Water Quality in the Trinity River Basin

Texas, 1992–95

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

Circular 1171

A COORDINATED EFFORT

Coordination among agencies and organizations is an integral part of the NAWQA Program. We thank the following agencies and organizations who contributed through their participation in the Study Unit Liaison Committee.

Federal Agencies:

- U.S. Army Corps of Engineers
- U.S. Department of Agriculture, Natural Resources Conservation Service
- U.S. Department of the Interior, Bureau of Reclamation
- U.S. Environmental Protection Agency
- U.S. Fish and Wildlife Service

State Agencies:

- Railroad Commission of Texas
- Texas Department of Agriculture
- Texas Natural Resource Conservation Commission
- Texas Parks and Wildlife Department
- Texas State Soil and Water Conservation Board
- Texas Water Development Board

Local Organizations:

- City of Arlington
- City of Fort Worth
- City of Irving
- Dallas Water Utilities Department
- Tarrant County Water Control and Improvement District No. 1
- Trinity River Authority

Universities and other organizations:

- Galveston Bay National Estuary Program
- North Central Texas Council of Governments
- Texas Water Resources Institute
- University of North Texas
- University of Texas at Austin

Summary of compound detections and concentrations tables (p. 30–35) were provided by Sarah J. Ryker, Jonathon C. Scott, and Alan L. Haggland.

Editing, graphics, and report-processing support were provided by Gloria J. Smith, Stanley H. Crenwelge, Peter W. Bush, Gail J. Sladek, and Judy A. Voigt.

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Information on the NAWQA Program is also available on the Internet via the World Wide Web. You may connect to the NAWQA Home Page using the Universal Resources Locator (URL):
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The Trinity River Basin Study Unit's Home Page is at URL:
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Front cover: Dallas skyline at dusk. The channelized Trinity River is in foreground. *(Photograph courtesy of TEXAS HIGHWAYS Magazine. © by Richard Stockton. Used with permission.)*

Back cover: Longhorns grazing north of Denton. *(Photograph by Larry F. Land, U.S. Geological Survey.)*

Water Quality in the Trinity River Basin, Texas, 1992–95

By Larry F. Land, J. Bruce Moring, Peter C. Van Metre, David C. Reutter, Barbara J. Mahler, Allison A. Shipp, *and* Randy L. Ulery

U.S. GEOLOGICAL SURVEY CIRCULAR 1171

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BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY

Thomas J. Casadevall, Acting Director

1998

Free on application to the
U.S. Geological Survey
Information Services
Box 25286 Federal Center
Denver, CO 80225

Library of Congress Cataloging in Publications Data

Water quality in the Trinity River Basin, Texas, 1992–95 / by Larry F. Land ... [et al.].

p. cm.— (U.S. Geological Survey circular ; 1171)

ISBN 0–607–89233–1 (pbk.)

1. Water quality—Texas—Trinity River watershed. I. Land, Larry F.

II. Series.

TD224.T4W378 1998

363.739'42'0976414—dc21 98–4639

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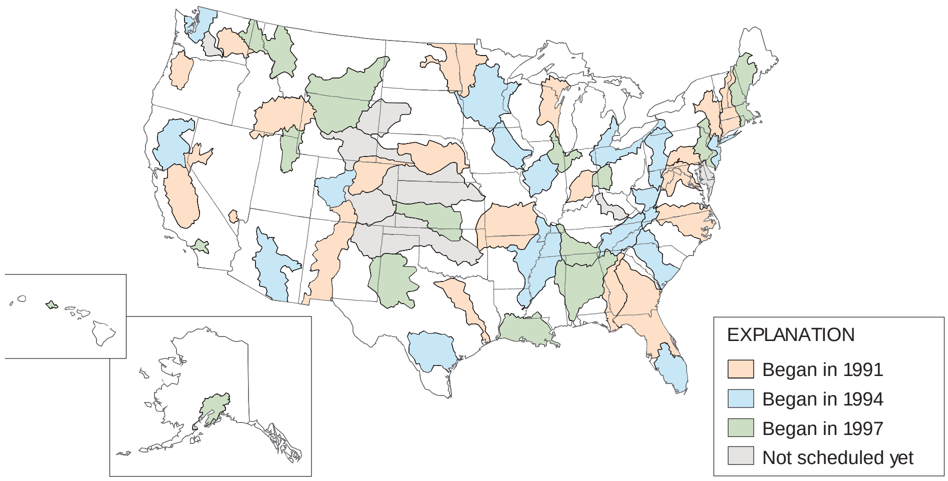


Knowledge of the quality of the Nation's streams and aquifers is important because of the implications to human and aquatic health and because of the significant costs associated with decisions involving land and water management, conservation, and regulation. In 1991, the U.S. Congress appropriated funds for the U.S. Geological Survey (USGS) to begin the National Water-Quality Assessment (NAWQA) Program to help meet the continuing need for sound, scientific information on the areal extent of the water-quality problems, how these problems are changing with time, and an understanding of the effects of human actions and natural factors on water-quality conditions.

The NAWQA Program is assessing the water-quality conditions of more than 50 of the Nation's largest river basins and aquifers, known as Study Units. Collectively, these Study Units cover about one-half of the United States and include sources of drinking water used by about 70 percent of the U.S. population. Comprehensive assessments of about one-third of the Study Units are ongoing at a given time. Each Study Unit is scheduled to be revisited every decade to evaluate changes in water-quality conditions. NAWQA studies rely heavily on existing information collected by the USGS and many other agencies as well as the use of nationally consistent study designs and methods of sampling and analysis. Such consistency simultaneously provides information about the status and trends in water-quality conditions in a particular stream or aquifer and, more importantly, provides the basis to make comparisons among watersheds and improve our understanding of the factors that affect water-quality conditions regionally and nationally.

This report is intended to summarize major findings that emerged between 1992 and 1995 from the water-quality assessment of the Trinity River Basin Study Unit and to relate these findings to water-quality issues of regional and national concern. The information is primarily intended for those who are involved in water-resource management. Indeed, this report addresses many of the concerns raised by regulators, water-utility managers, industry representatives, and other scientists, engineers, public officials, and members of stakeholder groups who provided advice and input to the USGS during this NAWQA Study Unit investigation. Yet, the information contained here might also interest those who simply wish to know more about the quality of water in the rivers and aquifers in the area where they live.

Robert M. Hirsch, Chief Hydrologist

"The USGS Trinity NAWQA Program has been an invaluable resource for the Texas Natural Resource Conservation Commission and the Texas Clean Rivers Program. Since 1993, NAWQA hydrologists and biologists have provided the TNRCC staff and Texas Clean Rivers Program partners with their technical expertise on data analysis procedures and monitoring and assessment protocols. As the challenges in data assessment and monitoring continue for the Texas Clean Rivers Program, the TNRCC will look to the USGS and the lessons learned from the Trinity NAWQA Program."

Sally C. Gutierrez,
Director,
Water Quality Division
Texas Natural Resource
Conservation Commission

Nutrients in streams (p. 6–7)

Nutrients in tributary streams rarely are at concentrations unacceptable for drinking water.

- Total nitrogen concentrations are similar in urban and agricultural streams and are larger in urban and agricultural streams than in streams in rangeland and forest areas.
- The only samples with nitrate concentrations greater than the U.S. Environmental Protection Agency (EPA) drinking-water standard are from Calloway Branch (an urban stream) and the Trinity River downstream from Dallas (affected by point sources).
- Total phosphorus concentrations are similar in all tributaries, regardless of land use.
- Nutrient concentrations in streams vary seasonally and are as much as 100 percent greater during the spring than during the winter.

Pesticides in streams (p. 8–9)

Pesticides are in most streams. Much of the streamflow is captured by reservoirs, which are sources of drinking water.

- Four to six herbicides commonly were detected in streams draining urban and agricultural areas. Atrazine was detected in samples from all streams draining urban and agricultural areas. Atrazine concentrations in agricultural streams often exceed the drinking-water standard during the spring when atrazine is applied to fields and rains producing runoff are most common.
- Two to four insecticides commonly were detected in streams draining urban areas, and usually no more than one insecticide was detected in streams draining agricultural areas. Diazinon is in all samples from streams draining urban areas. Diazinon concentrations in urban streams exceed the EPA health advisory level for drinking water in 15 percent of samples.

Determining water-quality trends using sediment cores (p. 10–11)

Lead, DDT, and polychlorinated biphenyl (PCB) concentrations have decreased, but chlordane, polycyclic aromatic hydrocarbon (PAH), and zinc concentrations have increased in sediments from urban streams since the mid-1960s.

- Environmental trends in contaminants tend to follow historical use. For example, lead concentrations in a White Rock Lake sediment core peaked in the 1970s at about 5 times background concentrations and decreased since the introduction of unleaded gasoline to about 2 times background concentrations by the early 1990s.
- DDT and PCB concentrations have decreased about 90 percent in the White Rock Lake core since their use was banned in the 1970s.
- Chlordane concentrations increased in response to urban growth and increasing use of chlordane during the 1970s and 1980s and peaked soon after use was banned in the late 1980s.
- PAH concentrations in the White Rock Lake sediment core are 20 times greater in recent sediments than in pre-urbanization sediments, and zinc concentrations have increased about 60 percent. Both probably result largely from automobile use in the watershed.

Organochlorines in streambed sediments and aquatic biota (p. 12–13)

Concentrations of some toxic compounds in sediments commonly exceed Texas Natural Resource Conservation Commission screening concentrations.

- Concentrations of chlordane, dieldrin, and the DDT environmental degradation products, DDD and DDE, in bed sediment are larger in streams draining urban areas than in streams draining agricultural areas and exceed Texas Natural Resource Conservation Commission screening concentrations for these compounds in sediment.
- Chlordane, DDT, and PCBs are more commonly detected in fish in streams draining urban areas than agricultural areas.

Stream-habitat characteristics and fish-community degradation (p. 14–16)

Fish communities are affected by characteristics of streamflow and the structure of physical habitats in the stream channel, in addition to water chemistry. In streams where historical patterns of streamflow have been altered by channelization, degradation in the fish community has occurred.

- Streams in developed urban and agricultural settings generally have more variable streamflow, more degraded and less diverse physical habitats, and more degraded fish communities than comparable streams in less-developed settings.
- The urban stream West Fork Trinity River in Fort Worth has highly variable streamflow, is channelized with little or no meandering, has few woody snags in the stream, and has low woody-species diversity in the riparian zone. As a result, more nonnative and generally more pollutant-tolerant species of fish are in this stream than in comparable natural streams.
- The Blackland Prairie stream Chambers Creek is channelized and leveed in its lower reach, which has reduced the structural complexity of physical habitat. A high percentage of tolerant fish species are present in this reach of Chambers Creek.

Use of a new method, semipermeable membrane device (SPMD), to assess the occurrence of water-borne PAHs in streams (p. 17–18)

The SPMD is an effective tool to detect trace organic compounds in water. The small concentrations of many compounds in streams might not be detected by more traditional water-sampling techniques.

- Twenty-five PAHs were detected in SPMDs deployed in urban streams in the Dallas-Fort Worth metropolitan area.
- Nine of the PAHs detected by the SPMDs are on the Public Health Service Agency for Toxic Substances and Disease Registry priority list of 275 hazardous substances, and two, benzo(*a*)pyrene and benzo(*b*)fluoranthene, are ranked in the top 10.

Fish-community changes reflect water-quality improvements (p. 19–21)

Improvements in the treatment of wastewater in the Dallas-Fort Worth area from the early 1970s through the mid-1990s have been beneficial to the water quality of the Trinity River.

- Ammonia plus organic nitrogen concentrations in the Trinity River downstream from Dallas have decreased about 95 percent from more than 10 milligrams per liter in the 1970s to near trace concentrations in the mid-1990s.
- Dissolved oxygen conditions in the Trinity River downstream from Dallas have improved vastly from the 1970s, when occurrences of nearly no dissolved oxygen were common, to the mid-1990s, when concentrations were almost never less than 5 milligrams per liter.
- The fish community has improved markedly since the mid-1980s when several fishkills occurred. Now (1998), many native species of fish that were absent in the 1970s have returned to the Trinity River downstream from Dallas.

Quality of ground water in aquifer outcrops (p. 22–23)

Pesticide, volatile organic compound (VOC), and elevated nutrient concentrations were present in some shallow (outcrop) water wells in urban and agricultural areas; however, most samples did not exceed drinking-water standards.

- About 10 to 30 percent of samples from the shallow zone (outcrop) of each of four aquifers contained herbicides, and about 5 to 50 percent contained insecticides. None of the pesticide concentrations in samples of shallow ground water exceeded drinking-water standards or health advisory levels. Thirteen percent of nitrate concentrations in the shallow zone of the Woodbine aquifer exceeded the EPA standard for drinking water.
- VOCs were detected in one or more samples from each of the four aquifers sampled. The most commonly detected VOC was MTBE, a gasoline additive, in the urban part of the Woodbine aquifer.
- None of the samples from the Trinity aquifer exceeded EPA maximum contaminant levels for drinking water; however, the insecticide diazinon was detected in nearly one-half the samples.

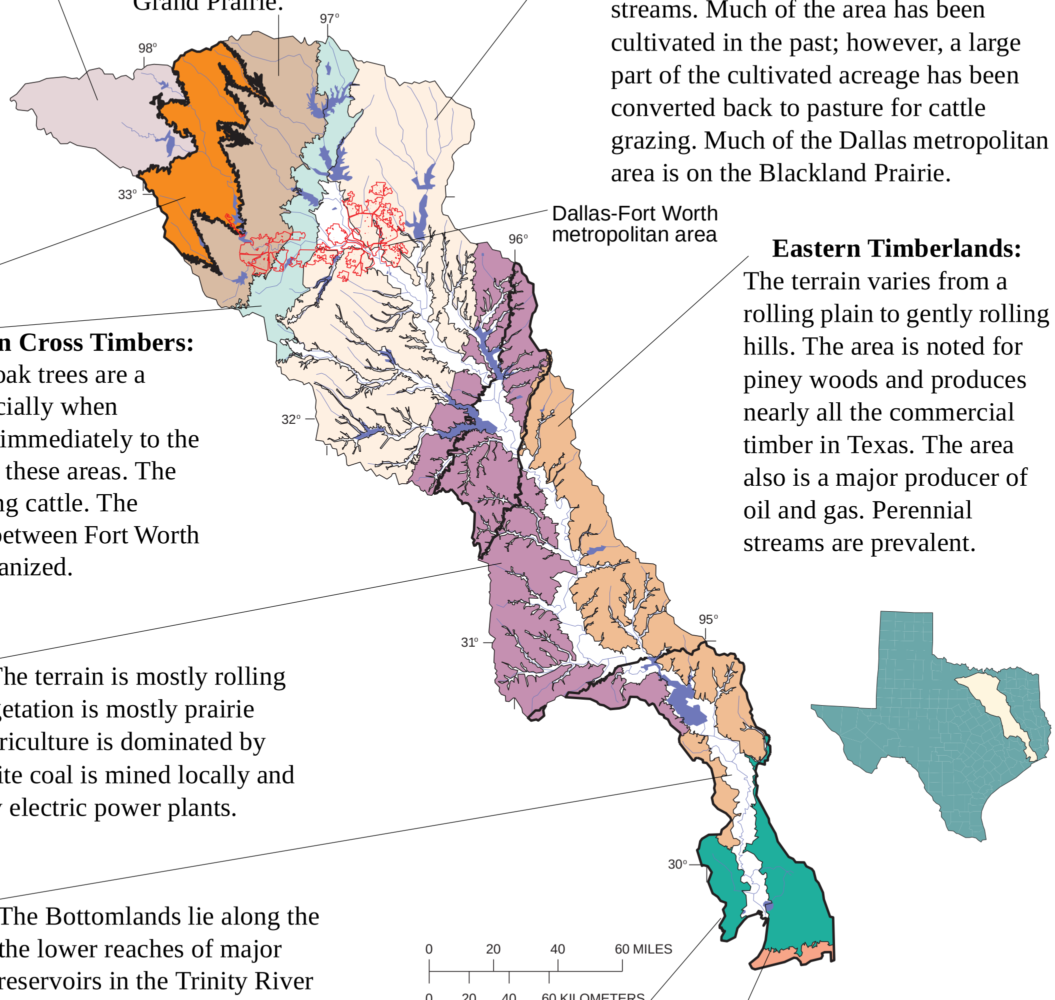
ENVIRONMENTAL SETTING AND HYDROLOGIC CONDITIONS IN THE TRINITY RIVER BASIN

The environmental setting is an integration of many physical and hydrologic features and human activities. Physical and hydrologic features include location, topography, physiography, geology, soils, climate, natural vegetation, streams, and aquifers. A classification of Integrated Land Resource Units characterizes the physical and hydrologic features (Ulery and others, 1993). Past and current human activities, including construction of reservoirs, urbanization, farming, ranching, and oil and gas production, have greatly altered the natural environment in the Trinity River Basin.

North Central Prairie: The terrain is nearly level to hilly and covered with natural vegetation, which mostly is prairie grass. However, brush has encroached into much of the area. Substantial amounts of oil and gas are produced in the area. The principal agricultural product is cattle.

Grand Prairie: The terrain is characterized by nearly level plains and rolling hills and is naturally devoid of trees except along streams. Much of Fort Worth is located on the Grand Prairie.

Blackland Prairie: The terrain varies from nearly level to rolling hills, has very fertile soils, and, in its natural state, is largely a grassy plain except along the streams. Much of the area has been cultivated in the past; however, a large part of the cultivated acreage has been converted back to pasture for cattle grazing. Much of the Dallas metropolitan area is on the Blackland Prairie.



Western and Eastern Cross Timbers: The terrain is hilly and oak trees are a prominent feature, especially when contrasted with prairies immediately to the east and west of each of these areas. The area is suitable for raising cattle. The Eastern Cross Timbers between Fort Worth and Dallas has been urbanized.

Eastern Timberlands: The terrain varies from a rolling plain to gently rolling hills. The area is noted for piney woods and produces nearly all the commercial timber in Texas. The area also is a major producer of oil and gas. Perennial streams are prevalent.

Texas Claypan: The terrain is mostly rolling hills. The natural vegetation is mostly prairie grasses and oaks. Agriculture is dominated by cattle ranching. Lignite coal is mined locally and is used to fuel nearby electric power plants.

Bottomlands: The Bottomlands lie along the Trinity River and the lower reaches of major tributaries. Many reservoirs in the Trinity River Basin have greatly reduced the historical magnitude and frequency of floods in the Bottomlands.

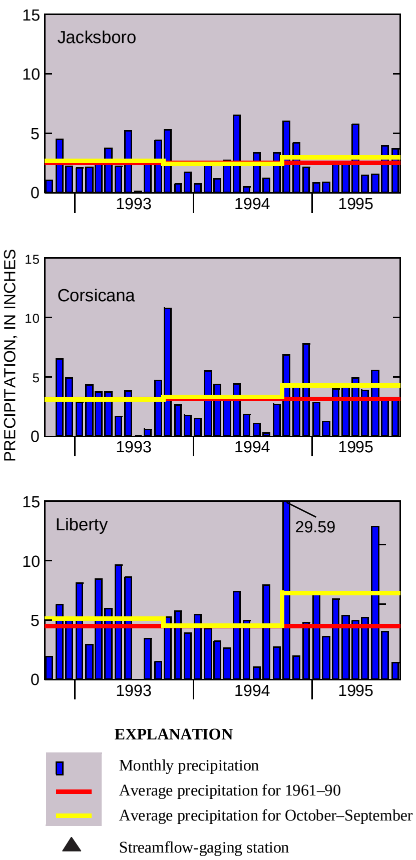
Coastal Prairie and Marsh: The area is very flat. Natural vegetation is prairie grasses with stands of hardwoods and pines. The area is extensively cultivated for growing rice. However, much of the cultivated acreage is being converted to pasture for cattle grazing. Oil and gas also are produced in the area.

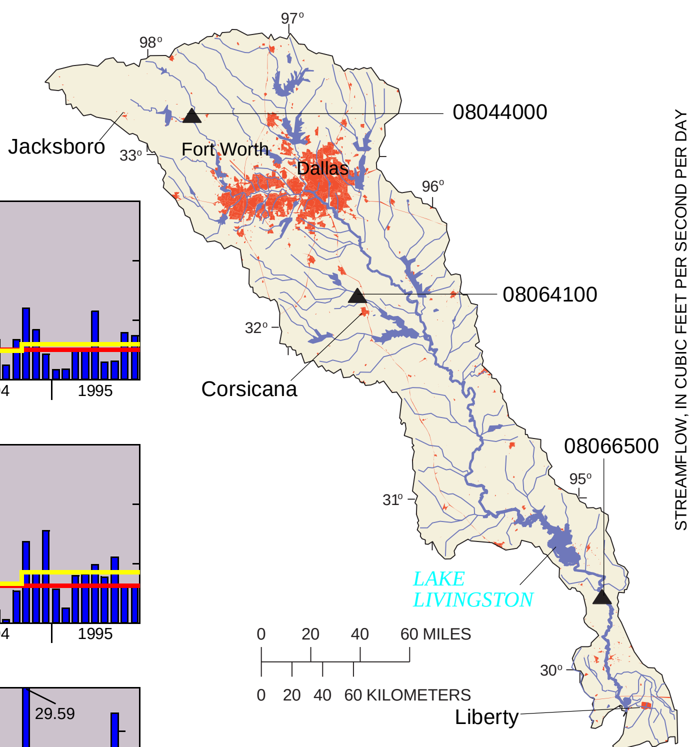
Surface water, almost entirely from reservoirs, supplies more than 90 percent of the water used in the basin. With the large population and concentration of businesses and industries in the Dallas-Fort Worth area, many reservoirs have been built for water supply and flood protection. Relatively little water is used for irrigating crops. Aquifers outcrop in all or parts of the Western and Eastern Cross Timbers, Eastern Timberlands, Texas Claypan, and Coastal Prairie and Marsh. Ground water is used for municipal and domestic supply in some of the smaller towns and in rural areas.

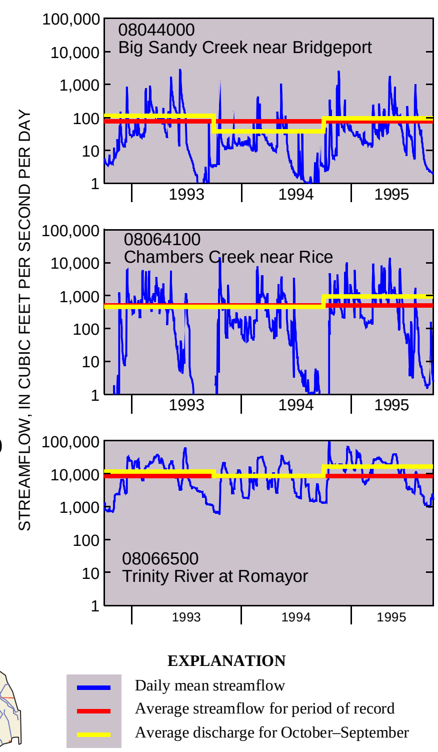
Hydrologic conditions in the Trinity River Basin are best characterized by precipitation and streamflow. Precipitation varies considerably across the Study Unit, with average annual rainfall ranging from about 27 inches in the northwestern part to about 52 inches in the southeastern part. Streamflow generally is proportional to precipitation and the size of the watershed, except downstream from reservoirs and point sources such as wastewater-treatment plants. To characterize the hydrologic conditions in the Trinity River Basin during the March 1993–September 1995 intensive sampling phase, monthly precipitation and daily streamflow from October 1992 to September 1995 at selected stations are graphed and interpreted.

Precipitation: Essentially all the precipitation in the Trinity River Basin is rain. At the three selected precipitation sites across the basin, rainfall was about normal in 1993 and 1994 and about one-third greater than normal in 1995. The greatest flooding occurred in October 1994 in the southern part of the study area where 18.5 inches was recorded in 1 day and more than 26 inches in 3 days. The rainfall data suggest that water-quality data collected during and shortly after the October 1994 flood would reflect unusual hydrologic conditions.

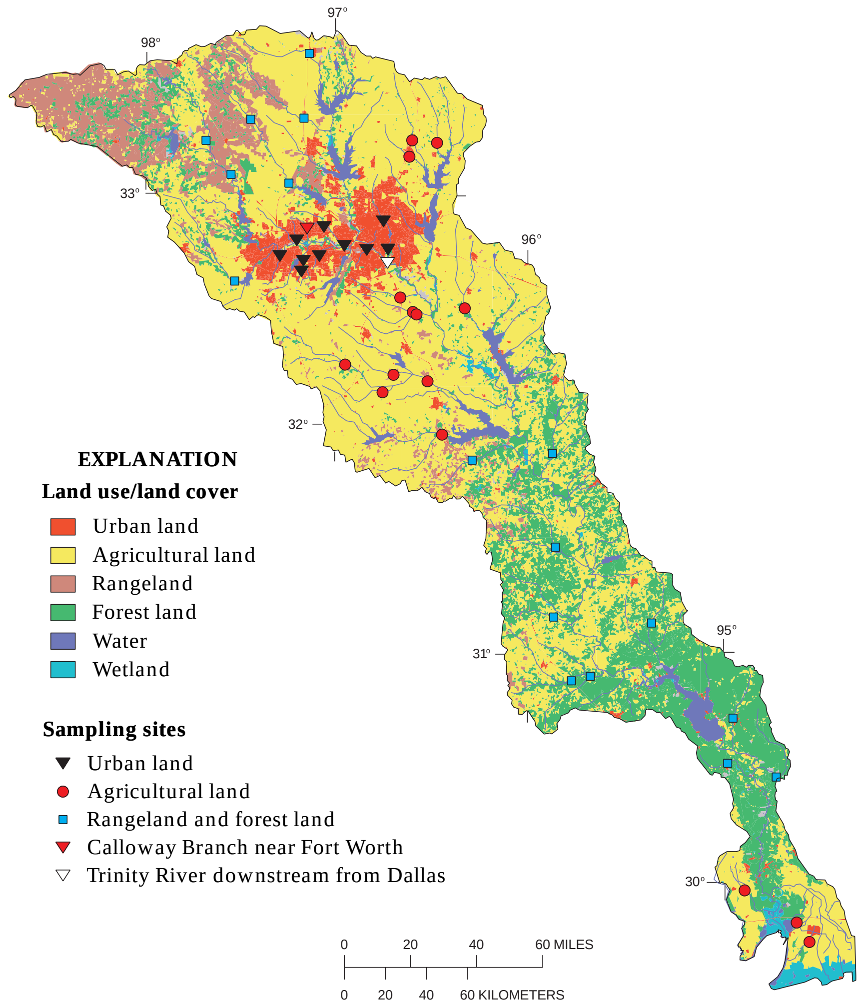
Streamflow: Two stream configurations are in the Trinity River Basin; one is tributary streams and the other is the main stem of the Trinity River. Much of the water in tributary streams is captured by reservoirs and becomes a water supply. Water in the main stem provides water to Lake Livingston, also used for water supply, and to coastal bays and estuaries. The hydrographs for two tributaries, Big Sandy Creek and Chambers Creek, show streamflow decreases to relatively low levels each year during the summer. Flow in the Trinity River at Romayor, about 70 miles upstream from the mouth, is controlled by releases from Lake Livingston. The hydrographs indicate that data collected during the sampling period are representative of normal conditions, except during 1995 in the lower reach of the Trinity River when flows were well above average.







Reservoirs: There are 22 reservoirs in the Trinity River Basin with more than 10,000 acre-feet of storage and hundreds of smaller reservoirs, mostly flood-control structures built by the Natural Resources Conservation Service (Ulery and others, 1993). These reservoirs have an appreciable effect on streamflow and water quality in the basin. They tend to increase base flow in streams by releasing stored water during dry periods. They tend to reduce flood peaks by storing floodwaters. They affect water quality by trapping sediment and associated nutrients and contaminants and by altering the stream habitat both in the flooded lake area and downstream.



Nutrient sampling sites on streams of the Trinity River Basin during 1993–95. The greatest density of sites is in agricultural and urban areas.

Nutrients (nitrogen and phosphorus compounds) in surface water are essential for aquatic plant and animal life; but large concentrations of nutrients can have adverse ecological effects. Fertilizer, manure, plant decay, and atmospheric fallout are major nonpoint sources of nitrogen and phosphorus. Wastewater-treatment plant effluent is a major point source.

The EPA (1996) maximum contaminant level (MCL) for nitrate (as nitrogen) is 10 milligrams per liter. Excessive nitrate can restrict oxygen transport in the bloodstream. Ammonia in surface water is naturally converted to nitrate. This conversion, in addition to increasing nitrate concentration, removes oxygen from the water, which also can adversely affect fish and invertebrates.

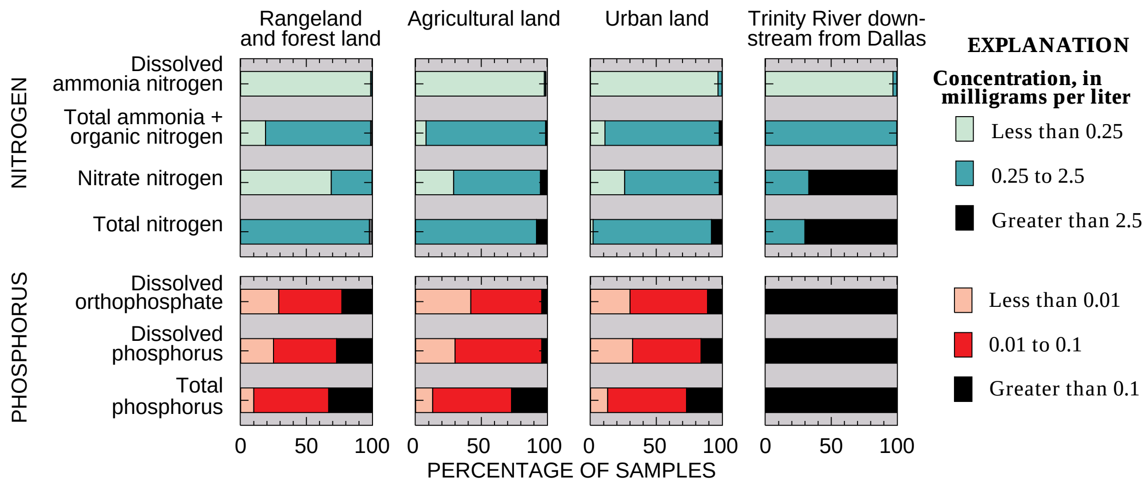
The EPA recommends that total phosphorus concentration (as phosphorus) not exceed 0.10 milligram per liter in streams not discharging directly into reservoirs and not exceed 0.05 milligram per liter in streams discharging directly into reservoirs. Phosphorus commonly is associated with eutrophication—the enrichment of a body of water with nutrients resulting in accelerated algal or plant production. Eutrophication can result in fishkills, unpleasant odors, loss of recreational value, and other water-quality-related problems.

Water samples of tributary streams draining rangeland and forest land, agricultural land, and urban land, and of the Trinity River downstream from Dallas were collected from March 1993 to September 1995. For nitrate, only two samples exceeded the MCL; one was from Calloway Branch, a small urban stream northeast of Fort Worth, and the other was from the Trinity River downstream from Dallas.

Only 2 of 480 samples from 44 stream sites had nitrate concentrations that exceeded 1996 EPA maximum contaminant levels.

Most nitrate (as nitrogen) concentrations were less than 2.5 milligrams per liter. The distribution patterns of total nitrogen and three nitrogen species in the tributary streams draining agricultural and urban areas were very similar. Tributary streams draining rangeland and forest land had fewer samples with concentrations greater than 2.5 milligrams per liter, a result that is attributed to lesser amounts of fertilizer applied in rangeland and forest land than in agricultural and urban lands. Samples from the Trinity River downstream from Dallas, where the streamflow is dominated by effluent from regional wastewater-treatment plants, had appreciably greater concentrations of nitrate and total nitrogen than streams affected only by nonpoint sources (Shipp, 1995a).

About 30 percent of the total phosphorus samples from tributary streams draining the three land-use areas had concentrations greater than the EPA guideline, and all the samples from the Trinity River downstream from Dallas had concentrations greater than the EPA guideline. For the 10 sampling sites on tributaries that flow directly into reservoirs, concentrations in about 50 percent of the samples exceeded the EPA guideline. The distributions of total and dissolved phosphorus and orthophosphate concentrations were similar for tributary streams draining urban, rangeland, and forest land. In agricultural areas, fewer sample concentrations were greater than 0.10 milligram per liter. Within the agricultural area, concentrations of total phosphorus (and total nitrogen) tend to increase as the percentage of cropland increases.



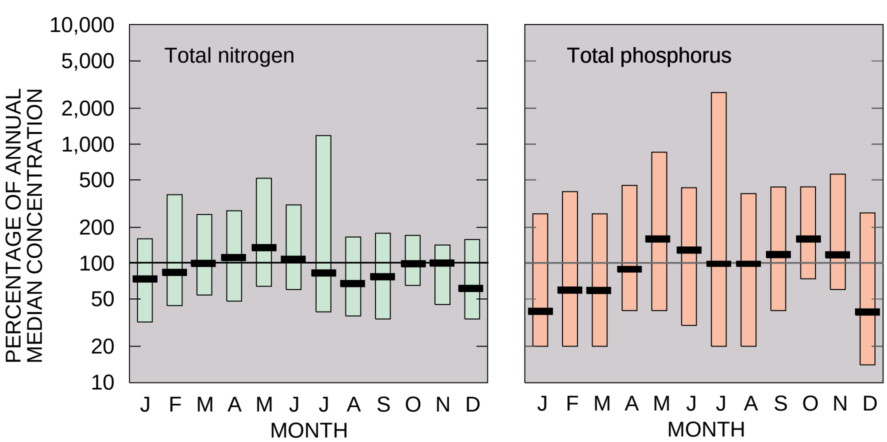
Distributions of nitrogen and phosphorus concentrations in streams of the Trinity River Basin during 1993–95 reflect agricultural and urban land-use practices.

The largest nutrient concentrations were downstream from wastewater point sources, and the smallest nutrient concentrations were immediately downstream from reservoirs.

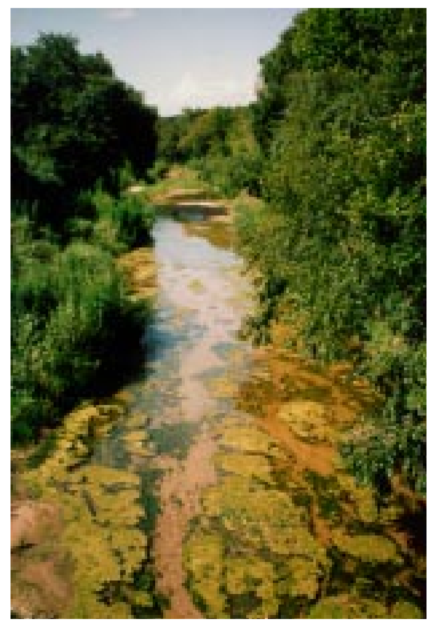
Total nitrogen and total phosphorus concentrations show noticeable seasonal patterns (Land and Shipp, 1996). Median total nitrogen concentrations increase from midwinter to midspring, decline in the summer, and increase again in the fall; median total phosphorus concentrations follow a generally similar pattern. Because much greater amounts of fertilizer are applied in the spring than in other seasons, the timing of the applications would seem to be the major reason for increases in concentrations in the spring. However, total nitrogen and (especially) total phosphorus concentrations were found to relate more closely to streamflow than to fertilizer applications. Monthly mean streamflow usually peaks in the spring, declines in the summer, and rises to a lesser peak in the fall.

Nutrient concentrations at most sampling sites did not change appreciably from 1974 to 1991.

Nutrient concentrations at most sampling sites did not change appreciably from 1974 to 1991 (Van Metre and Reutter, 1995). The exceptions are five sites downstream from major wastewater-treatment plants in the Dallas area. As a result of upgrades to the treatment plants, ammonia plus organic nitrogen at the sampling sites decreased about 95 percent; concurrently, nitrate increased by a similar magnitude. The decrease in ammonia has led to an increase in dissolved oxygen, which reduces the threat of fishkills downstream from the wastewater-treatment plants.



Seasonality of nitrogen and phosphorus concentrations in streams of the Trinity River Basin during 1993–95. Each bar shows the range between the 10th and 90th percentiles. The black line in each bar shows the monthly median concentration as a percentage of the annual median.

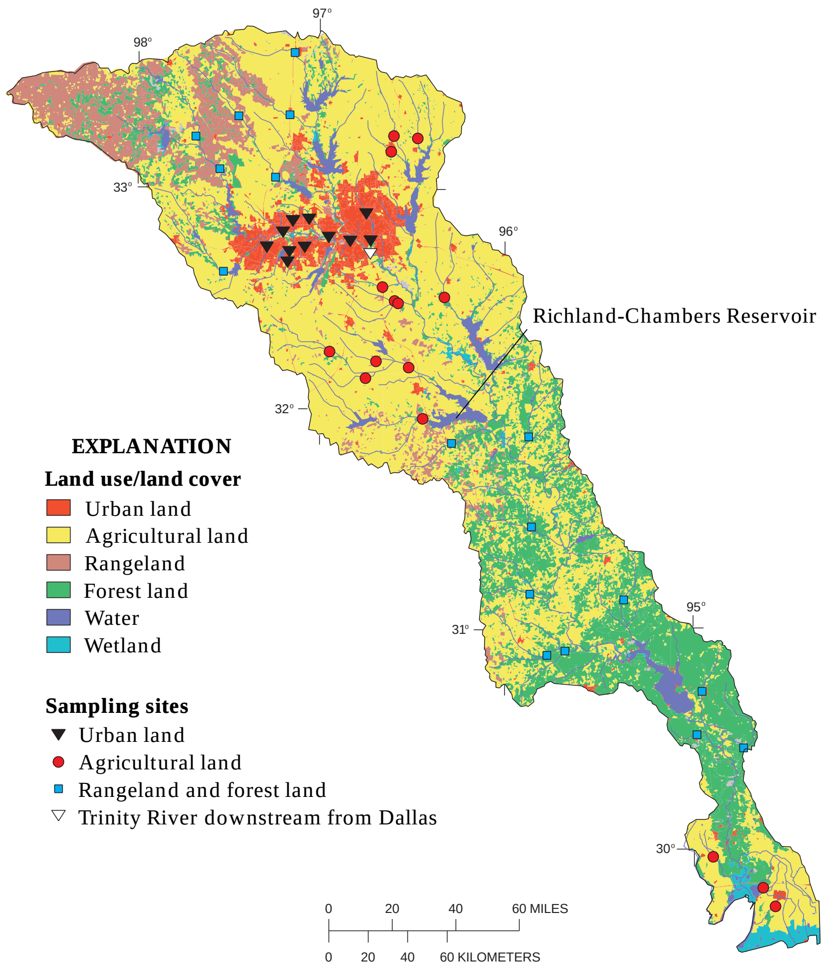


An algal bloom in Richland Creek is indicative of excess nutrients.

Pesticides (herbicides, insecticides, and fungicides) are present in streams throughout the basin (Shipp, 1995b; Ulery and Brown, 1995). Herbicides are used to control nuisance plants. In agricultural areas, they commonly are applied to the soil in late winter or early spring and during the growing season to improve crop yields and quality. In urban areas, they are used to control weeds in lawns and unwanted vegetation along streets and highways to improve safety and reduce maintenance. Insecticides are used to control insects that might damage crops, landscaping, and buildings or cause disease in humans and animals. Modern insecticides are designed to decompose into less harmful products faster than many older insecticides. Fungicides are used to control plants such as molds and mildews. Even though pesticides are very useful, they can be harmful to humans, domestic animals and wildlife, desirable plants and insects, and whole ecosystems.

In most streams of the Trinity Basin, herbicides are more prevalent than insecticides—the number of herbicide detections was greater than the number of insecticide detections. The most commonly detected herbicide in 284 samples collected from March 1993 to September 1995 is atrazine. Atrazine typically is used on fields of corn, hay, and sorghum and on lawns. Atrazine was detected in about one-half the 38 samples from 17 rangeland and forest stream sites, in more than 95 percent of the 148 samples from 15 agricultural stream sites, in all 75 samples from 11 urban stream sites, and in all 16 samples from a site on the Trinity River downstream from Dallas. The EPA 1996 MCL for atrazine is 3.0 micrograms per liter. Generally, the agricultural stream samples had larger atrazine concentrations than samples from rangeland and forest streams, urban streams, or the Trinity River downstream from Dallas. About 12 percent of the agricultural stream samples had atrazine concentrations greater than the MCL; none of the samples from rangeland and forest streams, urban streams, and the Trinity River downstream from Dallas had atrazine concentrations greater than the MCL.

About 6 percent of 277 samples from 44 stream sites had concentrations of atrazine, the most commonly detected herbicide, that exceeded the 1996 EPA MCL.

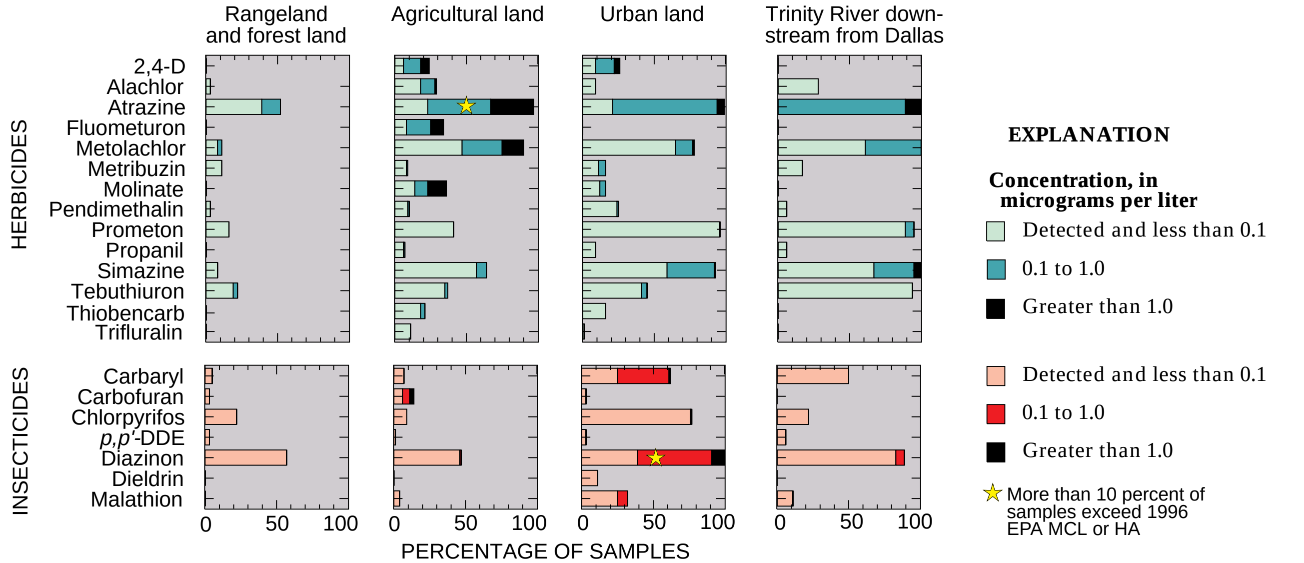


Pesticide sampling sites on streams of the Trinity River Basin during 1993–95. The greatest density of sites is in agricultural and urban areas.

Atrazine concentrations show a seasonal pattern. Concentrations tend to rise to seasonal highs in the spring and then decline to seasonal lows that last from late summer through midwinter (Land and Brown, 1996). The median atrazine concentration among all samples was 0.26 microgram per liter. The highest monthly median concentration, in April, was about 70 percent of the MCL for atrazine; monthly median concentrations from late summer to midwinter were less than one-tenth of the April median concentration.

The most commonly detected insecticide in the 277 samples was diazinon. Diazinon generally is applied to lawns, gardens, and landscaped areas. Diazinon was detected in about one-half of the rangeland and forest samples and agricultural samples, in all the urban samples, and in about 90 percent of the Trinity River downstream from Dallas samples. The EPA 1996 lifetime health advisory (HA) (the concentration in drinking water that is not expected to cause any adverse noncarcinogenic effects over a lifetime of exposure) for diazinon is 0.6 microgram per liter.

About 4 percent of 277 samples from 44 stream sites had concentrations of diazinon, the most commonly detected insecticide, that exceeded the 1996 EPA HA.



Distributions of selected herbicides and pesticides in streams of the Trinity River Basin during 1993–95 are related to land-use practices.

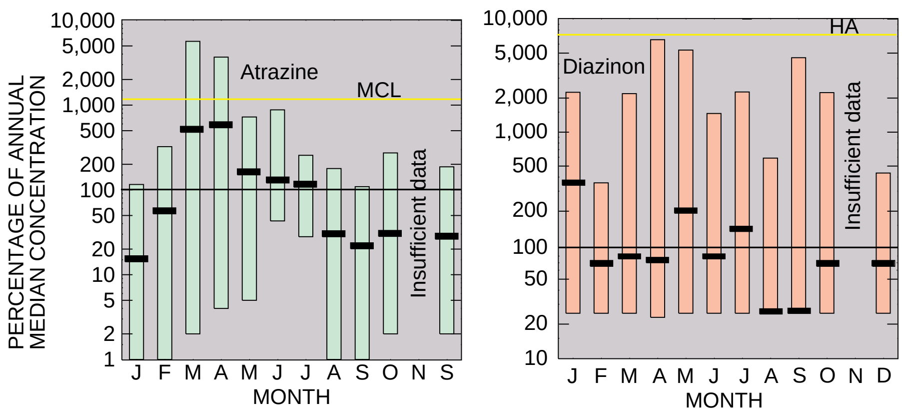
Generally, diazinon concentrations are larger in urban stream samples than in stream samples from other settings. About 15 percent of the diazinon concentrations in the urban streams exceeded the HA.

Diazinon concentrations do not show a distinct seasonal pattern. The median diazinon concentration among all samples was 0.008 microgram per liter. None of the monthly median concentrations exceeded the HA for diazinon.

Pesticides other than atrazine and diazinon also are commonly detected in basin streams. Twenty-three different herbicides were detected in rangeland and forest streams, 19 in agricultural streams, and 24 in urban streams. Among herbicides other than atrazine, prometon was detected in almost 40 percent of the agricultural stream samples and in more than 90 percent of the urban stream samples at concentrations well below its 1996 EPA HA of 100 micrograms per liter. Metolachlor and simazine were detected in more than one-half the samples from agricultural and urban streams and from the Trinity River downstream from Dallas, each at concentrations below its respective 1996 EPA HA (for metolachlor) and MCL (for simazine).

Five different insecticides were detected in rangeland and forest streams, 10 in agricultural streams, and 10 in urban streams. Among insecticides other than diazinon, carbaryl and chlorpyrifos were detected in slightly more than 60 percent of the urban tributary stream samples, each of those compounds at concentrations below its respective 1996 EPA HA.

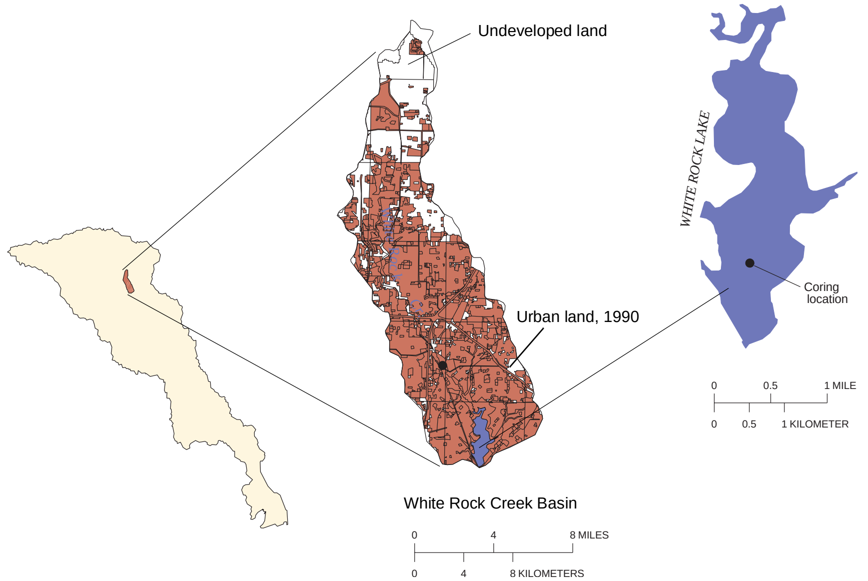
Although the concentrations of individual pesticides in most samples were less than EPA MCLs and HAs, some concerns remain. One involves pesticide concentrations in reservoirs: In the Trinity River Basin, nearly all streamflow is captured by reservoirs, many of which provide drinking water to urban areas. Pesticide concentrations in reservoirs could be greater than average concentrations in inflowing streams because much of the annual inflow to reservoirs occurs in the spring when runoff and pesticide use are greatest. For example, five samples from Richland-Chambers Reservoir collected in 1995 contained from six to eight pesticides each, and the three samples collected in June, after spring runoff, had atrazine concentrations of about 3 micrograms per liter (Land, 1997). Another concern involving pesticides in drinking water is that there is a lack of understanding of the toxicity of combinations of pesticides. Current EPA MCLs and HAs are only for individual compounds.



Seasonality of atrazine and diazinon concentrations in streams of the Trinity River Basin during 1993–95 reflects the timing of applications and runoff. Each bar shows the range between the 10th and 90th percentiles. The black line in each bar shows the monthly median concentration as a percentage of the annual median.

Determining Water-Quality Trends Using Sediment Cores, White Rock Lake, Dallas

White Rock Lake was built in 1912 at a time when agriculture dominated land use. Since that time, the watershed has been incorporated into the growing Dallas metropolitan area. In 1935, urban land use in the watershed was 6 percent; by 1990, urban land use was 72 percent. The watershed is 100 square miles, and the surface area of the reservoir is 1.7 square miles. Sedimentation in the reservoir since its construction has reduced its storage capacity by one-half.



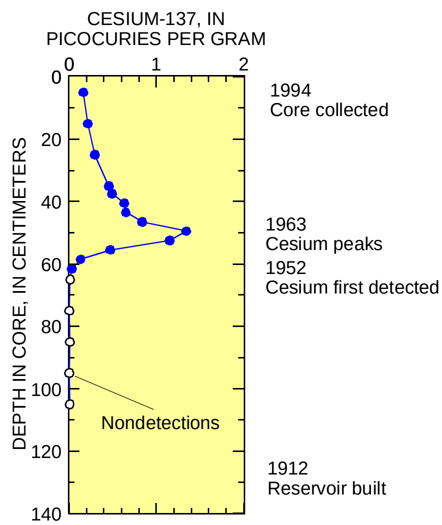
Cores are collected by lowering the coring tool from the 15-foot aluminum A-frame on a custom-built pontoon boat.

Removal of a 5-centimeter subsample of the sediment core for laboratory analysis.

Sediment cores were collected near the dam from a pontoon boat. The reservoir sediment has a large water content relative to the pre-reservoir sediment, which was dry and crumbly. The cores, measured in centimeters (2.54 centimeters = 1 inch), were sliced into 2- to 5-centimeter sections that were analyzed for a number of constituents, including trace elements, organochlorine compounds, and polycyclic aromatic hydrocarbons (PAHs).

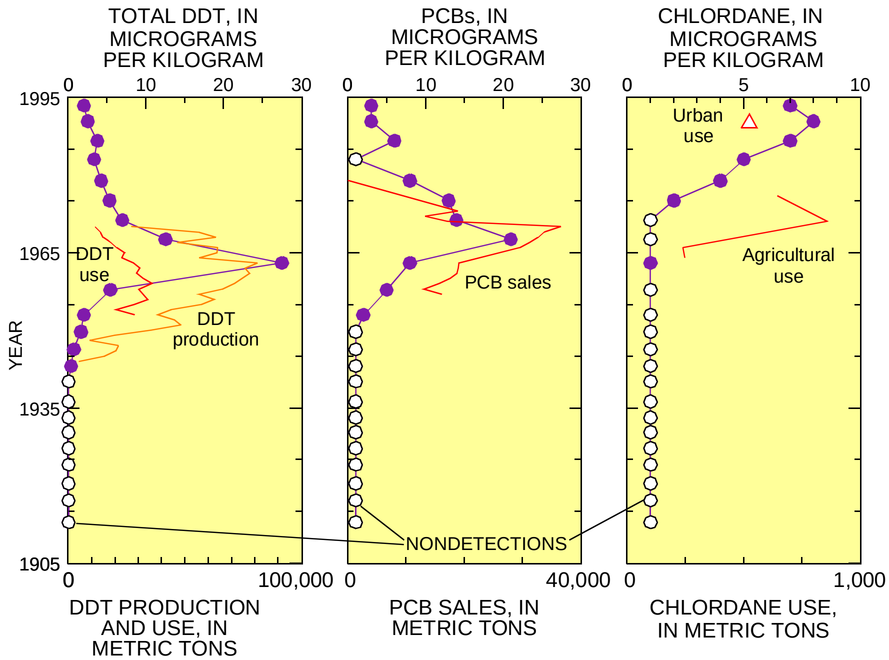
Age-dating of core sediments was done by analysis of their cesium-137 content. Cesium-137 is a by-product of nuclear weapons testing. It first occurred in the atmosphere in about 1952 and peaked during 1963–64. It adsorbs strongly to fine-grained sediments and therefore can be used to determine the time of deposition of sediments that have been exposed to atmospheric fallout. Cesium-137 first was detected in White Rock Lake core sediments at a depth of 60 to 63 centimeters (1952) and peaked at a depth of 48 to 51 centimeters (1963). The depth of the interface between pre-reservoir and reservoir sediment, 136 centimeters, corresponds to the reservoir construction date (1912), and the top of the core corresponds to the sampling date (July 1994).

Trends in DDT and PCBs in the White Rock Lake core coincide with historical use of these compounds. Use of the insecticide DDT peaked in the early 1960s before being banned by the EPA in 1972. Annual sales of PCBs, which have a variety of industrial uses, peaked in 1970. The EPA placed a voluntary ban on their use in 1973 and a complete ban in 1979. PCBs, DDT, and the DDT environmental degradation products DDE and DDD adsorb strongly to sediments and



Cesium-137, a by-product of nuclear testing, was used to date sections of reservoir sediment from the core.

are resistant to further chemical breakdown (Van Metre and Callender, 1997).



DDT, PCB, and chlordane concentrations in sediments reflect historical use. Concentrations decreased after their use was banned.

Sediment cores from White Rock Lake record the effects of DDT, PCB, and chlordane use, and their subsequent bans, on water quality in White Rock Creek.

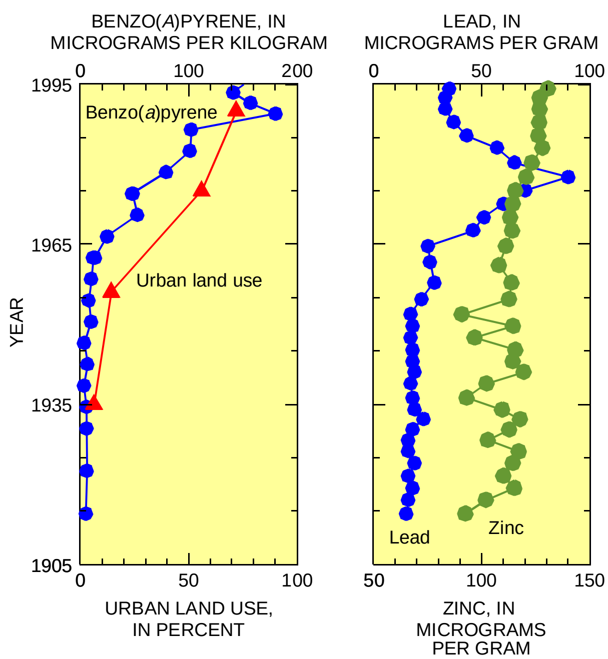
Unlike DDT and PCBs, chlordane was permitted for selected uses until the late 1980s. The primary uses in urban areas were the control of fire ants and termites. Chlordane concentrations in the White Rock Lake sediment core peaked about 1990 (Van Metre and Callender, 1997). Temporal trends in chlordane indicate relatively recent urban use of chlordane.

Concentrations of benzo(*a*)pyrene, lead, and zinc were relatively small and constant in sediments deposited before 1952 but began to increase in sediments deposited after that date.

Benzo(*a*)pyrene is a PAH and is in a class of carcinogenic compounds produced by the combustion of oil and gasoline. Elevated concentrations commonly are detected in urban areas. Benzo(*a*)pyrene is ranked eighth on the priority list of hazardous substances prepared by the Public Health Service in cooperation with EPA (Agency for Toxic Substances and Disease Registry, 1994). PAH and benzo(*a*)pyrene concentrations in sediments increased more than 20 times from pre-1950s to the early 1990s.

Lead concentrations in sediments deposited from 1952 to 1976 correspond to an increase in urbanization of the drainage basin and increased use of leaded gasoline. The marked decrease in lead concentrations in sediments deposited after 1976 coincides with the change from leaded to unleaded gasoline. Median lead concentrations have remained constant since the mid-1980s at double the pre-1952 concentrations, reflecting urban and industrial sources other than gasoline. The trend in lead concentrations thus reflects the effects of the change to unleaded gasoline and increased urbanization on water quality in White Rock Creek.

Zinc is used in tires and in a number of industrial processes and is present in concentrations 66 percent larger in recently deposited sediments than in those deposited before 1952.



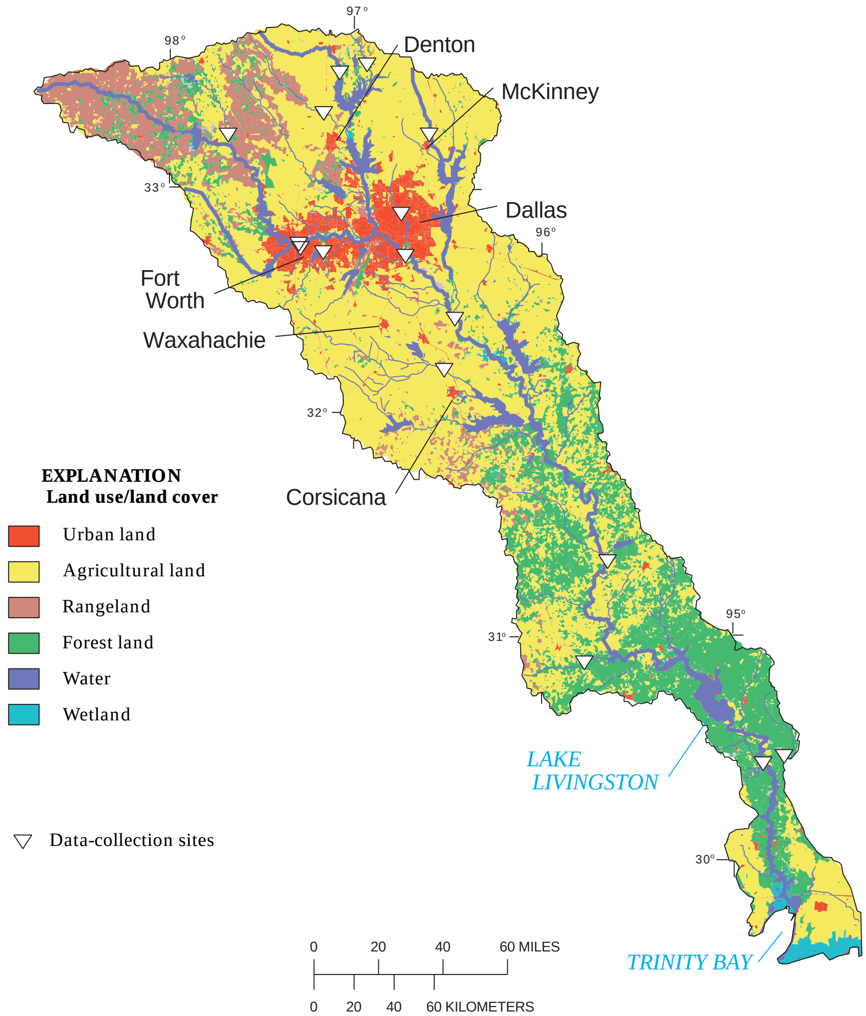
Increases in PAHs and heavy trace elements reflect the urbanization of the watershed.

Use of organochlorine pesticides and PCBs was widespread beginning in the 1940s until bans and use restrictions were placed on these compounds in the 1970s and 1980s. Organochlorine compounds tend to be persistent in the environment. Compounds such as chlordane, DDT and its environmental degradation products (DDD and DDE), and PCBs are water insoluble, are strongly associated with organic carbon and fine sediment, and have long half-lives. Organochlorine compounds were selected by NAWQA for assessment because these compounds are not metabolized rapidly and because they have high bioaccumulation and bioconcentration factors (Crawford and Luoma, 1993).

The distribution of organochlorine compounds in streambed sediments and biota is, in part, a reflection of the historical applications of pesticides. In the Trinity River Basin, pesticide uses were concentrated in agricultural areas, particularly the Blackland Prairie (Ulery and Brown, 1995), and in urban settings such as the Dallas-Fort Worth metropolitan area.

Surficial streambed-sediment and aquatic-biota samples were collected at 16 sites in the Trinity River Basin during late winter 1992 and early spring 1993 (Moring, 1997). Sites on Trinity River tributaries were chosen to reflect general urban, agricultural, rangeland, and forest land-use areas. Aquatic-biota samples from tributary sites were *corbicula* (asiatic clams). Four Trinity River main-stem sites also were selected. Because *corbicula* were scarce at the main-stem sites, aquatic-biota samples at these sites were common carp and blue catfish.

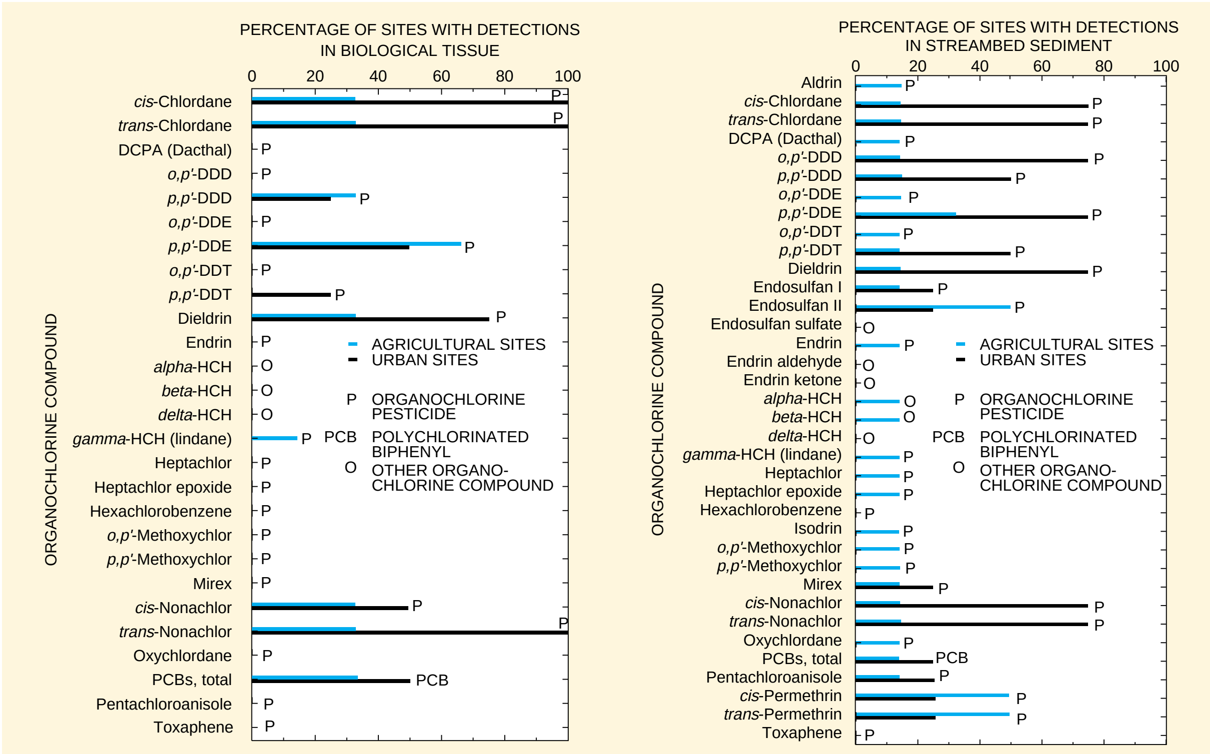
Overall, more organochlorine compounds were detected in sediment than in biological tissues; however, certain organochlorines like chlordane and PCBs were detected more frequently in aquatic biota than sediment.



Land-use and streambed-sediment and aquatic-biota collection sites in the Trinity River Basin, Texas.

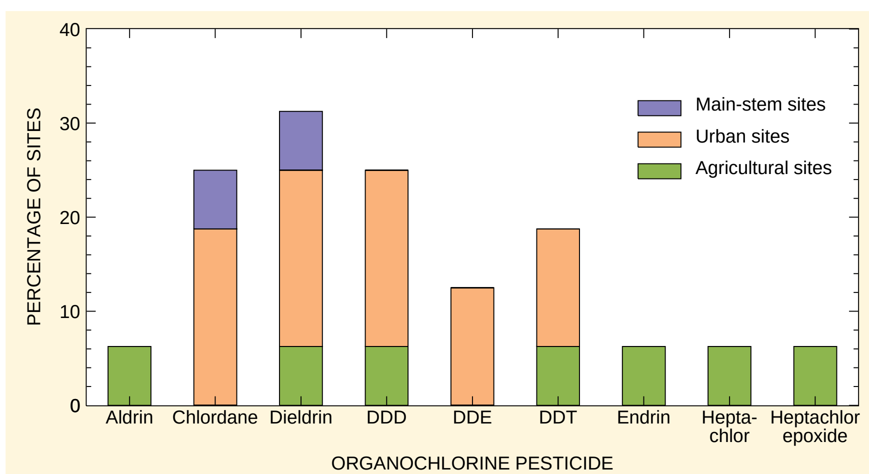
Organic compounds contained in chlordane (the sum of all chlordane and nonachlor compounds and oxychlordane), an insecticide typically used for the extermination of termites and fire ants, were more commonly detected in urban streams both in tissues and in sediment. The DDT degradation products, DDD and DDE, were more commonly detected in tissues at agricultural sites and more commonly detected in sediment at urban sites.

At least one concentration of each of nine organochlorine pesticides exceeded the TNRCC screening levels for these pesticides in streambed sediments (Texas Natural Resource Conservation Commission, 1996). These screening levels are based on the 85th-percentile concentration from statewide historical data and are not health or toxicity based. Each exceedance represents 1 of the 16 sites sampled. Concentrations of the insecticide dieldrin more frequently exceeded the TNRCC screening level than did concentrations of any other organochlorines. Urban sites, more than agricultural or Trinity River main-stem sites, had concentrations that exceeded the screening levels for chlordane, dieldrin, DDD, DDE, and DDT. Since their use in agriculture was restricted



Percentage of sites with detections of organochlorine compounds during 1992–93 differs according to land-use practices.

in the 1970s, chlordane and dieldrin were more extensively used in urban settings. However, DDT commonly was used for pest control in agricultural crops before its ban in 1972. The larger concentrations of DDD, DDE, and DDT in urban stream sediments of the Trinity River Basin could be a result of extensive applications of DDT in the 1950s and 1960s for mosquito control. Aldrin, endrin, heptachlor, and its environmental degradation product, heptachlor epoxide, exceeded their respective TNRCC screening levels only at agricultural sites in the Trinity River Basin. Aldrin, endrin, and heptachlor were used principally on crops such as corn, wheat, and cotton.



Percentage of sites with organochlorine concentrations in sediments that exceed TNRCC screening levels reflects major land uses and location on the main-stem Trinity River.

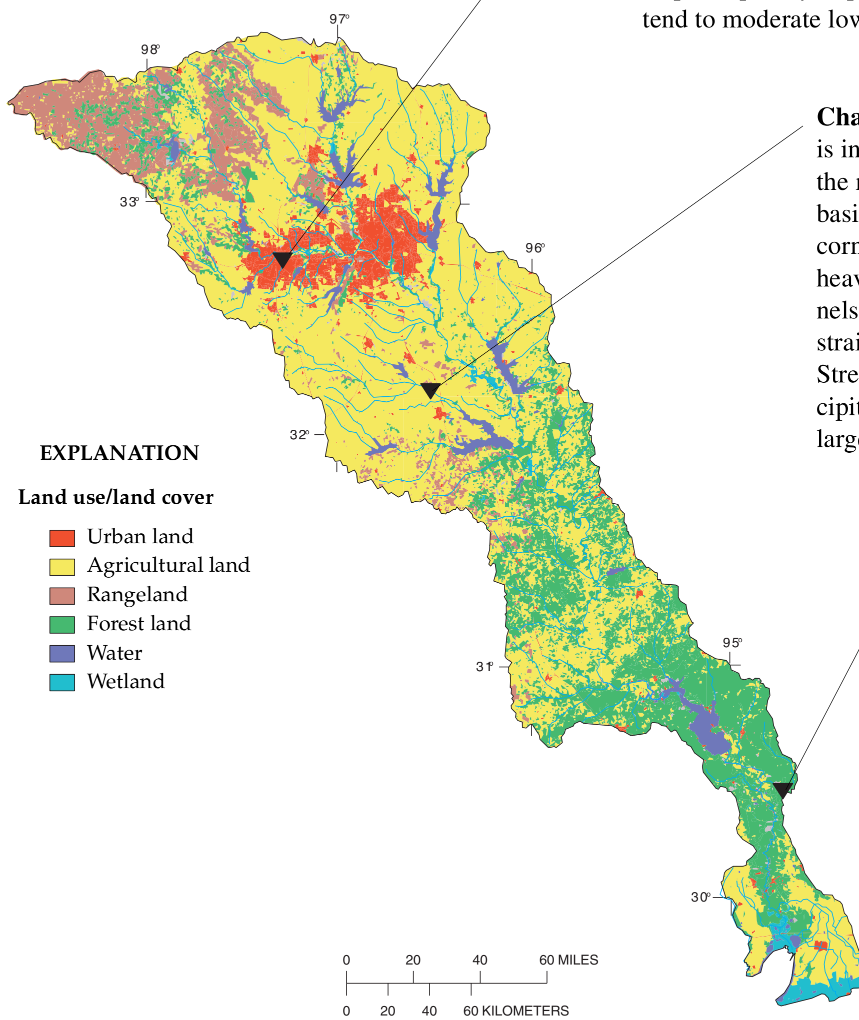
The USGS NAWQA Program includes an assessment of fish communities as one of the measures of water quality. Because fish communities are strongly influenced by their habitat, instream habitat conditions also are assessed. Combining the habitat data, the biological-community data, and the water-chemistry data provides opportunities for developing a comprehensive understanding of the aquatic life in a stream. Additionally, habitat analyses can assist in the identification of limiting physical or chemical factors critical to establishing or maintaining healthy biological communities in the streams.

Stream-habitat characteristics were related to fish-community degradation at three very different stream reaches in the Trinity River Basin. The reaches were chosen to reflect major differences in environmental settings, flow conditions, land uses, and stream biota. West Fork Trinity River is a relatively large stream in an urban area; Chambers Creek is a relatively large stream draining an intensively farmed area; and Menard Creek is considered a reference site (minimally affected by human activities) in the forested lands of southeast Texas.

West Fork Trinity River: The West Fork Trinity River reach is a few miles east of downtown Fort Worth and in the Central Oklahoma/Texas Plains Ecoregion (Omernik, 1987). This reach of the West Fork Trinity River has been channelized and leveed for flood control. The channel substrate is coarse, dominated by cobble and gravel from outcrops of limestone. Flows in the reach respond quickly to precipitation. However, upstream reservoirs tend to moderate low and high flows.

Chambers Creek: The Chambers Creek reach is in the Blackland Prairie Ecoregion, which is the most intensively cultivated ecoregion in the basin. The major crops are cotton, sorghum, corn, and wheat. This region is characterized by heavy clay soils, little relief, and stream channels in the lower part of the basin that have been straightened and leveed for flood control. Streams in this ecoregion respond to heavy precipitation with rapid rises and falls in stage and large sediment loads.

Menard Creek: The Menard Creek reach is in the Western Gulf Coastal Plain Ecoregion and in the National Park Service's Big Thicket Preserve. Adjacent land use is dominated by silviculture; however, the riparian zone and, to some extent, the flood plain contain secondary vegetative growth that has not been disturbed for many years. The watershed is characterized by acidic sandy soils, little relief, and meandering channels. Floods are attenuated by flood-plain and riparian vegetation, and stream stages change gradually.



Land use and land cover and location of selected survey reaches.

Stream-Habitat Characteristics

The physical and chemical characteristics of water combined with the physical features of the stream channel influence the presence or absence of particular aquatic organisms in a stream. Habitat affects species distributions at different spatial scales. For example, fish-species distribution in a stream reach is affected by climate on a regional scale, channel gradient on a local scale, and particle size of substrate at a very detailed scale. Other important factors such as stream meandering, steepness of banks, riparian vegetation, and variability of streamflow affect the habitat for fish in the stream. Not only does stream habitat have to be suitable for a particular species, it also has to support other biota that are prey for the species.

The measured habitat characteristics at the three stream reaches strongly reflect the differences in habitat among the reaches. The low bank height/channel width ratio and high density of woody vegetation in the Menard Creek reach create a setting where woody snags and logjams provide habitat for fish and an excellent environment for biota that supply food for fish. The low bank height/channel width ratio indicates bank stability and a lack of channel incision or cutting. The high density of woody vegetation moderates temperature, corresponds to stable banks with little erosion, and provides a source of organic material to the stream.

In contrast, the low sinuosity (meandering) and low channel gradient in the Chambers Creek reach could limit the number and size of pools and ripples that create a variety of habitats. Variety of habitat provides more opportunity for large numbers and varieties of species to thrive. The high variation in flow at Chambers Creek is associated with more frequent floods, in which organisms can be physically harmed or swept away, and more frequent very low flows, in which the volume of water is limited and species are subject to large and rapid changes in the pH, dissolved oxygen, and temperature of the water.

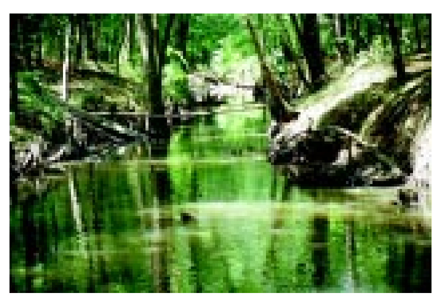
The high bank height/channel width ratio and low density of woody vegetation at the West Fork Trinity River site can be attributed to stream channelization associated with urban flood control. Channelization has resulted in a stream reach with little or no woody riparian vegetation to contribute structure and habitat to the channel. Channelization also causes deeper channel incision, which reduces the amount of stream-margin habitat for aquatic organisms.

Stream-habitat characteristics

Stream	Sinuosity (meandering) (dimensionless)	Channel gradient (feet/mile)	Bank height/ channel width ratio (dimensionless)	Density of woody vegetation (dimensionless)	Variation of monthly flow index (dimensionless)
West Fork Trinity River	2.2	6.7	0.75	3.4	39
Chambers Creek	1.1	1.1	.60	7.1	82
Menard Creek	1.9	10.6	.24	20.4	26

West Fork Trinity River.

Chambers Creek.



Menard Creek.

Fish-Community Degradation

The evaluation of fish-community degradation involved measures of the percentage of fish species in a reach that (1) are known to be tolerant of severe environmental stresses, (2) are known to be omnivorous, (3) are not native to the stream, and (4) have physical anomalies that can be visually detected. The fish-community degradation index is computed from the frequency of nonnative, tolerant, and omnivorous individuals at a site and from the frequency of external anomalies observed for each species of fish.

The table shows that Menard Creek, with an index of 6, is the least degraded of the three reaches discussed here. Menard Creek percentages are lowest in all the measured categories. The Menard Creek habitat and quality of water support a robust fish community. The two other reaches, West Fork Trinity River and Chambers Creek, each have an index of 12. These two reaches are examples of highly altered streams characterized by incised and leveed channels, low density of vegetation in the riparian zones, and unstable streamflow characteristics. These and other factors, possibly including water-chemistry conditions, have contributed to degraded fish communities.

Robust fish communities with many native species are most likely to be present in streams with a complex habitat and natural, unaltered flow regimes.

In the West Fork reach, the percentage of fish with external anomalies is the greatest among the three reaches. The relatively large incidence of external anomalies could be related to the quality of water and sediment originating in the urban area. In a separate study of organic contamination in bed sediment and tissue of aquatic biota, Moring (1997) reports the occurrence and degree of contamination in streambed sediments and tissues of aquatic biota in the Trinity River Basin to be much greater in urban streams than in non-urban streams.

Fish-community degradation

Stream	Tolerant species (percent)	Omnivorous species (percent)	Nonnative species (percent)	External anomalies (percent)	Fish-community degradation index
West Fork Trinity River	50	30	3	2.8	12
Chambers Creek	53	26	0	2.2	12
Menard Creek	37	8	0	.9	6

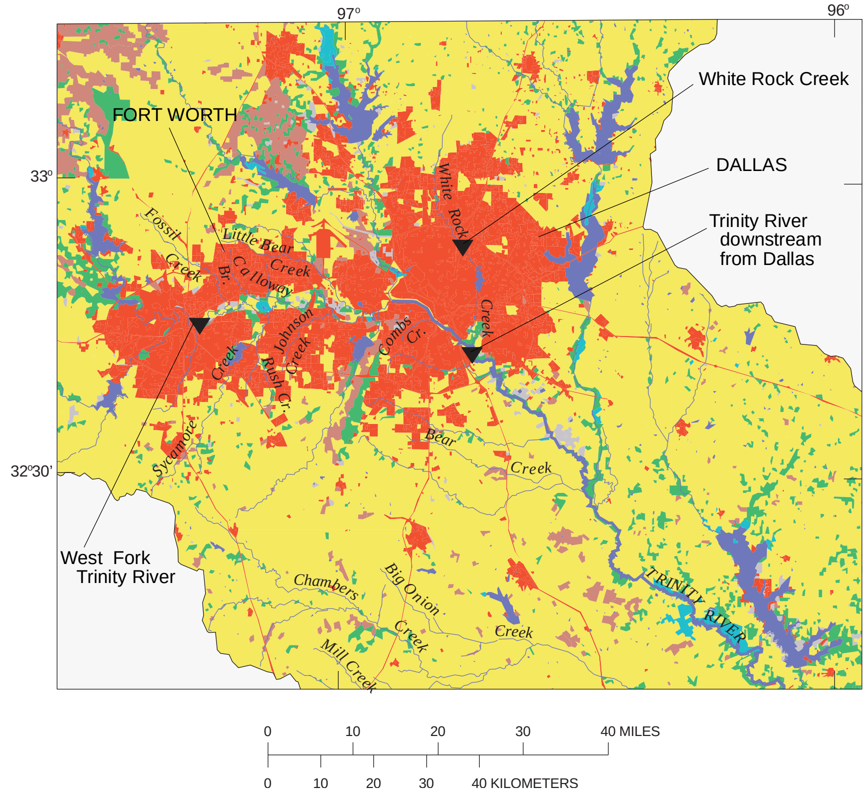
PAHs are a group of organic compounds that are abundant in the environment and are toxic and often carcinogenic to organisms. Major sources of PAHs are oil spills and the incomplete combustion of fossil fuels.

PAHs are metabolized and excreted by most higher vertebrates, particularly fishes, which can make assessment of concentrations in tissues impossible.

SPMD technology (Huckins and others, 1990) is new. An SPMD simulates the exposure to and passive uptake of highly lipid-soluble organic compounds by biological membranes. An SPMD typically consists of a long strip of low-density, polyethylene tubing filled with a thin film of a purified lipid such as triolein. The long strip of tubing and lipid film provide a large surface area/volume ratio that simulates a biological membrane such as a fish gill. The SPMDs used in this study concentrate PAHs above ambient concentrations in water and simulate biological exposure over a controlled period of deployment.

One site on each of three streams was selected for monitoring the occurrence of PAHs. The sites were chosen to reflect varied urban land uses and the influences of point and nonpoint sources of contaminants or PAHs. The monitoring was done using SPMDs during a 30-day period in late May and June 1994.

Twenty-five different PAHs were detected in the SPMDs. Twenty-three were detected at the Trinity River downstream from Dallas and White Rock Creek sites, and 21 were detected at the West Fork Trinity River site. Seventy-three percent of the PAHs from the White Rock Creek and Trinity River downstream from Dallas sites and 67 percent from the West Fork Trinity River site were substituted



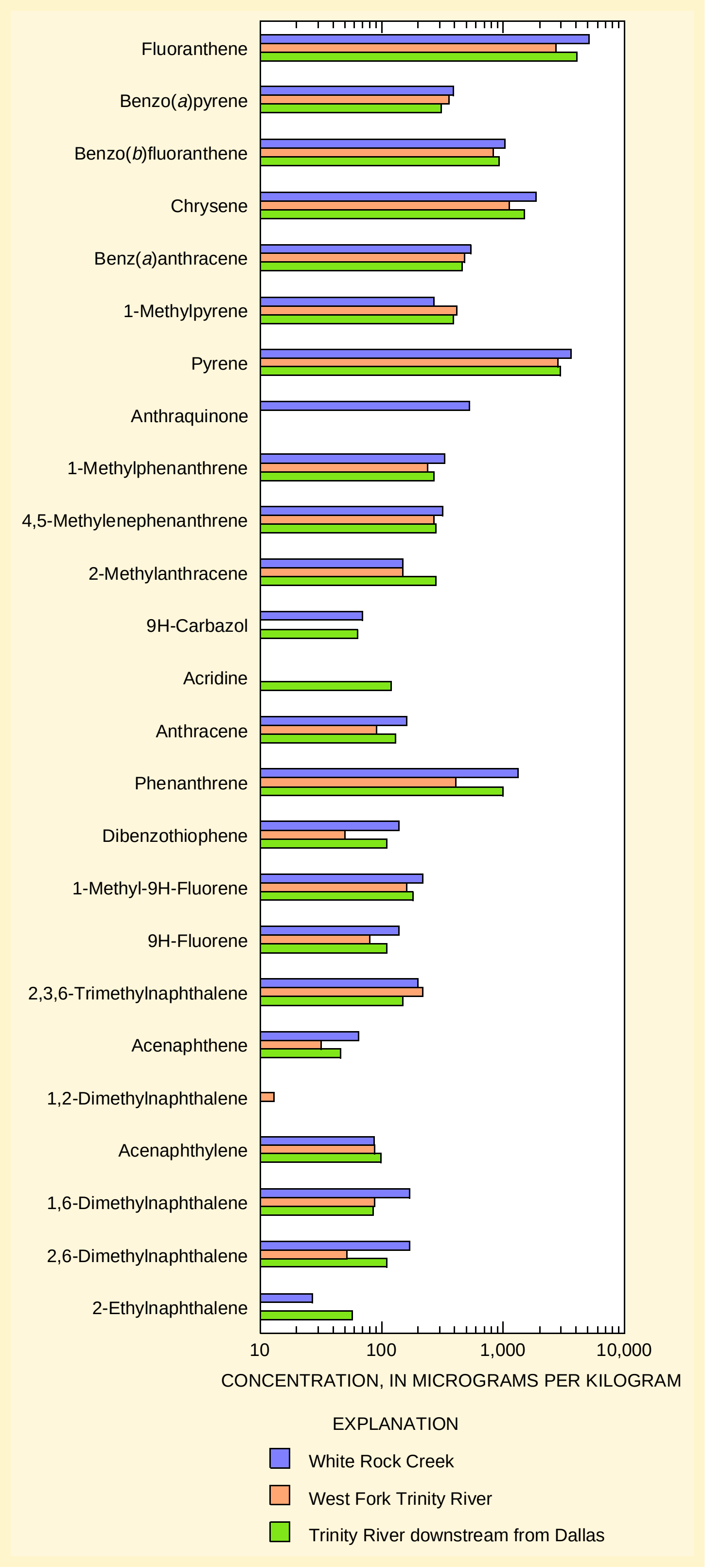
Location of SPMD deployment sites in the Dallas-Fort Worth metropolitan area.

PAHs—that is, PAHs with one or more substituted alkyl groups attached. The largest concentrations were of unsubstituted (parent) PAHs, such as fluoranthene, chrysene, pyrene, and phenanthrene; concentrations of these PAHs consistently were largest at the White Rock Creek site and smallest at the West Fork Trinity River site.

The Public Health Service Agency for Toxic Substances and Disease Registry (ATSDR), in cooperation with the EPA, has developed a comprehensive ranking of 275 hazardous substances on the basis of their frequency of occurrence at hazardous waste sites, toxicity, and potential for human exposure (Agency for Toxic Substances and Disease Registry, 1994).

Nine of the PAHs detected by the SPMDs have been ranked as hazardous substances by the Public Health Service. Benzo(a) pyrene and benzo(b)fluoranthene are ranked in the top 10.

The results of application of SPMDs indicate that aquatic organisms at three sites near Dallas are exposed to toxic PAH compounds. The SPMD is an effective tool to detect hydrophobic organics in water. The small concentrations of the compounds in the streams might not be detected by more traditional water-sampling techniques.



Hazardous PAHs detected in SPMDs

[ASTDR, Agency for Toxic Substances and Disease Registry]

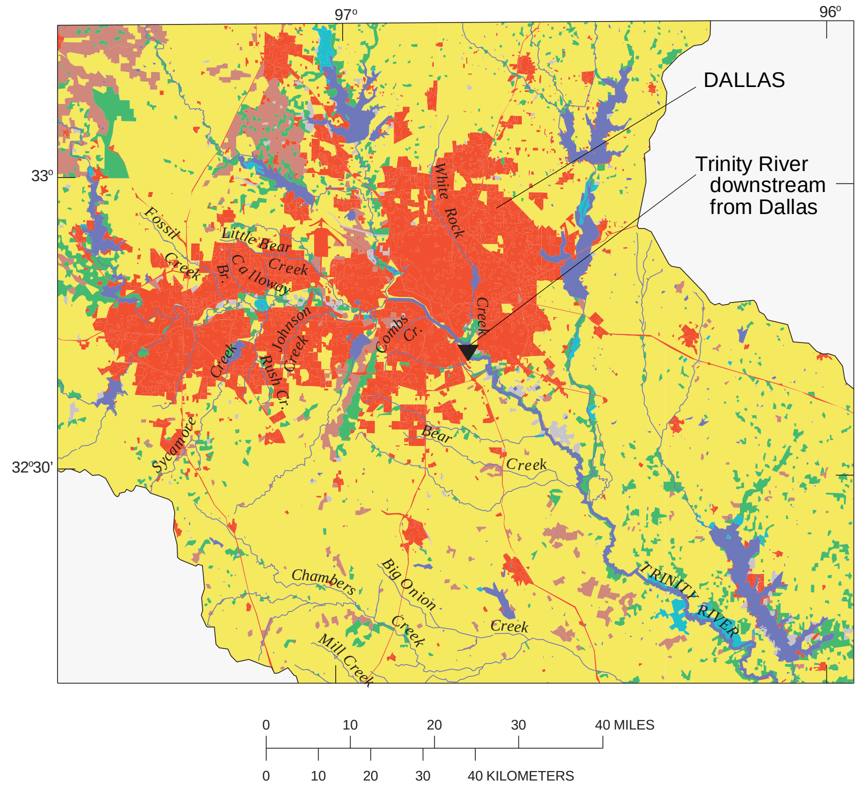
PAH	ASTDR ranking
Benzo(*a*)pyrene	8
Benzo(*b*)fluoranthene	10
Benz(*a*)anthracene	35
Fluoranthene	100
Chrysene	110
Acenaphthene	140
Phenanthrene	188
Pyrene	201
Anthracene	235

PAHs were frequently detected in SPMDs deployed in urban streams.

In 1925, the Trinity River in the Dallas-Fort Worth area was characterized by the Texas Department of Health as a "mythological river of death." With a rapid expansion of industry and population and only primary wastewater treatment beginning in the late 1920s and secondary treatment in the mid-1930s, water-quality conditions in the area were poor. They did not substantially improve until State and Federal pollution control laws, like the Federal Clean Water Act of 1972, stimulated efforts to address degraded water-quality conditions. The Upper Trinity River Basin Comprehensive Sewage Plan of 1971 resulted in the construction of large, regional wastewater-treatment plants, elimination of many small, industrial and municipal wastewater-treatment plants, and the upgrading of existing wastewater-treatment plants.

During 1970–85, 13 fishkills were documented in the Trinity River from a reach just downstream from Dallas to Lake Livingston in the lower part of the Trinity River Basin. The magnitude and frequency of the fishkills resulted in a depleted fish community, particularly in the reach of the Trinity River immediately downstream from Dallas. An estimated 1.04 million fish died in these 13 kills. Twelve of the 13 fishkills were associated with minor flooding on the Trinity River from rainfall in the Dallas-Fort Worth metropolitan area. According to the Texas Parks and Wildlife Department (TPWD), the probable cause of the kills was the resuspension of bottom sediments and associated organic material during floods that caused an increase in biochemical oxygen demand and a corresponding rapid drop in dissolved oxygen (Davis, 1987). Ironically, improvements in water quality during the 1970s set the stage for the fishkills by allowing appreciable fish populations to live in this reach of the Trinity River.

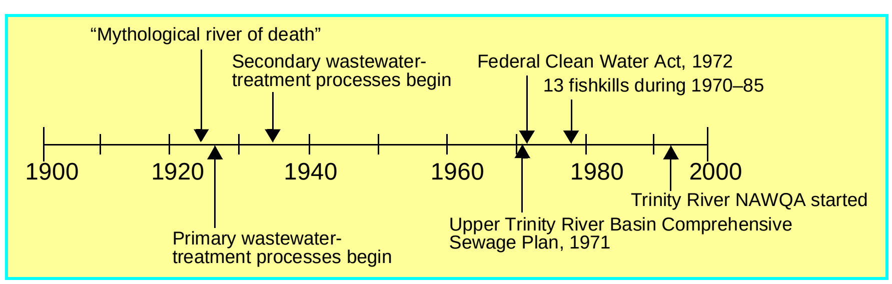
During 1970–85, more than 1 million fish were killed by water pollution in the Trinity River downstream from Dallas.



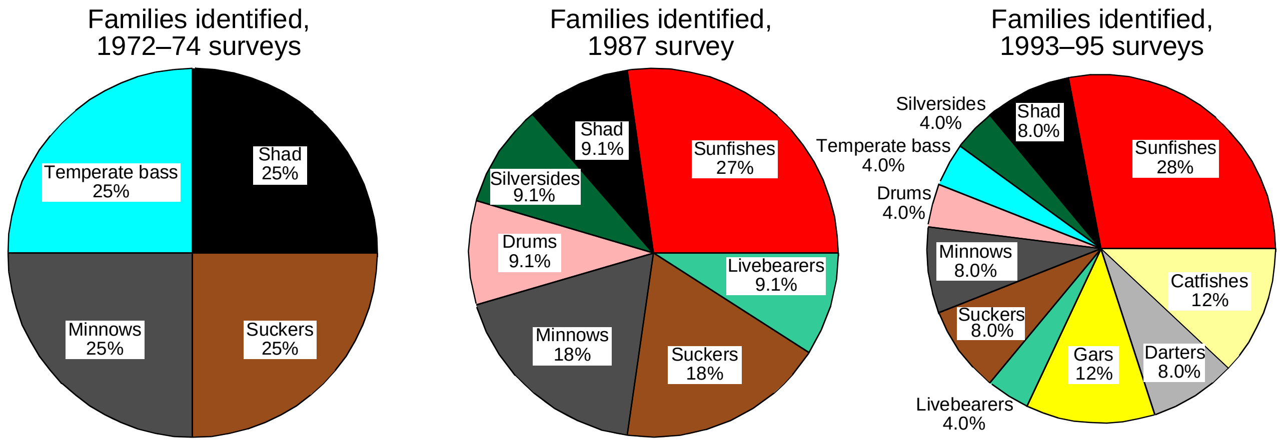
The Trinity River downstream from Dallas data-collection site.

How Has the Water Quality Improved?

Dissolved oxygen, measured as milligrams of oxygen per liter of water, has increased from lows of near zero in the early 1970s to highs of more than 10 milligrams per liter in 1996. Notable improvement in dissolved oxygen concentrations in the Trinity River downstream from Dallas began in the late 1970s and continued through the 1980s and into the 1990s. Dissolved oxygen was consistently recorded above the TNRCC (Texas Natural Resource Conservation Commission, 1996) dissolved oxygen criterion for the support of aquatic life (5.0 milligrams per liter) beginning in the late 1980s. The improvement in dissolved oxygen concentrations is attributable to improvements in wastewater-treatment practices and the corresponding reduction in the discharge of oxygen-demanding materials



A timeline of change for the Trinity River downstream from Dallas.



In slightly more than two decades, the fish community in a reach of the Trinity River downstream from Dallas has markedly improved. Improvement is most evident in the number of fish caught and the number of species, including those that are not tolerant of polluted water.

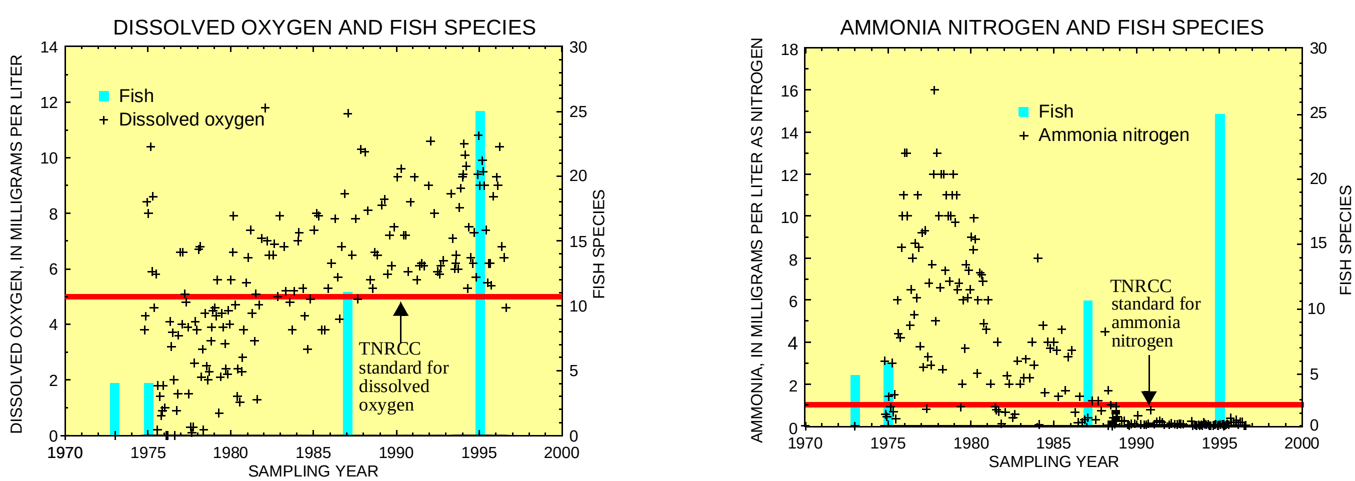
from wastewater-treatment plants and industry.

Advanced wastewater-treatment processes that include nitrification (conversion of ammonia nitrogen to nitrate) have been implemented at the large wastewater-treatment plants that discharge into the Trinity River in the Dallas-Fort Worth area. Ammonia consumes oxygen when it is converted to nitrate, and large concentrations of ammonia are toxic to fish and other aquatic organisms. Ammonia levels in the Trinity River downstream from Dallas exceeded the TNRCC criterion for dissolved ammonia in freshwater streams and reservoirs (1.0 milligram per liter) consistently until the late 1980s. Since then, the nitrification process used in wastewater-treatment plants has reduced the amount of ammonia nitrogen that is discharged to the river.

How Has the Fish Community Changed as a Result?

The fish community in the Trinity River immediately downstream from Dallas was almost nonexistent in the early 1970s (Texas Parks and Wildlife Department, 1974). Only four species of fish were collected by the TPWD during 1972–74—smallmouth buffalo, gizzard shad, common carp, and yellow bass. Four of the six surveys yielded no fish from this reach of the river. Two of the species, gizzard shad and common carp, generally are classified as tolerant taxa and could be expected to tolerate the water-quality conditions in this reach in the 1970s.

The TPWD collected 11 species of fish from this reach in 1987. Although the 1987 survey yielded more species than the 1972–74 surveys, the TPWD still considered the species richness low and attributed the condition to the fishes' exposure to ammonia nitrogen and heavy trace elements introduced from the upstream wastewater-treatment plants (Davis, 1991).



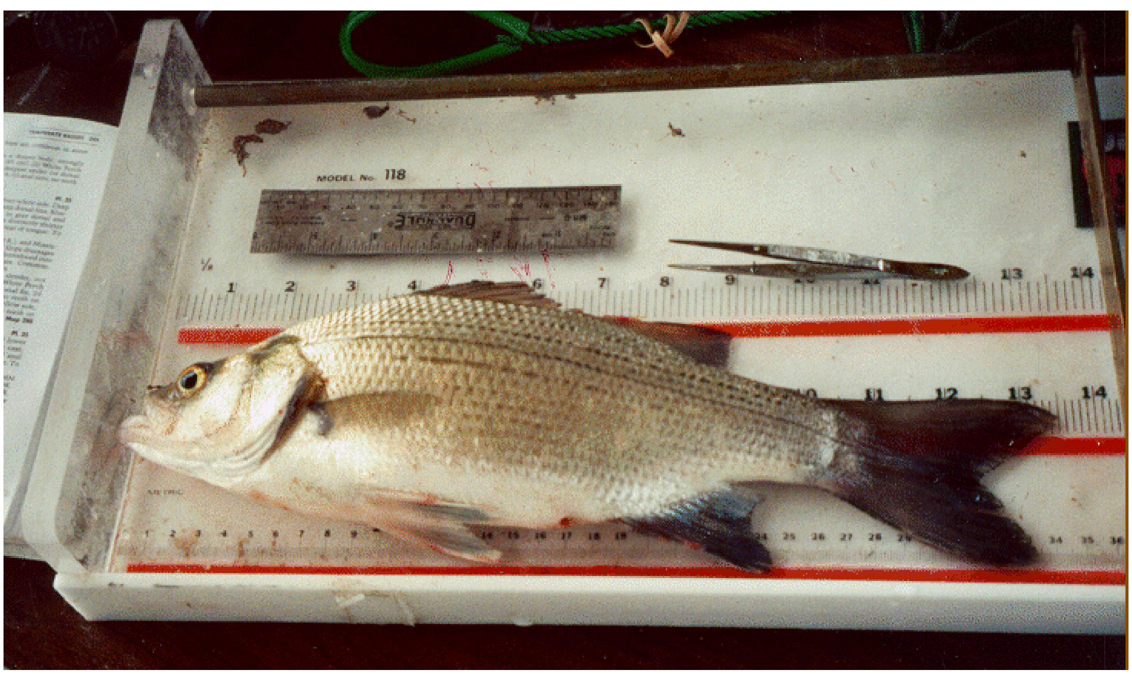
Fish species have increased as water quality improved in the Trinity River downstream from Dallas.

The USGS conducted fish-community surveys on the reach at Trinity River downstream from Dallas during 1993–95. The methods used by the USGS—seining, boat electrofishing, and gill netting—are identical to the methods used by the TPWD in 1987. A cumulative total of 25 species of fish were collected in this reach during the 3-year period.

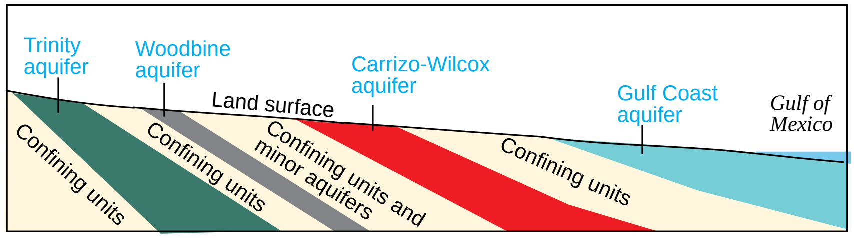
Fish surveys during 1993–95 indicate that the Trinity River downstream from Dallas is typical of a large stream in the region.

Several game species were collected including largemouth bass, white crappie, and white bass. None of these game species were collected in the reach during the 1972–74 or 1987 surveys. Two darter species, bigscale logperch and slough darter, also were collected. The presence of these indigenous species suggests a return of this reach to a more natural condition. Other species characteristic of warm-water southeastern streams—alligator, spotted, and longnose gars and flathead, blue, and channel catfish—frequently were collected during the USGS surveys of 1993–95. None of these gar or catfish species were reported in the reach downstream from Dallas in the 1972–74 or 1987 TPWD surveys. The change since 1972–74 is a likely consequence of improvements in water quality, particularly improvements in the quality of discharges from wastewater-treatment plants in the Dallas-Fort Worth area.

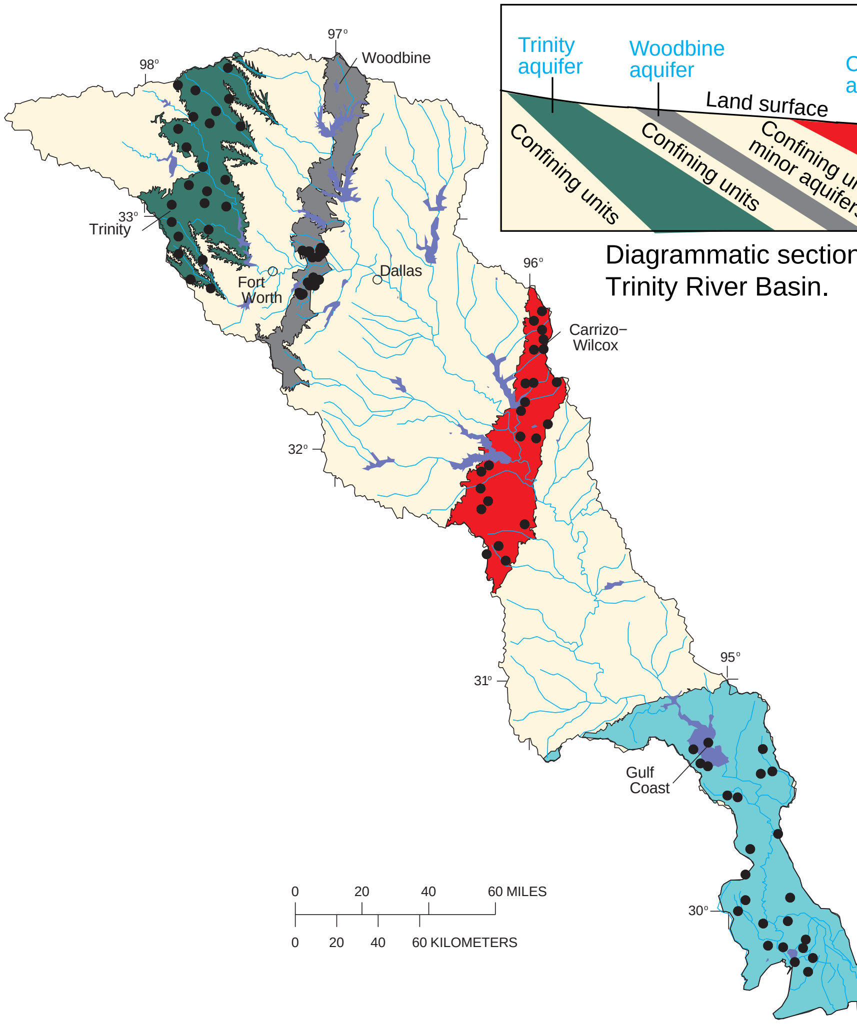
Catching fish with a backpack electrofishing device.



White bass being measured and examined.



Diagrammatic section showing aquifer configuration in the Trinity River Basin.



Ground-water sampling sites in outcrops of aquifers in the Trinity River Basin.

The Trinity, Woodbine, Carrizo-Wilcox, and Gulf Coast aquifers (and intervening confining units and minor aquifers) in the Trinity River Basin occur as a series of sloping layers that begin at land surface and become more deeply buried toward the gulf coast. The aquifer outcrops delineated on a map of the basin appear as generally coast-parallel bands. The Trinity, Carrizo-Wilcox, and Gulf Coast are major aquifers, on the basis of the quantity of water that can be supplied to wells. The Woodbine is a minor aquifer, but it is important to the study of water-quality conditions in the basin because it underlies the urban Dallas-Fort Worth metropolitan area.

Ground-water samples were collected from wells in the outcrops of the four aquifers from August 1993 to August 1994 and analyzed for nutrients, major inorganic compounds, trace elements, pesticides, organic carbon, and VOCs.

Trinity Aquifer

On the basis of samples from 24 wells less than 200 feet deep in the Trinity aquifer outcrop, ground water in the uppermost zone of the aquifer did not exceed 1996 EPA primary drinking-water standards (MCLs) for the analyzed constituents but has higher than acceptable dissolved solids concentration (salinity) in water from one-half of the wells. (Salinity has an EPA secondary MCL [SMCL]. An SMCL is based on factors such as taste and odor that affect the potability of water but do not pose a health concern.) The salinity could occur naturally or it could be from brines associated with oil and gas production.

Pesticides were detected in Trinity aquifer wells. The insecticide diazinon was detected in nearly one-half the samples, and the DDT derivative *p,p'*-DDE was detected in samples from four wells. None of the concentrations exceeded the 1996 EPA lifetime HA for diazinon. The herbicide atrazine or its metabolite deethylatrazine was detected in two wells. Benzene, a component of gasoline, was detected in one well at a concentration less than the 1996 MCL. The pesticide and VOC detections show the vulnerability of shallow ground water in the Trinity aquifer to contamination. The pathway of such compounds into shallow ground water could be through natural recharge or recharge along the outside of well casings that are not completely sealed at the land surface.

Trace concentrations of organic compounds, such as pesticides and solvents, show the vulnerability of these aquifers to contamination.

Woodbine Aquifer

Analyses of samples from the outcrop of the Woodbine aquifer could indicate shallow ground-water contamination associated with urban land use. Twenty-eight specially constructed monitoring wells less than 50 feet deep were used to sample water in the uppermost aquifer zone. Ten domestic wells were used to sample water in the deeper aquifer zone (50 to 150 feet deep). The water in the Woodbine aquifer (Reutter, 1996) can be naturally saline and high in iron and sulfate—71 percent of the 38 Woodbine water samples exceeded the EPA SMCL for dissolved solids, and 61 percent of the samples exceeded the SMCLs for both iron and sulfate. Five of the 38 samples exceeded the EPA MCL for nitrate.

Herbicides were detected in 11 of the 38 wells; *p,p'*-DDE was detected in samples from two wells. None of the sample concentrations of pesticides for which EPA has established MCLs or HAs exceeded those standards.

Samples from seven wells have detectable concentrations of VOCs. The most commonly detected VOC was MTBE (methyl *tert*-butyl ether), a gasoline additive, in the urban part of the Woodbine aquifer. The sample from one shallow monitoring well has concentrations of several VOCs greater than 10 micrograms per liter. Tetrachloroethylene and trichloroethylene, solvents for which the 1996 MCL is 5 micrograms per liter, were detected at concentrations of 6,000 and 230 micrograms per liter, respectively. Chloroethylene (vinyl chloride), a compound used as a solvent and as a refrigerant, for which the 1996 MCL is 2 micrograms per liter, was detected at a concentration of 32 micrograms per liter; and *cis*-1,2-dichloroethylene, a solvent for which the 1996 MCL is 70 micrograms per liter, was detected at a concentration of 82 micrograms per liter.

Carrizo-Wilcox Aquifer

In the outcrop of the Carrizo-Wilcox aquifer, 23 wells less than 300 feet deep were sampled. Samples from seven wells had dissolved solids or iron concentrations that exceeded EPA SMCLs. As in the Trinity aquifer, higher than acceptable salinity could occur naturally or be related to historical brine disposal from oil and gas production; the higher than acceptable iron concentrations occur naturally.

Summary of ground-water-quality data

	Trinity aquifer (24 samples)	Woodbine aquifer (38 samples)	Carrizo-Wilcox aquifer (23 samples)	Gulf Coast aquifer (24 samples)
Percentage of samples in which concentrations exceeded 1996 EPA drinking-water standards				
Major constituents (1996 EPA SMCL in milligrams per liter)				
Chloride (250)	12	18	0	4
Fluoride (2.0)	0	5	0	0
Sulfate (250)	4	61	0	0
Dissolved solids (500)	50	71	17	25
Nutrients (1996 EPA MCL in milligrams per liter)				
Nitrate nitrogen (10)	0	13	0	0
Trace elements (1996 EPA MCL or SMCL [iron, zinc] in milligrams per liter)				
Arsenic (0.05)	0	0	0	0
Chromium (0.1)	0	0	0	0
Iron (0.3)	12	61	17	17
Lead (0.015)	0	0	0	0
Nickel (0.1)	0	10	0	0
Selenium (0.05)	0	0	0	0
Zinc (5)	0	0	0	0
Percentage of samples in which pesticides and volatile organic compounds were detected				
Pesticides				
Herbicides	8	29	9	12
Insecticides	54	5	22	8
Volatile organic compounds	4	18	4	4

Herbicides were detected in samples from two wells and insecticides in samples from five wells. Trichlorofluoromethane, a VOC used as solvent, was detected in the sample from one well. None of the pesticides or VOCs for which EPA has established MCLs or HAs had concentrations that exceeded those standards.

Gulf Coast Aquifer

In the outcrop of the Gulf Coast aquifer, 24 wells less than 250 feet deep were sampled. Samples from six wells had dissolved solids concentrations that exceeded the EPA SMCL. The excess salinity probably is related to historical brine disposal from oil and gas production. Herbicides were detected in samples from three wells and insecticides in samples from two wells. Trichloromethane, a VOC used as a refrigerant or a solvent, was detected in the sample from one well. As in the Carrizo-Wilcox aquifer, none of the pesticides or VOCs for which the EPA has established MCLs or HAs had concentrations that exceeded those standards.

Water samples from wells in the outcrops of major aquifers did not exceed EPA drinking-water MCLs or SMCLs for trace elements, except for iron at some locations.

A comparison of pesticides detected in shallow ground water in the outcrops with those detected in streams in the outcrops (excluding the main-stem Trinity River sites) indicates that stream water generally contains a greater number of pesticides at higher concentrations than shallow ground water. A larger pesticide presence in streams than in ground water implies that pesticides applied to the land are more readily transported into the streams by runoff than into the shallow ground water by natural recharge or recharge associated with well construction (Brown, 1995).

Comparison of Trinity River Basin Study Unit Surface-Water Results with Nationwide NAWQA Findings

Seven major water-quality characteristics were evaluated for stream sites in each NAWQA Study Unit. Summary scores for each characteristic were computed for all sites that have adequate data. Scores for each site in the Trinity River Basin were compared with scores for all sites sampled in the 20 NAWQA Study Units during 1992–95. Results are summarized by percentiles; higher percentiles generally indicate poorer quality compared with other NAWQA sites. Water-quality conditions at each site also are compared to established criteria for protection of aquatic life. Applicable criteria are limited to nutrients and pesticides in water and semivolatile organic compounds (SVOCs), organochlorine pesticides, and PCBs in sediment. (Methods used to compute rankings and evaluate aquatic-life criteria are described in Gilliom and others, in press.)

EXPLANATION

Ranking relative to national conditions— Darker colored circles generally indicate poorer quality. Bold outline of circle indicates one or more drinking-water standards or aquatic-life criteria are exceeded

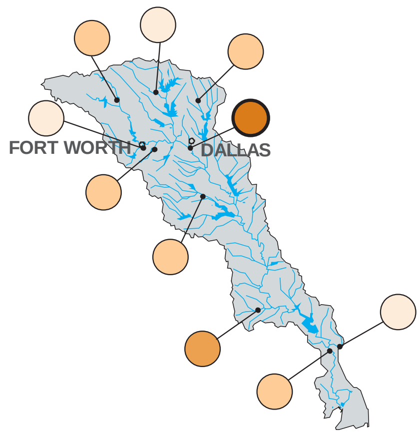
Greater than the 75th percentile (among the highest 25 percent nationally)

Between the median and the 75th percentile

Between the 25th percentile and the median

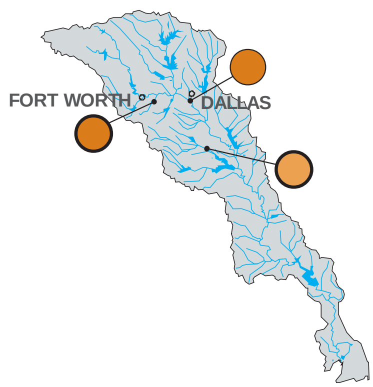
Less than the 25th percentile (among the lowest 25 percent nationally)

NUTRIENTS in water



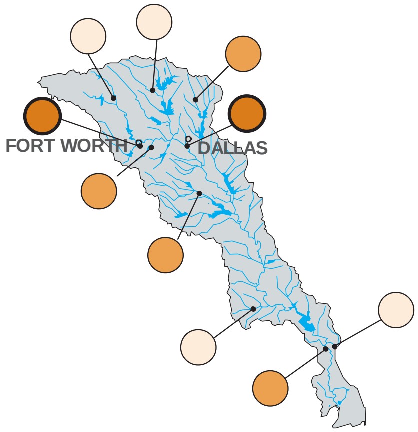
The median nutrient concentration at a Trinity River site downstream from large wastewater discharges is in the highest category of all NAWQA stream sites, and one sample from the site exceeded the EPA MCL. Otherwise, all the sites except one in a rural area are less than the national median. As expected, the median concentrations at reference sites are in the lowest quartile of all NAWQA Study Units across the Nation.

PESTICIDES in water



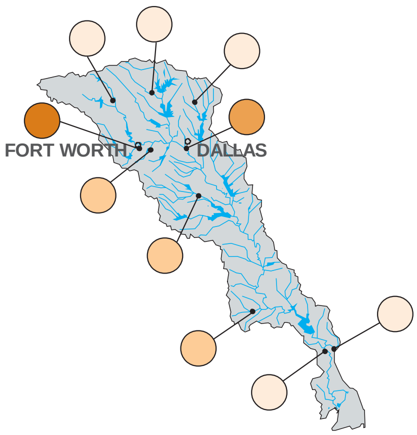
Median pesticide concentrations are greater than the national NAWQA median at all three sites for which there were adequate data to make the comparison. Sites with urban watersheds are in the highest category. A site with croplands in the watershed is in the second highest category. Exceedances of drinking-water standards are most often attributed to diazinon in urban streams and atrazine in agricultural streams.

ORGANOCHLORINES in streambed sediments and biota



Concentrations of organochlorine pesticides and PCBs in bed sediments and biota (clam and fish tissue) at two sites on the Trinity River in the Dallas-Fort Worth area are in the highest category of all NAWQA Study Units. Sites in watersheds with little development are in the lowest category.

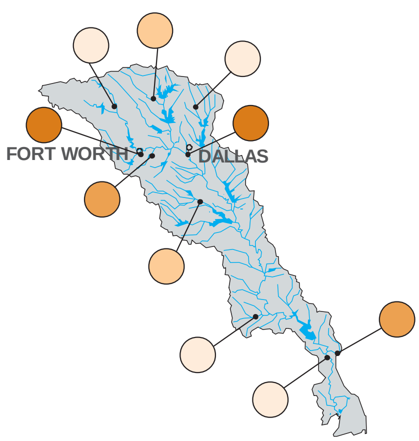
TRACE ELEMENTS
in streambed sediments



Concentrations of trace elements in sediments at a site on the West Fork Trinity River near downtown Fort Worth are in the highest category of all NAWQA sites. The next-highest concentrations are in the Trinity River downstream from Dallas. All other sites have concentrations less than the national median.

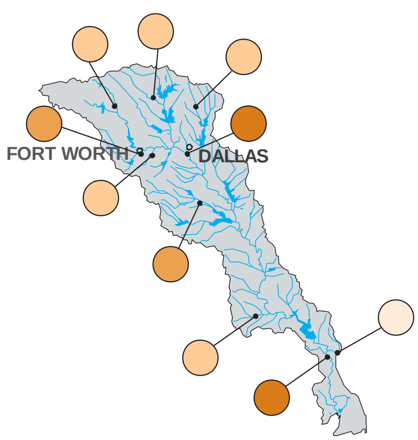
SEMIVOLATILE ORGANIC COMPOUNDS
in streambed sediments

Concentrations of SVOCs (primarily PAHs) in sediments at two sites on the Trinity River in the Dallas-Fort Worth area are in the highest category of all NAWQA sites. However, no compounds exceeded an aquatic-life criterion. Surprisingly, SVOCs at the reference site on Menard Creek are above the national median.



FISH COMMUNITIES

A fish-community index based on the number of diseased, pollution-tolerant, omnivorous, and nonnative fish is greater than the national NAWQA median at 4 of the 10 sites evaluated. The two most degraded sites are on the Trinity River; one is downstream from Dallas-Fort Worth, and the other is near the mouth of the Trinity River.



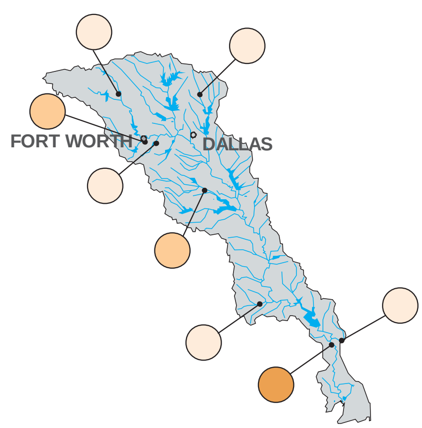
CONCLUSIONS

Nutrient concentrations in most streams in the Trinity River Basin were below national median concentrations for NAWQA Study Units. Two exceptions are the Trinity River downstream from Dallas and a rural site. Pesticide concentrations at two urban sites were in the highest category, and concentrations at an agricultural site were in the second highest category, all above the national NAWQA median.

In general, concentrations of trace elements, PCBs, organochlorine pesticides, and PAHs in streambed sediments and aquatic biota exceeded national medians (highest two categories) or 75th percentiles (highest category) at urban sites and were below national medians at more rural sites.

One urban site, one agricultural site, and two sites on the Trinity River downstream from Dallas had fish-community indices greater than the national median. One of those sites also had habitat degradation greater than the national median.

STREAM HABITAT

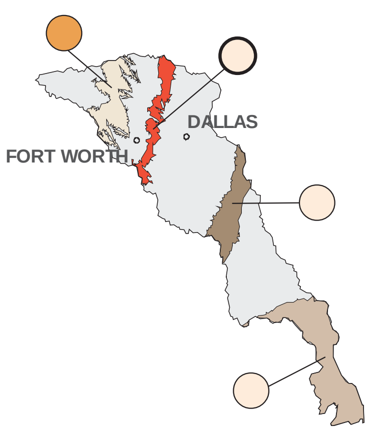


Habitat degradation is greater than the national median at one site on the Trinity River. Leveeing of the streams and bank erosion are the most influential factors for this degraded habitat. All the sites on relatively small rural streams are in the least-degraded category.

Comparison of Trinity River Basin Study Unit Ground-Water Results with Nationwide NAWQA Findings

Four major water-quality characteristics were evaluated for ground-water studies in each NAWQA Study Unit. Ground-water resources were divided into two categories: (1) drinking-water aquifers, and (2) shallow ground water underlying agricultural or urban areas. Summary scores were computed for each characteristic for all aquifers and shallow ground-water areas that have adequate data. Scores for each aquifer and shallow ground-water area in the Trinity River Basin were compared with scores for all aquifers and shallow ground-water areas sampled in the 20 NAWQA Study Units during 1992–95. Results are summarized by percentiles; higher percentiles generally indicate poorer quality compared with other NAWQA ground-water studies. Water-quality conditions for each drinking-water aquifer also are compared to established drinking-water standards and criteria for protection of human health. (Methods used to compute rankings and evaluate standards and criteria are described in Gilliom and others, in press.)

NITRATE



The median nitrate nitrogen concentrations are less than the median of comparable aquifers in NAWQA Study Units nationwide except for the Trinity aquifer, which has a median only slightly greater than the national median. The only sample that exceeded the drinking-water standard was from a shallow monitoring well in the Woodbine aquifer in an urban area. This part of the aquifer is not used for drinking-water supply.

EXPLANATION

Drinking-water aquifers

- Trinity
- Carrizo-Wilcox
- Gulf Coast

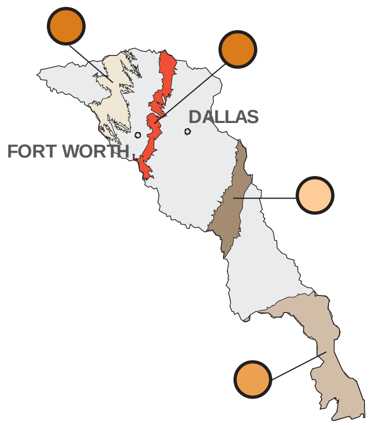
Shallow ground-water area

- Woodbine aquifer (urban area)

Ranking relative to national conditions— Darker colored circles generally indicate poorer quality. Bold outline of circle indicates one or more drinking-water standards or criteria are exceeded

- **Greater than the 75th percentile** (among the highest 25 percent nationally)
- **Between the median and the 75th percentile**
- **Between the 25th percentile and the median**
- **Less than the 25th percentile** (among the lowest 25 percent nationally)

DISSOLVED SOLIDS

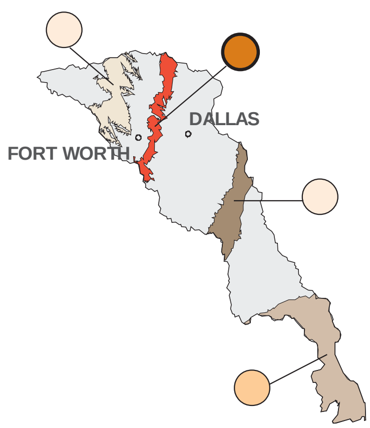


The median dissolved solids concentration of the Carrizo-Wilcox aquifer was slightly less than the median concentration of comparable aquifers in NAWQA Study Units nationwide. However, the medians of the Gulf Coast, Trinity, and Woodbine aquifers were greater than the national median. The percentage of wells with samples that exceeded the SMCL ranges from 17 percent in the Carrizo-Wilcox aquifer to 71 percent in the Woodbine aquifer.

CONCLUSIONS

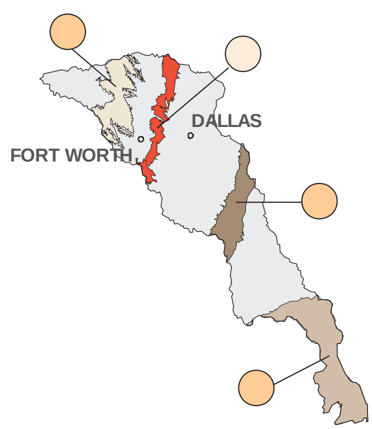
No samples of ground water in aquifers used for drinking water exceeded EPA MCLs and HAs for nutrients, pesticides, and VOCs; however, dissolved solids concentrations commonly exceed the SMCL. Dissolved solids in all four aquifers, nitrate in the Trinity aquifer, and VOCs in the Woodbine aquifer were at greater concentrations or were detected more frequently than national medians for comparable aquifers. The avenues of contamination could be natural recharge or recharge along the outside of well casings that are not completely sealed at the surface.

VOLATILE ORGANIC COMPOUNDS

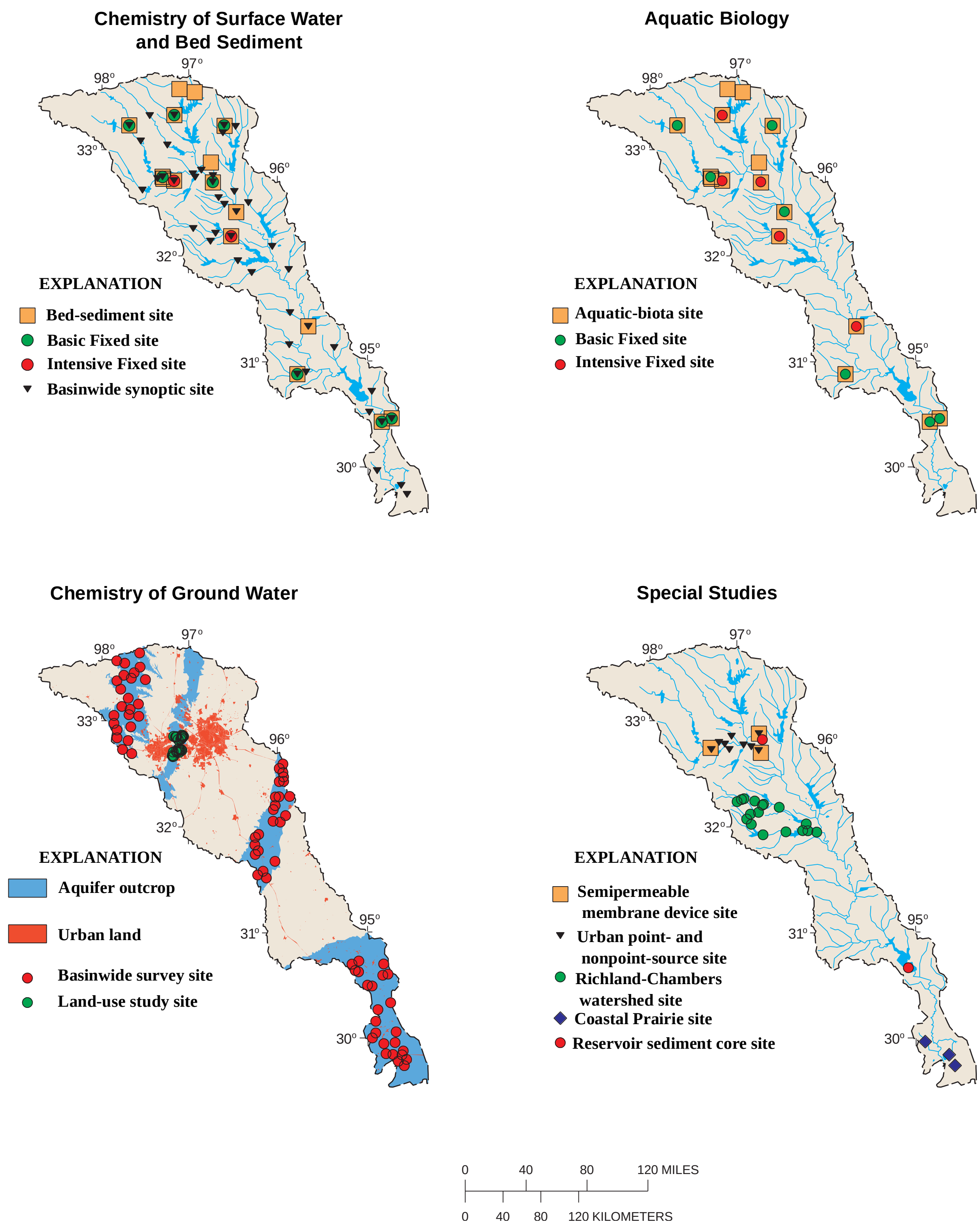


One or more VOCs were detected in less than 5 percent of the wells in the Trinity, Carrizo-Wilcox, and Gulf Coast aquifers. The percentage of detections in all three aquifers is less than the median percentage of detections for all comparable aquifers in NAWQA Study Units nationwide. These results are in contrast to a detection rate of 18 percent for the network of shallow wells in the Woodbine aquifer in an urban area. This detection rate is in the worst category for all comparable aquifers. Only one well in the urban area had a VOC concentration that exceeded the drinking-water standards.

PESTICIDES



The percentages of pesticide detections in the Trinity, Carrizo-Wilcox, and Gulf Coast aquifers are less than the median of all NAWQA ground-water surveys nationwide. Although pesticides were detected in 29 percent of the wells sampled in the Woodbine aquifer, that percentage is in the lowest category relative to nationwide results for shallow ground water underlying urban and agricultural areas.



Location of data-collection sites.

Summary of data collection in the Trinity River Basin Study Unit, 1992–95

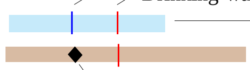
Study component	Objectives	Brief description and water-quality measures	Number of sites	Frequency during 1993–95
Chemistry of surface water and bed sediment				
Water chemistry—Basic and Intensive Fixed sites	Describe concentrations and loads of water-quality constituents at selected stream sites.	Sample at or near streamflow-gaging stations. Basic sites are sampled for major ions, organic carbon, suspended sediment, and nutrients. Intensive sites are a subset of the Basic sites and include sampling for pesticides.	8 Basic; 2 Intensive	~14 per year at Basic; ~25 per year at Intensive
Water chemistry—Basinwide synoptic studies	Describe short-term presence and distribution of contamination over the entire basin and how well the Basic and Intensive sites represent the Trinity River Basin.	Sample streams during winter base-flow and spring runoff conditions for major ions, organic carbon, suspended sediment, nutrients, and pesticides.	43	2
Bed-sediment contamination—Presence and distribution survey	Determine presence of potentially toxic compounds attached to sediment deposited on streambeds.	Sample depositional zones of streams for trace elements and hydrophobic organic compounds.	16	1
Aquatic biology				
Ecological assessments—Basic and Intensive Fixed sites	Assess in detail biological communities and habitat in streams representing primary ecological and land-use regions.	Sample and quantify fish, macroinvertebrates, and algae in streams at stream-chemistry sites and describe stream habitat. Intensive sites are a subset of the Basic sites where there is replicate sampling over three stream reaches.	7 Basic; 5 Intensive	1 at Basic; 1 per year and multiple reaches at Intensive
Aquatic-biota contamination—Presence and distribution survey	Determine presence of contaminants that can accumulate in tissues of aquatic biota.	Collect clam and fish species that are present in most streams of the Trinity River Basin. Sample composites of clams or fish for organic compounds and trace elements.	16	1
Chemistry of ground water				
Water chemistry—Basinwide survey	Describe the overall water quality and natural chemical patterns of water in aquifers.	Sample existing supply wells in the outcrop of three major aquifers for major ions, nutrients, pesticides, trace elements, and VOCs.	71	1
Water chemistry—Land-use study	Determine the effects of urban land use on the quality of shallow ground water.	Sample shallow monitoring and supply wells where there is residential and commercial development for major ions, nutrients, pesticides, trace elements, and VOCs.	38	1
Water chemistry—Flow-path study	Describe changes in water quality in an urban area along flow paths from a shallow aquifer to small streams.	Sample clusters of wells in land-use effects survey and a nearby small stream for major ions, nutrients, pesticides, and age-dating constituents.	3	1
Special studies				
Water chemistry—Use of SPMDs	Determine presence of organic contaminants in water and sediment by deploying caged clams and SPMDs and comparing the results of the two approaches.	Deploy caged native clams and SPMDs side by side for 1 month and determine the presence and concentration of PCBs and PAHs in each medium.	3	1
Water chemistry—Comparison of urban point- and nonpoint-source contaminants	Compare the presence and distribution of nutrients and pesticides in small urban streams and in effluent from regional wastewater-treatment plants in the same service area.	Sample streams and effluent from regional wastewater-treatment plants during late winter to summer for major ions, nutrients, and pesticides.	6 streams: 3 wastewater-treatment plants	6
Water chemistry—Richland-Chambers watershed	Describe presence and distribution of agricultural chemicals in streams and reservoirs in a major crop-producing area.	Sample streams from late winter to late summer for major ions, nutrients, pesticides, and suspended sediment. Reservoirs sampled at beginning or end of study, or both.	5 streams; 11 reservoirs	7 at streams; 1 or 2 at reservoirs
Water chemistry—Coastal Prairie agricultural area	Describe presence and distribution of agricultural chemicals in streams in a major crop-producing area with irrigation.	Sample streams for 1 year for major inorganic ions, nutrients, pesticides, and suspended sediment. Sampling much more frequent during late spring and summer than fall and winter.	3	~25
Water-quality trends—Reservoir sediment cores	Determine temporal trends of trace elements, organochlorine compounds, and PAHs in streams.	Collect sediment cores at Lake Livingston and White Rock Lake. Horizontal slices analyzed for age-dating elements, trace elements, organochlorine compounds, and PAHs.	2 reservoirs	1

The following tables summarize data collected for NAWQA studies from 1992–95 by showing results for the Trinity River Basin Study Unit compared to the NAWQA national range for each compound detected. The data were collected at a wide variety of places and times. In order to represent the wide concentration ranges observed among Study Units, logarithmic scales are used to emphasize the general magnitude of concentrations (such as 10, 100, or 1,000), rather than the precise number. The complete dataset used to construct these tables is available upon request.

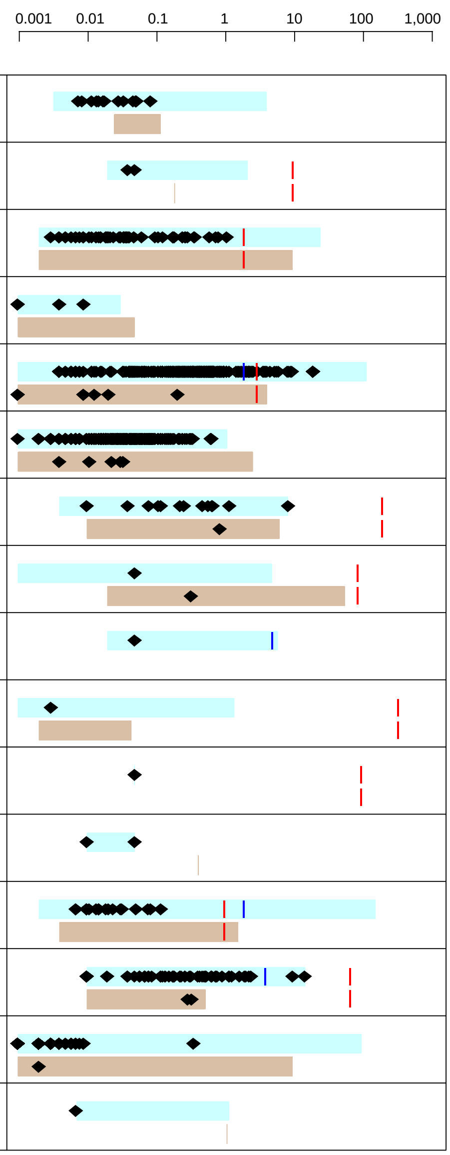
Concentrations of herbicides, insecticides, volatile organic compounds, and nutrients detected in ground and surface waters of the Trinity River Basin Study Unit

[µg/L, micrograms per liter; %, percent; <, less than; --, not measured; mg/L, milligrams per liter; trade names might vary]

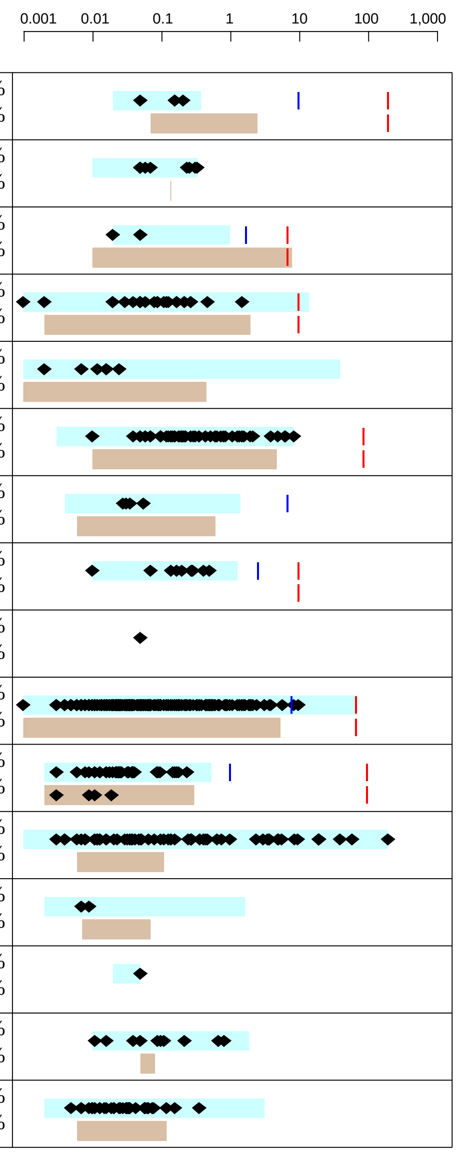
EXPLANATION



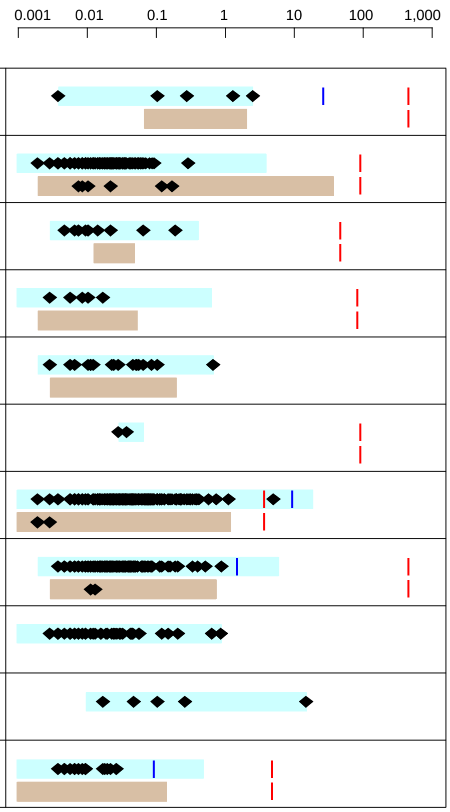
Herbicide (Trade or common name)	Rate of detection [b]
Acetochlor	7% 0%
Acifluorfen (Blazer, Tackle 2S)	1% 0%
Alachlor (Lasso)	15% 0%
2,6-Diethylaniline (Alachlor metabolite)	<1% 0%
Atrazine (AAtrex, Gesaprim)	88% 3%
Deethylatrazine[c] (Atrazine metabolite)	71% 4%
Bentazon (Basagran, bentazone)	4% 1%
Bromacil (Hyvar X, Urox B, Bromax)	<1% 1%
Bromoxynil (Buctril, Brominal, Torch)	<1% 0%
Butylate (Sutan, Genate Plus, butilate)	<1% 0%
Chloramben (Amiben, Vegiben)	<1% 0%
Clopyralid (Stinger, Lontrel, Dowco 290)	1% 0%
Cyanazine (Bladex, Fortrol)	5% 0%
2,4-D (2,4-PA)	17% 2%
DCPA (Dacthal, chlorthal-dimethyl)	<1% <1%
Dacthal, mono-acid (Dacthal metabolite)	<1% 0%



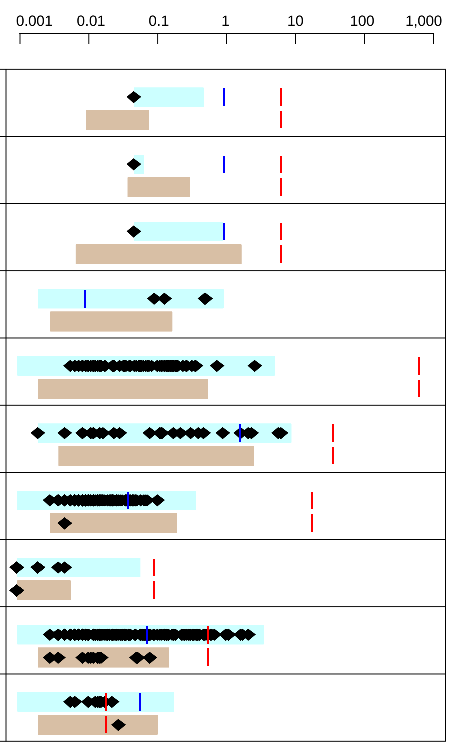
Herbicide (Trade or common name)	Rate of detection [b]
Dicamba (Banvel, Mediben, dianat)	1% 0%
Dichlorprop (2,4-DP, Seritox 50, Kildip)	3% 0%
Dinoseb (DNBP, DN 289, Premerge, Aretit)	1% 0%
Diuron (Karmex, Direx, DCMU)	7% 0%
EPTC (Eptam)	1% 0%
Fluometuron (Flo-Met, Cotoran)	17% 0%
Linuron (Lorox, Linex, Sarclex)	1% 0%
MCPA (Agritox, Agroxone)	3% 0%
MCPB (Can-Trol, Thistrol, Tropotox)	<1% 0%
Metolachlor (Dual, Pennant)	69% 0%
Metribuzin (Lexone, Sencor)	10% 2%
Molinate (Ordram)	18% 0%
Napropamide (Devrinol)	<1% 0%
Neburon (Neburex, Noruben, Kloben)	<1% 0%
Oryzalin (Surflan, Dirimal, Ryzelan)	3% 0%
Pendimethalin (Prowl, Stomp)	10% 0%



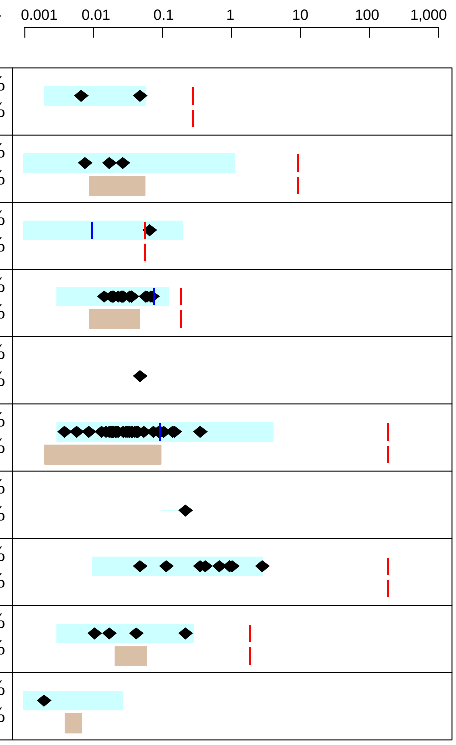
Herbicide (Trade or common name)	Rate of detection[b]
Picloram (Tordon, Amdon)	1% 0%
Prometon (Gesagram, prometone)	50% 4%
Pronamide (Kerb, propyzamid)	2% 0%
Propachlor (Ramrod, propachlore)	1% 0%
Propanil (Stampede, Surcopur)	5% 0%
Propham (Chem-Hoe, IPC, prophame)	1% 0%
Simazine (Aquazine, Princep, Gesatop)	63% <1%
Tebuthiuron (Spike, Perflan)	42% 2%
Thiobencarb (Bolero, Saturn, benthiocarb)	8% 0%
Triclopyr (Garlon, Grazon, Crossbow)	1% 0%
Trifluralin (Treflan, Trinin, Elancolan)	3% 0%



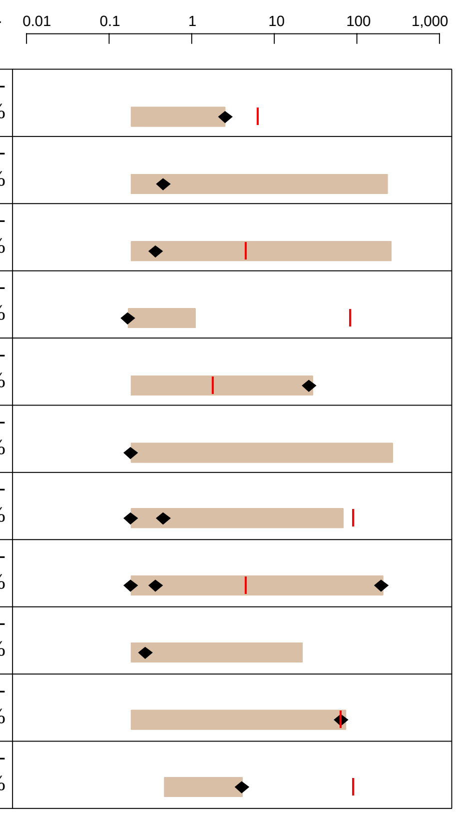
Insecticide (Trade or common name)	Rate of detection[b]
Aldicarb[c] (Temik)	<1% 0%
Aldicarb sulfone[c] (Standak)	<1% 0%
Aldicarb sulfoxide[c] (Aldicarb metabolite)	<1% 0%
Azinphos-methyl[c] (Guthion)	1% 0%
Carbaryl[c] (Sevin, Savit)	24% 0%
Carbofuran[c] (Furadan, Curaterr)	7% 0%
Chlorpyrifos (Dursban, Lorsban)	21% <1%
p,p'-DDE (*p,p'*-DDT metabolite)	<1% <1%
Diazinon	47% 10%
Dieldrin (Panoram D-31, Octalox)	2% 1%



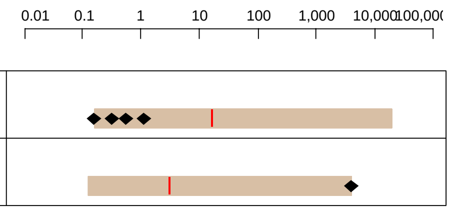
Insecticide (Trade or common name)	Rate of detection[b]
Disulfoton[c] (Disyston, Dithiosystox)	<1% 0%
Fonofos (Dyfonate)	1% 0%
alpha-HCH (*alpha*-BHC, *alpha*-lindane)	<1% 0%
gamma-HCH	5% 0%
3-Hydroxycarbofuran	<1% 0%
Malathion (maldison, malathon, Cythion)	10% 0%
Methiocarb (Grandslam, Mesurol, Draza)	<1% 0%
Methomyl (Lannate, Nudrin)	2% 0%
Methyl parathion (Penncap-M)	1% 0%
cis-Permethrin[c] (Ambush, Pounce)	<1% 0%



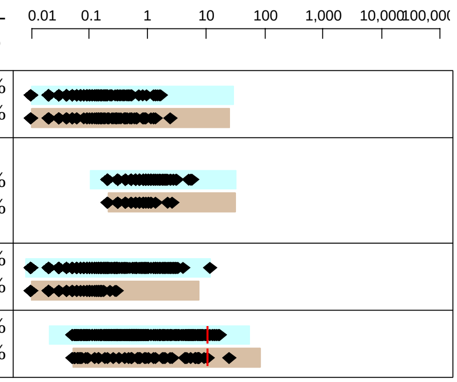
Volatile organic compound (Trade or common name)	Rate of detection[b]
1,1-Dichloroethene (Vinylidene chloride)	-- 1%
1,2,4-Trimethylbenzene (Pseudocumene)	-- 1%
Benzene	-- 1%
Chlorobenzene (Monochlorobenzene)	-- 1%
Chloroethene (Vinyl Chloride)	-- 1%
Dimethylbenzenes (Xylenes (total))	-- 1%
total Trihalomethanes	-- 3%
Trichloroethene (TCE)	-- 3%
Trichlorofluoromethane (CFC 11)	-- 1%
cis-1,2-Dichloroethene)	-- 1%
trans-1,2-Dichloroethene)	-- 1%



Volatile organic compound (Trade or common name)	Rate of detection [b]	Concentration, in µg/L
Methyl *tert*-butyl ether[d] (MTBE)	-- 4%	
Tetrachloroethene (Perchloroethene)	-- 1%	



Nutrient	Rate of detection [b]	Concentration, in mg/L
Dissolved ammonia	90% 92%	
Dissolved ammonia plus organic nitrogen as nitrogen	91% 41%	
Dissolved phosphorus as phosphorus	77% 66%	
Dissolved nitrite plus nitrate	87% 50%	



Herbicides, insecticides, volatile organic compounds, and nutrients not detected in ground and surface waters of the Trinity River Basin Study Unit.

Herbicides

2,4,5-T

2,4,5-TP (Silvex, Fenoprop)

2,4-DB (Butyrac, Butoxone, Embutox Plus, Embutone)

Benfluralin (Balan, Benefin, Bonalan, Benefex)

Ethalfluralin (Sonalan, Curbit)

Fenuron (Fenulon, Fenidim)

Norflurazon (Evital, Predict, Solicam, Zorial)

Pebulate (Tillam, PEBC)

Terbacil (Sinbar)

Triallate (Far-Go, Avadex BW, Tri-allate)

Insecticides

Ethoprop (Mocap, Ethoprophos)

Oxamyl (Vydate L, Pratt)

Parathion (Roethyl-P, Alkron, Panthion, Phoskil)

Phorate (Thimet, Granutox, Geomet, Rampart)

Propargite (Comite, Omite, Ornamite)

Propoxur (Baygon, Blattanex, Unden, Proprotox)

Terbufos (Contraven, Counter, Pilarfox)

Volatile organic compounds

1,1,1,2-Tetrachloroethane (1,1,1,2-TeCA)

1,1,1-Trichloroethane (Methylchloroform)

1,1,2,2-Tetrachloroethane

1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113, CFC 113)

1,1,2-Trichloroethane (Vinyl trichloride)

1,1-Dichloroethane (Ethylidene dichloride)

1,1-Dichloropropene

1,2,3-Trichlorobenzene (1,2,3-TCB)

1,2,3-Trichloropropane (Allyl trichloride)

1,2,4-Trichlorobenzene

1,2-Dibromo-3-chloropropane (DBCP, Nemagon)

1,2-Dibromoethane (EDB, Ethylene dibromide)

1,2-Dichlorobenzene (*o*-Dichlorobenzene, 1,2-DCB)

1,2-Dichloroethane (Ethylene dichloride)

1,2-Dichloropropane (Propylene dichloride)

1,3,5-Trimethylbenzene (Mesitylene)

1,3-Dichlorobenzene (*m*-Dichlorobenzene)

1,3-Dichloropropane (Trimethylene dichloride)

1,4-Dichlorobenzene (*p*-Dichlorobenzene, 1,4-DCB)

1-Chloro-2-methylbenzene (*o*-Chlorotoluene)

1-Chloro-4-methylbenzene (*p*-Chlorotoluene)

2,2-Dichloropropane

Bromobenzene (Phenyl bromide)

Bromochloromethane (Methylene chlorobromide)

Bromomethane (Methyl bromide)

Chloroethane (Ethyl chloride)

Chloromethane (Methyl chloride)

Dibromomethane (Methylene dibromide)

Dichlorodifluoromethane (Freon 12, CFC 12)

Dichloromethane (Methylene chloride)

Ethenylbenzene (Styrene)

Ethylbenzene (Phenylethane)

Hexachlorobutadiene

Isopropylbenzene (Cumene)

Methylbenzene (Toluene)

Naphthalene

Tetrachloromethane (Carbon tetrachloride)

cis-1,3-Dichloropropene ((Z)-1,3-Dichloropropene)

n-Butylbenzene (1-Phenylbutane)

n-Propylbenzene (Isocumene)

p-Isopropyltoluene (*p*-Cymene)

sec-Butylbenzene

tert-Butylbenzene

trans-1,3-Dichloropropene ((E)-1,3-Dichloropropene)

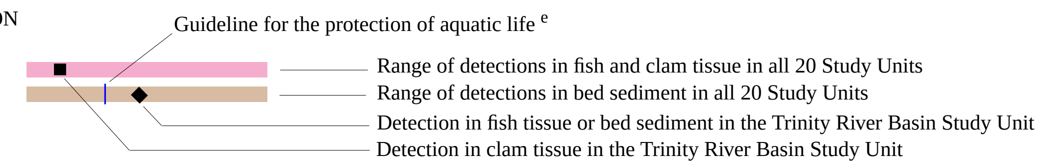
Nutrients

No nondetects

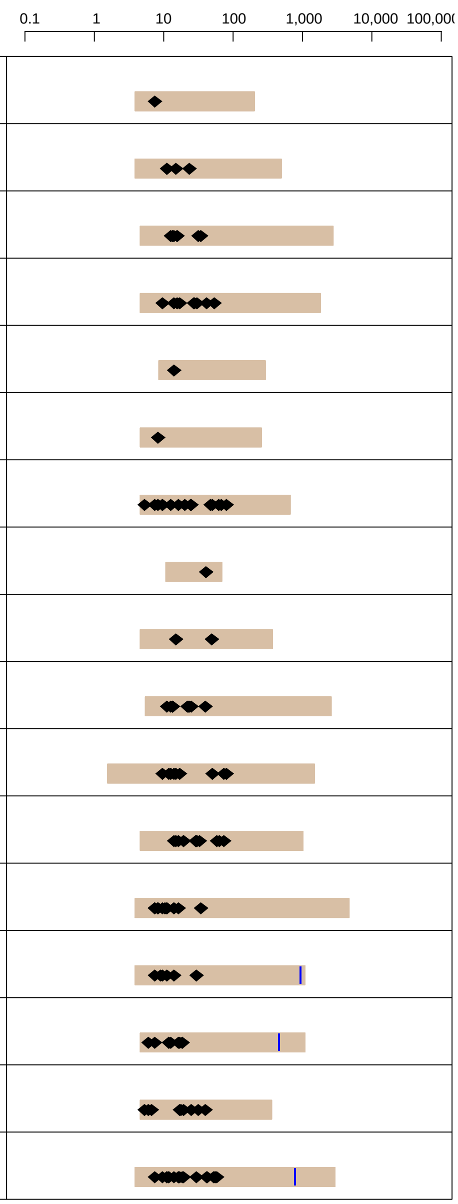
Concentrations of semivolatile organic compounds, organochlorine compounds, and trace elements detected in fish and clam tissue and bed sediment of the Trinity River Basin Study Unit

[µg/kg, micrograms per kilogram; --, not measured; %, percent; µg/g, micrograms per gram; trade names may vary]

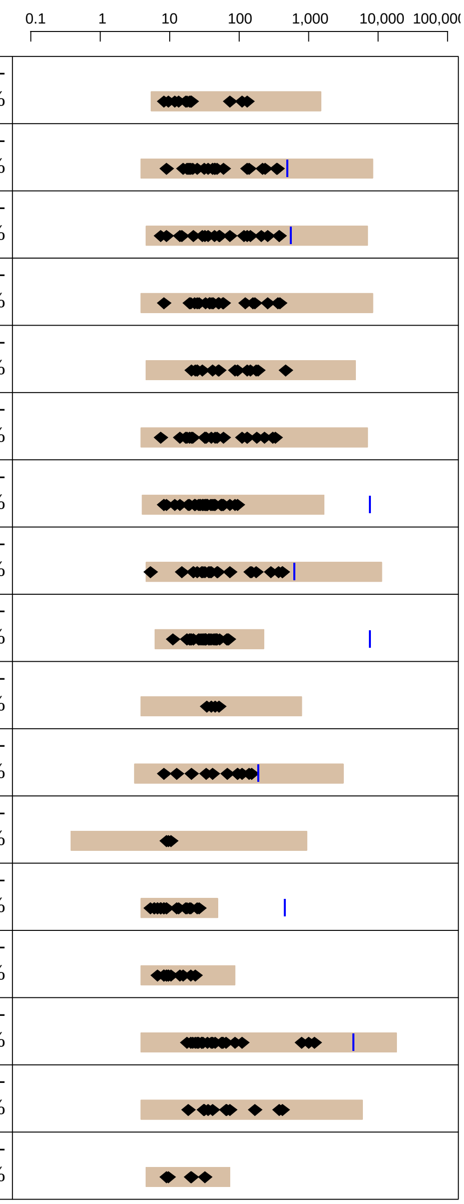
EXPLANATION



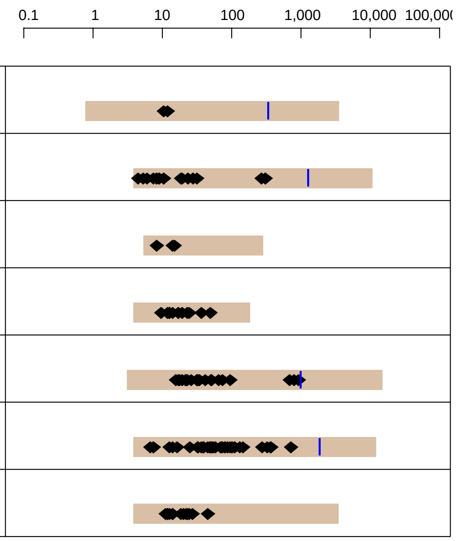
Semivolatile organic compound	Rate of detection [b]	Concentration, in µg/kg
1,2-Dimethylnaphthalene	-- 4%	
1,6-Dimethylnaphthalene	-- 15%	
1-Methylphenanthrene	-- 27%	
1-Methylpyrene	-- 35%	
2,2-Biquinoline	-- 4%	
2,3,6-Trimethylnaphthalene	-- 4%	
2,6-Dimethylnaphthalene	-- 58%	
2,6-Dinitrotoluene	-- 2%	
2-Ethylnaphthalene	-- 8%	
2-Methylanthracene	-- 35%	
4,5-Methylenephenanthrene	-- 35%	
9H-Carbazole	-- 46%	
9H-Fluorene	-- 39%	
Acenaphthene	-- 15%	
Acenaphthylene	-- 22%	
Acridine	-- 35%	
Anthracene	-- 46%	



Semivolatile organic compound	Rate of detection [b]	Concentration, in µg/kg
Anthraquinone	-- 50%	
Benz(*a*)anthracene	-- 51%	
Benzo(*a*)pyrene	-- 49%	
Benzo(*b*)fluoranthene	-- 51%	
Benzo(*g*,*h*,*i*)perylene	-- 37%	
Benzo(*k*)fluoranthene	-- 51%	
Butylbenzylphthalate	-- 88%	
Chrysene	-- 51%	
Di-*n*-butylphthalate	-- 95%	
Di-*n*-octylphthalate	-- 15%	
Dibenz(*a*,*h*)anthracene	-- 27%	
Dibenzothiophene	-- 12%	
Diethylphthalate	-- 61%	
Dimethylphthalate	-- 32%	
Fluoranthene	-- 85%	
Indeno(1,2,3-*cd*)pyrene	-- 46%	
Isoquinoline	-- 19%	



Semivolatile organic compound	Rate of detection [b]
Naphthalene	-- 8%
Phenanthrene	-- 69%
Phenanthridine	-- 12%
Phenol	-- 50%
Pyrene	-- 81%
bis(2-Ethylhexyl)phthalate	-- 100%
p-Cresol	-- 50%



Organochlorine compound (Trade name)	Rate of detection [b]
Aldrin (HHDN, Octalene)	3% 0%
total Chlordane	60% 20%
DCPA (dacthal, chlorthal-dimethyl)	3% 0%
p,p'-DDE	61% 49%
total DDT	67% 49%
Dieldrin (Panoram D-31, Octalox)	42% 18%
gamma-HCH (lindane, *gamma*-BHC)	11% 0%
Heptachlor epoxide	14% 2%
Heptachlor (heptachlore, Velsicol 104)	3% 0%
Mirex (Dechlorane)	0% 2%
PCB, total	28% 4%
Pentachloroanisole	8% 0%
Toxaphene (camphechlor, Hercules)	3% 0%

Trace element	Rate of detection [b]
Arsenic	73% 100%
Cadmium	73% 98%
Chromium	93% 100%
Copper	100% 100%
Lead	67% 100%
Mercury	67% 67%
Nickel	73% 100%
Selenium	100% 100%
Zinc	100% 96%

Semivolatile organic compounds, organochlorine compounds, and trace elements not detected in fish and clam tissue and bed sediment of the Trinity River Basin Study Unit.

Semivolatile organic compounds

1,2,4-Trichlorobenzene

1,2-Dichlorobenzene (*o*-Dichlorobenzene, 1,2-DCB)

1,3-Dichlorobenzene (*m*-Dichlorobenzene)

1,4-Dichlorobenzene (*p*-Dichlorobenzene, 1,4-DCB)

1-Methyl-9H-fluorene

2,4-Dinitrotoluene

2-Chloronaphthalene

2-Chlorophenol

3,5-Dimethylphenol

4-Bromophenyl-phenyl-ether

4-Chloro-3-methylphenol

4-Chlorophenyl-phenyl-ether

Azobenzene

Benzo(*c*)cinnoline

C8-Alkylphenol

Isophorone

N-Nitrosodi-*n*-propylamine

N-Nitrosodiphenylamine

Nitrobenzene

Pentachloronitrobenzene

Quinoline

bis(2-Chloroethoxy) methane

Organochlorine compounds

Chloroneb (chloronebe, Demosan, Soil Fungicide 1823)

Endosulfan I (*alpha*-Endosulfan, Thiodan, Cyclodan, Beosit, Malix, Thimul, Thifor)

Endrin (Endrine)

Hexachlorobenzene (HCB)

Isodrin (Isodrine, Compound 711)

alpha-HCH (*alpha*-BHC, *alpha*-lindane, *alpha*-hexachlorocyclohexane, *alpha*-benzene hexachloride)

beta-HCH (*beta*-BHC, *beta*-hexachlorocyclohexane, *alpha*-benzene hexachloride)

cis-Permethrin (Ambush, Astro, Pounce, Pramex, Pertox, Ambushfog, Kafil, Perthrine, Picket, Picket G, Dragnet, Talcord, Outflank, Stockade, Eksmin, Coopex, Peregin, Stomoxin, Stomoxin P, Qamlin, Corsair, Tornade)

delta-HCH (*delta*-BHC, *delta*-hexachlorocyclohexane, *delta*-benzene hexachloride)

o,p'-Methoxychlor

p,p'-Methoxychlor (Marlate, methoxychlore)

trans-Permethrin (Ambush, Astro, Pounce, Pramex, Pertox, Ambushfog, Kafil, Perthrine, Picket, Picket G, Dragnet, Talcord, Outflank, Stockade, Eksmin, Coopex, Peregin, Stomoxin, Stomoxin P, Qamlin, Corsair, Tornade)

Trace elements

No nondetects

[a] Selected water-quality standards and guidelines (Gilliom and others, in press).

[b] Rates of detection are based on the number of analyses and detections in the Study Unit, not on national data. Rates of detection for herbicides and insecticides were computed by counting only detections equal to or greater than 0.01 µg/L to facilitate equal comparisons among compounds, which had widely varying detection limits. For herbicides and insecticides, a detection rate of "<1%" means that all detections are less than 0.01 µg/L, or the detection rate rounds to less than 1%. For other compound groups, all detections were counted and minimum detection limits for most compounds were similar to the lower end of the national ranges shown. Method detection limits for all compounds in these tables are summarized in (Gilliom and others, in press).

[c] Detections of these compounds are reliable, but concentrations are determined with greater uncertainty than for the other compounds and are reported as estimated values (Zaugg and others, 1995).

[d] The guideline for methyl *tert*-butyl ether is between 20 and 40 µg/L; if the tentative cancer classification C is accepted, the lifetime health advisory will be 20 µg/L (Gilliom and others, in press).

[e] Selected sediment-quality guidelines (Gilliom and others, in press).

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The terms in this glossary were compiled from numerous sources. Some definitions have been modified and may not be the only valid ones for these terms.

Algae - Chlorophyll-bearing, nonvascular, primarily aquatic species that have no true roots, stems, or leaves; most algae are microscopic, but some species can be as large as vascular plants.

Ammonia - A compound of nitrogen and hydrogen (NH_3) that is a common by-product of animal waste. Ammonia readily converts to nitrate in soils and streams.

Anomalies - As related to fish, externally visible skin or subcutaneous disorders, including deformities, eroded fins, lesions, and tumors.

Aquifer - A water-bearing layer of soil, sand, gravel, or rock that will yield usable quantities of water to wells.

Bank - The sloping ground that borders a stream and confines the water in the natural channel when the water level, or flow, is normal.

Basic Fixed sites - Sites on streams at which streamflow is measured and samples are collected for temperature, salinity, suspended sediment, major ions and trace elements, nutrients, and organic carbon to assess the broad-scale spatial and temporal character and transport of inorganic constituents of stream water in relation to hydrologic conditions and environmental settings.

Bed sediment - The material that temporarily is stationary in the bottom of a stream or other watercourse.

Bioaccumulation - The biological sequestering of a substance at a higher concentration than that at which it occurs in the surrounding environment or medium. Also, the process whereby a substance enters organisms through the gills, epithelial tissues, dietary, or other sources.

Biochemical oxygen demand (BOD) - The amount of oxygen, measured in milligrams per liter, that is removed from aquatic environments by the life processes of microorganisms.

Bioconcentration - A process by which there is a net accumulation of a chemical directly from water into aquatic organisms resulting from simultaneous uptake (for example, by gill or epithelial tissue) and elimination.

Biota - Living organisms.

Channelization - Modification of a stream, typically by straightening the channel, to provide more uniform flow; often done for flood control or for improved agricultural drainage or irrigation.

Chlordane - Octachloro-4,7-methanotetrahydroindane. An organochlorine insecticide no longer registered for use in the United States. Technical chlordane is a mixture in which the primary components are *cis*- and *trans*-chlordane, *cis*- and *trans*-nonachlor, and heptachlor.

Concentration - The amount or weight of a substance present in a given volume or weight of sample. Usually expressed as micrograms per liter (water sample) or micrograms per kilogram (sediment or tissue sample).

Constituent - A chemical or biological substance in water, sediment, or biota that can be measured by analytical methods.

Contamination - Degradation of water quality compared to original or natural conditions due to human activity.

Cubic foot per second - The rate of water discharge representing a volume of 1 cubic foot passing a given point during 1 second, approximately equivalent to 7.48 gallons per second or 448.8 gallons per minute or 0.02832 cubic meter per second.

DDT - Dichlorodiphenyltrichloroethane. An organochlorine insecticide no longer registered for use in the United States.

Detection limit - The concentration below which a particular analytical method cannot determine, with a high degree of certainty, a concentration.

Dieldrin - An organochlorine insecticide no longer registered for use in the United States. Also a degradation product of the insecticide aldrin.

Discharge - Rate of fluid flow passing a given point at a given moment in time, expressed as volume per unit of time.

Dissolved constituent - Operationally defined as a constituent that passes through a 0.45-micrometer filter.

Ecoregion - An area of similar climate, landform, soil, potential natural vegetation, hydrology, or other ecologically relevant variables.

Effluent - Outflow from a particular source, such as a stream that flows from a lake or liquid waste that flows from a factory or sewage-treatment plant.

Environmental setting - Land area characterized by a unique combination of natural and human-related factors, such as row-crop cultivation or glacial-till soils.

Eutrophication - The process by which water becomes enriched with plant nutrients, most commonly nitrogen and phosphorus.

Fish community - A group of populations of fish that interact in a common area.

Fixed sites - NAWQA's most comprehensive monitoring sites. *See* Basic Fixed sites and Intensive Fixed sites.

Flow-path study - Network of clustered wells located along a flow path extending from a recharge zone to a discharge zone, preferably a shallow stream. The studies examine the relations of land-use practices, ground-water flow, and contaminant occurrence and transport. The studies are located in the area of one of the land-use studies.

Fumigant - A substance or mixture of substances that produce gas, vapor, fume, or smoke intended to destroy insects, bacteria, or rodents.

Gaging station - A particular site on a stream, canal, lake, or reservoir where systematic observations of hydrologic data are obtained.

Habitat - The part of the physical environment where plants and animals live.

Health advisory (HA) - Nonregulatory levels of contaminants in drinking water that can be used as guidance in the absence of regulatory limits. They consist of estimates of concentrations that would result in no known or anticipated health effects (for carcinogens, a specified cancer risk) determined for a child or for an adult for various exposure periods.

Herbicide - A chemical or other agent applied for the purpose of killing undesirable plants. *See also* Pesticide.

Hydrograph - Graph showing variation of water elevation, velocity, streamflow, or other property of water with respect to time.

Indicator sites - Stream sampling sites located at outlets of drainage basins with relatively homogeneous land-use and physiographic conditions; most indicator-site basins have drainage areas ranging from 20 to 200 square miles.

Insecticide - A substance or mixture of substances intended to destroy or repel insects.

Integrator or mixed-use site - Stream sampling site located at an outlet of a drainage basin that contains multiple environmental settings. Most integrator sites are on major streams with relatively large drainage areas.

Intensive Fixed sites - Basic Fixed sites with increased sampling frequency during selected seasonal periods and analysis of dissolved pesticides for 1 year. Most NAWQA Study Units have 1 to 2 integrator Intensive Fixed sites and 1 to 4 indicator Intensive Fixed sites.

Invertebrate - An animal with no backbone or spinal column.

Land-use study - A network of existing shallow wells in an area with a relatively uniform land use. These studies are a part of the Study Unit Survey and have the goal of relating the quality of shallow ground water to land use. *See also* Study Unit Survey.

Main stem - The principal course of a river or stream.

Major ions - Constituents commonly present in concentrations exceeding 1.0 milligram per liter. Major cations generally are calcium, magnesium, sodium, and potassium; major anions are sulfate, chloride, fluoride, nitrate, and those contributing to alkalinity, generally assumed to be bicarbonate and carbonate.

Maximum contaminant level (MCL) - Maximum permissible level of a contaminant in water that is delivered to any user of a public water system. MCLs are enforceable standards established by the U.S. Environmental Protection Agency.

Mean - The average of a set of observations, unless otherwise specified.

Mean discharge - The arithmetic mean of individual daily mean discharges during a specific period, usually daily, monthly, or annually.

Median - The middle or central value in a distribution of data ranked in order of magnitude. The median is also the 50th percentile.

Micrograms per liter - A unit expressing the concentration of constituents in solution as weight (micrograms) of solute per unit volume (liter) of water; equivalent to 1 part per billion in most stream water and ground water. One thousand micrograms per liter equals 1 milligram per liter.

Milligrams per liter - A unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water; equivalent to 1 part per million in most stream water and ground water. One thousand micrograms per liter equals 1 milligram per liter.

Nitrate - An ion consisting of nitrogen and oxygen (NO_3^-). Nitrate is a plant nutrient and is very mobile in soils.

Nonpoint source - A pollution source that cannot be defined as originating from discrete points such as pipe discharge. Areas of fertilizer and pesticide applications, atmospheric deposition, manure, and natural inputs from plants and trees are types of nonpoint-source pollution.

Nutrient - Element or compound essential for animal and plant growth. Common nutrients in fertilizer include nitrogen, phosphorus, and potassium.

Organochlorine compound - Synthetic organic compounds containing chlorine. As generally used, term refers to compounds containing mostly or exclusively carbon, hydrogen, and chlorine. Examples include organochlorine insecticides, polychlorinated biphenyls, and some solvents containing chlorine.

Organochlorine insecticide - A class of organic insecticides containing a large percentage of chlorine. Includes dichlorodiphenylethanes (such as DDT), chlorinated cyclodienes (such as chlordane), and chlorinated benzenes (such as lindane). Most organochlorine insecticides are banned because of their carcinogenicity, tendency to bioaccumulate, and toxicity to wildlife.

Pesticide - A chemical applied to crops, rights of way, lawns, or residences to control weeds, insects, fungi, nematodes, rodents or other “pests.”

pH - The logarithm of the reciprocal of the hydrogen ion concentration (activity) of a solution; a measure of the acidity (pH less than 7) or alkalinity (pH greater than 7) of a solution; a pH of 7 is neutral.

Phosphorus - A nutrient essential for growth that can be important in stimulating aquatic growth in lakes and streams.

Picocurie - One trillionth (10^{-12}) of the amount of radioactivity represented by a curie. A curie is the amount of radioactivity that yields 3.7×10^{10} radioactive disintegrations per second. A picocurie yields 2.22 disintegrations per minute.

Point source - A source at a discrete location such as a discharge pipe, drainage ditch, tunnel, well, concentrated livestock operation, or floating craft.

Polychlorinated biphenyl (PCB) - A mixture of chlorinated derivatives of biphenyl, marketed under the trade name Aroclor with a number designating the chlorine content (such as Aroclor 1260). PCBs were used in transformers and capacitors for insulation and in gas pipeline systems as a lubricant. Further sale for new use was banned by law in 1979.

Polycyclic aromatic hydrocarbon (PAH) - A class of organic compounds with a fused-ring aromatic structure. PAHs result from incomplete combustion of organic carbon (including wood), municipal solid waste, and fossil fuels, as well as from natural or anthropogenic introduction of uncombusted coal and oil. PAHs include benzo(a)pyrene, fluoranthene, and pyrene.

Precipitation - Any or all forms of water particles that fall from the atmosphere, such as rain, snow, hail, and sleet.

Recharge - Water that infiltrates the ground and reaches the saturated zone.

Reference site - A NAWQA sampling site selected for its relatively undisturbed conditions.

Riparian zone - Pertaining to or located on the bank of a body of water, especially a stream.

Runoff - Excess rainwater or snowmelt that is transported to streams by overland flow, tile drains, or ground-water flow.

Salinity - In this report, refers to the concentration of dissolved solids in water.

Secondary maximum contaminant level (SMCL) - The maximum contamination level in public water systems that, in the judgment of the U.S. Environmental Protection Agency (EPA), are required to protect the public welfare. SMCLs are secondary (nonenforceable) drinking-water regulations established by the EPA for contaminants that may adversely affect the odor or appearance of such water.

Sediment - Particles, derived from rocks or biological materials, that have been transported by a fluid or other natural process, suspended or settled in water.

Semivolatile organic compound (SVOC) - Operationally defined as a group of synthetic organic compounds that are solvent-extractable and can be determined by gas chromatography/mass spectrometry. SVOCs include phenols, phthalates, and PAHs.

Streamflow - A type of channel flow, applied to that part of surface runoff in a stream whether or not it is affected by diversion or regulation.

Study Unit - A major hydrologic system of the United States in which NAWQA studies are focused. Study Units are geographically defined by a combination of ground- and surface-water features and generally encompass more than 4,000 square miles of land area.

Study Unit Survey - Broad assessment of the water-quality conditions of the major aquifer systems of each Study Unit. The Study Unit Survey relies primarily on sampling existing wells and, wherever possible, on existing data collected by other agencies and programs. Typically, 20 to 30 wells are sampled in each of 3 to 5 aquifer subunits.

Survey - Sampling of any number of sites during a given hydrologic condition.

Synoptic sites - Sites sampled during a short-term investigation of specific water-quality conditions during selected seasonal or hydrologic conditions to provide improved spatial resolution for critical water-quality conditions.

Tolerant species - Those species that are adaptable to (tolerant of) human effects on the environment.

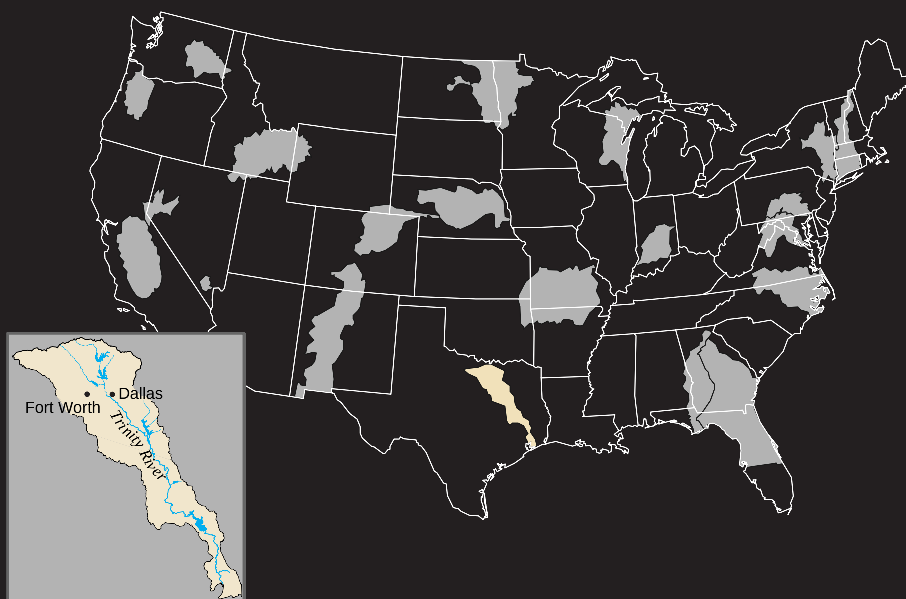
Total concentration - Refers to the concentration of a constituent regardless of its form (dissolved or bound) in a sample.

Trace element - An element found in only minor amounts (concentrations less than 1.0 milligram per liter) in water or sediment; includes arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc.

Volatile organic compound (VOC) - Organic chemical that has a high vapor pressure relative to its water solubility. VOCs include components of gasoline, fuel oils, and lubricants, as well as organic solvents, fumigants, some inert ingredients in pesticides, and some by-products of chlorine disinfection.

NAWQA

National Water-Quality Assessment (NAWQA) Program
Trinity River Basin



Land and others • Water Quality in the Trinity River Basin
USGS Circular 1171 • 1998

ISBN 0-607-89233-1