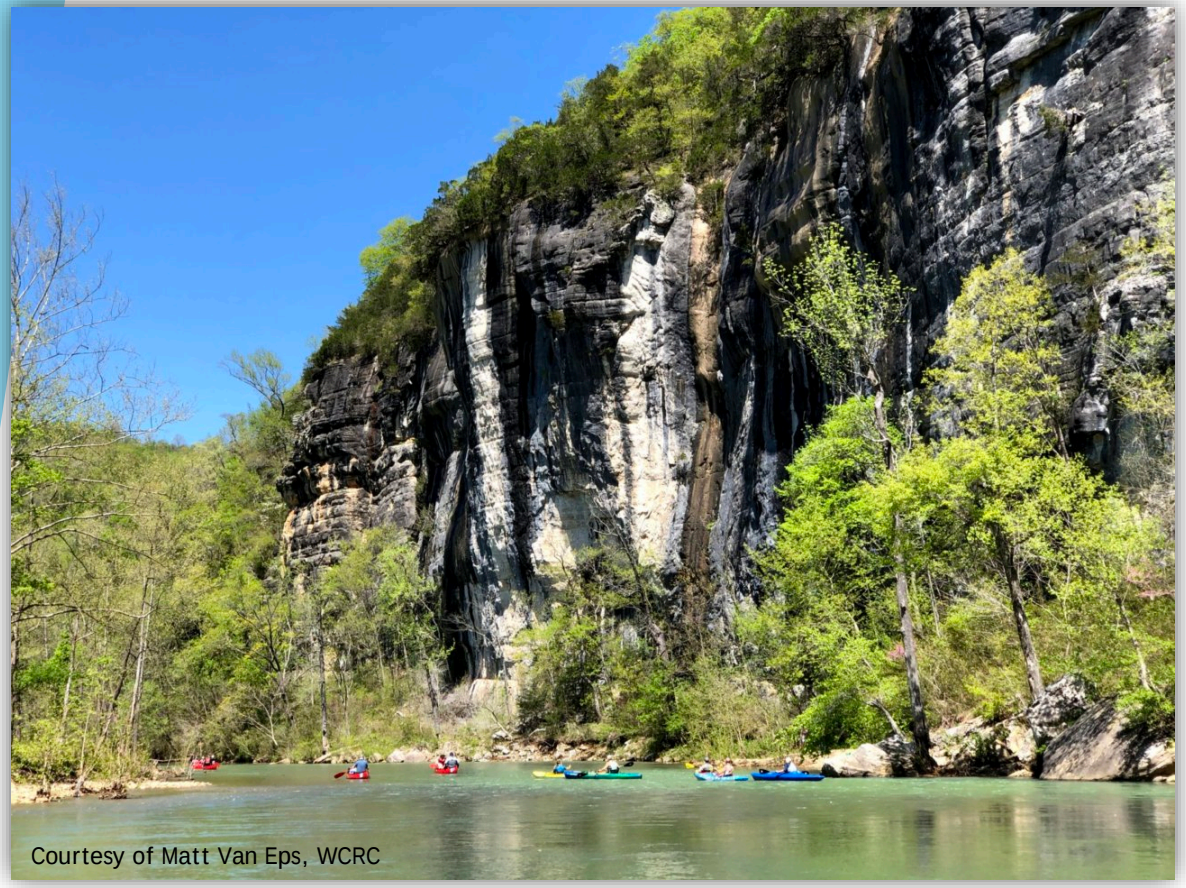
Surface-Water Quality in the Buffalo National River (1985–2011)


Courtesy of Matt Van Eps, WCRC


Courtesy of Matt Van Eps, WCRC

Sandi J. Formica, Executive Director
Watershed Conservation Resource Center

1st Annual Buffalo National River Science Symposium
Harrison, Arkansas
April 23, 2019

Watershed Conservation Resource Center
WCRC

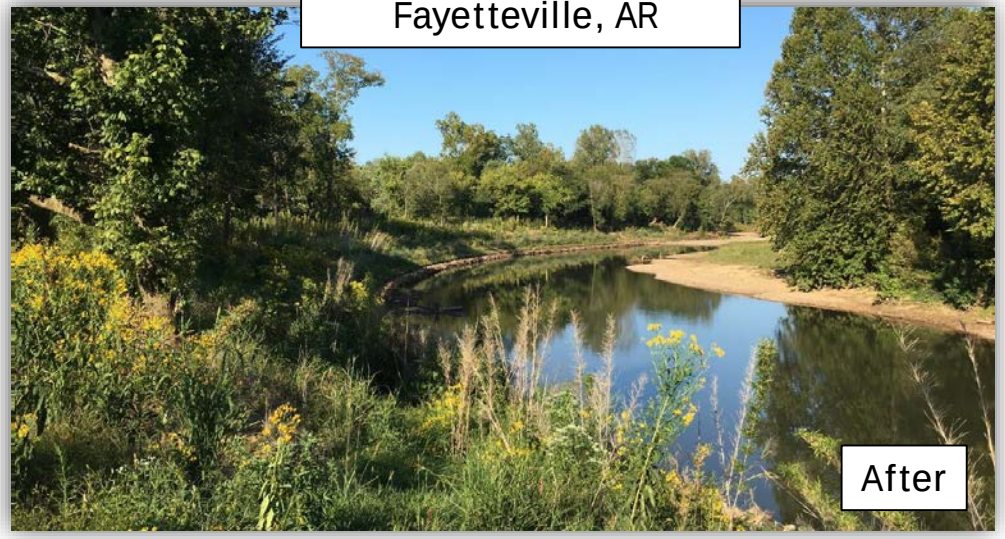
Who Are We?

- 501 (C)(3) Non Profit Organization
- Located in Fayetteville, Arkansas
- Specialize in
  - Stream and River Restoration
  - Watershed Assessment
  - Watershed Planning
- Provide assistance to Government Agencies, Local Municipalities, Watershed Groups, Landowners, Water Districts, other NGOs, and more
- 15 years old (founded in 2004) with 11 staff persons

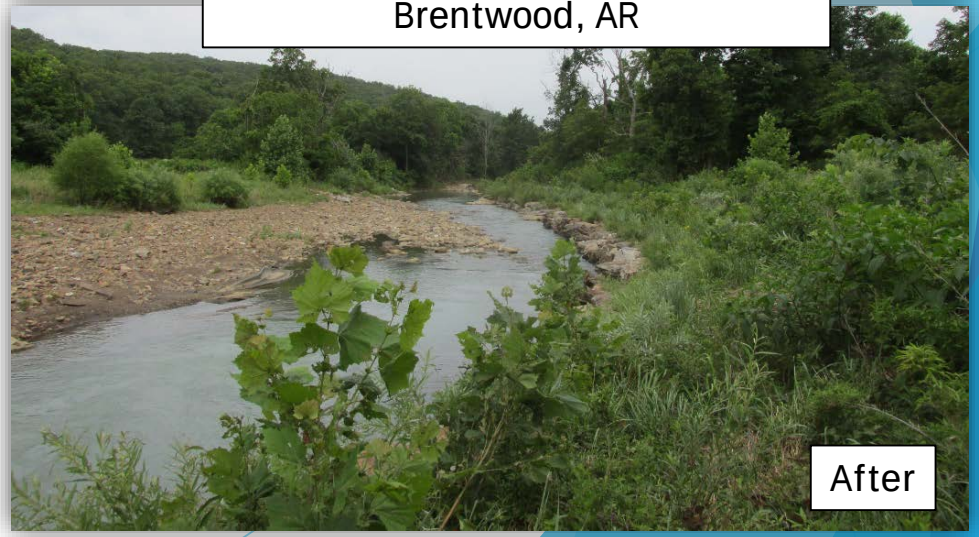
Watershed Conservation Resource Center

Specialization in River Restoration

White River Restoration
Fayetteville, AR



West Fork White River Restoration
Brentwood, AR



Surface-Water Quality in the Buffalo National River (1985–2011)

Overview

- WQ monitoring began in 1985 at BNR and tributaries (Joint effort between NPS and ADEQ)
- Presentation focuses on data collected from 1995 to 2011
- Compared data to previous studies (Mott 1997, Mott and Laurans 2004)
- Includes the main stem of the river and its tributaries
- Recommendations developed based on study results

Buffalo National River

Surface-Water Quality in the Buffalo National River (1985–2011)

Acknowledgements

- National Park Services – assistance in report development
  - Faron Usrey
  - Chuck Bitting
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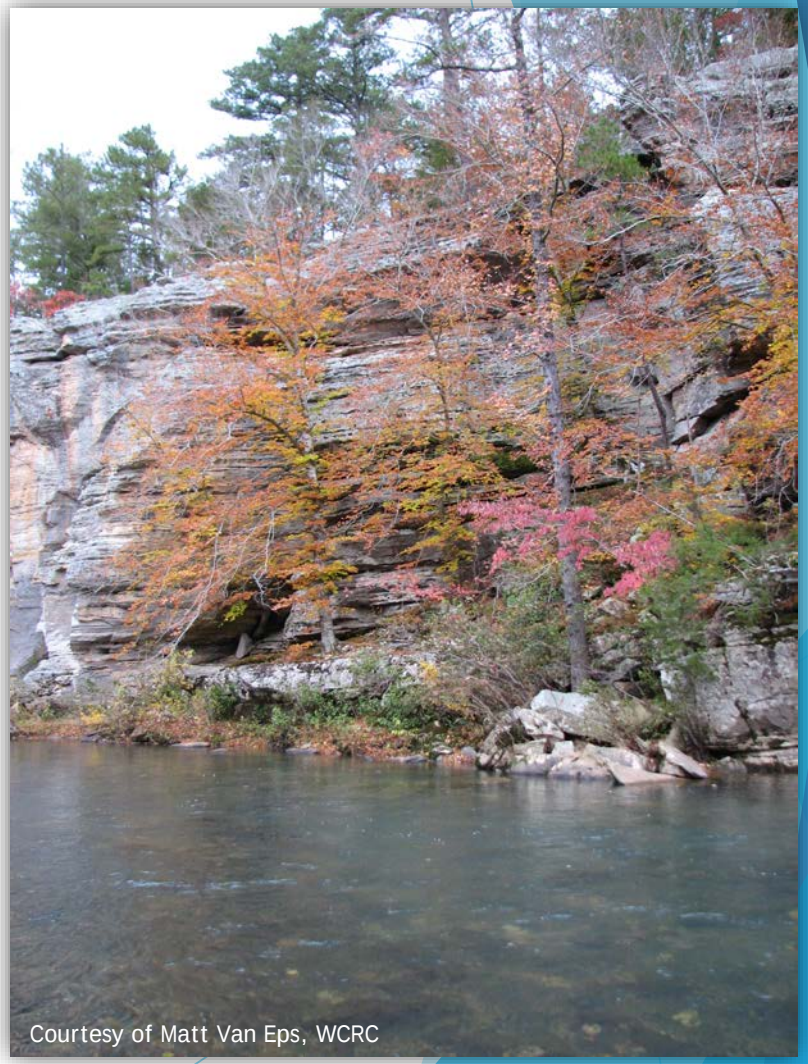
- Jim Peterson – comprehensive review and editing
- US Geological Survey
  - Tim Kresse – comprehensive review
- Watershed Conservation Resource Center – report development
  - Sandi J. Formica
  - Tyler Anderson
  - Matthew Van Eps



Buffalo National River

Surface-Water Quality in the Buffalo National River (1985–2011)

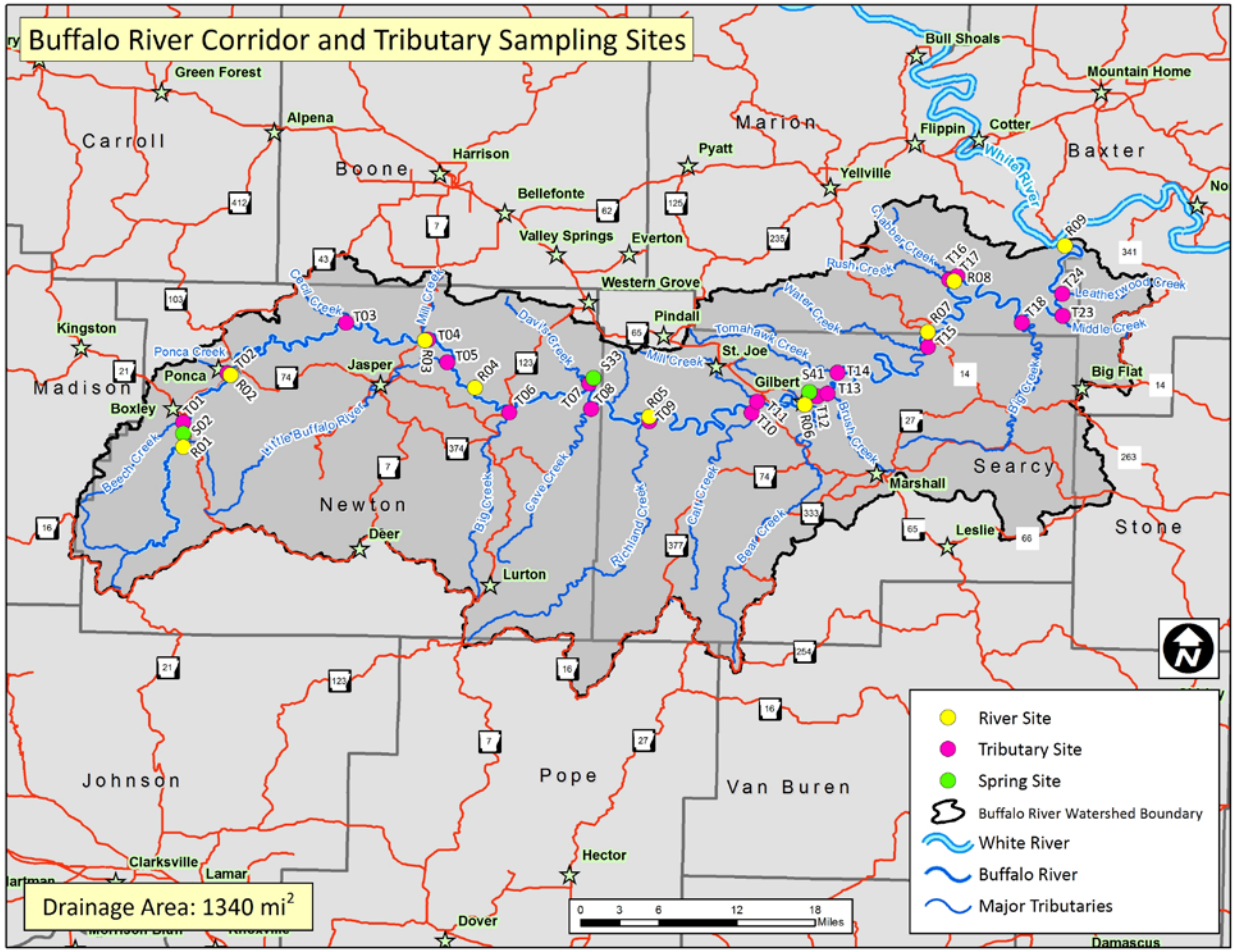
Purpose of Water Quality Sampling

- Provide base-line conditions so that degradation of water quality can be recognized and addressed (Mott 1997)
- Describe water quality
  - 9 stations on Buffalo River
  - 20 stations on major tributaries just before confluence and within the Park
  - 3 springs
- Evaluate historical trends
- Compare data to water quality standards (ADPC&E Regulation No. 2)

Buffalo National River

Surface-Water Quality in the Buffalo National River (1985–2011)

Buffalo River Watershed & Sampling Sites



- Drainage area - 1,340 mi^2
- Total sampling stations – 32
- Sampling frequency has varied over the years and includes both base flow and storm flow

Table 3.1.1 Buffalo River corridor sites

River					
R01	Wilderness Boundary	R04	Hasty	R07	Highway 14
R02	Ponca	R05	Woolum	R08	Rush
R03	Pruitt	R06	Gilbert	R09	Mouth

Table 3.1.2 Buffalo River tributary sites

Tributaries					
T01	Beech Creek	T08	Cave Creek	T15	Water Creek
T02	Ponca Creek	T09	Richland Creek	T16	Rush Creek
T03	Cecil Creek	T10	Calf Creek	T17	Clabber Creek
T04	Mill Creek	T11	Mill Creek-Middle	T18	Big Creek-Lower
T05	Little Buffalo River	T12	Bear Creek	T23	Middle Creek
T06	Big Creek	T13	Brush Creek	T24	Leatherwood Creek
T07	Davis Creek	T14	Tomahawk Creek		

Table 3.1.3 Buffalo River spring sites

Springs					
S02	Luallen Spring	S33	Mitch Hill Spring	S41	Gilbert Spring

Surface-Water Quality in the Buffalo National River (1985–2011)

Land Use - Buffalo River Watershed

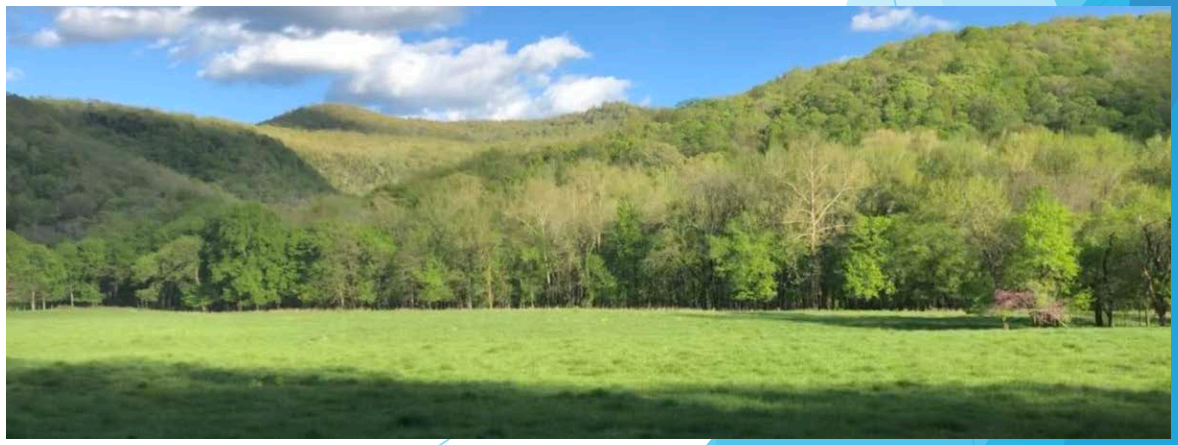
River Sites	Site ID	Drainage Area mi^2	Dominant Land Uses %		
			Forest/Woodland	Agriculture/Grass	Other
	R01	58.6	93.6	4.5	1.9
	R02	115	90.8	7.3	1.9
	R03	191	90.8	7.3	1.9
	R04	198	88.1	9.3	2.6
	R05	601	85.8	11.5	2.6
	R06	841	84.6	12.8	2.6
	R07	1071	82.0	15.2	2.8
	R08	1095	82.2	15.0	2.8
	R09	1335	81.7	15.5	2.8

Site Interval	Acres of Adjacent Agriculture/Grasses	Miles of River	Acres of Agriculture/Grasses Per Mile
Source-R01	0.0	13.7	0.0
R01-R02	971.6	7.7	126.2
R02-R03	224.3	23.6	9.5
R03-R04	103.7	7.3	14.3
R04-R05	224.9	19.4	11.6
R05-R06	1409.9	21.0	67.1
R06-R07	391.2	21.5	18.2
R07-R08	39.2	8.9	4.4
R08-R09	0.0	23.2	0.0

- Overall as drainage area increases, percent agriculture lands increase and forested decrease
- Acres of pasture per mile of river
  - Highest is R01 to R02 (between Boxley and Ponca)

Table 3.1.1 Buffalo River corridor sites

River					
R01	Wilderness Boundary	R04	Hasty	R07	Highway 14
R02	Ponca	R05	Woolum	R08	Rush
R03	Pruitt	R06	Gilbert	R09	Mouth



Pasture along the Buffalo River in Boxley Valley

Surface-Water Quality in the Buffalo National River (1985–2011)

Land Use - Tributary Watersheds

	Site ID	Drainage Area mi^2	Dominant Land Uses %		
			Forest/Woodland	Agriculture/Grass	Other
Tributary Sites	**T01**	19.4	91.6	7.1	1.3
	T02	4.5	89.9	7.3	2.8
	T03	22.6	86.7	11.2	2.1
	T04	21.2	79.5	16.7	3.8
	T05	143	87.7	9.1	3.1
	T06	89.8	82.2	15.3	2.5
	T07	27.9	70.4	26.8	2.8
	T08	52.2	84.8	13.1	2.1
	T09	130	91.6	6.3	2.1
	T10	49.3	67.7	29.7	2.6
	T11	14.2	72.3	24.5	3.1
	T12	91.8	67.6	29.0	3.5
	T13	20.0	69.5	25.7	4.8
	T14	36.6	66.1	31.4	2.4
	T15	38.3	79.0	18.1	2.9
	T16	15.1	89.2	8.2	2.6
	T17	26.4	74.3	23.9	1.9
	T18	134	71.4	25.3	3.3
	T23	11.1	98.7	0.0	1.3
	T24	12.6	98.0	0.7	1.3

- Mostly Forested Tributaries
  - Middle Creek (T23): 98.7%
  - Leatherwood Creek (T24): 98.0%
  - Beach Creek (T08): 91.6%
  - Richland Creek (T09): 91.6%

Table 3.1.2 Buffalo River tributary sites

Tributaries					
T01	Beech Creek	T08	Cave Creek	T15	Water Creek
T02	Ponca Creek	T09	Richland Creek	T16	Rush Creek
T03	Cecil Creek	T10	Calf Creek	T17	Clabber Creek
T04	Mill Creek	T11	Mill Creek-Middle	T18	Big Creek-Lower
T05	Little Buffalo River	T12	Bear Creek	T23	Middle Creek
T06	Big Creek	T13	Brush Creek	T24	Leatherwood Creek
T07	Davis Creek	T14	Tomahawk Creek		

Surface-Water Quality in the Buffalo National River (1985–2011)

Land Use - Tributary Watersheds

- Tomahawk Creek (T14) had the highest percentage of agricultural lands at 31.4%

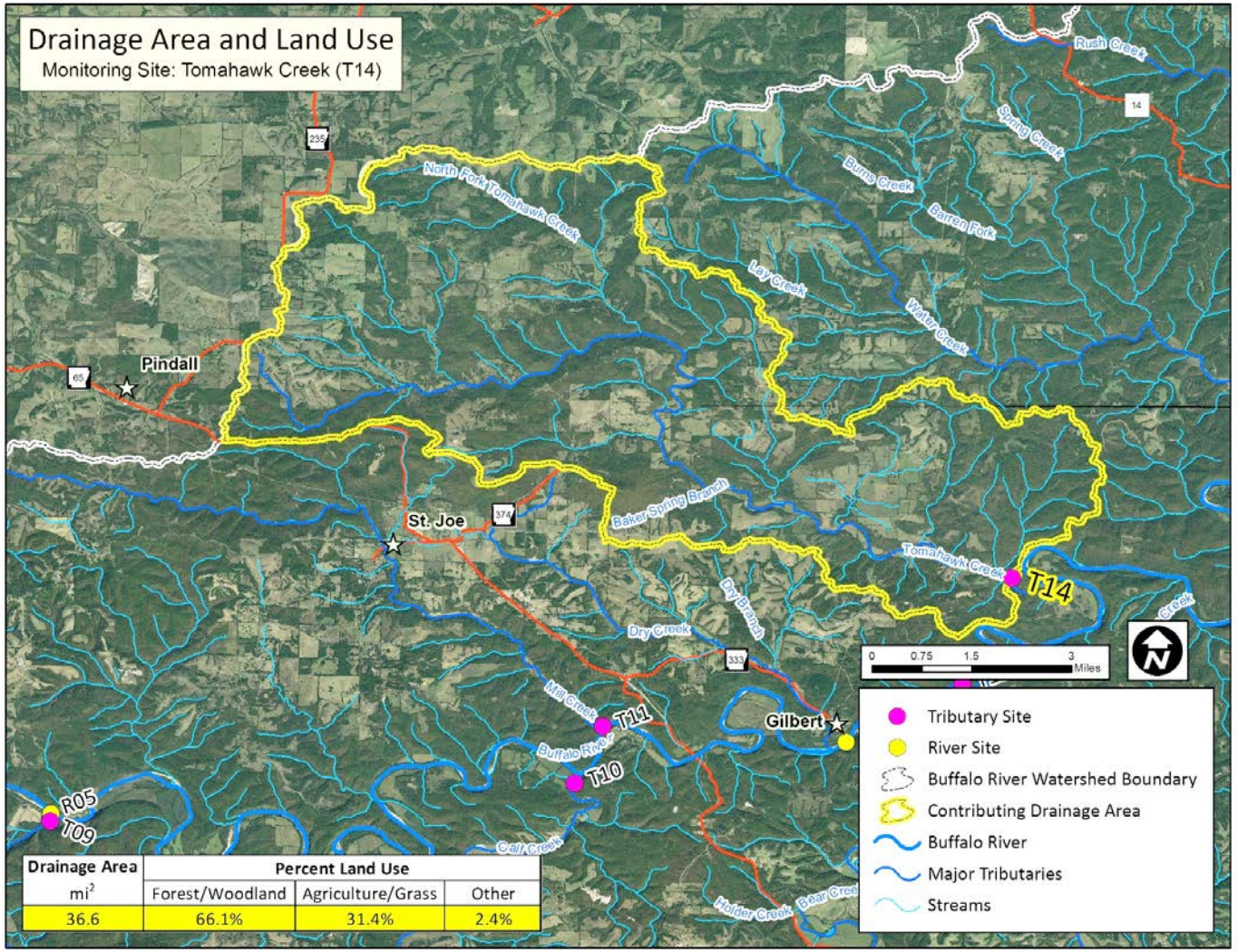
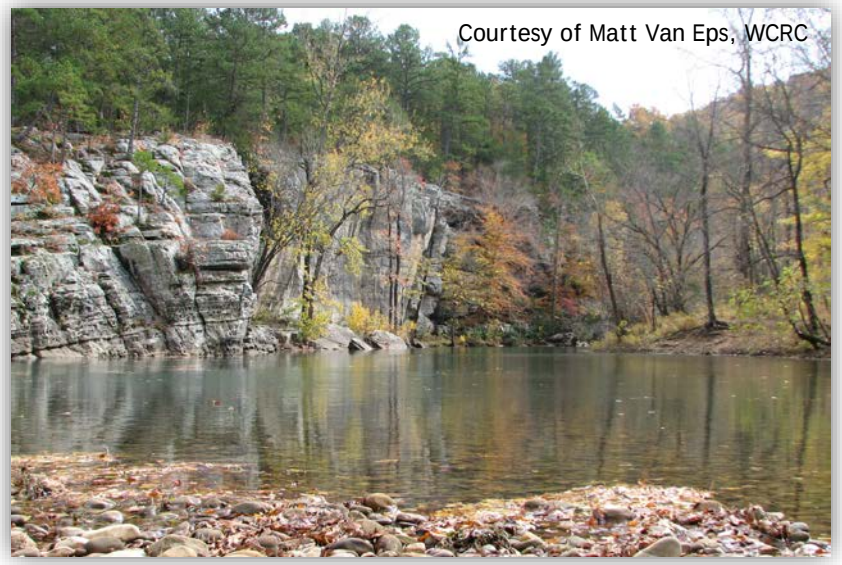


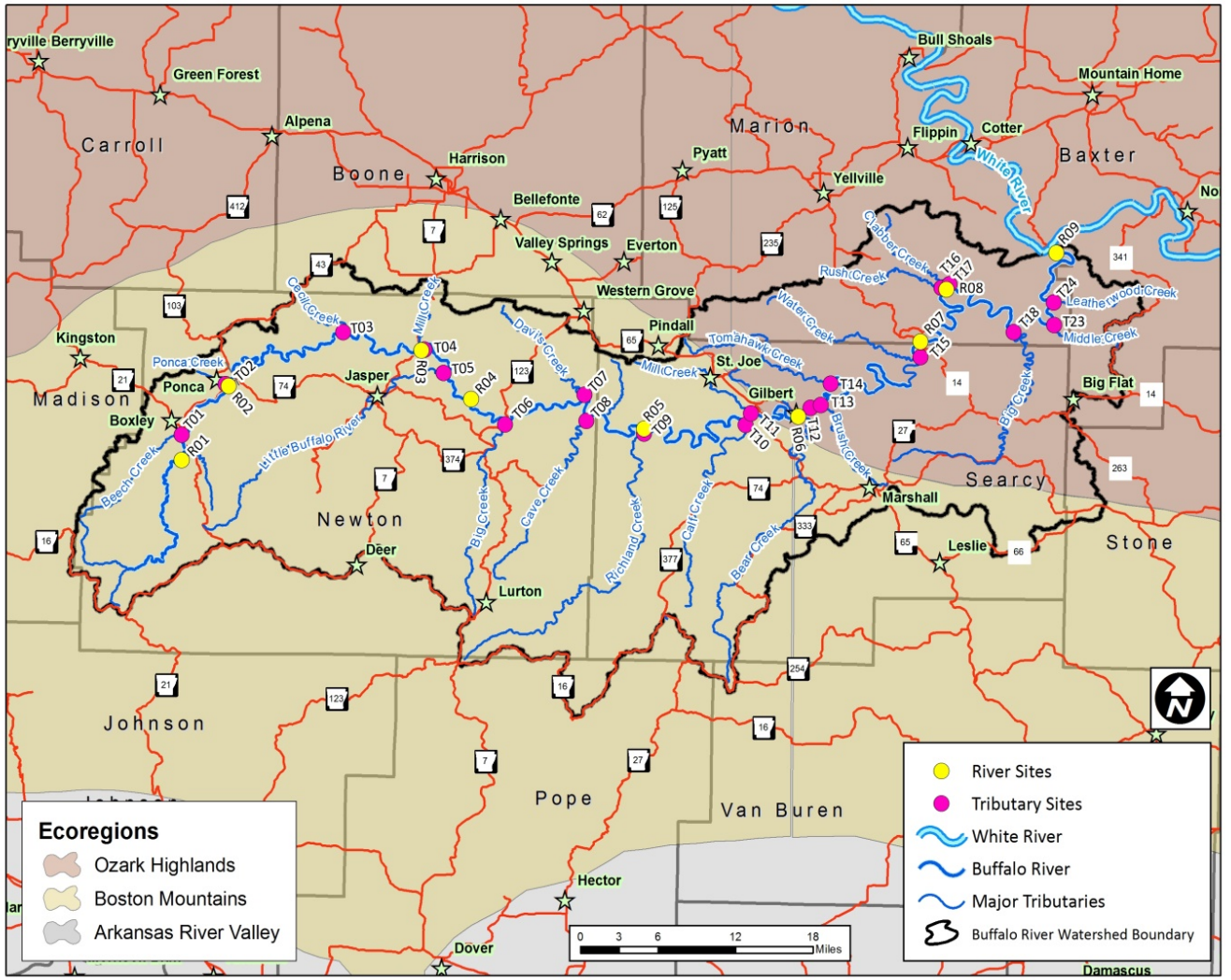
Figure 2.4.2 Tomahawk Creek (T14) watershed area and land-use (Other tributary site maps can be found in Appendix 1)

Surface-Water Quality in the Buffalo National River (1985–2011)

Buffalo River Watershed Lies in Two Ecoregions

- Boston Mountains (upper)
- Ozark Highlands (lower)
- Water quality standards are Ecoregion-based





Surface-Water Quality in the Buffalo National River (1985–2011)

Statistical Summary of River Corridor Data

- Base flow samples only
- Data collected from 1985-2011
- Includes all samples collected on the main stem of the river
- Results are compared to standards*

*cannot be directly compared, useful only to evaluate results

Table 4.1.1 Arkansas water quality standards and Buffalo River corridor base-flow sample statistics

[col/100 ml, colonies per 100 milliliters; NTU, nephelometric turbidity units; N/A, not applicable; mg/L, milligrams per liter; C, Celsius; µS, microsiemens; mi², square miles]

Parameter	Period of Record	Number of Samples	Mean	Standard Deviation	Current Standard[1] Boston Mountains Ecoregion	Current Standard[1] Ozark Highlands Ecoregion
Fecal coliform bacteria (col/100 mL)	1985-2011	1148	16	66	200 - 400	
Turbidity (NTU) base/all flow	1988-2011	949	1.98	2.02	10[2]/19[3]	10[2]/17[3]
Nitrate, as nitrogen (mg/L)	1985-2011	792	0.087	0.114	N/A	
Orthophosphate, as phosphorus (mg/L)	1999-2011	163	0.012	0.005	N/A	
Chloride (mg/L)	2003-2011	233	2.63	0.93	20	
Sulfate (mg/L)	2003-2011	232	5.04	1.12	20	
Dissolved oxygen (mg/L)	1985-2011	1016	9.88	2.11	Primary season > 6 Critical season >6[5]/2[4]	Primary season >6 Critical season >6[7]/5[6]/2[4]
Water temperature (°C)	1985-2011	1164	17.8	10.5	31	29
pH	1999-2011	361	8.02	0.35	6-9	
Specific conductance (µS/cm at 25 °C)	1985-2011	1158	180	64	N/A	
Alkalinity, as $CaCO_3$ (mg/L)	2003-2011	232	96	29	N/A	
Fluoride (mg/L)	1985-2011[8]	416	0.061	0.025	N/A	

[1] Arkansas Pollution Control and Ecology Commission (2014)
[2] Samples collected during base flow
[3] All collected samples
[4] Watershed is less than 10 mi²
[5] Watershed is greater than 10 mi²
[6] Watershed is greater than 10 mi² and less than 100 mi²
[7] Watershed is greater than 100 mi²
[8] Samples were not taken in all years

Surface-Water Quality in the Buffalo National River (1985–2011)

Statistical Summary of Tributary Data

- Base flow samples only
- Data collected from 1985-2011
- Includes all samples collected on at 20 tributary stations
- Results are compared to standards*
- Mean Values are higher when compared to river corridor
  - Fecal coliform – 2.1 times
  - Nitrate –nitrogen – 2.5 times
  - Orthophosphate – 1.4 times

*cannot be directly compared, useful only to evaluate results

Table 4.1.2 Arkansas water quality standards and Buffalo River tributary base-flow sample statistics

[col/100 ml, colonies per 100 milliliters; NTU, nephelometric turbidity units; N/A, not applicable; mg/L, milligrams per liter; C, Celsius; µS, microsiemens; mi², square miles]

Parameter	Period of Record	Number of Samples	Mean	Standard Deviation	Current Standard[1] Boston Mountains Ecoregion	Current Standard[1] Ozark Highlands Ecoregion
Fecal coliform bacteria (col/100 mL)	1985-2011	2262	33	133	200 - 400	
Turbidity (NTU) base/all flow	1988-2011	2025	1.64	7.48	10[2]/19[3]	10[2]/17[3]
Nitrate, as nitrogen(mg/L)	1985-2011	1547	0.220	0.242	N/A	
Orthophosphate, as phosphorus (mg/L)	1999-2011	426	0.017	0.025	N/A	
Chloride (mg/L)	2003-2011	540	3.75	1.68	20	
Sulfate (mg/L)	2003-2011	536	6.45	2.08	20	
Dissolved oxygen (mg/L)	1985-2011	1944	9.98	2.80	Primary season >6 Critical season >6[5]/2[4]	Primary season >6 Critical season >6[7]/5[6]/2[4]
Water temperature (°C)	1985-2011	2286	17.3	6.8	31	29
pH	1999-2011	841	8.04	0.28	6-9	
Specific conductance (µS/cm at 25 °C)	1985-2011	2268	273	90	N/A	
Alkalinity, as $CaCO_3$ (mg/L)	2003-2011	537	154	50	N/A	
Fluoride (mg/L)	1985-2011[8]	933	0.065	0.024	N/A	

[1] Arkansas Pollution Control and Ecology Commission (2014)
[2] Samples collected during base flow
[3] All collected samples
[4] Watershed is less than 10 mi²
[5] Watershed is greater than 10 mi²
[6] Watershed is greater than 10 mi² and less than 100 mi²
[7] Watershed is greater than 100 mi²
[8] Samples were not taken in all years

Surface-Water Quality in the Buffalo National River (1985–2011)

Statistical Summary of Spring Data

- Base flow samples only
- Data collected from 1985-2011
- Includes all samples collected on at 20 tributary stations
- Results are compared to standards*
- Mean Values are higher when compared to river corridor
  - Fecal coliform – 1.6 times
  - Nitrate –nitrogen – 7.6 times
  - Orthophosphate – 1.8 times

*cannot be directly compared, useful only to evaluate results

Table 4.1.3 Arkansas water quality standards and spring base-flow sample statistics

[col/100 ml, colonies per 100 milliliters; NTU, nephelometric turbidity units; N/A, not applicable; mg/L, milligrams per liter; C, Celsius; µS, microsiemens; mi^2, square miles]

Parameter	Period of Record	Number of Samples	Mean	Standard Deviation	Current Standard[1] Boston Mountains Ecoregion	Current Standard[1] Ozark Highlands Ecoregion
Fecal coliform bacteria (col/100 mL)	1985-2011	380	26	105	200 - 400	
Turbidity (NTU) base/all flow	1988-2011	344	1.46	1.67	$10^2/19^3$	$10^2/17^3$
Nitrate, as nitrogen (mg/L)	1987-2011	288	0.662	0.399	N/A	
Orthophosphate, as phosphorus (mg/L)	2002-2011	86	0.022	0.010	N/A	
Chloride (mg/L)	2003-2011	86	4.12	1.70	20	
Sulfate (mg/L)	2003-2011	86	6.97	3.75	20	
Dissolved oxygen (mg/L)	1985-2011	328	8.82	1.41	Primary season > 6 Critical season $>6^5/2^4$	Primary season >6 Critical season $>6^7/5^6/2^4$
Water temperature (°C)	1985-2011	383	14.2	2.0	31	29
pH	1999-2011	154	7.46	0.28	6-9	
Specific conductance (µS/cm at 25 °C)	1985-2011	383	317	91	N/A	
Alkalinity, as $CaCO_3$ (mg/L)	2003-2011	86	181	42	N/A	
Fluoride (mg/L)	1985-2011[8]	150	0.065	0.027	N/A	

[1] Arkansas Pollution Control and Ecology Commission (2015)

[2] Samples collected during base flow

[3] All collected samples

[4] Watershed is less than 10 mi^2

[5] Watershed is greater than 10 mi^2

[6] Watershed is greater than 10 mi^2 and less than 100 mi^2

[7] Watershed is greater than 100 mi^2

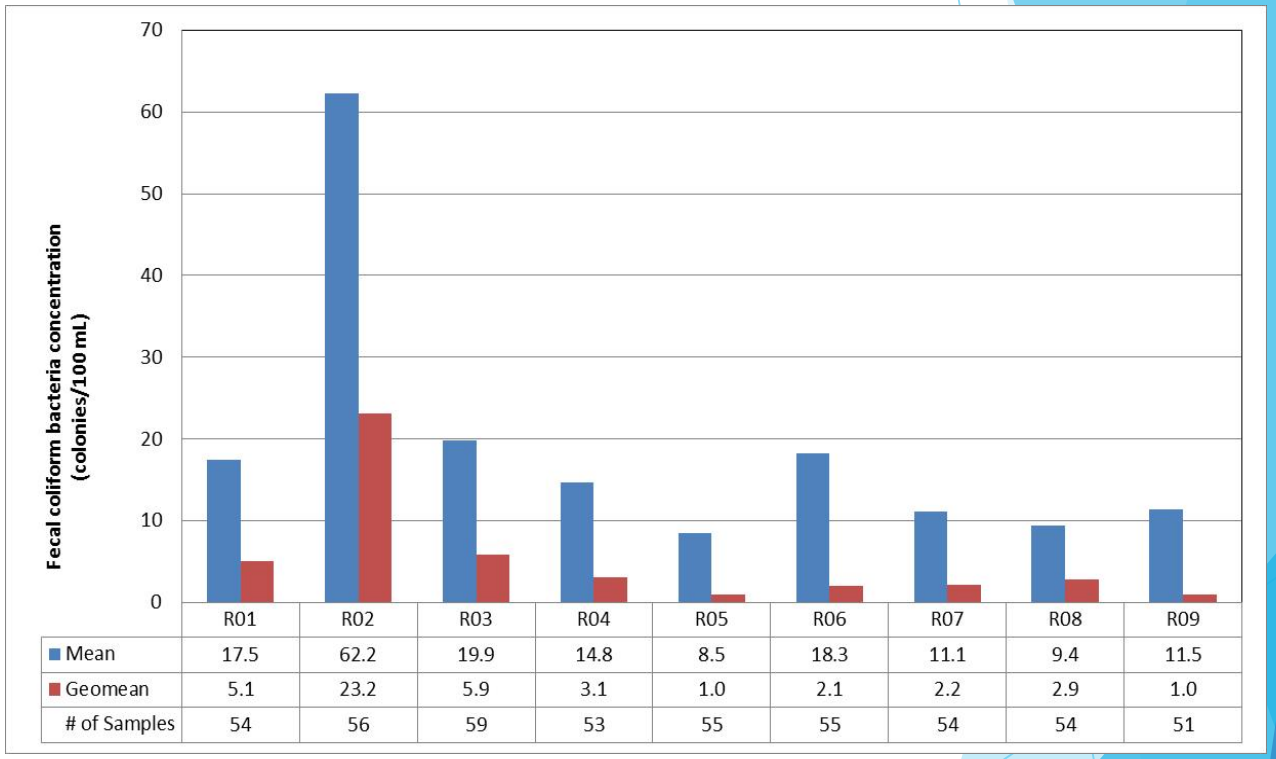
[8] Samples were not taken in all years

Surface-Water Quality in the Buffalo National River (1985–2011)

Fecal Coliform Bacteria

River Corridor Sites – base flow samples 1995-2011

- R02 (Ponca) had the highest mean concentration of 62.2 col/100 ml
  - All others were less than 20
  - Boxley Valley has the densest agricultural land use along the Buffalo River (126 acres/mile of river)
- R02 (Ponca) had the highest geometric mean concentration of 23.2 col/100 ml
  - All others were less than 5.9
- Results similar to Mott's 1997 study



	R01	R02	R03	R04	R05	R06	R07	R08	R09
Mean	17.5	62.2	19.9	14.8	8.5	18.3	11.1	9.4	11.5
Geomean	5.1	23.2	5.9	3.1	1.0	2.1	2.2	2.9	1.0
# of Samples	54	56	59	53	55	55	54	54	51

Figure 4.2.1 Geometric mean (geomean) and mean fecal coliform bacteria concentrations for Buffalo River corridor sites sampled between 1995-2011 during base-flow conditions.

Table 3.1.1 Buffalo River corridor sites

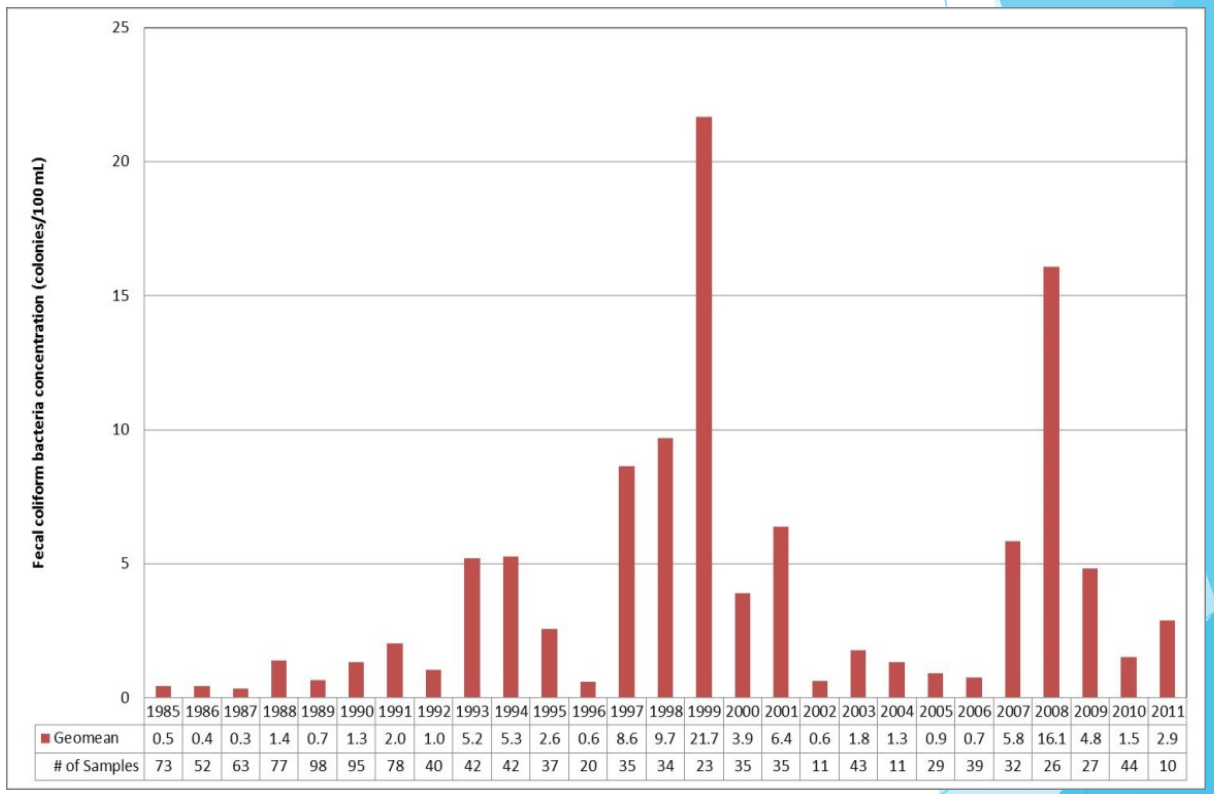
River					
R01	Wilderness Boundary	R04	Hasty	R07	Highway 14
R02	Ponca	R05	Woolum	R08	Rush
R03	Pruitt	R06	Gilbert	R09	Mouth

Surface-Water Quality in the Buffalo National River (1985–2011)

Fecal Coliform Bacteria

River Corridor Sites – base flow samples
Annual Geometric Mean
1985-2011

- All sampling sites
- Geometric Mean ranged from 0.3 to 21.7 col/100 ml
- 1999 and 2008 highest values



	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Geomean	0.5	0.4	0.3	1.4	0.7	1.3	2.0	1.0	5.2	5.3	2.6	0.6	8.6	9.7	21.7	3.9	6.4	0.6	1.8	1.3	0.9	0.7	5.8	16.1	4.8	1.5	2.9
# of Samples	73	52	63	77	98	95	78	40	42	42	37	20	35	34	23	35	35	11	43	11	29	39	32	26	27	44	10

Figure 4.2.4 Annual geometric means for fecal coliform bacteria concentrations for Buffalo River corridor sites sampled from 1985-2011 during base-flow conditions.

Table 3.1.1 Buffalo River corridor sites

River					
R01	Wilderness Boundary	R04	Hasty	R07	Highway 14
R02	Ponca	R05	Woolum	R08	Rush
R03	Pruitt	R06	Gilbert	R09	Mouth

Surface-Water Quality in the Buffalo National River (1985–2011)

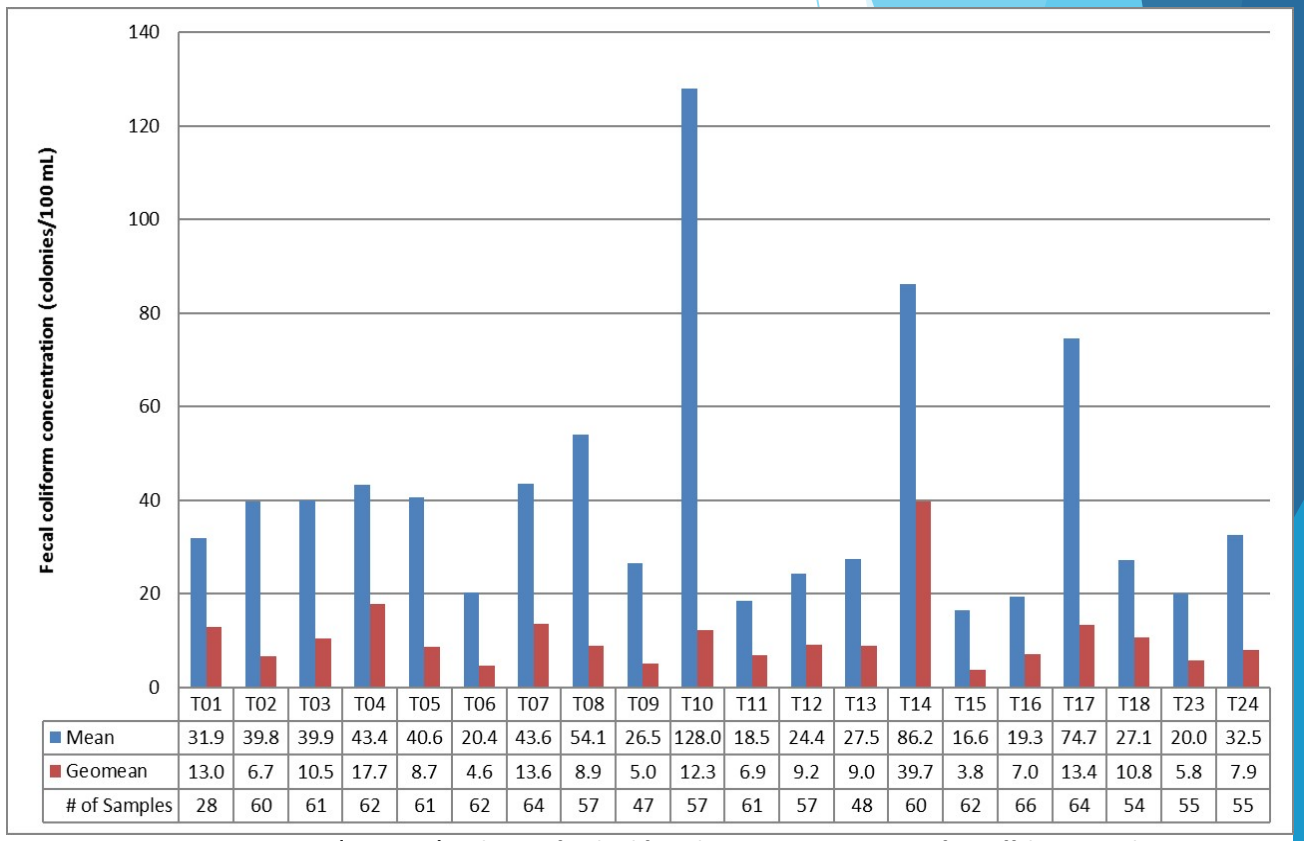
Fecal Coliform Bacteria

Tributary Sites – base flow samples 1995-2011

- T14 (Tomahawk Creek) had the highest geometric mean concentration of 39.7 col/100 ml
- All others were less than 13.6 col/100 ml except T04 (Mill Creek) at 17.7 col/100 ml
- Results similar to Mott's 1997 study

Table 3.1.2 Buffalo River tributary sites

Tributaries					
T01	Beech Creek	T08	Cave Creek	T15	Water Creek
T02	Ponca Creek	T09	Richland Creek	T16	Rush Creek
T03	Cecil Creek	T10	Calf Creek	T17	Clabber Creek
T04	Mill Creek	T11	Mill Creek-Middle	T18	Big Creek-Lower
T05	Little Buffalo River	T12	Bear Creek	T23	Middle Creek
T06	Big Creek	T13	Brush Creek	T24	Leatherwood Creek
T07	Davis Creek	T14	Tomahawk Creek		



	T01	T02	T03	T04	T05	T06	T07	T08	T09	T10	T11	T12	T13	T14	T15	T16	T17	T18	T23	T24
Mean	31.9	39.8	39.9	43.4	40.6	20.4	43.6	54.1	26.5	128.0	18.5	24.4	27.5	86.2	16.6	19.3	74.7	27.1	20.0	32.5
Geomean	13.0	6.7	10.5	17.7	8.7	4.6	13.6	8.9	5.0	12.3	6.9	9.2	9.0	39.7	3.8	7.0	13.4	10.8	5.8	7.9
# of Samples	28	60	61	62	61	62	64	57	47	57	61	57	48	60	62	66	64	54	55	55

Figure 4.2.6 Geometric mean (geomean) and mean fecal coliform bacteria concentrations for Buffalo River tributary sites sampled between 1995-2011 during base-flow conditions.

Surface-Water Quality in the Buffalo National River (1985–2011)

Fecal Coliform Bacteria

Tributary Sites – base flow samples
Annual Geometric Mean
1985-2011

- All sampling sites
- Geometric Mean ranged from 2.8 to 30.0 col/100 ml
- 1989 and 1998 highest values

Table 3.1.2 Buffalo River tributary sites

Tributaries					
T01	Beech Creek	T08	Cave Creek	T15	Water Creek
T02	Ponca Creek	T09	Richland Creek	T16	Rush Creek
T03	Cecil Creek	T10	Calf Creek	T17	Clabber Creek
T04	Mill Creek	T11	Mill Creek-Middle	T18	Big Creek-Lower
T05	Little Buffalo River	T12	Bear Creek	T23	Middle Creek
T06	Big Creek	T13	Brush Creek	T24	Leatherwood Creek
T07	Davis Creek	T14	Tomahawk Creek		

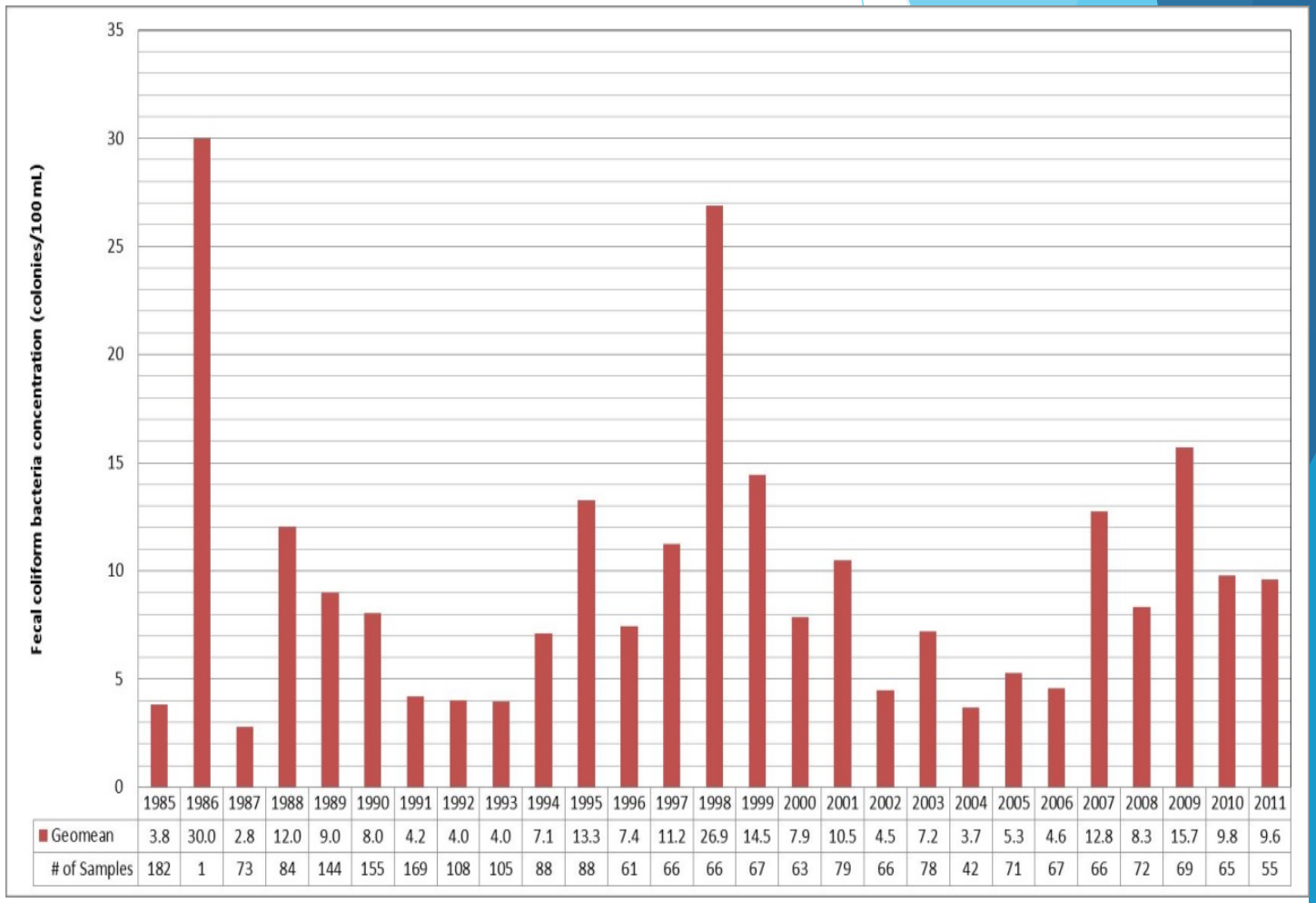


Figure 4.2.8 Annual geometric means for fecal coliform bacteria concentrations for Buffalo River tributary sites sampled from 1985-2011 during base-flow conditions.

Surface-Water Quality in the Buffalo National River (1985–2011)

Relation Between Bacteria and Land Use

Tributary Sites – base flow and storm flow samples 1985-2011

- Fecal Coliform Bacteria Geometric Mean Verses Percent Pasture within Tributary Watershed (using Spearman's rank correlation)
- A general upward trend was noted

Table 3.1.2 Buffalo River tributary sites

Tributaries					
T01	Beech Creek	T08	Cave Creek	T15	Water Creek
T02	Ponca Creek	T09	Richland Creek	T16	Rush Creek
T03	Cecil Creek	T10	Calf Creek	T17	Clabber Creek
T04	Mill Creek	T11	Mill Creek-Middle	T18	Big Creek-Lower
T05	Little Buffalo River	T12	Bear Creek	T23	Middle Creek
T06	Big Creek	T13	Brush Creek	T24	Leatherwood Creek
T07	Davis Creek	T14	Tomahawk Creek		

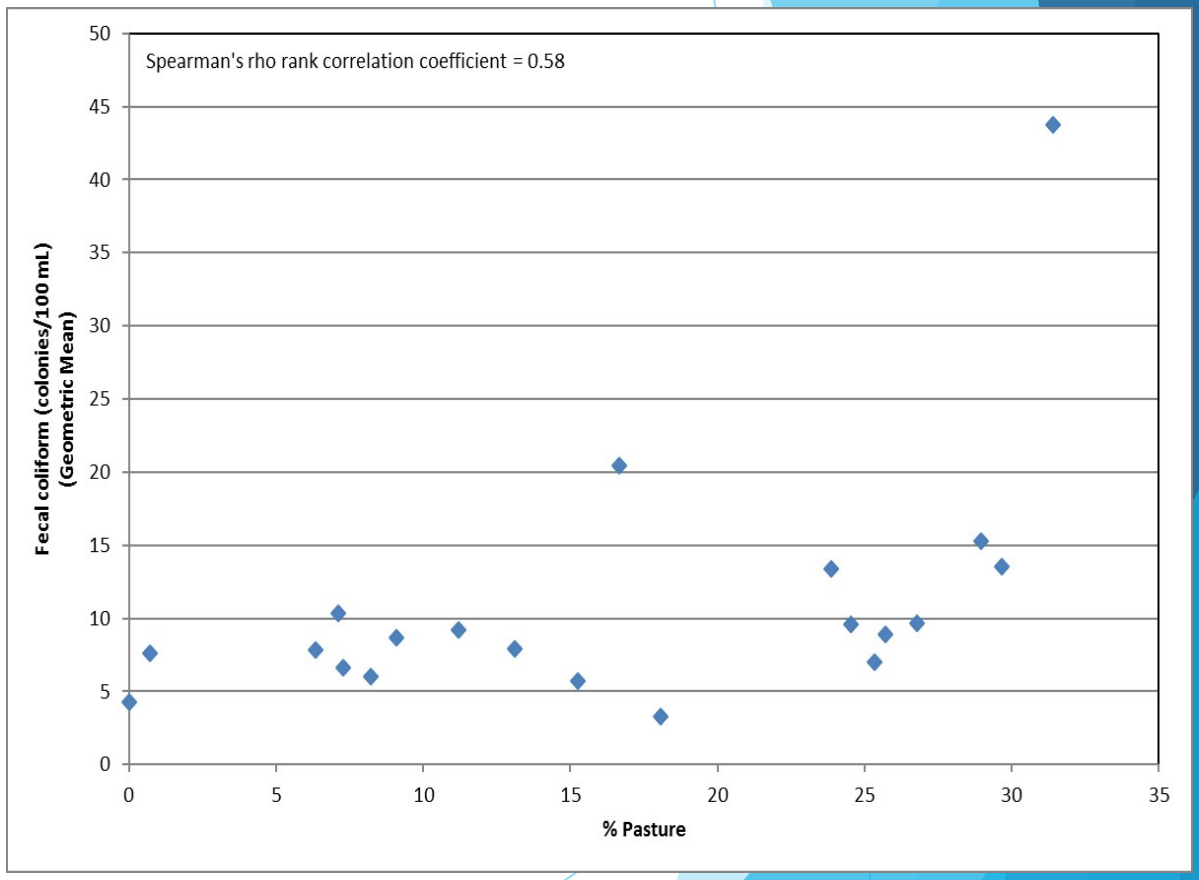


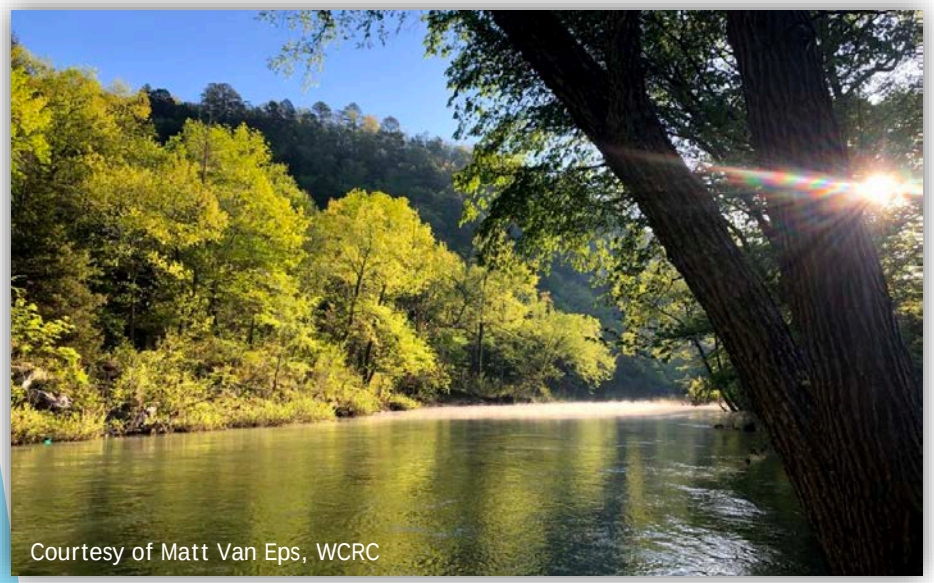
Figure 4.2.9 Relation between geometric mean fecal coliform bacteria concentrations and percent pasture of watersheds of Buffalo River tributary sites sampled between 1985-2011 during storm- flow and base-flow conditions.

Surface-Water Quality in the Buffalo National River (1985–2011)

Nitrate

River Corridor Sites – base flow samples 1995-2011

- Mean concentrations ranged from 0.04 mg/L to 0.12 mg/L
- Except R01, values were 25% to 55% higher than Mott's 1997 study



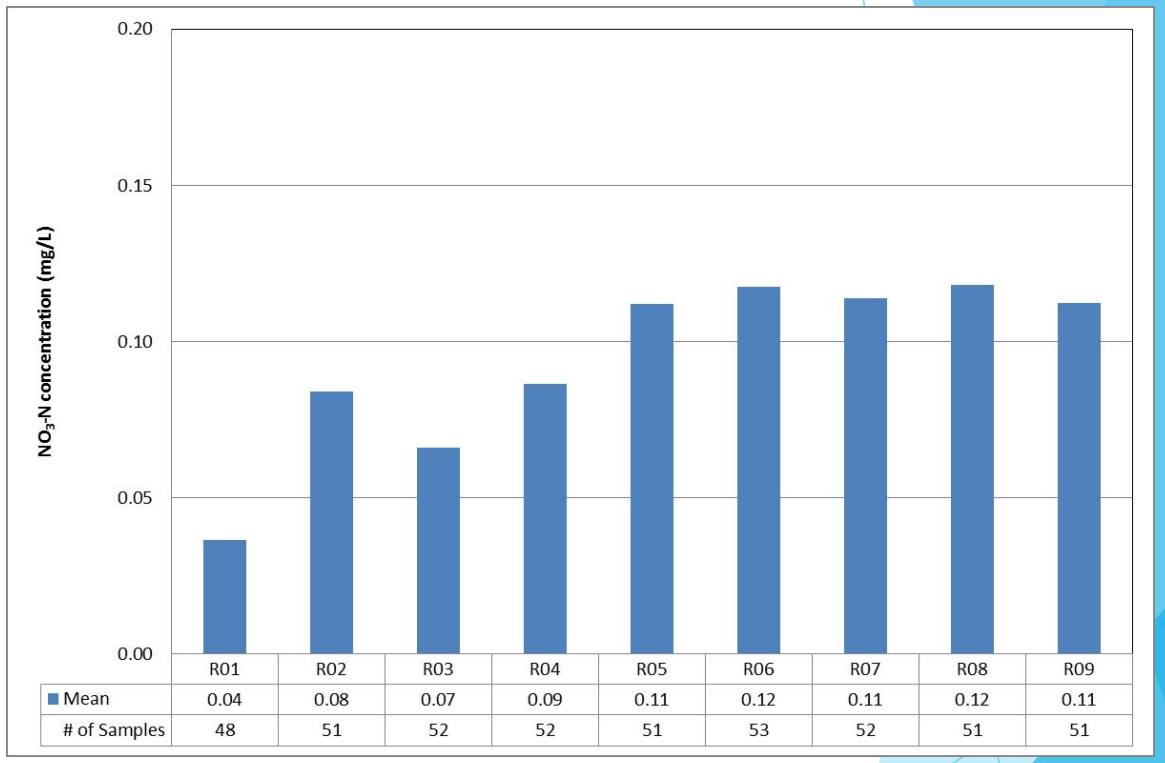


Figure 4.3.1 Mean NO_3-N concentration for Buffalo River corridor sites sampled between 1995-2011 during base-flow conditions.

Table 3.1.1 Buffalo River corridor sites

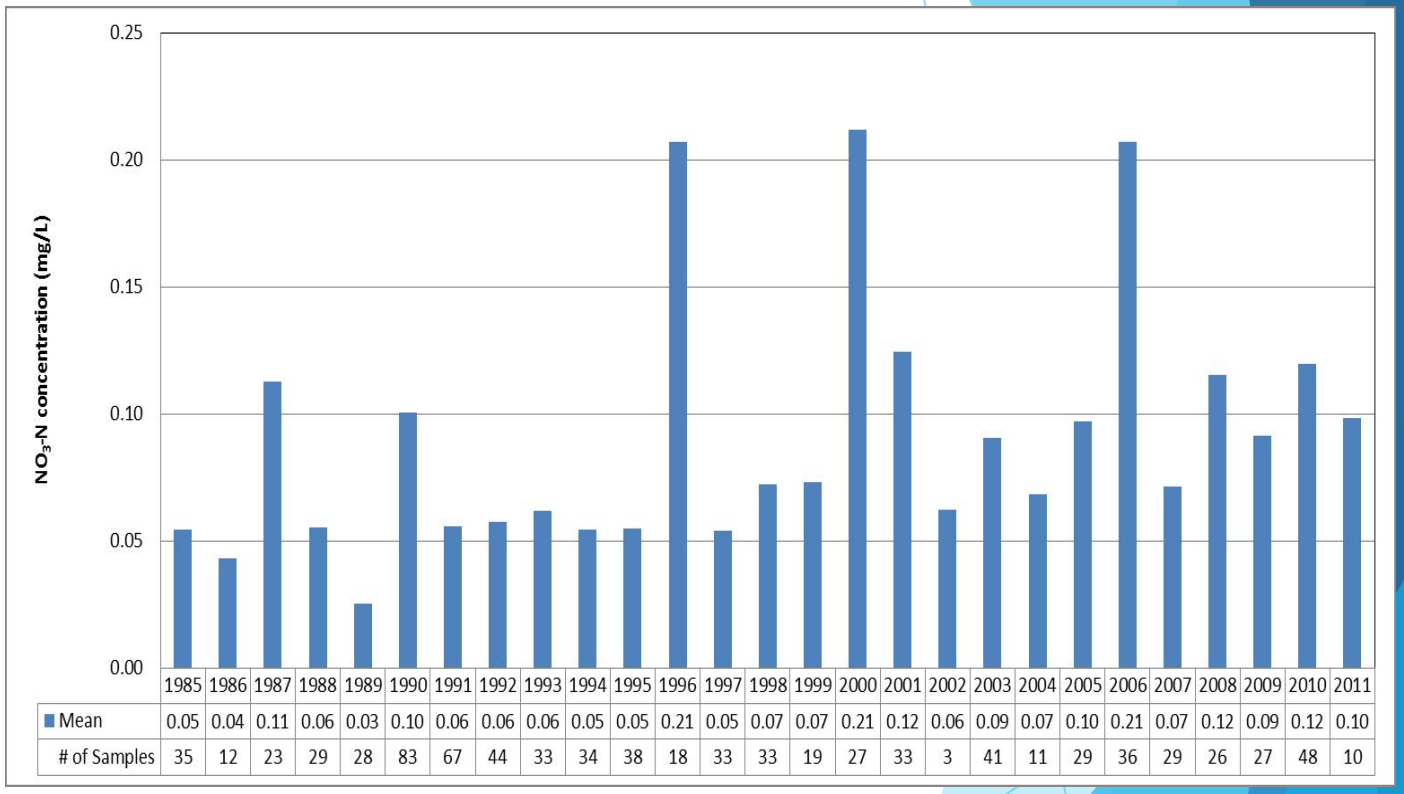
River					
R01	Wilderness Boundary	R04	Hasty	R07	Highway 14
R02	Ponca	R05	Woolum	R08	Rush
R03	Pruitt	R06	Gilbert	R09	Mouth

Surface-Water Quality in the Buffalo National River (1985–2011)

Nitrate

River Corridor Sites – base flow samples 1985-2011

- All sampling sites
- Mean concentrations ranged from 0.03 to 0.21 mg/L
- Generally increased over time
- 1996, 2000, and 2006 highest values



	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Mean	0.05	0.04	0.11	0.06	0.03	0.10	0.06	0.06	0.06	0.05	0.05	0.21	0.05	0.07	0.07	0.21	0.12	0.06	0.09	0.07	0.10	0.21	0.07	0.12	0.09	0.12	0.10
# of Samples	35	12	23	29	28	83	67	44	33	34	38	18	33	33	19	27	33	3	41	11	29	36	29	26	27	48	10

Figure 4.3.3 Mean annual NO_3-N concentrations for Buffalo River corridor sites sampled from 1985-2011 during base-flow conditions.

Table 3.1.1 Buffalo River corridor sites

River					
R01	Wilderness Boundary	R04	Hasty	R07	Highway 14
R02	Ponca	R05	Woolum	R08	Rush
R03	Pruitt	R06	Gilbert	R09	Mouth

Surface-Water Quality in the Buffalo National River (1985–2011)

Relation Between Nitrate and Land Use

River Corridor Sites – base flow and storm flow samples 1985-2011

- Mean Nitrate Concentrations verses Percent Pasture of Upstream Watershed Area (using Spearman's rank correlation)
- Generally an upward trend

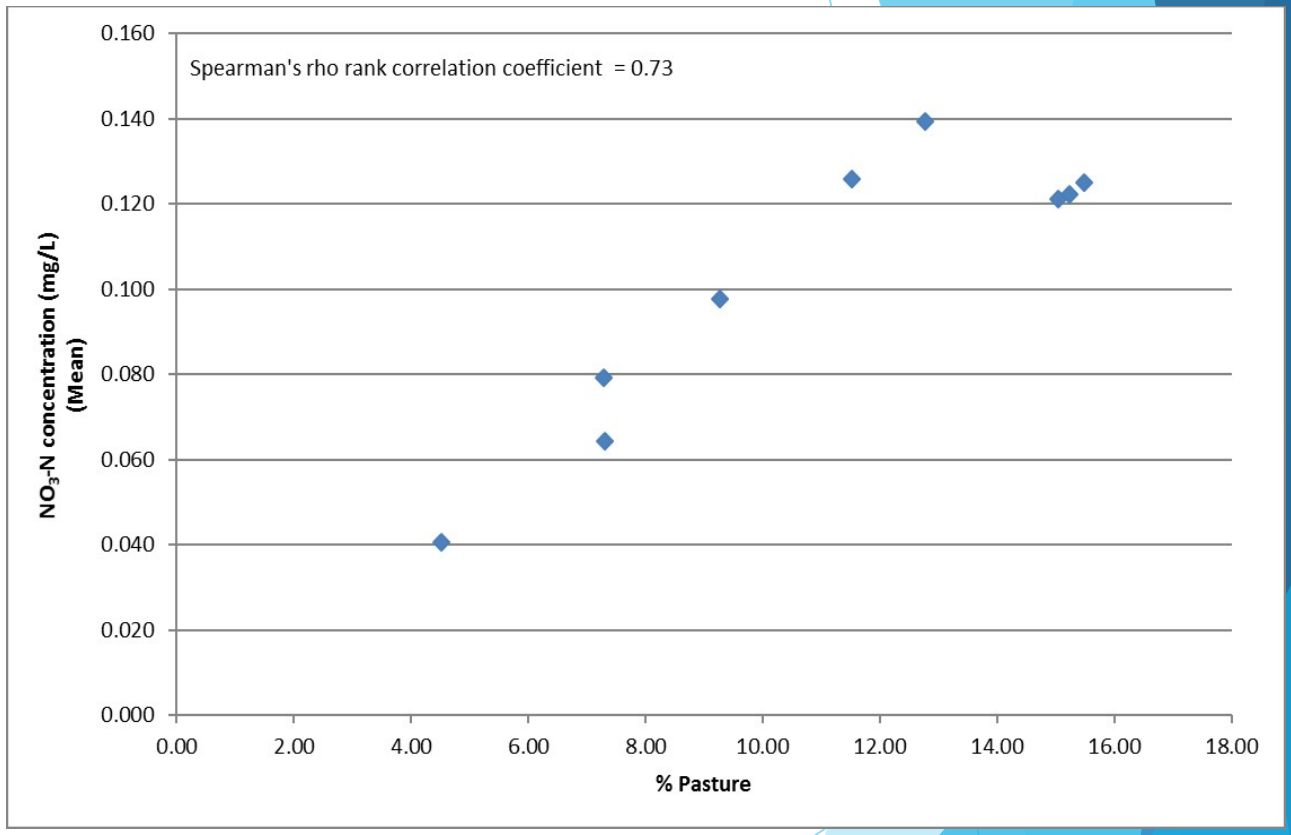


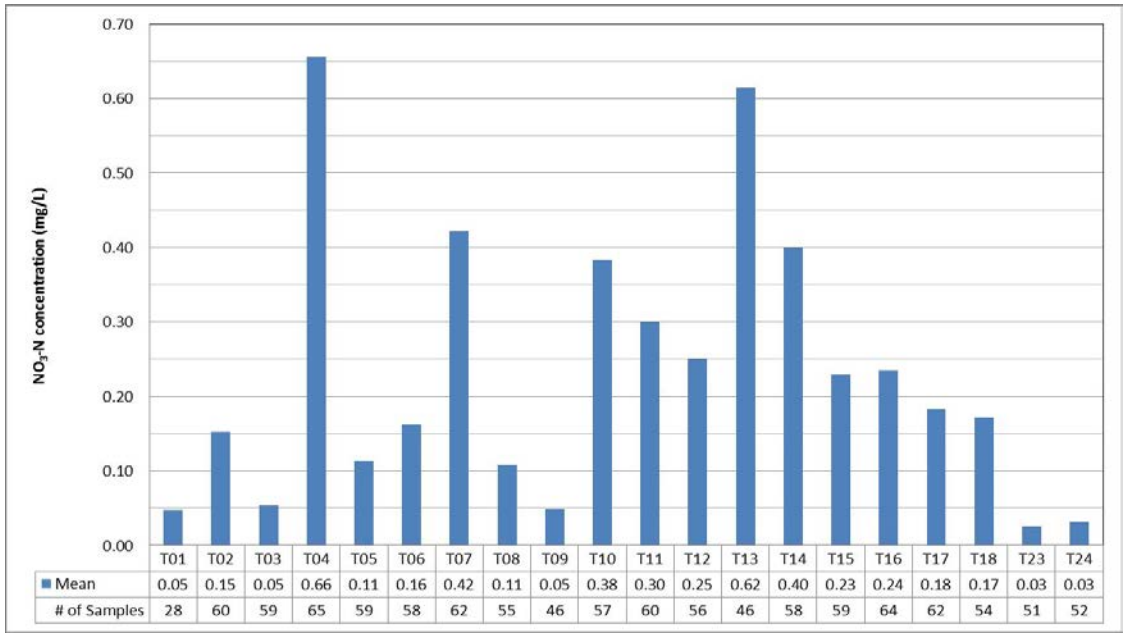
Table 3.1.1 Buffalo River corridor sites

River					
R01	Wilderness Boundary	R04	Hasty	R07	Highway 14
R02	Ponca	R05	Woolum	R08	Rush
R03	Pruitt	R06	Gilbert	R09	Mouth

Surface-Water Quality in the Buffalo National River (1985–2011)

Nitrate

Tributary Sites – base flow samples 1995-2011

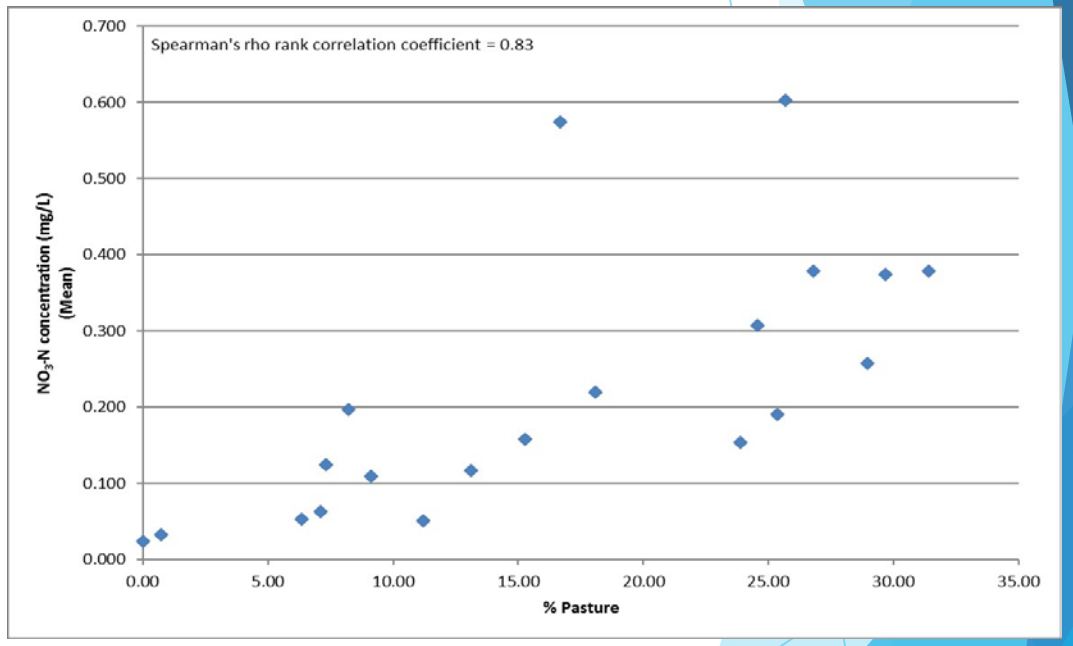


	T01	T02	T03	T04	T05	T06	T07	T08	T09	T10	T11	T12	T13	T14	T15	T16	T17	T18	T23	T24
Mean	0.05	0.15	0.05	0.66	0.11	0.16	0.42	0.11	0.05	0.38	0.30	0.25	0.62	0.40	0.23	0.24	0.18	0.17	0.03	0.03
# of Samples	28	60	59	65	59	58	62	55	46	57	60	56	46	58	59	64	62	54	51	52

Figure 4.3.5 Mean NO_3-N concentrations for Buffalo River tributary sites between 1995-2011 during base-flow

- T04 (Mill Creek) and T13 (Brush Creek) had the highest mean concentration of 0.66 and 0.62 mg/L, respectively

Tributary Sites – base and storm flow samples 1985-2011



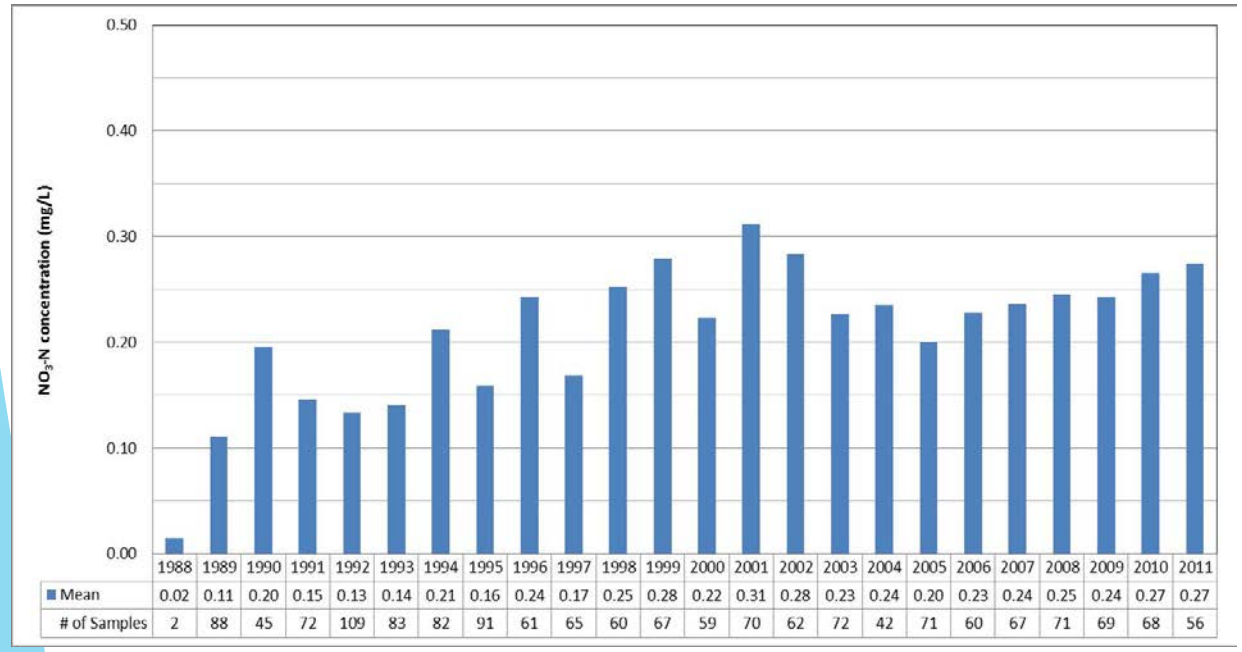
- Mean Nitrate Concentration verses Percent Pasture (using Spearman's rank correlation)
- A general upward trend was noted

Surface-Water Quality in the Buffalo National River (1985–2011)

Nitrate

Tributary Sites – base flow samples 1985-2011

- All sampling sites
- Mean concentration generally, increased over time
- 2001 highest value



	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Mean	0.02	0.11	0.20	0.15	0.13	0.14	0.21	0.16	0.24	0.17	0.25	0.28	0.22	0.31	0.28	0.23	0.24	0.20	0.23	0.24	0.25	0.24	0.27	0.27
# of Samples	2	88	45	72	109	83	82	91	61	65	60	67	59	70	62	72	42	71	60	67	71	69	68	56

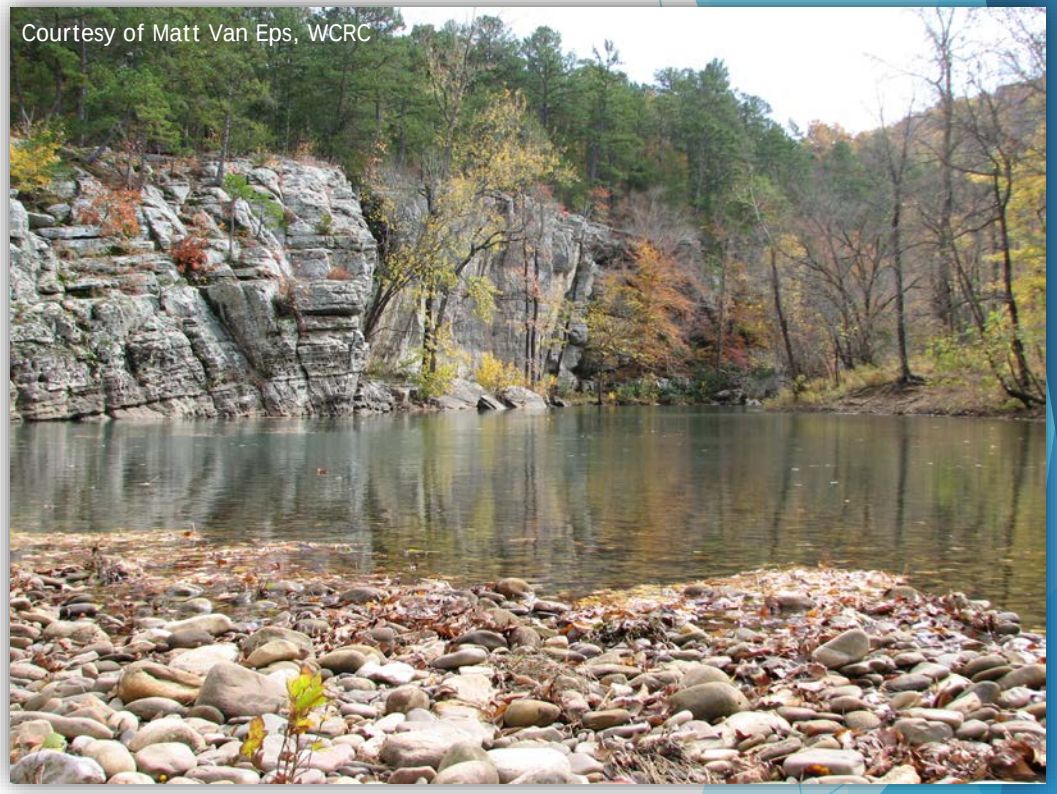


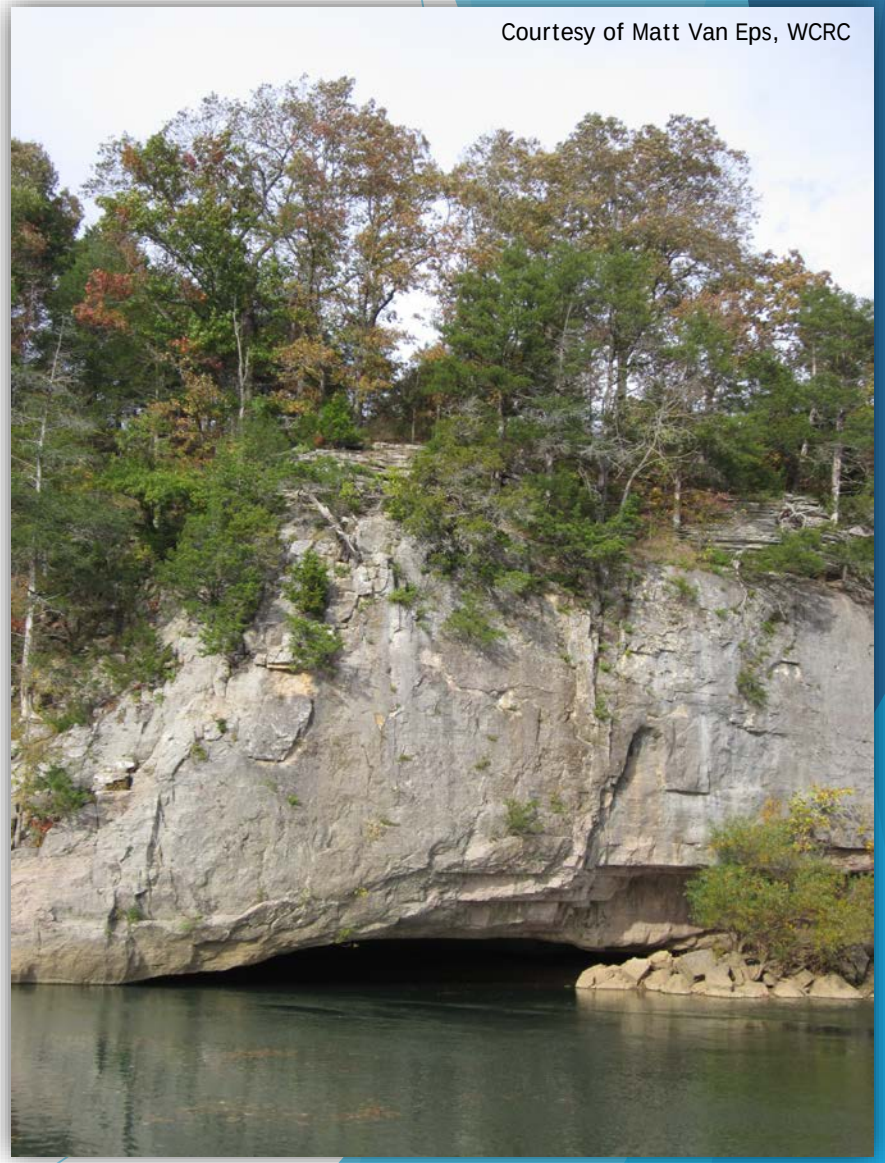
Table 3.1.2 Buffalo River tributary sites

Tributaries					
T01	Beech Creek	T08	Cave Creek	T15	Water Creek
T02	Ponca Creek	T09	Richland Creek	T16	Rush Creek
T03	Cecil Creek	T10	Calf Creek	T17	Clabber Creek
T04	Mill Creek	T11	Mill Creek-Middle	T18	Big Creek-Lower
T05	Little Buffalo River	T12	Bear Creek	T23	Middle Creek
T06	Big Creek	T13	Brush Creek	T24	Leatherwood Creek
T07	Davis Creek	T14	Tomahawk Creek		

Surface-Water Quality in the Buffalo National River (1985–2011)

Additional Results

- Fecal Coliform Bacteria at Base Flow
  - Both river corridor and tributary sites - the water quality standard appears to generally be met (but not sufficient frequency to make ultimate determination)
  - River corridor sites – Only 5 of 491 had concentrations that exceeded 200 colonies/100 ml (1995-2011)
    - Three occurred at R02 (Ponca)
  - Tributary sites – 33 of 1,141 had concentrations that exceeded 200 colonies/100 ml (1995-2011)
    - Most occurred at T17 (Water Creek) and T14 (Tomahawk Creek)
- General upward trend when fecal coliform and nitrate mean concentrations were compared to percent pasture land for both river corridor and tributary sites
- For most river corridor and tributary sites during base-flow conditions, the mean turbidity was less than 2 NTU (except T02 Ponca Creek)
- Water temperature exceeded standards for
  - 35 measurements at river corridor sites (most at R09 (Mouth))
  - 9 measurements at tributary sites
  - Most exceedances occurred in the Ozark Highlands during June - August


Courtesy of Matt Van Eps, WCRC

Surface-Water Quality in the Buffalo National River (1985–2011)

Recommendations

- Implementation of the following recommendations will require a coordinated effort among Buffalo River watershed stakeholders including
  - Landowners
  - Businesses
  - Agriculture-based operations and industry
  - Federal, state, and local government agencies
  - Non-governmental organizations (NGOs)
- Pressures from population growth and associated development, visitor use, agricultural activities, and climate change
  - suggest that stressors on the physical and biological components of the Buffalo National River will increase.
  - Dependence on crisis management cannot protect the Buffalo River or its watershed from this future threat.
  - It is important to develop and implement programs now that are proactive and consider economic development, environmental protection, land conservation, and restoration of impacted areas.
- A proactive approach can be initiated immediately by the formation of a Buffalo River Watershed (BRW) Planning Team to help implement voluntary, non-regulatory strategies.

Surface-Water Quality in the Buffalo National River (1985–2011)

Recommendations

- To address the consistently higher fecal coliform bacteria concentrations at RO2 (Ponca) seen since 1985 and reduce sediment and nutrient loadings:
  - Restore 25 to 50 feet of riparian corridor along the tributaries that run through the pastures in Boxley Valley using native plants.
  - Enhance the nutrient, bacterial, and sediment trapping abilities as well as the width of the riparian areas along the Buffalo River with native plants
  - Evaluate the river channel and small tributaries for stream instability and restore stream channel function and streambanks that are impacting riparian areas and pastures.
  - Reduce cattle access to tributaries that run across the pastures to the Buffalo River by implementing alternative shade and watering sources
  - Enhance winter cover crops.
  - Develop and implement rotational grazing practices.
  - Provide one-on-one assistance and financial support to landowners to implement these practices

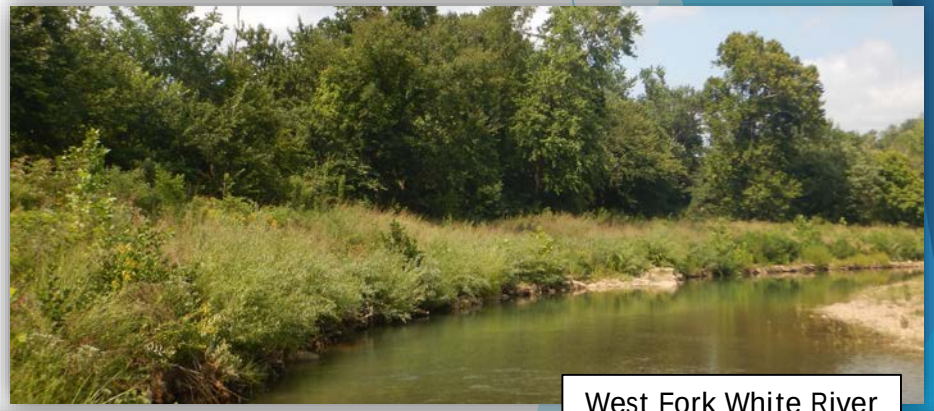
Boxley Valley

Surface-Water Quality in the Buffalo National River (1985–2011)

Recommendations

- To address the consistently higher fecal coliform bacteria concentrations at T14 (Tomahawk Creek) seen since 1985 and reduce sediment and nutrient loadings:
  - Restore 25 to 50 feet of riparian corridor along Tomahawk Creek and small tributaries where there are cattle operations using native plants
  - Evaluate Tomahawk Creek and tributaries for stream instability and restore stream channel function and streambanks that are impacting riparian areas and pastures.
  - Reduce cattle access to the Creek by implementing alternative shade and watering sources
  - Enhance winter cover crops.
  - Develop and implement rotational grazing practices.
  - Provide one-on-one assistance and financial support to landowners to implement these practices
  - Evaluate other potential sources of fecal coliform bacteria, such as septic tanks or community package plants, and implement measures to reduce their impacts if needed.

West Fork White River
Example of River Restoration
Before Restoration



West Fork White River
After Restoration

Surface-Water Quality in the Buffalo National River (1985–2011)

Recommendations

- Implement Voluntary, Best Management Practices to Address:
  - The numerous unpaved roads in the watershed
  - Other sources of fecal coliform, such as, outdated community waste water package plants and septic tanks
  - Confined animal operations to minimize their impact
- Measured water temperatures exceeded state water quality standards 44 times. Collection of updated stream geometry data and comparison to the historical data and data from other Boston Mountains and Ozark Highlands streams could provide insight about causation.
- The ecological and recreational significance of the Buffalo National River is important to the citizens of Arkansas and the nation:
  - Funding should be secured to support the existing and an expansion of the water quality monitoring
  - The National Park Service and other entities find opportunities to cooperate in conducting additional scientific studies.

Courtesy of Matt Van Eps, WCRC

Surface-Water Quality in the Buffalo National River (1985–2011)