 injection conducted by the USGS, losing stream Hurd Hollow, tributary to Roubidoux Creek, was identified as an additional recharge area for Roubidoux Creek. The dye travel time was estimated to be 8-15 days. Based on historical dye tests, the probable catchment area for several springs is illustrated in the water resources report (Imes et al. 1996). Furthermore, the Imes et al. water resources report contains further information about other dye tests that cannot be covered in the scope of this inventory.

Surface water quality is collected at Gage Station # 06930800 on the Gasconade River above Jerome, MO by the USGS. The period of record for this station is from January 1978 to the current year.

Selected ranges for water quality parameters for water years 1978, 1983, 1988, and 1998 are presented for the Gasconade River in Table 12. During this period water temperature reached a maximum of 34EC on August 11 and 17, 1980, which exceeded the state standard of 32.2EC for warm-water fish and as low as 0.0EC during winter. In the selected water years listed in Table 12, temperature did not exceed the state standard for cold-water or warm-water fish. Specific conductance reached a daily maximum of 588 microsiemens per centimeter (um/cm) on September 23, 1981, and a low of 132 um/cm on November 8, 1996. Over the past 20 years, specific conductance rarely fell below 240 um/cm or exceeded 360 um/cm. Some of the major ions that constitute conductance are the dissolved Mg, Ca, and HCO3 ions. A dynamic chemical equilibrium exists with the cations and the anions that constitute the hardness of the water. Because of the karst geology of the Gasconade River watershed, hardness is relatively high (130-200 mg/l as CaCO3 over the 20-year period). This hardness affects the ability of soap to lather, thus the derivation of the term.

Nitrate in drinking water supplies may reduce the oxygen carrying capacity of the blood (cyanosis) if ingested in sufficient amounts by infants less than six months of age. The EPA maximum contaminant level (MCL) and the Missouri State Standard for nitrate is 10 mg/l. Nitrate levels in the Gasconade River watershed have not exceeded state standards during the collection period of 1978-98.

A maximum of 200 fecal coliform colonies/100ml of water is the standard for whole-body-contact recreation (swimming) in Missouri. The gage station at Jerome exceeded the state limited for fecal coliform in 1978 and 1988 with 1,900 colonies/100ml and 680 colonies/100ml, respectively. Both fecal coliform and fecal streptococci are found together in water. The presence of one bacterium will indicate the presence of the other. No state standard is listed for fecal streptococci. When levels exceed the state standard, contamination could be from two sources: human or animal (Eubank et al. 1993). Because levels of coliform were much greater than streptococci, a human source may have been the cause in 1978. In 1988, levels of streptococci were far greater than levels of coliform, which may indicate the presence of animal contamination.

## Health Advisories, Fish Kills, and Contamination Levels

Health advisories from the Missouri Department of Health, working in conjunction with the Missouri Department of Conservation, Missouri Department of Natural Resource, and the EPA to monitor fish tissue chemical contaminants, state that fish are safe to eat within the Gasconade River watershed. Fish kills and pollution investigations are accomplished through cooperative effort of the Missouri Department of Conservation and the Department of Natural Resources.

The Gasconade River, one of the last free-flowing rivers contained entirely in the Missouri, has the dubious status of having suffered the largest pipeline oil spill in the nation. The oil pipeline break that occurred December 24, 1988 poured over 863,000 gallons of crude oil into Shoal Creek, and eventually to the Gasconade River and the Missouri River (Table 13). Surveys and studies of the pollution effects were conducted on birds, reptiles and amphibians, mussels, benthic macroinvertebrates, larval and adult fish populations, sediment toxicity, tissue contamination, fish flesh palatability (Duchrow 1992). The total cost to Shell Oil Company was 22 million dollars for fines, environmental cleanup, and federal allegations. No fish were killed at the time of the pollution event.

Hog manure contaminated Cedar Creek in April of 1990, killing an estimated 43,118 organisms (Table 13). During biochemical decomposition, manure uses oxygen, creates ammonia, and thus, can be toxic in high concentrations to fish.

The MDNR and the United States EPA maintain a fish tissue contaminant database. MDNR and the United States EPA analyzed whole body samples of river redhorse, common carp, sunfish, largemouth bass, black redhorse, and black sucker for fish tissue contaminant levels within the Gasconade River from 1979 to 1994 and in 1998 (Table 14). No fish sampled were beyond action levels during the given time period. Missouri Department of Conservation (MDC) supplied fillets of requested fish in 1989 and in 1998. (Table 14).

Separate fish tissue contaminant sampling was performed by MDC during 1994, 1996, and 1997 on sites within Missouri. No fish tissue samples were taken from the Gasconade River watershed in 1994 and 1996. However, on a statewide basis, Chlordane and DDE were detected in 80% and 94% of the samples, respectively. In addition, mercury was the most frequently found heavy metal (Buchanan 1995). Food and Drug Administration action levels for Chlordane are 0.3 mg/kg. Food and Drug Administration and the World Health Organization (WHO) have identified action levels for lead as 0.3 mg/kg, mercury as 1.0 mg/kg, and PCBs as 1.0 mg/kg. Several inch groups of carp, suckers, and bass were collected from the Gasconade River at Highway 50 for tissue contaminant sampling in 1997 (Buchanan 1998). Processed in 1998, fish tissue samples were not above the action limits, although mercury, dieldrin, chlordane, and lead were found in the samples (Table 14).

Water use refers to "water used for any purpose" (MDNR 1986). Total water use in Missouri exceeded 8.65 trillion gallons in 1993 (Ducharme and Todd 1996). All classified streams within the Gasconade River watershed are designated as warm-water aquatic life protection and fishing (AQL), and livestock and wildlife watering (LWW). Table 15 lists the major water uses for counties within the Gasconade River watershed.

Public water supply with river intakes are few within the Gasconade River Watershed. The only river intake is within the Big Piney River watershed (MDNR 1986). The remaining public water is supplied by groundwater. Safe Drinking Water Information System (SDWIS) within the Lower Gasconade River watershed (HU# 10290203) and the Upper Gasconade River watershed (HU# 10290201) lists municipal drinking water facilities regulated by EPA.

In the 1974 Missouri Stream Pollution Survey, Frank Ryck noted that the Gasconade River watershed was one of the least polluted river systems in Missouri (Ryck 1974). However, at that time water quality was being impaired by point source discharges to the Big Piney River, a tributary that influences the Lower Gasconade River watershed, from several sources. Fort Leonard Wood (FLW) area has several losing streams that provide flow to springs. For example, Ryck (1974) noted that the FLW sewage treatment plant was discharging to Dry Creek, a losing stream tributary to the Big Piney River. At that time Shanghai Springs, which receives flow from Dry Creek, was being contaminated by sewage.

Although conditions have improved since this report, FLW area with its many losing streams was reported to have several poorly constructed sewage treatment facilities that could impair water quality (MDNR 1994b). The most recent sampling of Shanghai Springs by the USGS in 1995 showed probable effects from septic contamination (Imes et al. 1996). Also, the USGS noted that Shanghai Springs had larger than background concentrations of NA, CL, NO2 and

NO3, NH3, and SO4. The USGS also verified, using dye tracings, that the probable catchment area for Shanghai Springs extends into Fort Leonard Wood Military Reservation portion of Roubidoux Creek, especially Smith Branch and Bard Hollow Creek.

During low flow conditions, several point source discharges have the potential to impact water quality for several miles downstream. A 1.2 million gallon per day (mgd) discharge from the City of Mountain Grove affects about one mile of receiving stream (MDNR 1984, 1997). Also, a discharge of smaller size from the City of Waynesville, listed on the Permit Compliance System, affects about one-half mile of Roubidoux Creek. Other discharges include the Newburg, Niangua, the Rolla Vichy Road, and Rolla SW waste water treatment plants that have the potential to affect between 0.2-0.5 miles of stream (MDNR 1984, 1997).

Improvements in the chemical composition of discharges to receiving streams are achieved through monitoring and sewage treatment upgrades. According to Ryck (1974), Waynesville Waste Water Treatment Facility (WWTF) was impacting Roubidoux Creek, and serious algae growth was developing downstream of the discharge. As a result, upgrades to the plant were made. In 1987 and 1995, the water pollution survey conducted by the Missouri DNR, Waynesville WWTF was not impacting Roubidoux Creek (MDNR 1984, 1997).

CAFOs are agricultural enterprises that keep and raise animals in confined situations. CAFOs congregate animals, feed, manure and urine, dead animals, and production operations on a small land area. Feed is brought to the animals rather than the animals grazing or otherwise seeking feed in pastures or fields.

CAFOs can pose a number of risks to water quality and public health, mainly because of the amount of animal manure and waste water they generate. Manure and waste water from CAFOs have the potential to contribute pollutants such as nutrients (e.g., nitrogen, phosphorus), sediment, pathogens, heavy metals, hormones, antibiotics, and ammonia to the environment. Within the Gasconade River watershed, 22 CAFOs (Table 17) can be found in Gasconade, Laclede, Maries, Texas, Webster, and Wright counties (MDNR 1999). The waste types for all CAFOs, as defined by the Missouri Department of Natural Resources, are from the dairy milking or cow, hog, poultry, and beef feeding operations. Several dairy-milk operations are located in the Upper Gasconade River watershed, especially in the vicinity of Beaver Creek, West Piney Creek, and Whetstone Creek. The hog operations are found in both the Upper Gasconade River watershed and the Lower Gasconade River watershed.

All watersheds defined as critical watersheds by the MDNR in the Clean Water Commission, Chapter 6—Permits, Title 10 CSR 20-6.3 paragraph 9 and Section C are excluded for construction of Class IA concentrated feeding operations (MDNR 1996). Within the Gasconade River watershed, a river drinking water intake is within the Big Piney River watershed (MDNR 1986), which is considered a critical watershed and excludes it from CAFO construction under the above rule.

## Pipeline Oil Spill

Several pipelines cross the Gasconade River watershed, and if ruptured, they could cause harmful effects on the environment. On December 24, 1988 a break in a 22-inch pipeline operated by Shell Pipe Line Corporation poured an estimated 863,000 gallons of crude oil into Shoal Creek and into approximately 65 miles of the Gasconade River. A major evaluation of the Gasconade River took place as result. The effects of the oil spill were monitored by studying fish and benthic invertebrate communities and by testing the toxicity of the stream sediment.

Several studies were conducted to determine the spill's impact on the fish of the Gasconade River. William Pflieger, MDC Ichthyologist, evaluated the fish fauna of the Gasconade River by seining six sites on the River in 1989. These collections were compared to samples collected during the period between 1942 and 1980. Species composition of the lower Gasconade River has been relatively stable during the 1942 - 1989 period. However, spotted bass became established in the 1970s. Faunal differences between 1980 and 1989 collections involved an increase in species richness, a reduction in species diversity, and changes in relative abundance of some species. These changes probably are natural responses to year-to-year fluctuations in environmental conditions that affect recruitment, and none were attributed to impacts of the oil spill (Pflieger 1990).

Another study evaluated the adult fish community after the oil spill. George Kromrey, MDC Fisheries Regional Supervisor, sampled four sites, one above and three within the oil spill area during the same week in September 1989. Species diversity was assessed using Simpson's Diversity Index, abundance using catch per unit effort, and condition using length-weight relationships. Statistical analysis revealed few significant differences between pools at each site or among the four sites. The study demonstrated the presence of a diverse and healthy population of fish below the oil spill site (Kromrey 1990).

Collections of the benthic invertebrate community and tests of the toxicity of the stream sediment were done to determine the effects of the oil spill. Preliminary invertebrate samples were collected in March 1989 by the MDNR, and as a result of this sampling, a one year study was started in July 1989 by the Fisheries Contaminant Research Center. Using kick net samples from riffle habitats and Ponar grab samples from backwater habitats upstream and downstream from the spill site, abundance, taxa richness, and total number of pollution tolerant and intolerant invertebrates were quantified (Finger et al. 1990).

Water quality and total petroleum hydrocarbons (TPH) of stream sediment were collected. The study indicated a change in abundances and community composition of the riffle community that may have occurred immediately after the oil spill, but a May 1990 flood likely impacted both riffle and backwater habitats. Therefore, no effects to the riffle benthic community were attributed to the oil spill. In backwater areas, some invertebrate groups showed reduced abundances. These areas had longer retention of TPH than riffle habitats, but concentrations of TPH decreased over time.

Non-point source (NPS) pollution is the leading source of surface water and ground water quality impairments. Runoff from farms, mining operations, construction sites, forest operations, residential septic tanks, impervious surfaces in urban areas are considered non-point pollutant sources. At the Jerome USGS Gage Station in Phelps County and the Rich Fountain USGS Gage Station (Vandike 1995), the annual runoff is 12.49 inches and 12.66 inches, respectively.

In a 1978 Water Quality Survey report by the Missouri Department of Conservation, the Osage Fork of the Gasconade River was noted to be affected by excessive aquatic plant growth and habitat reduction (Duchrow 1978). In the same survey, the author observed reductions in habitat quality on the Gasconade River from NPS pollution at the Highway 89 crossing for 1 mile and also at the Route J crossing for 8 miles. Today, cursory observation of these sites indicates that the watershed problems associated with the tributary streams near Highway 89 are still loading nutrients. The Route J and Route D area has been under bridge construction for several years and conditions in the area have not improved. Increased fine sediments and loss of riparian corridor from road and bridge construction are symptoms of the degraded water quality.

More recently, the 1997 DNR Water Quality Basin Plan identified numerous dairy calf, milking, or feeding operations as sources of potential non-point source pollution areas in Wright, Webster, Texas, and Gasconade counties. Within this same area (Upper Gasconade River, Roubidoux Creek, and Woods Fork) the NRCS has a Special Area Land Treatment project to reduce nutrients from these operations.

Also, several hog operations in Wright and Laclede counties have the potential to impair water quality (MDNR 1997).

Urban development can contribute to the sediment supply when erosion control structures are not used properly during construction. A construction site in Waynesville in March 1997, discharged muddy water into a tributary of Roubidoux Creek following rainfall events (Duchrow 1997). Investigation by MDC Fisheries Division personnel determined that developers at the construction site were negligent in the use of Best Management Practices (BMPs) to reduce erosion during rainfall events. In this incident, developers were required to comply with BMPs and the Missouri Clean Water Law.

## Sanitary Landfills

Sanitary landfills permitted by MDNR can be a source of water pollutants if not properly maintained by the owner. The only landfill permitted in the Upper Gasconade River watershed is found within Wright County near Hartville. No active landfills are found in the Lower Gasconade River watershed. No landfill-related water quality problems from active sites are noted by the Missouri Department of Natural Resources, however several closed landfills and inactive landfills are being monitored by the MDNR. Two landfills, the Wright County Landfill and the McDowell Landfill, in Wright and Phelps counties, respectively, are potential NPS pollution areas (MDNR 1997). No new landfills are proposed by the MDNR within the upper or lower watersheds (MDNR 1999b).

The Chemical Sites Database (CARES 1999a) is a combination of 105 databases that were reviewed for the presence of the 54 chemicals monitored by MDNR. Staff at the Center for Agricultural, Resource and Environmental Systems (CARES) made trips to the regional offices of MDNR, and the regional staff located the sites on USGS 1:24,000 scale topographic maps. CARES digitized the locations and entered the attribute data into ESRI database software. Sites that had an area of greater than 10 acres were put in this map layer, all other were put in the SCHEMCOV point layer.

The chemical sites (from CARES) that are known to exist in the Gasconade River watershed are potential sources of non-point pollution. Approximately 35 sites are known to exist in the Gasconade River watershed. The highest concentration can be found in Texas County of the Upper Gasconade River watershed.

## 303(d) Pollutant Discharges

Section 303(d) of the Federal Clean Water Law requires that states identify those stream segments lacking proper pollution control measures. In addition, Total Maximum Daily Load (TMDL) studies are needed for those waters to determine measures needed to remove the water quality impairment. In 1998, two streams in the Upper Gasconade River watershed were identified by the Missouri Department of Natural Resources as Section 303 (d) Category 1 streams (Table 16). In Wright County, a 2-mile segment of Whetstone Creek was ranked high for TMDL studies because of the BOD problems. In addition, a 0.1-mile segment of Little Beaver Creek was affected by Rolla South West WWTF, but was lower in priority for TMDL studies.

Table 11. Location and discharge of major springs ( >1,000,000 gal/day) into the Gasconade River watershed. Rate of flow represents records for dates ranging from 1924-72 (Vineyard and Feder 1982).

| Spring | Nearest Town/County | Twnshp-Rge-Sec | Rate of Flow | |
|---|---|---|---|---|
| | | | Sec. Ft. (cfs) | 1,000 gal./day |
| **Bartlett Mill** | Waynesville/Pulaski | 36N-12W-16-SWSE | 15.6 68.0 0.31 | 10,100 44,200 200 |
| **Boiling** | Pulaski | 32N-10W-24-SWSW | 65.0 | 42,000 |
| **Roubidoux** | Pulaski | 36N-12W-25-NENW | 58.3 192.0 | 37,700 124,000 |
| **Yancy Mills** | Phelps | 36N-8W-32-SESW | 1.5 3.0 | 1,000 1,960 |
| **Lane Spring** | Phelps | 36N-8W-32-SWNW | 17.9 | 11,600 |

Table 12. Selected water quality data for the Gasconade River watershed at Phelps County, Hydrologic Unit #10290203, Gage station #06930800 for water years (USGS 1978 - 1998; Code of Regulations 10 CSR 20.7). Mean values are presented withyear.

| Parameter | State Standard of Uses | | | | Water Year (means) | | | |
|---|---|---|---|---|---|---|---|---|
| | I | III | VI | VII | 1978 | 1983 | 1988 | 1998 |
| Water Temperature (°C) | 32.2° Max[1] 28.9° Max[2] | | | | 2.0-28.0 | 5.0-28.0 | 2.5-26.0 | 5.0-25.0 |
| Specific Conductance (us/cm) | | | | | 264.0-360.0 | 264.0-351.0 | 240.0-338.0 | 277.0-340.0 |
| $O^2$, Dissolved (mg/l) | 5[1]6[2] | | | | 6.1-15.8 | 5.6-12.4 | 6.8-14.2 | 6.0-11.8 |
| pH | # | | | | 7.7-8.3 | 7.8-8.3 | 7.9-8.3 | 7.9-8.2 |
| Hardness, Total (mg/l $CaCO^3$) | | | | | 160-190 | 130-190 | 120-200 | 150-170 |
| Calcium, Dissolved (mg/l as Ca) | | | | | 29-39 | 27-36 | 24-40 | 31-34 |
| Magnesium, Dissolved (mg/l as Mg) | | | | | 19-24 | 16-23 | 14-25 | 17-19 |
| Fluoride, Dissolved (mg/l as Fl) | | 4 | | 4 | <0.1-0.2 | <0.1 | <0.1-0.2 | <0.1 |
| Sulfate, Dissolved (mg/l as $SO^4$) | | 250 | | | 3.9-11 | 6.3-9.2 | 5.5-13.0 | 4.7-7.0 |
| Nitrogen, Total Ammonia (mg/l as $NH^4$) | | | | | <0.01-0.1 | — | <0.01-0.06 | — |
| Nitrate-N (mg/l N) | | 10 | | 10 | .08-.81 | .11-.33A | | .01-.05B |
| Phosphorus, Total P (mg/l as $PO^4$) | | | | | .01-.12 | .01-.04 | <.01-.09 | - |
| Coliform, Fecal (colonies/100ml) | | | 200 | | 4-1900 | 1-200 | 1-680 | 2-180 |
| Streptococci, Fecal (colonies/100ml) | | | | | 4-1600 | 21-540 | <1-4200 | 1-77 |
| Iron Dissolved (mg/l FE) | | | | | 20-30 | 5-50 | <3-10 | <10-31 |

I: Protection of aquatic life. [1]For warm-water fisheries.
III: Drinking water supply. [2]For cold-water fisheries.
VI: Whole-body-contact recreation. # $H_2O$ contaminants should not cause
VII: Groundwater pH fall out of 6.5-9.0 range.
[A]1981 water year B1997 water year

Table 13. Fish kills for the last 10 years in streams of the Gasconade River watershed sorted by year within county (Missouri Department of Conservation Environmental Services and East Central files).

| Date | Stream Name | CNTYTNSP-RGE-SEC | Discharge Substance | Number of Organisms | Fine $ |
|---|---|---|---|---|---|
| **12-24-88** | Shoal Creek/Gasconade River | Maries-40N-8W-29 | Oil | undetermined | 7 million |
| **08-28-89** | Woods Fork | Wright-29N-15W-01 | Unknown | 186 | 261.10 |
| **04-28-90** | Cedar Creek | Osage-44N-08W-18&19 | Hog Manure | 43,118 | 3,555 |

Table 14. Contaminants in fish tissue (mg/kg) within sampling sites of the Gasconade River. Sample sites 3 were at Jerome, MO (1), Mt. Sterling, MO (2), Gasconade River @ Highway 50 (3).

| YR | Site[3] | Species | RF[1] | P[2] | Chlordn | Dieldrn | DDT/MTB | PCBs | PB | HG |
|---|---|---|---|---|---|---|---|---|---|---|
| **79** | 1 | Red | 12 | W | 0.052 | 0.008 | | Trace | | 0.15 |
| **79** | 1 | Carp | 12 | W | 0.026 | Trace | | Trace | | 0.17 |
| **79** | 1 | L Bass | 12 | W | 0.025 | 0.005 | | Trace | | 0.430 |
| **79** | 1 | Red | 12 | W | 0.041 | 0.009 | | Trace | | 0.1 |
| **79** | 1 | Sun | 12 | W | 0.017 | 0.005 | | Trace | | 0.14 |
| **79** | 1 | Red | 12 | W | 0.005 | 0.010 | | Trace | | 0.15 |
| **80** | 1 | Red | 11 | W | ND | ND | ND | ND | | 0.04 |
| **81** | 1 | Carp | 11 | W | ND | ND | ND | ND | | 0.05 |
| **82** | 1 | Red | 11 | W | ND | ND | 0.024 | ND | | 0.06 |
| **83** | 1 | Carp | 11 | W | 0.23 | 0.10 | 0.077 | 0.25 | | 0.03 |
| **84** | 1 | B Red | 11 | W | ND | ND | 0.030 | ND | | 0.07 |
| **84** | 1 | B Red | 11 | W | ND | ND | 0.014 | ND | | 0. 06 |
| **84** | 1 | B Red | 11 | W | ND | ND | 0.009 | ND | | 0.06 |
| **85** | 1 | G Red | 11 | W | 0.04 | ND | ND | ND | | 0.06 |
| **85** | 1 | B Red | 11 | W | 0.05 | ND | ND | ND | | 0.05 |
| **86** | 1 | B Red | 11 | W | 0.038 | 0.041 | 0.27 | 0.075 | | |
| **87** | 1 | B Red | 11 | W | 0.02 | 0.007 | 0.033 | LT 0.183 | 0.088 | |
| **88** | 1 | G Red | 11 | W | 0.027 | 0.012 | 0.053 | LT 0.210 | 0.306 | |
| **89** | 2 | G Red | 18 | F | LT 0.20 | | | LT 0.050 | | |
| **89** | 2 | CH Cat | 18 | F | 0.109 | | | LT 0.050 | | |
| **89** | 2 | CH Cat | 18 | F | 0.062 | | | LT 0.050 | | |
| **89** | 1 | B Red | 11 | W | 0.036 | LT 0.007 | 0.033 | LT 0.120 | | 0.288 |
| **90** | 1 | Carp | 11 | W | 0.04 | 0.019 | 0.024 | LT 0.160 | | 0.092 |
| **92** | 1 | B Red | 11 | W | ND | ND | ND | ND | LT 0.500 | 0.153 |
| **93** | 1 | G Red | 11 | W | 0.047 | LT 0.002 | 0.038 | 0.060 | LT 0.170 | 0.159 |
| **94** | 1 | B Red | 11 | W | LT 0.03 | LT 0.002 | 0.025 | LT 0.050 | LT 0.170 | 0.074 |
| **94** | 1 | B Red | 11 | W | LT 0.03 | LT 0.002 | 0.035 | LT 0.058 | LT 0.170 | 0.144 |
| **97** | 3 | Carp | 18 | F | LT 0.020 | LT 0.002 | ND | ND | LT 0.01 | 0.144 |
| **97** | 3 | Red | 18 | F | 0.036 | LT 0.002 | ND | ND | LT 0.002 | 0.260 |
| **97** | 3 | Bass | 18 | F | ND | ND | ND | ND | LT 0.01 | 0.494 |

**Levels of Concern:** FDA and the World Health Organization (WHO) have identified action levels for chlordane as 0.3 mg/kg, (HG) mercury as 1.0 mg/kg, and PCBs as 1.0 mg/kg. National Academy of Sciences action levels for DDT, dieldrin, chlordane (sum total)—0.3 mg/kg; and 5 mg/kg for DDT.

[1]RF 11,12=DNR/EPA, 18=MDC; 2P W=Whole, F=Fillet; Species— Red=redhorse, Carp=carp, Sun=sunfish, L Bass=Largemouth bass, B Red=black redhorse,
G Red=golden redhorse, CH Cat=channel catfish, BL Red=black sucker.

Table 15. Major water users (greater than 100,000 gallons of water or more daily) registration summary for counties within the Gasconade River basin. Use totals are shown as 1000 gallons per year rounded to the nearest 1000th. (Reference: Missouri Major Users Database, Missouri Department of Natural Resources, Ducharme and Todd 1996).

| County | Domestic | Municipal | Irrigation | Recreation[1] | Industrial | Fish & Wildlife[2] | Total Water Use |
|---|---|---|---|---|---|---|---|
| **Dent** | | | 43,824 | | | 9,406,780 | 9,450,604 |
| **Gasconade** | | 324,861 | 15,168 | | | | 340,029 |
| **Howell** | 108,280 | 902,367 | | 400 | 10,327 | | 1,021,354 |
| **Laclede** | | 871,335 | | | 96,801 | 7,300,000 | 8,268,136 |
| **Maries** | 1,642 | 27,301 | | 704,000 | 3,690 | | 736,632 |
| **Osage** | | 171,314 | | | | | 12,020,874 |
| **Phelps** | 53,773 | 901,955 | | 2,020 | | 2,595,938 | 3,553,687 |
| **Pulaski** | 1,379,683 | 621,785 | 5,000 | 5,326 | 60,000 | | 2,071,794 |
| **Texas** | 36 | 434,524 | 214,834 | | 206,830 | | 856,224 |
| **Webster** | | 330,170 | 259,584 | | | | 589,754 |
| **Wright** | | 328,898 | | 800 | 11,042 | | 340,742 |
| **Totals** | 1543414 | 4914510 | 538410 | 712546 | 388690 | 19302718 | 392,49,830 |
| **Percent** | 3.9 | 12.5 | 1.4 | 1.8 | 1.0 | 49.2 | 100.0 |

[1]**Recreation:** Water used for recreational purposes, such as swimming and fishing. Water used for aesthetic purposes is also included under the recreational water use category.
[2]**Fish and Wildlife:** Uses which require water for the maintenance of fish and wildlife habitat, as well as subsistence of fish and wildlife populations. Water used for aquaculture is also registered under this category.

Table 16. 303(d) pollutant discharges list by the Missouri Department of Natural Resources in the Final 1998 303(d) List for Missouri. Category 1 recommended Section 303(d) waters required to have TMDLs analysis.

| Water | County | Miles/Acres Affected | Pollutant | Source | Priority for Analysis |
|---|---|---|---|---|---|
| **Little Beaver Creek** | Phelps | 0.1 | NFR | Rolla SW WWTP | Low |
| **Whetstone Creek** | Wright | 2 | BOD | Mountain Grove WWTPs | High |

BOD—Biological oxygen demand
NFR—Non-filterable residue

Table 17. Location of permitted animal waste facilities within the Gasconade River Watershed as of October 1, 1999 (MDNR 1999). * Section is from smallest to largest area.

| Operation Type | Amount of Units | Location Twn-Rng-Sec* | County |
|---|---|---|---|
| **hog operation** | 1,650 | 41N-6W-SWNE 1 | Gasconade |
| **hog operation** | 4,800 | 39-9W-NESE 5 | Maries |
| **hog operation** | 3,200 | 39-10W-NWNW 34 | Maries |
| **dairy milking or cow** | 250 | 29-11W-NWNW 3 | Texas |
| **dairy milking or cow** | 280 | 33-14-NWSE 36 | Laclede |
| **dairy milking or cow** | 250 | 32-14W-SESE 1 | Laclede |
| **dairy milking or cow** | 300 | 33-15W-SWSW 23 | Laclede |
| **dairy milking or cow** | 200 | 31-16W-NESW 12 | Webster |
| **poultry operation** | 280,000 | 30-16W-NWNE 29 | Webster |
| **poultry operation** | 280,000 | 30-16W-NWNE 29 | Webster |
| **poultry operation** | 280,000 | 30-16-NWNE3 29 | Webster |
| **dairy milking or cow** | 300 | 30-17W-SWSENW 14 | Webster |
| **dairy milking or cow** | 300 | 30-17-SWNE 14 | Webster |
| **dairy milking or cow** | 100 | 30-12W-SWNE 08 | Wright |
| **dairy milking or cow** | 470 | 29-15W-NW 2 | Wright |
| **dairy milking or cow** | 150 | 29-13W-NENE 20 | Wright |
| **hog operation** | 40 | 31-15-NENE 14 | Wright |
| **hog operation** | 3,000 | 31-15-SWSE 11 | Wright |
| **hog operation** | 3,000 | 31-15W-NENE 14 | Wright |
| **hog operation** | 3,000 | 31-15W-NENE 14 | Wright |
| **hog operation** | 3,000 | 31-15W-SWSE 11 | Wright |
| **beef feeding operation** | 500 | 29-12W-SWSE 33 | Wright |

# Habitat Conditions

Historically, the Army Corps of Engineers (COE) maintained the Gasconade River for navigation from the mouth of the river to Jerome, Missouri, or approximately 104 miles of stream (Missouri Department of Natural Resources 1986). According to the Missouri Water Atlas (1986), the Gasconade River has no altered segments, meaning it has been neither channelized nor impounded. The Osage Fork of the Gasconade River is also listed as having no altered segments.

Accelerated stream channel changes are possible consequences of in-channel sand and gravel mining. In-channel mining has the potential to artificially accelerate a stream's natural geomorphic processes by increasing channel slope, water velocity, and sedimentation. A stable stream is in dynamic equilibrium. Gravel improperly removed from a streambed location can result in stream disequilibrium by causing erosion upstream from the nick-point (removal area) and within the nick-point. As the stream seeks new mass-balance equilibrium, the nick-point will eventually erode away and migrate upstream in a process known as "head-cutting" (Patrick, D.M. et al. 1993).

Segments of the Gasconade River and some of its tributaries have been altered by gravel mining activity. Army Corps of Engineer's Regulatory Analysis Management System database, which encompasses the entire Gasconade River watershed, contained 1-25 permits per 11-digit hydrologic unit (COE 1999). The number of sand and gravel site permits was determined for the period of February 1992 - February 1999 (Figure 7). The 8-digit Lower Gasconade River watershed with approximately 500,000 acres had higher densities of permitted sand and gravel sites than the 8-digit Upper Gasconade River watershed with its more than one million acres. Lower gradient and corresponding slower water velocities in the Lower Gasconade River watershed allows more gravel to accumulate in the form of gravel bars, which contributes to the instability of the channel. As demonstrated in the Bourbeuse River Watershed Inventory and Assessment (Blanc 1999), land use and stream reach position in a watershed can influence channel instability; likewise, gravel mining can lead to further stream channel instability. In addition, improperly mined areas may experience side effects that may incur a reclamation liability.

## Stream Gravel Mining Recommendations

The MDNR's Land Reclamation Program strongly encourages that commercial instream gravel miners conduct mining in accordance with the Missouri Department of Conservation's Stream Gravel Mining Removal Guidelines (Missouri Department of Conservation 1991c). These guidelines give general operational recommendations on how, where, and when instream gravel mining should be conducted in order to minimize effects on habitat and biota.

Some essential elements include confining active mining to unconsolidated bars rather than flowing water, leaving buffers around mined areas, restricting damage to streambanks and bank vegetation, preventing the discharge of petroleum products into water. Another operational guideline states that gravel miners should not remove gravel during certain times in several designated reaches to avoid effects on spawning habitats. Prohibiting instream gravel mining seasonally to protect critical spawning habitat is usually incorporated into permits issued by the Army Corps of Engineers for restrictions regulated under Section 404 of the Clean Water Act or by MDNR under Section 401 of the Clean Water Act. Specifically, within the Gasconade River watershed, MDC recommends gravel miners observe seasonal spawning closures within the following times and streams:

1) **November 15 to February 15**—Little Piney Creek, from the mouth of Beaver Creek to the first crossing of Dent County line (Section (S) 16, Township (T) 35N, Range (R) 8W) for 15.8 miles to protect trout spawning habitat, Mill Creek, from the mouth (S20, T37N, R9W) to the mouth of Deep Hollow Creek (S32, T36N, R9W) for 9.0 miles to protect trout spawning habitat, Roubidoux Creek, from the mouth (S14, T36N, R12W) to East Section Line (S6, T35N, R11W) to protect a MDC trout management area; and
2) **March 15 to June 15**—Roubidoux Creek, from the south section line (S3, T34N, R12W) to Highway 32 (S2, T32N, R12W) for 20.2 miles, to protect critical habitat of sensitive endemic aquatic species.

The Missouri Natural Features Inventories are completed for Phelps, Laclede, Pulaski (Ryan 1992), Gasconade, Maries (Currier 1991), Texas, and Wright (Ryan 1993) counties. The objective of the MDC statewide Natural Features Inventory objective 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 in the state natural-areas system, by voluntary landowner agreements, or by allowing informed decisions in sensitive areas.

Within counties of the Gasconade River watershed, identifying sites and adjacent areas involved surveying seven categories: natural communities (undisturbed 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), the Geologic Natural Feature Classification System for Missouri (Hebrank 1989), and the Aquatic Community Classification System for Missouri (Pflieger 1989). Following the classification, biologists graded sites for their natural quality, and ranked sites to provide a means of comparing similar features for the preservation value (Currier 1991; Ryan 1992, 1993). Ranking assignments were: significant, exceptional, and notable. According to Ryan (1992, 1993) and Currier (1991), 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 were not of natural area quality but deserving of some protection. Lastly, notable areas on private land did not merit special management or protection.

The focus of this inventory was to identify high-quality natural communities. In the Currier (1991) survey, Spring Creek Gap Glades Natural Area, owned by MDC and located within Spring Creek Gap Conservation Area (Figure 9), was ranked as significant. The site is 12 acres but is considered the best glade system on Jefferson City Cotter dolomite in the upper Ozarks. The Clifty Creek Natural Area, located within the Clifty Creek Conservation Area, contains exceptional limestone and dolomite cliffs, notable sandstone forests, and a rare dry-mesic chert forest. The entire natural area is ranked as significant.

A total of 14 significant natural communities was identified in the Ryan (1992) survey. In fact, several of these communities were found within a few miles of each other. The US Forest Service (USFS) owns two sandstone glades that are located in Phelps County. The first sandstone glade is a string of glades within close proximity of each other. The second glade, the Kaintuck Hollow sandstone glade, is about 2.5 acres and is near several rare species, an unique forest, and a deep muck fen (Table 18). Contained near this site is an exceptional 15-acre dry-mesic sandstone forests with 100-year-old pines. The deep muck fen, Kaintuck Hollow Fen, is about 10 acres in size but is low quality. The largest of these communities, a mesic bottomland forest, is found on private land and is 30 acres.

Aquatic communities were ranked based on recommendation from William Pflieger of Missouri Department of Conservation (Currier 1991). Currier (1991) commented that the Gasconade River is one of the few unimpounded rivers in the Ozarks and is one of only three rivers in the Mississippi Valley where the anadromous Alabama shad still spawns. Currier (1989) surveyed the Webster County portion of the Osage Fork of the Gasconade River and ranked it as a significant Ozark-Missouri headwater creek and small river that supports numerous sensitive species. In Ryan's 1992 survey of Laclede, Phelps, and Pulaski counties, Little Piney Creek was identified as a notable creek and small river, and Gasconade River and Osage Fork of the Gasconade River were identified as significant small rivers. Multiple sections of the Gasconade River from T37N to T38N, R9W to R10W were listed as a significant large river. In the Ryan (1991) survey of Texas County, Ryan mentioned Roubidoux Creek (T31N-T33N, R11W-R12W) as a significant small creek and headwater Ozark-Missouri stream, supporting a diverse fish fauna. In the same survey of Webster County, once again the Gasconade River was mentioned as a significant large river with numerous endemic fish species. Other portions of the Gasconade River watershed were described in the Natural Features Inventories, some mentioning heron rookeries and others, backwater pools.

Ryan (1992) described other special aquatic communities in the survey. Pulaski County has a large number of springs (Figure 10) and caves. These include two spring branches, Howell Spring and Prewett Spring, and two springs, Boiling Spring and Roubidoux Spring. Ryan noted no disturbance at Howell Spring and moderate plant diversity, but Prewett Spring was grazed. The solution cave was an added feature of the Howell Spring community. Another cave that has a small population of *Myotis sodalis* is Great Spirit Cave, owned by Missouri Department of Conservation. A slough in Pulaski County was described as having 0.6 miles of the old river channel, cliffs, a spring, and wooded streambanks.

One purpose of these surveys was to rank bottomland forests within the respective counties. No bottomland forests were surveyed in the Gasconade River watershed portion of Texas and Wright counties or Webster County, but in the Gasconade River watershed portion, bottomland forests were surveyed in Gasconade, Maries, and Osage counties, three in each county. Only eight bottomland forests were surveyed in the Laclede County, Phelps County, and Pulaski County Natural Features Inventory.

Most bottomland forests were mesic bottomland forest of young to mature second growth and not high quality. Within the Gasconade, Maries and Osage county surveys these bottomland forests were mid-successional and moderately to heavily disturbed communities, which may have included moderate recent disturbance or heavy past disturbance. The sizes ranged from seven to 40 acres. Within the Laclede, Phelps, and Pulaski county surveys, three of the eight survey sites were lightly or heavily grazed. Three of the eight survey sites were recently logged. One of the eight survey sites was the Strawhaun Bottomland Forest that was ranked as significant.

The habitats of some state-listed species are found on sites within the watershed. These sites are identified as information becomes available. Individual state-listed species that located in the watershed are identified in the Rare and Endangered Species subsection.

To control streambank erosion, improve water quality, and establish fish habitat, MDC fisheries biologists use cedar tree revetments, corridor reforestation, streambank re-vegetation, willow staking, and rock blankets (riprap). Table 19 lists some projects in the Gasconade River watershed that make use of these techniques. Eight of the stream improvement sites used the cedar tree revetment technique to stabilize streambank. Cedar tree revetment involves the use of eastern red cedar trees anchored along a streambank to protect the toe of the bank and to slow water velocity (Fantz et al. 1993). This low cost bank stabilization technique involves using refined methodology that must be tailored to the erosion site. Not all streambank erosion sites are conducive to cedar tree revetments because of watershed influences. The numerous projects on Mill Creek make use of a variety of techniques to stabilize streambanks and provide instream habitat on Forest Service as well as private land.

Corridor improvements are an important part of streambank erosion reduction and fish habitat enhancement. The future ecological benefits to the aquatic community are reduced sediment supply, shade from the sun, temperature reductions, and leaf litter inputs for the aquatic food web.

## Stream Habitat Assessment Corridor Conditions

Using Arc/Info (Environmental Systems Research Institute's Geographic Information Systems software), the Gasconade River 1:100,000 scale stream network, and Missouri Resource Assessment Partnership's (MORAP 1997) Phase II Land Use/Land Cover (LULC) individual stream segments were classified by the percentages of surrounding land use types (for GIS methodology contact the Missouri Department of Conservation). For example, stream segments were classified by the ranges of the percentage of the forest class contained within the stream buffer area to identify those segments that had the highest probability of direct exposure of forest to stream a channel (Figure 18 and 20). To highlight the forested corridors within the Lower Gasconade River watershed, the lowest and the highest percentage of forested corridors was, respectively, the Lower Gasconade 11-digit HU at 48.8% and the 11-digit Lower Gasconade River Hills at 55.3%. Values within the Lower Gasconade River HU were probably somewhat higher than the 20-40% forested corridor presented, because within this 90-meter buffer the 8-digit Lower Gasconade River watershed had approximately 5% of the pixels as water (Figure 18). LULC satellite imagery was dated 1992-93 during years of high water, which likely influenced the resulting forested segments.

The entire 8-digit Upper Gasconade River watershed was poorly forested along major segments of its tributaries and main stem compared to the 8-digit Lower Gasconade River watershed (Table 20 and Figure 20). A total of 38.2% of the major segments (main stem river and tributaries segments with permanent flow) within the Upper Gasconade had forested corridors, and 46.1% of the major segments in the Lower Gasconade supported forested corridors. To highlight the forested corridors in the Upper Gasconade River watershed, the lowest and highest percentages were the 11-digit Upper Osage River HU at 38.5% forested corridor and the 11-digit Upper Gasconade River HU at 48.9% forested corridor, which was a spread of 10.4% (Table 20). The Mark Twain National Forest influences the quantity of forested corridors within the 11-digit Upper Gasconade River HU. In reality, its corridor quality was good in comparison to other watersheds (Figure 21).

Corridor quality was determined to assess the stream segments within 11-digit hydrologic units (Figure 19 and Figure 21). While many factors impact the quality of the corridor, stream channel stability, and water quality, forest and woodland land uses improve stream quality because of their soil holding capacity, whereas grassland, cropland, and urban land uses do not improve stream water quality (Jacobson and Primm 1994; Blanc, Caldwell, and Hawks 1998). Grassland, cropland, and urban areas are known to have higher soil erosion and runoff rates. To determine where land uses were influencing corridor quality, the following ratio was developed: (% grassland and cropland and urban)/(% forest and woodland).

The quality of a stream corridor varied as the sum of the percentage of forest and woodland changed with respect to the changes in the sum of grassland, cropland, and urban. As values of the numerator increased and the denominator decreased, the quality of the corridor within the buffer zone declined. These areas were shown as the "poor" ratio values from 5-100%. Conversely, within a 90-meter buffer zone, as grassland and cropland declined and forest corridor increased, this translated into better quality corridors. More poor quality stream segments were found in the tributaries to major order segments. An "acceptable" corridor had, depending on the stream order, 15-35 meters of corridor (Wehnes 1996), which was approximately 17-40 % or greater forest and woodland within the buffer zone. Hence, the quality ratio of "acceptable" had to be within the range of 1.5-5. A quality ratio value of 0.0-1.49 had better corridor conditions and were rated as "good."

The results of the quality ratio show the differences between the 8-digit Upper Gasconade River watershed and the 8-digit Lower Gasconade River watershed. Using the limitations of the 1:100,000 scale stream network, which did not have many 1st- and 2nd-order streams, stream segments within the Lower Gasconade River watershed had 81% (6,752) as good (quality ratio range of 0.0-1.49), another 12.5% (1,041) as acceptable, and the remaining 0.6% (526) of the segments as poor. There were 8,319 stream segments within the Lower Gasconade River watershed and 14,404 stream segments within the Upper Gasconade River watershed that had an average length of 361 meters. The Lower Gasconade River watershed had more good quality segments than the Upper Gasconade River watershed, which had 63.8% (9,199) rated as good, 17.5% (2,518) as acceptable, and the remaining 18.7% (2,687) segments as poor.

Several 11-digit hydrologic units could be targeted for private lands incentive programs. Lower Gasconade River HU below Highway 68 Bridge and the confluence with Spring Creek could be targeted for stream incentive programs (Figure 19). The upper portion of the main stem Little Piney Creek HU has much cropland and grassland that should be surveyed for possible restoration. Third Creek HU has some troubled tributaries that need attention. Second Creek within the Lower Gasconade River Hills has stream segments near the confluence with the main stem Gasconade River that may need attention.

Roubidoux Creek HU has in the past received attention but does merit further emphasis because of its unique combination of land uses (Figure 21). The water quality challenges within this watershed were identified by Imes et al. (1996) in the USGS water quality assessment of the Fort Leonard Wood military base. Groundwater resources are particularly sensitive in this region of the Upper Gasconade River watershed. Within the Upper Gasconade River Tributaries HU, Whetstone Creek and Woods Fork had stream segments with extreme amounts of grassland land uses. Forested corridor was limited in selected portions of both Whetstone Creek and Woods Fork (Figure 21).

Identifying other degraded or healthy streams, narrowing the list of potential causes of degradation within stream segments, and selecting the most pristine or degraded reaches will be done interactively within ArcView by MDC East Central Region personnel. Measures to be taken by personnel within the Gasconade River watershed to improve riparian corridors include offering financial assistance to help landowners fence cattle from riparian corridors and revegetate riparian zones. Studies have shown that fencing cattle from a stream and its riparian corridor can reduce soil losses (Ownes et al. 1996, Magilligan and McDowell 1997). Researchers observed two consistent stream channel changes with the restoration of riparian corridor: a decrease in channel widths and development of more channel pools.

The researchers concluded that the regrowth of streambank vegetation added stream channel roughness, which increased channel scour holes or pools during floods.

## Land Use Conditions

Using Arc/Info Geographic Information Systems (GIS), MORAP Phase II Land Use/Land Cover (LULC) Classification and the Gasconade River watershed boundaries were combined (for GIS methodology contact the Missouri Department of Conservation). A rating system was developed to determine the overall impact of land uses to each hydrologic unit within the Upper and Lower Gasconade River watersheds. Beneficial to stream health were the forest and woodland classes, because watershed roughness components from vegetative land cover were a vital part of the stream's erosion protection and the water filtering capacity. Also, the forest and the woodland classes were land uses that were positively correlated with biotic integrity (Wang et al. 1997). These percentages were added to make another field called percentage of forest and woodland. Other classes such as urban and cropland tend to have detrimental effects on stream habitat and water quality. Likewise, these percentages were added to make an additional field called percentage of urban and cropland. These combined percentages are negatively correlated with biotic integrity (Wang et al. 1997). The urban and cropland land uses were subtracted from the percentage of forest and woodland to obtain a third field, called impacted. Working with the resulting range of values, the highest value was given a value of "100" and the lowest, a value of "zero." The value of "zero" represented the most impacted area and the value of "100," the least impacted. A range of rating values was developed from this third field range, impacted, and subsequently assigned to the remaining impacted values (Table 21).

## Hydrologic Unit LULC Ratings

Within Upper and Lower Gasconade River watersheds, the percentage of forest and woodland and percentage of urban and cropland for each 14-digit hydrologic unit provided a means of comparing among HUs (Table 21). The three highest ratings and three lowest ratings were compiled in Table 21 for each 8-digit watershed.

These ratings provided a useful means of assessing the watershed and gave insight to potential problem areas to be better managed with the best available practices. Hydrologic units that have poor ratings can be earmarked for further investigation, and landowners within these units targeted for possible landowner incentive programs.

Within the Upper Gasconade River watershed (Table 22), averaging all 14-digit HUs within each 11-digit HU indicated that the Middle Gasconade River HU had the highest mean value of 85.91. The Roubidoux Creek HU had the lowest average rating because two of its 14-digit HUs had relatively low ratings. However, the Roubidoux Creek 11-digit HU had the third highest rating 14-digit HU within the 8-digit Upper Gasconade River watershed (Table 22; 95.9). Sections of the upper Roubidoux were within the Mark Twain National Forest and the private holdings were forest or woodland land use, which explains the higher 14-digit rating. The Upper Osage Fork had a fairly low rating that may merit attention given its present status as a NRCS Conservation Priority Area to target water quality problems (Missouri Unified Watershed Assessment Steering Committee 1998). While the Upper Gasconade River Tributaries HU rates as a relatively pristine environment due to the presence of the Mark Twain National Forest, the Upper Gasconade River HU was more impacted. In fact, areas within the 11-digit Upper Gasconade River HU are NRCS Conservation Priority Areas (Missouri Unified Watershed Assessment Steering Committee 1998). Within the Lower Gasconade River watershed (Table 23), averaging all 14-digit HUs within each 11-digit HU indicated that the Little Piney Creek HU had the highest mean rating of 70.10. The lowest mean value of 48.11 was found in the Lower Gasconade River HU.

Based on this analysis, priority for improvement should be given to those hydrologic units that were rated low. The Lower Gasconade River HU (#10290203-020) was rated poor due to the lack of forested stream corridor (Table 23). But the present land use information may have under-represented the amount of forest in that HU, however no other information is available. A cross referencing with helicopter videos (Missouri Department of Conservation 1993) of the Lower Gasconade HU, filmed from the confluence with Little Piney Creek down Paydown Access on the Gasconade River, showed that, in general, the corridor varied from forested areas intermixed with pastured areas to one or two rows of trees progressing toward Paydown Access. These narrow corridors may not have been detected by image analysis. Still, the results showed that relative to other HUs, the Lower Gasconade River HU remained in poorer condition. An additional HU, the Lower Roubidoux Creek HU, should be given priority management attention because of its sensitive springs and fisheries (Figure 10) and the presence of a growing human population (Figure 7).

## Erosion and Deposition

Contributions of woody vegetation to streambank stability and to stream energy dissipation have been supported by researchers (McKenney, Jacobson, and Wertheimer 1995). Woody vegetation imparts overall strength to the streambed and streambank and greater erosion resistance, and as a result, greater channel stability. Based on this information, land and stream managers have advocated increased stream corridor widths and densities of streamside vegetation to decrease streambank erosion (Missouri Department of Conservation 1997; Reno, Pulliam, and Priesendorf 1995; Roell 1994). Recent photogrammetric/GIS studies on Little Piney Creek (a 12-kilometer 5th-order segment extending from, approximately, Yancy Mills to Hickory Point) have determined that the benefits derived from vegetation in the maintenance and recovery of stream channels were influenced by watershed wide factors and land cover and land use characteristics of individual reaches (Jacobson and Pugh 1997). In this GIS analysis, Jacobson and Pugh assumed that woodland had a greater chance of being eroded than grassland/cropland, which were positioned farther away from the stream channel. To determine erosion and deposition susceptibility of the Little Piney Creek study segment, Jacobson and Pugh performed calculations in a digital GIS format using a polygon identity map (intersection of two maps) from each pair of successive maps, i.e., transition periods 1938-48, 1948-55, 1955-64, 1964-76, and 1976-89.

Jacobson and Pugh (1997) concluded that the results of their GIS analysis were applicable to other 4th - 6th order Ozark streams with similar physiographic controls and land use histories. Evidence presented in Jacobson and Primm (1994) supports the theory that streams were destabilized by historic land-use practices and their present state of instability is the result of decreased riparian vegetation. The results of the GIS analysis performed by Jacobson and Pugh (1997) indicate that erosion or deposition susceptibilities are not solely controlled by riparian vegetation. Reaches are susceptible to disturbance by mechanisms such as valley wall geometry, bank height greater than root depth, upstream changes, and sediment size changes, that are quite complex. Finally, Jacobson and Pugh (1997) believe that before a biologist attempts a stream improvement project, as listed in Table 19, he or she should have additional information on disturbance history, streambank soil cohesion, channel gradient, and if possible, runoff rates and stream bed load.

## National Wetland Inventory

The U.S. Fish and Wildlife National Wetland Inventory (NWI) data for the Gasconade River watershed was summarized for like wetland polygons within each hydrologic unit. To interpret the NWI coding system, several sources were used. Translating the wetland types from the Cowardin System (Cowardin et al. 1979) to the Missouri Wetland system was done with the aid of the Epperson (1992) (Table 24). A database containing the all polygonal (the cartographic representation of a wetland's geometry) wetland types, identified using the Cowardin System code, in the Gasconade River watershed was translated into systems, subsystems or classes, modifiers, and descriptions (for GIS methodology contact the Missouri Department of Conservation).

The NWI dataset is the most detailed information available for water bodies. The existing 1:100,000 scale water body file, extracted from the USGS digital line graph files (DLGs), had fewer water bodies represented. The NWI database had a total of 17,795 polygonal wetlands in the Upper Gasconade River watershed and 8,071 polygonal wetlands in the Lower Gasconade River watershed. Percentage of total wetland acres for each wetland system/class and description within the each 8-digit Gasconade River watershed illustrates the distribution of wetland types over the changing topography (Table 25).

Several Riverine subsystems and classes are describing temporary-semi-permanent pool within the river. Pools are important for fish population growth and production. In the Upper Gasconade River watershed, 13.1% of the total polygonal wetland acreage (TPWA) are temporary-semi-permanent pools (Table 25).

Riverine wetlands comprise 54.8% of total wetland acreage in the Upper Gasconade River, representing the largest wetland system. A total of 30% of the TPWA is the pool/riffle complex in the Upper Gasconade River watershed. Because this watershed is the headwater of the Gasconade River, 0.36% is permanent pool.

The predominant wetland types in the Lower Gasconade River watershed are Palustrine. Palustrine wetlands represent the largest wetland system with 43% of the TPWA (Table 25). The lower gradient and larger order stream system has setup conditions for more Palustrine wetlands. The lower watershed has a large percentage (42.4%) of deciduous bottomland forests. Many of these bottomland forests are temporarily or seasonally flooded, which makes them unavailable to cropland conversion without substantial diking. However, many of the wetland polygons have special modifiers identifying them as drained, diked, impounded, or excavated. These modified bottomland areas may be providing a buffer from flooding for cropland that is farther upland. A very large percentage of the total acreage of wetlands in Gasconade River watershed are farm ponds (NWI code: PUBGh, PUBFh), 33.4% for the upper watershed and 28.2% for the lower watershed.

## Nursery Wetlands

Mark Caldwell of MDC Fisheries Research used NWI data to identify potential nursery wetlands for fish in the Meramec River Watershed Inventory and Assessment (Blanc, Caldwell, and Hawks 1998). Using the criteria that the classes had to be Palustrine (non-channel, non-lake, perennial, or nearly perennial, and be a natural wetland, i.e., not excavated or impounded) and connected to a perennial stream, he identified polygonal wetlands that had potential to function as fish nursery habitat. A similar procedure was used for the Gasconade River watershed (for GIS methodology contact the Missouri Department of Conservation).

Overall, total nursery wetland acreage was 107.8 acres for the Upper Gasconade River watershed and 43.8 acres for the Lower Gasconade River watershed. Of the total wetland acreage within the Upper Gasconade River watershed, 0.9% met the nursery wetland criteria, and within the Lower Gasconade River watershed another 0.6% met the criteria. Connectivity to streams was not tested.

## Channel Condition

Habitat for fish, especially smallmouth bass, is best where there is good pool development. Using the NWI data sets, several classes of the Riverine system identify stream reaches that have suitable fish habitat. Several Riverine system classes were summarized into the groups that help interpret the Cowardin System code: temporary-semi-permanent pool, temporary pool, pool/riffle complex, and permanent pool (Table 27). For instance, grouped into the temporary-semi-permanent pool description, the R3UBF, R3UBG, and R2UBG attributed polygons are upper (3) and lower (2) perennial stream segments with 25% of particles smaller than stones, vegetative cover less than 30%, and unstable bottoms that can be sand, mud, gravel or organic materials. As described by Cowardin, L. M. et al. (1979), modifiers F or G describe these habitats as semi-permanent flooded or intermittently exposed. These water regime modifiers are an important feature of the wetland classification because they indicate the hydrologic characteristics of the wetland. Indicating how long water stands in the habitat, a Riverine system habitat can be classified within the range temporarily flooded to saturated to intermittently exposed to permanently flooded.

Having a more rugged topography and higher gradient than the Lower Gasconade River watershed, the Upper Gasconade River watershed has 2.56% of the total polygonal wetland acreage as temporary pool, and the Lower Gasconade River watershed has 0.11% as temporary pool (Table 25). This subsystem is intermittent and contains flowing water only part of the year (Cowardin et al. 1979). Intermittently, habitat classified within this subsystem will have temporary pools for extended periods. This habitat type is found within the Upper Osage Fork HU (0.06% TPWA), Roubidoux Creek HU (22% TPWA), and Little Piney Creek HU (0.48% TPWA) of the Upper Gasconade River watershed. To a lesser extent, some tributaries to Little Piney Creek (0.48% TPWA), Lower Gasconade River Hills HU (0.08% TPWA), and Lower Gasconade River Tributaries (0.06% TPWA) have temporary pool habitat. Poor in terms of sport fish habitat, these wetland types are likely to have, at a minimum, frogs and a few non-game fish species.

More acres of permanent habitat types, like the temporary-semi-permanent pool, are found within the Upper Gasconade River watershed (13.13%) and fewer acres in the Lower Gasconade River watershed (4.42%). Density of streams is much greater in the upper watershed areas as compared to the lower, which explains the large difference in percentages. All hydrologic units have this habitat type. It represents the largest Riverine habitat. When its percentage of the TPWA is small, a habitat with a permanent water regime is present. The 8-digit Upper Gasconade River watershed had numerous acres of the temporary-semi-permanent Riverine pool habitat types that are replaced by a permanent water regime in the form of very long pool/riffe complexes (Table 25). In contrast, the 8-digit Lower Gasconade River watershed had more permanent pools. The largest expanse of the pool/riffle complex habitat was found in the Middle Gasconade River HU (67.4%). Lower gradient and many tributaries lend to the development of this habitat. Somewhat lower in gradient than the Upper Osage Fork HU, the Lower Osage Fork HU had 32.1% of TPWA as pool/riffle complex Riverine habitat. Fifty-seven acres of permanent pool or 6.26% of TPWA were found in the Little Piney Creek HU. While lower perennial streams of the Lower Gasconade River Hills HU made up 84 acres of the 97 total temporary-semi-permanent pool acres, their water regime was not classified as permanent but rather intermittently exposed. Permanent pool became more a feature of the Lower Gasconade River HU with 0.16% of the TPWA.

## Gravel Bars

Channel condition of streams within hydrologic units of the Gasconade River watershed was characterized by evaluating the gravel bar status. The total acreage of gravel bars can be a good indicator of overall watershed and stream channel health. Channel stability, as well as fish habitat, is influenced by a variety of factors, such as bed load and gradient.

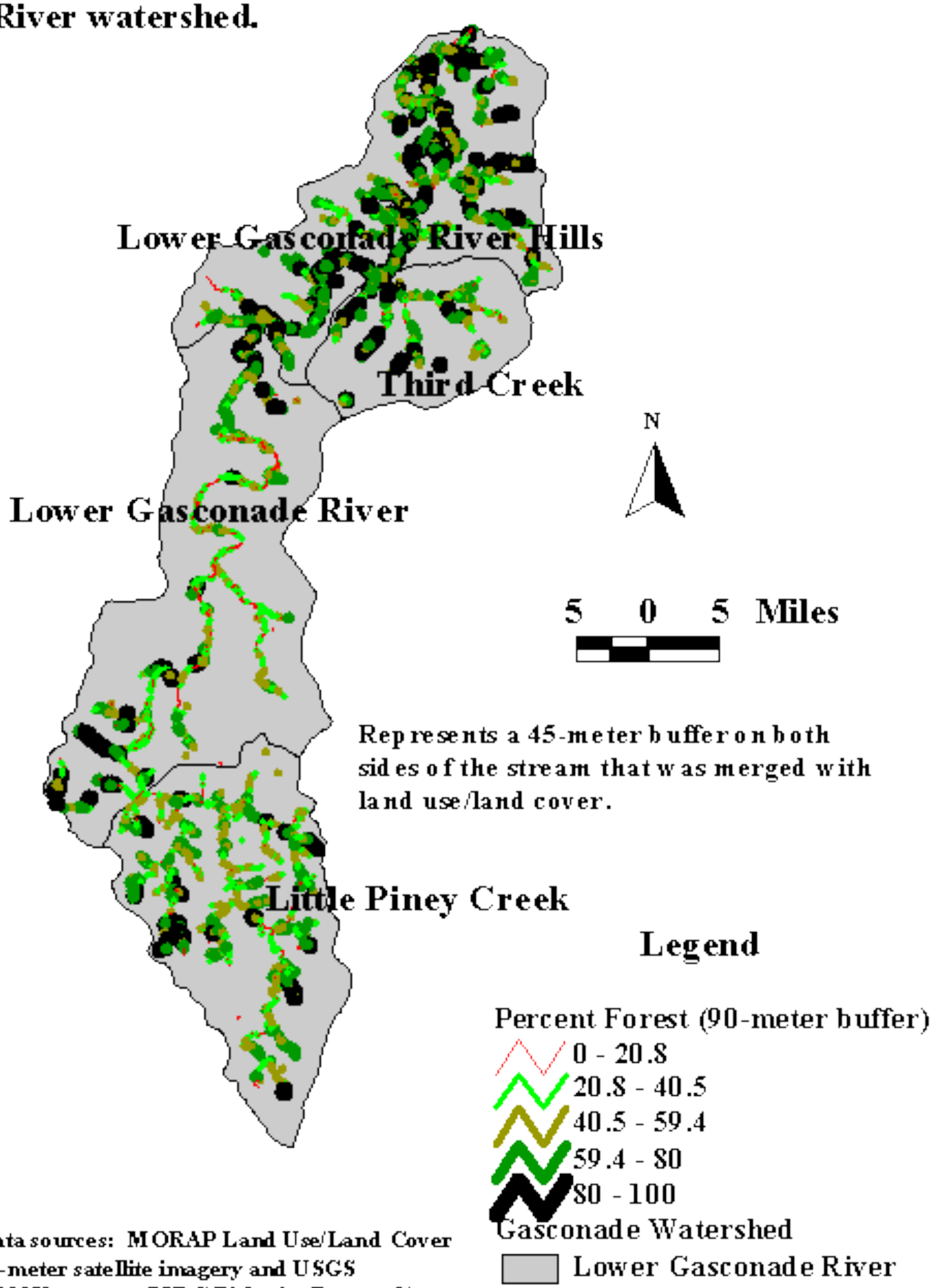
Channel condition may be poorest in those HUs with a high percentage of gravel bar acres per HU acres. R2USA (Riverine, Lower Perennial Unconsolidated Shore, Unaltered wetland type) and R3USA (Riverine, Upper Perennial Unconsolidated Shore, Unaltered wetland type) were represented as gravel bars in the summarization of polygon acreage (Table 26). To compare the quantity of gravel bars between 11-digit hydrologic units (HUs), the total 11-digit unit acreage was used to normalize the gravel bar acreage within each HU. The percentage of gravel bar acres per HU area was highest in three of the eleven 11-digit hydrologic units, Upper Gasconade River Tributaries at 0.149%, Third Creek at 0.149%, and Upper Osage Fork at 0.128%, respectively. Third Creek has the smallest HU area of all 11-digit units but had the highest percentage of gravel bar acres relative to its small size. Upper Gasconade River Tributaries has the fourth smallest HU area and the Upper Osage Fork HU, the third smallest HU area.

Other HUs that were larger in size, such as the Upper Gasconade River HU and the Little Piney Creek HU, were low in gravel bar acres, and the Little Piney Creek HU was the lowest in the total gravel bar acreage.

Sources of gravel may not have been from with the tributaries of each HU but from upstream adjoining HUs. The presence of a forested corridor (Table 20) may have contributed to slower water velocity and subsequent bed load deposition. To illustrate, a continuum of gravel bars along the main stem Gasconade River indicated decreases in percentage of gravel bar acres/HU area from the Upper Gasconade River HU (#10290201-010) to the Lower Gasconade River Hills HU (#10290203-040). Within five main stem HUs starting with the Upper Gasconade River HU and ending with the Lower Gasconade River Hills HU, the percentage of gravel bar acres per HU area was 0.041, 0.149, 0.088, 0.081, and 0.077. The total gravel bar acreage in the Upper Gasconade River HU was only 61.2 acres, which was considerably less than those HUs along the river continuum such as the following Upper Gasconade River Tributaries HU with 224.3 acres and the adjoining Middle Gasconade River HU with 136.5 acres. The Upper Gasconade River HU had more land uses that contribute to sediment loading and streambank erosion (see Hydrologic Unit LULC Ratings, Table 21), while the Upper Gasconade River Tributaries HU had mostly forest and woodland land uses – beneficial to streams. The forested corridor areas of the Upper Gasconade River Tributaries may have slowed water velocity and allowed gravel deposition. This suggests that the source of much of the sediment loading to Upper Gasconade River Tributaries HU (LULC rating of 85.9) may be areas within the Upper Gasconade River

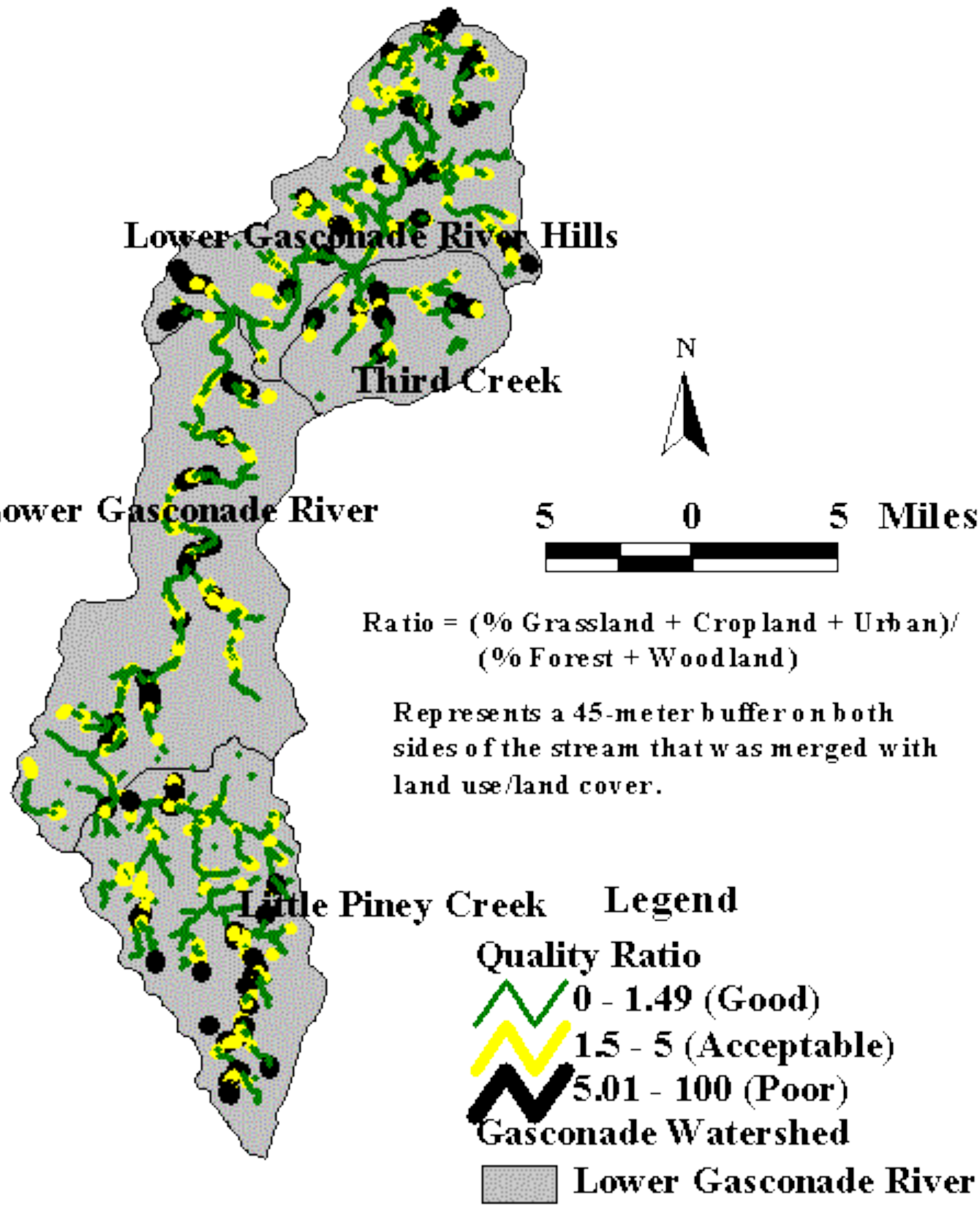
HU (LULC rating of 59.4), the largest HU of the eleven 11-digit HUs, and possibly from an additional major tributary, Beaver Creek HU (LULC rating of 68.4). Furthermore, the sources may be upland areas because the percentage of forested stream corridors within the Upper Gasconade River HU was the highest within the 8-digit Upper Gasconade River watershed (Table 20). A large number of gravel mining permits were issued for the Upper Gasconade River HU and Beaver Creek HU (Figure 7), which indicated that gravel was available, and possibly the information contained within the NWI dataset was deficient of those smaller gravel bars less than one-tenth acre in size. These smaller gravel bars would have been common in upper watershed areas. Also, the forested corridor canopy may have made gravel bars invisible to the stereoscopic analysis of the high altitude aerial photographs performed by the National Wetland Inventory.
The several 11-digit units within the 8-digit Upper Gasconade River watershed may be the source of sediment for gravel bars of the Middle Gasconade River HU. The Upper and Lower Osage Fork (61.0 and 66.4, respectively) were rated relatively low in the LULC rating, compared to the Middle Gasconade River watershed (Table 22). Also, these HUs had several acres of gravel bars. Lower in percentage of forested corridor than other HUs, the gravel bars in the Upper and Lower Osage Fork may have been more visible to the stereoscopic analysis of aerial photographs or channel instability was contributing to their presence. Once this sediment load arrived in the Middle Gasconade River HU, the better forested corridor and possibly the drop in channel gradient slowed water velocity and deposited the bed load.
Also, a tributary to the Middle Gasconade River HU, Roubidoux Creek, although it scored low in LULC rating, had few gravel bars, which likely may have been attributed to its more stable forested upper watershed.
In conclusion, Jacobson and Primm (1994) support the theory that historic land-use practices destabilized streams and their present state of instability is the result decreased riparian vegetation. Channel stability is not solely controlled by riparian vegetation; other mechanisms such as valley wall geometry and upstream changes can significantly affect channel stability (Jacobson and Pugh 1997). As demonstrated within relatively low impacted HUs with healthy forested stream corridors, potentially healthy channels may be adversely affected by poorer upper watershed conditions. Channel condition and stability are a complex combination of variables, of which several variables, such as those previously mentioned, play an important role.

**Figure 18. Percent forested corridor within 90-meter buffer of major stream segments of the Lower Gasconade River watershed.**



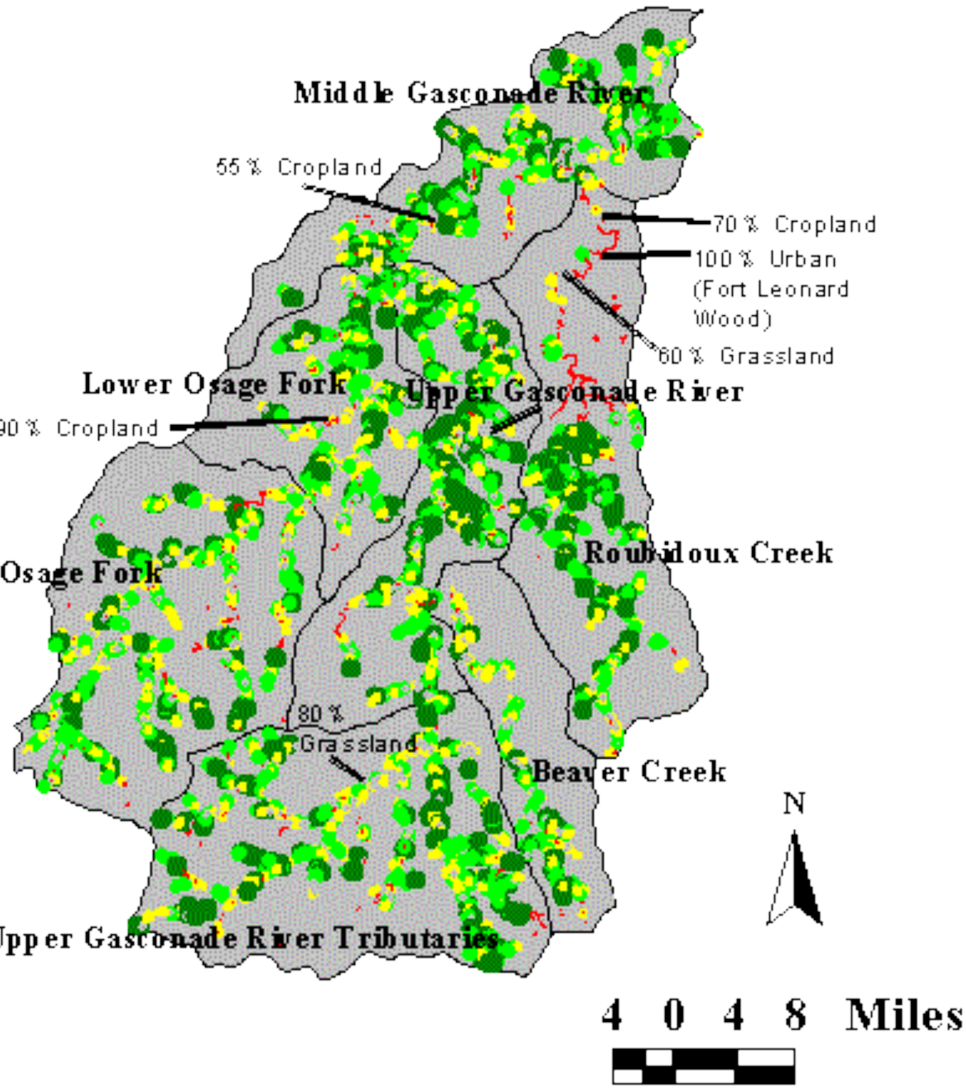

Data sources: MORAP Land Use/Land Cover 30-meter satellite imagery and USGS 1:100K streams (MDC Fisheries Research). Map production: Todd Blanc, 1/00

**Figure 19. Corridor quality of major stream segments within 90-meter buffer of the Lower Gasconade River watershed. Based on % land use ratio within buffer.**




Data sources: MORAP Land Use/Land Cover 30-meter satellite imagery and USGS 1:100K streams (MDC Fisheries Research).
Map production: Todd Blanc, 1/00

**Figure 20. Percent forested corridor within a 90-meter buffer of major stream segments of the Upper Gasconade River watershed.**




Represents a 45-meter buffer on both sides of the stream that was merged with land use/land cover.

**Data sources: MORAP Land Use/Land Cover 30-meter satellite imagery and USGS 1:100K streams (MDC Fisheries Research). Map production: Todd Blanc, 1/00**

**Legend**

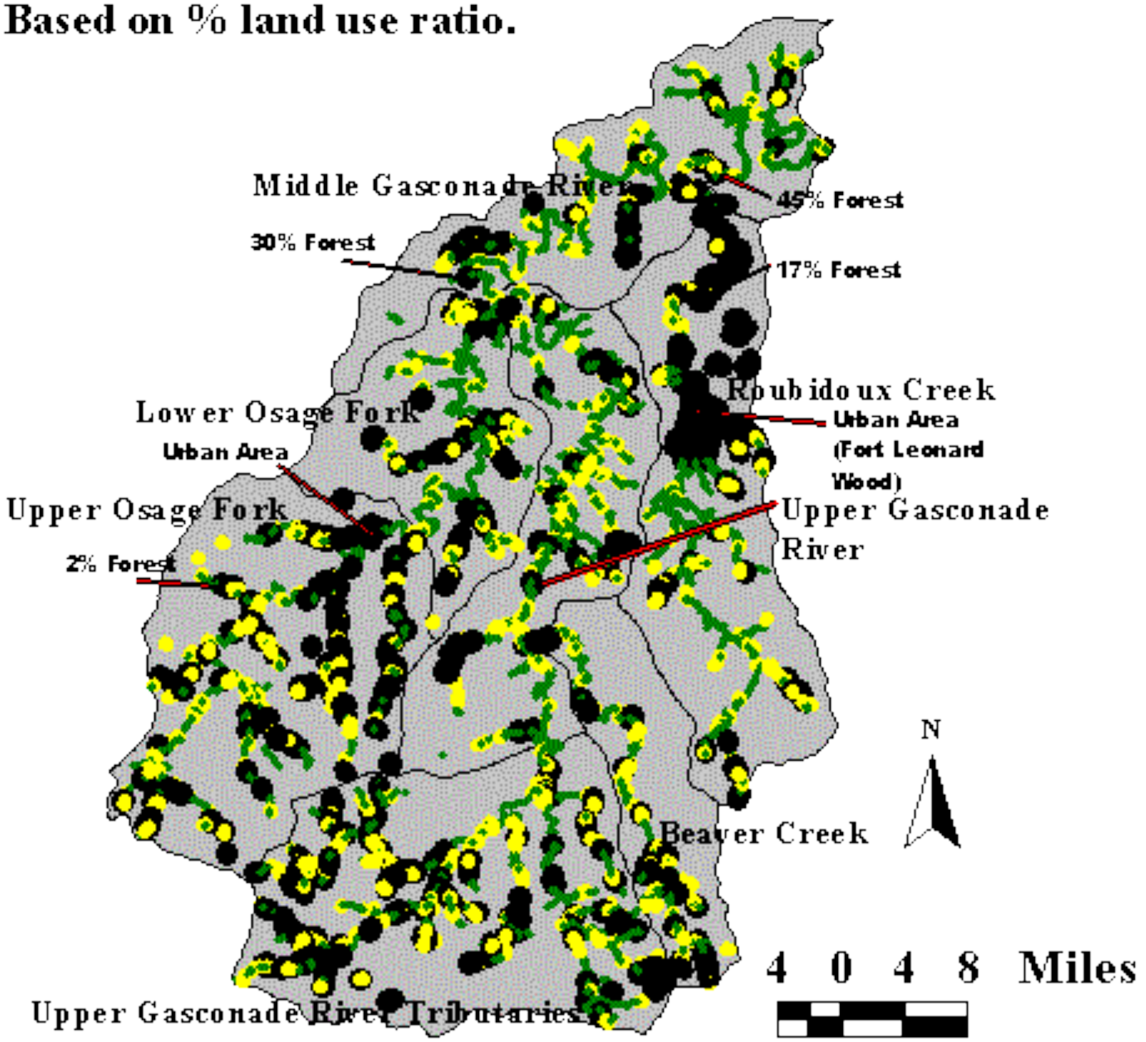
Percent Forest (90-meter buffer)

- 0 - 14.9
- 14.9 - 33.3
- 33.3 - 52.2
- 52.2 - 72.7
- 72.7 - 100

Gasconade Watershed

- Upper Gasconade River

**Figure 21. Corridor quality within 90-meter buffer of major stream segments of the Upper Gasconade River watershed. Based on % land use ratio.**




Ratio = (% Grassland + Cropland + Urban)/
(% Forest + Woodland)

**Legend**

Quality Ratio
0 - 1.5 (Good)
1.5 - 5 (Acceptable)
5 - 100 (Poor)
Gasconade Watershed
Upper Gasconade River

**Represents a 45-meter buffer on both sides of the stream that was merged with land use/land cover.**

**Data sources: MORAP Land Use/Land Cover 30-meter satellite imagery and USGS 1:100K streams (MDC Fisheries Research).**
**Map production: Todd Blanc, 1/00**

Table 18. Significant natural communities identified in the Natural Features Inventory: Phelps, Pulaski, and Laclede Counties (Ryan1992).

| Site Name and Community | Owner | Size (acres) | Natural Quality[1] |
|---|---|---|---|
| **Laclede County** | | | |
| **Mayfield Spring and Wet Meadow Fen** | USFS | 5 | B/C |
| **Flagmire Hollow Fen** | USFS | 1.5 | B |
| **Phelps County** | | | |
| **Hwy. T Forest Dry-Mesic Sandstone Forest** | B | USFS | 20 |
| **Wilkins Spring Fen/Wetland** | USFS | 4 | B |
| **Kaintuck Hollow Sandstone Glade** | USFS | 2.5 | B |
| **Apple Tree Farm Deep Muck Fen** | Pvt. | 7 | B/C |
| **Mill Creek Fen Deep Muck Fen** | USFS | 1.5 | B |
| **Kaintuck Hollow Fen** | USFS | 10 | C/C+ |
| **Strawhun Forest Mesic Bottomland Forest** | Pvt. | 30 | B |
| **Solomon Hollow Glades** | USFS | 3 | B |
| **Pulaski County** | | | |
| **Tunnel Cave Influent Cave** | Pvt. TNC reg. | - | B |
| **Great Spirit Cave N.H.A. Effluent Cave** | MDC | - | B |
| **Falls Hollow Sandstone Glades** | DA | 4 | B |
| **Karen's Fen Fen** | USFS | 6 | B |

[1]Natural quality:
A-Relative stable and undisturbed natural community (e.g., old growth, ungrazed forest)
B-Late successional or lightly disturbed communities; disturbed in past but now recovered; diversity not greatly reduced.
C-Mid-successional, moderate to heavily disturbed communities; moderate recent disturbance or heavy past disturbance; diversity lowered.
D-Early successional or severely disturbed communities; structure and composition severely altered.
E- Original community removed or nearly so (e.g., rowcrop).

Table 19. Description of stream improvement projects in the Gasconade River watershed, Missouri (Missouri Department of Conservation, East Central Region Fisheries, unpublished data).

| Stream | Technique/Program | County Twn-Rng-Sec | Completion | Comments |
|---|---|---|---|---|
| **3rd Order unnamed trib. to Gasconade** | cedar tree revetment, willow staking, corridor fencing/Equipment Loan | Osage T44N R7W S24 | 1994 | Private land |
| **Beaver Creek** | cedar tree revetment/Cost Share | Phelps T37N R8W S33 | 1991 | Private land |
| **Clear Fork** | cedar tree revetment/State Land | Gasconade T41N R5W S4 | 1994 | Canaan CA |
| **Contrary Creek** | cedar tree revetment/Equipment Loan | Osage T43N R8W S23 | 1991 | Private land partially complete |
| **Gasconade River** | streambank revegetation/State Land | Osage T43N R7W S31 | 1991 | Pointer's Creek Access |
| **Little Piney Creek** | cedar tree revetment/Cooperative-USFS | Phelps T37N R9W S36 | 1991 | Little Piney Allotment |
| **Little Piney Creek** | cedar tree revetment/Cost Share | Phelps T37N R9W S25 | 1994 | Private land, project failed |
| **Mill Creek** | rootwads & boulders | Phelps T36N R9W S4 | 1993 | USFS Gabel tract |
| **Mill Creek** | anchored rootwads/Cooperative-USFS | Phelps T36N R9W S4 | 1993 | Mill Creek Rec. Area |
| **Mill Creek** | cedar tree and rock revetment, rootwads/Cost Share | Phelps T36N R9W S33 | 1994 | Private land |
| **Mill Creek** | rootwads/Cooperative-USFS/Trout Unlimited | Phelps T36N R9W S33 | 1998 | USFS Gabel Tract |
| **Mill Creek** | rootwads, cedar tree revetment/Cooperative-USFS/Trout Unlimited | Phelps T36N R9W S33 & S4 | 1999 | USFS Gabel Tract |
| **Samples Creek** | riparian planting/Cost Share | Phelps T34N R8W S21 | 1993 | Private land |
| **Second Creek** | cedar tree revetment[1]/Equipment Loan | 1994 | 1994 | Private land |

[1]Anchoring of trees along an eroding bank to control erosion.

Table 20. Mean % forested corridor within 1:100K 90-meter buffered streams of Gasconade River 11-digit hydrologic units.

| 11-digit Hydrologic Units (HUs) | Mean % | Mean % of Major Segments[1] |
|---|---|---|
| **Upper Gasconade River 8-digit HU** | 42.4 | 38.2 |
| **Upper Gasconade River** | 48.9 | |
| **Upper Gasconade River Tributaries** | 42.7 | |
| **Upper Osage Fork** | 38.5 | |
| **Lower Osage Fork** | 40.1 | |
| **Middle Gasconade River** | 45.2 | |
| **Beaver Creek** | 44.3 | |
| **Roubidoux Creek** | 38.9 | |
| **Lower Gasconade River 8-digit HU** | 49.6 | 46.1 |
| **Lower Gasconade River Hills** | 55.3 | |
| **Third Creek** | 54.4 | |
| **Lower Gasconade River** | 44.4 | |
| **Little Piney Creek** | 48.8 | |

[1]those main stem river and tributaries segments with permanent flow

Table 21. Most and least impacted hydrologic units within the Gasconade River watershed (HUC # 10290201- and 10290203-) determined using Phase II Land Use/Land Cover MORAP 30-meter resolution satellite imagery. Gasconade rating scores the % LULC classes of the Gasconade River HUs according to a derived high and low range.

| 14-digit Hydrologic Units | % Forest & Woodland | % Urban & Cropland | Gasconade Rating |
|---|---|---|---|
| **Upper Gasconade River watershed** | | | |
| **-060004** | 31.31 | 62.37 | 0.4 |
| **-060005** | 29.31 | 57.42 | 3.99 |
| **-010005** | 38.49 | 9.28 | 32.47 |
| **-060002** | 66.70 | 4.66 | 95.9 |
| **-070005** | 69.62 | 4.80 | 98.9 |
| **-050005** | 68.84 | 3.93 | 98.95 |
| **Lower Gasconade River watershed** | | | |
| **-040004** | 57.63 | 15.64 | 2.50 |
| **-020003** | 57.241 | 13.539 | 7.10 |
| **-020007** | 53.185 | 6.57 | 14.60 |
| **-040005** | 72.961 | 5.985 | 83.10 |
| **-010005** | 73.954 | 10.509 | 85.70 |
| **-010003** | 82.614 | 2.831 | 99.90 |

Table 22. Impacted 14-digit hydrologic units within the Upper Gasconade River watershed (HUC # 10290201-) determined using Phase II Land Use/Land Cover MORAP 30-meter resolution satellite imagery. Ratings from 0 (most) to 100 (least) impacted. Gasconade rating scores the % LULC classes of the Gasconade River HUs according to a derived high and low range.

| 14-digit Hydrologic Units | % Forest & Woodland | % Urban & Cropland | Gasconade Rating |
|---|---|---|---|
| **Upper Gasconade River** | | | |
| **-010001** | 35.53 | 9.62 | 59.00 |
| **-010002** | 45.55 | 6.76 | 72.18 |
| **-010003** | 34.08 | 10.57 | 56.60 |
| **-010004** | 38.52 | 6.06 | 65.75 |
| **-010005** | 38.49 | 9.28 | 32.47 |
| **-010006** | 43.30 | 6.11 | 70.20 |
| | | Average | 59.36 |
| **Beaver Creek** | | | |
| **-020001** | 32.34 | 6.02 | 59.45 |
| **-020002** | 49.54 | 5.75 | 77.30 |
| | | Average | 68.37 |
| **Upper Osage Fork** | | | |
| **-030001** | 37.94 | 64.00 | |
| **-030002** | 42.03 | 7.37 | 68.00 |
| **-030003** | 38.03 | 9.05 | 62.20 |
| **-030004** | 46.32 | 7.71 | 71.95 |
| **-030005** | 30.63 | 15.81 | 47.80 |
| **-030006** | 36.90 | 17.69 | 52.20 |
| | | Average | 61.02 |
| **Lower Osage Fork** | | | |
| **-040001** | 45.95 | 7.77 | 71.30 |
| **-040002** | 29.16 | 12.75 | 49.30 |
| **-040003** | 53.48 | 7.20 | 78.80 |
| | | Average | 66.46 |
| **Upper Gasconade River Tributaries** | | | |
| **-050001** | 43.59 | 5.97 | 70.90 |
| **-050002** | 45.39 | 6.47 | 72.20 |
| **-050003** | 61.61 | 4.50 | 90.80 |
| **-050004** | 64.12 | 6.14 | 91.75 |
| **-050005** | 68.84 | 3.93 | 98.95 |
| | | Average | 84.92 |
| **Roubidoux Creek** | | | |
| **-060001** | 50.15 | 8.89 | 74.70 |
| **-060002** | 66.70 | 4.66 | 95.90 |
| **-060003** | 58.88 | 24.13 | 68.10 |
| **-060004** | 31.31 | 62.37 | 0.40 |
| **-060005** | 29.31 | 57.42 | 3.99 |
| **Middle Gasconade River** | | | |
| **-070001** | 45.35 | 10.53 | 68.10 |

| 14-digit Hydrologic Units | % Forest & Woodland | % Urban & Cropland | Gasconade Rating |
|---|---|---|---|
| **-070002** | 64.37 | 4.72 | 93.40 |
| **-070003** | 54.53 | 8.58 | 78.90 |
| **-070004** | 63.79 | 7.20 | 90.26 |
| **-070005** | 69.62 | 4.80 | 98.90 |
| | | Average | 85.91 |

Table 23. Impacted 14-digit hydrologic units within the Lower Gasconade River watershed (HUC # 10290203-) determined using Phase II Land Use/Land Cover MORAP 30-meter resolution satellite imagery. Ratings from 0 (most) to 100 (least) impacted. Gasconade rating rates the % LULC classes according to a derived the high and low range.

| 14-digit Hydrologic Units | % Forest & Woodland | % Urban & Cropland | Gasconade Rating |
|---|---|---|---|
| **Lower Gasconade River Hills** | | | |
| **-040005** | 72.961 | 5.985 | 83.10 |
| **-040004** | 57.63 | 15.64 | 2.50 |
| **-040003** | 71.753 | 6.886 | 79.95 |
| **-040002** | 67.363 | 8.325 | 68.00 |
| **-040001** | 58.867 | 6.057 | 31.10 |
| | | Average | 52.93 |
| **Third Creek** | | | |
| **-030001** | 67.672 | 8.435 | 69.30 |
| **-030002** | 64.21 | 4.615 | 60.30 |
| | | Average | Average |
| **Lower Gasconade River** | | | |
| **-020007** | 53.185 | 6.57 | 14.60 |
| **-020006** | 63.319 | 7.982 | 37.10 |
| **-020005** | 71.304 | 7.3 | 78.70 |
| **-020004** | 63.16 | 8.76 | 57.40 |
| **-020003** | 57.241 | 13.539 | 7.10 |
| **-020002** | 67.234 | 6.27 | 68.25 |
| **-020001** | 69.307 | 3.62 | 73.60 |
| | | Average | 48.11 |
| **Little Piney Creek** | | | |
| **-010004** | 68.659 | 6.438 | 72.10 |
| **-010005** | 73.954 | 10.509 | 85.70 |
| **-010003** | 82.614 | 2.831 | 99.90 |
| **-010002** | 67.986 | 6.471 | 70.10 |
| **-010001** | 59.891 | 10.126 | 22.72 |
| | | Average | 70.10 |

Table 24. Cross-reference of wetland classification systems. Taken from Epperson (1992).

| Missouri Wetland Types | SCS Food Security Act | Missouri Natural Terrestrial Communities | Cowardin et al. |
|---|---|---|---|
| **1. Swamp** | Wetland (Wetland Wooded or Wetland Forested) | Swamp Ponded Swamp | Palustrine Forested Wetland |
| **2. Shrub Swamp** | Wetland (Wetland Shrub) | Shrub Swamp Pond Shrub Swamp | Palustrine Scrub-shrub Wetland |
| **3. Forested Wetland** | Wetland (Wetland Wooded or Wetland Forested) | Mesic Bottomland Forest (in part) Wet Mesic Bottomland Forest Wet Bottomland Forest Flat Woods (in part) Wet-Mesic Savanna | Palustrine Forested Wetland |
| **4. Marsh** | Wetland | Freshwater Marsh Saline Marsh Pond Marsh | Palustrine Emergent Wetland, Lacustrine Emergent Wetland, Riverine Emergent Wetland |
| **5. Wet Meadow** | Wetland Wetland Pasture | Wet-Mesic Prairie Wet Prairie | Palustrine Emergent Marsh |
| **6. Fens and Seeps** | Fen, Deep muck fen, Prairie fen, Forested fen, Seep, Acid seep, Forested acid seep, Saline seep | Palustrine Emergent Marsh | Wetland |
| **7. Natural Ponds and Lakes** | Wetland (Wetland Open Water) (Wetland Emergent) | N/A | Palustrine Open Water Wetland, Palustrine Unconsolidated Bottom Wetland, Palustrine Aquatic Bed Wetland, Lacustrine Littoral Wetland |
| **8. Streams** | Wetland (Wetland Open Water) (Wetland Emergent) | Sandbar, Gravelwash | Riverine Upper Perennial, Riverine Lower Perennial, Riverine Intermittent Stream |

Table 25. Percentage of total wetland acres for each wetland systems/classes and description within the Gasconade River watershed.

| Cowardin Wetland System/Class | Description | Total Acres | % of total acres |
|---|---|---|---|
| **Upper Gasconade River watershed (#10290201)** | | | |
| **Total Lacustrine** | | | |
| | Lake/Reservoir | 69.64 | 0.63 |
| **Total Palustrine** | | 609.3 | 5.49 |
| **Total Aquatic Bed** | | 27.99 | 0.25 |
| **Total Deciduous Bottomland Forest** | | 513.13 | 4.63 |
| **Total Scrub Shrub** | | 68.18 | 0.61 |
| **Total Emergent** | | 364.19 | 3.28 |
| | Upland Marsh or Fen | 11.06 | 0.10 |
| | Wet meadow or flat | 137.40 | 1.24 |
| | Shallow marsh | 172.82 | 1.56 |
| | Deep marsh | 42.91 | 0.39 |
| **Total Unconsolidated Bottom** | | 3806.39 | 34.33 |
| | Pond | 99.4 | 0.90 |
| | Drained waterbody | 7.57 | 0.07 |
| | Excavated pond | 121.75 | 1.10 |
| | Farm pond | 3577.58 | 32.26 |
| **Total Riverine** | | 5874.77 | 52.98 |
| | Gravel bar | 919.73 | 8.29 |
| | Permanent pool | 38.46 | 0.35 |
| | Pool/riffle complex | 3221.97 | 29.06 |
| | Sand flat or gravel flat | 11.75 | 0.11 |
| | Temporary pool | 274.94 | 2.48 |
| | Temporary-semi-permanent pool | 1407.92 | 12.70 |
| **Total Wetland Polygons** | | 11088.48 | 100.00 |
| **Lower Gasconade River watershed (#10290203)** | | | |
| **Total Lacustrine** | | | |
| | Lake/Reservoir | 429.19 | 6.07 |
| **Total Palustrine** | | 3043.17 | 43 |
| **Total Aquatic Bed** | | 9.36 | 0.13 |
| **Total Deciduous Bottomland Forest** | | 3000.56 | 42.40 |
| **Total Scrub Shrub** | | 33.25 | 0.47 |
| **Total Emergent** | | 483.33 | 6.62 |
| | Upland Marsh or Fen | 17.55 | 0.25 |
| | Wet meadow or flat | 316.17 | 4.47 |
| | Shallow marsh | 134.80 | 1.90 |
| | Deep marsh | 14.81 | 0.21 |
| **Total Unconsolidated Bottom** | 2247.3 | 31.75 | |

| Cowardin Wetland System/Class | Description | Total Acres | % of total acres |
|---|---|---|---|
| | Excavated pond | 175.83 | 2.48 |
| | Pond | 73.71 | 1.04 |
| | Farm pond | 1997.76 | 28.23 |
| **Total Riverine** | | 873.44 | 12.34 |
| | Permanent pool | 54.43 | 0.77 |
| | Sand flat or gravel flat | 3.53 | 0.05 |
| | Excavated channel | 15.37 | |
| | Temporary pool | 8.02 | 0.11 |
| | Temporary-semi-permanent pool | 312.80 | 4.42 |
| | Vegetated Island bar | 12.99 | 0.18 |
| | Gravel bar | 466.30 | 6.59 |
| **Total Wetland Polygons** | | 7076.42 | 100.00 |

Table 26. Percentage gravel bars acreage per 11-digit hydrologic unit (HU) area within the Gasconade River watershed.

| Wetland System/Description | Acres | % gravel bar acres/HU acres | % of total wetlands in HU |
|---|---|---|---|
| **Upper Gasconade River** | 61.17 | 0.041 | 4.25 |
| **Upper Gasconade River Tributaries** | 224.26 | 0.149 | 15.63 |
| **Roubidoux Creek** | 65.90 | 0.036 | 5.34 |
| **Beaver Creek** | 60.29 | 0.071 | 9.07 |
| **Middle Gasconade River** | 136.47 | 0.088 | 4.41 |
| **Upper Osage Fork** | 274.35 | 0.128 | 17.01 |
| **Lower Osage Fork** | 98.13 | 0.090 | 7.87 |
| **Lower Gasconade River** | 178.93 | 0.081 | 9.99 |
| **Little Piney Creek** | 43.69 | 0.023 | 5.30 |
| **Lower Gasconade River Hills** | 146.72 | 0.077 | 3.95 |
| **Third Creek** | 96.96 | 0.149 | 12.98 |

# Biotic Communities

## Fish Community Sampling Protocol

Fish sampling community site selection of representative reaches within the Gasconade River watershed was based on stream order, flow, stream complexity within each 11-digit hydrologic unit, and access to the site (Figure 22). East Central Fisheries personnel evaluated the fish community on all streams 4th-order or greater during years 1997-99. Site selection was augmented by

1) constructing gradient plots of potential areas to provide variation in gradient among the sites,
2) consulting a topographic map or aerial photos for surrounding land use and access to site,
3) viewing video tapes of the watershed areas, and
4) using ArcView 3.1 so that previously sampled sites and all road crossings were identified.

Final selection was based on relative difference of the areas and access to the site. For ease of stream assessment and avoidance of trespass, a ford or a bridge was often near or part of the site. Fish sampling gear was backpack electroshocker or boat-boom electroshocking equipment. From 1900-96, historic fish community sampling used fixed sampling sites with little change among most historic sample dates. Sampling methods varied and involved the use of kick seine, drag seine, and electrofishing.

## Historic and Recent Fish Collections

The Gasconade River is one of the few remaining unimpounded rivers from the source to the mouth, which allows the free movement of fish such as the American eel and the Alabama shad. A diverse assemblage of ichthyofauna was collected by MDC's Regional Fisheries staff and Fisheries Research Section within the confines of the Gasconade River watershed. A grand total of 103 species of fish was collected from 1900-96 and more recently from 1997-99 (Table 27). This total includes the southern cave fish found within Roubidoux Spring of Pulaski County. These species were distributed among 49 genera and 21 families of fish ranging from the prehistoric *Petromyzontidae* (lampreys) to the more modern *Percidae* (perches) and *Sciaenidae* (drums). Three of the most common Centrarchidae hybrids were retained in the list but not included in the grand total.

Dominance within the 103 species was concentrated within five families. The five dominant families and the number of genera were: *Cyprinidae* (16 genera), *Catostomidae* (6 genera), *Ictaluridae* (4 genera), *Centrarchidae* (4 genera), and *Percidae* (3 genera). In general, ecological dominance reflects the aquatic food web, where the more dominant *Cyprinidae* feeding upon the invertebrates and become forage for genera within the Centrarchidae or *Percidae* family.

The most widely distributed species of *Cyprinidae* were the bleeding shiner, *hornyhead* chub, and largescale and central stonerollers. Among the Centrarchidae, the longear sunfish, rock bass, bluegill, sunfish, smallmouth bass, largemouth bass, and the spotted bass were some of the most widely distributed species. Spotted bass are a relatively new species in the Gasconade River fish assemblage that appear to be expanding their range for reasons that are not clear. It is possible that before, during, or after the introduction of spotted bass, some streams have become warmer through loss of riparian shading and have experienced degraded water quality (increased nutrient loads), or perhaps streams have experienced physical habitat modifications, such as increased gravel loads or fine sediment that has made it easier for spotted bass to occupy habitats formally containing only largemouth and smallmouth bass.

## Aquatic Invertebrates

Living and dead mussel species collected from 1980-94 and again from July 21, 1998 and September 16, 1999 in Roubidoux Creek, Osage Fork, and the main stem Gasconade River total 42 different naiade species (also see Benthic Research Collection below) (Table 28). These species were distributed among 27 different genera. The dominant genera were *Lampsilis* (6 species), *Quadrula* (3 species), and *Fusconaia* (2 species).

Among the dominant genera, the pocketbook mussel *(Lampsilis cardium)* was the most widely distributed with 30 occurrences throughout the watershed. The pink mucket *(Lampsilis abrupta),* a federally endangered species, was collected in the main stem Gasconade River during 1983 and 1994. The pimpleback *(Quadrula pustulosa)* and the mapleleaf (*Quadrula quadrula)* were collected in the main stem Gasconade River from 1981 to 1994. The pimpleback was also collected in the Osage Fork of the Gasconade River in 1983. The genus *Fusconaia* was collected in the Roubidoux Creek, Gasconade River, and the Osage Fork of the Gasconade River from 1980-94. The ebonyshell *(Fusconaia ebena)* has no historic record in Gasconade River watershed and was first collected in 1994 in the main stem Gasconade River.

In the 1998-99 field survey 35 living unionid species were observed in the Upper Gasconade River watershed and its tributaries, Osage Fork, Woods Fork, Whetstone Creek, and Roubidoux Creek. Seven species of conservation concern *(Leptodea leptodon, Elliptio crassidens, Cumberlandia monodonta, Alasmidonta marginata, Ligumia recta, Plethobasus cyphus,* and *Ptychobranchus occidentalis)* were found.

### Crayfish

Crayfish remain an important component of the riverine ecosystem, as converters of leaf litter and as prey for a variety of fish species. Five species of crayfish, including the Salem cave crayfish *(Cambarus hubrichti),* (also see Benthic Research Collection below) have been collected in the Gasconade River watershed and three genera comprise the five species (Table 29). The dominant genus, Orconectes, was most commonly collected and comprised over 99% of the crayfish composition. Both species of *Orconectes* were collected throughout the watershed in Whetstone Creek, Woods Fork, Roubidoux Creek, Little Piney Creek, Beaver Creek, and the main stem Gasconade River. The devil crayfish *(Cambarus diogenes)* and the digger crayfish *(Fallicambarus fodiens)* were collected, respectively, in Roubidoux Creek and the Lower Gasconade River in 1980. The rare Salem cave crayfish is located in some caves of the watershed.

Benthic collections in the Gasconade River watershed were performed by MDC Fisheries Research from 1962-92. A total of five orders and 64 families were collected in various locations of the watershed (Table 30).

This database collection contains some crayfish species and some mussels species not found in the other databases. Two additional *Orconectes* genera within the Cambaridae family were identified in this database, making a total of seven species of crayfish in the Gasconade River watershed. Also, four unique species of mussels were identified within four different genera, *Ferrissia, Planorbula, Elimia,* and *Pleurocera,* making a total of 46 mussels species (Table 30).

## Rare, Threatened, and Endangered Species

Fish species decline within the Gasconade River watershed is due to several factors, but the largest contributor may be habitat alteration. A list of those fish species of concern (Table 31) can be found within the Natural Heritage Database (the database is updated periodically with recent locations and new species).

Alabama shad *(Alosa alabamae).* At one time the Alabama shad had a fairly wide distribution and was common enough to support a limited fishery (Pflieger 1997). The Alabama shad is anadromous in the Mississippi River system, entering freshwater to spawn. The occurrence of the adults are from mid-April to early July. The young migrate after the first few months of life.

Highfin carpsucker *(Carpiodes velifer).* 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.

Crystal darter *(Crystallaria asprella).* The crystal darter occurred in the Gasconade, Meramec, Black, St. Francis and Little River drainage systems. According to Pflieger (1997), the crystal darter has never been common in any collections, most collections with only three to four specimens.

Bluestripe darter *(Percina cymatotaenia).* The bluestripe darter is endemic to the Osage and Gasconade river systems of central Missouri. The bluestripe is a former USFWS category-2 candidate species. The practice of categorizing species with this federal status was eliminated in 1996. The bluestripe remains an imperiled state species of conservation concern because of its rarity and rather few occurrences.

However, its vulnerability to extinction is less than the Niangua darter because it exists in two different drainages (Pflieger 1984) The closest relative of the bluestripe darter is a rather nebulous species in Kentucky.

Least darter *(Etheostoma microperca).* The least darter state-wide population has been reported to have changed very little in the last 35 years (Pflieger 1997). The least darter is found in clear, quiet, heavily vegetated waters, such as pools of small creeks with permanent flow and spring pools.

Mooneye *(Hiodon tergisus).* Never common in Missouri collections, this species is less common than the goldeye. It inhabits the larger, deeper pools of streams and prefers slightly clearer water than the goldeye, which can tolerate more turbid conditions. Where goldeye may be found within current, the mooneye prefers the quieter pools (Pflieger 1997).

Of special concern to biologists are amphibians that have recently experienced die-offs and mutations in some areas within the United States. Three genera of amphibians have declined and are state-listed species of conservation concern (Table 31). These species include the ringed salamander, Eastern hellbender, and the four-toed salamander.

A total of 13 invertebrates (mussels, crustaceans, and insects) are state listed as species of conservation concern within the Gasconade River watershed. Five state-listed endangered mussels species, the elephant ear *(Elliptio crassidens),* ebonyshell *(Fusconaia ebena),* the scaleshell *(Leptodea leptodon),* the pink mucket *(Lampsilis abrupta),* and html *(Plethabasus cyphyus)* are found within the Gasconade River watershed. The pink mucket is the only federally endangered mussel, and for that matter, the only federally endangered aquatic species within the watershed. The rare Salem cave crayfish *(Cambarus hubrichti)* is located in some caves of the watershed. Finally, a rare perlid stonefly *(Acroneuria ozarkensis)* is found in the watershed.

Funk (1968) published only qualitative information about the fish harvest of the Gasconade River watershed, however, quantitative estimates of fish harvest were needed to make stream management plans. From 1976-79, estimates of recreational use of the Gasconade River were obtained during the 3-year survey period that involved 27,600 personal interviews conducted by trained clerks (Fleener 1982). Estimates of angler effort and catch rate were presented for the upper, middle, lower segments of the Gasconade River, and the Osage Fork of the Gasconade River (Table 32). Anglers spent a total of 46,710 hours harvesting fish by pole and line, set line, and gigging within the upper segment of the Gasconade River, State Route M near Hartville to State Highway 133 (89 miles) from March 12, 1978 to March 10, 1979. The overall catch rate was 0.78 fish per hour, while the catch rate by pole-and-line anglers was 0.73. The catch rate by pole-and-line anglers was considerably higher on the upper segment than on the middle (0.35) and lower segment (0.43). Within the middle segment of the Gasconade River, State Highway 133 to Route E (86 miles), March 14, 1976 to March 12, 1977, anglers spent a total of 81,500 hours harvesting fish by pole and line, set line, and gigging. The overall catch rate for this segment was 0.40, which was slightly lower than the catch rate of 0.5 fish per hour for many Ozark streams. Anglers spent a total of 51,060 hours harvesting fish by all methods combined within the lower segment of Gasconade River, Route E in Maries County to the mouth (89 miles), from March 13, 1977 to March 11, 1978. An estimated 88,270 fish were caught on the lower segment in 353,070 hours of fishing (Table 32). Anglers, harvesting by pole and line and by gigging from Osage Fork of the Gasconade River (56 miles from Wright-Laclede County line to confluence) from March 12, 1978 to March 10, 1979, spent an estimated 30,200 hours and caught 15,390 fish at a rate of 0.54 fish per hour. The combined catch rate of the Osage Fork was higher than any other segment except the upper segment of the Gasconade River.

No commercial harvest of fish or mussels is allowed in the Gasconade River watershed (Wildlife Code of Missouri 2000).

## Sport Fish

Anglers are provided a multitude of sport fishing opportunities as the Gasconade River changes character from an Ozark headwater stream system to a large river system. The Gasconade River is the largest unimpounded stream in Missouri. Black bass, buffalo, crappie, channel and flathead catfish, drum, rock bass, redhorse, suckers, sauger, and walleye can all be found in various reaches of the Gasconade River. In addition, trout can be caught in a number of spring branches and spring fed streams within the Gasconade River watershed.

The Gasconade River was divided into three zones for the purpose of fish sampling. The upper zone included the headwater and continued to about the Jerome Access. The middle zone continued downstream to the Paydown Access. The lower zone extended downstream from the Paydown Access to the mouth of the river. Some species were more abundant in the upper reaches, while other species increased as we fished downstream.

Generally, sport fish samples collected in the 1990s have focused on smallmouth and rock bass. During the early part of the decade, samples were collected from a number of public fishing access points from Jerome to Fredericksburg Ferry. More recently, specific segments of the river were the focus of the seasonal sample. In 1998, the segment between Indian Ford Resort and Paydown Access was intensively sampled. In 1999, the segment between Jerome Access and Indian Ford Resort was sampled.

The black basses were not evenly distributed throughout the main stem of the Gasconade River. Smallmouth bass became more abundant farther upstream, though some very large smallmouth were found in the lower river. Spotted bass were most abundant on the lower end of river and were virtually absent above Jerome. Largemouth bass were found throughout the sampled area, though not necessarily in great numbers. However, largemouth bass were usually the largest bass captured at a given sample site.

Rock bass (goggle-eye) are found throughout the Gasconade River watershed. This secretive fish can be found in association with cover. They are at home in the large holes with boulders, rootwads, and aquatic vegetation. Most rock bass are < 7 inches long, though fish catches contain an occasional 8-inch or larger rock bass. Rock bass numbers tend to increase upstream on the Gasconade River, while rock bass size tends to increase downstream.

Sauger have been collected as far upstream as the Jerome Access. However, they were most abundant in the lower Gasconade River near the Missouri River. Catch has declined in recent years. Walleye are found throughout the river and have been sampled as far downstream as the First Creek confluence.

Samples from walleye have been submitted for genetic comparison with other systems in the state. The Gasconade River population does not appear to be unique, though this is based on a relatively small sample. Efforts to sample them during the spring spawning run have been unsuccessful to date.

Apparently, there are a number of good walleye spawning areas throughout the river and they do not remain in those areas for an extended period of time. Spawning riffles are widely spaced and are not necessarily used annually. If substrate and flow produce favorable conditions, spawning will take place. However, to date no specific spawning sites have been identified (Michael Smith, MDC Fisheries Management Biologist, personal communication). Interest in the winter fishery for sauger and walleye has steadily increased and as a result has caused a decline in that fishery. Most Gasconade River walleye and sauger are caught on crankbaits while fishing for other species. The 15-inch minimum length limit should show some improvement, if excessive harvest has been responsible for the recent decline in the quality of this fishery.

The Gasconade River supports an excellent catfish fishery. Popular catfish fishing methods are still fishing, limb lining, and trot lining. Channel catfish were the most abundant catfish in the river. Flathead catfish were also present. Catfish have been collected while targeting other sport fish. Representing the river in general, Figure 23 is a summary of a recent collections. Smaller (younger) fish were under-represented due to a sampling bias that selects for larger fish. However, channel catfish numbers and size distribution were excellent.

The Gasconade River is home to numerous redhorse and other suckers. There have not been any systematic evaluations of the suckers in the past decade. Some future attention is probably warranted as gigging continues to be a popular harvest method. Water conditions impact the amount of gigging pressure as high turbidity during floods or low water reducing the mobility of boats can determine the availability of redhorse and suckers.

## Special Management Areas

A Special Research Area (Gasconade River from Highway Y in Pulaski County to Highway D in Phelps County) was established with a 18-inch smallmouth bass length limit in 1994. The numbers of smallmouth bass > 18 inches have not increased dramatically, though the numbers of 12 to 15-inch smallmouth bass have increased. Growth slows dramatically as smallmouth age and an > 18-inch smallmouth is seven to nine years old. A creel study has been conducted in conjunction with this study. Rock bass numbers have fluctuated during the study. The average harvested size of rock bass is about seven inches. While fishing trips and hours have not recovered from the initial drop that occurred when the more restrictive regulation was enacted, overall both have been variable. The MDC Fisheries Research Unit will continue to evaluate the impacts of this regulation through at least 2001.

### Osage Fork

The Osage Fork is also included in the upper Gasconade zone. Both smallmouth bass and rock bass will receive special management. A Smallmouth Bass Management Area (SMBMA) was created in 2000.

This area has a 15-inch length limit and a daily limit of six black bass, which may include only one smallmouth bass. A Special Management Area was established for rock bass beginning March 2001. This area has a 8-inch length limit. A management evaluation was conducted to assess the rock bass and black bass populations within the Osage Fork of the Gasconade River. The Osage Fork was sampled using boom-mounted electrofishing equipment from 1996-1999. Sampling concentrated near three MDC accesses, Drynob, Davis Ford, and Hull Ford, and near county road crossings, Orla and Highway B. No spotted bass were present in any of the samples. Relative stock density (RSD) represents the proportion of fish that are quality size (> 11 inches) out those that are stock size or larger. Stock size for smallmouth bass is at least seven inches. The number of smallmouth bass greater than seven inches total length was greatest in 1998. The smallmouth bass fishery showed improvement in quality size fish. Largemouth bass boasted a bigger percent of larger-sized fish than smallmouth bass. Rock bass stock size was considered to be four inches. The number of rock bass greater than four inches was highest in 1997 and lowest in 1996. Overall, management evaluations have revealed that numbers of black basses and rock bass were satisfactory, but could be improved. The SMBMA and SMA are expected to restore quality fishing in an excellent reach of Ozark stream.

### Little Piney Creek

Little Piney Creek provides excellent fishing opportunity as it has considerable stream frontage on land in the Mark Twain National Forest. Much of it is a cold water stream due in part to the discharge of Piney, Yancy Mill, and Lane springs. On March 1, 2001, a Wild Trout Management Area (WTMA) was formed and a Trout Management Area (TMA) was relocated. Little Piney Creek supported a TMA at Lane Spring, which has received put-and-take rainbow trout since 1969. Wild trout are present from the springs above U.S. Hwy. 63 to a few miles below the Vida Slab Bridge. MDC conducted a number of studies, beginning in 1994, to evaluate the fisheries potential of Little Piney Creek. Temperatures were recorded, fish populations were sampled, trout were tagged, and anglers were surveyed at Lane Spring to assist in the formulation of a trout management plan for Little Piney Creek. As a result of these studies, the primary objective was the protection and enhancement of the self-sustaining rainbow trout population of Little Piney Creek.

The Little Piney Creek WTMA begins at the Phelps County line about 1.75 miles upstream of the Piney Spring confluence and extends to the Milldam Hollow Access at the end of Forest Service Road #1735. The upgrade of the forest road was a key component of the regulation. Upgrade costs were shared between MDC and the U.S. Forest Service, and the access provides the necessary geographic demarcation to make the regulation enforceable. Anglers will be able to identify this location to know where they are and also have an opportunity to access or leave the stream where regulations change. The adoption of this regulation created a 9.9 mile long WTMA, though Little Piney goes dry most years along the first 1.3 miles below the county line. The Lane Spring TMA was discontinued due to the creation of the WTMA, which includes the Lane Spring frontage. The Lane Spring stockings have maintained a locally popular put-and-take fishery. Many of the surveyed anglers expressed satisfaction with the current management regime. Other anglers expressed support for regulations similar to the one proposed. Most anglers were in favor of catch-and-release fishing. The decision to cease rainbow trout stockings at Lane Spring is a biological one with sociological implications. The new TMA (3.7 miles) is managed similarly, but not identically to, the one formerly at Lane Spring. It is bounded by the Milldam Hollow Access and Phelps County Road 7360. This Forest Service property can be accessed from Phelps County Road 7400, off State Hwy. T near Newburg. The TMA technically starts where the WTMA ends. However, only the lower mile of the Forest Service's Little Piney Allotment is stocked. The stocked area is roughly 0.5 miles above and below the intersection of Phelps County Road 7400 and Forest Service Road #1735, well below the end of the WTMA. The initial stocking regime provided 300 rainbow trout that were stocked over seven trips for a total annual stocking of 2100 10-12" trout. The buffer between areas is intentional, though some fish will move both up and downstream. MDC is evaluating fish movement from the stockings. A foot path and additional parking will eventually be developed. Stockings occurs during the spring and fall, but is suspended during the hottest weather because this portion of Little Piney Creek warms above the preferred temperature of rainbow trout during July and August (Table 33).

Concerns about mixing hatchery-strain rainbow trout with the self-sustaining rainbows near the Little Piney Creek allotment was addressed with a genetics study. MDC collected tissue samples from trout produced in the stream. Genetic analysis showed that more than half of those samples had characters also contained in samples from our hatchery stock.

Little Piney supports an excellent smallmouth bass and rock bass fishery downstream of the trout management area where the water has warmed. Bluff holes with boulders and rootwads are common and provide a home for both species.

### Mill Creek

A Wild Trout Management Area exists on the lower 7.7 miles of Mill Creek, a tributary to Little Piney Creek in Phelps County. Base flow is supported by Wilkins, Hudgen's, Elm springs, and during wet years, Yelton Spring. The area has been managed for wild rainbow trout since 1972 when a fishing refuge was established. In 1982, a WTMA was established with an 18-inch minimum length limit. This regulation effectively creates a catch-and-release fishery as the vast majority of the trout present are < 9 inches long (Figure 24). Mill Creek has benefitted from a number of conservancy efforts in recent years. Organized anglers have contributed to the purchase of frontage along Mill Creek. They have also been active in annual work projects geared toward improving instream habitat. Volunteers have assisted in the installation of cedar tree revetments to stabilize the banks, installation of rootwads to narrow the channel and create greater depth, corridor plantings, monitoring of the stream channel morphometry, and fish population sampling. These projects have taken place in cooperation with the Mark Twain National Forest who owns the frontage. In addition, a major private lands initiative is underway where a number of landowners have addressed streambank erosion by installing rip rap at the bank toe and improved instream habitat with rootwad and boulder placements.

### Roubidoux Creek

An urban trout fishery (0.9 miles) has been established within the city limits of Waynesville. Rainbow trout have been stocked by the Department of Conservation since at least 1979. Roubidoux Creek receives discharge from Roubidoux Spring, which creates a coldwater fishery to where Roubidoux Creek enters the Gasconade River. The area immediately below the spring and along city park frontage receives periodic stockings of catchable-size rainbow trout. In a typical year about 6,500 catchable-size rainbow trout are stocked. The stocking dates are no longer announced. Residence time is still relatively short after stocking, but some trout survive until the next stocking.

The final 2.2 miles is a Trout Special Management Area (TSMA) where brown trout have been stocked annually since 1991. Currently, 800 eight-inch to ten-inch brown trout are stocked each spring. MODOT right-of-way and Roubidoux Conservation Area provide access to some of the TSMA. The brown trout fishing has not lived up to expectations as the lower end warms considerably and the brown trout have the tendency to move upstream into a less regulated (protected) area during floods. However, classic habitat continues to hold a few nice fish and catch rates fairly high for a while after each spring stocking.

## Gasconade River Tributaries

Less is known about the sport fisheries of the Gasconade River tributaries. One would expect excellent wade fishing in a number of them, especially where quality habitat exists.

## Fishing Regulations

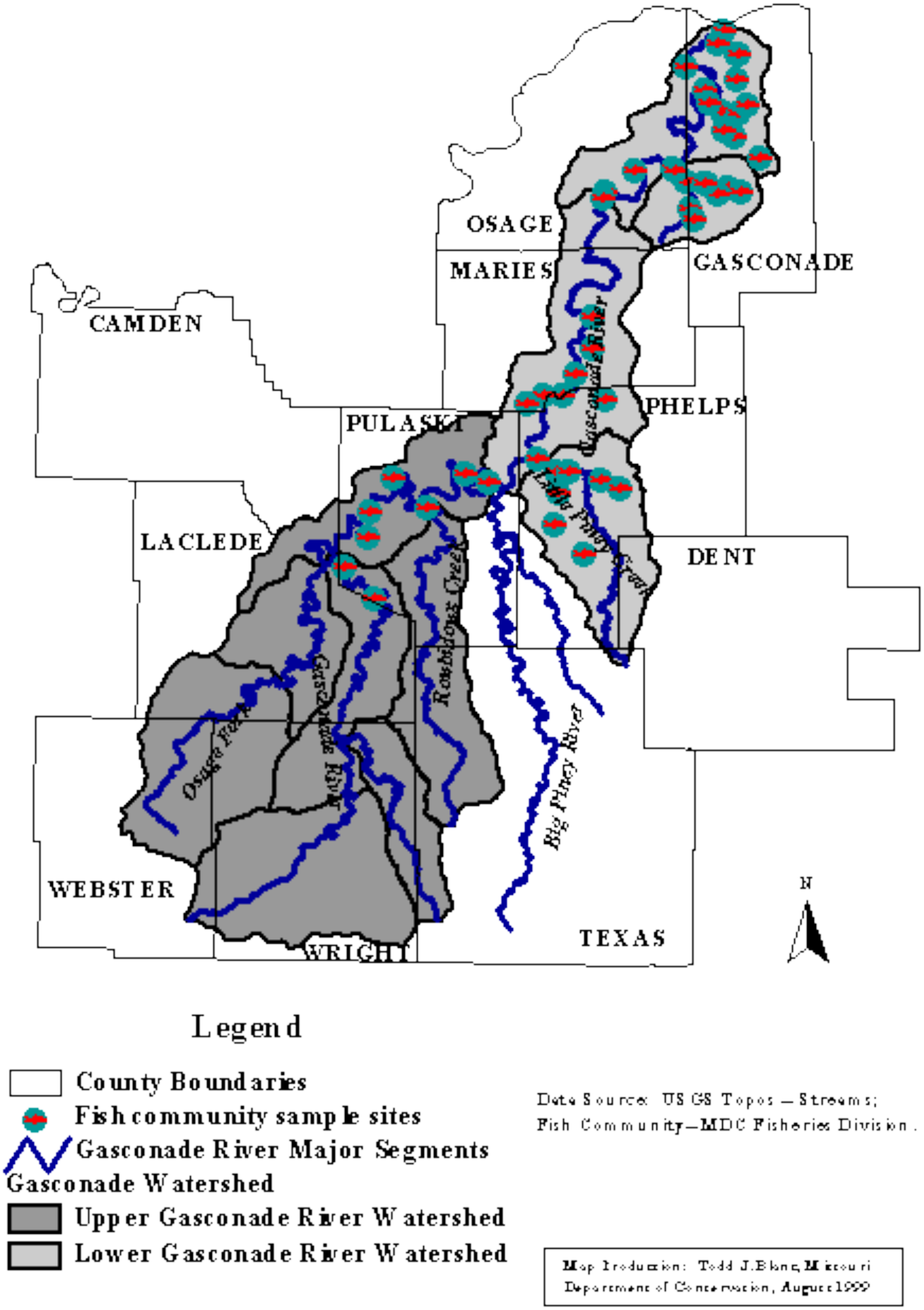
*The Wildlife Code of Missouri* contains specific information about the statewide fishing regulations (creel limits, size limits, seasons, and gear) that apply to the Gasconade River. In addition, the following special regulations currently apply. Please check the *Missouri Wildlife Code* for additional information.

1) Black Bass (largemouth, smallmouth, and spotted) open season is from the fourth Saturday in May until the last day of February. The daily limit is six in the aggregate with a 12-inch minimum length limit.
2) Possession limit is twice the daily limits. Within the Gasconade River watershed, smallmouth bass are protected in the following two restrictive zones: 1) In the Gasconade River from Highway Y Bridge in Pulaski County to Highway D Bridge in Phelps County, smallmouth bass are protected by an 18-inch minimum length limit; only one of the six black bass may be a smallmouth; 2) In the Osage Fork of the Gasconade River from Skyline Drive bridge near Orla to its confluence with the Gasconade River, smallmouth bass are protected by an 15-inch minimum length limit; only one of the six black bass may be a smallmouth.
3) The Osage Fork of the Gasconade River from Skyline Drive bridge near Orla to its confluence with the Gasconade River adds the following restriction: Rock bass minimum length limit is eight inches, and the daily limit is eight.
4) Three Wild Trout Management Areas (WTMAs), two Trout Management Areas (TMAs) and one Special Management Area (SMA) are found within the boundaries of the Gaconade River watershed. A trout permit, in addition to a Missouri fishing permit, is required to possess trout.
5) Wild Trout Management Areas (WTMAs) are found within Little Piney Creek, Mill Creek, and Spring Creek and are all located in Phelps County. The Little Piney WTMA begins at the Phelps/Dent County Line and extends to Milldam Hollow Access. It includes the Piney and Lane Spring branches. Mill Creek WTMA begins at Yelton Spring and extends to the Little Piney. It includes Wilkins Spring and spring branch. The Spring Creek WTMA begins at Relfe Spring and extends to the Big Piney. The daily limit for these WTMAs is one trout with a 18-inch minimum length

limit. Only flies and artificial lures may be used, and soft plastic baits and natural and scented baits are prohibited. Gigging is specifically prohibited in the Little Piney WTMA.

6) Trout Management Areas (TMAs) are found within the Roubidoux Creek TMA in Pulaski County (Waynesville) and the Little Piney Creek TMA in Phelps County near Newburg. The Roubidoux Creek TMA begins at Roubidoux Spring and extends about 0.5 miles downstream of the Business I-44 Bridge. The boundary is marked by an overhead utility cable. The Little Piney Creek TMA begins at Milldam Hollow Access and extends to the Phelps County Road 7360 Bridge. The daily limit is five trout with no special restrictions on tackle.
7) A Special Management Area (SMA) for trout is found within Roubidoux Creek in Pulaski County. The area begins at the overhead utility cable about 0.5 miles downstream of the Business I-44 Bridge and extends down to the Gasconade River. The daily limit is three trout with a 15-inch minimum length limit. Gigging and bowfishing are prohibited.
8) For walleye and sauger a 15-inch minimum length limit has been established for certain waters of the state including all streams within the Gasconade River watershed. The Department of Conservation started a new walleye initiative in 1998. This effort included a focus on several streams. The Gasconade River was not included as one of the priority rivers, therefore it does not receive any supplemental stocking. A statewide 15-inch minimum length limit was enacted for walleye and sauger in March 2000. A more restrictive length limit is available but has not been applied to the Gasconade to date.
9) Gigging is allowed throughout the Gasconade River watershed, unless specifically prohibited. The gigging season runs from September 15 to January 31. Non-game species may be taken by this method.
10) Snagging is allowed throughout the Gasconade River watershed. The snagging season runs from March 15 to May 15. Non-game species may be taken by this method.

**Figure 22. Fish community collection sites from 1996-99 in the Gasconade River Watershed**



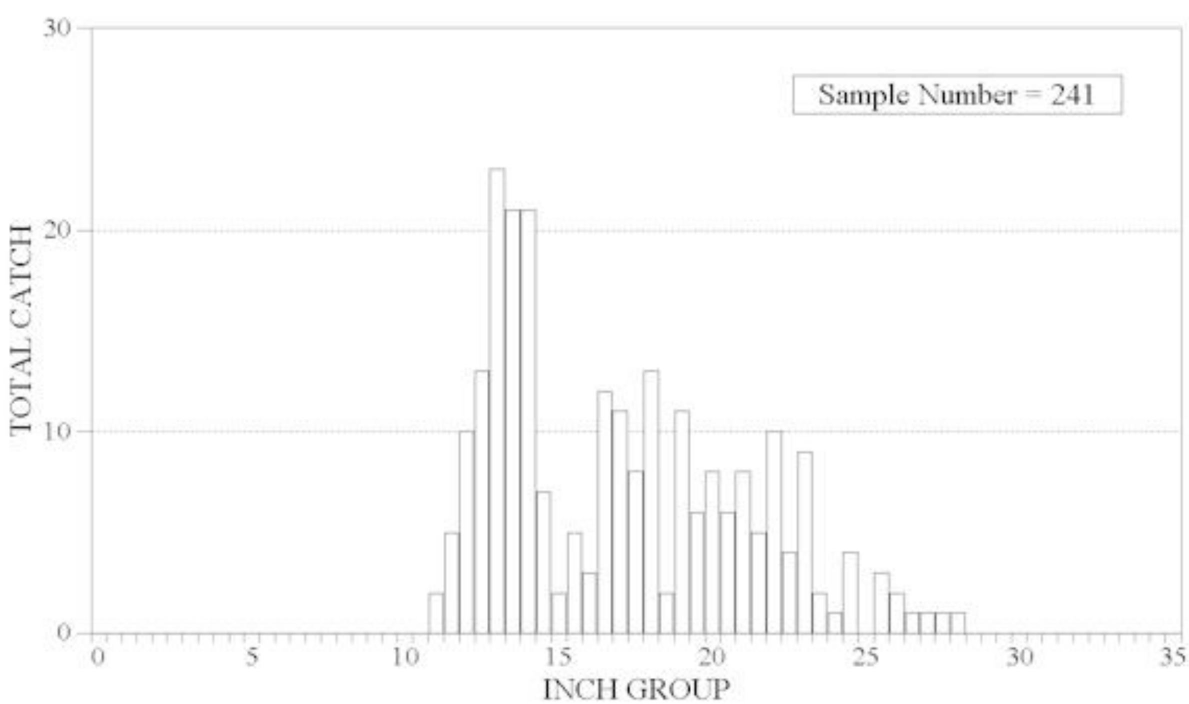



Figure 23. Gasconade River Channel Catfish 1999 Sample from Jerome Access to Highway 42.

Mill Creek Gabel Tract Rainbow Trout of the Gasconade River watershed. September 30, 1995. Sample size = 149.

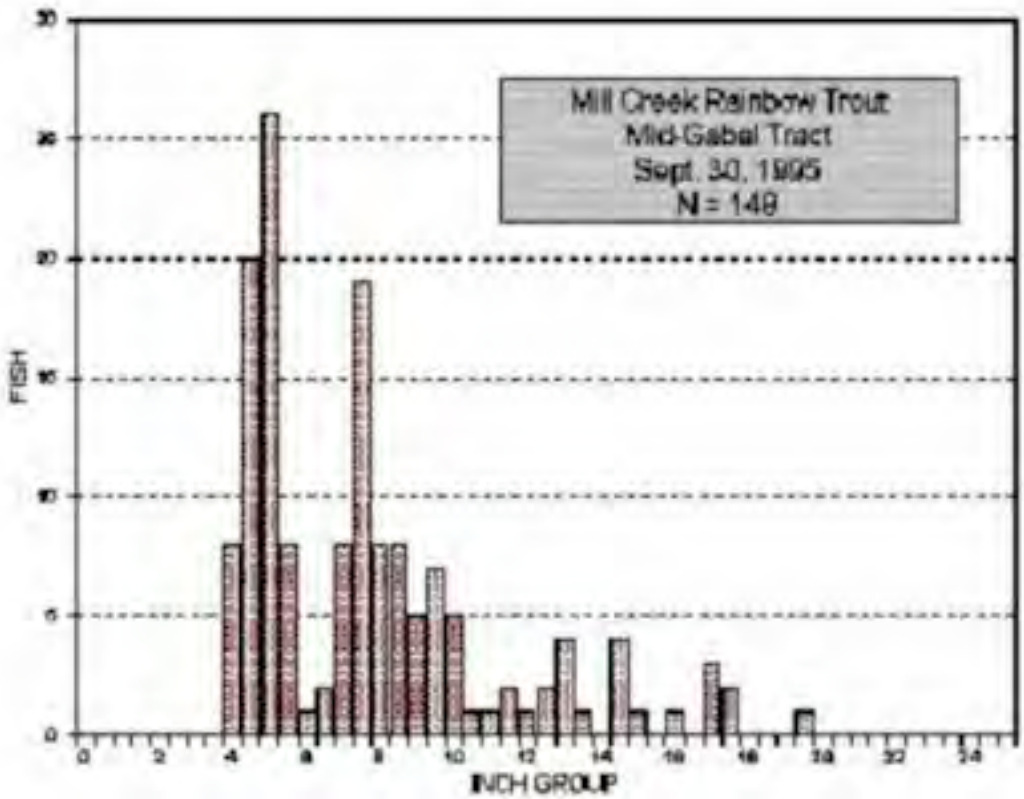


Table 27. Fish species collected within the Gasconade River watershed. Represented are both Missouri Department of Conservation Fisheries Research Section and Fisheries Management Section. Historic collections – 1900-96. Recent collections – 1997-99.

| Scientific Name | Common Name |
|---|---|
| **Petromyzontidae (Lampreys)** | |
| ***Ichthyomyzon castaneus*** | Chestnut lamprey |
| ***Ichthyomyzon gagei*** | Southern brook lamprey |
| ***Ichthyomyzon fossor*** | Northern brook lamprey |
| ***Ichthyomyzon*** | Larval lamprey |
| **Acipenseridae (Sturgeons)** | |
| ***Scaphirhynchus platorynchus*** | Shovelnose sturgeon |
| **Polyodontidae (Paddlefishes)** | |
| ***Polyodon spathula*** | Paddlefish |
| **Lepisosteidae (Gars)** | |
| ***Lepisosteus platostomus*** | Shortnose gar |
| ***Lepisosteus osseus*** | Longnose gar |
| **Anguillidae (Freshwater Eels)** | |
| ***Anguilla rostrata*** | American eel |
| **Clupeidae (Shad)** | |
| ***Dorosoma cepedianum*** | Gizzard shad |
| ***Alosa alabamae*** | Alabama shad |
| **Hiodontidae (Mooneyes)** | |
| ***Hiodon alosoides*** | Goldeye |
| ***Hiodon tergisus*** | Mooneye |
| **Salmonidae (Trouts)** | |
| ***Oncorhynchus mykiss*** | Rainbow trout |
| **Cyprinidae (Minnows)** | |
| ***Campostoma oligolepis*** | Largescale stoneroller |
| ***Campostoma anomalum*** | Central stoneroller |
| ***Carassius auratus*** | Goldfish |
| ***Cyprinella lutrensis*** | Red shiner |
| ***Cyprinella spiloptera*** | Spotfin shiner |
| ***Cyprinus carpio*** | Common carp |
| ***Erimystax X-punctatus*** | Gravel chub |
| ***Hygonathus argyritis*** | Western silvery minnow |
| ***Luxilus chrysocephalus*** | Striped shiner |
| ***Luxilus zonatus*** | Common shiner |
| ***Lythrurus U umbratilis*** | Western redfin shiner |
| ***Macrhybopsis storeriana*** | Silver chub |
| ***Nocomis biguttatus*** | Hornyhead chub |
| ***Notemigonus crysoleucas*** | Golden shiner |
| ***Notropis heterolepis*** | Blacknose shiner |
| ***Notropis volucellus >*** | Mimic shiner |
| ***Notropis rubellus*** | Rosyface shiner |
| ***Notropis stramineus*** | Sand shiner |

| Scientific Name | Common Name |
|---|---|
| ***Notropis nubilus*** | Ozark minnow |
| ***Notopis boops*** | Bigeye shiner |
| ***Notropis atherinoides*** | Emerald shiner |
| ***Notropis greenei*** | Wedgespot shiner |
| ***Notropis volucellus*** | Mimic shiner |
| ***Phenacobius mirabilis*** | Suckermouth minnow |
| ***Phoxinus erythrogaster*** | Southern redbelly dace |
| ***Pimephales promelas*** | Fathead minnow |
| ***Pimephales notatus*** | Bluntnose minnow |
| ***Semotilus atromaculatus*** | Creek chub |
| **Catostomidae (Suckers)** | |
| ***Carpiodes carpio*** | River carpsucker |
| ***Carpiodes velifer*** | Highfin carpsucker |
| ***Carpiodes cyprinus*** | Quillback |
| ***Catostomus commersonni*** | White sucker |
| ***Hypentelium nigricans*** | Northern hog sucker |
| ***Ictiobus bubalus*** | Smallmouth buffalo |
| ***Ictiobus cyprinellus*** | Bigmouth buffalo |
| ***Ictiobus niger*** | Black buffalo |
| ***Minytrema melanops*** | Spotted sucker |
| ***Moxostoma duquesnei*** | Black redhorse |
| ***Moxostoma carinatum*** | River redhorse |
| ***Moxostoma erythrurum*** | Golden redhorse |
| ***Moxostoma anisurum*** | Silver redhorse |
| ***Moxostoma macrolepidotum*** | Shorthead redhorse |
| **Ictaluridae (Catfishes)** | |
| ***Ameiurus melas*** | Black bullhead |
| ***Ameiurus natalis*** | Yellow bullhead |
| ***Ictalurus furcatus*** | Blue catfish |
| ***Ictalurus punctatus*** | Channel catfish |
| ***Noturus exilis*** | Slender madtom |
| ***Noturus flavus*** | Stonecat |
| ***Noturus nocturnus*** | Freckled madtom |
| ***Pylodictis olivaris*** | Flathead catfish |
| **Percopsidae (Trout-perches)** | |
| ***Percopsis omiscomaycus*** | Trout-perch |
| **Cyprinodontidae (Killifishes)** | |
| ***Fundulus catenatus*** | Studfish |
| ***Fundulus olivaceous*** | Blackspotted topminnow |
| ***Fundulus sciadicus*** | Plains topminnow |
| ***Fundulus notatus*** | Blackstripe topminnow |
| **Poecilliidae (Livebearers)** | |
| ***Gambusia affinis*** | Mosquitofish |
| ***Atherinidae (Silversides)*** | |

| Scientific Name | Common Name |
|---|---|
| ***Labidesthes sicculus*** | Brook silverside |
| **Cottidae (Sculpins)** | |
| ***Cottus carolinae*** | Banded sculpin |
| ***Cottus bairdi*** | Mottled sculpin |
| ***Cottus hypselurus*** | Ozark sculpin |
| **Percichthyidae (Sea Basses)** | |
| ***Morone chrysops*** | White bass |
| **Centrarchidae (Basses)** | |
| ***Ambloplites rupestris*** | Rock bass |
| ***Lepomis microlophus*** | Redear sunfish |
| ***Lepomis megalotis*** | Longear sunfish |
| ***Lepomis macrochirus X Lepomis megalotis*** | Bluegill X Longear sunfish |
| ***Lepomis macrochirus*** | Bluegill |
| ***Lepomis humilis*** | Orangespotted sunfish |
| ***Lepomis gulosus*** | Warmouth |
| ***Lepomis cyanellus X Lepomis megalotis*** | Green sunfish X Longear sunfish |
| ***Lepomis cyanellus X Lepomis macrochirus*** | Green sunfish X Bluegill |
| ***Lepomis cyanellus*** | Green sunfish |
| ***Micropterus salmoides*** | Largemouth bass |
| ***Micropterus punctulatus*** | Spotted bass |
| ***Micropterus dolomieu*** | Smallmouth bass |
| ***Pomoxis annularis*** | White crappie |
| ***Pomoxis nigromaculatus*** | Black crappie |
| **Percidaes (Perches)** | |
| ***Etheostoma tetrazonum*** | Missouri saddled darter |
| ***Etheostoma spectabile spectabile*** | Northern orangethroat |
| ***Etheostoma flabellare lineolatum*** | Striped fantail |
| ***Etheostoma blennioides*** | Greenside darter |
| ***Etheostoma punctulatum*** | Stippled darter |
| ***Etheostoma nigrum*** | Johnny darter |
| ***Etheostoma zonale*** | Banded darter |
| ***Etheostoma caeruleum*** | Rainbow darter |
| ***Percina cymatotaenia*** | Bluestriped darter |
| ***Percina phoxocephala*** | Slenderhead darter |
| ***Percina caprodes fulvitaenia*** | Ozark logperch |
| ***Percina evides*** | Gilt darter |
| ***Stizostedion canadense*** | Sauger |
| ***Stizostedion vitreum*** | Walleye |
| **Sciaenidae (Drums)** | |
| ***Aplodinotus grunniens*** | Freshwater drum |

Table 28. Living and dead mussel species collected from 1980-94 and 1998-1999 within streams of the Gasconade River watershed (Missouri Department of Conservation Fisheries Research Collection 1995b and 1999).

| Scientific Name | Common Name |
|---|---|
| ***Actinonaias ligametina*** | Mucket |
| ***Alasmidonta marginata*** | Elktoe |
| ***Amblema plicata*** | Threeridge |
| ***Corbicula fluminea*** | Asiatic Clam |
| ***Cumberlandia monodonta*** | Spectaclecase |
| ***Cyclonaias tuberculata*** | Purple Wartyback |
| ***Ellipsaria lineolata*** | Butterfly |
| ***Elliptio crassidens*** | Elephant-ear |
| ***Elliptio dilatata*** | Spike |
| ***Fusconaia ebena*** | Ebonyshell |
| ***Fusconaia flava*** | Wabash Pigtoe |
| ***Lampsilis reeviana reeviana*** | Arkansas Broken-ray |
| ***Lampsilis reeviana brittsi*** | Northern Broken Shell |
| ***Lampsilis siliquoidea*** | Fatmucket |
| ***Lampsilis abrupta*** | Pink Mucket |
| ***Lampsilis teres*** | Yellow SandShell |
| ***Lampsilis cardium*** | Plain Pocketbook |
| ***Lasmigona costata*** | Fluted-shell |
| ***Lasmigona omplanata complanata*** | White Heelsplitter |
| ***Leptodea fragilis*** | Fragile Paper shell |
| ***Leptodea leptodon*** | Scaleshell |
| ***Ligumia recta*** | Black Sandshell |
| ***Ligumia subrostrata*** | Pondmussel |
| ***Megalonaias nervosa*** | Washboard |
| ***Obliquaria reflexa*** | Threehorn Wartyback |
| ***Pleurobema sintoxia*** | Round Pigtoe |
| ***Potamilus alatus*** | Pink Heelsplitter |
| ***Potamilus ohiensis*** | Pink Papershell |
| ***Ptychobranchus occidentalis*** | Ouachita Kidneyshell |
| ***Pyganodon grandis*** | |
| ***Quadrula quadrula*** | Mapleleaf |
| ***Quadrula metanevra*** | Monkeyface |
| ***Quadrula pustulosa*** | Pimpleback |
| ***Strophitus undulatus*** | Squawfoot |
| ***Tritigonia verrucosa*** | Pistolgrip |
| ***Toxolasma parvus*** | Lilliput |
| ***Truncilla truncata*** | Deertoe |
| ***Truncilla donaciformis*** | Fawnsfoot |
| ***Utterbackia imbecillis*** | Paper Pondshell |
| ***Venustaconcha ellipsiformis*** | Ellipse |
| ***Villosa iris*** | Rainbow |
| ***Villosa lienosa*** | Little Spectaclecase |

Table 29. Total specimens, occurrences, and the percentage composition of crayfish species within the Gasconade River watershed (Missouri Department of Conservation 1995a), excluding the Salem cave crayfish.

| Species | Occurrences | Total Specimens | % Composition |
|---|---|---|---|
| ***Orconectes punctimanus* (Spothanded crayfish)** | 59 | 1922 | 46.36 |
| ***Orconectes luteus* (Golden crayfish)** | 59 | 2207 | 53.23 |
| ***Cambarus diogenes* (Devil crayfish)** | 1 | 2 | 0.05 |
| ***Fallicambarus fodiens* (Digger crayfish)** | 1 | 15 | 0.36 |
| | | 4146 | 100.00 |

Table 30. Benthic macroinvertebrate collections for the Gasconade River from 1962-92 (printout from the Fisheries Research Benthic Collection).

| Family | Species | Stream | Mile | Order |
|---|---|---|---|---|
| **Annelida** | | | | |
| | *Hirudinea* | Gasconade River | 77 | 7 |
| | *Oligochaeta* | L Piney River | 17 | 5 |
| | *Branchiobdellidae* | L Piney River | 14 < | 5 |
| **Arthropoda** | | | | |
| **Aeshnidae** | *Aeshna sp.* | L Piney River | 15 | 5 |
| **Asellidae** | *Caecidotea sp.* | Gasconade River | 106 | 7 |
| | *Lirceus sp.* | Gasconade River | 229 | 6 |
| | *Caecidotea stygius (Packard)* | Gasconade River | 77 | 7 |
| **Athericidae** | *Atherix lantha Webb* | L Piney River | 17 | 5 |
| **Baetidae** | *Acentrella sp.* | L Piney River | 17 | 5 |
| | *Baetis tricaudatus Dodds* | L Piney River | 17 | 5 |
| | *Baetis sp.* | Gasconade River | 77 | 7 |
| **Baetiscidae** | *Baetisca lacustris McDunnough* | Gasconade River | 77 | 7 |
| | *Baetisca sp.* | Gasconade River | 106 | 7 |
| **Brachycentridae** | *Brachycentrus sp.* | Gasconade River | 106 | 7 |
| | *Brachycentrus americanus* (Banks) | Gasconade River | 77 | 7 |
| **Caenidae** | *Brachycercus prudens* (McDunnough) | Gasconade River | 106 | 7 |
| **Caenidae** | *Caenis sp.* | L Piney River | 17 | 5 |
| **Calopterygidae** | *Hetaerina americana* (Fabricius) | Gasconade River | 106 | 7 |
| **Cambaridae** | *Orconectes sp.* | Gasconade River < | 77 | 7 |
| | *Orconectes meeki* (Faxon) | Gasconade River | 114 | 7 |
| | *Orconectes marchandi Hobbs* | L Piney River | 17 | 5 |
| **Capniidae** | *Paracapnia sp.* | Gasconade River | 77 | 7 |
| | *Allocapnia sp.* | Gasconade River | 77 | 7 |

| Family | Species | Stream | Mile | Order |
|---|---|---|---|---|
| **Ceratopogonidae** | *Dasyheleinae* | Gasconade River < | 84 | 7 |
| | *Culicoides sp.* | Gasconade River | 77 | 7 |
| | *Bezzia/Probezzia...* | L Piney River | 17 | 5 |
| **Coenagrionidae** | *Enallagma praevarum* (Hagen) | Gasconade River | 106 | 7 |
| | *Chromagrion sp.* | Gasconade River | 2 | 7 |
| | *Enallagma sp.* | Gasconade River | 106 | 7 |
| | *Argia sp.* | Gasconade River | 77 | 7 |
| | *Argia moesta* (Hagen) | L Piney River | 17 | 5 |
| **Corydalidae** | *Nigronia fasciatus* (Walker) | Whetstone Ck | 1 | 5 |
| | *Corydalus cornutus* (Linnaeus) | Gasconade River | 77 | 7 |
| | *Nigronia serricornis* (Say) | Gasconade River | 116 | 6 |
| **Crangonyctidae** | *Crangonyx minor Bousfield* | L Piney River | 17 | 5 |
| **Curculionidae** | *Onychylis sp.* | Gasconade River | 229 | 6 |
| **Dryopidae** | *Helichus lithophilus* (Germar) | Gasconade River | 106 | 7 |
| | *Helichus sp.* | Gasconade River | 106 | 7 |
| **Dytiscidae** | *Hydroporus niger Say* | Dove Creek | 2 | 3 |
| | *Hydroporus undulatus Say* | L Piney River | 15 | 5 |
| **Elmidae** | *Stenelmis lateralis Sanderson* | Gasconade River | 77 | 7 |
| | *Dubiraphia sp.* | Gasconade River | 77 | 7 |
| | *Ancyronyx variegata* (Germar) | Gasconade River | 77 | 7 |
| | *Optioservus sandersoni Collier* | L Piney River | 17 | 5 |
| | *Stenelmis crenata* (Say) | Gasconade River | 77 | 7 |
| | *Macronychus glabratus Say* | Gasconade River | 77 | 7 |
| | *Heterelmis vulnerata* (LeConte) | Gasconade River | 106 | 7 |
| | *Stenelmis sp.* | L Piney River | 17 | 5 |

| Family | Species | Stream | Mile | Order |
|---|---|---|---|---|
| | *Stenelmis beameri Sanderson* | Gasconade River | 77 | 7 |
| **Ephemerellidae** | *Eurylophella sp.* | Gasconade River | 77 | 7 |
| | *Serratella sp.* | Gasconade River | 77 | 7 |
| | *Ephemerella* (invaria grp.) | Gasconade River | 77 | 7 |
| | *Ephemerella sp.* | Gasconade River | 77 | 7 |
| | *Eurylophella temporalis* (McDunnough) | L Piney River | 14 | 5 |
| | *Eurylophella* (bicolor grp.) | Gasconade River | 77 | 7 |
| **Serratella deficiens (Morgan)** | *Serratella deficiens* (Morgan) | Gasconade River | 77 | 7 |
| **Ephemeridae** | *Hexagenia sp.* | Gasconade River | 54 | 7 |
| **Ephemera simulans Walker** | *Ephemera simulans Walker* | Gasconade River | 77 | 7 |
| **Ephemera sp.** | *Ephemera sp.* | Gasconade River | 77 | 7 |
| **Hexagenia limbata Serville** | *Hexagenia limbata Serville* | Gasconade River | 77 | 7 |
| **Gammaridae** | *Gammarus pseudolimnaeus Bousfield* | Gasconade River | 116 | 6 |
| **Gammarus sp.** | *Gammarus sp.* | Gasconade River | 77 | 7 |
| **Glossosomatidae** | *Agapetus sp.* | L Piney River | 17 | 5 |
| **Gomphidae** | *Ophiogomphus rupinsulensis* (Walsh) | Gasconade River | 116 | 6 |
| **Stylogomphus albistylus (Hagen)** | *Stylogomphus albistylus* (Hagen) | Gasconade River | 114 | 7 |
| **Hagenius brevistylus Selys** | *Hagenius brevistylus Selys* | Gasconade River | 84 | 7 |
| **Ophiogomphus sp.** | *Ophiogomphus sp.* | Gasconade River | 77 | 7 |
| **Erpetogomphus designatus Hagen** | *Erpetogomphus designatus Hagen* | Gasconade River | 77 | 7 |
| **Helicopsychidae** | *Helicopsyche borealis* (Hagen) | L Piney River | 17 | 5 |
| **Heptageniidae** | *Stenacron gildersleevei* (Traver) | Gasconade River | 77 | 7 |
| | *Stenonema pulchellum* (Walsh) | L Piney River | 17 | 5 |

| Family | Species | Stream | Mile | Order |
|---|---|---|---|---|
| | *Stenonema femoratum* (Say) | L Piney River | 14 | 5 |
| | *Rhithrogena pellucida Daggy* | Gasconade River | 77 | 7 |
| | *Stenonema mediopunctatum* (McDunnough) | L Piney River | 14 | 5 |
| | *Heptagenia* (group 3) | Gasconade River | 106 | 7 |
| | *Stenonema bednariki McCafferty* | Gasconade River | 229 | 6 |
| | *Stenacron sp.* | Gasconade River | 77 | 7 |
| | *Heptagenia sp.* | L Piney River | 17 | 5 |
| | *Stenacron* (interpunctatum grp.) | Gasconade River | 77 | 7 |
| **Hydrophilidae** | *Laccobius sp.* | Gasconade River | 106 | 7 |
| | *Hydrochus sp.* | Gasconade River | 106 | 7 |
| | *Berosus sp.* | Gasconade River | 77 | 7 |
| **Hydropsychidae** | *Ceratopsyche piatrix Ross* | L Piney River < | 15 | 5 |
| | *Ceratopsyche morosa Hagen* | Gasconade River | 106 | 7 |
| | *Ceratopsyche slossonae Banks* | L Piney River | 17 | 5 |
| | *Hydropsyche simulans/incommoda* | L Piney River | 14 | 5 |
| | *Hydropsyche sp.* | Osage Fork | 75 | 4 |
| | *Ceratopsyche (morosa grp.)* | L Piney River | 17 | 5 |
| | *Hydropsyche venularis Banks* | Gasconade River | 77 | 7 |
| | *Hydropsyche frisoni Ross* | Gasconade River | 77 | 7 |
| | *Hydropsyche betteni Ross* | Gasconade River | 77 | 7 |
| | *Cheumatopsyche sp.* | L Piney River | 17 | 5 |
| | *Hydropsyche cuanis Ross* | Gasconade River | 77 | 7 |
| | *Macrostemum carolina* (Banks) | Gasconade River | 229 | 6 |
| **Hydroptilidae** | *Ochrotrichia sp.* | L Piney River | 17 | 5 |

| Family | Species | Stream | Mile | Order |
|---|---|---|---|---|
| | *Ithytrichia clavata Morton* | Gasconade River | 116 | 6 |
| | *Oxyethira sp.* | L Piney River | 17 | 5 |
| | *Agraylea multipunctata Curtis* | Gasconade River | 77 | 7 |
| | *Ithytrichia sp.* | Gasconade River | 77 | 7 |
| | *Hydroptila sp.* | Gasconade River | 77 | 7 |
| **Isonychiidae** | *Isonychia sp.* | L Piney River | 17 | 5 |
| **Leptoceridae** | *Oecetis inconspicua* (Walker) | Gasconade River | 77 | 7 |
| | *Nectopsyche sp.* | Gasconade River | 77 | 7 |
| | *Leptophlebia cupida* (Say) | Gasconade River | 106 | 7 |
| | *Choroterpes sp.* | Shoal Creek | 1 | 2 |
| | *Paraleptophlebia moerens* (McDunnough) | Gasconade River | 116 | 6 |
| | *Traverella sp.* | Gasconade River | 106 | 7 |
| | *Choroterpes basalis* (Banks) | Woods Fork | 1 | 4 |
| **Leuctridae** | *Leuctra tenuis* (Pictet) | L Piney River | 17 | 5 |
| **Limnephilidae** | *Neophylax fuscus Banks* | Gasconade River | 114 | 7 |
| | *Ironoquia sp.* | Woods Fork | 1 | 4 |
| | *Limnephilus sp.* | L Piney River | 15 | 5 < |
| | *Pycnopsyche sp.* | Shoal Creek | 1 | 2 |
| **Limnicidae** | *Lutrochus laticeps Casey* | Gasconade River | 77 | 7 |
| **Macromiidae** | *Didymops sp.* | Gasconade River | 106 | 7 |
| **Nemouridae** | *Prostoia sp.* | Gasconade River | 77 | 7 |
| | *Amphinemura delosa* (Ricker) | Shoal Creek | 1 | 2 |
| **Neoephemeridae** | *Neoephemera bicolorMcDunnough* | Gasconade River | 77 | 7 |
| **Perlidae** | *Perlesta placida* (Hagen) | Gasconade River | 77 | 7 |
| | *Perlinella drymo* (Newman) | Gasconade River | 77 | 7 |

| Family | Species | Stream | Mile | Order |
|---|---|---|---|---|
| | *Paragnetina media* (Walker) | L Piney River | 15 | 5 |
| | *Neoperla clymene* (Newman) | Gasconade River | 77 | 7 |
| | *Acroneuria sp.* | L Piney River | 14 | 5 |
| | *Agnetina capitata* (Pictet) | Osage Fork | 75 | 4 |
| **Perlodidae** | *Isoperla mohri Frison* | Gasconade River | 77 | 7 |
| | *Hydroperla sp.* | Woods Fork | 1 | 4 |
| | *Isoperla bilineata* (Say) | Gasconade River | 77 | 7 |
| | *Isoperla sp.* | Gasconade River | 106 | 7 |
| **Philopotamidae** | *Chimarra aterrima Hagen* | Gasconade River | 77 | 7 |
| | *Chimarra obscura* (Walker) | L Piney River | 17 | 5 |
| **Phryganeidae** | *Phryganea sp.* | Gasconade River | 106 | 7 |
| **Polycentropodidae** | *Neureclipsis crepuscularis* (Walker) | Gasconade River | 116 | 6 |
| | *Polycentropus sp.* | Gasconade River | 77 | 7 |
| **Potamanthidae** | *Anthopotamus sp.* | Gasconade River | 77 | 7 |
| **Psephinidae** | *Psephenus herricki* (DeKay) | L Piney River | 17 | 5 |
| | *Ectopria nervosa* (Melsheimer) | L Piney River | 17 | 5 |
| **Psychomyiidae** | *Psychomyia flavida Hagen* | L Piney River | 14 | 5 |
| **Pteronarcyidae** | *Pteronarcys pictetii Hagen* | Gasconade River | 77 | 7 |
| | *Pteronarcys sp.* | Gasconade River | 77 | 7 |
| **Pyralidae** | *Petrophila sp.* | Gasconade River | 77 | 7 |
| **Rhyacophilidae** | *Rhyacophila sp.* | Shoal Creek | 1 | 2 |
| **Sialidae** | *Sialis sp.* | Gasconade River | 77 | 7 |
| **Tabanidae** | *Chrysops sp.* | Gasconade River | 77 | 7 |
| **Taeniopterygidae** | *Strophopteryx fasciata* (Burmeister) | Gasconade River | 77 | 7 |
| | *Strophopteryx sp.* | Gasconade River | 77 | 7 |

| Family | Species | Stream | Mile | Order |
|---|---|---|---|---|
| | *Taeniopteryx sp.* | Gasconade River | 77 | 7 |
| | *Taeniopteryx parvula* Banks | Gasconade River | 106 | 7 |
| | *Taeniopteryx metequi* Ricker & Ross | L Piney River | 14 | 5 |
| **Talitridae** | *Hyalella azteca* (Saussure) | Gasconade River | 77 | 7 |
| **Tanyderidae** | *Protoplasa fitchii* Osten-Sacken | L Piney River | 14 | 5 |
| **Tipulidae** | *Limonia sp.* | Gasconade River | 229 | 6 |
| | *Dicranota sp.* | Shoal Creek | 1 | 2 |
| | *Erioptera sp.* | Gasconade River | 77 | 7 |
| | *Tipula sp.* | L Piney River | 14 | 5 |
| | *Hexatoma sp.* | L Piney River | 17 | 5 |
| | *Antocha sp.* | L Piney River | 17 | 5 |
| **Tricorythidae** | *Tricorythodes sp.* | L Piney River | 17 | 5 |
| **Veliidae** | *Rhagovelia sp.* | Woods Fork | 1 | 4 |
| **Mollusca** | | | | |
| **Ancylidae** | *Ferrissia fragilis* (Tryon) | Gasconade River | 77 | 7 |
| | *Ferrissia sp.* | Gasconade River | 77 | 7 |
| **Corbiculidae** | *Corbicula fluminea* (Muller) | Gasconade River | 77 | 7 |
| | *Corbicula sp.* | Gasconade River | 54 | 7 |
| **Margaritiferidae** | *Cumberlandia monodonta* (Say) | Gasconade River | 106 | 7 |
| **Physidae** | *Physa (Physella) sp.* | Gasconade River | 77 | 7 |
| **Planorbidae** | *Planorbula armigera* (Say) | Gasconade River | 84 | 7 |
| **Pleuroceridae** | *Elimia potosiensis plebeius* (Gould) | L Piney River | 17 | 5 |
| | *Pleurocera acuta* Rafinesque | Gasconade River | 106 | 7 |
| | *Elimia sp.* | Gasconade River | 77 | 7 |
| | *Pleurocera sp.* | Gasconade River | 77 | 7 |
| **Nematomorpha** | | | | |

| Family | Species | Stream | Mile | Order |
|---|---|---|---|---|
| **Gordiida** | | Roubidoux Creek | 1 | 5 |
| **Platyhelminthes** | | | | |
| **Planariidae** | | L Piney River | 17 | 5 |

Table 31. Sensitive animal species known from the Gasconade River (printout from the Missouri Department of Conservation's (MDC) Fish Research collection and the Natural Heritage Database, 2000).

| Sensitive Animal Species | Federal Status[1] | State Status | State Rank |
|---|---|---|---|
| **Fish** | | | |
| ***Alosa alabamae*** **(Alabama shad)** | | | S2 |
| ***Carpiodes velifer*** **(Highfin carpsucker)** | | | S2 |
| ***Crystallaria asprella*** **(Crystal darter)** | | E | S1 |
| ***Etheostoma microperca*** **(Least darter)** | | | S2 |
| ***Fundulus sciadicus*** **(Plains topminnow)** | | | S3 |
| ***Hiodon tergisus*** **(Mooneye)** | | | S3 |
| ***Ichthyomyzon gagei*** **(Southern brook Lamprey)** | | | S2S3 |
| ***Notropis heterolepis*** **(Blacknose shiner)** | | | S2 |
| ***Percina cymatotaenia*** **(Bluestripe darter)** | | | S2 |
| ***Typhichthys subterraneus*** **(Southern cavefish)** | | | S2S3 |
| **Amphibians** | | | |
| ***Ambystoma annulatum*** **(Ringed salamander)** | | | S3 |
| ***Cryptobranchus alleganiensis alleganiensis*** **(Eastern hellbender)** | | | S2 |
| ***Hemidactylium scumtatum*** **(Four-toed salamander)** | | | S4 |
| **Mollusks** | | | |
| ***Alasmidonta marginata*** **(Elktoe)** | | | S2? |
| ***Cumberlandia monodonta*** **(Spectalcecase)** | | S3 | |
| ***Elliptio crassidens*** **(Elephant-ear)** | | E | |
| ***Fusconaia ebena*** **(Ebonyshell)** | E | S1? | |
| ***Lampsilis abrupta*** **(Pink mucket)** | E | E | S2 |

| Sensitive Animal Species | Federal Status[1] | State Status | State Rank |
|---|---|---|---|
| ***Leptodea leptodon* (Scaleshell)** | | S2 | E |
| ***Ligumia recta* (Black Sandshell)** | | | S1S2 |
| ***Ptychobranchus occidentalis* (Ouachita Kidneyshell)** | | | S2S3 |
| ***Plethabasus cyphyus* (Sheepnose)** | | E | |
| **Crustaceans** | | | |
| ***Allocrangonyx hubrichti* (Central Missouri cave amphipod)** | | | S1S2 |
| ***Cambarus hubrichti* (Salem cave crayfish)** | | | S3 |
| ***Fallicambarus fodiens* (Digger crayfish)** | | | S2S3 |
| ***Stygobromus onondagaensis* (Onondoga Cave amphipod)** | | | S3? |
| **Insects** | | | |
| ***Acroneuria ozarkensis* (Perlid stonefly)** | | | S2 |
| **Birds** | | | |
| ***Accipiter cooperii* (Cooper's hawk)** | | | S3 |
| ***Accipiter striatus* (Sharp-Shined hawk)** | | | S2 |
| ***Ammodramus henslowii* (Henslow's sparrow)** | | | S2 |
| ***Ardea herodias* (Great blue heron)** | | | S5 |
| ***Buteo lineatus* (Red-Shouldered hawk)** | | | S3 |
| ***Cistothorus palustris* (Marsh wren)** | | | S2 |
| ***Dendroica cerulea* (Cerulean warbler)** | | | S2S3 |
| ***Gallinula chloropus* (Common moorhen)** | | | S2 |
| ***Haliaeetus leucocephalus* (Bald eagle)** | T | E | S2 |
| ***Vireo bellii* (Bell's vireo)** | | | S3 |

**State status:** E=Endangered

**Federal status:** E=Endangered; T=Threatened
**State rank:** S1=critically imperiled in Missouri; S2=Imperiled in Missouri; S3=rare in Missouri.

Table 32. Estimated angler effort by angling, set line fishing, gigging, and all methods combined (Fleener, G. 1982).

| Totals | Angling | Set line Fishing | Gigging | All methods combined |
|---|---|---|---|---|
| **From the upper segment of Gasconade River, State Route M near Hartville to State Highway 133 (89 miles) from March 12, 1978 to March 10, 1979.** | | | | |
| **Total fish** | 81,210 | 160 | 12,200 | |
| **Total hours** | 110,710 | 3,230 | 5,310 | |
| **Fish per hour** | 0.73 | 0.05 | 2.30 | |
| **Total fisherman** | 43,050 | 150 | 3,510 | |
| **From the middle segment of Gasconade River, State Hwy 133 to Route E (86 miles), March 14, 1976 to March 12, 1977.** | | | | |
| **Total fish** | 88,650 | 3,070 | 29,740 | |
| **Total hours** | 250,380 | 31,630 | 21,360 | |
| **Fish per hour** | 0.35 | .10 | 1.39 | |
| **Total fishermen** | 71,120 | 4,590 | 5,790 | |
| **From the lower segment of Gasconade River, Route E in Maries County to the mouth (89 miles), from March 13, 1977 to March 11, 1978.** | | | | |
| **Total Fish** | 62,560 | 23,590 | 2,120 | |
| **Total hours** | 146,980 | 200,590 | 5,500 | |
| **Fish per hour** | 0.43 | 0.11 | 0.39 | |
| **Total fishermen** | 33,030 | 16,300 | 1,730 | |
| **From Osage Fork of the Gasconade River (56 miles from Wright-LaClede County line to confluence) March 12, 1978 to March 10, 1979.** | | | | |
| **Total fish** | 12,920 | - | 2,470 | 15,390 |
| **Total hours** | 29,580 | - | 620 | 30,200 |
| **Fish per hour** | 0.44 | - | 3.99 | 0.54 |
| **Total fishermen** | 11,910 | - | 310 | 12,220 |

Table 33. Summary statistics of the 1996 Little Piney Creek temperature monitoring project.

| Date/Location | Minimum | Maximum | Average | Standard Error |
|---|---|---|---|---|
| **July 10 - August 5** | | | | |
| **Air Temperature** | 51.4 | 91.1 | 71.2 | 7.96 |
| **Below Spring Branch** | 56.8 | 67.0 | 60.5 | 2.58 |
| **Vida Slab** | 58.1 | 71.7 | 64.3 | 3.08 |
| **Little Piney Allotment** | 60.7 | 77.9 | 68.5 | 3.92 |
| **August 7 - September 10** | | | | |
| **Air Temperature** | 56.3 | 83.5 | 70.4 | 5.99 |
| **Below Spring Branch** | 57.0 | 66.2 | 60.5 | 2.20 |
| **Vida Slab** | 58.9 | 72.0 | 64.0 | 2.79 |
| **Little Piney Allotment** | 61.8 | 76.2 | 67.9 | 2.83 |
| **Lower Bridge** | 62.8 | 78.1 | 68.9 | 2.85 |

# Management Problems and Opportunities

## Action Plan

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 Gasconade River watershed.

## Goal 1: Maintain and improve water quality in the Gasconade River Watershed so all streams are capable of supporting healthy native aquatic communities.

**Status:** Water quality in the Gasconade River watershed is generally good, with some exceptions, and room for improvement. In general, non-point source 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. The Upper Gasconade River hydrologic unit was rated as a Category I watershed by the Missouri Watershed Assessment Steering Committee in September 1998, although it did not rank in the top 10 watersheds in greatest need of improvement.

Contaminant sampling for pesticide bioaccumulation in fish indicates that Gasconade 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 and within subwatersheds in the watershed.

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.

1) 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.
2) Review Section 404, NPDES, and other permits and either recommend denial or appropriate mitigation for those that 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.
3) 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.

4) 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.
5) Cooperate with MDNR in creating a Clean Water Action Plan for the Upper Gasconade River watershed as specified in the Missouri Unified Watershed Assessment Final Report which is based on section 303 of the Clean Water Act.

## Goal II. Improve riparian and aquatic habitat conditions in the Gasconade River Watershed to meet the needs of native aquatic species.

**Status:** Stream habitat conditions within the Gasconade River and its tributaries are variable. To date public water use is quite limited and has not created instream flow concerns. The main stem has no channelized segments, although highway bridge and ford crossings are numerous within the watershed. 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. Approximately 19% of the stream corridors in the Upper Gasconade River hydrologic unit were found to be in poor condition by methodology described in the Habitat Conditions section.

### 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.

1) Work with MDC's Outreach and Education Division to develop stream management related materials and present related courses for elementary and secondary school teachers.
2) Establish and maintain stream management demonstration sites.
3) 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.

1) 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.
2) Provide technical recommendations to all landowners that request assistance and who are willing to reestablish and maintain an adequate riparian corridor.
3) Work with NRCS and SWCD boards to help them address watershed management concerns with their programs.
4) 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 subwatersheds cooperatively selected by MDC, NRCS, and the SWCD boards. Possibilities include Little Piney, Third, Second, Roubidoux, Whetstone, and Woods Fork creeks.
5) 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.
6) Utilize contacts with landowners, contractors, developers, and municipal and county officials as opportunities to educate people about how to obtain sand and gravel according to accepted guidelines and to control construction site erosion by utilizing practices that minimize damage to stream systems.

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

**Status:** The Gasconade River watershed has a diverse assemblage of 103 fish species collected from 1900 to 1999. These species are distributed among 49 genera and 21 families of fish ranging from the ancient Petromyzontidae (lampreys) to the more modern *Percidae* (perches) and *Sciaenidae* (drums). The dominant families and the number of genera in each are: *Cyprinidae* (16 genera), Catostomidae (6 genera), *Ictaluridae* (4 genera), Centrarchidae (4 genera), and *Percidae* (3 genera). Despite the high number of fish species in the Gasconade River watershed, 9 species are listed on the Missouri Species of Conservation Concern Checklist of June 2000 as critically imperiled, imperiled, or rare. The crystal darter *(Crystallaria asprella)* is classified as a state endangered species, and the bluestripe darter *(Percina cymatotaenia)* is a state imperiled species.

A total of 46 mussel species were collected in 1980-94 and again from July 21, 1998 and September 16, 1999 from Roubidoux Creek, Osage Fork, and the main stem Gasconade River. These species were distributed among 27 different genera. The dominant genera were *Lampsilis* (6 species), *Quadrula* (3 species), and *Fusconaia* (2 species). The pocketbook mussel *(Lampsilis cardium)* was the most widely distributed mussel in the watershed. Species that are much less abundant include three state-listed endangered mussel species, the elephant ear *(Elliptio* *crassidens),* ebonyshell *(Fusconaia ebena),* and the pink mucket *(Lampsilis abrupta).* The pink mucket is also classed as federally endangered.

Seven species of crayfish have been collected in the Gasconade River watershed and three genera comprise the five species. *Orconectes* was the dominant genus and comprised over 99% of the crayfish composition. Devil crayfish *(Cambarus diogenes)* were collected in Roubidoux Creek, and digger crayfish *(Fallicambarus fodiens)* were collected in the lower Gasconade River. The rare Salem cave crayfish *(Cambarus hubrichti)* is located in some caves of the watershed.

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

**Strategy:** Assess the quality of populations of sportfishing 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.

1) 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.
2) Maintain aquatic biodiversity and protect or enhance fish and invertebrate species diversity and abundance using regulations, stocking, habitat improvement, and related techniques.
3) Cost share priority areas emphasizing practices designed to protect water quality and promote stream system integrity should be pursued with agricultural agencies and interested landowners in subwatersheds of importance to sensitive species such as the crystal darter and bluestripe darter.

## Goal IV. Improve the public's appreciation for stream resources in the Gasconade River Watershed.

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

1) Working with MDC's Education Division, use streams for aquatic education programs. Identify stream locations appropriate for educational field trips near participating schools.
2) Provide a stream resource emphasis at public events such as local fairs.
3) Promote the formation of STREAM TEAMs and STREAM TEAM associations within the watershed.
4) Make the Gasconade River Watershed Inventory and Assessment available to the public on the internet.

# Angler Guide

"In every catch-and-release fisherman's past there is an old black frying pan...."

— John Gierach, *The View From Rat Lake*

Gasconade River game fish species that are commonly fished by the pole-and-line method include smallmouth bass, largemouth bass, rock bass, channel catfish, flathead catfish and crappie species. Panfish species such as longear sunfish and bluegill sunfish are less commonly fished but are a good addition to the creel. Other species of fish such as the sucker and redhorse are taken by gigging or other methods and are excellent fish species for the fish fry. The paddlefish is also sought in reaches of the main stem Gasconade River.

In streams the statewide black bass regulation is a daily limit of six, in aggregate including smallmouth bass, largemouth bass, spotted bass, and all black bass hybrids; bass may not be taken from March 1 to the fourth Saturday in May. The stream statewide minimum size limit is 12 inches.

Largemouth bass are the dominant black bass species due to the many large pools found in the Maries County portion of the river. Largemouth bass have preference for pools greater that 3' in depth. During spring, largemouth can be found in the backwater off-channel areas, but summer temperatures (prefer water temperatures of 82-87E F) force largemouth into the main channel habitats where the water quality is better. The larger bass defend a territory that gives them the best access to cover and food that may consist of insects, crayfish, frogs, or fish. Sampling by fisheries biologists shows that largemouth are the largest bass species within any pool. Spotted bass look similar to largemouth bass in appearance except for their lower maximum total length and tooth patch on the tongue. Spotted bass can also be caught with some regularity in the Gasconade River by fishing the rootwads and snags associated with current along cut banks.

## Largemouth Bass Fishing Tips

Look for largemouth bass near prominent structure. The river's weedy backwater pools may be a good choice to fish during spring but during the summer try the main channel where newly fallen trees or large rocky areas are found. Where to fish on the main channel during summer months can be a tricky decision. Fishing areas with the appropriate combination of current to bring food and to provide cover, and shade for thermal refuge, a vigilant angler can be successful.

Largemouth bass can be found in slower flowing water than smallmouth bass. Anglers throw a vast array of artificial lures at largemouth bass, from plastic worms and jigs to topwater lures and spinnerbaits. Plastic worms fished Texas style work well for largemouth bass and spotted bass.

Smallmouth bass habitat is slightly different from the largemouth bass. Smallmouth prefer slightly cooler water (approximately 78 degrees F) with woody structure or boulders. A small pocket hole along an undercut bank, just outside of swiftly-moving water, may be good cover for a smallmouth bass waiting in ambush for a foraging crayfish, aquatic insect, or small fish.

## Smallmouth Bass Fishing Tips

The great fighting ability of smallmouth bass has attracted recreational anglers for years. In the main stem Gasconade River smallmouth bass can be found in cover associated with current at the top ends of bluff holes. In the Gasconade River tributaries look for smallmouth bass where rootwads and boulders or sturdy current-breaking structure and current meet. In the Osage Creek, smallmouth up to 16.5 inches are sampled and Master-Angler-size fish (17 inches) are reported annually. Missouri Department of Conservation (MDC) created a regulation in March 2000 that protects smallmouth bass in the Osage Fork of the Gasconade River, from Skyline Drive bridge near Orla to its confluence with the Gasconade River, by an 18-inch minimum length limit. Only one of the six black bass may be a smallmouth bass.

Artificial lures, such as small, floating crayfish colored crankbaits and plastic worms fished around cover, are successful. Live bait (crayfish, worms, minnows) also work well.

Rock bass (goggle-eye) have no size limit and have a daily limit of fifteen. Rock bass make a great addition to the creel and frying pan. Found in similar habitat as the smallmouth, these smaller members of the sunfish family prefer rocky bottoms and streams with sluggish or moderate currents. In tributaries to the Gasconade River, rock bass seek cover near water willow, rootwads, or boulders near the shoreline. An angler can expect 7"-9" rock bass and a few one-pound rock bass. MDC created a regulation in March 2001 that protects rock bass in the Osage Fork of the Gasconade River, from Skyline Drive bridge near Orla to its confluence with the Gasconade River, with a minimum length limit of eight inches, and a daily limit of eight rock bass.

## Rock Bass Fishing Tips

Rock bass have the habit of streaking out of nowhere to attack virtually any bait or lure.

This spunky fighting fish takes lures or natural baits. Artificial lures may include tiny jigs, in-line spinner, small spoons, or small spinner baits. Worms, grubs, leeches, small minnows, crickets, grasshoppers are effective natural baits.

Channel catfish are bottom feeders. They are found in water that ranges from 82-87 degrees F. Feeding behavior is poor outside of the optimal temperature range, so you should plan your fishing on hot days in deeper water or in the cool morning or late evening hours. Look for them in habitat containing current, deep pools, and cover such as downed trees.

## Catfish Fishing Tips

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 or beef 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. Unlike the channel catfish, flathead catfish prefer live bait or freshly killed baits. Use large minnows, goldfish, green sunfish, or bullheads. In the 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 Gasconade River.

Meaty river redhorse, golden redhorse, and hog sucker are taken by grabbing, (or snagging), pole-and-line angling using bait, or by gigging. Gigging has long been a local tradition in the Ozarks. Nongame fish may be taken by the gig method in the Gasconade River between sunrise and midnight from September 15 to January 31 with a daily limit of 20 fish in aggregate (See Summary of Missouri Fishing Regulations).

## Sucker Fishing Tips

Sucker species are more often taken by gigging and snagging, but less dependent on clear water, pole-and-line methods have been successful using earthworm or mussels (clams) as bait. After scaling, filleting, and scoring (cut-vertically through the flesh every 1/4 inch but not through the skin), deep-frying scored fillets rolled in cornmeal is probably the most common way to fix suckers.

Other species of fish sought after are longear sunfish, bluegill sunfish and the paddlefish. Enjoy fishing for longear sunfish, bluegill sunfish using earthworms or larva mimics on jigs. Bluegill can be found in a variety of water temperatures but will avoid temperatures greater than 86 EF. Feeding behavior declines outside of the optimal temperature range, so plan your fishing on hot days in the shaded areas or in the cooler morning hours. Found in good abundance, these species co-exist in association with basses and other sunfish species. Longear can be taken throughout the year using the same fishing methods as bluegill sunfish. The paddlefish is one of Missouri's unique fisheries and when water conditions are right, paddlefish can be caught at the mouth of the Gasconade River. This plankton feeder is popular with anglers during the March 15 to April 30 season. Limit is two paddlefish daily and legal fish must be 24 inches from eye to fork of tail. Snagging with large treble hooks is the only practical method to take paddlefish. Because this fish has the potential to top 100 pounds, anglers are generally outfitted with heavy duty rods and reels. Check Missouri Fishing Regulations for details.

Thermal Preferences of major game fish.

| Species | Optimum - F | Lethal - F |
|---|---|---|
| **channel catfish** | 82.5-87 | 98 |
| **bluegill sunfish** | 84-86 | 98.5 |
| **largemouth bass** | 79-82.5 | 97.5 |
| **smallmouth bass** | 79 | 95 |

## Links for Angling

- http://www.bassmaster.com/
- Fishing Prospects
- State Fishing Regulations
- The Complete Angler
- The Smallmouth Bass Alliance
- Missouri Fishing Links
- Tips and techniques

# 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.
**Nektonic:** 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.

# Literature Cited


*A Reminiscent History of the Ozark Region: A condensed general history, a brief descriptive history of each county, and numerous biographical sketches of prominent citizens of such counties.* 1956. Cape Girardeau, MO.

Alan Buchanan 1995. *Atrazine in Missouri waters.* Unpublished memorandum. Missouri Department of Conservation.

— 1995. *Contaminant levels in Missouri fish: 1994.* Missouri Department of Conservation, Fisheries Research Division, Columbia Missouri. Printout from the contaminant database.

— 1998. *Contaminant levels in Missouri fish: 1998.* Missouri Department of Conservation, Fisheries Research Division, Columbia Missouri. Printout from the contaminant database.

Blanc, T. J., M. Caldwell, M. Hawks. 1998. *Meramec River watershed demonstration project.* Funded by: US Environmental Protection Agency. Missouri Department of Conservation, Sullivan and Columbia, MO. November 1998.

Blanc, T. J. 1999. *Bourbeuse River watershed inventory and assessment.* Missouri Department of Conservation, Fisheries Division, Sullivan, MO. http://www.conservation.state.mo.us/fish/watershed/bourbeuse/contents/500cotxt.htm

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.

— 1981. *Missouri pollution and fish kill investigations 1980.* Missouri Department of Conservation, Fish and Wildlife Research Center, Columbia, Missouri.

CARES 1996. *Critical watersheds as defined by the Missouri Clean Water Commission (MDNR 10 CSR 20-7.010).* 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/wshed6.html Date of access: July 26, 1999.

CARES (Center for Agricultural, Resource and Environmental Systems) 1997a. *Selected chemical sites in Missouri (areas).* 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/chemdeal6.html Date of access: July 26, 1999.

CARES 1997b. *Selected past & present pesticide applicators and operators (points).* 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/chemdeal6.html Date of access: July 26, 1999.

CARES 1999c. *Special Area Land Treatment (SALT) watersheds, EARTH Project watersheds, Originator: CARES, NRCS/MDNR Scale:1:24,000.* Based on basin series used in the Missouri Water Atlas 1986. http://www.cares.missouri.edu/cwic/mowater/wsheds6.html Date of access: July 26, 1999.

CARES 1997d. *Public water supply facilities.* Originator: CARES, NRCS/MDNR; Scale:1:24,000.Based on basin series used in the Missouri Water Atlas 1986. http://www.cares.missouri.edu/cwic/mowater/pwsfac6.html Date of access: July 26, 1999.

Cowardin, L. M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. *Classification of wetlands and deepwater habitat of the United States.* U.S. Fish and Wildlife Service, Washington, D.C. 131 pp.

Crunkilton, Ronald 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. 1989. *Missouri natural feature inventory: Dallas, Greene, Hickory, Polk, and Webster counties.* Natural History Division, Missouri Department of Conservation, Jefferson City, MO.

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.

Dake, C. L. 1918. *The sand and gravel resources of Missouri.* Missouri Bureau of Geology and Mines, Rolla, Missouri.

Ducharme, Charles B. and Miller, Todd 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, Richard 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.

— 1997. *Report of pollution and fish kill investigation at Waynesville/Robertsville, Pulaski County.* Sedimentation from construction sites into Roubidoux Creek. Event date: 3/13/99. Missouri Department of Conservation, Columbia, Missouri

East Central Regional Coordination Team (EC RCT) 1998. *Regional Management Guidelines for the East Central Region.* Missouri Department of Conservation, East Central Region, Sullivan MO.

EPA *Surf Your Watershed 1999.* Upper Gasconade USGS Cataloging Unit: 10290201: Environmental Profile. http://www.epa.gov/surf2/hucs/10290201/Date of access: July 26, 1999.

Eubank, W. et al. 1993. *Bacteria in drinking water.* University Extension, University of Missouri-System WQ 102.

EPA *Surf Your Watershed 1999.* Lower Gasconade USGS Cataloging Unit: 10290203: Environmental Profile. http://www.epa.gov/surf2/hucs/10290203/Date of access: July 26, 1999.

Finger S. E., B. C. Poulton and S. A. Humphrey 1990. *Effects of a crude oil spill on the benthic invertebrate community on the Gasconade River, Missouri.* National Fisheries Contaminant Research Center, Columbia, MO 65201.

Fleener, G. G. 1982. *Recreational use of Gasconade. Missouri Department of Conservation*. Jefferson City, MO. Final Report. Dingell-Johnson Project F-1-R-30. Study S-21. Date Prepared: July 14, 1982.

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

Epperson, J. E. 1992. *Missouri wetlands: a vanishing resource.* Missouri Department of Natural Resources, Division of Geology and Land Survey, Rolla, Missouri.

Goodspeed Publishing Co., 1889. *History of Laclede, Camden, Dallas, Webster, Wright, Texas, Pulaski, Phelps, and Dent counties.* 1219 pp.

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.
Imes, J.L., J. G. Schumacher, and M. J. Kleeshulte. 1996. *Geohydrologic and water-quality assessment of the Fort Leonard Wood Military Reservation, Missouri,* 1994-95. USGS Water Resources Investigations Report 96-4270.
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, R. B. and A. L. Pugh 1997. *Riparian vegetation controls on the spatial pattern of stream-channel instability, Little Piney Creek, Missouri: U.S. Geological Survey Water-supply Paper 2494.*
Kromrey, G. 1990. *Adult fish survey of the Gasconade River.* Missouri Department of Conservation, Sullivan MO. November 15, 1990.
McGrath, K.E. 1988. *Contaminant levels in Missouri Fish — 1986.* Missouri Department of Conservation, Columbia, Missouri.
Missouri Agricultural Statistics Service (MASS). 1997. *Missouri farm facts.* Missouri Agricultural Statistics Service, Columbia, Missouri.
Missouri Agricultural Statistics Service (MASS). 1997. *County Agri-facts.* Missouri Agricultural Statistics Service, Missouri Department of Agriculture, Columbia, Missouri.
Missouri Department of Conservation. 1991a. *Rare and endangered species of Missouri checklist.* Missouri Department of Conservation, Jefferson City, Missouri.
Missouri Department of Conservation. 1991b. *Gasconade River public use and benefits survey, Summer 1989.* Missouri Department of Conservation, Jefferson City, Missouri.
Missouri Department of Conservation. 1991c. *Stream Gravel Removal Guidelines.* December 1991. Missouri Department of Conservation, Jefferson City, Missouri.
Missouri Department of Conservation. 1993. *Helicopter video tape of Gasconade River from Jerome, MO to river mouth.* Flight date: February 22, 1993. Missouri Department of Conservation, Sullivan, Missouri.
– 1995. *Stamp of character – from trees to tracks.* Missouri Department of Conservation, Media Library, Jefferson City, MO.
— 1995a. *Pflieger's fish and crayfish collections.* Missouri Department of Conservation Fisheries Research Section, Columbia, Missouri.
— 1995b and 1999. *Missouri benthos collections.* Missouri Department of Conservation Fisheries Research Section, Columbia, Missouri.
— 1996. *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.
— 1997. *Guidelines for recommending stream side management zones on private land.* Fisheries Division, Missouri Department of Conservation. Memorandum from Norm Stucky, April 30, 1997.
— 1999. *Stream environmental review database.* Summary dataset. Missouri Department of Conservation, East Central Region Fisheries, Sullivan, Missouri.
Missouri Department of Natural Resources (MDNR). 1979. *Geologic map of Missouri.* Missouri Department of Natural Resources, Division of Geology and Land Survey, Rolla, Missouri.

Missouri Department of Natural Resources (MDNR). 1984, 1997. *Missouri water quality basin plans.* Volume 4. Osage and Gasconade Rivers. Missouri Department of Natural Resources, Jefferson City, Missouri.

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

— 1994a. *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.

— 1994b. *Missouri water quality report 1994.* Missouri Department of Natural Resources. Jefferson City, Missouri.

— 1994c. *Rules of Department of Natural Resources, Division 40 - Land Reclamation Commission.* Chapter 10 - Permit and Performance Requirements for Industrial Mineral Open Pit and In-Stream Sand and Gravel Operations, CSR 40-10.020 (2)(D). Code of State Regulations, Office of Secretary of State, Jefferson City, Missouri.

— 1999a. *Active permits: Operation and construction permits for animal waste facilities for classes of operation.* Print out from the Division of Water Pollution Control, October 1, 1999.

— 1999b. Inventory of Mine Occurrences and Prospects (IMOP) Database. Database printout of counties in the Gasconade Watershed. Missouri Department of Natural Resources, Geologic Survey Program, PO Box 250, Rolla, MO 65402.

— 1999c. *Solid Waste Management Program.* Information pertaining to solid waste management facilities. Sanitary landfills in Missouri, closed facilities, and inactive facilities. http://www.dnr.state.mo.us/deq/swmp/homeswmp.htm Date of Access: November 8, 1999.

Missouri Unified Watershed Assessment Steering Committee. 1998. State of Missouri *Unified Watershed Assessment. Final Report.* C/o USDA-Natural Resources, Conservation Service Parkade Center, Suite 250, 601 Business Loop 70 West, Columbia, MO 65203-2546. September 28, 1998. http://www.cares.missouri.edu/mowiap/Date of Access: February 21, 2000.

McKenney, R., R. B. Jacobson and R. C. Wertheimer. 1995. *Woody vegetation and channel morphogenesis in low-gradient, gravel-bed streams in the Ozarks Region, Missouri and Arkansas: in Hupp, C., Ostercamp, W., and Howard, A. eds,* Biogeomorphology-terrestrial and freshwater aquatic systems. Geomorphology, p. v. 7, pp 46-56.

McKenney, Rose. 1997. *Formation and maintenance of hydraulic habitat units in streams of the Ozark Plateaus, Missouri and Arkansas.* Graduate Thesis. The Pennsylvania State University. The Graduate School. December 1997.

McKenney, Rose and Robert B. Jacobson. 1996. *Erosion and deposition at the riffle-pool scale in gravel-bed streams, Ozark Plateaus, Missouri and Arkansas, 1990–95.* US Geological Survey Open-File Report 96-655A. Rolla, Missouri.

MORAP 1997. *Missouri Resource Assessment Partnership.* Phase I Land Cover Map. December 1997.

National Climatic Data Center (NCDC) 1999. *National Climatic Data Center Online Line Climate and Weather Observations.* Precipitation data by state for the period 1948-1997. http://www.ncdc.noaa.gov/ol/climate/coop-precip.html Date of Access: October 25, 1999.

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

Ohunan, Marian M. 1983. *A history of Missouri counties, county seats, and courthouse squares.* University of MO-Columbia, Extension Division, Columbia, MO.
OSEDA 1999. USDC, *Bureau of the Census, Census of Agriculture.* Accessed August 1999. County population information from: http://www.oseda.missouri.edu/countypage/
Owens, L. B., W. M. Edwards, and R.W. Keuren 1996. *Sediment losses from a pastured watershed before and after stream fencing.* Journal of Soil and Water Conservation 51(1) 90-94.
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, William. 1989. *Aquatic community classification system for Missouri.* Aquatic Series No. 19. Missouri Department of Conservation, Jefferson City. 70 pp.
Pflieger, William. 1990. *An evaluation of the impacts of an oil spill on the fish fauna on the Gasconade River.* Missouri Department of Conservation. Columbia, MO.
Reno, Kyle, Rob Pullium, and Tom Priesendorf. 1995. *Riparian Guidelines.* Missouri Department of Conservation Memorandum. July 10, 1995.
Roell, M. 1994. Considerations for recommending streamside protection zones in Missouri. Missouri Department of Conservation, Columbia.
Roell, Michael J. 1999. *Sand and gravel mining in Missouri stream systems: Aquatic resource effects and management alternatives.* White paper. Missouri Department of Conservation, Conservation Resource Center, 1110 South College Avenue, Columbia, Missouri 65201.
Ryan, J. and Timothy E. Smith. 1991. *Missouri natural features inventory: Howell, Texas, and Wright 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.
Ryck, Frank. 1974. *Missouri Stream Pollution Survey.* Missouri Department of Conservation, Jefferson City, Missouri.
Ryck, Frank. 1998. *Planning Division MEMO: December 15, 1998.* Missouri Department of Conservation, Jefferson City, Missouri.
Sheffield, R.E. et al. 1996. *Off-stream water sources for grazing cattle as a stream stabilization and water quality BMP.* Presentation at the ASAE 1996 International Meeting, Phoenix, Arizona.
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, B. W. 1990. *Timber Resources of Missouri's Northwest Ozarks.* Resource Bulletin NC-114. St. Paul, MN; U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 44 p.
Soil Conservation Service (SCS). 1971. *Soil survey of Dent County, Missouri.* United States Department of Agriculture, Columbia, Missouri.
Soil Conservation Service. 1990. *Soil survey of Webster County, Missouri.* United States Department of Agriculture, Columbia, Missouri.

Soil Conservation Service. 1990. *Soil survey of Pulaski County, Missouri.* United States Department of Agriculture, Columbia, Missouri.

U.S. Department of Agriculture and Soil Conservation Service. 1981. *Watersheds in Missouri, based on water resources council hydrological units.* United States Department of Agriculture, Soil Conservation Service, Columbia, Missouri.

U.S. Department of Agriculture and Natural Resources Conservation Service. 1991. *State Soils Geographic Database (STATSGO).* United States Department of Agriculture, Conservation Service Columbia, Missouri.

USDA. 1998. *Unified National Strategy for Animal Feeding Operations.* Web Site: http://www.nhq.usda.gov/cleanwater/afohttp://www.nhq.nrcs.usda.gov/cleanwater/afo/Access date: January 19, 2000.

USDA Forest Service. 1999. *1998 Forest Health Highlights Missouri.* Web Site: http://willow.ncfes.umn.edu/states/fact_mo.htm Access date: January 19, 2000.

U.S. Department of the Army Corps of Engineers 1999. *Regulatory Analysis Management System.* Database printout of Gasconade River watershed counties with sand and gravel mining permits for the period 1992-99. US COE, Regulatory Office, Kansas City Missouri 64106.

United States Geological Survey (USGS). 1998. *Water resources data, Missouri, Water Year 1997.* USGS Water-Data Report MO-96-1. USGS, Rolla, Missouri.

United States Geological Survey (USGS). 1999. *Duration table of daily flow values at the Jerome Gage Station # 06933500 for period October - September.* Printout from the daily values statistical program. USGS, Rolla, Missouri.

Vineyard, J. D., G. L. Feder, R. G. Lipscomb, and W. L. Pflieger. 1974. *Springs of Missouri.* Missouri Geological Survey & Water Resources, U. S. Geological Survey, and Missouri Department of Conservation.

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.

Wang, Lizhu, John Lyons, Paul Kanehl, and Ronald Gatti. *Influences of watershed land use on habitat quality and biotic integrity in Wisconsin streams.* Fisheries Volume 22, No. 6, 1997.

Wehnes, Richard E. 1996. *Private lands stream corridor policy.* Missouri Department of Conservation Fisheries Division. Jefferson City, MO.

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