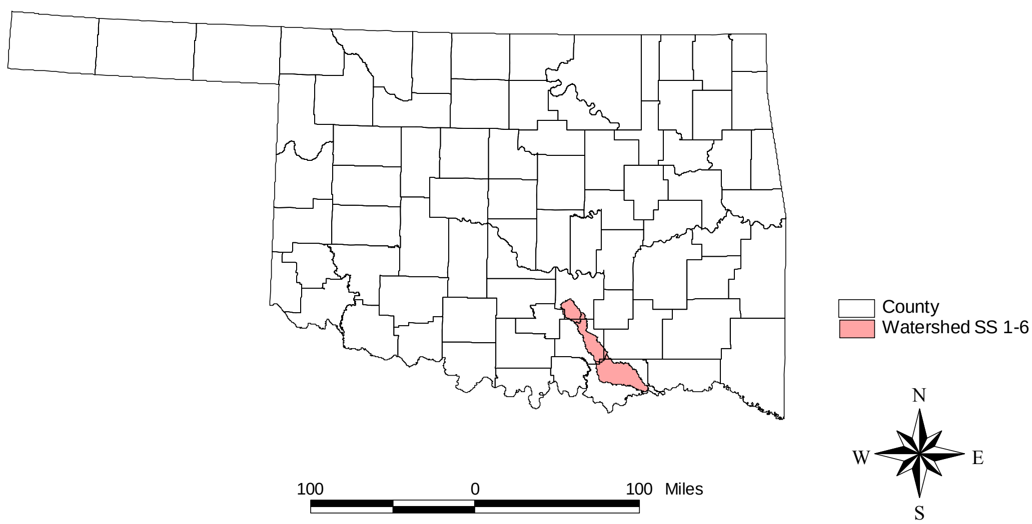
# HYDROLOGIC INVESTIGATION OF BLUE RIVER (STREAM SYSTEM 1-6)

**Technical Report 2008-01**





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December 2008

# STREAM SYSTEM 1-6: BLUE RIVER

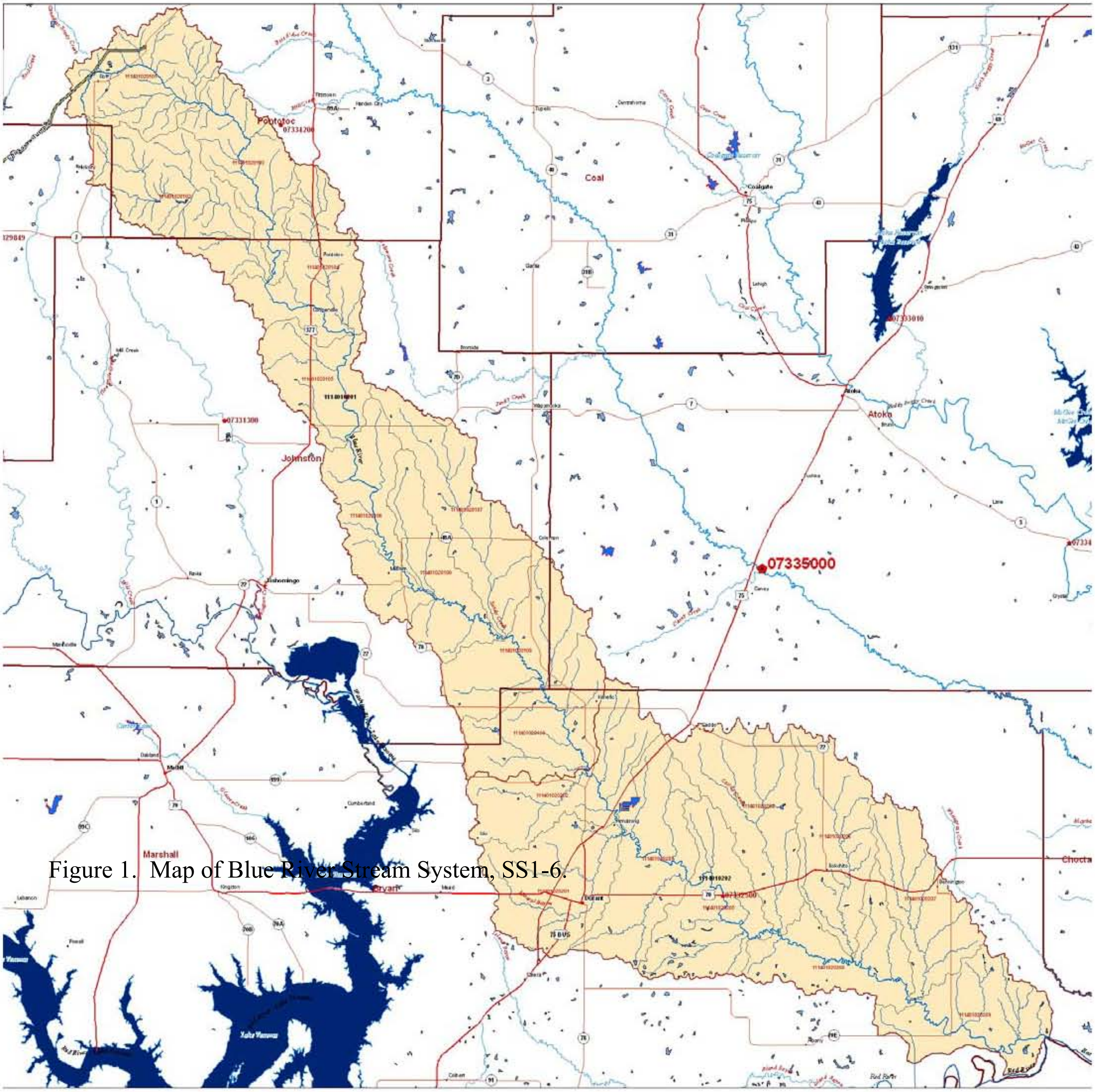



Figure 1. Map of Blue River Stream System, SS1-6.

**Figure 1. Map showing Blue River Stream System, SS1-06.**

# STREAM SYSTEM 1-6: BLUE RIVER BASIN

## General Information

**TABLE 1. DRAINGAGE AREAS FOR WATERSHEDS OF THE BLUE RIVER.**

| | HUC10 Watershed | HUC12 Sub-Watershed | Drainage Area of Stream System within Oklahoma | |
|---|---|---|---|---|
| | | | square miles | acres |
| **RED RIVER SYSTEM** | | | | |
| **1-6 Blue River Stream System** | | | **686** | **439,399** |
| Upper Blue River | 11140102 01 | | 348 | 223,005 |
| Limestone Creek - Blue River | | 1114010201 01 | 37 | 23,727 |
| West Little Blue Creek | | 1114010201 02 | 45 | 28,510 |
| 111403030103 - Blue River | | 1114010201 03 | 32 | 20,734 |
| Little Blue Creek - Blue River | | 1114010201 04 | 36 | 23,128 |
| Pecan Creek - Blue River | | 1114010201 05 | 26 | 16,682 |
| Desperado Spring Falls - Blue River | | 1114010201 06 | 34 | 21,458 |
| Sandy Creek | | 1114010201 07 | 42 | 27,107 |
| Little Sandy Creek - Blue River | | 1114010201 08 | 28 | 17,987 |
| Reeder Creek - Blue River | | 1114010201 09 | 34 | 21,534 |
| Bois d' Arc Creek - Blue River | | 1114010201 10 | 35 | 22,138 |
| Lower Blue River | 11140102 02 | | 338 | 216,394 |
| Mineral Bayou | | 1114010202 01 | 39 | 25,124 |
| Little Blue River - Blue River | | 1114010202 02 | 39 | 24,684 |
| Kanola Creek - Blue River | | 1114010202 03 | 41 | 25,972 |
| Caddo Creek | | 1114010202 04 | 43 | 27,806 |
| J&N Creek - Blue River | | 1114010202 05 | 37 | 23,614 |
| Bokehito Creek | | 1114010202 06 | 38 | 24,314 |
| Sulphur Creek | | 1114010202 07 | 32 | 20,709 |
| Cherokee Lake - Blue River | | 1114010202 08 | 33 | 21,146 |
| Lower Blue River | | 1114010202 09 | 36 | 23,025 |

Major tributaries – West Little Blue Creek; Little Blue Creek; Sandy Creek; Little Sandy Creek; Little Blue River; Caddo Creek; Bokchito Creek; Sulphur Creek.

The hydrologic basin of the Blue River has a total drainage area of 686 square miles or 439,399 acres and flows from its headwaters, near Roff, OK, for approximately 150 river miles to the Red River. The Blue River originates in Pontotoc County and flows in a southern direction through Johnston and Bryan Counties to join with the Red River. The perennial portion of Blue River begins only three miles Northwest of Connerville, near where sub-watersheds of West Little Blue Creek (111401020102), 111401020103, and Little Blue Creek (111401020104) meet. Perennial stream flow of the upper reach of the Blue River is sustained by discharge from the Arbuckle Simpson aquifer. The exact location of where the river becomes perennial varies depending on the water level in the Arbuckle-Simpson aquifer. During some years the main stem of the Blue River has been reported to be perennial all of the way to its headwaters.

**TABLE 2. NON-FEDERAL RESERVOIR AND LAKE STORAGE (National Inventory of Dams Database).**

| STREAM SYSTEM | HUC10 | HUC12 | Total Normal Storage of Lakes | Average Age of Lakes | Estimated Lake Yield |
|---|---|---|---|---|---|
| | | | acre-feet | years | acre-feet/year |
| **1-6 Blue River** | | | **7,911** | **38** | **7,100** |
| Upper Blue River | 1114010201 | | **1,181** | **45** | **876** |
| Limestone Creek - Blue River | | 111401020101 | 37 | 5 | 60 |
| West Little Blue Creek | | 111401020102 | | | |
| 111403030103 - Blue River | | 111401020103 | 173 | 65 | 109 |
| Little Blue Creek - Blue River | | 111401020104 | | | |
| Pecan Creek - Blue River | | 111401020105 | 52 | 42 | 15 |
| Desperado Spring Falls - Blue River | | 111401020106 | 210 | 76 | 11 |
| Sandy Creek | | 111401020107 | | | |
| Little Sandy Creek - Blue River | | 111401020108 | 179 | 46 | 153 |
| Reeder Creek - Blue River | | 111401020109 | 106 | 55 | 55 |
| Bois d' Arc Creek - Blue River | | 111401020110 | 424 | 27 | 463 |
| Lower Blue River | 1114010202 | | **6,731** | **31** | **6,230** |
| Mineral Bayou | | 111401020201 | 237 | 26 | 311 |
| Little Blue River - Blue River | | 111401020202 | 3,900 | 13 | 4,157 |
| Kanola Creek - Blue River | | 111401020203 | 123 | 39 | 90 |
| Caddo Creek | | 111401020204 | 93 | 30 | 116 |
| J&N Creek - Blue River | | 111401020205 | 1,218 | 37 | 883 |
| Bokehito Creek | | 111401020206 | 227 | 6 | 24 |
| Sulphur Creek | | 111401020207 | 50 | 27 | 65 |
| Cherokee Lake - Blue River | | 111401020208 | 297 | 33 | 270 |
| Lower Blue River | | 111401020209 | 586 | 32 | 312 |

There are approximately 35 non-NRCS structures used for water supply, recreation, fish, and wildlife management, or other uses. Durant Lake, built in 1980, is the largest lake in the stream systems with 3,900 af normal storage. There are three NRCS Structures with a combined normal storage of 89 af. In many instances most of the lakes within a stream system have not had a dependable yield analysis completed. In these cases the Oklahoma Water Resources Board estimates the yield of the non-NRCS lakes using the formula:

$$Yld_{lake} = ((St_{norm} * ((1-(Age/Life*100))) * \alpha) - (evap_{lake} * surf_{lake}) \qquad \textbf{equation 1}$$

Where estimated yield of the lake is determined by the normal lake storage, $St_{norm}$; the percentage of the life of the lake remaining (1-(Age/Life*100); the reservoir refill factor, α; lake evaporation rate, $evap_{lake}$; and surface area of the lake at its normal storage capacity, $surf_{lake}$.

The estimated reservoir refill factor (α) for the stream system is 1.8.

As an example, Durant Lake has a normal storage of 3,900 acre-feet of water and an estimated yield of 4,157 acre-feet per year.

Modeled annual pan evaporation for the Blue River, based on Mesonet data (1994 – 2006), ranges from 63 to 73 inches per year (Oklahoma Climatological Survey). Typically evaporation from open bodies of water, such as ponds and lakes is less than the pan evaporation. Net lake evaporation varies from 0.5 to 0.7 of pan evaporation. In the Blue River watershed net lake evaporation varies from 37 to 46 inches per year, with an average of 43.3 inches per year. Net evaporative losses from lakes within the Blue River stream system are about 2,200 acre-feet per year.

## Stream Water Flows

USGS gage 07332500 Blue River near Blue, OK: Period of Record - 1936 to Present
Gauge Location: Between Sec 27 and Sec.36, T6S-R10EIM, Bryan County - 476 $mi^2$ drainage area – HUC10: 1114010202.

**TABLE 3. MONTHLY PERCENT EXCEEDANCES - USGS GAGE 07332500 NEAR BLUE, OK.**

| Total Flow Above USGS Gage 07332500 | **Mean** | **90% Exceedance** | **80% Exceedance** | **50% Exceedance** | **20% Exceedance** |
|---|---|---|---|---|---|
| | af/month | af/month | af/month | af/month | af/month |
| January | 16,290 | 1,975 | 3,148 | 7,676 | 18,719 |
| February | 20,383 | 2,180 | 3,549 | 9,018 | 22,910 |
| March | 31,059 | 2,697 | 4,550 | 12,370 | 33,630 |
| April | 32,381 | 2,833 | 4,718 | 12,512 | 33,185 |
| May | 34,480 | 2,762 | 4,648 | 12,581 | 34,056 |
| June | 23,575 | 2,113 | 3,517 | 9,319 | 24,694 |
| July | 6,773 | 1,197 | 1,812 | 4,005 | 8,851 |
| August | 4,244 | 598 | 959 | 2,367 | 5,845 |
| September | 9,558 | 596 | 1,046 | 3,072 | 9,021 |
| October | 17,002 | 877 | 1,491 | 4,113 | 11,342 |
| November | 18,989 | 1,321 | 2,238 | 6,142 | 16,852 |
| December | 19,245 | 1,715 | 2,852 | 7,544 | 19,954 |
| **Mean Monthly Flows** | 19,498 | 1,739 | 2,877 | 7,560 | 19,922 |
| **Total Annual Flows** | 233,979 | 20,865 | 34,528 | 90,718 | 239,060 |

The mean annual flow for the Blue River near Blue, OK is 323 cfs, or 234,000 acre-feet per year. Median annual flow (50% exceedance) is 125 cfs or 90,700 acre-feet per year (TABLE 3). The mean annual flow data is skewed due to the peak flow values. There is a slight upward trend in mean annual flows (Figure 2), which might be attributable to an extended period of above normal rainfall in 1980’s and 1990’s.

Seasonal variability is similar to many streams in Oklahoma with higher stream flows during the spring and lower flows during the summer months. Blue River has recorded zero flow at the stream gage near Blue, OK. 28 days during the gage’s period of record. The 90% and 80% exceedance flows show subdued seasonal variability, which reflects the stabilizing impact of groundwater discharge to the base flow of the stream (Figure 3).

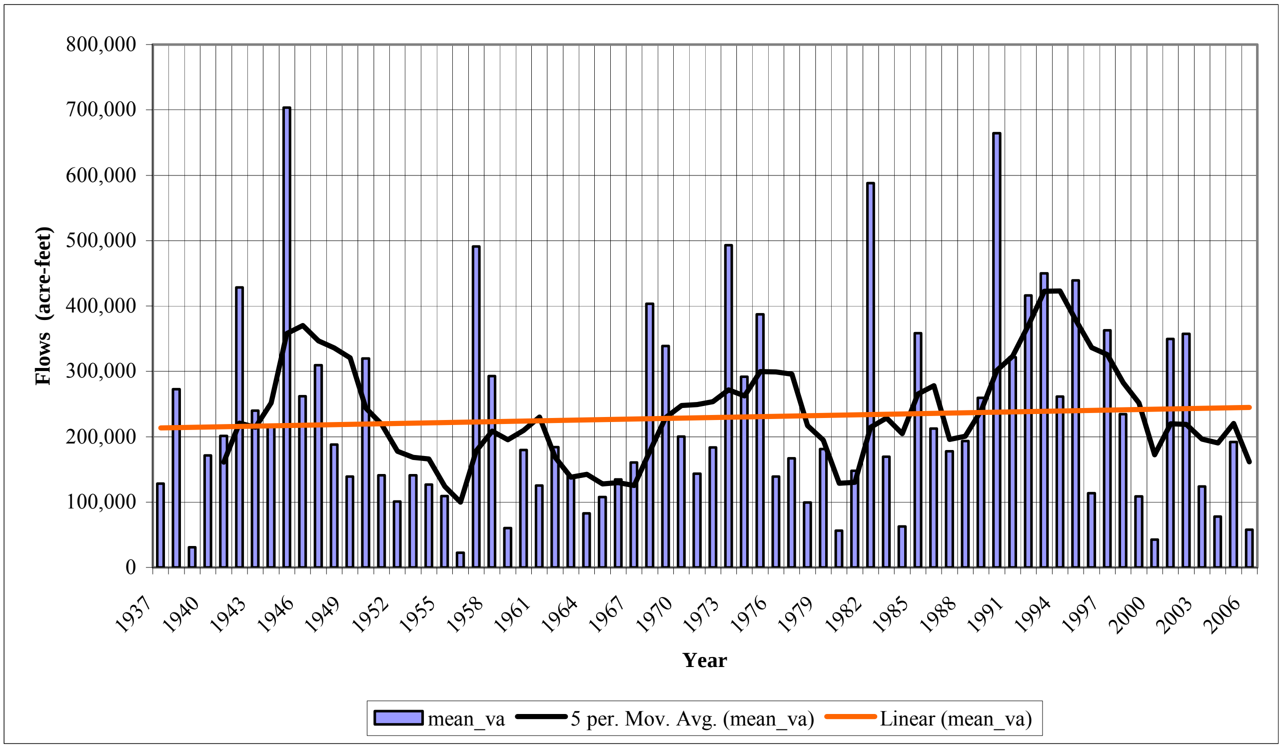



**Figure 2. Mean Annual Daily Discharge in Blue River near Blue, OK. 1936 – 2006.**

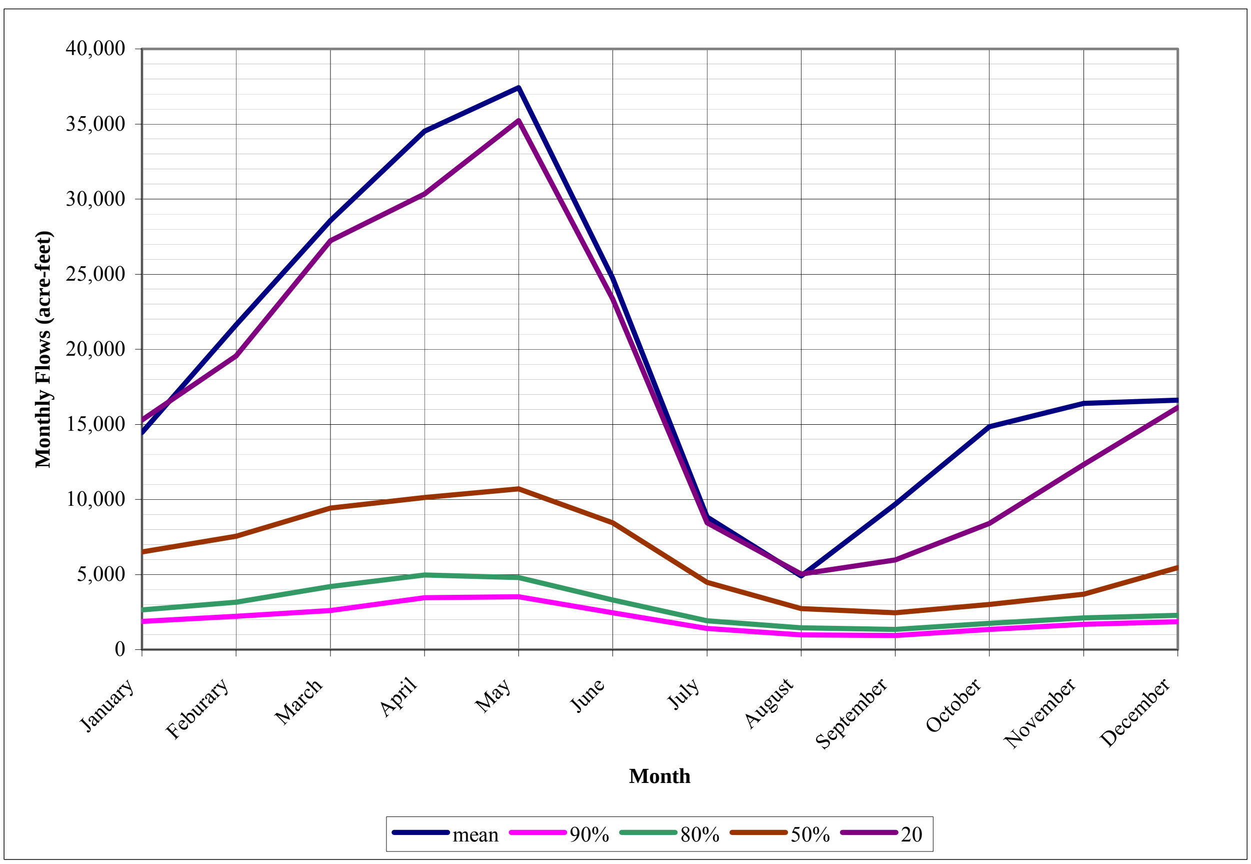



**Figure 3. Monthly flow exceedance for Blue River near Blue, OK. for 1936 – 2006.**

Peak flows at the gage at Blue, OK. (Figure 4) show a slight trend upwards, but this trend appears to be the result of the extremely high flow, over 60,000 cfs, in 1983. If that value is disregarded then there are no significant trends to the peak flows.

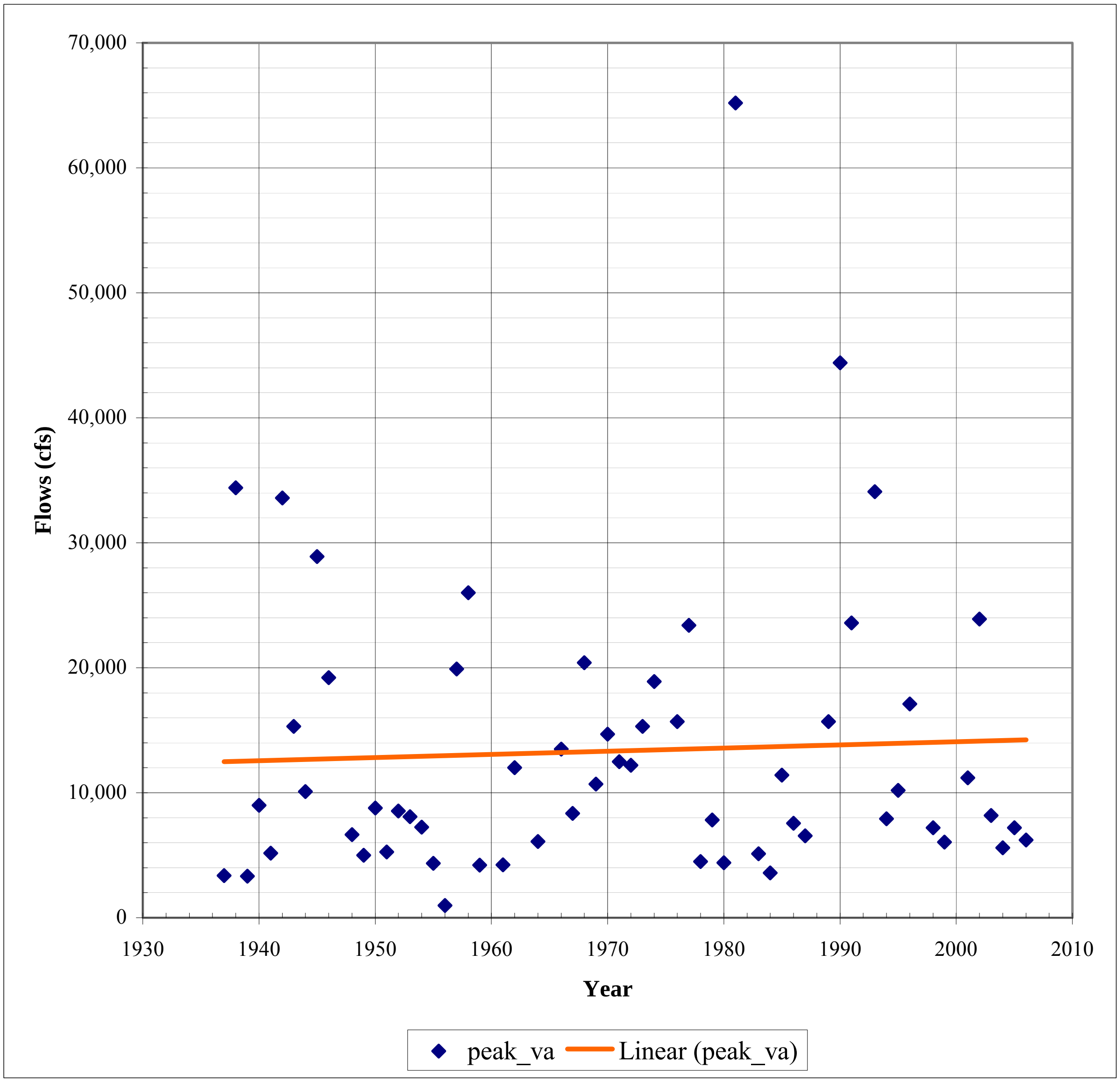



**Figure 4. Peak Flows for Blue River near Blue, OK. 1936-2006.**

The flow duration curve (Figure 5) shows the amount of flow that, for a given probability, can be expected to be equaled or exceeded. This information is valuable for someone who wants to use stream water to be able to predict the probability that some flow will be available for use. As an example, a flow of 264 cfs can be expected to be available approximately 20% of the time, while 10 cfs is available more than 98% of the time. However, as illustrated in Figure 3, there is considerable seasonal variability, particularly at higher flows. As an example, a flow of 100 cfs would only be available only during the high flow season of November through May and would not be available during the summer months.

The steeper slope of the curve indicates that base flow is not a large fraction of the total flow of the river at Blue, OK. Shallower curves, such as seen for the Blue River near Milburn (Figure 9) would indicate greater influence from baseflow. TABLE 4 gives the base flow component of the lower two-thirds of the Blue River. Mean monthly base flow is approximately 10% of the total flow in the lower portion of the Blue River, however, on average, there is no base flow discharge within the lower reach from August through October and the base flow is very low in June, July, and November. This is probably attributable to the nature of the aquifers in the area, primarily the Antlers Sandstone and Woodbine aquifers, which do not appear to discharge appreciable quantities of groundwater to the stream.

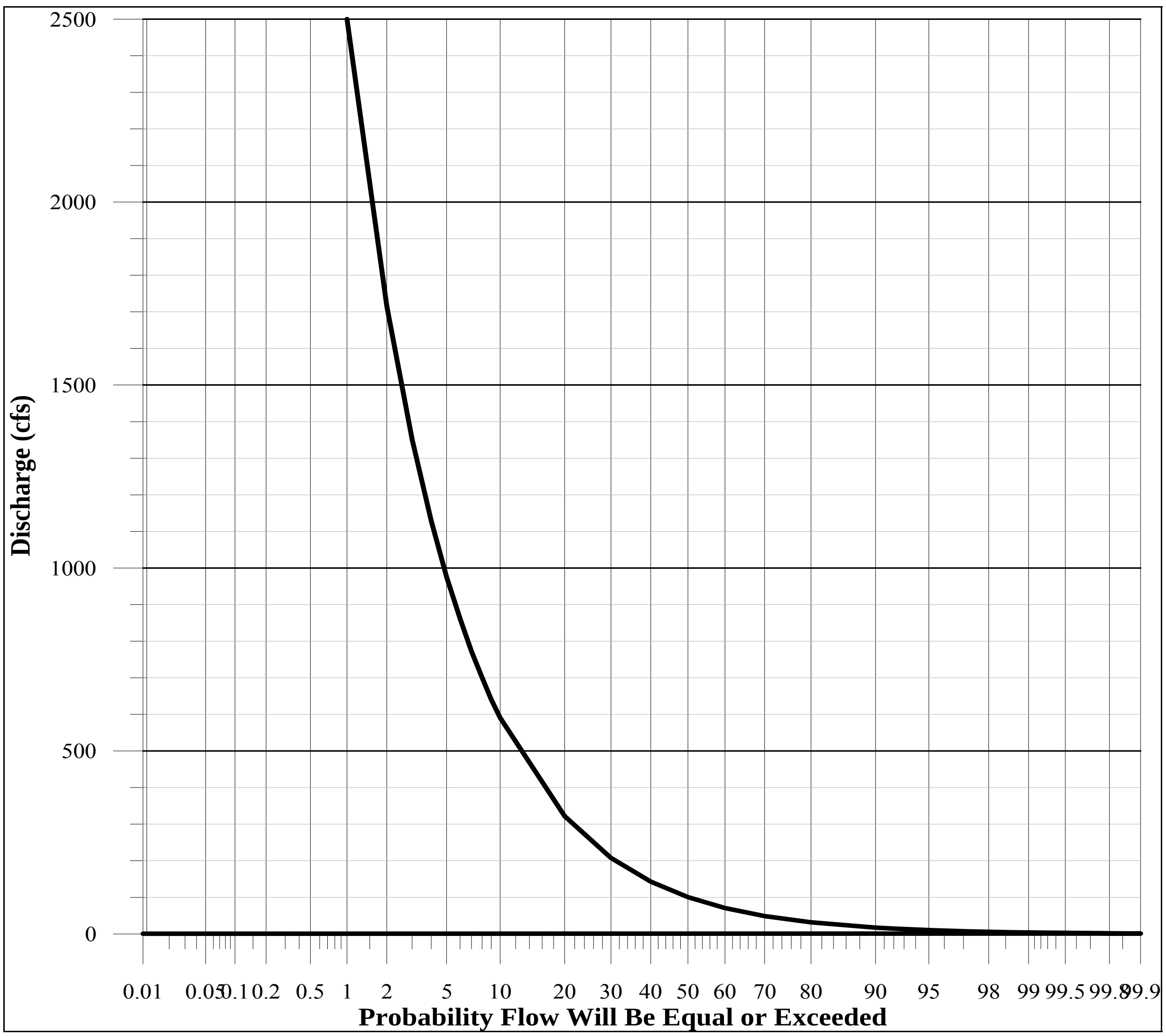



**Figure 5. Flow Duration Curve for Blue River near Blue, OK. 1936 - 1999.**

The annual mean daily flow for the Blue River at Milburn, OK was 165 cfs, or 120,000 acre-feet per year. Annual median daily flow (50% exceedance) is 90 cfs or 58,600 acre-feet per year (TABLE 5). There was a slight upward trend in annual flows (Figure 6) during the period the gage was active.

Seasonal variability is similar to that observed at the USGS gage near Blue, OK, with increased stream flows during the spring and low flows during the summer months. The 90% and 80% exceedance flows show subdued seasonal variability, which reflects the stabilizing impact of groundwater discharge to the base flow of the stream (Figure 7).

USGS Stream Gage 07332400 Blue River near Milburn, OK: Period of Record - 1966 through 1987. Gage Location: Section 35, T03E-R07EIM, Johnston County – 203 $mi^2$ drainage area – HUC10: 1114010201.

**TABLE 4. MONTHLY FLOWS OF BLUE RIVER BELOW MILBURN STREAM GAGE TO THE RED RIVER.**

| Total Flow Below Milburn to Red River 1961-2006 | Ratio of Base Flow to Mean Monthly Flow | Mean Total Flow | Mean Base Flow | Mean Surface Run-off |
|---|---|---|---|---|
| | | af/month | af/month | af/month |
| January | 0.222 | 16,309 | 3,627 | 12,682 |
| February | 0.190 | 22,309 | 4,236 | 18,074 |
| March | 0.164 | 33,165 | 5,428 | 27,737 |
| April | 0.146 | 35,141 | 5,146 | 29,995 |
| May | 0.125 | 36,437 | 4,560 | 31,877 |
| June | 0.081 | 23,982 | 1,934 | 22,049 |
| July | 0.084 | 4,427 | 371 | 4,056 |
| August | 0.000 | 2,284 | 0 | 2,284 |
| September | 0.000 | 9,469 | 0 | 9,469 |
| October | 0.000 | 15,456 | 0 | 15,456 |
| November | 0.080 | 19,074 | 1,531 | 17,542 |
| December | 0.156 | 19,123 | 2,977 | 16,147 |
| **Mean Monthly Flows** | **0.104** | **19,765** | **2,484** | **17,281** |
| Total Annual Flows | | 237,4177 | 29,810 | 207,368 |

(Drainage area below USGS stream gage 07332400 at Milburn, OK. is 483 $mi^2$.)

**TABLE 5. MONTHLY PERCENT EXCEEDANCES – STREAM FLOWS IN BLUE RIVER NEAR MILBURN, OK.**

| Total Flow Above USGS Gage 07332400 | **Mean** | **90% Exceedance** | **80% Exceedance** | **50% Exceedance** | **20% Exceedance** |
|---|---|---|---|---|---|
| | af/month | af/month | af/month | af/month | af/month |
| January | 9,351 | 1,832 | 2,488 | 4,468 | 8,024 |
| February | 8,207 | 1,725 | 2,436 | 4,719 | 9,141 |
| March | 14,246 | 1,994 | 3,028 | 6,736 | 14,984 |
| April | 14,466 | 2,188 | 3,244 | 6,896 | 14,659 |
| May | 15,251 | 2,422 | 3,640 | 7,932 | 17,286 |
| June | 11,640 | 2,158 | 3,138 | 6,425 | 13,154 |
| July | 5,597 | 1,801 | 2,318 | 3,754 | 6,081 |
| August | 4,880 | 1,556 | 1,890 | 2,653 | 3,978 |
| September | 5,017 | 1,238 | 1,638 | 2,797 | 4,775 |
| October | 9,849 | 1,106 | 1,673 | 3,688 | 8,133 |
| November | 10,198 | 1,468 | 2,103 | 4,184 | 8,323 |
| December | 11,097 | 1,697 | 2,347 | 4,364 | 8,115 |
| **Mean Monthly Flows** | 9,983 | 1,765 | 2,495 | 4,885 | 9,721 |
| Total Annual Flows | 119,799 | 21,185 | 29,943 | 58,617 | 116,653 |

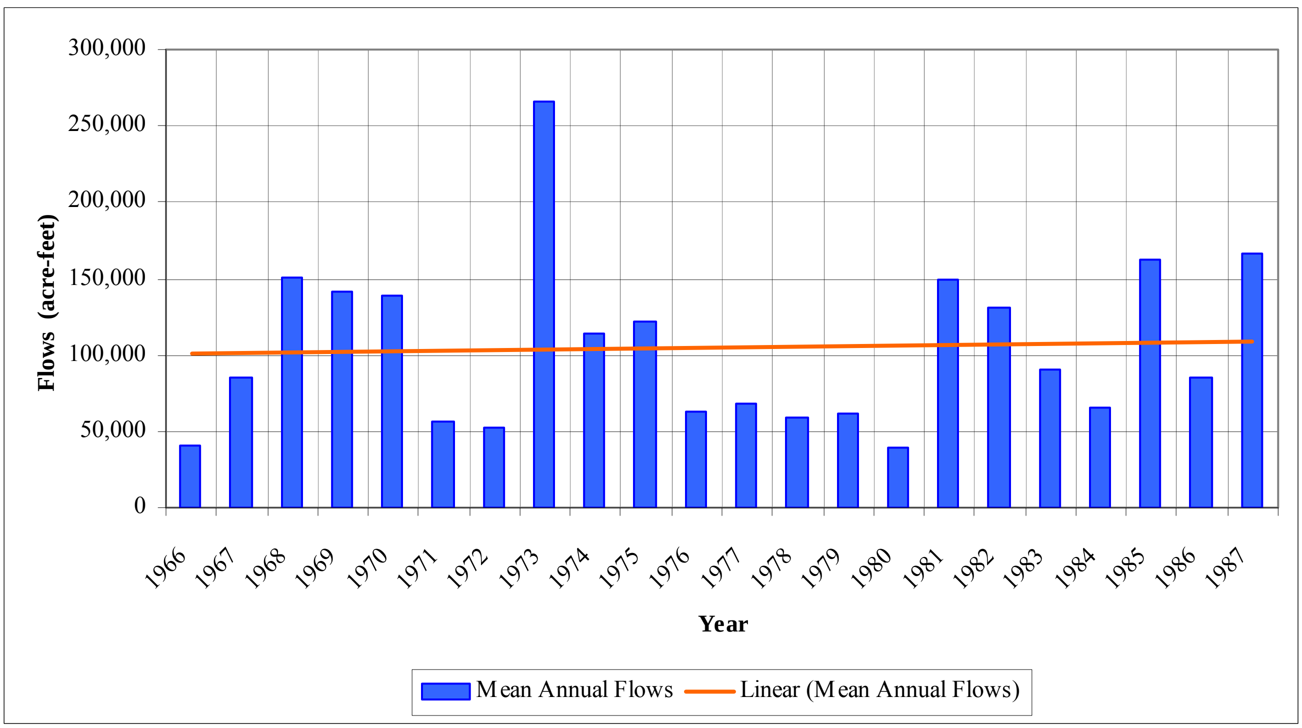



**Figure 6. Mean Annual Daily Discharge in Blue River near Milburn, OK. 1966 – 1987.**

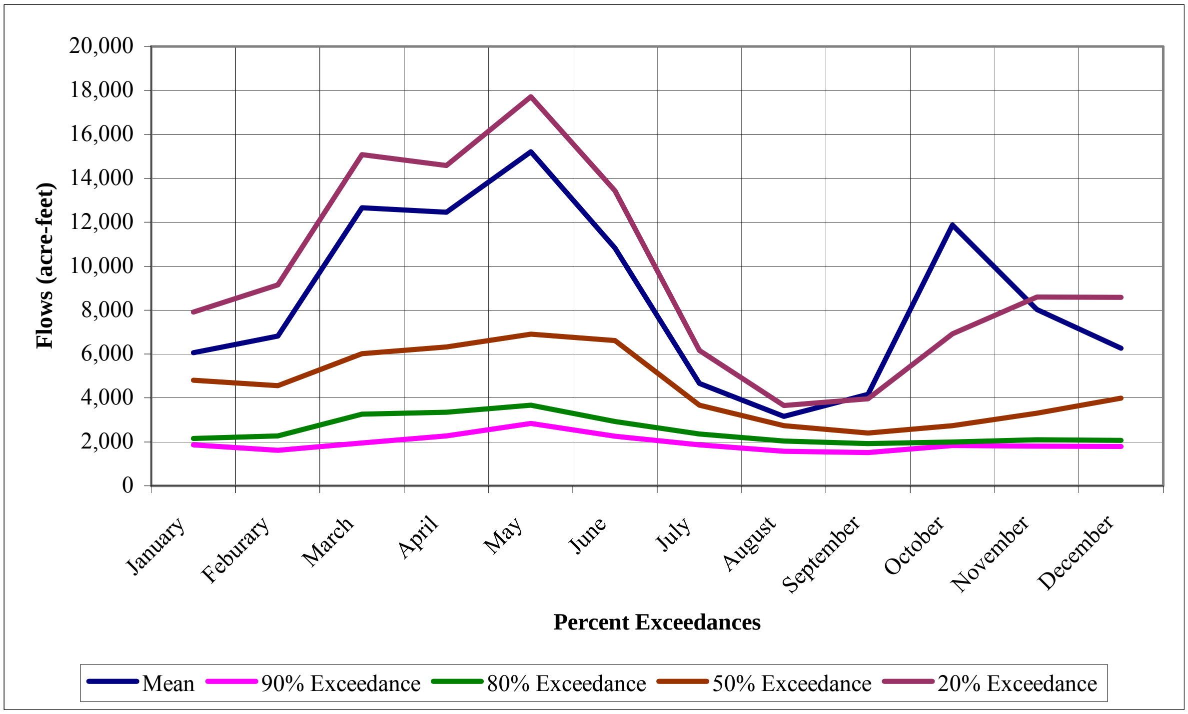



**Figure 7. Monthly flow exceedance for Blue River near Milburn, OK. for 1966 – 1987.**

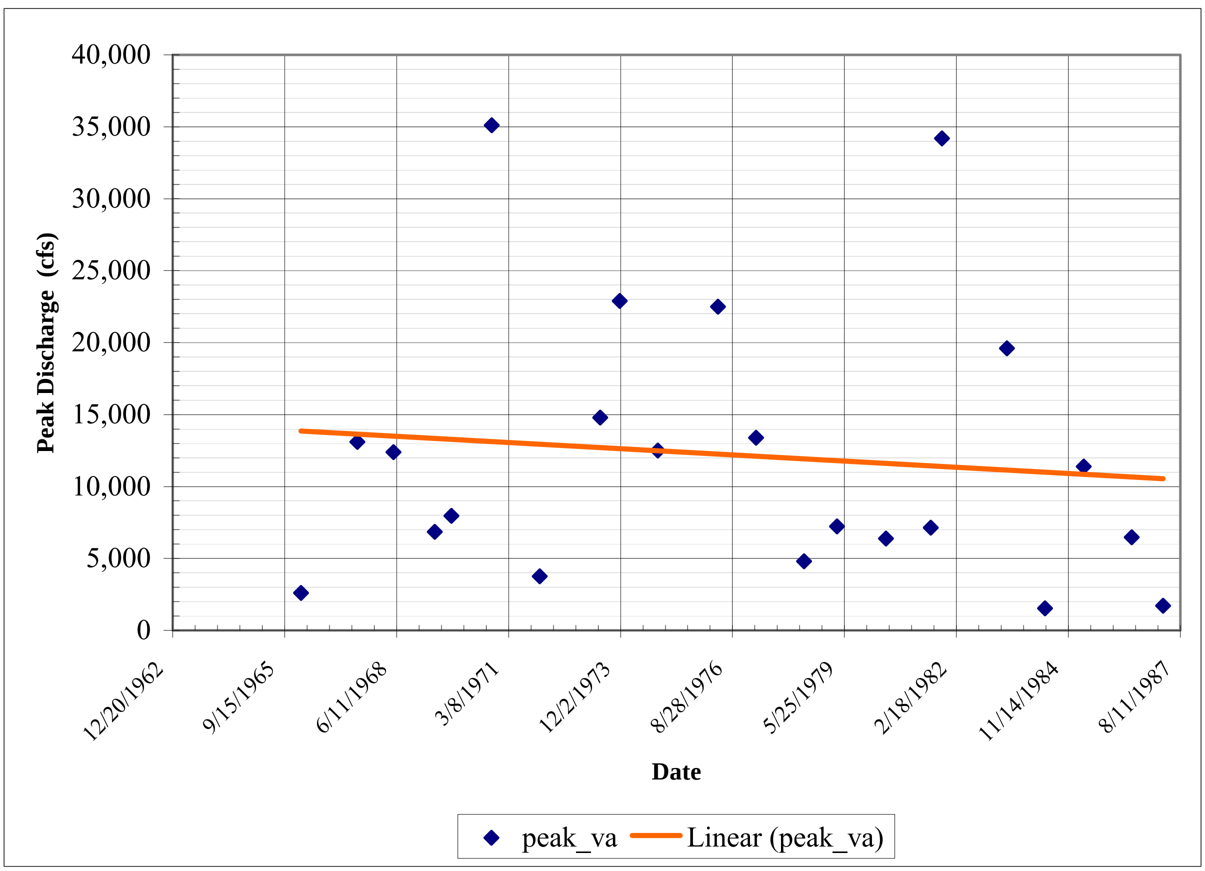



**Figure 8. Peak Flows for Blue River at Milburn, 1966 - 1987.**

Peak flows at the gage at Milburn, OK. (Figure 8) shows a slight downward trend over the period of record. The cause of the decline is unknown, but one possibility is from climatic variability.

The flow duration curve (Figure 9) shows that amount of flow that, during a year, can be expected to be equal or exceeded. This information is valuable to be able to predict the probability that some flow will be available for use. As an example a flow of 155 cfs can only be expected to be available approximately 20% of the time, while 31 cfs is available more than 90% of the time. However, as illustrated in Figure 7, there is considerable seasonal variability, particularly at higher flows. As an example a flow of 100cfs would only be available during the high flow season of November through May and would not be available in the summer months.

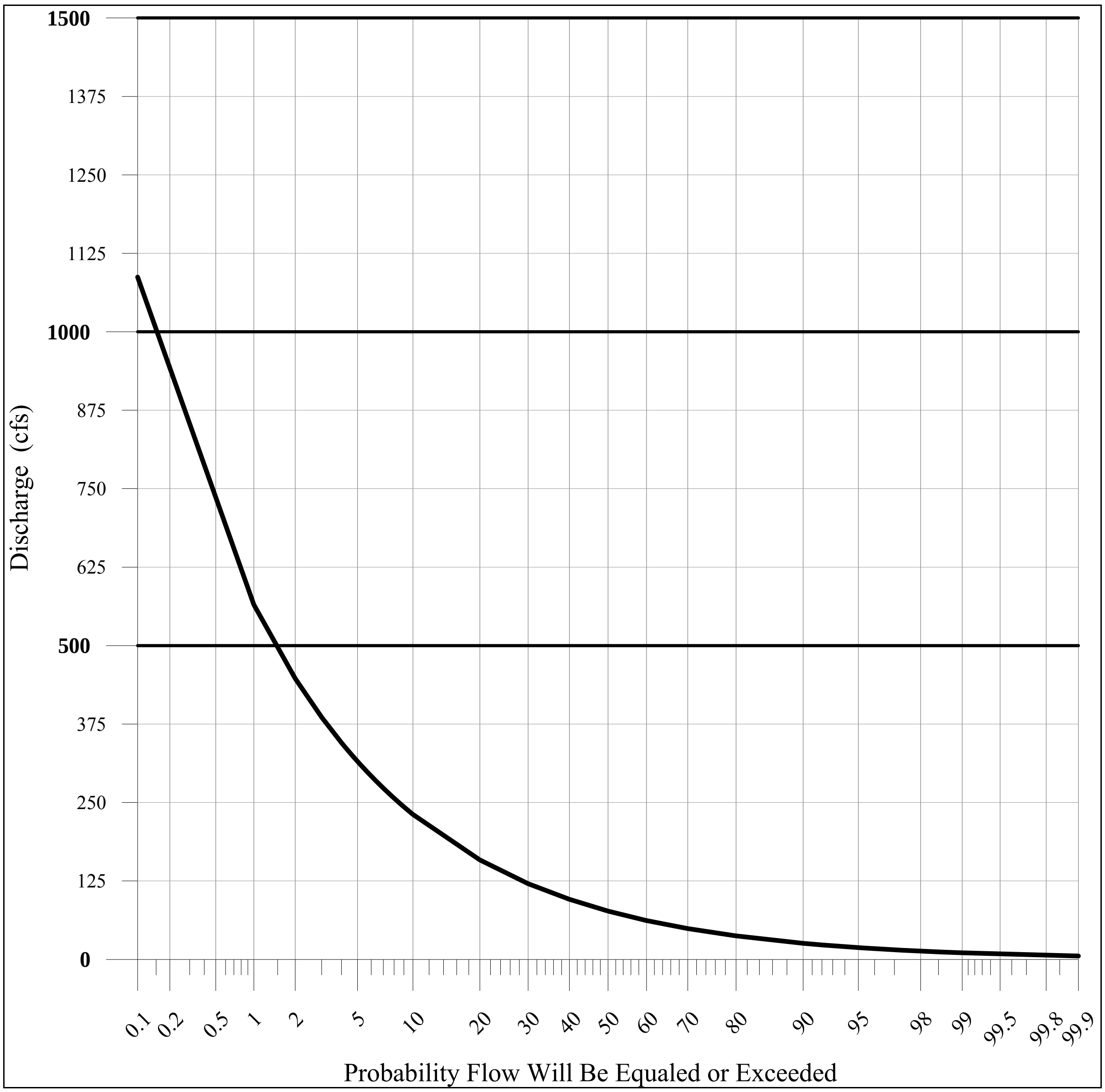



**Figure 9. Flow Duration Curve for Blue River at Milburn, 1966 - 1987.**

The shallow slope of the curve indicates that base flow is important fraction of the total flow. Steeper curves indicate greater influence from surface run-off. TABLE 6 shows the base flow component of the upper one-third of the Blue River above the gage at Milburn. Mean monthly base flow is approximately 53% of the total flow in the upper portion of the Blue River, however base flow can vary from 25% to 83% of the flow during different months. This is probably attributable to the Arbuckle Simpson aquifer in the area, which is a fracture, karst aquifer that allows water to flow rapidly through the aquifer and discharge to the Blue River.

Monthly stream gage data for the Blue River near Milburn, OK was extended using the data from the stream gage data located near Blue, OK. The data was extended using simple statistical correlation techniques (Fiering, 1963). A regression equation was developed between the stream flow data at Milburn and at Blue, OK which was used to extend the length of the monthly mean flows for the Milburn gage.

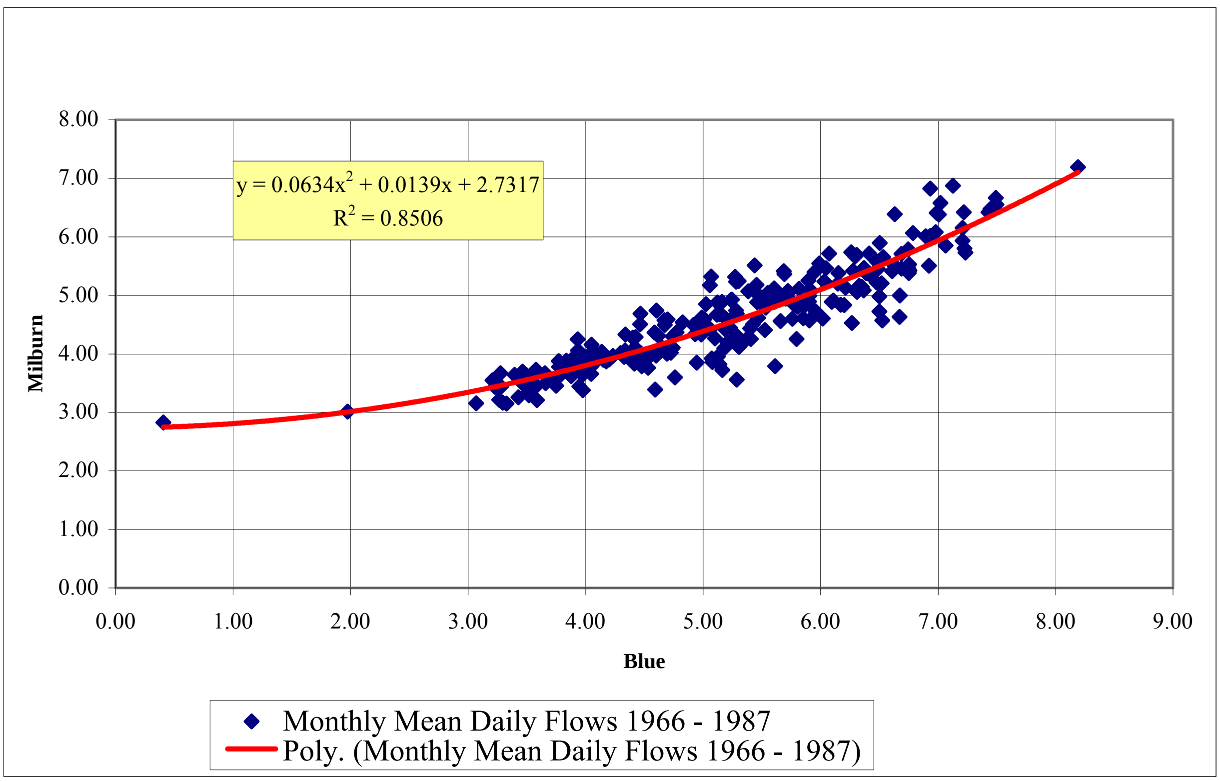



**Figure 10. Fitted line plot for monthly stream flows at Milburn, OK. and Blue, OK for Blue River, 1966 - 1987.**

The monthly flow data was transformed using lognormal and graphed. The fitted line plot, Figure 10, illustrates the good correlation between the data. The high value of the $R^2$ function, 0.85, indicates the model is a good fit (Helsel and Hirsch, 1995). The regression equation was then used to extend the stream gage data near Milburn from 1961 to 2006.

**TABLE 6. MONTHLY FLOWS OF BLUE RIVER AT THE MILBURN STREAM GAGE.**

| Total Flow Above Milburn 1961-2006 | Ratio of Base Flow to Mean Monthly Flow | Mean Total Flow | Mean Base Flow | Mean Surface Run-off |
|---|---|---|---|---|
| | | af/month | af/month | af/month |
| January | 0.737 | 6,983 | 5,259 | 1,877 |
| February | 0.618 | 7,614 | 4,810 | 2,969 |
| March | 0.464 | 12,052 | 5,710 | 6,603 |
| April | 0.461 | 12,277 | 5,778 | 6,766 |
| May | 0.386 | 13,590 | 5,358 | 8,527 |
| June | 0.515 | 9,814 | 5,159 | 4,867 |
| July | 0.791 | 4,284 | 3,464 | 913 |
| August | 0.832 | 3,092 | 2,628 | 531 |
| September | 0.589 | 4,227 | 2,544 | 1,775 |
| October | 0.255 | 8,204 | 2,134 | 6,248 |
| November | 0.501 | 8,046 | 4,119 | 4,102 |
| December | 0.681 | 8,288 | 5,765 | 2,703 |
| **Mean Monthly Flows** | **0.532** | **8,206** | **4,394** | **3,990** |
| Total Annual Flows | | 100,608 | 52,727 | 47.881 |

The differences in the amount of contribution base flow makes to stream flows above and below Milburn illustrates the dependence the lower two-thirds of the stream system has with regards to the base flow contribution from the upper third of the system. The lower two-thirds of the stream system is dominated by surface water run-off, while the upper reach of the Blue River is dominated by base flow discharge from groundwater. Base flow was calculated using a computer base flow separation program named BFIW (Wahl and Wahl, 1995).

During the aquifer study for the Arbuckle Simpson periodic synoptic stream discharge measurements were made. These discharge measurements were taken during low flow conditions and therefore represent base flow conditions. Perennial flow within Blue River begins approximately three miles above the town of Connerville (Figure 11). Little West Blue Creek is perennial near the town of Pontotoc and the lower reaches of West Little Blue Creek also appear to be perennial.

While there has been some data to suggest that the main stem of the Blue River is occasionally perennial further upstream, this hydrologic investigation is going to operate on the assumption that the Blue River is only intermittent in the HUC12 subwatersheds of 1114010201 01, 1114010201 02, and 1114010201 03. While the data is limited, point discharge data does seem to indicate that the main stem of the Blue River, in subwatershed 1114010201 03, is sometimes a losing stream.

Even below Connerville, where the main stem of the Blue River is perennial, the tributaries to the Blue River general are intermittent or ephemeral until they are within a short distance of the main stem.

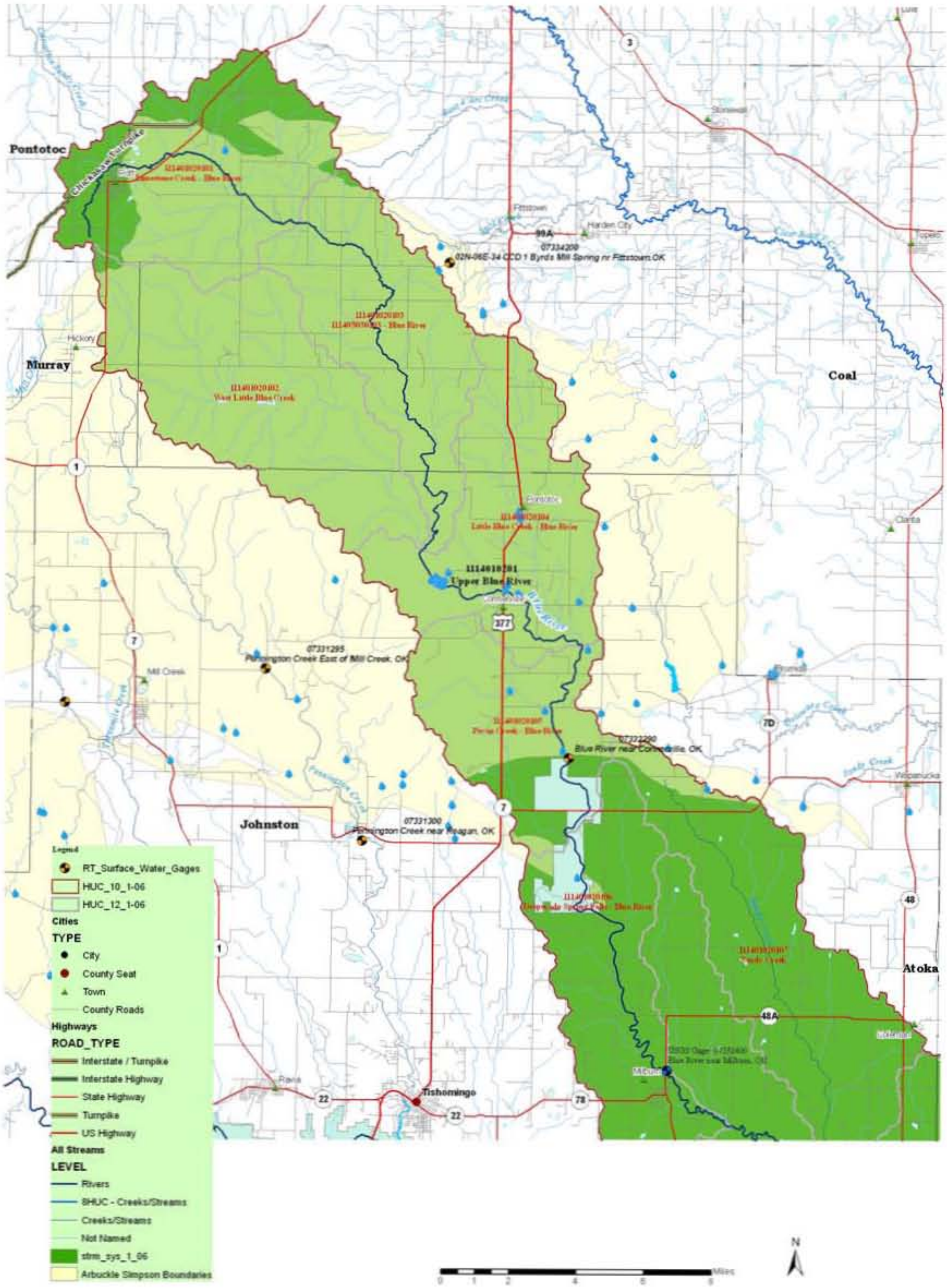



**Figure 11. Map showing USGS spring inventory for portion of Blue River watersheds overlying the Arbuckle Simpson aquifer.**

## Water Rights and Water Use

The amount of water authorized for use by permit use within the Blue River Stream System is small compared to the total amount of water in the system. The number of permits increased over the years (Figure 12) until early 1990s when the Oklahoma Water Resources Board held cancellation and reduction hearings within the stream system. A total of 55 permits were cancelled in the 1990s, which made almost 17,000 acre-feet of additional water available for appropriation. As of 2006 there were 57 stream water permits within the Blue River stream system authorizing a maximum use of 33,705 acre-feet/year.

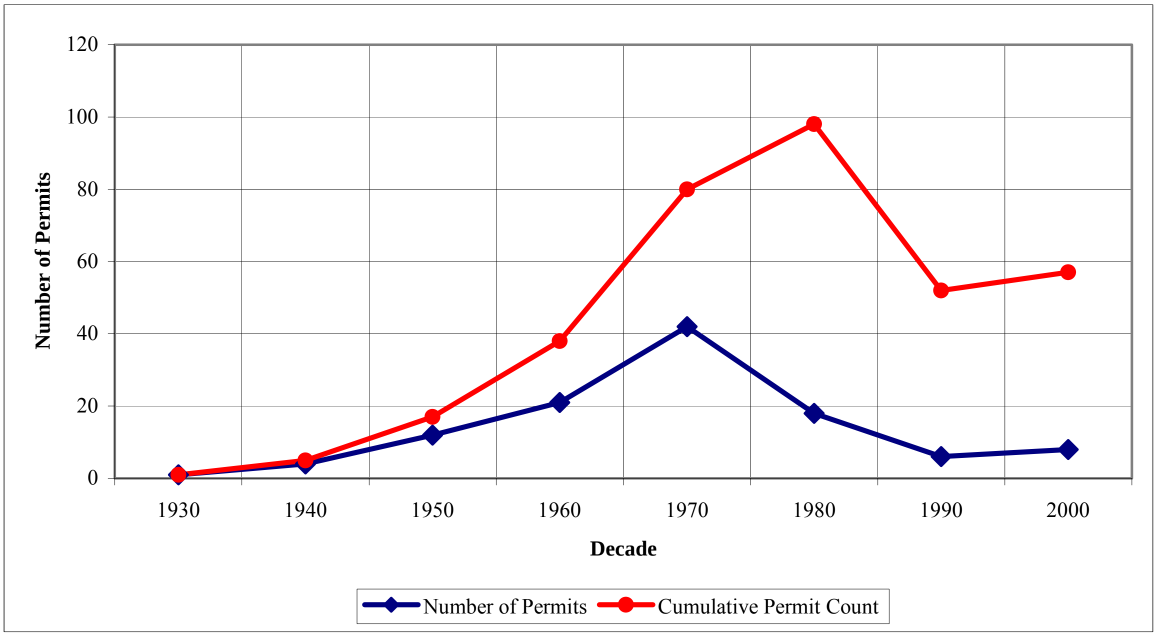



**Figure 12. Diagram showing number of active permits within the Blue River Stream System issued each year and total (cumulative) number of permits that were active each year.**

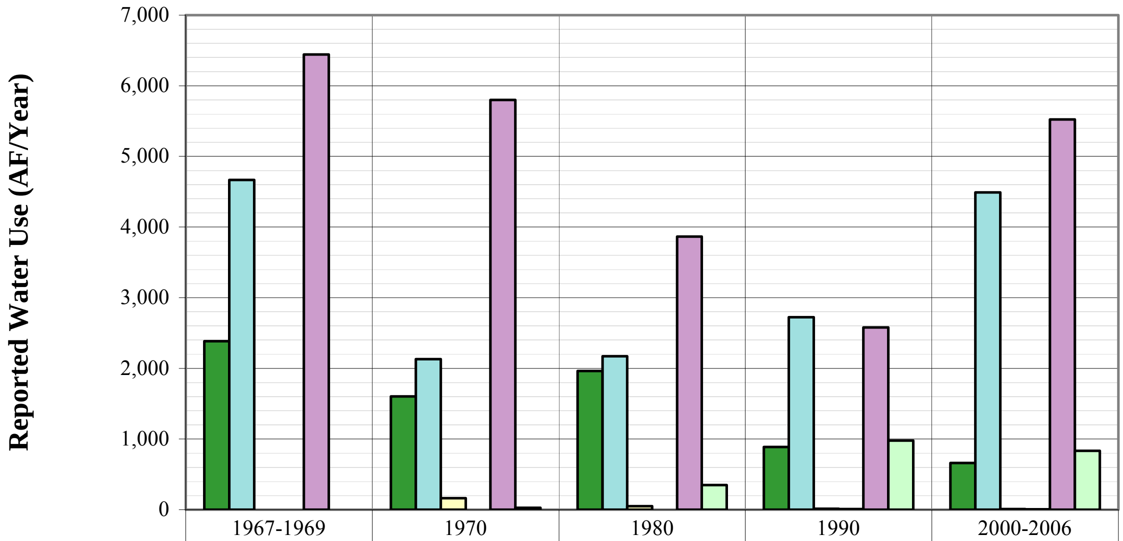
**TABLE 7. CUMULATIVE AMOUNTS OF WATER, BY PURPOSE, ALLOCATED TO WATER RIGHTS IN THE BLUE RIVER STREAM SYSTEM.**

| Cumulative Amount of Water Allocated (AF) by Purpose | | | | | | |
|---|---|---|---|---|---|---|
| Decade | Irrigation | Industrial | Public Water Supply | Commercial | Agriculture | Recreation, Fish & WL |
| 1930 | | | | | | 6,445 |
| 1940 | 208 | | 1,842 | | | 6,445 |
| 1950 | 3,227 | | 1,842 | | | 6,445 |
| 1960 | 13,127 | | 1,842 | | 25 | 6,445 |
| 1970 | 18,743 | 29 | 13,435 | | 25 | 6,445 |
| 1980 | 22,154 | 29 | 13,435 | 5 | 995 | 6,445 |
| 1990 | 6,851 | 12 | 13,281 | 5 | 995 | 6,445 |
| 2000 | 12,895 | 12 | 14,202 | 5 | 995 | 6,535 |

The Oklahoma Water Resources Board has records of 57 active water rights within the stream system as of the end of 2006. Two water rights were for agriculture, one for commercial, one for industrial, 45 are for irrigation, six were for public water supply, and two for recreation, fish, & wildlife.

Peanuts are the primary irrigated crop in Bryan, Johnston, and Pontotoc Counties according to the U.S. Department of Agriculture statistics. Irrigated peanuts require 11 to 15 inches of irrigation water annually.

The number of permits issued for irrigation represents 79%, of all permits. The amount of water allocated to irrigation is 12,895 acre-feet/year, which were 38% of the total amount authorized for use. Six permits, for a total of 14,202 acre-feet/year, were for public water supply, representing approximately 42% of the total allocation. There were two permits for recreation, fish, & wildlife purpose, with an annual allocation of 6,535 acre-feet/year. Finally, there are one or two permits each for commercial, industrial, and agriculture with an allocation of 1,012 acre-feet/year (TABLE 7).




| | 1967-1969 | 1970 | 1980 | 1990 | 2000-2006 |
|---|---|---|---|---|---|
| Irrigation | 2,381 | 1,602 | 1,963 | 890 | 662 |
| PWS | 4,667 | 2,131 | 2,170 | 2,721 | 4,491 |
| Industrial | 0 | 163 | 50 | 12 | 10 |
| Commerical | 0 | 0 | 0 | 8 | 4 |
| RFW | 6,445 | 5,800 | 3,867 | 2,578 | 5,525 |
| Agriculture | 0 | 26 | 348 | 977 | 832 |

Decade

**Figure 13. Chart showing mean annual reported water use for each decade by primary purpose. Note: RFW is recreation, fish, and wildlife and is non-consumptive.**

Reported water use records generally do not exist prior to 1967. Reporting has been inconsistent by water right holders over the years. Figure 13 shows the average annual amounts of reported water use, by purpose, for each decade since 1967. As can be seen reported irrigation usage has declined significantly over the years, from a high of 2,381 acre-feet (1967-1969) to 662 acre-feet (2000-2006).

**TABLE 8. ANNUAL REPORTED WATER USE BY PURPOSE – BLUE RIVER STREAM SYSTEM.**

| Year | Irrigation | PWS | Industrial [1] | Commercial[1] | RFW[2] | Agriculture | Other | Total |
|---|---|---|---|---|---|---|---|---|
| 1967 | 1,550.9 | 3,921.0 | 0.0 | 0.0 | 6,444.7 | 0.0 | 0.0 | 11,916.6 |
| 1968 | 2,725.4 | 5,600.7 | 0.0 | 0.0 | 6,445.0 | 0.0 | 0.0 | 14,771.1 |
| 1969 | 2,866.7 | 4,480.6 | 0.0 | 0.0 | 6,444.7 | 0.0 | 0.0 | 13,792.0 |
| 1970 | 1,828.6 | 4,503.0 | 0.0 | 0.0 | 6,444.7 | 25.0 | 0.0 | 12,801.3 |
| 1971 | 2,009.7 | 1,977.4 | 195.3 | 0.0 | 6,444.7 | 36.8 | 0.0 | 10,663.9 |
| 1972 | 1,904.1 | 0.0 | 184.1 | 0.0 | 0.0 | 30.0 | 0.0 | 2,118.2 |
| 1973 | 416.0 | 4,577.8 | 129.6 | 0.0 | 6,444.7 | 30.0 | 0.0 | 11,598.1 |
| 1974 | 1,008.9 | 2,418.5 | 184.1 | 0.0 | 6,445.0 | 30.0 | 0.0 | 10,086.5 |
| 1975 | 1,856.0 | 2,482.0 | 184.1 | 0.0 | 6,445.0 | 30.0 | 0.0 | 10,997.1 |
| 1976 | 1,149.7 | 2,473.6 | 184.1 | 0.0 | 6,444.7 | 27.0 | 0.0 | 10,279.1 |
| 1977 | 1,892.1 | 2.8 | 184.1 | 0.0 | 6,444.7 | 21.0 | 0.0 | 8,544.7 |
| 1978 | 2,471.1 | 2.9 | 184.1 | 0.0 | 6,444.7 | 0.0 | 0.0 | 9,102.8 |
| 1979 | 1,482.7 | 2,875.7 | 199.4 | 0.0 | 6,444.6 | 30.0 | 0.0 | 11,032.4 |
| 1980 | 2,557.6 | 178.1 | 214.8 | 0.0 | 6,444.7 | 27.0 | 0.0 | 9,422.2 |
| 1981 | 2,094.1 | 2,262.2 | 184.1 | 0.0 | 6,445.0 | 20.0 | 0.0 | 11,005.4 |
| 1982 | 1,213.0 | 3,151.6 | 0.0 | 0.0 | 6,445.0 | 30.0 | 0.0 | 10,839.6 |
| 1983 | 2,077.7 | 2,849.6 | 26.6 | 0.0 | 6,445.0 | 0.0 | 0.0 | 11,398.9 |
| 1984 | 2,224.8 | 792.3 | 12.0 | 0.0 | 6,445.0 | 30.0 | 0.0 | 9,504.1 |
| 1985 | 2,100.7 | 2,984.2 | 11.9 | 0.0 | 6,445.0 | 30.0 | 0.0 | 11,571.8 |
| 1986 | 1,427.7 | 3,158.5 | 12.0 | 0.0 | 0.0 | 1,384.0 | 0.0 | 5,982.2 |
| 1987 | 1,732.9 | 2,502.8 | 12.0 | 0.0 | 0.0 | 167.0 | 0.0 | 0.0 |
| 1988 | 2,716.8 | 793.7 | 12.0 | 0.0 | 0.0 | 794.0 | 0.0 | 4,316.5 |
| 1989 | 1,488.1 | 3,022.3 | 12.0 | 0.0 | 0.0 | 995.0 | 0.0 | 5,517.4 |
| 1990 | 1,349.4 | 1,176.1 | 12.0 | 0.0 | 0.0 | 970.0 | 0.0 | 3,507.5 |
| 1991 | 1,115.8 | 3,428.6 | 12.0 | 0.0 | 0.0 | 994.0 | 0.0 | 5,550.4 |
| 1992 | 529.5 | 2,671.0 | 12.0 | 0.0 | 0.0 | 994.0 | 0.0 | 4,206.5 |
| 1993 | 1,070.5 | 642.1 | 12.0 | 0.0 | 0.0 | 995.0 | 0.0 | 2,719.6 |
| 1994 | 744.3 | 3,454.3 | 12.0 | 1.0 | 6,445.4 | 970.0 | 0.0 | 11,627.0 |
| 1995 | 660.6 | 3,543.4 | 12.0 | 1.0 | 6,445.4 | 970.0 | 0.0 | 11,632.4 |
| 1996 | 775.9 | 3,814.6 | 12.0 | 1.0 | 6,445.4 | 970.4 | 0.0 | 12,019.3 |
| 1997 | 890.3 | 3,843.9 | 12.0 | 25.0 | 0.0 | 970.4 | 0.0 | 5,741.6 |
| 1998 | 1,376.1 | 3,808.3 | 12.0 | 25.0 | 0.0 | 970.4 | 0.0 | 6,191.8 |
| 1999 | 385.2 | 825.7 | 12.0 | 23.4 | 6,445.4 | 970.4 | 0.0 | 8,662.1 |
| 2000 | 286.2 | 4,739.0 | 12.0 | 25.0 | 6,445.4 | 970.4 | 0.0 | 12,478.0 |
| 2001 | 254.5 | 4,090.8 | 12.0 | 2.0 | 6,445.4 | 970.4 | 0.0 | 11,775.1 |
| 2002 | 200.7 | 3,731.3 | 0.0 | 0.0 | 6,445.4 | 970.4 | 0.0 | 11,347.8 |
| 2003 | 441.6 | 4,340.1 | 12.0 | 3.1 | 6,445.0 | 970.4 | 0.0 | 6,411.7 |
| 2004 | 1,097.7 | 4,628.1 | 12.0 | 0.2 | 0.0 | 970.4 | 245.5 | 6,953.9 |
| 2005 | 1,435.9 | 4,867.0 | 12.0 | 0.0 | 6,445.4 | 970.4 | 0.0 | 13,730.7 |
| 2006 | 917.4 | 5,041.2 | 12.0 | 0.0 | 6,445.4 | 0.0 | 0.0 | 12,416.0 |
| **Mean** | **1,408** | **2,891** | **58** | **3** | **6,445** | **483** | **6.1** | **9,106** |

1. Industrial and Commercial purposes are self-supplied and do not include the industrial and commercial uses associated with Public Water Supply.
2. Recreation, Fish, & Wildlife purpose is non-consumptive.

Public water supply has increased from the 1970s to the present. The City of Durant, Bryan County RWD #2, and Bryan County RWD #5 are the primary public water supply users from the Blue River. Recreation, fish, & wildlife use is typically non-consumptive within this stream system. TABLE 8 shows the annual reported water use, by purpose, within the Blue River stream system.

## Total Estimated Available Water

The Oklahoma Water Resources Board issues stream water permits based on the amount of water available within a stream systems and its watersheds. The amount of water available for appropriation is based on the mean annual flow within the stream system. This flow data is typically obtained from stream gages maintained by the U.S. Geological Survey, U.S. Army Corps of Engineers, and the Oklahoma Water Resources Board.

The total estimated available water within a stream system is determined by naturalizing the stream flow. Naturalization of the stream flow is accomplished by adding the consumptive water usage within the stream system back to the stream flow data. Effects of evaporation and variation in lake levels within a stream system are also taken into account. This is done to compensate for the impacts caused by stream water withdrawals and other impacts caused by human activity. Return flows from wastewater treatment facilities are not subtracted from the stream data. Non-consumptive use, or water that is not diverted, is not considered when trying to naturalize the stream flows.

Consumptive use of water is typically less than the actual reported usage by the water right holder. The amount of reported water use is the amount of water diverted from the stream, but the amount consumed is less since some of the water is returned to the stream. Returns flows might include irrigation tail water, leaks from water transmission pipelines, and waste water discharges. However, for purposes of this hydrologic investigation the average reported water used is used to obtain the naturalized flows of the stream.

As was mentioned earlier, there are considerable flow variations over the year. These flows can be summarized and divided into low and high flow seasons. The low flow season occurs from June through October; and a high flow season is from November through May of each year. This information will allow the State and water right applicant or user to identify potential problems that could occur because of seasonal flow variability. Individuals who are irrigating will, generally, want to use the water during the low flow season when stream flow is at its lowest. Most other users spread their usage out over the year, but typically have larger demand needs during the low flow season.

Direct diversions within the stream system are typically only possible, with any reliability, from the main stem of the Blue River and within lower reaches of the large tributaries. In the tributary headwater areas, water may not be available for diversion unless the water is stored in a lake or pond.

In the Blue River watershed there are 38 existing dams and associated lakes that are large enough to be contained in the Dam Inventory database. Total estimated normal storage capacity is 7,900 acre-feet. The largest of the lakes in the stream system is Durant Lake. The lake has an estimated normal storage capacity of 3,900 acre-feet. Three of the 38 lakes are SCS structures constructed by the Natural Resources Conservation Service, previously known as the Soil Conservation Service. Private entities, rural water districts, or municipalities constructed the other 35 lakes. Three lakes have water rights for the water in storage of those lakes. The remaining 35 lakes do not have any water rights associated with them therefore the only annual "use" from those lakes is evaporation loss.

The water available for appropriation from lake storage is considered to be a separate amount of water than that which is available by direct diversion from the streams or rivers. As water is diverted from lake storage, stream flow refills lake storage, therefore the amount of water available from the streams is reduced by that amount. The OWRB is unaware of any dependable yield analysis completed for any of the lakes within the stream system. Therefore, the yields from these lakes have been estimated. Estimated yields were determined using the formula described on page 4. Lake yields will decline over the years as the storage within the lakes is reduced in capacity by silting from erosion in their drainage watersheds. The total estimated yield from all 38 lakes is about 7,100 acre-feet/year.

TABLE 9 provides the total seasonal and annual mean flow available for appropriation within each watershed within the Blue River. Figures 14 and 15 provide a graphical representation of the available water within the two watersheds comprising the Blue River Stream System.

**TABLE 9. SEASONAL AND TOTAL AVAILABLE WATER FOR THE BLUE RIVER.**

| Total Available Stream Water | | | Low Flow Season | High Flow Season | Total |
|---|---|---|---|---|---|
| | HUC10 Watershed | HUC12 Sub-watershed | (June-Oct.) | (Nov.-May) | (Annual) |
| **1-6 Blue River** | | | **91,200** | **252,300** | **343,500** |
| Upper Blue River Watershed | 1114010201 | | 47,800 | 122,500 | 170,200 |
| Limestone Creek - Blue River | | 111401020101 | 2,700 | 6,100 | 8,800 |
| West Little Blue Creek | | 111401020102 | 3,100 | 7,200 | 10,300 |
| 111403030103 - Blue River | | 111401020103 | 2,300 | 5,300 | 7,500 |
| Little Blue Creek - Blue River | | 111401020104 | 8,600 | 19,500 | 28,000 |
| Pecan Creek - Blue River | | 111401020105 | 6,100 | 14,000 | 20,100 |
| Desperado Spring Falls - Blue River | | 111401020106 | 8,300 | 18,100 | 26,400 |
| Sandy Creek | | 111401020107 | 4,900 | 15,900 | 20,800 |
| Little Sandy Creek - Blue River | | 111401020108 | 3,900 | 10,600 | 14,500 |
| Reeder Creek - Blue River | | 111401020109 | 3,900 | 12,700 | 16,600 |
| Bois d' Arc Creek - Blue River | | 111401020110 | 4,100 | 13,000 | 17,100 |
| Lower Blue River Watershed | 1114010202 | | 43,400 | 129,800 | 173,300 |
| Mineral Bayou | | 111401020201 | 5,600 | 15,700 | 21,400 |
| Little Blue River - Blue River | | 111401020202 | 6,200 | 15,800 | 22,000 |
| Kanola Creek - Blue River | | 111401020203 | 4,700 | 15,300 | 20,000 |
| Caddo Creek | | 111401020204 | 5,000 | 16,300 | 21,300 |
| J&N Creek - Blue River | | 111401020205 | 4,800 | 14,100 | 18,900 |
| Bokehito Creek | | 111401020206 | 4,400 | 14,300 | 18,700 |
| Sulphur Creek | | 111401020207 | 3,700 | 12,200 | 15,900 |
| Cherokee Lake - Blue River | | 111401020208 | 4,200 | 12,500 | 16,600 |
| Lower Blue River | | 111401020209 | 4,800 | 13,600 | 18,500 |

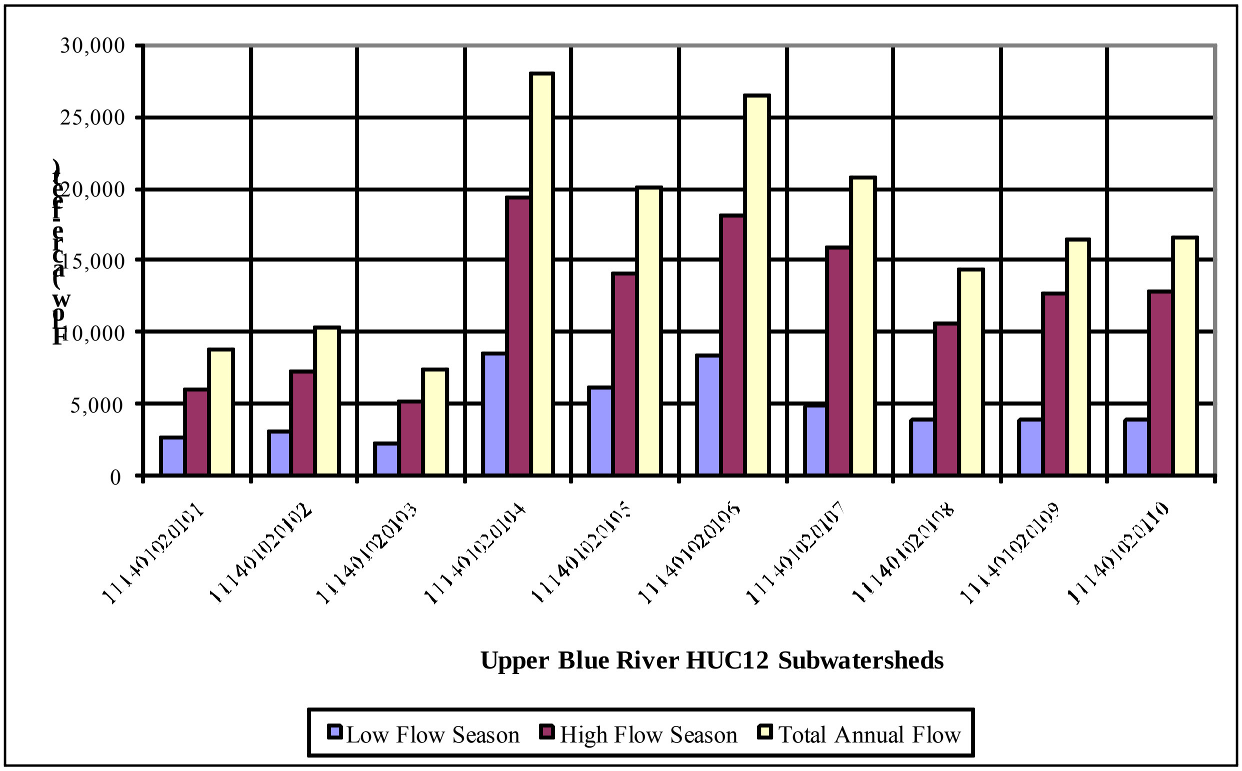



**Figure 14. Seasonal and annual water availability in the Upper Blue River watershed (1114010201).**

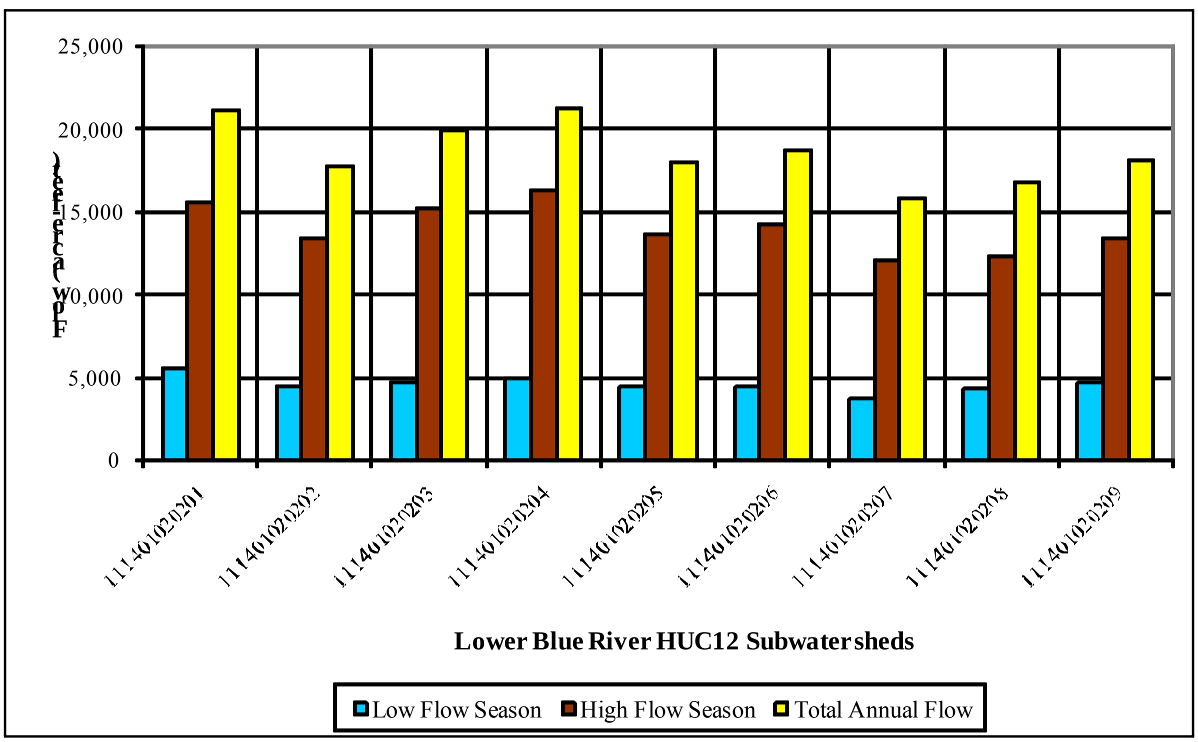



**Figure 15. Seasonal and annual water availability in the Lower Blue River watershed (1114010202).**

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