Prepared in cooperation with the
OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY

Chloride in Ground Water and Surface Water in the Vicinity of Selected Surface-Water Sampling Sites of the Beneficial Use Monitoring Program of Oklahoma, 2003

Scientific Investigations Report 2004–5060

U.S. Department of the Interior
U.S. Geological Survey

Cover: Photographs of Cimarron River alluvium near Mocane, Oklahoma, (left) and Buffalo, Oklahoma, (right) taken by Michael P. Sughru, U.S. Geological Survey.

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Conversion Factors and Datum

Multiply	By	To obtain
Length		
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Flow rate		
gallon per minute (gal/min)	0.00223	cubic foot per second (ft^3/s)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$°F = (1.8 \times °C) + 32$

Vertical coordinate information is referenced to North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to North American Datum of 1983 (NAD 83).

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (μS/cm at 25°C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (μg/L).

Chloride in Ground Water and Surface Water in the Vicinity of Selected Surface-Water Sampling Sites of the Beneficial Use Monitoring Program of Oklahoma, 2003

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Abstract

The Oklahoma Water Resources Board Beneficial Use Monitoring Program reported exceedances of beneficial-use standards for chloride at 11 surface-water sampling sites from January to October 2002. The U.S. Geological Survey, in cooperation with the Oklahoma Department of Environmental Quality, conducted a study to determine the chloride concentrations in ground water in the vicinity of Beneficial Use Monitoring Program surface-water sampling sites not meeting beneficial use standards for chloride and compare chloride concentrations in ground water and surface water. The chloride-impaired Beneficial Use Monitoring Program surface-water sampling sites are located in the western and southern regions of Oklahoma. The ground-water sampling sites were placed in proximity to the 11 surface-water sampling sites designated impaired by chloride by the Oklahoma Water Resources Board. Two surface-water sampling sites were located on the Beaver River (headwaters of the North Canadian River), three sites on the Cimarron River, one site on Sandy Creek, one site on North Fork Red River, and four sites on the Red River.

Six ground-water samples were collected, when possible, from two test holes located upstream from each of the 11 Beneficial Use Monitoring Program surface-water sampling sites. One test hole was placed on the left bank and right bank, when possible, of each Beneficial Use Monitoring Program surface-water sampling site. All test holes were located on alluvial deposits adjacent to the Beneficial Use Monitoring Program surface-water sampling sites within 0.5 mile of the stream. Top, middle, and bottom ground-water samples were collected from the alluvium at each test hole, when possible. Water properties of specific conductance, pH, water temperature, and dissolved oxygen were recorded in the field before sampling for chloride.

The ground-water median chloride concentrations at 8 of the 11 Beneficial Use Monitoring Program sites were less than the surface-water median chloride concentrations. The Turpin and Beaver sites had similar ground-water and surface-water median chloride concentrations. The Buffalo site was the only site that had a large difference between the ground-water and surface-water chloride concentrations. The ground-water median chloride concentration was approximately 14,500 mg/L greater than the surface-water median chloride concentration at the Buffalo site.

Introduction

The Beneficial Use Monitoring Program (BUMP) of Oklahoma, under the direction of the Oklahoma Water Resources Board (OWRB), consists of sampling 100 surface-water sites 10 times annually (Oklahoma Water Resources Board, 2002). The program monitors whether concentrations in streams and lakes meet or exceed beneficial-use standards established by the State for section 303d of the Clean Water Act. The OWRB reported exceedances of beneficial-use standards for chloride at 11 surface-water sampling sites from January to October 2002. The OWRB uses the agriculture beneficial-use standard for chloride as the criteria for designating a stream impaired by chloride (Oklahoma Water Resources Board, 2002). The OWRB standard for chloride is based on the yearly mean of chloride concentrations in samples from the previous years. The U.S. Geological Survey (USGS), in cooperation with the Oklahoma Department of Environmental Quality (ODEQ), conducted a study to determine the chloride concentrations in ground water in the vicinity of BUMP surface-water sampling sites not meeting beneficial-use standards for chloride and compare chloride concentrations in ground water and surface water. A comparison of chloride concentrations in ground water and surface water is needed to determine the possible role that sources of chloride in ground water may have in affecting large chloride concentrations at the BUMP surface-water sampling sites.

Purpose and Scope

The purpose of this report is to (1) present chloride concentrations in local ground water adjacent to 11 chloride-impaired BUMP surface-water sampling sites, and (2) compare chloride concentrations of the ground-water sites to chloride concentrations of the BUMP surface-water sampling sites. The relative volume of ground water discharging to the stream compared to the volume of streamflow determines whether the chloride concentrations in ground water could increase or decrease chloride concentrations in the stream. The effects of these relative volumes are not addressed in this report. Ground-water samples were collected from two test holes located upstream from each BUMP surface-water sampling site from August to December 2003. The ground-water samples were collected by USGS personnel and analyzed by ODEQ laboratory. The sur-

face-water chloride data were collected from December 1998 to October 2002. The surface-water chloride data used in this report were collected by OWRB personnel and analyzed by ODEQ laboratory.

Acknowledgments

This study would not have been possible without the cooperation from landowners who provided access to their land; their help is much appreciated. The authors thank USGS staff, Mark Becker and Jerrod Smith.

Description of Sampling Sites

The chloride-impaired BUMP surface-water sampling sites were located in the western and southern regions of Oklahoma. The ground-water sampling sites were placed in proximity to the 11 surface-water sampling sites designated impaired by chloride by the OWRB (Oklahoma Water Resources Board, 2002). Two surface-water sampling sites were located on the Beaver River (headwaters of the North Canadian River), three sites on the Cimarron River, one site on Sandy Creek, one site on North Fork Red River, and four sites on the Red River (fig. 1).

Beaver River

The ground-water and surface-water sampling sites on Beaver River, Turpin (AT233900) were located near U.S. Highway 83 (fig. 2). The Beaver River channel and floodplain consists of Quaternary-age alluvium composed of sand, gravel, silt, and clay (Morton and Goemaat, 1973). The alluvium is unconfined and uncemented and yields about 400 to 2,000 gallons per minute (gpm) to wells (Morton and Goemaat, 1973). The alluvium on the left bank (northwest) is in contact with Tertiary-age Ogallala Formation[1]. The Ogallala consists of interbedded sand, siltstone, clay, gravel lenses, and thin limestone (Morton and Goemaat, 1973). It is partly consolidated by calcium carbonate, and caliche is found near the surface (Marine and Schoff, 1962). The Ogallala is the principal aquifer in Beaver County and yields 200 to 1,760 gpm to wells (Morton and Goemaat, 1973). It is hydraulically connected to the alluvium and water passes freely from one to the other (Marine and Schoff, 1962). Water from the Ogallala is moderately hard (Marine and Schoff, 1962). The alluvium on the right bank (southeast) is in contact with Quaternary-age dune sand and Permian-age reddish sandstone, siltstone, and shale with lesser amounts of limestone, dolomite, gypsum, and salt (Morton and Goemaat, 1973). The dune sand is composed of windblown deposits of fine, subrounded grains of sand (Morton and Goemaat, 1973). The dune sand is hydraulically connected to the underlying units by absorbing and transmitting precipitation (Marine and Schoff, 1962). The lower part of the Permian-age units acts as a confining layer that creates a saturated zone where water flows laterally to discharge in springs (Marine and Schoff, 1962). Wells in the Permian-age units yield small amounts of water that are very hard and contain large concentrations of sulfate and chloride (Marine and Schoff, 1962).

The ground-water and surface-water sampling sites on Beaver River, Beaver (AT234000) were located near U.S. Highway 270 (fig. 3). The USGS maintains a real-time surface-water station near the Beaver site (07234000). Mean annual discharge near the Beaver site was 0.075 cubic feet per second (ft^3/s) for the 2002 water year (Blazs and others, 2003a). The Beaver River channel and floodplain characteristics at the Beaver site are similar to the Turpin site. The alluvium on the left bank (north) is in contact with Permian-age units and Quaternary-age dune sand. The alluvium on the right bank (south) is in contact with the Tertiary-age Ogallala Formation.

Cimarron River

The ground-water and surface-water sampling sites on Cimarron River, Mocane (AT157000) were located near north 1510 Road (fig. 4). The USGS maintains a real-time surface-water station located approximately 11 miles upstream from the Mocane site (07156900). Mean annual discharge at station 07156900 near the Mocane site was 31.39 ft^3/s for the 2002 water year (Blazs and others, 2003a). More surface water flows through the Mocane site than at the Beaver site. The Cimarron River channel width is larger than the Beaver River channel width. The Cimarron River channel and floodplain consists of Quaternary-age alluvium composed of sand, gravel, silt, and clay (Morton and Goemaat, 1973). The alluvium is unconfined and uncemented and yields about 400 to 2,000 gpm to wells (Morton and Goemaat, 1973). The alluvium on the left bank (north) and right bank (south) is bordered by Tertiary-age Ogallala Formation. Some Quaternary-age dune sand also occurs near the alluvium. The dune sand is composed of windblown deposits of fine, subrounded grains of sand (Morton and Goemaat, 1973).

The ground-water and surface-water sampling sites on Cimarron River, Buffalo (AT157950) were located near U.S. Highway 64 (fig. 5). The USGS maintains a real-time surface water station near the Buffalo site (07157950). Mean annual discharge at station 07157950 near the Buffalo site was 18.78 ft^3/s for the 2002 water year (Blazs and others, 2003a). The alluvium on the left bank (east) is in contact with Quaternary-age terrace deposits. The terrace deposits consist of gravel, sand, silt, clay, and volcanic ash, which also include sand dunes that are common in the area (Morton, 1980). The alluvium on the right bank (west) is in contact with Permian-age Flowerpot

[1]Geologic names and stratigraphic ages in this report are accepted by the Oklahoma Geological Survey and are not necessarily the same as those used by the U.S. Geological Survey.

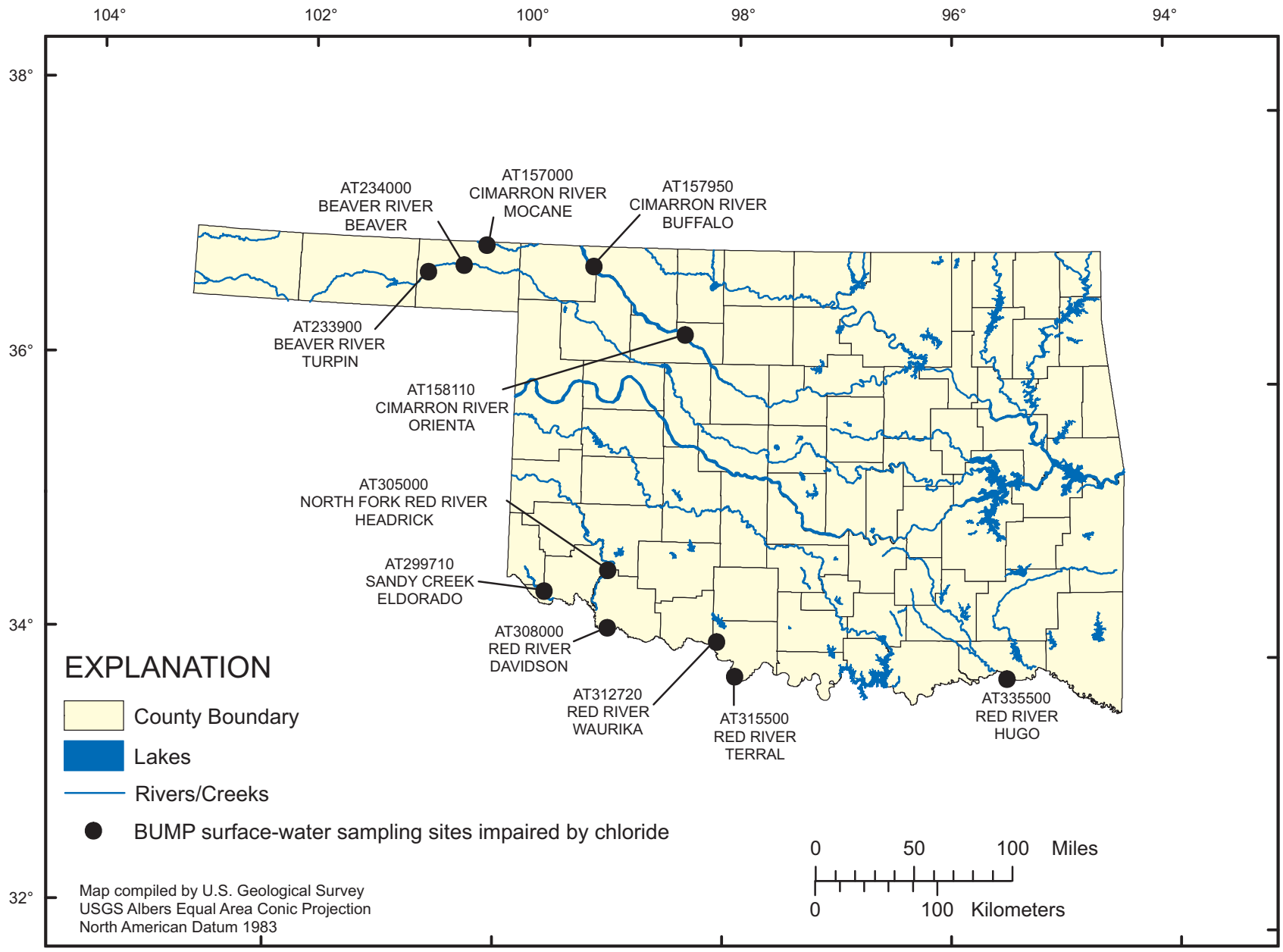

Figure 1. Location of Beneficial Use Monitoring Program surface-water sampling sites impaired by chloride (Oklahoma Water Resources Board, 2002).

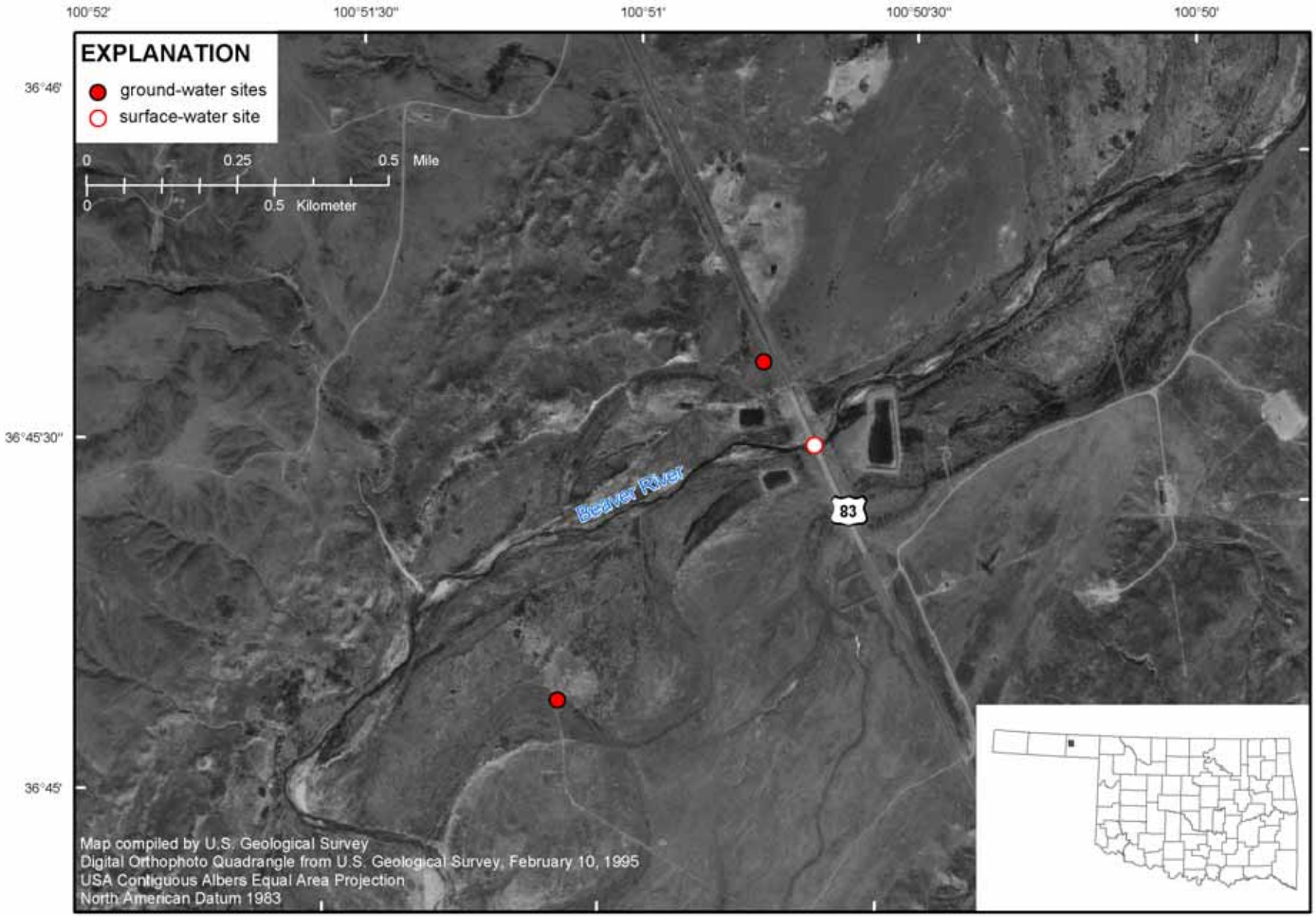

Figure 2. Location of ground-water and surface-water Beneficial Use Monitoring Program sampling sites at Beaver River, Turpin, Oklahoma.

Figure 3. Location of ground-water and surface-water Beneficial Use Monitoring Program sampling sites at Beaver River, Beaver, Oklahoma.

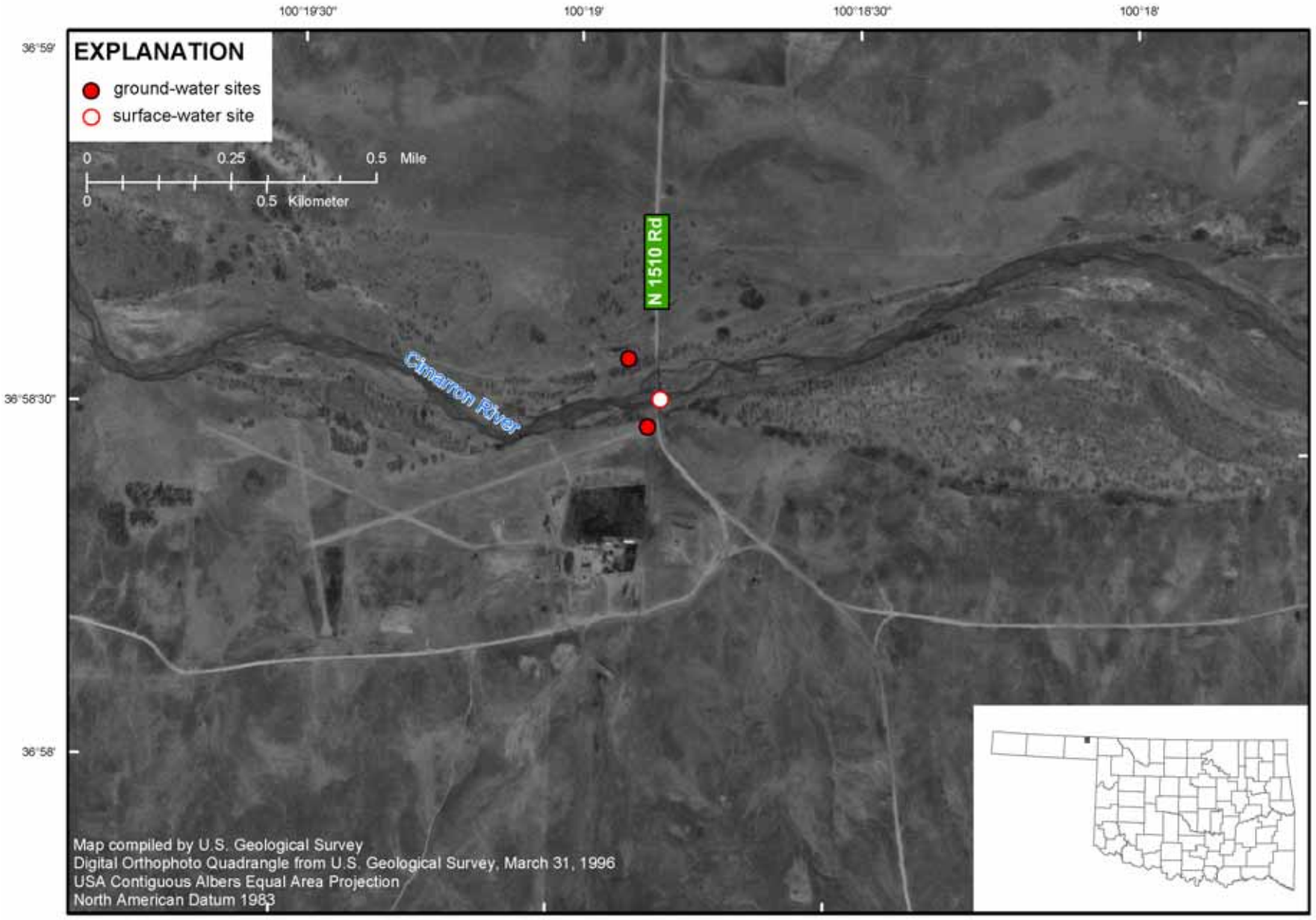

Figure 4. Location of ground-water and surface-water Beneficial Use Monitoring Program sampling sites at Cimarron River, Mocane, Oklahoma.

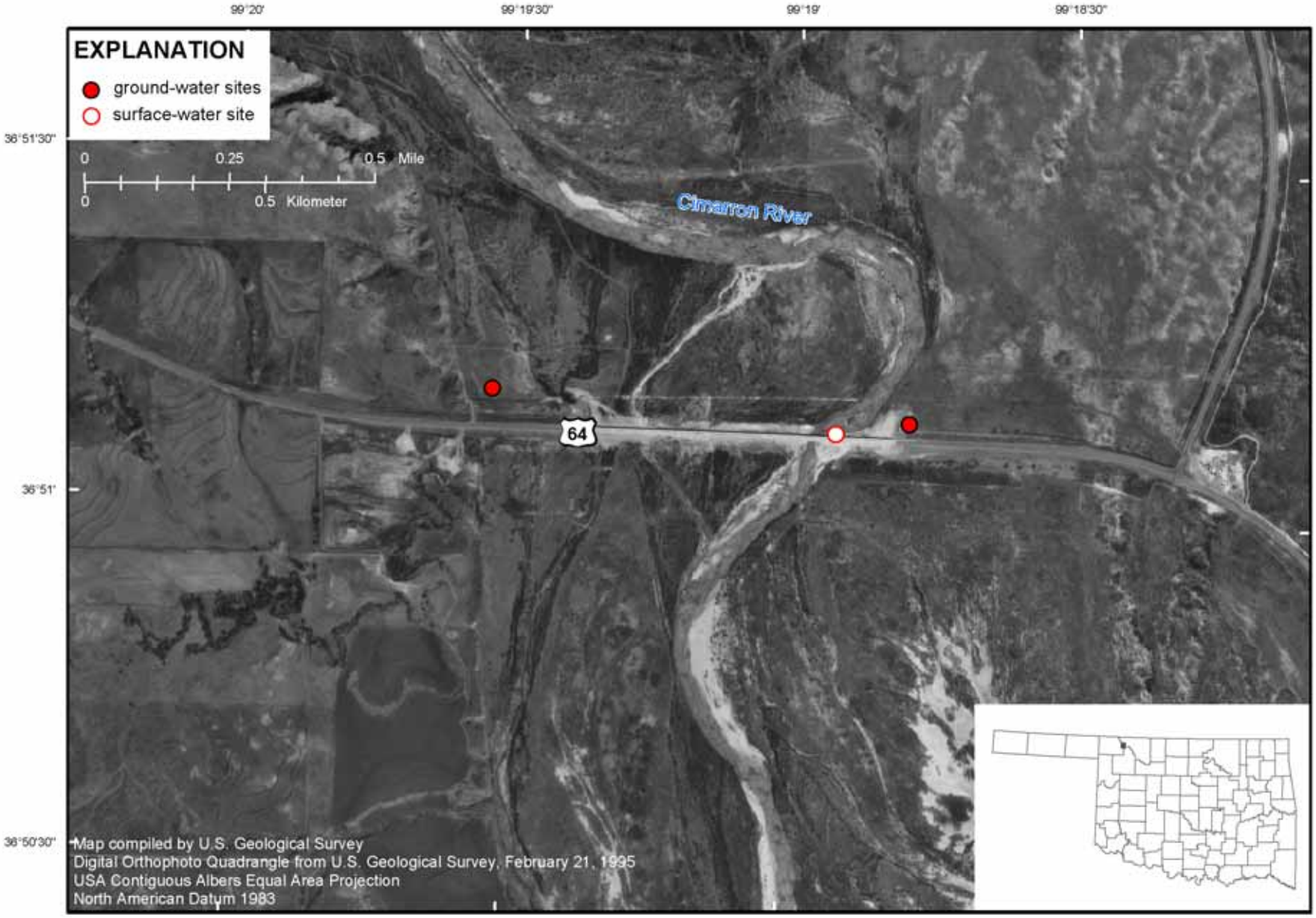

Figure 5. Location of ground-water and surface-water Beneficial Use Monitoring Program sampling sites at Cimarron River, Buffalo, Oklahoma.

Shale. The Flowerpot Shale consists of red-brown silty shale with some thin gypsum and dolomite beds, and rock salt in the middle and upper parts (Morton, 1980). Springs are common near the contact between the Permian-age units and the overlying Quaternary-age units (Myers, 1959). The Permian-age units yield up to 50 gpm to wells (Myers, 1959). Water from the Permian units contains large concentrations of dissolved gypsum (Myers, 1959).

The ground-water and surface-water sampling sites on Cimarron River, Orienta (AT158110) were located near U.S. Highway 412 (fig. 6). The USGS maintains a real-time surface water station located approximately 30 miles upstream from the Orienta site (07158000). Mean annual discharge at station 07158000 near the Orienta site was 46.01 ft^3/s for the 2002 water year (Blazs and others, 2003a). The Cimarron River channel and floodplain characteristics at the Orienta site are similar to the Buffalo site. The alluvium on the left bank (northeast) is in contact with Quaternary-age terrace deposits and the alluvium on the right bank (southwest) is in contact with Permian-age Cedar Hills Sandstone. The Cedar Hills sandstone consists of orange-brown to greenish-gray fine-grained sandstone and siltstone, with some red-brown shale (Morton, 1980). Wells in the Cedar Hills yield 150 to 300 gpm (Morton, 1980).

Sandy Creek

The ground-water and surface-water sampling sites on Sandy Creek, Eldorado (AT299710) were located near State Highway 6 (fig. 7). The Sandy Creek channel and floodplain consists of Quaternary-age alluvium composed of sand, clay, and gravel (Havens, 1977). The extent of the Sandy Creek alluvium at the Eldorado site is limited. Wells in the Quaternary-age alluvium yield from 300 to 2,500 gpm (Havens, 1977). The alluvium on the left bank (east) and right bank (west) is in contact with the Permian-age Van Vacter Member and Elm Fork Member. The Van Vacter and Elm Fork Members consist of dolomite-gypsum-shale sequences (Havens, 1977). The Van Vacter and Elm Fork Members contain calcium sulfate and sodium chloride water types (Havens, 1977).

North Fork Red River

The ground-water and surface-water sampling sites on North Fork Red River, Headrick (AT305000) were located near U.S. Highway 62 (fig. 8). The USGS maintains a real-time surface water station near the Headrick site (07305000) located on the downstream side of bridge on U.S. Highway 62. Mean annual discharge at station 07305000 near the Headrick site was 68.25 ft^3/s for the 2002 water year (Blazs and others, 2003b). The North Fork Red River channel and floodplain consists of Quaternary-age alluvium composed of sand, clay, and gravel (Havens, 1977). The alluvium on the left bank (east) is in contact with Quaternary-age terrace deposits. The alluvium on the right bank (west) is in contact with Cambrian-age Wichita Granite Group and Quaternary-age terrace deposits. The terrace deposits consist of sand, clay, and gravel that are hydraulically connected to the alluvium (Havens, 1977). The Cambrian-age Wichita Granite Group is composed of various textures of granite (Havens, 1977).

Red River

The ground-water and surface-water sampling sites on the Red River, Davidson (AT308000) were located near U.S. Highway 183 (fig. 9). The Pease River is the tributary upstream from the Red River near the Davidson site. The Red River channel and floodplain consists of Quaternary-age alluvium composed of sand, clay, and gravel (Havens, 1977). The Red River alluvium is extensive at the Davidson site. The alluvium is unconfined and uncemented and yields up to 2,500 gpm to wells (Havens, 1977). The alluvium on the left bank (north) and right bank (south) is bordered by Quaternary dune sand that is composed of windblown deposits of fine, subrounded grains of sand (Havens, 1977).

The ground-water and surface-water sampling sites on the Red River, Waurika (AT312720) were located near State Highway 79 (fig. 10). The USGS maintains a real-time surface water station located approximately 35 miles upstream from the Waurika site (07308500). Mean annual discharge at station 07308500 near the Waurika site was 371.3 ft^3/s for the 2002 water year (Blazs and others, 2003b). The alluvium on the left bank (east) is in contact with Pennsylvanian-age Oscar Group. The Oscar Group consists of shale and sandstone (Havens, 1977). Wells in the Oscar yield from 0 to 25 gpm (Havens, 1977). The alluvium on the right bank (west) is in contact with Quaternary-age terrace deposits. The terrace deposits consist of sand, clay, and gravel (Havens, 1977).

The ground-water and surface-water sampling sites on the Red River, Terral (AT315500) were located near U.S. Highway 81 (fig. 11). The USGS maintains a real-time surface water station near the Terral site (07315500) located on downstream side of bridge on U.S. Highway 81. Mean annual discharge at station 07315500 near the Terral site was 848.0 ft^3/s for the 2002 water year (Blazs and others, 2003b). The alluvium on the left bank (north) is in contact with the Pennsylvanian-age Oscar Group. The alluvium on the right bank (south) is in contact with Quaternary-age terrace deposits.

The ground-water and surface-water sampling sites on the Red River, Hugo (AT335500) were located near U.S. Highway 271 (fig. 12). The USGS maintains a real-time surface water station near Hugo (07335500) located on downstream side of bridge on U.S. Highway 271. Mean annual discharge at station 07335500 near the Hugo site was 8,725 ft^3/s for the 2002 water year (Blazs and others, 2003b). The alluvium on the left bank (north) and right bank (south) is bordered by Quaternary-age terrace deposits. The terrace deposits consists of gravel, sand, silt, clay and volcanic ash and yields 100 to 500 gpm to wells (Marcher and Bergman, 1983).

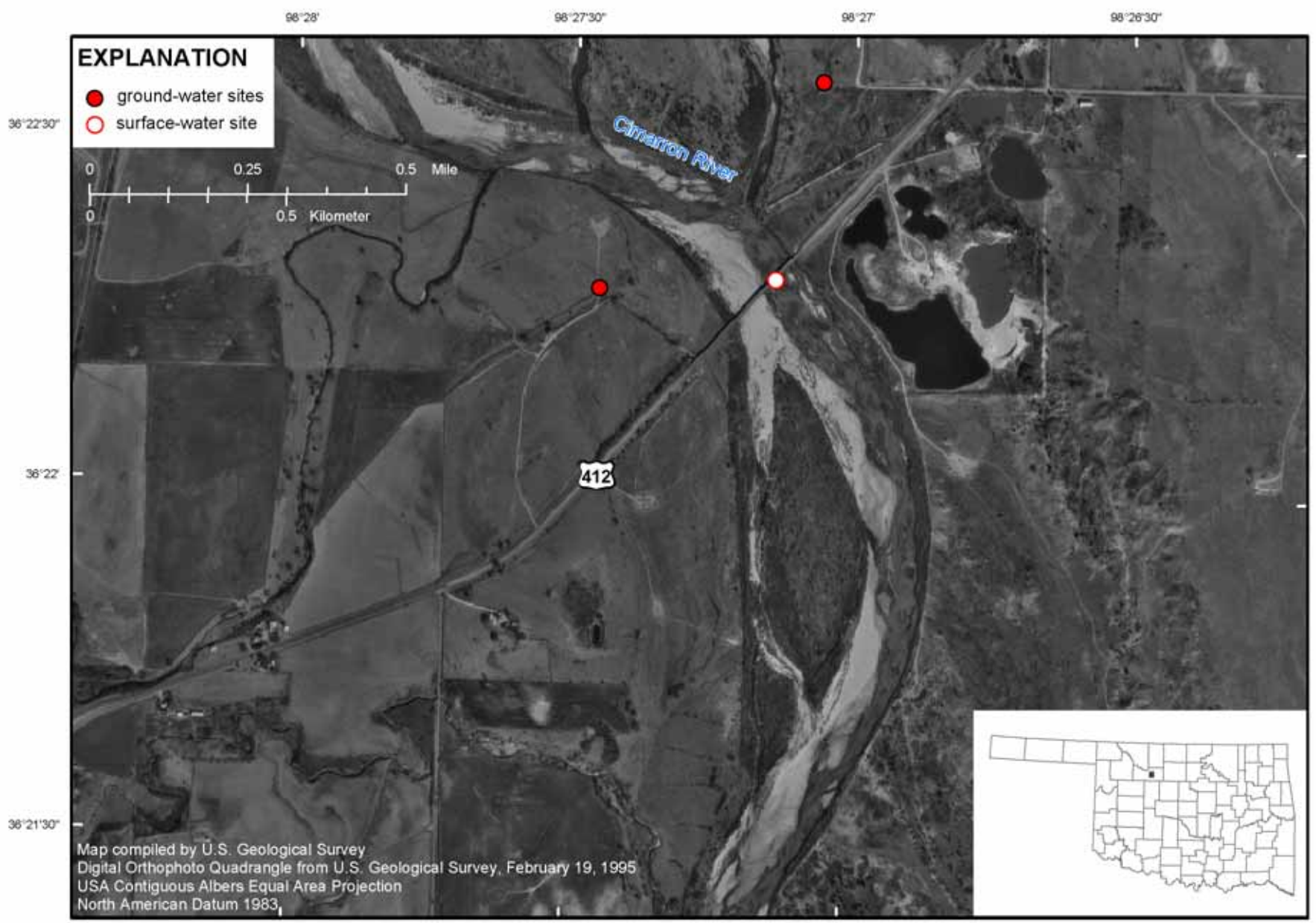

Figure 6. Location of ground-water and surface-water Beneficial Use Monitoring Program sampling sites at Cimarron River, Orienta, Oklahoma.

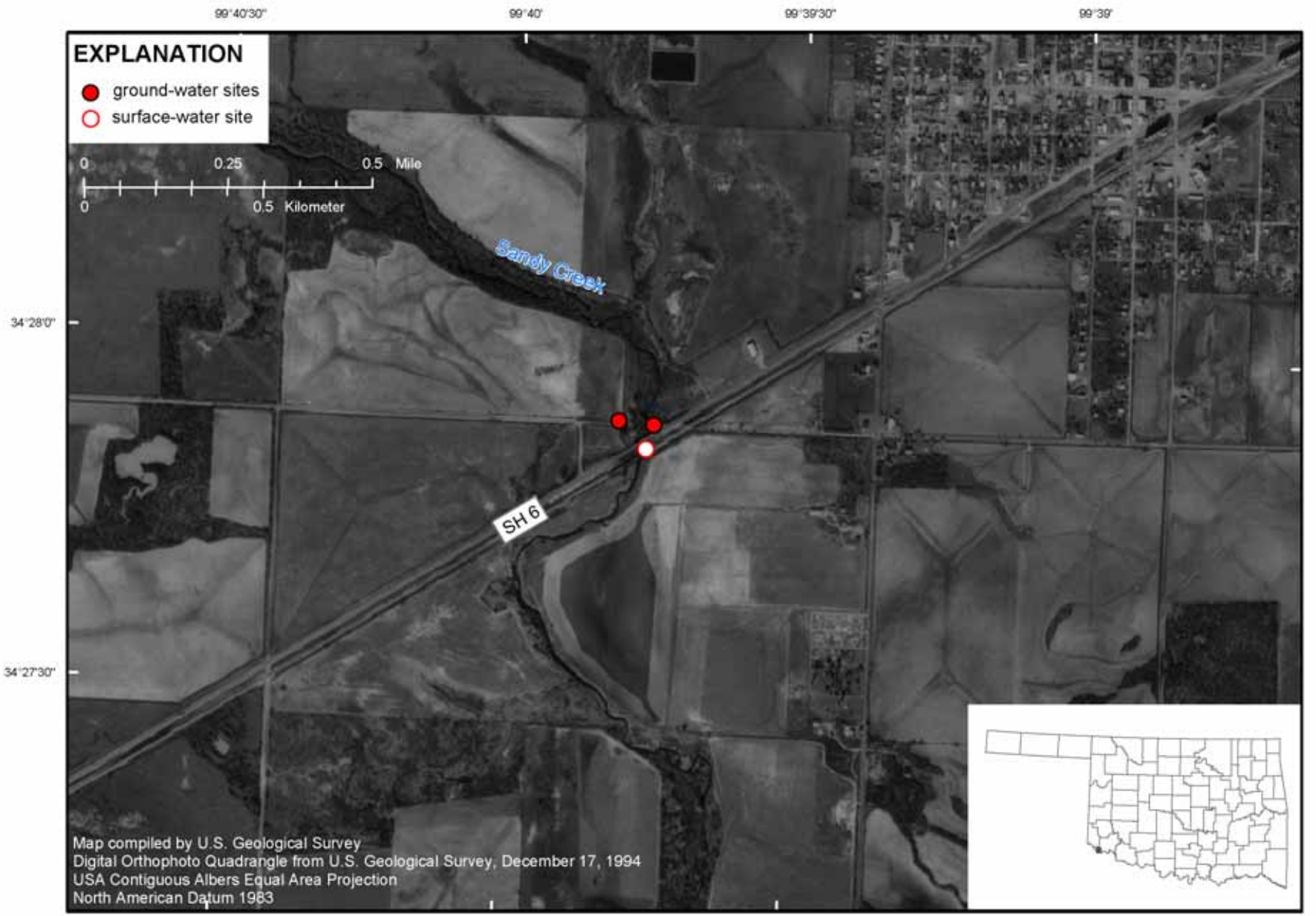

Figure 7. Location of ground-water and surface-water Beneficial Use Monitoring Program sampling sites at Sandy Creek, Eldorado, Oklahoma.

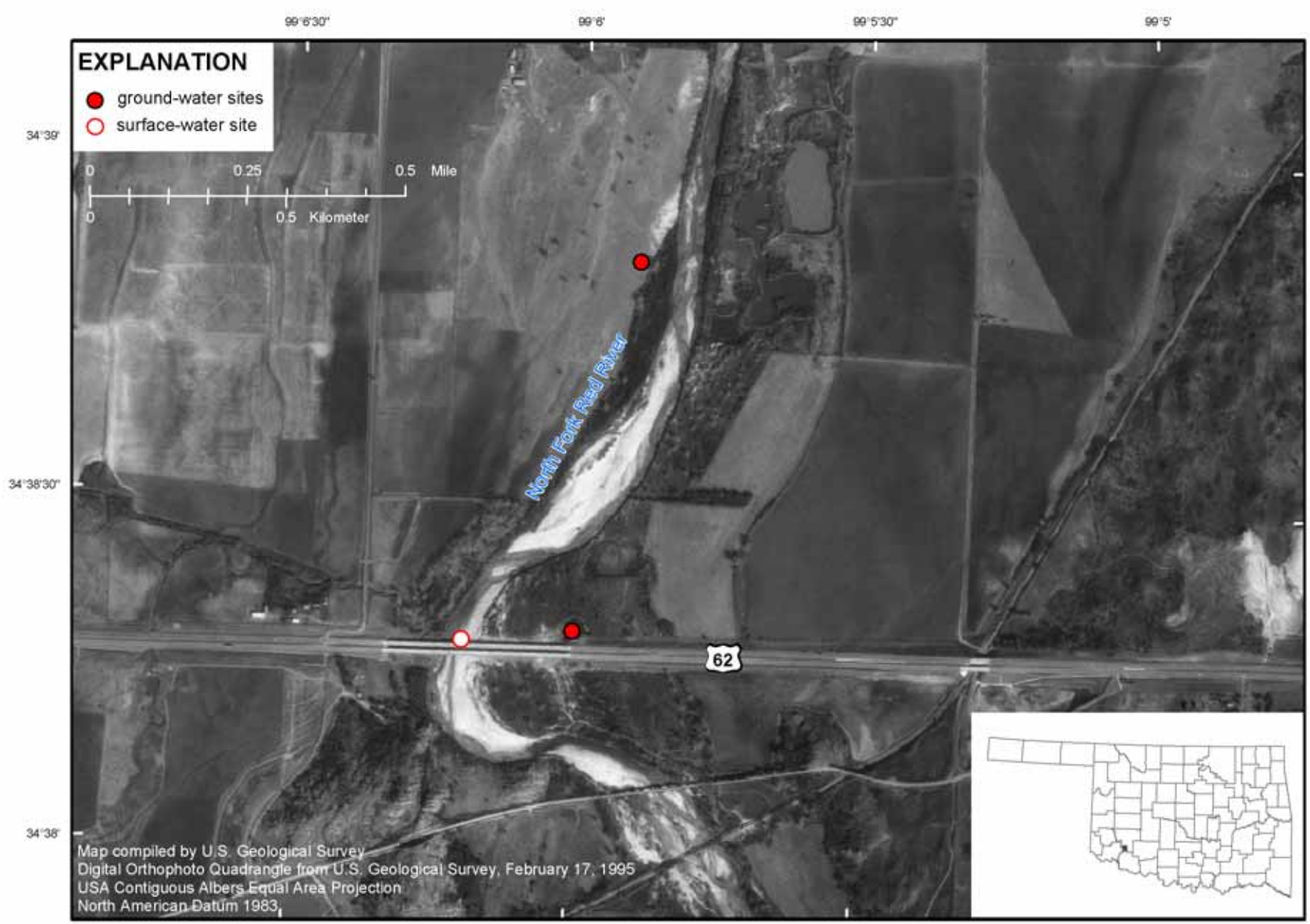

Figure 8. Location of ground-water and surface-water Beneficial Use Monitoring Program sampling sites at North Fork Red River, Headrick, Oklahoma.

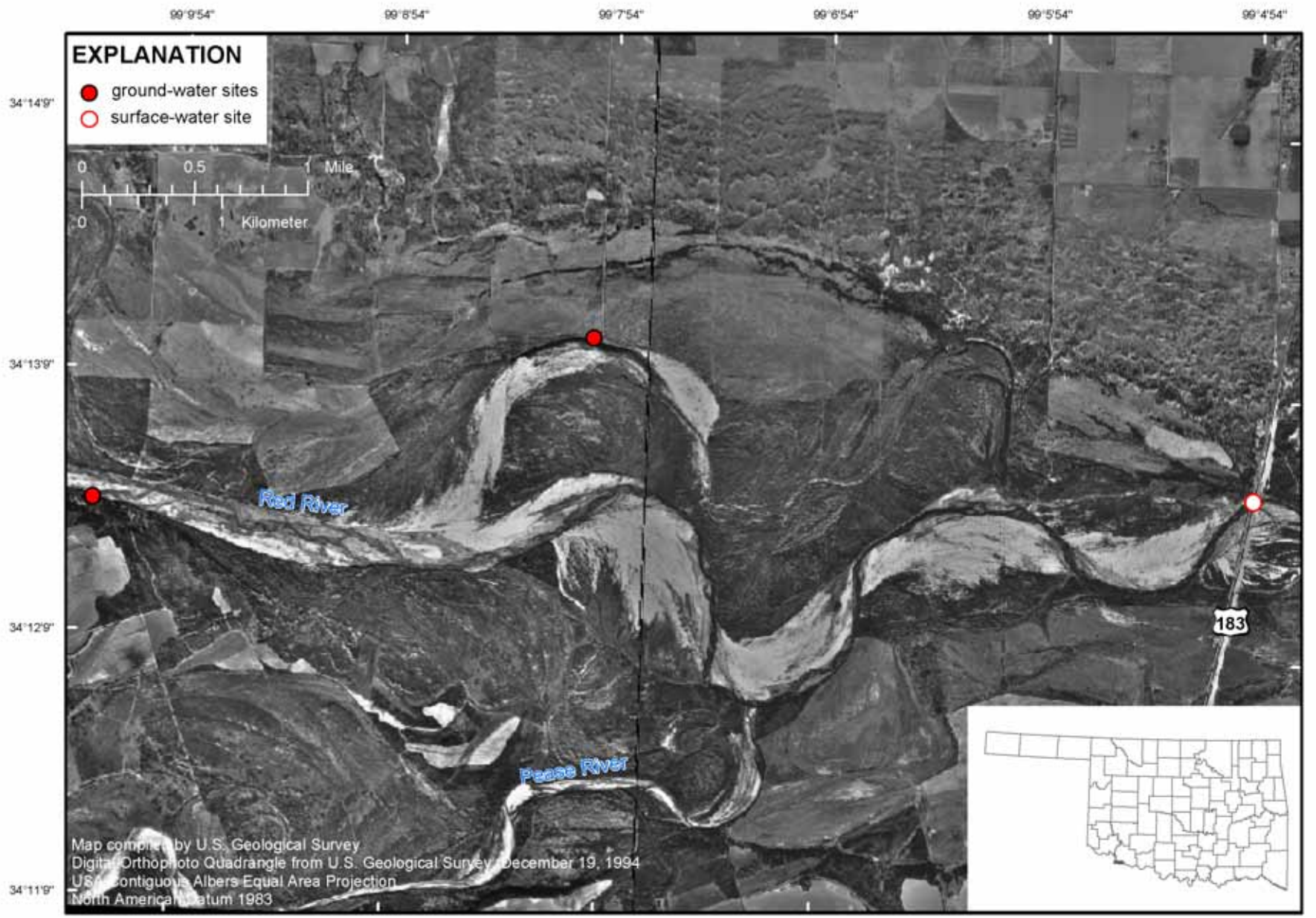

Figure 9. Location of ground-water and surface-water Beneficial Use Monitoring Program sampling sites at Red River, Davidson, Oklahoma.

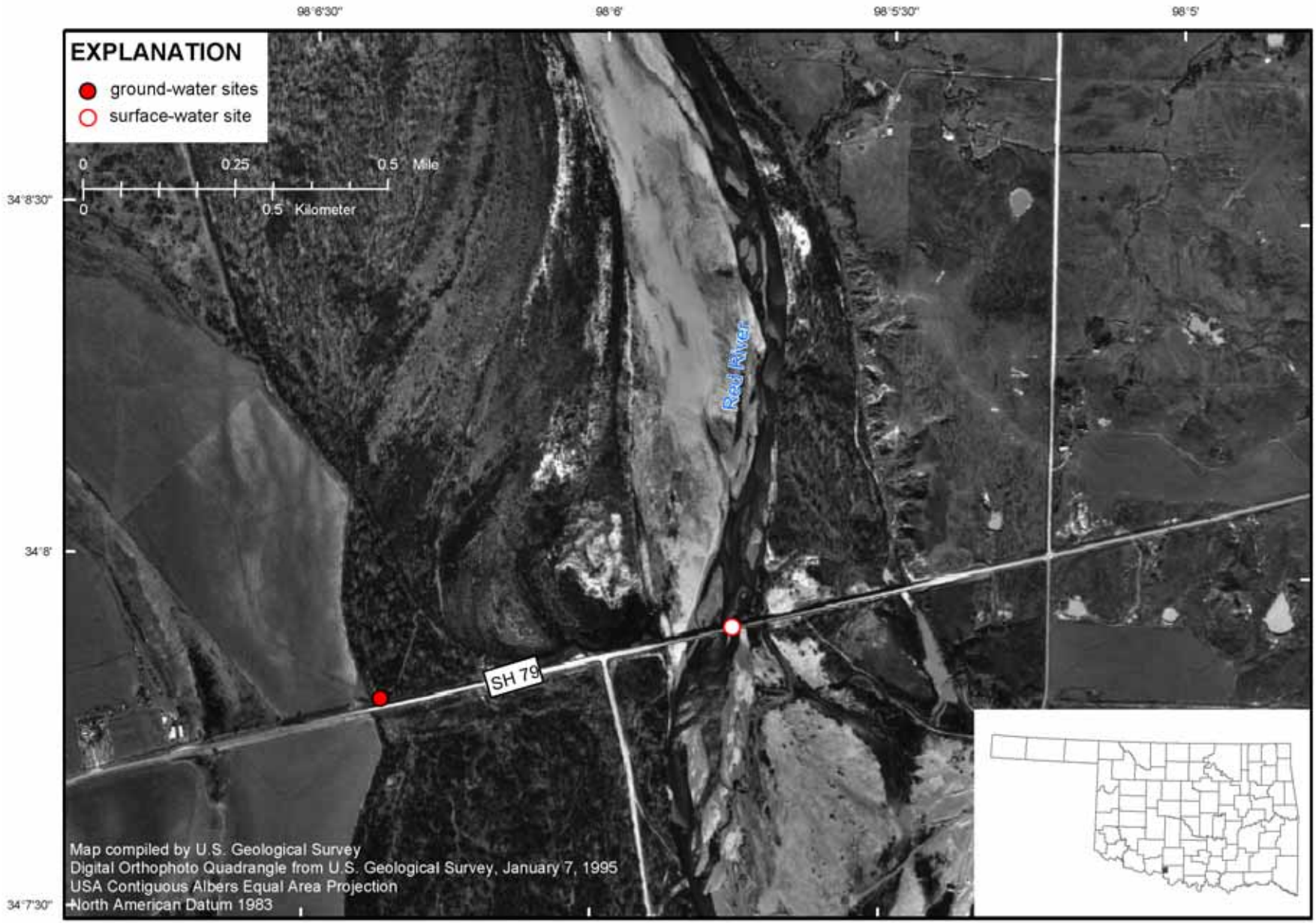

Figure 10. Location of ground-water and surface-water Beneficial Use Monitoring Program sampling sites at Red River, Waurika, Oklahoma.

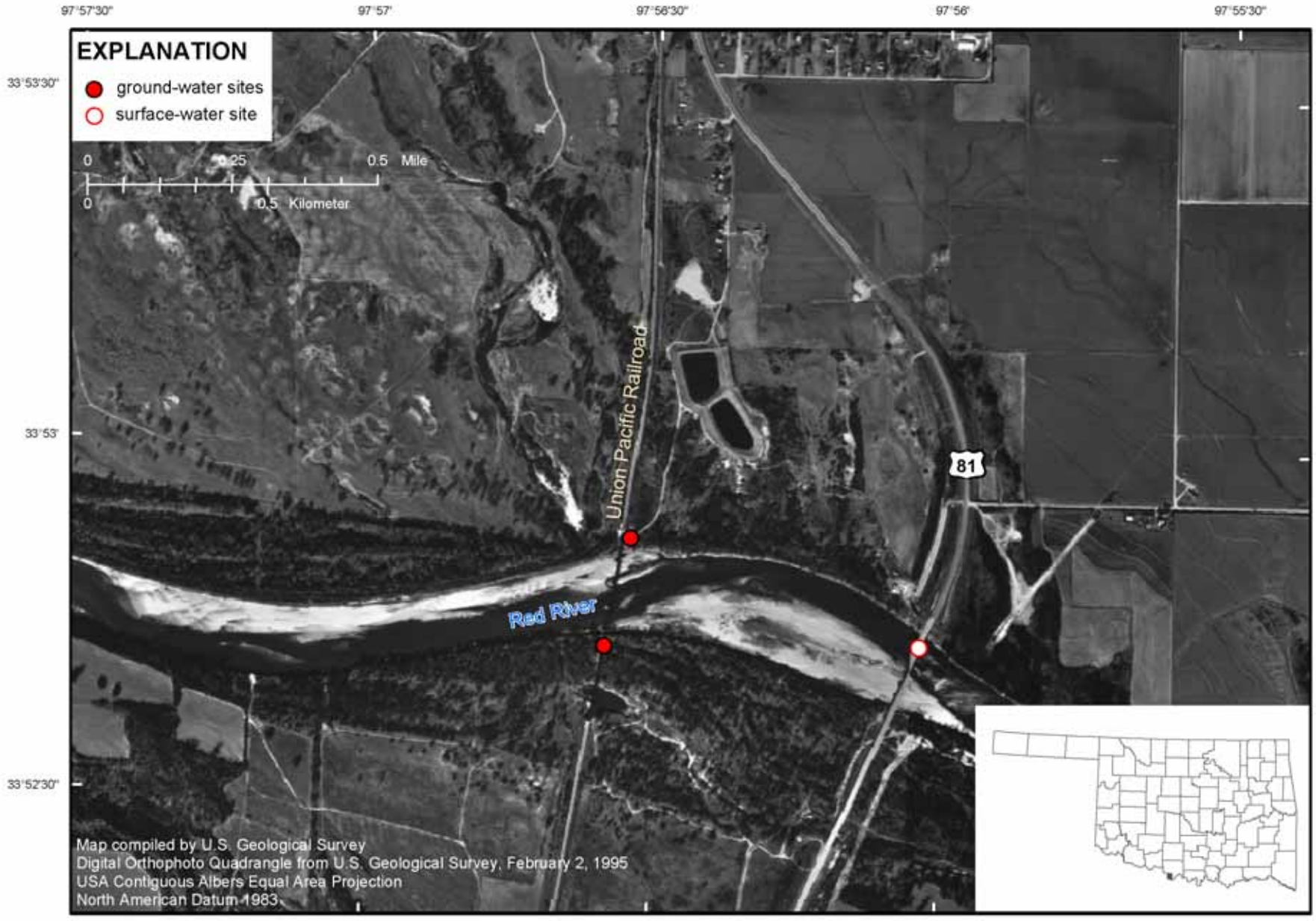

Figure 11. Location of ground-water and surface-water Beneficial Use Monitoring Program sampling sites at Red River, Terral, Oklahoma.

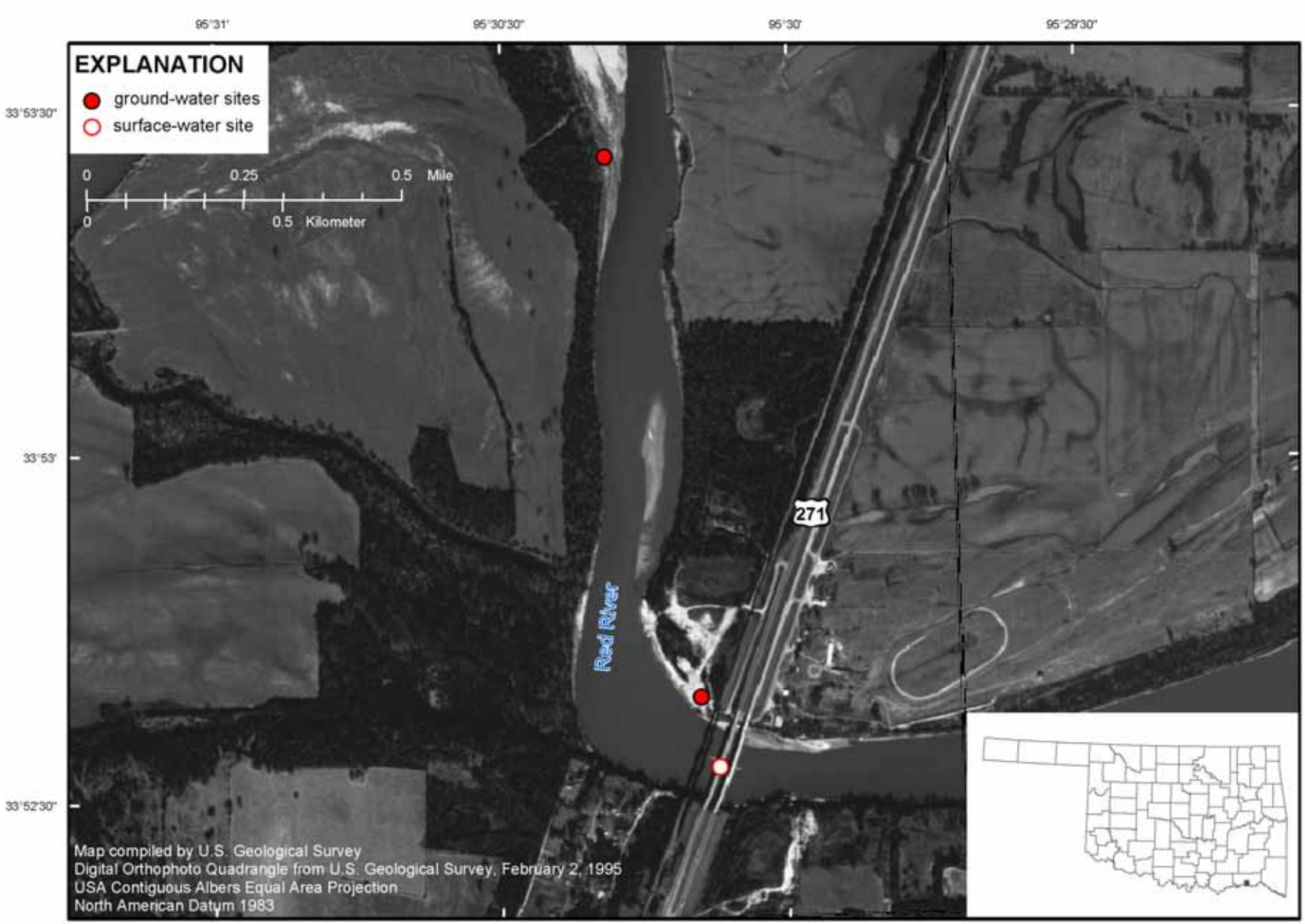

Figure 12. Location of ground-water and surface-water Beneficial Use Monitoring Program sampling sites at Red River, Hugo, Oklahoma.

Possible Sources of Chloride

Possible anthropogenic sources of chloride are septic waste, wastewater treatment plant effluent, industrial waste, animal waste, fertilizer, road salting for de-icing of roadways, and produced water from oilfield operations. Possible natural sources of chloride are precipitation and geologic units containing chloride. These chloride sources could possibly be located upstream at great distances or nearby the surface-water sampling sites. Each of these sources would contribute varying amounts of chloride to the sampled streams depending on the output chloride concentrations. The determination of sources of chloride near the BUMP sites was not within the scope of the study.

Methods and Sampling Procedures

Six ground-water samples were collected, when possible, from two test holes located upstream from each of the 11 Beneficial Use Monitoring Program surface-water sampling sites. One test hole was placed on the left bank and right bank, when possible, of each BUMP surface-water sampling site. Left bank and right bank designations were assigned by looking downstream. Top, middle, and bottom ground-water samples were collected from the alluvium at each test hole, when possible. Only five ground-water samples were obtained at Orienta, due to limited alluvial thickness on the right bank. Only four ground-water samples were obtained at Eldorado due to the limited alluvial thickness on the left and right bank. Only four ground-water samples were obtained at Davidson due to the limited alluvial thickness on the right bank. Only three ground-water samples were obtained from the right bank at the Waurika site, because the left bank was inaccessible.

All test holes were located on alluvial deposits adjacent to the BUMP surface-water sampling sites within 0.5 mile of the stream. Test hole locations depended on landowner permission and road accessibility. Site locations were determined using a global positioning system with a horizontal accuracy of about 10 feet.

A truck-mounted Geoprobe was used to make the temporary test holes. A Geoprobe is a hydraulically powered sampling and logging tool that uses both static force and percussion to advance into the ground. No materials were permanently installed in the ground. A 1-foot long stainless steel screen of 1.25-inch diameter was driven into the ground to collect water samples. Top, middle, and bottom ground-water samples were collected from the alluvium at each test hole, when possible. First, the screen was driven down to the top of the water table to collect a top sample. Then, the screen was driven until the penetration slowed markedly at the assumed bedrock or clay boundary at the base of the alluvium to collect a bottom sample. Finally, the screen was pulled up to the midpoint between the top and bottom to collect a middle sample. Polyethylene tubing and a peristaltic pump were used to pump water samples to the surface for collection. Each sampling level (top, middle, bottom) in the test hole was purged for approximately 15 minutes and water properties of specific conductance, pH, water temperature, and dissolved oxygen were measured. Samples were collected after water properties stabilized to assure that a representative sample was collected from the alluvium. Field water property data are listed in Appendix 1.

Chloride samples were collected as whole water samples in 250-milliliter polyethylene bottles. Each sample was assigned a local identifier made up of two letters identifying left bank (LB) or right bank (RB), the OWRB surface-water sampling site identification number (335500), and a letter identifying top sample (T), middle sample (M), or bottom sample (B). For example, a top sample taken from the left bank of the Hugo, Oklahoma, site would have a local identifier of LB335500T. After samples were collected, they were sent to the ODEQ laboratory to be analyzed for chloride concentration using a colorimetric, automated ferricyanide method (U.S. Environmental Protection Agency, 1979).

Quality-assurance samples were collected to evaluate the degree of accuracy, precision, and bias of chloride samples. One equipment blank was prepared in the laboratory by processing blank water through all sampling equipment before initial field sampling proceeded. Five field blanks were prepared in the field by processing blank water in exactly the same manner as the chloride samples. Six replicate samples (10 percent of samples) were prepared in the field by filling a second bottle after the initial chloride sample was collected. Quality-assurance data are listed in Appendix 2.

The surface-water chloride data used in this report were collected by OWRB personnel and analyzed by ODEQ laboratory (Appendix 3). OWRB personnel measured the water properties in the field.

Chloride in Ground Water and Surface Water

The two surface-water sampling sites on the Beaver River were near Turpin, (AT233900); and Beaver, (AT234000) Oklahoma (fig. 1). The ground-water and surface-water medians for chloride concentration were both approximately 2,600 milligrams per liter (mg/L) at Turpin (fig. 13 and table 1). The ground-water chloride concentrations on the left bank were slightly less than the chloride concentrations on the right bank at the Turpin site. The ground-water chloride concentrations on the left and right banks increased with depth at the Turpin site (Appendix 1). The ground-water median chloride concentration exceeded the surface-water median chloride concentration by approximately 750 mg/L at Beaver (fig. 13 and table 1). All the ground-water chloride concentrations at the Beaver site were greater than the surface-water median chloride concentration. The ground-water chloride concentrations on the left bank were greater than the chloride concentrations on the right bank at the Beaver site. The ground-water chloride concentrations on the

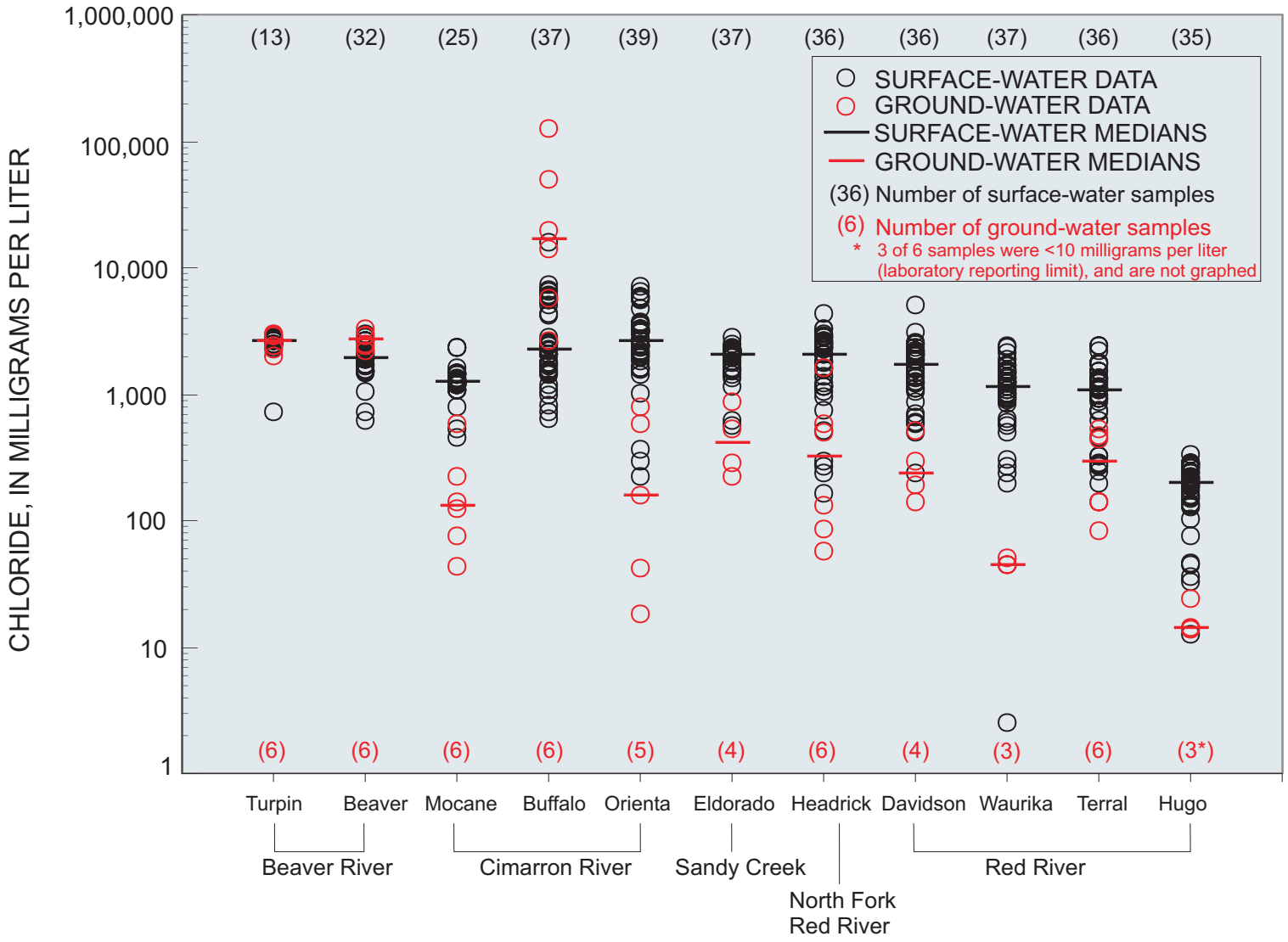

Figure 13. Comparison of ground-water data 2003 and surface-water data 1998-2002 for Beneficial Use Monitoring Program surface-water sampling sites impaired by chloride. (Surface-water data from Oklahoma Water Resources Board.)

Table 1. Minimum, median, and maximum chloride concentrations from ground-water samples 2003 and surface-water samples 1998-2002 at the Beneficial Use Monitoring Program sampling sites.

[min, minimum; med, median; max, maximum]

Site Name	Ground-water chloride concentration, in milligrams per liter			Surface-water chloride concentration, in milligrams per liter		
	min	med	max	min	med	max
Beaver River, Turpin, Oklahoma	2,010	2,660	3,000	729	2,618	2,811
Beaver River, Beaver, Oklahoma	2,190	2,690	3,270	619	1,934	3,000
Cimarron River, Mocane, Oklahoma	43	132	586	453	1,255	2,347
Cimarron River, Buffalo, Oklahoma	2,610	16,750	125,000	630	2,247	15,750
Cimarron River, Orienta, Oklahoma	18	161	802	226	2,639	6,424
Sandy Creek, Eldorado, Oklahoma	221	411	872	559	2,099	2,481
North Fork Red River, Headrick, Oklahoma	58	319	1,590	163	2,084	4,314
Red River, Davidson, Oklahoma	140	240	521	504	1,729	5,118
Red River, Waurika, Oklahoma	45	45	51	2	1,138	2,413
Red River, Terral, Oklahoma	84	294	523	198	1,082	2,438
Red River, Hugo, Oklahoma	14	14	24	33	196	338

left and right banks decreased with depth at the Beaver site (Appendix 1).

The three sites on the Cimarron River were near Mocane, (AT157000); Buffalo, (AT157950); and Orienta, (AT158110) Oklahoma. The ground-water median chloride concentration was less than the surface-water median chloride concentration by approximately 1,100 mg/L at Mocane (fig. 13 and table 1). The ground-water chloride concentrations on the left bank were greater than the chloride concentrations on the right bank at the Mocane site. The ground-water chloride concentrations on the left and right banks decreased with depth at the Mocane site (Appendix 1). The ground-water median chloride concentration was approximately 16,750 mg/L at Buffalo, which exceeded the surface-water median chloride concentration of 2,247 mg/L (fig. 13 and table 1). The ground-water chloride concentrations on the left bank were larger than the chloride concentrations on the right bank at the Buffalo site. The ground-water chloride concentrations on the left and right banks increased with depth at the Buffalo site (Appendix 1). The ground-water median chloride concentration was less than the surface-water median chloride concentration by approximately 2,500 mg/L at the Orienta site (fig. 13 and table 1). The ground-water chloride concentrations on the left bank were less than the chloride concentrations on the right bank at the Orienta site. The ground-water chloride concentrations on the left bank increased with depth, and on the right bank decreased with depth at the Orienta site (Appendix 1).

The ground-water median chloride concentration at the Eldorado, Oklahoma, site on Sandy Creek (AT299710) was less than the surface-water median chloride concentration by approximately 1,700 mg/L (fig. 13 and table 1). The ground-water chloride concentrations on the left bank were less than the chloride concentrations on the right bank at the Eldorado site. The ground-water chloride concentrations on the right and left banks increased with depth at the Eldorado site (Appendix 1).

All the ground-water chloride concentrations were less than the surface-water median chloride concentration of 2,084 mg/L at the Headrick, Oklahoma, site on the North Fork Red River (AT305000) (fig. 13 and table 1). The ground-water chloride concentrations on the left bank were greater than the chloride concentrations on the right bank at the Headrick site. The ground-water chloride concentrations on the right and left banks increased with depth at the Headrick site (Appendix 1).

The four sites on the Red River were near Davidson, (AT308000); Waurika, (AT312720); Terral, (AT315500); and Hugo, (AT335500) Oklahoma. The ground-water median chloride concentration was less than the surface-water median chloride concentration by approximately 1,500 mg/L at the Davidson site (fig. 13 and table 1). The ground-water chloride concentration in the top sample on the left bank was less than the chloride concentration in the top sample on the right bank at the Davidson site. The ground-water chloride concentrations varied with depth at the Davidson site (Appendix 1). The ground-water median chloride concentration was less than the surface-water median chloride concentration at the Waurika site

(fig. 13 and table 1). Only right bank samples were collected at the Waurika site. The ground-water chloride concentrations on the right bank did not vary substantially with depth at the Waurika site (Appendix 1). The ground-water median chloride concentration was less than the surface-water median chloride concentration by approximately 800 mg/L at Terral (fig. 13 and table 1). The ground-water chloride concentrations on the left bank were less than the chloride concentrations on the right bank at the Terral site. The ground-water chloride concentrations on the left and right banks increased with depth at the Terral site (Appendix 1). Three of the six ground-water samples had chloride concentrations less than 10 mg/L at Hugo (fig. 13 and table 1). The other three ground-water samples had a median chloride concentration of 14 mg/L, which was less than the surface-water median chloride concentration at Hugo. The ground-water chloride concentrations on the left and right banks were similar and increased with depth at the Hugo site (Appendix 1).

The ground-water median chloride concentrations at 8 of the 11 BUMP sites were less than the surface-water median chloride concentrations. The Turpin and Beaver sites had similar ground-water and surface-water median chloride concentrations. The Buffalo site was the only site that had a large difference between the ground-water and surface-water chloride concentrations. The ground-water median chloride concentration was approximately 14,500 mg/L greater than the surface-water median chloride concentration at the Buffalo site (fig. 13 and table 1).

There were some differences in ground-water chloride concentrations between the left and right banks and with depth at each site. Differences in ground-water chloride concentrations between the left and right banks may be due to differences in alluvial materials, varying distances from the stream, differences in depth of alluvium, and differences in ground-water flow gradients or directions. An increase in ground-water chloride concentrations with depth may indicate that chloride was diluted near the surface due to recharge to the alluvium and/or chloride was upwelling in ground-water from bedrock below the alluvium. A decrease in ground-water chloride concentrations with depth may indicate that chloride was precipitating out as salt crust near the surface due to evaporation and/or chloride was leaching down from a source on the surface of the alluvium and chloride concentrations were diluted by deeper ground water.

The interaction of ground water and surface water in alluvial valleys is affected by local and regional flow systems that could cause chloride concentrations to increase or decrease within the alluvium. The effects of these flow systems are not addressed in this report. Each water sample collected from the alluvium or stream represents one point and time in the hydrologic system. The ground-water and surface-water samples were collected during different years. The amount and distribution of precipitation from one year to the next can be significantly different, introducing some inconsistency in comparing ground-water and surface-water chloride concentrations in this report.

Summary

The Oklahoma Water Resources Board Beneficial Use Monitoring Program reported exceedances of beneficial-use standards for chloride at 11 surface-water sampling sites from January to October 2002. The U.S. Geological Survey, in cooperation with the Oklahoma Department of Environmental Quality, conducted a study to determine the chloride concentrations in ground water in the vicinity of Beneficial Use Monitoring Program surface-water sampling sites not meeting beneficial use standards for chloride and compare chloride concentrations in ground water and surface water. The chloride-impaired Beneficial Use Monitoring Program surface-water sampling sites are located in the western and southern regions of Oklahoma. The ground-water sampling sites were placed in proximity to the 11 surface-water sampling sites designated impaired by chloride by the Oklahoma Water Resources Board. Two surface-water sampling sites were located on the Beaver River (headwaters of the North Canadian River), three sites on the Cimarron River, one site on Sandy Creek, one site on North Fork Red River, and four sites on the Red River.

Six ground-water samples were collected, when possible, from two test holes located upstream from each of the 11 Beneficial Use Monitoring Program surface-water sampling sites. One test hole was placed on the left bank and right bank, when possible, of each BUMP surface-water sampling site. All test holes were located on alluvial deposits adjacent to the Beneficial Use Monitoring Program surface-water sampling sites within 0.5 mile of the stream. Test hole locations depended on landowner permission and road accessibility. Site locations were determined using a global positioning system with a horizontal accuracy of about 10 feet. Top, middle, and bottom ground-water samples were collected from the alluvium at each test hole, when possible. Water properties of specific conductance, pH, water temperature, and dissolved oxygen were recorded in the field before sampling for chloride.

Quality-assurance samples were collected to evaluate the degree of accuracy, precision, and bias of chloride samples. One equipment blank was prepared in the laboratory by processing blank water through all sampling equipment before initial field sampling proceeded. Five field blanks were prepared in the field by processing blank water in exactly the same manner as the chloride samples. Six replicate samples (10 percent of samples) were prepared in the field by filling a second bottle after the initial chloride sample was collected.

The surface-water chloride data used in this report were collected by OWRB personnel and analyzed by ODEQ laboratory. OWRB personnel measured the water properties in the field.

The ground-water and surface-water medians for chloride concentration were both approximately 2,600 mg/L at Turpin. The ground-water median chloride concentration exceeded the surface-water median chloride concentration by approximately 750 mg/L at Beaver. The ground-water median chloride con-

centration was less than the surface-water median chloride concentration by approximately 1,100 mg/L at Mocane. The ground-water median chloride concentration was approximately 16,750 mg/L at Buffalo, which exceeded the surface-water median chloride concentration of 2,247 mg/L. The ground-water median chloride concentration was less than the surface-water median chloride concentration by approximately 2,500 mg/L at the Orienta site. The ground-water median chloride concentration was less than the surface-water median chloride concentration by approximately 1,700 mg/L at the Eldorado site. All the ground-water chloride concentrations were less than the surface-water median chloride concentration of 2,084 mg/L at the Headrick site. The ground-water median chloride concentration was less than the surface-water median chloride concentration by approximately 1,500 mg/L at the Davidson site. The ground-water median chloride concentration was less than the surface-water median chloride concentration at the Waurika site. The ground-water median chloride concentration was less than the surface-water median chloride concentration by approximately 800 mg/L at Terral. Three of the six ground-water samples had chloride concentrations less than 10 mg/L at Hugo. The other three ground-water samples had a median chloride concentration of 14 mg/L, which was less than the surface-water median chloride concentration at Hugo.

The ground-water median chloride concentrations at 8 of the 11 Beneficial Use Monitoring Program sites were less than the surface-water median chloride concentrations. The Turpin and Beaver sites had similar ground-water and surface-water median chloride concentrations. The Buffalo site was the only site that had a large difference between the ground-water and surface-water chloride concentrations. The ground-water median chloride concentration was approximately 14,500 milligrams per liter greater than the surface-water median chloride concentration.

There were some differences in ground-water chloride concentrations between the left and right banks and with depth at each site. Differences in ground-water chloride concentrations between the left and right banks may be due to differences in alluvial materials, varying distances from the stream, differences in depth of alluvium, and differences in ground-water flow gradients or directions. An increase in ground-water chloride concentrations with depth may indicate that chloride was diluted near the surface due to recharge to the alluvium and/or chloride was upwelling in ground-water from bedrock below the alluvium. A decrease in ground-water chloride concentrations with depth may indicate that chloride was precipitating out as salt crust near the surface due to evaporation and/or chloride was leaching down from a source on the surface of the alluvium and chloride concentrations were diluted by deeper ground water.

Selected References

Blazs, R.L., Walters, D.M., Coffey T.E., Boyle D.L., and Wellman, J.J., 2003a, Water resources data, Oklahoma, water year 2002, Volume 1. Arkansas River Basin: U.S. Geological Survey Water-Data Report OK-02-1, 375 p.

Blazs, R.L., Walters, D.M., Coffey T.E., Boyle D.L., and Wellman, J.J., 2003b, Water resources data, Oklahoma, water year 2002, Volume 2. Red River Basin: U.S. Geological Survey Water-Data Report OK-02-2, 198 p.

Carr, J.E. and Bergman, D.L., 1976, Reconnaissance of the water resources of the Clinton Quadrangle, west-central Oklahoma: Oklahoma Geological Survey Hydrologic Atlas 5, 4 sheets, scale 1:250,000.

Havens, J.S., 1977, Reconnaissance of the water resources of the Lawton Quadrangle, southwestern Oklahoma: Oklahoma Geological Survey Hydrologic Atlas 6, 4 sheets, scale 1:250,000.

Hem, J.D., 1992, Study and interpretation of the chemical characteristics of natural water (3d ed.): U.S. Geological Survey Water-Supply Paper 2254, 263 p.

Marcher, M.V., and Bergman, D.L., 1983, Reconnaissance of the water resources of the McAlester and Texarkana Quadrangles, southeastern Oklahoma: Oklahoma Geological Survey Hydrologic Atlas 9, 4 sheets, scale 1:250,000.

Marine, I.W., and Schoff, S.L., 1962, Ground-water resources of Beaver County, Oklahoma: Oklahoma Geology Survey Bulletin 97, 74 p.

Morton, R.B., 1980, Reconnaissance of the water resources of the Woodward Quadrangle, northwestern Oklahoma: Oklahoma Geological Survey Hydrologic Atlas 8, 4 sheets, scale 1:250,000.

Morton, R.B., and Goemaat, R.L., 1973, Reconnaissance of the water resources of Beaver County, Oklahoma: U.S. Geological Survey Hydrologic Investigations Atlas 450, 3 sheets, scale 1:250,000.

Myers, Arthur J., 1959, Geology of Harper County, Oklahoma: Oklahoma Geological Survey Bulletin 80, 108 p.

Oklahoma Water Resources Board, 2002, 2002 Report of the Oklahoma Beneficial Use Monitoring Program, 696 p.

U.S. Environmental Protection Agency, 1979, Methods for Chemical Analysis of Water and Wastes: EPA-600/4-79-020, Method 325.2.

Appendices

Appendix 1. Ground-water data collected near Beneficial Use Monitoring Program surface-water sampling sites impaired by chloride, 2003

[LB, left bank; RB, right bank; T, top; B, bottom; Sample depth, deepest depth of screened interval during sampling; bls, below land surface; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; <, less than]

Site identifier	Local identifier	Date sampled	Sample depth (feet bls)	Specific conductance (µ S/cm)	pH (standard units)	Water temperature (°C)	Dissolved oxygen (mg/L)	Chloride (mg/L)
Beaver River, Turpin, Oklahoma								
364539100504501	LB233900T	10/21/03	11.0	6,560	7.2	19.9	4.3	2,010
364539100504501	LB233900M	10/21/03	14.0	7,240	7.3	21.4	4.0	2,300
364539100504501	LB233900B	10/21/03	17.0	8,780	7.3	21.0	4.4	2,940
364510100510601	RB233900T	10/20/03	11.0	7,980	7.1	22.4	4.1	2,420
364510100510601	RB233900M	10/20/03	16.5	9,160	7.1	19.9	3.4	2,900
364510100510601	RB233900B	10/20/03	27.5	9,560	7.0	19.7	3.8	3,000
Beaver River, Beaver Oklahoma								
364923100311101	LB234000T	10/21/03	7.0	10,300	7.1	21.7	3.9	3,270
364923100311101	LB234000M	10/21/03	13.5	9,210	7.2	19.9	3.7	2,900
364923100311101	LB234000B	10/21/03	20.3	9,020	7.1	20.1	3.7	2,880
364921100311101	RB234000T	10/22/03	8.0	9,890	7.2	17.0	3.2	2,500
364921100311101	RB234000M	10/22/03	14.8	9,290	7.2	16.9	3.1	2,190
364921100311101	RB234000B	10/22/03	21.5	9,990	7.5	15.8	3.0	2,410
Cimarron River, Mocane, Oklahoma								
365836100185301	LB157000T	10/22/03	11.0	2,680	7.1	22.3	4.3	586
365836100185301	LB157000M	10/22/03	19.8	846	7.4	26.0	5.5	124
365836100185301	LB157000B	10/22/03	28.5	1,220	7.3	20.6	5.2	222
365830100185101	RB157000T	10/22/03	12.0	1,520	6.9	28.0	4.1	141
365830100185101	RB157000M	10/22/03	13.0	1,030	7.2	18.9	4.2	75
365830100185101	RB157000B	10/22/03	17.0	782	7.4	19.7	7.4	43
Cimarron River, Buffalo, Oklahoma								
365108099184701	LB157950T	10/23/03	11.0	10,500	7.1	17.2	2.1	2,610
365108099184701	LB157950M	10/23/03	17.3	112,000	7.1	17.1	1.1	49,900
365108099184701	LB157950B	10/23/03	28.3	216,000	6.7	15.9	0.3	125,000
365110099193201	RB157950T	10/23/03	2.5	18,400	7.3	23.1	5.8	5,800
365110099193201	RB157950M	10/23/03	4.5	41,500	6.9	20.9	2.2	13,900
365110099193201	RB157950B	10/23/03	7.0	49,500	6.9	21.1	2.2	19,600

Appendix 1. Ground-water data collected near Beneficial Use Monitoring Program surface-water sampling sites impaired by chloride, 2003—Continued

[LB, left bank; RB, right bank; T, top; B, bottom; Sample depth, deepest depth of screened interval during sampling; bls, below land surface; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; <, less than]

Site identifier	Local identifier	Date sampled	Sample depth (feet bls)	Specific conductance (µ S/cm)	pH (standard units)	Water temperature (°C)	Dissolved oxygen (mg/L)	Chloride (mg/L)
Cimarron River, Orienta, Oklahoma								
362235098270301	LB158110T	10/31/03	13.0	636	7.5	20.2	0.5	18
362235098270301	LB158110M	10/31/03	19.8	794	7.5	18.8	0.0	42
362235098270301	LB158110B	10/31/03	26.6	1,090	7.6	18.0	0.1	161
362217098272701	RB158110T	10/31/03	12.0	3,520	8.0	16.1	6.5	802
362217098272701	RB158110B	10/31/03	14.0	2,950	8.0	18.5	7.0	585
Sandy Creek, Eldorado, Oklahoma								
342753099394501	LB299170T	9/11/03	12.5	3,140	7.8	31.6	7.3	221
342753099394501	LB299170B	9/11/03	15.0	3,870	6.9	23.2	5.1	287
342753099394902	RB299710T	9/11/03	13.0	3,310	7.6	30.7	7.9	535
342753099394902	RB299710B	9/11/03	15.0	5,500	6.9	23.0	0.9	872
North Fork Red River, Headrick, Oklahoma								
343819099060001	LB305000T	9/10/03	11.0	2,370	7.1	24.9	0.4	505
343819099060001	LB305000M	9/10/03	15.4	2,700	7.3	23.1	0.4	575
343819099060001	LB305000B	9/10/03	19.8	6,240	7.2	22.8	0.3	1,590
343851099055401	RB305000T	9/10/03	11.0	1,270	7.1	27.1	0.6	58
343851099055401	RB305000M	9/10/03	14.3	1,420	7.1	26.1	0.4	85
343851099055401	RB305000B	9/10/03	17.5	1,600	7.2	25.1	0.4	133
Red River, Davidson, Oklahoma								
341319099075901	LB308000T	12/11/03	11.0	1,760	7.4	17.9	0.4	189
341319099075901	LB308000M	12/11/03	16.5	1,330	7.4	18.8	0.3	140
341319099075901	LB308000B	12/11/03	22.0	2,770	7.2	18.4	0.3	521
341239099101801	RB308000T	12/10/03	8.0	7,150	6.9	15.4	5.5	292
Red River, Waurika, Oklahoma								
340748098062201	RB312720T	9/9/03	15.0	1,030	7.2	23.6	0.5	45
340748098062201	RB312720M	9/9/03	19.7	1,060	7.3	22.9	0.4	45
340748098062201	RB312720B	9/9/03	24.7	1,080	7.3	22.6	0.4	51

Appendix 1. Ground-water data collected near Beneficial Use Monitoring Program surface-water sampling sites impaired by chloride, 2003—Continued

[LB, left bank; RB, right bank; T, top; B, bottom; Sample depth, deepest depth of screened interval during sampling; bls, below land surface; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; <, less than]

Site identifier	Local identifier	Date sampled	Sample depth (feet bls)	Specific conductance (µ S/cm)	pH (standard units)	Water temperature (°C)	Dissolved oxygen (mg/L)	Chloride (mg/L)
			Red River, Terral, Oklahoma					
335252097563201	LB315500T	8/27/03	19.0	1,010	7.9	32.3	7.2	84
335252097563201	LB315500M	8/27/03	21.2	1,340	7.3	21.9	0.7	139
335252097563201	LB315500B	8/27/03	23.3	1,300	7.3	27.9	0.8	142
335243097563501	RB315500T	8/28/03	19.0	2,000	7.4	21.3	0.8	447
335243097563501	RB315500M	8/28/03	23.0	2,090	7.4	21.5	0.7	467
335243097563501	RB315500B	8/28/03	27.0	2,420	7.4	21.2	0.6	523
			Red River, Hugo, Oklahoma					
335239095300901	LB335500T	8/28/03	17.0	1,210	6.8	27.3	3.9	<10
335239095300901	LB335500M	8/28/03	20.3	1,100	6.8	23.9	1.3	14
335239095300901	LB335500B	8/28/03	22.5	1,080	6.9	23.8	1.4	24
335326095301901	RB335500T	8/29/03	15.0	1,040	6.8	23.4	1.2	<10
335326095301901	RB335500M	8/29/03	22.0	1,160	6.9	23.6	1.0	<10
335326095301901	RB335500B	8/29/03	29.0	1,110	6.9	22.6	0.9	14

Appendix 2. Ground-water quality assurance data collected near Beneficial Use Monitoring Program surface-water sampling sites impaired by chloride, 2003

[LB, left bank; RB, right bank; EB, equipment blank; FB, field blank; T, top; M, middle; B, bottom; R, replicate; mg/L, milligrams per liter; #, number; <, less than]

Sample type	Site identifier	Local identifier	Date sampled	Analysis date	Chloride (mg/L)	Media	Bottle #	Batch #	Lot #	Date media bottled
Equipment Blank	335252097563201	LB315500EB	8/27/03	9/19/03	<10	Inorganic Blank Water	284	67	2330	11/26/02
Field Blank	340748098062201	RB312720FB	9/9/03	9/30/03	<10	Inorganic Blank Water	281	67	2330	11/26/02
Field Blank	343819099060001	LB305000FB	9/10/03	9/30/03	<10	Inorganic Blank Water	282	67	2330	11/26/02
Field Blank	365830100185101	RB157000FB	10/22/03	11/19/03	<10	Inorganic Blank Water	146	70	3227	8/15/03
Field Blank	364923100311101	LB234000FB	10/21/03	11/19/03	<10	Inorganic Blank Water	148	70	3227	8/15/03
Field Blank	364510100510601	RB233900FB	10/20/03	11/19/03	<10	Inorganic Blank Water	147	70	3227	8/15/03

Sample type	Site identifier	Local identifier	Date sampled	Analysis date	Chloride (mg/L)
Sample	335326095301901	RB335500M	8/29/03	9/19/03	<10
Replicate	335326095301901	RB335500MR	8/29/03	9/19/03	<10
Sample	343851099055401	RB305000M	9/10/03	9/30/03	85
Replicate	343851099055401	RB305000MR	9/10/03	9/30/03	84
Sample	364510100510601	RB233900M	10/20/03	11/19/03	2,900
Replicate	364510100510601	RB233900MR	10/20/03	11/19/03	2,990
Sample	364923100311101	LB234000T	10/21/03	11/19/03	3,270
Replicate	364923100311101	LB234000TR	10/21/03	11/19/03	3,270
Sample	365830100185101	RB157000B	10/22/03	11/14/03	43
Replicate	365830100185101	RB157000BR	10/22/03	11/14/03	43
Sample	362235098270301	LB158110T	10/31/03	11/14/03	18
Replicate	362235098270301	LB158110TR	10/31/03	11/14/03	18

Appendix 3. Surface-water data for Beneficial Use Monitoring Program surface-water sampling sites impaired by chloride, 1998–2002 (Data were provided by the Oklahoma Water Resources Board)

[OWRB, Oklahoma Water Resources Board; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius, mg/L, milligrams per liter; ND, no data]

OWRB identifier	Date sampled	Specific conductance (µ S/cm)	pH (standard units)	Water temperature (°C)	Dissolved oxygen (mg/L)	Chloride (mg/L)
Beaver River, Turpin, Oklahoma						
AT233900	12/12/00	10,638	7.6	0.0	11.2	2,518
AT233900	2/6/01	8,392	8.0	5.8	14.1	2,313
AT233900	3/6/01	9,337	8.1	6.0	10.3	2,526
AT233900	4/3/01	8,689	7.4	13.0	7.3	2,686
AT233900	5/8/01	9,139	7.6	13.5	7.6	2,520
AT233900	6/5/01	8,858	7.5	17.1	6.2	2,479
AT233900	7/10/01	9,290	7.7	20.0	7.7	2,646
AT233900	8/7/01	10,421	7.5	21.4	8.0	2,638
AT233900	10/2/01	9,856	8.4	24.0	11.7	2,811
AT233900	2/11/02	7,754	8.3	11.0	12.3	729
AT233900	3/18/02	9,675	7.7	15.0	7.6	2,618
AT233900	4/15/02	10,050	7.6	18.3	13.3	2,656
AT233900	6/18/02	7,979	8.0	25.1	14.0	2,712
Beaver River, Beaver, Oklahoma						
AT234000	1/11/99	6,857	7.5	6.3	12.4	2,167
AT234000	2/16/99	6,747	8.0	11.6	11.0	1,510
AT234000	3/30/99	6,285	7.7	20.0	10.2	1,462
AT234000	4/12/99	7,564	8.4	17.0	9.8	1,508
AT234000	5/10/99	3,825	8.3	23.6	4.5	1,035
AT234000	6/14/99	2,350	8.0	24.1	ND	619
AT234000	7/13/99	2,410	8.0	ND	ND	1,498
AT234000	8/23/99	3,929	8.0	30.0	9.0	1,727
AT234000	9/13/99	7,273	8.1	27.2	16.3	1,949
AT234000	10/5/99	7,752	7.9	23.8	13.2	1,508
AT234000	11/30/99	6,623	8.0	12.0	9.9	1,961
AT234000	1/4/00	6,240	8.5	1.0	ND	1,934
AT234000	2/7/00	6,990	8.0	12.0	14.8	1,655
AT234000	3/6/00	7,675	7.4	17.5	8.5	1,900
AT234000	5/1/00	6,860	8.2	13.0	12.1	1,875
AT234000	6/5/00	6,128	9.1	29.0	8.0	1,741
AT234000	7/10/00	9,620	7.7	32.0	9.3	1,563
AT234000	8/8/00	7,702	7.8	22.0	6.3	1,978
AT234000	9/5/00	8,454	7.4	27.0	5.2	2,685
AT234000	10/3/00	13,048	7.4	13.3	4.2	2,654
AT234000	11/1/00	7,538	8.3	14.0	11.5	2,781
AT234000	2/6/01	7,381	8.0	6.5	14.5	1,923
AT234000	3/6/01	7,716	8.9	7.0	11.0	2,047
AT234000	4/3/01	7,059	7.5	14.0	7.7	2,169
AT234000	5/8/01	7,509	7.8	15.8	8.4	2,052
AT234000	6/5/01	7,545	7.6	19.2	7.1	2,142
AT234000	7/10/01	7,840	7.2	22.0	2.2	2,365

Appendix 3. Surface-water data for Beneficial Use Monitoring Program surface-water sampling sites impaired by chloride, 1998–2002—Continued
(Data were provided by the Oklahoma Water Resources Board)

[OWRB, Oklahoma Water Resources Board; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius, mg/L, milligrams per liter; ND, no

OWRB identifier	Date sampled	Specific conductance (µ S/cm)	pH (standard units)	Water temperature (°C)	Dissolved oxygen (mg/L)	Chloride (mg/L)
AT234000	8/7/01	12,289	7.6	26.7	7.9	3,000
AT234000	2/11/02	8,213	7.6	8.0	16.3	720
AT234000	3/18/02	9,596	7.6	15.0	7.1	2,637
AT234000	4/15/02	10,170	7.6	27.1	12.8	2,775
AT234000	6/18/02	5,750	7.9	26.8	7.8	2,186
			Cimarron River, Mocane, Oklahoma			
AT157000	10/5/99	3,924	8.3	22.6	8.7	453
AT157000	11/2/99	3,955	8.2	14.0	19.7	1,187
AT157000	11/30/99	3,716	8.5	13.0	12.7	1,231
AT157000	1/4/00	3,790	8.7	2.0	21.8	1,184
AT157000	2/7/00	4,260	8.5	13.0	14.0	1,085
AT157000	3/6/00	4,419	7.7	18.2	7.3	1,096
AT157000	5/1/00	4,480	8.3	13.0	11.9	1,296
AT157000	7/10/00	5,208	8.5	33.0	10.6	1,271
AT157000	8/8/00	4,165	8.5	26.3	9.3	2,347
AT157000	9/5/00	5,192	8.1	32.0	7.1	2,313
AT157000	10/3/00	8,438	7.6	19.2	10.1	1,431
AT157000	11/1/00	4,167	8.8	17.0	10.2	1,606
AT157000	2/6/01	4,550	8.5	9.8	12.6	1,287
AT157000	3/6/01	4,826	8.6	8.0	12.1	1,342
AT157000	4/3/01	4,332	8.0	15.0	9.3	1,255
AT157000	5/8/01	4,356	8.3	20.2	10.0	1,209
AT157000	7/10/01	4,610	8.5	26.0	9.3	1,468
AT157000	8/7/01	5,016	8.2	30.5	9.0	1,444
AT157000	10/2/01	4,561	8.4	18.0	10.5	1,455
AT157000	2/12/02	3,381	8.4	3.0	10.8	533
AT157000	3/19/02	4,144	7.9	6.0	11.8	798
AT157000	4/16/02	4,303	8.3	22.8	9.5	1,090
AT157000	6/18/02	3,711	8.5	32.0	6.1	1,257
AT157000	7/16/02	4,900	8.2	27.0	9.3	1,223
AT157000	8/13/02	4,674	7.9	17.8	7.8	1,197
			Cimarron River, Buffalo, Oklahoma			
AT157950	1/11/99	7,597	7.6	1.0	14.4	2,247
AT157950	2/16/99	7,608	8.4	8.2	6.3	1,690
AT157950	3/30/99	5,822	8.3	16.2	10.2	1,498
AT157950	4/12/99	6,653	8.4	13.1	9.8	1,424
AT157950	5/10/99	6,742	8.3	20.1	3.9	2,050
AT157950	6/14/99	2,030	8.3	ND	ND	820
AT157950	7/13/99	4,180	8.4	24.5	12.4	1,077
AT157950	8/23/99	8,371	8.3	34.0	7.8	2,052
AT157950	9/7/99	14,156	8.1	31.7	13.5	15,750
AT157950	10/18/99	7,004	8.3	18.0	11.2	988
AT157950	11/15/99	4,908	8.3	27.0	8.1	1,737

Appendix 3. Surface-water data for Beneficial Use Monitoring Program surface-water sampling sites impaired by chloride, 1998–2002—Continued
(Data were provided by the Oklahoma Water Resources Board)

[OWRB, Oklahoma Water Resources Board; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius, mg/L, milligrams per liter; ND, no

OWRB identifier	Date sampled	Specific conductance (µ S/cm)	pH (standard units)	Water temperature (°C)	Dissolved oxygen (mg/L)	Chloride (mg/L)
AT157950	12/13/99	5,754	8.4	4.0	12.2	1,562
AT157950	1/31/00	12,440	8.1	2.0	19.3	2,794
AT157950	2/22/00	8,660	8.4	15.0	11.4	2,591
AT157950	3/21/00	9,519	8.1	10.4	10.1	2,546
AT157950	4/17/00	6,690	8.2	18.0	9.9	1,776
AT157950	5/15/00	6,171	8.0	26.5	7.8	1,770
AT157950	6/20/00	5,114	8.0	33.0	4.9	1,255
AT157950	7/24/00	3,886	8.7	32.0	12.6	718
AT157950	8/21/00	17,360	8.3	27.0	8.1	6,083
AT157950	11/1/00	19,180	7.9	-1.0	13.3	5,105
AT157950	12/12/00	8,849	8.3	10.2	11.3	5,619
AT157950	2/6/01	7,893	8.6	10.0	11.6	2,580
AT157950	3/6/01	7,926	7.9	5.0	9.7	2,224
AT157950	4/3/01	5,443	8.1	24.8	9.1	2,395
AT157950	5/8/01	5,702	7.9	23.0	8.7	1,478
AT157950	6/5/01	7,660	8.2	33.0	7.0	2,046
AT157950	7/10/01	11,617	7.7	36.2	7.1	2,501
AT157950	8/7/01	11,850	7.9	25.0	8.6	4,381
AT157950	10/2/01	17,863	8.1	24.0	7.5	5,711
AT157950	2/13/02	5,012	8.4	2.0	11.4	630
AT157950	3/19/02	32,840	7.6	8.0	10.4	5,512
AT157950	4/16/02	11,870	8.0	23.8	8.5	4,159
AT157950	6/17/02	19,666	8.2	33.4	7.7	6,731
AT157950	7/16/02	ND	ND	ND	ND	6,003
AT157950	8/13/02	28,137	7.8	19.9	9.3	7,280
AT157950	9/17/02	ND	ND	ND	ND	6,421
			Cimarron River, Orienta, Oklahoma			
AT158110	12/2/98	16,763	8.1	11.7	12.7	3,534
AT158110	1/19/99	13,931	8.3	8.7	13.9	3,110
AT158110	2/8/99	11,902	8.3	9.7	10.8	3,054
AT158110	3/7/99	13,225	8.2	7.5	14.9	6,424
AT158110	4/5/99	7,993	8.2	16.0	10.2	1,415
AT158110	5/5/99	8,581	8.6	18.6	7.2	2,323
AT158110	6/7/99	7,230	8.2	26.6	18.8	1,940
AT158110	7/6/99	6,662	8.2	30.1	8.3	1,551
AT158110	8/2/99	10,182	7.4	31.0	8.1	2,434
AT158110	10/18/99	18,477	8.0	15.0	11.0	5,940
AT158110	12/13/99	13,285	8.5	5.0	12.7	3,305
AT158110	1/31/00	21,188	8.1	1.0	18.8	5,835
AT158110	2/22/00	14,620	8.2	13.0	10.6	4,758
AT158110	3/21/00	14,053	7.9	11.1	11.6	3,593
AT158110	4/17/00	8,554	8.1	16.0	10.6	2,408
AT158110	5/15/00	12,695	8.0	19.6	8.6	3,093
AT158110	6/20/00	7,860	8.0	26.0	5.8	1,609

Appendix 3. Surface-water data for Beneficial Use Monitoring Program surface-water sampling sites impaired by chloride, 1998–2002—Continued
(Data were provided by the Oklahoma Water Resources Board)

[OWRB, Oklahoma Water Resources Board; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius, mg/L, milligrams per liter; ND, no

OWRB identifier	Date sampled	Specific conductance (µ S/cm)	pH (standard units)	Water temperature (°C)	Dissolved oxygen (mg/L)	Chloride (mg/L)
AT158110	7/24/00	14,015	8.1	28.0	8.3	2,011
AT158110	8/21/00	4,920	8.5	30.0	12.2	2,451
AT158110	9/19/00	1,773	8.1	24.4	10.1	366
AT158110	10/16/00	8,688	7.7	23.0	9.1	2,428
AT158110	11/13/00	13,634	7.9	5.0	8.8	3,627
AT158110	2/6/01	13,634	7.9	10.0	9.9	3,775
AT158110	3/6/01	1,053	8.1	9.0	9.5	3,289
AT158110	4/3/01	11,363	8.0	18.4	10.2	3,176
AT158110	5/8/01	5,213	8.3	24.0	8.4	1,847
AT158110	6/5/01	8,261	8.1	26.0	8.0	2,142
AT158110	7/10/01	11,904	7.8	32.7	7.2	3,140
AT158110	8/7/01	1,753	7.9	33.0	8.6	296
AT158110	9/11/01	1,561	8.2	26.0	8.8	226
AT158110	10/2/01	4,489	8.0	23.0	10.0	2,062
AT158110	11/6/01	ND	ND	ND	ND	1,602
AT158110	2/5/02	24,500	8.0	2.0	9.9	5,753
AT158110	3/12/02	20,220	7.7	13.0	7.5	2,725
AT158110	4/9/02	20,180	7.7	19.0	10.3	7,020
AT158110	5/14/02	ND	ND	ND	ND	5,536
AT158110	7/9/02	9,900	8.0	33.3	10.4	2,639
AT158110	8/27/02	6,510	7.9	27.0	7.3	2,225
AT158110	9/24/02	4,095	8.0	23.0	13.7	1,011
			Sandy Creek, Eldorado, Oklahoma			
AT299710	12/7/98	9,544	7.9	11.8	11.9	2,181
AT299710	1/25/99	9,198	8.1	11.0	16.2	2,481
AT299710	2/22/99	9,279	8.0	12.3	13.3	1,550
AT299710	3/15/99	8,113	8.0	14.1	11.9	1,521
AT299710	5/24/99	2,955	7.9	24.7	8.8	626
AT299710	6/21/99	8,130	7.8	24.0	8.0	1,827
AT299710	7/19/99	8,016	7.6	28.7	11.2	1,585
AT299710	8/16/99	9,270	8.2	30.4	17.8	2,369
AT299710	9/20/99	8,759	8.3	24.5	15.8	2,200
AT299710	10/31/99	9,485	7.6	15.0	16.6	2,275
AT299710	11/28/99	10,783	ND	12.0	10.7	2,129
AT299710	12/20/99	9,748	8.1	8.0	14.3	2,106
AT299710	1/24/00	9,390	7.8	8.0	6.1	2,060
AT299710	2/29/00	7,640	7.9	15.0	15.5	1,604
AT299710	4/4/00	3,107	7.2	15.1	9.6	559
AT299710	5/22/00	9,107	7.9	26.0	2.1	2,105
AT299710	6/26/00	8,357	7.4	23.0	5.4	1,414
AT299710	7/31/00	8,872	7.9	25.0	15.3	2,842
AT299710	8/29/00	9,581	8.4	27.4	17.1	2,253
AT299710	9/26/00	8,644	7.5	19.0	12.2	2,248
AT299710	10/30/00	ND	ND	ND	ND	1,150

Appendix 3. Surface-water data for Beneficial Use Monitoring Program surface-water sampling sites impaired by chloride, 1998–2002—Continued
(Data were provided by the Oklahoma Water Resources Board)

[OWRB, Oklahoma Water Resources Board; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius, mg/L, milligrams per liter; ND, no

OWRB identifier	Date sampled	Specific conductance (µ S/cm)	pH (standard units)	Water temperature (°C)	Dissolved oxygen (mg/L)	Chloride (mg/L)
AT299710	11/27/00	9,073	7.5	11.0	13.7	2,126
AT299710	3/21/01	9,867	7.5	13.6	10.8	2,074
AT299710	4/18/01	10,072	7.6	14.0	10.3	2,006
AT299710	6/19/01	9,887	8.4	26.8	ND	2,185
AT299710	7/24/01	10,049	7.6	26.0	11.0	2,292
AT299710	8/21/01	6,437	7.7	25.0	8.6	1,352
AT299710	9/18/01	9,635	7.7	22.0	9.6	2,099
AT299710	10/23/01	7,509	7.6	18.3	7.1	2,147
AT299710	11/14/01	ND	ND	ND	ND	2,163
AT299710	2/19/02	7,307	7.8	14.7	15.0	2,091
AT299710	4/3/02	8,765	ND	14.9	8.6	2,096
AT299710	5/1/02	8,722	7.6	20.4	6.1	1,999
AT299710	5/29/02	8,754	7.3	21.1	5.5	1,774
AT299710	8/7/02	2,395	7.3	25.0	5.6	2,181
AT299710	8/20/02	9,991	8.1	27.8	10.7	2,181
AT299710	9/24/02	9,541	7.7	21.3	10.9	1,963
			North Fork Red River, Headrick, Oklahoma			
AT305000	12/7/98	7,777	8.2	9.5	11.9	2,081
AT305000	1/25/99	7,845	8.4	7.8	15.2	2,346
AT305000	2/22/99	8,513	8.2	7.8	11.5	1,635
AT305000	3/15/99	4,066	8.0	9.5	10.9	962
AT305000	6/21/99	2,490	8.0	24.8	ND	515
AT305000	7/19/99	5,032	7.9	29.1	7.7	1,215
AT305000	8/16/99	6,834	8.1	29.7	8.7	1,795
AT305000	9/20/99	13,328	8.1	24.3	8.8	3,280
AT305000	10/31/99	2,878	7.7	14.0	14.1	741
AT305000	1/24/00	10,110	8.2	8.0	10.6	2,372
AT305000	2/29/00	8,780	8.4	17.0	13.8	2,087
AT305000	4/5/00	1,912	7.8	12.3	9.7	234
AT305000	5/22/00	6,940	7.9	31.0	6.9	1,853
AT305000	6/26/00	4,594	8.0	27.0	6.2	1,149
AT305000	7/31/00	7,298	7.7	32.0	8.0	2,938
AT305000	8/29/00	9,862	8.3	33.4	9.2	2,623
AT305000	9/26/00	7,663	8.0	24.0	9.9	2,388
AT305000	10/30/00	ND	ND	ND	ND	1,137
AT305000	11/27/00	9,359	8.0	11.0	12.3	2,648
AT305000	2/28/01	2,132	7.7	2.0	5.6	267
AT305000	3/20/01	6,782	7.9	17.6	11.2	1,567
AT305000	4/17/01	6,290	7.8	14.0	10.6	1,392
AT305000	5/21/01	1,194	7.6	21.0	5.6	163
AT305000	6/18/01	5,057	8.0	31.1	7.6	1,151
AT305000	7/23/01	9,117	7.8	35.0	8.7	2,480
AT305000	8/20/01	9,759	8.3	33.0	8.4	2,494
AT305000	9/17/01	1,565	7.8	24.0	8.3	297

Appendix 3. Surface-water data for Beneficial Use Monitoring Program surface-water sampling sites impaired by chloride, 1998–2002—Continued
(Data were provided by the Oklahoma Water Resources Board)

[OWRB, Oklahoma Water Resources Board; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius, mg/L, milligrams per liter; ND, no

OWRB identifier	Date sampled	Specific conductance (µ S/cm)	pH (standard units)	Water temperature (°C)	Dissolved oxygen (mg/L)	Chloride (mg/L)
AT305000	10/22/01	4,519	7.9	17.0	8.3	3,244
AT305000	11/14/01	ND	ND	ND	ND	4,314
AT305000	2/19/02	8,268	8.2	18.3	11.1	2,791
AT305000	4/2/02	11,495	ND	14.1	7.0	2,987
AT305000	4/30/02	7,586	8.3	27.4	8.9	2,086
AT305000	5/28/02	4,867	8.1	26.7	7.4	1,055
AT305000	8/6/02	ND	7.7	24.0	7.5	2,270
AT305000	8/20/02	10,799	7.7	22.7	7.9	2,811
AT305000	9/24/02	9,173	7.7	16.0	8.9	2,593
			Red River, Davidson, Oklahoma			
AT308000	1/25/99	8,208	8.6	8.2	15.2	1,118
AT308000	2/22/99	8,446	8.4	6.7	13.9	1,570
AT308000	3/15/99	5,836	8.1	9.4	11.1	1,323
AT308000	4/19/99	9,069	8.3	18.0	11.8	2,132
AT308000	6/21/99	3,650	8.1	24.6	ND	574
AT308000	7/19/99	5,430	7.9	28.4	7.5	1,106
AT308000	8/16/99	5,365	8.2	28.1	9.5	1,239
AT308000	9/20/99	12,457	8.1	23.3	8.7	3,060
AT308000	10/31/99	2,610	7.7	13.0	14.6	698
AT308000	12/20/99	6,802	8.5	6.0	13.2	1,847
AT308000	1/24/00	8,880	8.3	8.0	11.5	2,049
AT308000	2/29/00	10,640	8.4	16.0	12.8	2,464
AT308000	4/4/00	4,642	7.6	15.2	12.2	1,238
AT308000	5/22/00	7,319	8.1	29.0	8.3	1,870
AT308000	6/26/00	8,202	8.1	26.0	6.7	1,611
AT308000	7/31/00	5,870	7.9	32.0	9.1	2,176
AT308000	8/29/00	8,400	8.3	32.2	7.7	1,995
AT308000	9/26/00	2,833	7.8	22.0	8.7	596
AT308000	10/31/00	ND	ND	ND	ND	660
AT308000	11/27/00	ND	7.9	11.0	11.8	2,073
AT308000	3/21/01	9,342	7.9	11.4	9.2	2,179
AT308000	4/18/01	9,020	8.1	11.0	10.9	2,035
AT308000	5/22/01	1,319	7.9	19.0	6.5	241
AT308000	6/19/01	5,476	8.1	23.2	7.4	1,254
AT308000	7/24/01	5,294	7.8	25.0	8.2	1,042
AT308000	8/21/01	7,389	7.8	24.0	7.0	1,479
AT308000	9/18/01	3,868	7.9	22.0	9.4	867
AT308000	10/23/01	6,756	8.0	17.1	7.5	2,211
AT308000	11/14/01	ND	ND	ND	ND	5,118
AT308000	2/20/02	8,649	8.2	11.2	10.7	2,473
AT308000	4/2/02	9,105	ND	16.8	6.5	2,567
AT308000	4/30/02	9,389	8.4	26.6	11.5	2,338
AT308000	5/28/02	2,329	7.7	24.4	6.2	504
AT308000	8/6/02	3,492	8.1	29.0	9.0	1,372

Appendix 3. Surface-water data for Beneficial Use Monitoring Program surface-water sampling sites impaired by chloride, 1998–2002—Continued
(Data were provided by the Oklahoma Water Resources Board)

[OWRB, Oklahoma Water Resources Board; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius, mg/L, milligrams per liter; ND, no

OWRB identifier	Date sampled	Specific conductance (µ S/cm)	pH (standard units)	Water temperature (°C)	Dissolved oxygen (mg/L)	Chloride (mg/L)
AT308000	8/21/02	7,858	7.9	24.9	8.2	2,043
AT308000	9/24/02	7,902	8.0	22.0	10.1	1,866
			Red River, Waurika, Oklahoma			
AT312720	12/14/98	6,641	8.3	7.9	12.7	1,500
AT312720	2/2/99	2,047	7.9	5.5	11.8	596
AT312720	3/1/99	6,273	8.3	14.3	12.9	1,395
AT312720	4/27/99	561	7.7	16.8	7.7	199
AT312720	5/15/99	1,472	7.8	25.0	8.1	305
AT312720	6/28/99	1,670	8.0	28.4	7.1	267
AT312720	7/26/99	5,998	8.1	28.5	7.8	1,468
AT312720	8/30/99	4,290	8.4	26.8	9.1	887
AT312720	9/21/99	4,651	7.9	17.2	10.5	1,090
AT312720	11/1/99	4,670	7.8	16.0	14.6	1,138
AT312720	12/21/99	4,501	8.5	3.0	14.4	1,230
AT312720	3/1/00	6,610	8.4	13.0	16.9	1,545
AT312720	4/26/00	6,261	8.0	20.8	8.2	916
AT312720	5/23/00	5,105	8.2	24.0	7.9	1,273
AT312720	6/27/00	5,611	7.9	26.0	5.1	1,232
AT312720	8/1/00	6,020	7.9	26.0	8.1	2,413
AT312720	8/30/00	6,429	8.5	26.1	9.0	2,369
AT312720	9/27/00	5,706	8.1	16.0	10.7	1,670
AT312720	11/1/00	ND	ND	ND	ND	239
AT312720	11/28/00	2,374	7.7	9.0	12.3	493
AT312720	2/12/01	4,295	7.8	7.0	8.9	2
AT312720	3/12/01	2,732	7.6	14.0	9.2	632
AT312720	4/9/01	6,923	8.1	25.0	14.0	1,892
AT312720	5/14/01	4,670	8.1	28.0	9.3	1,163
AT312720	6/11/01	3,806	8.4	31.0	9.5	836
AT312720	7/16/01	4,980	8.5	34.0	5.7	1,354
AT312720	8/13/01	4,997	8.6	30.0	14.8	1,084
AT312720	9/4/01	6,605	8.3	26.0	11.1	1,475
AT312720	10/15/01	3,377	8.3	19.0	9.6	961
AT312720	11/26/01	ND	ND	ND	ND	2,106
AT312720	2/19/02	6,609	8.6	16.0	10.8	1,707
AT312720	4/2/02	4,237	8.1	17.0	9.5	1,029
AT312720	4/29/02	3,658	7.9	21.4	8.2	570
AT312720	5/28/02	7,259	8.4	22.8	8.0	1,326
AT312720	8/5/02	4,757	8.6	32.4	9.8	985
AT312720	8/21/02	4,289	8.4	27.0	9.6	1,025
AT312720	9/24/02	4,757	8.6	31.6	8.8	1,271
			Red River, Terral, Oklahoma			
AT315500	12/14/98		8.4	8.8	13.1	1,520
AT315500	2/2/99	1,792	7.8	6.1	11.4	326

Appendix 3. Surface-water data for Beneficial Use Monitoring Program surface-water sampling sites impaired by chloride, 1998–2002—Continued
(Data were provided by the Oklahoma Water Resources Board)

[OWRB, Oklahoma Water Resources Board; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius, mg/L, milligrams per liter; ND, no

OWRB identifier	Date sampled	Specific conductance (µ S/cm)	pH (standard units)	Water temperature (°C)	Dissolved oxygen (mg/L)	Chloride (mg/L)
AT315500	3/1/99	5,830	8.8	15.9	14.6	1,340
AT315500	4/27/99	984	7.8	19.1	8.2	321
AT315500	5/29/99	1,504	7.9	26.0	6.6	283
AT315500	6/28/99	1,400	7.8	29.0	6.5	248
AT315500	7/26/99	6,653	8.0	29.9	7.1	1,751
AT315500	8/30/99	5,261	8.8	28.5	13.2	880
AT315500	9/21/99	4,636	8.5	19.4	11.6	1,075
AT315500	10/29/99	4,397	8.2	17.0	18.7	921
AT315500	3/1/00	5,030	8.8	14.0	19.2	1,108
AT315500	4/26/00	6,446	7.9	22.2	7.8	922
AT315500	5/23/00	4,125	8.1	26.0	8.1	983
AT315500	6/27/00	4,753	8.0	27.0	5.5	1,149
AT315500	8/1/00	6,076	7.8	28.0	8.3	2,438
AT315500	8/30/00	6,545	8.4	28.4	9.2	2,431
AT315500	9/27/00	6,056	8.3	19.0	11.6	1,775
AT315500	11/1/00	ND	ND	ND	ND	198
AT315500	11/28/00	ND	7.7	9.0	14.6	272
AT315500	2/13/01	3,353	7.8	8.0	11.1	737
AT315500	3/13/01	3,023	7.8	13.0	10.4	454
AT315500	4/10/01	4,884	7.7	20.0	11.4	1,266
AT315500	5/15/01	4,187	8.2	24.0	7.1	980
AT315500	6/12/01	2,922	8.1	26.0	7.2	618
AT315500	7/17/01	5,065	8.1	27.0	3.4	1,330
AT315500	8/14/01	4,150	8.1	27.0	8.3	915
AT315500	9/5/01	6,869	8.2	24.0	9.3	1,537
AT315500	10/16/01	2,616	8.5	13.0	9.7	728
AT315500	11/27/01	ND	ND	ND	ND	2,198
AT315500	2/19/02	6,752	8.8	14.0	13.1	1,738
AT315500	4/2/02	ND	ND	ND	ND	1,293
AT315500	4/29/02	1,006	7.6	19.5	6.5	274
AT315500	5/28/02	7,928	8.6	22.5	8.9	1,110
AT315500	8/5/02	6,204	8.3	30.1	8.8	1,352
AT315500	8/20/02	4,462	8.2	32.0	8.4	1,090
			Red River, Hugo, Oklahoma			
AT335500	12/9/98	ND	7.8	12.6	7.9	46
AT335500	1/6/99	1,091	8.0	4.1	9.7	160
AT335500	2/2/99	353	7.7	9.8	9.2	33
AT335500	3/3/99	1,167	8.1	12.1	9.9	191
AT335500	4/19/99	1,290	8.6	17.0	8.6	217
AT335500	5/5/99	1,396	8.0	21.5	9.3	246
AT335500	6/9/99	1,627	7.9	26.1	6.5	274
AT335500	7/11/99	1,667	8.4	27.0	4.9	275
AT335500	8/4/99	1,656	8.7	30.5	4.2	266
AT335500	9/8/99	1,633	7.9	27.8	5.4	241

Appendix 3. Surface-water data for Beneficial Use Monitoring Program surface-water sampling sites impaired by chloride, 1998–2002—Continued
(Data were provided by the Oklahoma Water Resources Board)

[OWRB, Oklahoma Water Resources Board; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius, mg/L, milligrams per liter; ND, no

OWRB identifier	Date sampled	Specific conductance (µ S/cm)	pH (standard units)	Water temperature (°C)	Dissolved oxygen (mg/L)	Chloride (mg/L)
AT335500	10/5/99	1,648	7.7	19.4	9.4	261
AT335500	11/3/99	1,508	8.3	12.2	9.1	288
AT335500	2/8/00	1,379	7.7	8.7	9.3	196
AT335500	3/7/00	791	7.8	15.7	8.2	133
AT335500	5/3/00	265	7.2	18.2	5.5	36
AT335500	6/7/00	943	8.1	24.0	6.7	149
AT335500	8/9/00	1,839	ND	ND	ND	262
AT335500	9/13/00	2,207	7.9	25.2	6.8	282
AT335500	10/4/00	1,911	8.0	24.0	6.4	338
AT335500	11/8/00	811	7.5	15.0	7.4	127
AT335500	2/13/01	1,189	7.9	7.0	11.1	198
AT335500	3/13/01	865	7.1	12.0	11.7	137
AT335500	4/10/01	1,068	7.8	20.0	9.5	172
AT335500	6/12/01	1,324	8.2	28.0	9.2	226
AT335500	7/17/01	1,462	8.2	30.0	10.3	237
AT335500	8/14/01	1,493	7.9	31.0	8.4	216
AT335500	9/4/01	1,323	8.4	28.0	9.6	213
AT335500	10/16/01	228	7.9	17.5	8.3	13
AT335500	11/27/01	967	8.3	12.0	7.9	186
AT335500	2/12/02	489	8.2	8.0	11.1	75
AT335500	3/19/02	423	8.4	14.0	ND	45
AT335500	5/14/02	971	8.4	22.0	11.9	154
AT335500	7/16/02	1,095	8.4	27.3	5.6	183
AT335500	9/10/02	675	8.1	27.0	8.6	103
AT335500	10/8/02	1,152	8.1	20.1	7.1	205