

Relations Among Land Cover, Streamflow, and Water Quality in the North Canadian River Basin near Oklahoma City, Oklahoma, 1968–2009

Introduction

The U.S. Geological Survey, in cooperation with the city of Oklahoma City, has collected water-quality samples at the North Canadian River near Harrah, Oklahoma (the Harrah station), since 1968, and the North Canadian River at Britton Road at Oklahoma City, Oklahoma (the Britton Road station), since 1988 (fig. 1). The North Canadian municipal wastewater-treatment plant, managed by the city of Oklahoma City, is the largest wastewater-treatment plant in the North Canadian River Basin and discharges effluent between the Britton Road and Harrah stations. Water-quality constituent concentrations were summarized, and trends in concentrations and frequencies of detection of selected constituents with time were evaluated to determine if changes in land cover, streamflow, and other potential sources of constituents in water had significant effects on water quality in the North Canadian River downstream from Oklahoma City.

Changes in Land Cover and Streamflow with Time

Predominant land-cover changes between 1992 and 2001 in the basin between the Harrah station and Lake Overholser upstream were an increase in developed/barren land cover and a decrease in pasture/hay land cover (figs. 1, 2). Increases in developed land can increase concentrations of nitrogen, phosphorus, and related manmade chemicals, such as pesticides and volatile organic compounds, in rivers and associated streambed sediments and fish tissues (Gilliom and others, 2007; Dubrovsky and others, 2010). Streamflow at the time of sampling also can affect water-quality data. Streamflow during base-flow (low-flow) conditions is composed largely of groundwater seepage and discharge from point sources, whereas, streamflow during runoff (high-flow) conditions is composed largely of rainfall runoff from the land surface of a basin. There were no notable trends with time in median and higher streamflow at either station (fig. 3). There were

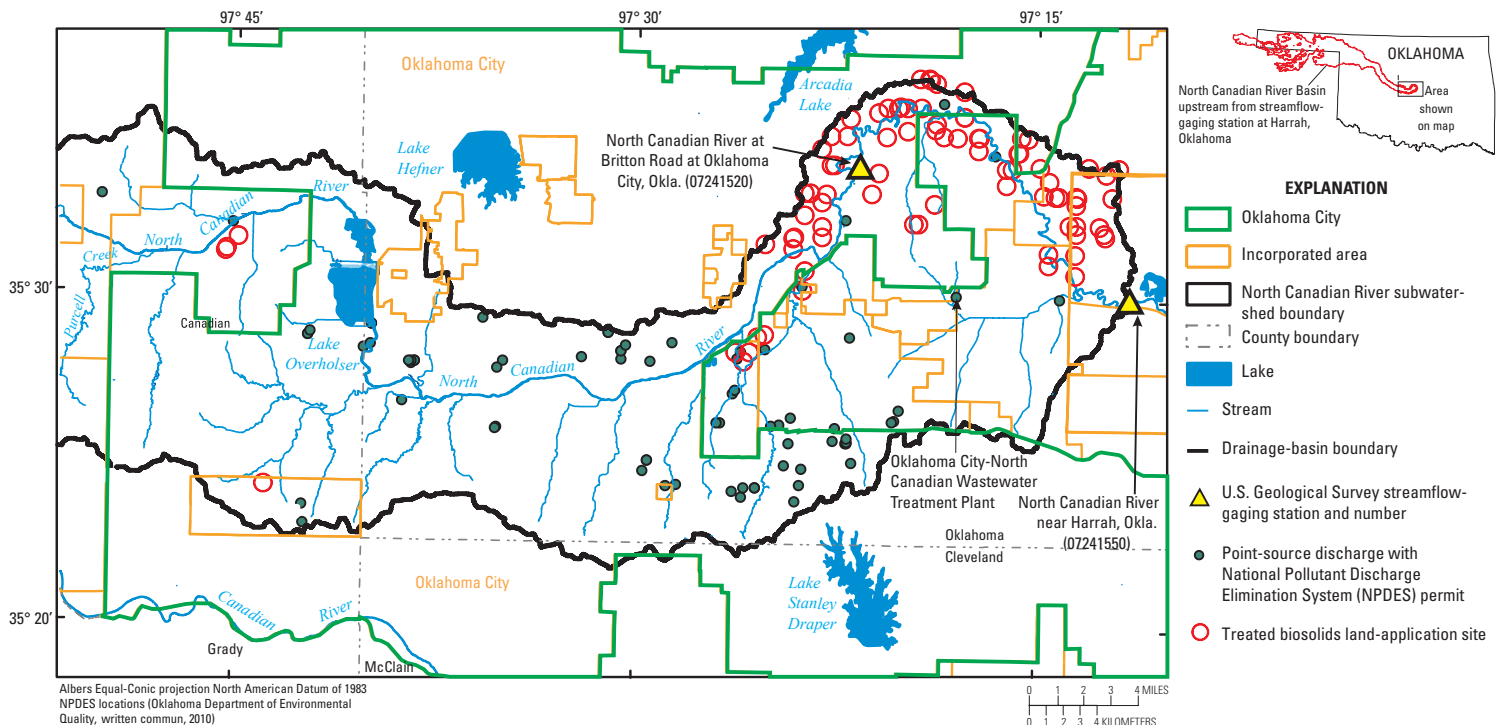
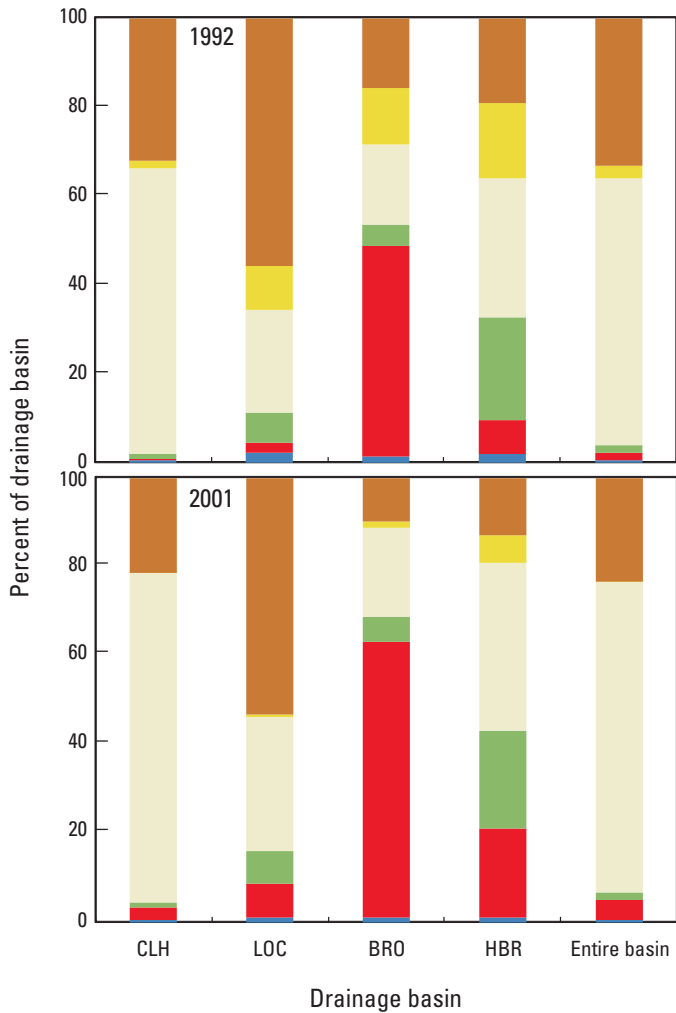


Figure 1. Locations of two sampled streamflow-gaging stations, point-source discharges, and treated biosolids land-application sites in the North Canadian River Basin near Oklahoma City, Oklahoma.



EXPLANATION

- Water/Wetland
 - Developed/Barren
 - Forest
 - Grassland/Scrub
 - Pasture/Hay
 - Cropland
- CLH—Canton Lake Dam to Headwaters
- LOC—Lake Overholser Dam to Canton Lake Dam
- BRO—Streamflow-gaging station at North Canadian River at Britton Road at Oklahoma City (07241520) to Overholser Dam
- HBR—Streamflow-gaging station at North Canadian River near Harrah (07241550) to streamflow-gaging station at Britton Road at Oklahoma City (07241520)
- Land-cover areas from National Land-Cover Datasets (U.S. Geological Survey, 2002; Homer and others, 2004)

Figure 2. Percentages of land-cover for six reclassified land-cover categories from the 1992 and 2001 National Land Cover Dataset in four subbasins of the North Canadian River Basin upstream from the North Canadian River near Harrah, Oklahoma, streamflow-gaging station.

significant downward trends in streamflow characteristics that represented lower streamflow at both stations (p-value of Kendall tau test less than or equal to 0.05 (Kendall and Gibbons, 1990)). There were no significant trends in precipitation-adjusted annual streamflow at either station.

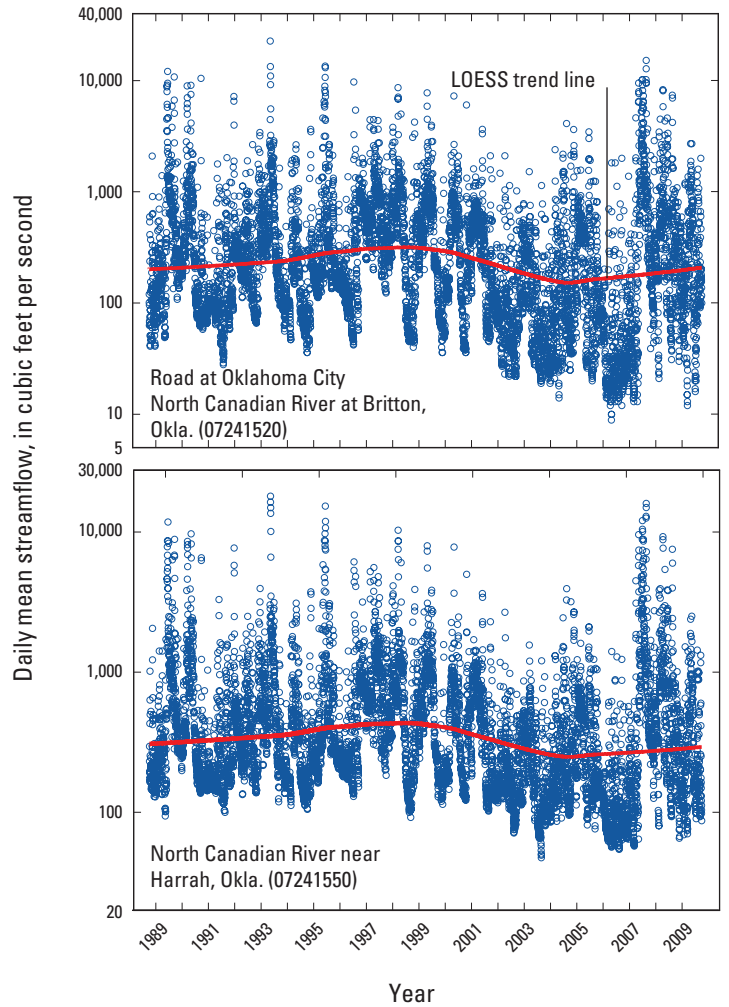


Figure 3. Daily mean streamflow at the North Canadian River at Britton Road at Oklahoma City, Oklahoma, and the North Canadian River near Harrah, Okla., streamflow-gaging stations, 1988–2009.

Water-Quality Comparisons

Statistical summaries, frequencies of detection, and percentages of samples with concentrations exceeding Criterion Continuous Concentrations (established to protect fish and other aquatic life, U.S. Environmental Protection Agency, 2010) were calculated for 157 water-quality constituents for both streamflow-gaging stations. Concentrations of dissolved chloride, lead, cadmium, and chlordane most frequently exceeded the Criterion Continuous Concentration in water-quality samples collected at both stations. Water samples collected at the Harrah station had more frequently (greater than 10 percent) detected pesticides than water samples collected at the Britton Road Station from 1988 to 2009.

Dissolved nitrogen and phosphorus concentrations, which can affect growth of aquatic plants, dissolved oxygen concentrations in water, and fish habitat, were significantly greater in water samples collected at the Harrah station than at the Britton Road station (p-values of the Wilcoxon rank-sum test less than or equal to 0.05 (Wilcoxon, 1945)), whereas, specific conductance, an indicator of total dissolved solids commonly associated with groundwater, was greater at the Britton Road station (fig. 4). Dissolved oxygen concentrations indicate suitability of water for

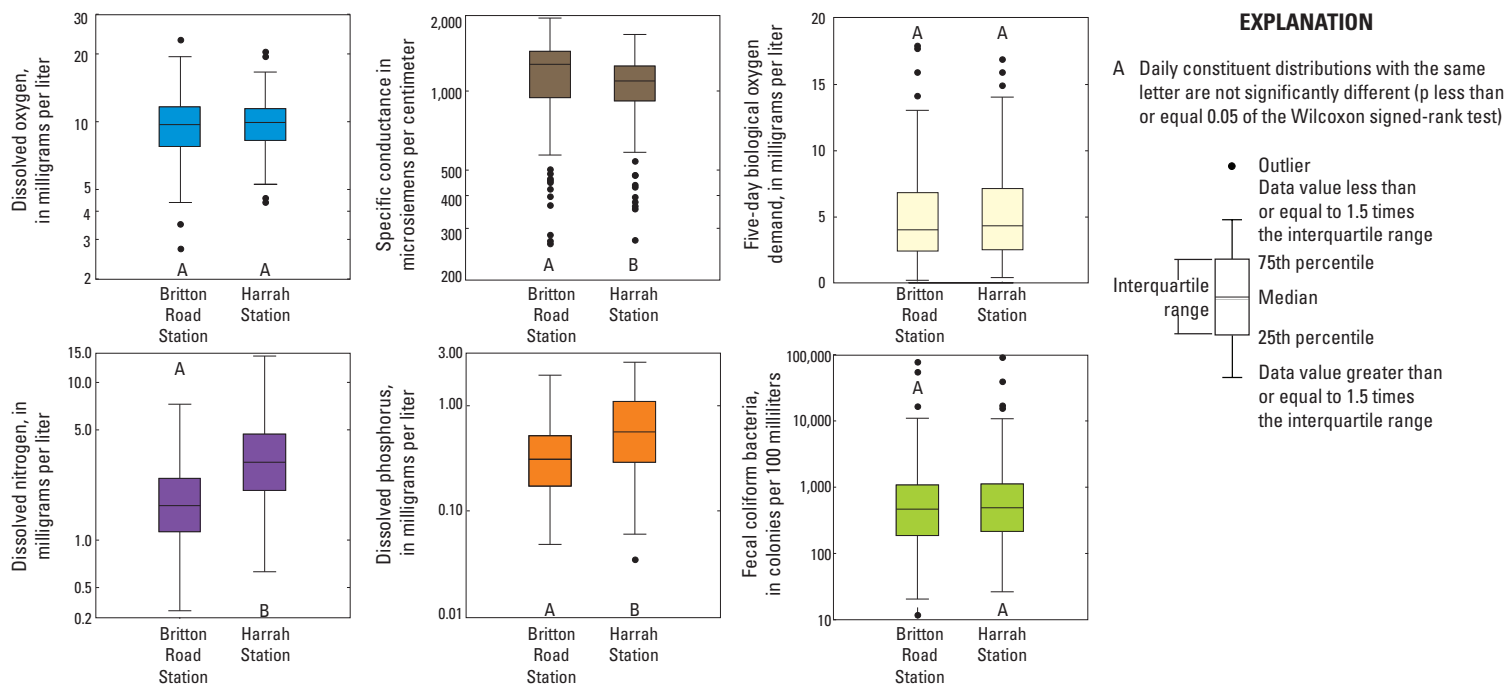


Figure 4. Distribution of concentrations of selected constituents in water samples collected at the North Canadian River at Britton Road at Oklahoma City, Oklahoma, and the North Canadian River near Harrah, Okla., streamflow-gaging stations, 1988–2009.

oxygen-breathing aquatic organisms such as fish and amphibians. Biochemical oxygen demand indicates the propensity of chemicals and microorganisms in water to consume dissolved oxygen. Fecal coliform bacteria indicate contamination of water by feces from humans, livestock, and wildlife. Concentrations of dissolved oxygen, biochemical oxygen demand, and fecal coliform bacteria were not significantly different between the Britton Road and Harrah stations. Water temperatures also can affect the suitability of water for aquatic animals, many of which are temperature-sensitive and require greater concentrations of dissolved oxygen associated with lower water temperatures. Daily minimums and maximums and diurnal fluctuations of water temperature were significantly greater at the Harrah station than at the Britton Road station. Daily maximum and diurnal range of dissolved oxygen concentrations were significantly greater at the Britton Road station than at the Harrah station.

Water-Quality Trends with Time

Based on p-values of the non-parametric Kendall tau test (Kendall and Gibbons, 1990) of less than or equal to 0.05, daily and monthly mean water temperature increased with time. Daily and monthly mean specific conductance at the two stations decreased with time. There were small downward trends in daily mean dissolved oxygen in water samples collected at both stations and low daily mean dissolved oxygen concentrations (less than 2 milligrams per liter) were measured more frequently at both stations after 1999.

Slight decreases in fecal coliform bacteria concentrations occurred from 1988-2009 in water samples collected at the Britton Road station. There were no trends with time, however, in fecal streptococcal bacteria concentrations in water samples collected at either station. Chlorophyll *a* concentrations, which commonly are used to estimate the amount of aquatic plant growth,

did not change with time at the Harrah station in water samples collected after 1987.

From 1988-2009, there was a downward trend in flow-adjusted dissolved phosphorus concentration (p-value less than or equal to 0.05) at the Britton Road station. Flow adjustment is a procedure used to normalize the concentration of a constituent to streamflow, which can change considerably over time. From 1988-98, there were no significant trends in unadjusted and flow-adjusted dissolved oxygen concentration at either station, and there were significant downward trends in unadjusted and flow-adjusted nitrogen and phosphorus concentrations. From 1999-2009, there were significant downward trends in unadjusted dissolved oxygen concentrations at both stations. From 1999-2009, there were also significant downward trends in flow- and temperature-adjusted dissolved oxygen concentrations in water samples collected at the Harrah station, significant upward trends in flow-adjusted dissolved nitrogen concentrations in water samples collected at both stations, and significant upward trends in flow-adjusted dissolved phosphorus concentrations only at the Harrah station (fig. 5). Decreases in dissolved oxygen concentrations that coincide with increases in nitrogen and phosphorus concentrations may indicate increased eutrophication (plant growth that affects aquatic habitat structure and reduces dissolved oxygen concentrations through aerobic decomposition of organic matter). In flowing streams, much of that increased growth can be in periphyton growing on solid substrates in a stream, rather than phytoplankton floating in the water, which may explain why chlorophyll-*a* concentrations in the water column did not increase significantly at the Harrah station with increases in nitrogen and phosphorus concentrations.

Annual frequencies of detection of the pesticides 2, 4-dichlorophenoxyacetic acid and bromacil increased with time. Annual frequencies of detection of atrazine, chlorpyrifos, diazinon, dichlorprop, and lindane decreased with time. Annual frequencies of detection of dieldrin, heptochlor epoxide, and simazine did not change with time.

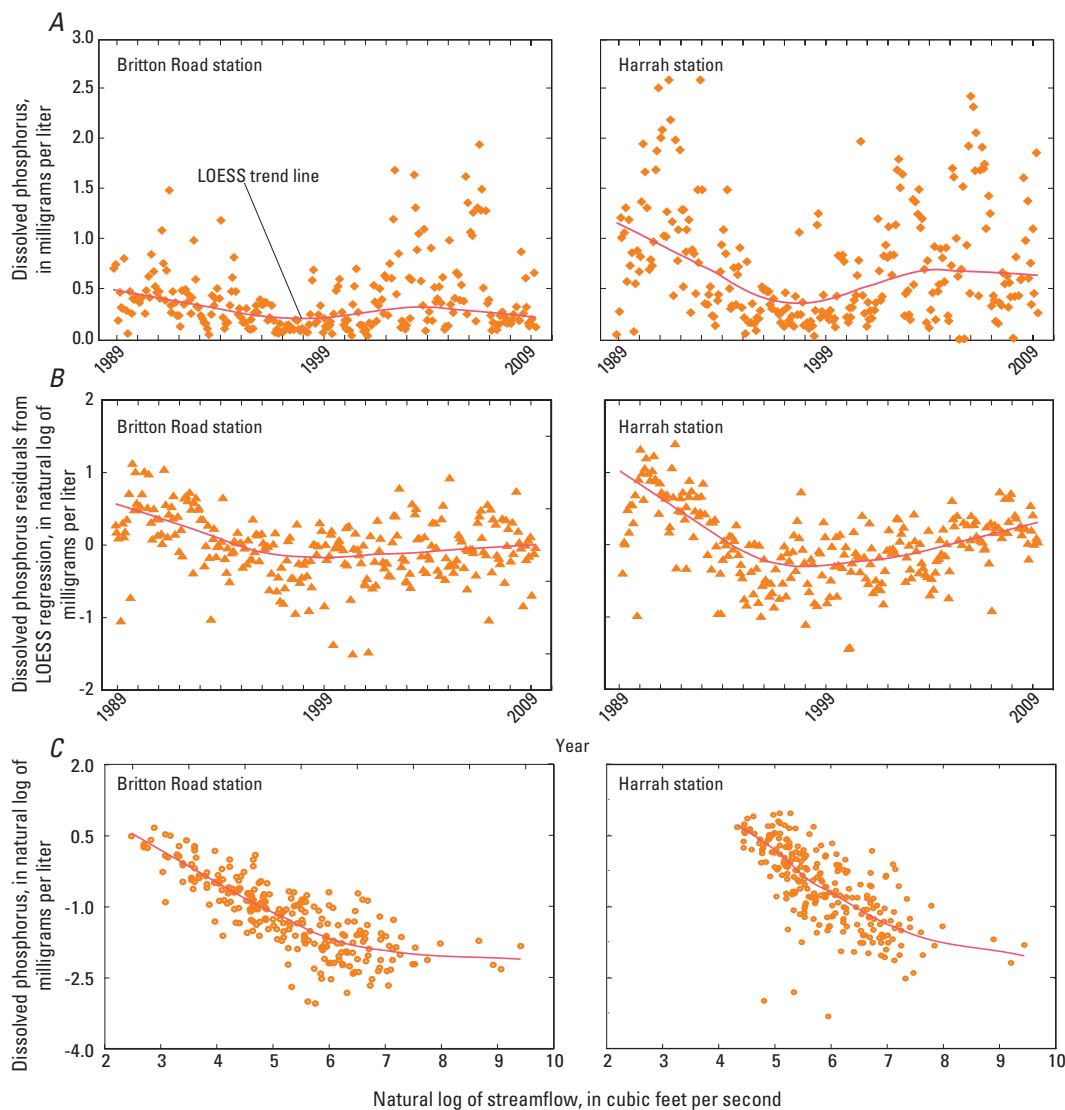


Figure 5. Trends in dissolved phosphorus at the North Canadian River at Britton Road at Oklahoma City, Oklahoma, and the North Canadian River near Harrah, Okla., streamflow-gaging stations showing *A.*, dissolved phosphorus with time; *B.*, flow-adjusted dissolved phosphorus (error residuals) from a LOESS regression; and *C.*, relation between dissolved phosphorus and streamflow.

Conclusions

Significant spatial differences and temporal trends in water quality may have been caused, in part, by increased urban development in the basins upstream from the Britton Road and Harrah stations. Decreasing dissolved oxygen concentrations coinciding with increasing nitrogen and phosphorus concentrations indicate that point and non-point sources of nitrogen and phosphorus compounds may be increasing eutrophication in the reach of the North Canadian River between those stations.

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By Rachel A. Esralew, William J. Andrews, and S. Jerrod Smith

For more information, contact:

Director
U.S. Geological Survey,
Oklahoma Water Science Center
202 NW 66th Street
Oklahoma City, OK 73116
405-810-4400
<http://ok.water.usgs.gov>