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Water Quality in the Upper Colorado River Basin

Colorado, 1996–98

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Front cover: Maroon Creek in the Elk Mountains above Aspen, Colorado. (Photograph by Michael Collier.)

Back cover: Left, Drilling sampling well (photograph by Lori Apodaca); center, sampling the Colorado River near Dotsero (photograph by Norman Spahr); right, collecting invertebrate samples (photograph by Jeffrey Deacon).

Water Quality in the Upper Colorado River Basin, Colorado, 1996–98

By Norman E. Spahr, Lori E. Apodaca, Jeffrey R. Deacon, Jeffrey B. Bails, Nancy J. Bauch, C. Michelle Smith, *and* Nancy E. Driver

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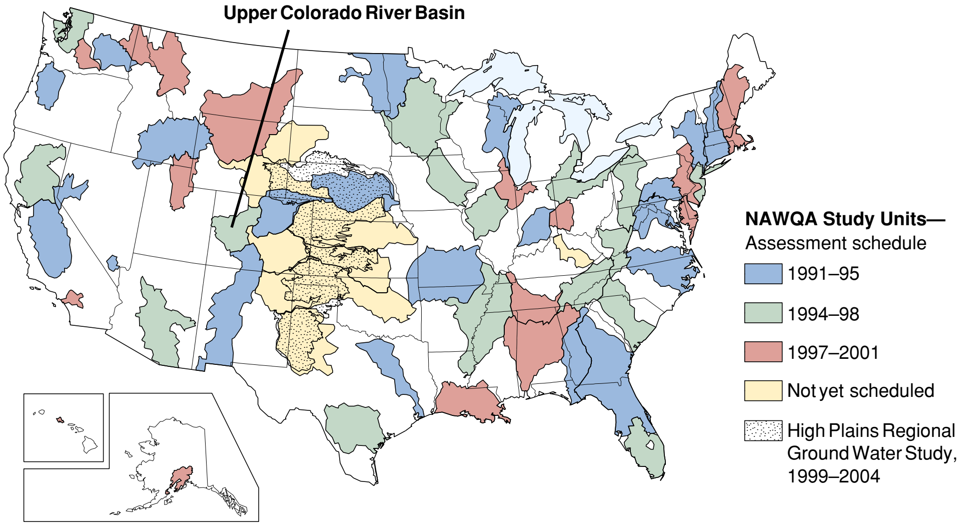
CONTENTS

THIS REPORT summarizes major findings about water quality in the Upper Colorado River Basin that emerged from an assessment conducted between 1996 and 1998 by the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program. Water quality is discussed in terms of local and regional issues and compared to conditions found in all 36 NAWQA study areas, called Study Units, assessed to date. Findings are also explained in the context of selected national benchmarks, such as those for drinking water quality and the protection of aquatic organisms. The NAWQA Program was not intended to assess the quality of the Nation's drinking water, such as by monitoring water from household taps. Rather, the assessments focus on the quality of the resource itself, thereby complementing many ongoing Federal, State, and local drinking-water monitoring programs. The comparisons made in this report to drinking-water standards and guidelines are only in the context of the available untreated resource. Finally, this report includes information about the status of aquatic communities and the condition of instream habitats as elements of a complete water-quality assessment.

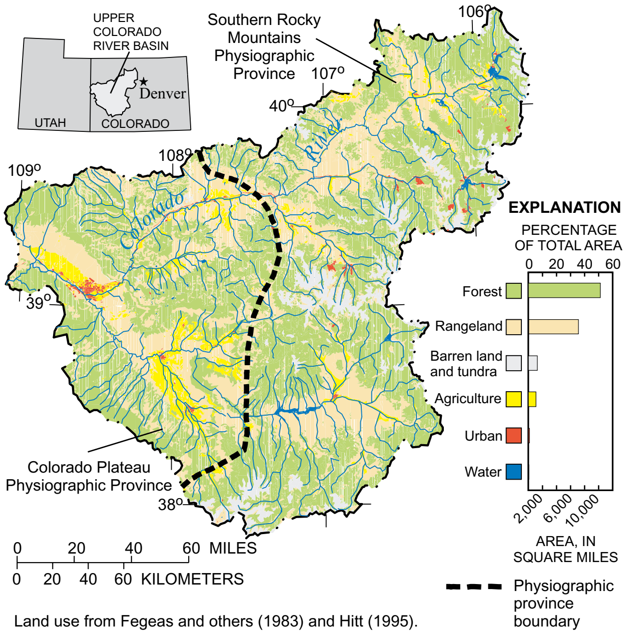
Many topics covered in this report reflect the concerns of officials of State and Federal agencies, water-resource managers, and members of stakeholder groups who provided advice and input during the Upper Colorado River Basin assessment. Basin residents who wish to know more about water quality in the areas where they live will find this report informative as well.



THE NAWQA PROGRAM seeks to improve scientific and public understanding of water quality in the Nation's major river basins and ground-water systems. Better understanding facilitates effective resource management, accurate identification of water-quality priorities, and successful development of strategies that protect and restore water quality. Guided by a nationally consistent study design and shaped by ongoing communication with local, State, and Federal agencies, NAWQA assessments support the investigation of local issues and trends while providing a firm foundation for understanding water quality at regional and national scales. The ability to integrate local and national scales of data collection and analysis is a unique feature of the USGS NAWQA Program.

The Upper Colorado River Basin is one of 51 water-quality assessments initiated since 1991, when the U.S. Congress appropriated funds for the USGS to begin the NAWQA Program. As indicated on the map, 36 assessments have been completed, and 15 more assessments will conclude in 2001. Collectively, these assessments cover about one-half of the land area of the United States and include water resources that are available to more than 60 percent of the U.S. population.

SUMMARY OF MAJOR FINDINGS



Land use from Fegeas and others (1983) and Hitt (1995).

The Upper Colorado River Basin (UCOL) of the National Water-Quality Assessment (NAWQA) Program includes the 17,800-square-mile drainage basin of the Colorado River upstream from the Colorado-Utah State line. The study area is almost equally divided between the Southern Rocky Mountains and the Colorado Plateau Physiographic Provinces. Population in the basin is approximately 308,000. The major use of water is irrigation, but transmountain diversions provide water to more than 1 million people in the eastern part of Colorado (outside of the study area).

Stream and River Highlights

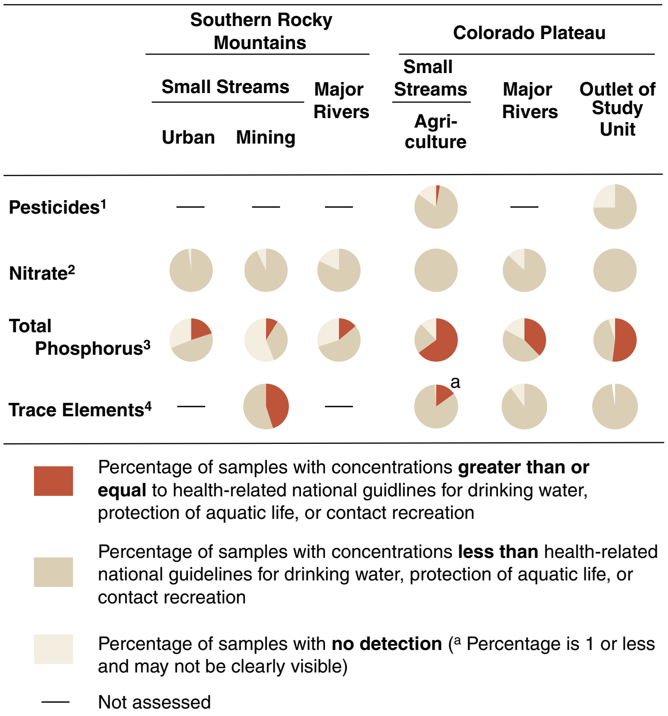
Streams and rivers in the Upper Colorado River Basin (UCOL) are very different in the two major physiographic provinces. In general, streams within the Southern Rocky Mountains are characterized by lower sediment and dissolved-solids concentrations, cooler temperatures, and somewhat higher gradients than streams in the Colorado Plateau. Sediment, salinity, and nutrient (nitrogen and phosphorus) concentrations increase along the major rivers as the water flows from the upstream areas in the Southern Rocky Mountains down through the Colorado Plateau.

Coupled with the general differences due to physiography and geology are the effects of different land uses. Recreation and urban development are becoming major land-use issues throughout the basin, precious metal mining was historically prevalent in the Southern Rocky Mountains, and intensive agriculture is located in the valleys of the Colorado Plateau.

Most of the streams and rivers sampled within the UCOL met State and Federal water-quality guidelines. Major exceptions to this statement were trace-element concentrations in some streams in the Southern Rocky Mountains and selenium concentrations in some streams in the Colorado Plateau.

- In the Southern Rocky Mountains, concentrations of nutrients (nitrogen and phosphorus) were generally low but were greater in urban streams than in streams in areas with minimal development (p. 6).
- Urban streams in the Southern Rocky Mountains had greater amounts of algae and a change in the invertebrate community from pollution-sensitive insects to pollution-tolerant insects compared to streams in areas with minimal development (p. 6–7). Similarly, in some mining areas of the Southern Rocky Mountains, the invertebrate community was also composed of pollution-tolerant insects, indicating more degraded sites (p. 13).

Selected Indicators of Stream-Water Quality



[1] Insecticides, herbicides, and pesticide metabolites, sampled in water.

[2] Nitrate (as nitrogen), sampled in water.

[3] Total phosphorus, sampled in water.

[4] Selenium and metals (such as cadmium, lead, and zinc), sampled in water.

- Concentrations of trace elements, such as cadmium, zinc, copper, and lead, in streambed sediments in many historical mining areas were greater than guidelines for the protection of aquatic life (p. 11–12).
- Pesticides were commonly detected in streams in agricultural areas of the Colorado Plateau during the growing season; however, the concentrations were typically low. Pesticide concentrations that exceeded guidelines for the protection of aquatic life were detected in only 5 of 90 samples (p. 16). Not all detected pesticides have established guidelines.
- The herbicides atrazine and alachlor were detected in more than one-half of the water samples collected in agricultural areas of the Colorado Plateau. These compounds, commonly used for weed control in corn, were also commonly detected in agricultural areas nationwide (p. 17).
- Nutrient and suspended-sediment concentrations in streams in the Colorado Plateau were typically greater than concentrations found in streams in other areas of the UCOL (p. 18–19). These concentrations can generally be associated with a more degraded status of algae, invertebrates, and fish (p. 19).

Major Influences on Streams and Rivers

- Urban development
- Abandoned/inactive mines
- Agricultural return flows

Ground-Water Highlights

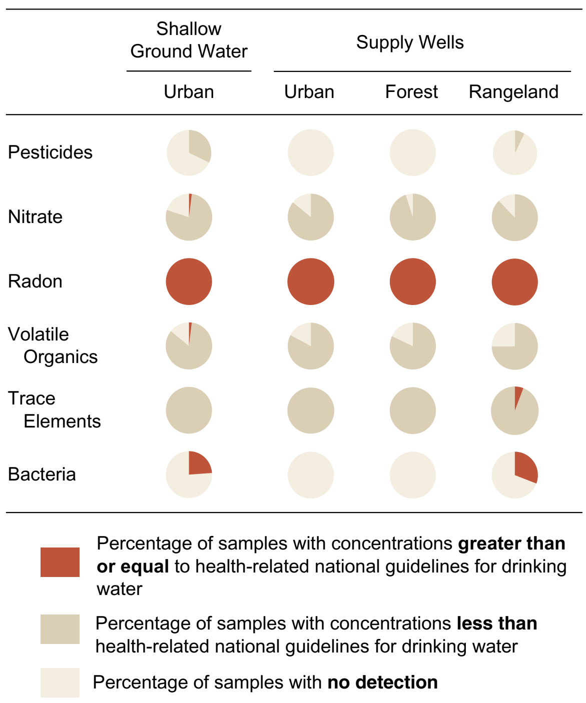
Historical ground-water-quality data for the UCOL are limited. The studies completed in the UCOL by NAWQA provide baseline information that can be used for identifying future water-quality changes. With the exception of radon, ground-water quality in the urban areas of the Southern Rocky Mountains generally met Federal and State standards for drinking water. The presence of a few elevated nitrate concentrations, a few pesticides, and generally low concentrations of volatile organic compounds indicate some influence on the quality of ground water from human activities. Bacteria were detected in ground-water samples and can occur naturally or indicate human influences.

- A concentration of nitrate greater than the U.S. Environmental Protection Agency (USEPA) drinking-water standard was found in 1 of 57 shallow ground-water samples collected in urban land-use settings (p. 8).
- Ground water in urban areas recharged in the late 1980s or 1990s tends to have higher concentrations of nitrate than ground water recharged before the 1980s (p. 10).
- Pesticides and volatile organic compounds were detected infrequently and generally at concentrations less than drinking-water standards. In only one sample, dichloromethane and tetrachloroethene, which are solvents, were detected at concentrations greater than their drinking-water standards (p. 10). Low concentrations of methyl *tert*-butyl ether (MTBE), a gasoline additive, were detected in shallow ground water in four of the five urban areas sampled (p. 9).
- Total coliform bacteria were detected in 21 percent of the shallow ground-water samples collected in urban areas in the Southern Rocky Mountains; none of the samples contained the potentially pathogenic *Escherichia coli* (*E. coli)* bacteria (p. 10).
- Radon, a naturally occurring radioactive gas, was detected in all wells sampled in urban areas in the Southern Rocky Mountains. Concentrations were greater than the proposed USEPA drinking-water standard of 300 picocuries per liter. Currently (2000), radon in drinking water is not regulated; however, if a new drinking-water regulation is implemented, treatment of drinking water for radon may be required in the UCOL (p. 9).

Major Influences on Ground Water

- Urban development in the Southern Rocky Mountains
- Natural background conditions

Selected Indicators of Ground-Water Quality



The Upper Colorado River Basin encompasses about 17,800 square miles. The primary river, the Colorado River, originates in the mountains of central Colorado and flows about 230 miles southwest into Utah. The basin is composed of two physiographic provinces: the Southern Rocky Mountains and the Colorado Plateau (fig. 1). The topography varies from rugged mountainous regions in the east to high plateaus bordered by steep cliffs along valleys in the west. Because of differences in altitude of about 10,000 feet from east to west, the climate ranges from alpine conditions to semiarid/arid conditions. Precipitation ranges from 40 inches or more per year at high elevations in the eastern part of the basin to less than 10 inches per year at low elevations in the western part of the basin (fig. 2).

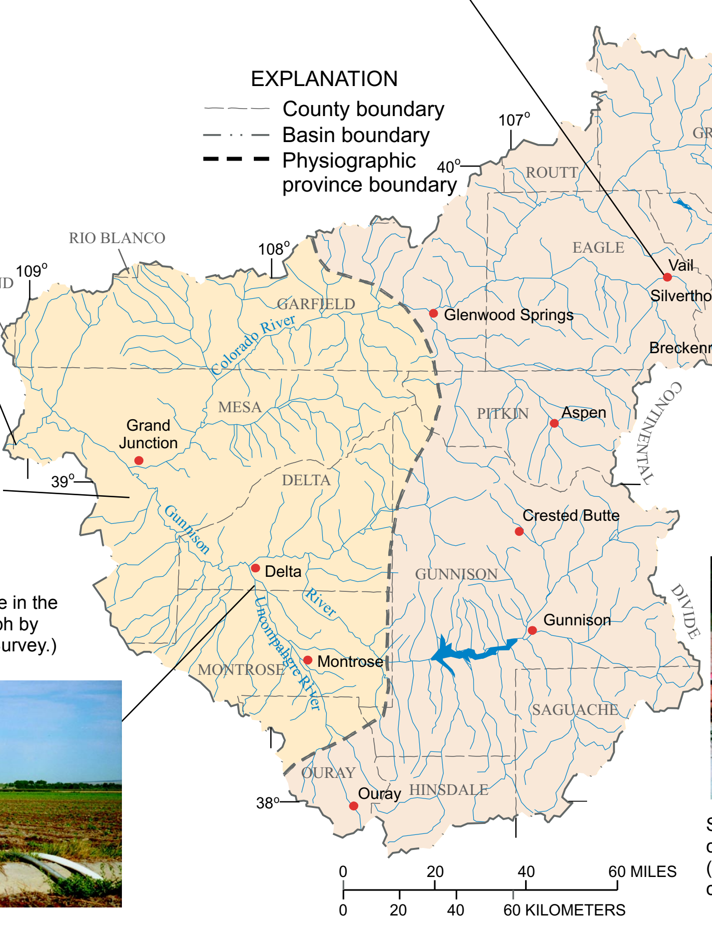
Snowmelt Runoff Dominates the Streamflow in Many Areas of the UCOL

The amount of water derived from the winter snowpack generally determines the magnitude and quality of streamflow for the UCOL. Streamflows are typically highest in the spring and lowest

The Colorado Plateau contains warm, saline streams that drain sedimentary geologic settings. (Photograph by Jeffrey Deacon, U.S. Geological Survey.)

Urban development is occurring in areas of the Southern Rocky Mountains. (Photograph by Scott Mize, U.S. Geological Survey.)

Cool and clear mountain streams are present in the forested areas of the Southern Rocky Mountains. (Photograph by Scott Mize, U.S. Geological Survey.)



Agriculture is a major land use in the Colorado Plateau. (Photograph by Scott Mize, U.S. Geological Survey.)

Streams have been affected by runoff and discharge from past and present mined areas. (Photograph by Jeffrey B. Bails, U.S. Geological Survey.)

Figure 1. The combinations of physiography and land use produce different environments found in the UCOL. Physiographic provinces from Fenneman, 1946.

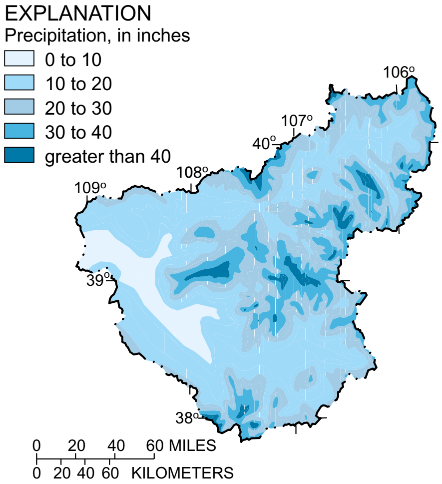


Figure 2. Average annual precipitation (1951–80) in the UCOL (Colorado Climate Center, 1984).

during the winter (fig. 3). The primary data-collection period for the UCOL study was water years 1996–98. Streamflow during water years 1996–97 was above average for most of the basin. Streamflow during water year 1998 was about average. High streamflows will dilute many water-quality constituents, resulting in lower concentrations. Suspended sediment and constituents associated with sediment may have larger concentrations during periods of high flow than during low flow.

Irrigation is the Principal Water Use Within the UCOL

Irrigation accounts for 97 percent of the water use in the UCOL (fig. 4). Ninety-nine percent of the water used in the Study Unit is derived from surface-water sources (U.S. Geological Survey, 1995). Ground water accounts for 1 percent of water use and is an important resource in remote and rural areas where the water is used primarily for domestic purposes.

Water diverted eastward from the UCOL, through transmountain diversions, is used by many municipalities in the eastern plains of Colorado. This diverted water from the UCOL constitutes about 35 percent of the water supply for the city of Denver (Denver Water Department, 1999) and about 65 percent of the water supply for Colorado Springs (Scott Campbell, Colorado Springs Water Utility, oral commun., 2000). In addition, the Colorado Big Thompson project, using water diverted from the UCOL, provides complete or partial supply for more than 30 cities and towns in northern Colorado (Northern Colorado Water Conservancy District, 2000). Transmountain diversions can affect the water quality in the basin because the diversions can account for a substantial portion of the local streamflow in upstream areas. In addition, the diverted water commonly has low salinity that is no longer available to dilute more mineralized water in the downstream part of the Study Unit.

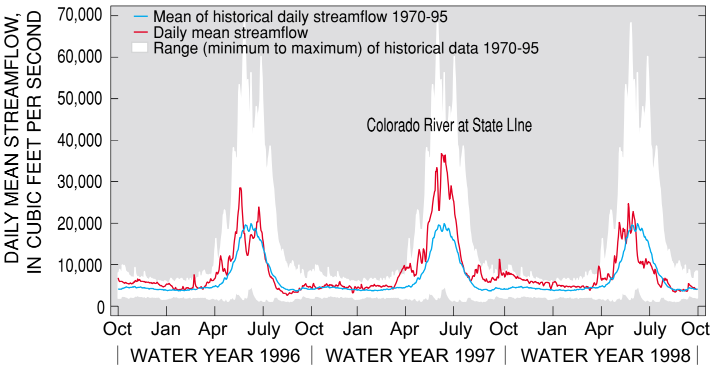


Figure 3. Streamflows in the UCOL were above average in water years 1996 and 1997. Water year 1998 streamflow was near average.

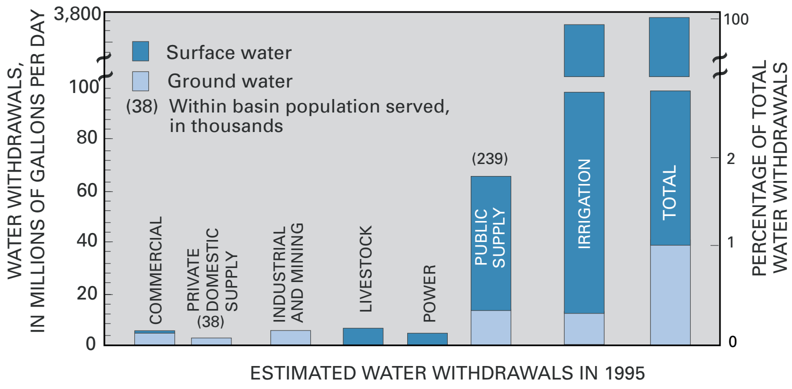


Figure 4. Water use in the basin is primarily derived from surface water; however, ground water is used for some domestic and public water supplies. Transmountain diversions to eastern Colorado from the UCOL accounted for about 451 million gallons per day in 1995 (Upper Colorado River Commission, 1999).

Water Quality is Influenced by Geologic Factors

The underlying bedrock in the Study Unit is made up of crystalline and sedimentary rocks (fig. 5). Alluvium consisting of stream, landslide, terrace, and glacial deposits is present in valleys throughout the basin. Weathering of the different geologic units affects water-quality conditions in the basin. The sedimentary, igneous, and metamorphic rocks contribute material such as salts and trace elements to the streams. High concentrations of some materials, particularly salts, are derived from the sedimentary rocks, which are more common in the western part of the basin. Also, highly mineralized areas in the upper basin contribute trace metals to surface and ground water. Selenium occurs naturally in the shale bedrock of the middle and lower reaches of the basin and is present in surface and ground water. In addition, mineral hot springs located primarily in carbonate rock units in the north-central part of the basin contribute about 13 percent of the total salt load at the outlet of the UCOL (U.S. Department of the Interior, 1995; Butler, 1996).

Water Quality is Influenced by Land Use

The UCOL study was designed to investigate land-use influences on water quality (see “Study Unit Design,” page 21, for details). Urban development, mining, and agricultural were the three primary land uses investigated in the UCOL.

Urban development has the potential to affect the quality of surface and ground water by adding nutrients, bacteria, pesticides, hydrocarbons, trace elements, and salts from point and nonpoint sources and by changes to the natural landscape. Urban land use accounts for only 1 percent in the UCOL, which has a population of about 308,000 people (Bureau of the Census, 1999). By the year 2020, the population is projected to increase to more than 500,000 (Colorado Department of Local Affairs, 2000). Resident population increases do not reflect development and services for vacation properties. There are large seasonal fluctuations in nonresident populations within the basin due to recreational activities. During the 1996–97 ski season, more than 9 million skiers visited ski areas within the UCOL (Colorado Ski Country USA, 2000). Effects on water quality from urban development are evident in some communities in the Southern Rocky Mountains.

Topography representative of the Southern Rocky Mountains. (Photograph by Jeffrey Deacon, U.S. Geological Survey.)

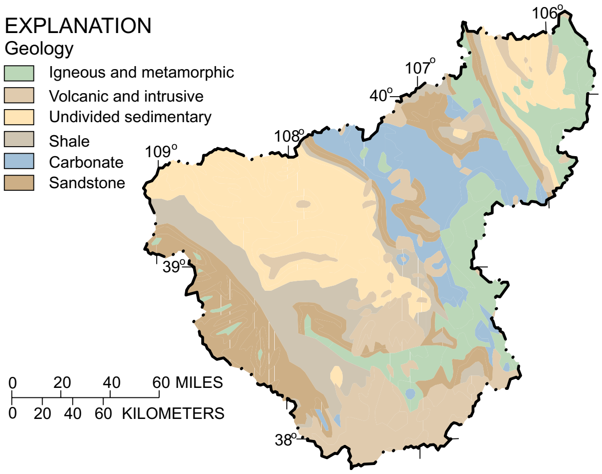


Figure 5. The bedrock geology within the UCOL changes from predominately igneous, metamorphic, and volcanic rock types in the eastern and central areas to predominantly sedimentary rock types in the western areas (Tweto, 1979; Green, 1992).

Lode and placer mining, a historically significant land use in the UCOL, was common throughout the Southern Rocky Mountains. Streams and ground water have been affected by point-source mine discharge and nonpoint-source runoff from mined areas.

Areas of intensive agriculture are located primarily in the Colorado Plateau. Salinity, sediment, nutrients, pesticides, and selenium and other trace elements are common constituents in agricultural runoff. These constituents can have an adverse effect on the surface water, ground water, and aquatic life.

Urban Development is a Water-Quality Issue Within the Southern Rocky Mountains

Recreation in the mountains of Colorado is becoming a significant land-use activity in many areas. Urban development and the infrastructure to support recreation have increased substantially in the last decade. Between 1990 and 1997, the population increase in Summit and Eagle Counties exceeded 40 percent (http://www.colorado.edu/libraries/govpubs/colonumb/counties.htm). In addition to resident population increases, seasonal population fluxes due to recreation are large. These temporary population increases occur in winter during periods of extreme low flow and minimal dilution in rivers and streams.

Although urban development may be only a small percentage of total watershed area, development and transportation systems tend to be adjacent to riparian areas in mountainous terrain (fig. 6). This land-use pattern has placed human populations in locations that have the greatest effects on the quality of the water resources. Surface- and ground-water studies were implemented to investigate the water-quality issues in urban areas of the Southern Rocky Mountains.

Surface-water studies investigated the effects of urban land use. Two stream-monitoring sites were located in areas of urban development (fig. 6). The Gore Creek site is downstream from Vail, and the East River site is downstream from Crested Butte. Development in Vail is approaching build-out, whereas there is potential for large increases of development in the Crested Butte area. The Colorado River below Baker Gulch, a reference site with little urban development in the Southern Rocky Mountains, was also sampled monthly to provide a comparison with other sites.

Nutrient concentrations at sites in areas of urban development were greater than concentrations at the reference site. Concentrations of nitrite plus nitrate and total phosphorus were slightly elevated at Gore Creek and East River compared to reference concentrations (fig. 7). Concentrations for nitrate were below the 10-mg/L Colorado instream standard at all three sites. Un-ionized ammonia concentrations, computed from dissolved ammonia, pH, and temperature, did not exceed State instream standards. Dissolved and orthophosphate phosphorus concentrations were greater at Gore Creek than the other sites. Gore Creek and East River are not wastewater-effluent-dominated streams such as might be found in large metropolitan areas; however, small amounts of nitrogen and phosphorus can increase algal growth and eutrophication processes.

The amount of algae and the types of aquatic invertebrates (insects) are influenced by nutrient enrichment from urban sources. The amount of algae (algal biovolume) determined from algae samples collected in 1996 and 1997 was largest in Gore Creek (fig. 8), where nutrient levels were higher. The percentage of the invertebrate community represented by pollution sensitive

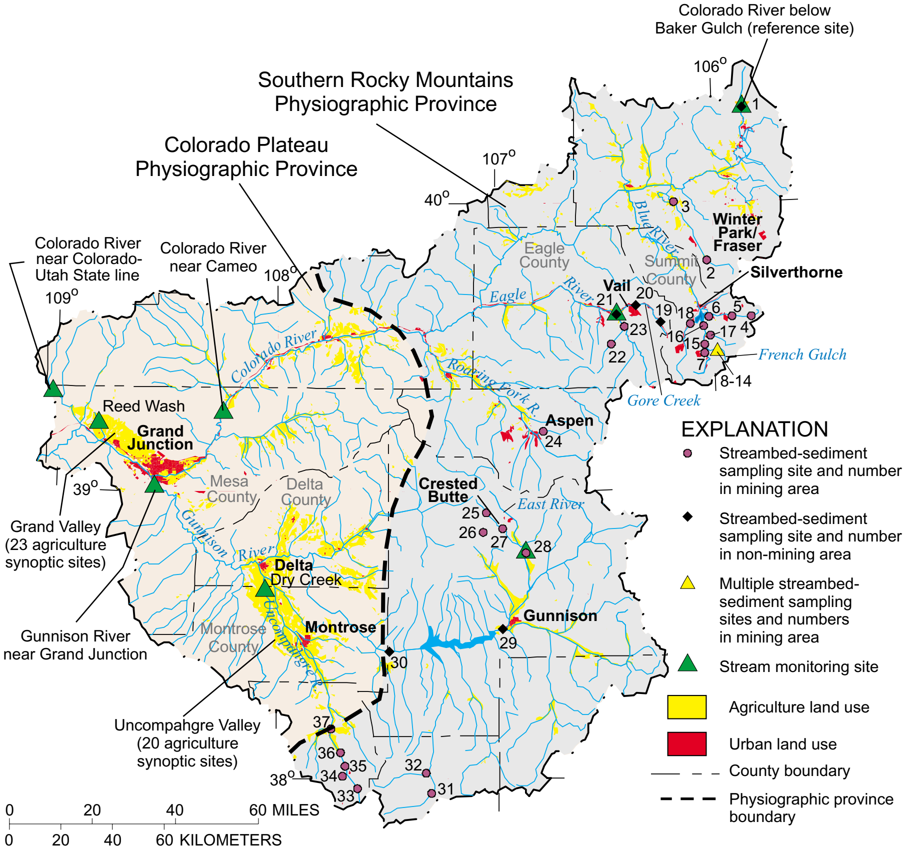


Figure 6. Sampling sites and study areas were selected to assess effects of urban, mining, and agricultural land uses on water quality.

insects (mayflies, stoneflies, and caddisflies) was greater at sites with less urban influence (Colorado River below Baker Gulch, fig. 8). The percentage of midges (insects generally tolerant of pollution) increased with increasing urban influence (East River and Gore Creek sites, fig. 8). Even though the percentage of midges was greater at Gore Creek, the invertebrate status of Gore Creek was less degraded than other urban sites in the NAWQA Program (p. 8).

Nutrient concentrations were generally largest during winter. Concentrations of nitrite plus nitrate and dissolved and total phosphorus were greatest during the late winter low-flow period prior to snowmelt runoff (fig. 9). With the onset of snowmelt runoff, nutrient concentrations were diluted. Algal uptake of nutrients during warm weather (July-October) probably lower concentrations during the summer. With reduced dilution and diminished algal uptake, nutrient concentrations increase again during the winter low-flow period.

Ground-water studies investigated the effects of urban land use on water in selected alluvial aquifers. Although many communities in the UCOL rely on surface water as their primary source of drinking water, a few mountain towns and many thousands of individual homes in the Southern Rocky Mountains use ground water as their primary water source. Effects of urban land use can be indicated by elevated concentrations of nitrate, detections of synthetic organic compounds (pesticides and VOCs), and bacteria.

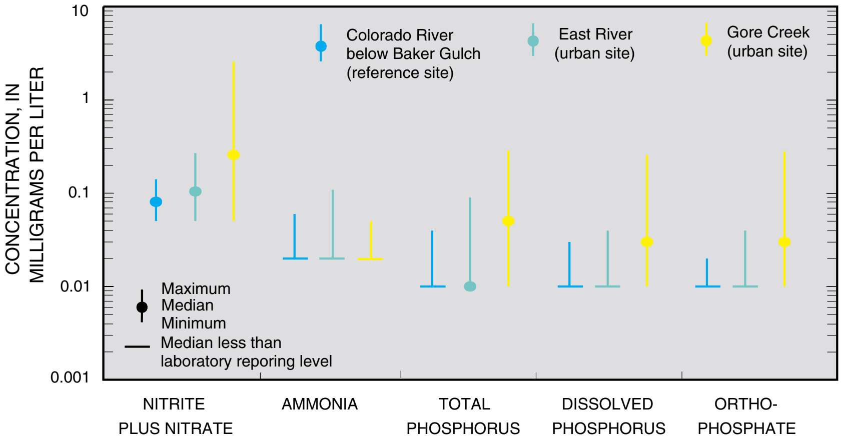


Figure 7. Concentrations of nitrite plus nitrate and total phosphorus were greater at sites with urban development (Gore Creek and East River) than at the reference site (Colorado River below Baker Gulch). Sites shown in order of increasing urban development. A log scale is used due to the large range of concentrations.

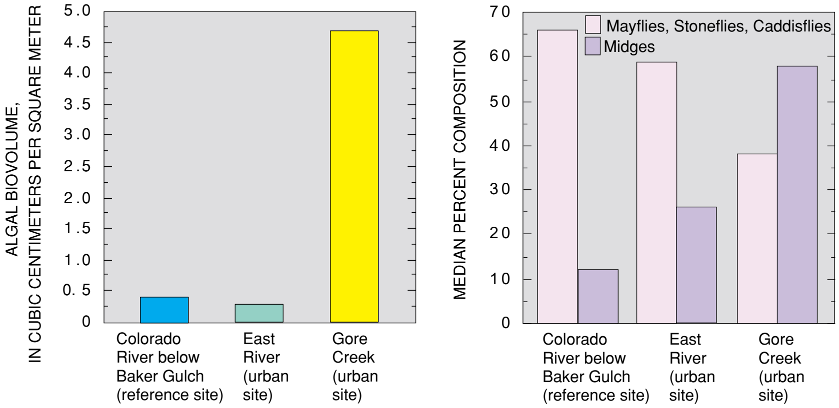


Figure 8. Algal biovolume (the amount of algae) was greater at Gore Creek, which also has greater urban development. The percentage of mayflies, stoneflies, and caddisflies decreased, and the percentage of midges (indicative of more degraded water quality) increased with urban development. Sites shown in order of increasing urban development.

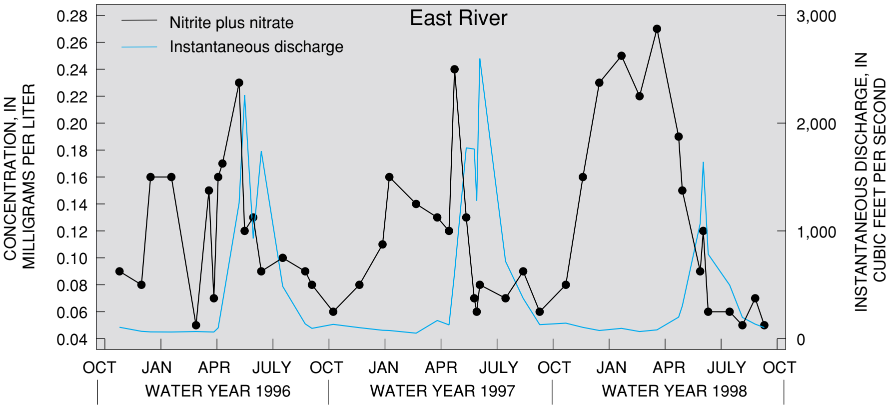
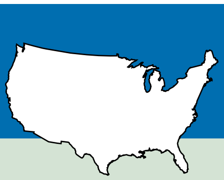


Figure 9. Nutrient concentrations were greatest during the late winter low-flow period prior to peak snowmelt runoff. This pattern was similar for total phosphorus at East River and for nitrite plus nitrate and total phosphorus at Gore Creek.



BIOLOGICAL MEASURES INDICATE THAT URBAN SITES IN THE UCOL ARE LESS DEGRADED WHEN COMPARED TO OTHER URBAN SITES NATIONALLY

Within the UCOL, there are changes in the algal and invertebrate communities in areas of urban development. Algal biovolume (amount of algae) and midges (insects considered more tolerant of degraded conditions) were greater at sites with urban development than sites with little urban development. However, with the exception of algal status at the Gore Creek site, biological indices for UCOL urban sites are in the lowest 25 percent of urban sites from other NAWQA Study Units. The Gore Creek watershed is more urbanized than the East River watershed, and the changes in the algal community reflect increased nutrient concentrations at this site, making it more typical of other urban sites nationally. The invertebrate and fish communities are ranked among the least degraded nationally at both UCOL urban sites.

Site name	Biological indicators		
	Algal status	Invertebrate status	Fish status
Colorado River below Baker Gulch (reference site)	🟦	🟦	🟦
East River (area of urban development)	🟦	🟦	🟦
Gore Creek (area of urban development)	🟨	🟦	🟦

EXPLANATION

🟦 Lowest 25 percent nationally, least degraded sites

🟨 Middle 50 percent nationally

Explanation of Biological Rankings

The three selected biological indicators respond to changes in stream degradation. Degradation can result from a variety of factors that modify habitat or other environmental features such as land use, water chemistry, and flow. Algal status focuses on the changes in the percentage of certain algae in response to increasing siltation and often is positively correlated with higher nutrient concentrations in many regions of the Nation. Invertebrate status is the average of 11 invertebrate metrics that summarize changes in richness, tolerance, trophic conditions, and dominance associated with water-quality degradation. Fish status focuses on changes in the percentage of tolerant fish species that make up the total number of fish. "Tolerant" fish are reported to thrive in degraded water quality. For all indicators, higher values indicate degraded water quality.

Ground water was sampled from shallow monitoring wells in the Crested Butte, Gunnison, Silverthorne, Vail, and Winter Park/Fraser areas (fig. 6). Domestic (household and private) and public supply drinking-water wells of various depths were also sampled in urban areas throughout the Southern Rocky Mountains.

Some ground-water samples collected in urban areas contained elevated levels of nitrate. Nutrients in ground water can originate from various natural sources (such as atmospheric deposition or dissolution of geologic materials); however, elevated concentrations in ground water are often related to human activities, such as effluent from septic systems or the application of fertilizers. Nitrate concentrations greater than the USEPA Maximum Contaminant Level (MCL) drinking-water standard of 10 mg/L (U.S. Environmental Protection Agency, 1996) were detected in one sample collected from a shallow monitoring well in an urban area but in none of the drinking-water wells. Nutrient concentrations in undeveloped areas (determined from data from the 20 NAWQA Study Units that began in 1991) indicate a national background concentration for nitrate of 2.0 mg/L (U.S. Geological Survey, 1999). The undeveloped areas are considered to be minimally affected by agriculture, urban development, or associated land uses. Twenty percent of the samples collected from monitoring wells (and none of the samples collected from drinking-water wells) contained nitrate concentrations greater than 2.0 mg/L. These findings indicate that portions of the shallow ground-water system have been affected by urban land use, but these effects were not found in the deeper ground water used for drinking water.

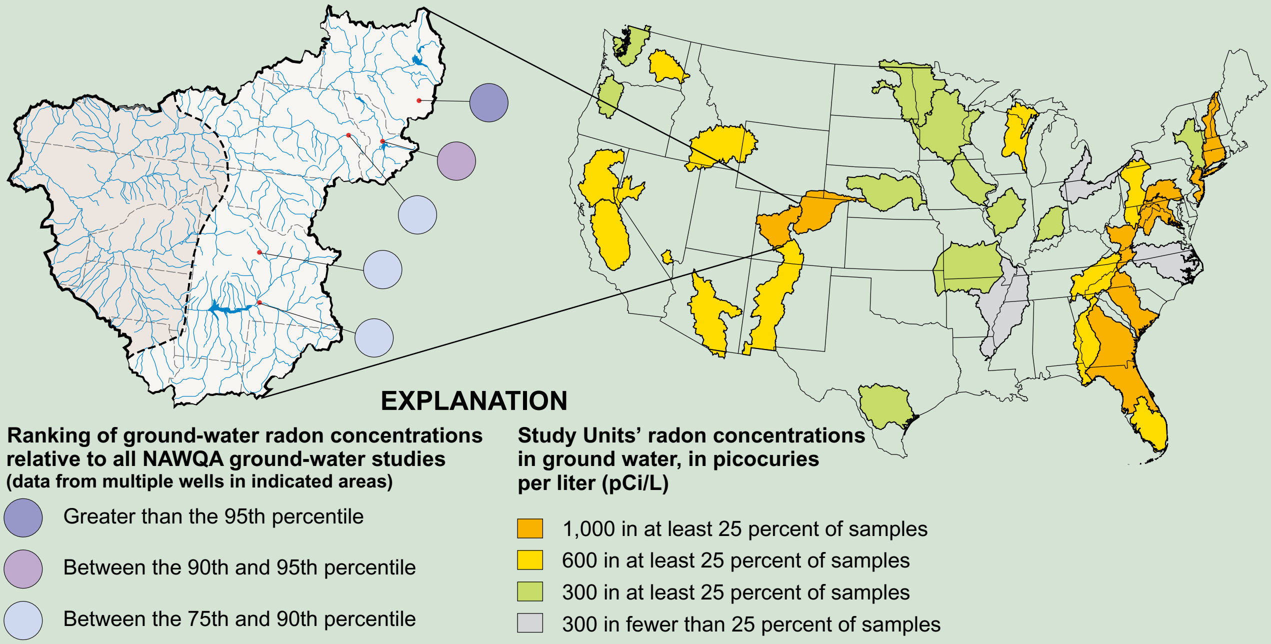
Generally, low levels of pesticides and volatile organic compounds were detected in ground water from shallow alluvial aquifers in urban areas. Most agriculture (and pesticide use) in the basin occurs in the Colorado Plateau where ground-water studies were not conducted. The pesticides that were detected in the ground water sampled in the Southern Rocky Mountains were primarily herbicides used for controlling grasses and weeds in nonagricultural areas. Concentrations were very low (less than 0.1 µg/L) for most of the pesticides detected. Two herbicides, bromacil and prometon, were detected in urban areas at concentrations less than the USEPA drinking-water guidelines (U.S. Environmental Protection Agency, 1996).

Volatile organic compounds (VOCs) were detected in ground-water samples at generally low concentrations. The six most frequently detected VOCs were methyl *tert*-butyl ether (MTBE), tetrachloroethene, chloroform, 1,1,1-trichloroethane, 1,2,4-trimethylbenzene, and dichloro-methane (fig. 10). MTBE, a gasoline additive, was detected in at least one well in four of the five urban areas where shallow ground water was sampled. In addition,

RADON CONCENTRATIONS IN UCOL GROUND WATER WERE GENERALLY HIGHER THAN OTHER AREAS OF THE NATION

Radon concentrations in alluvial aquifers of the UCOL are among the highest of all NAWQA ground-water samples nationwide (S.J. Ryker, USGS, written commun., 1999). Radon is a naturally occurring, colorless, odorless, radioactive gas derived from the decay of uranium. Radon has been identified as a human carcinogen and can enter a building from seepage of air through dirt floors, cracks in concrete floors or walls, floor drains, or through the use of water supplied from wells. A greater risk of exposure to radon exists in urban areas due to the prevalence of enclosed structures, such as basements, which can trap radon gas.

Though the USEPA does not currently (2000) regulate radon in drinking water, there is a proposed maximum contaminant level (MCL) of 300 picocuries per liter (pCi/L) for radon in drinking water (U.S. Environmental Protection Agency, 1999). Radon concentrations were greater than the proposed MCL for all wells sampled in the Southern Rocky Mountains. Higher radon concentrations were measured in the Winter Park/Fraser and Silverthorne areas. Igneous and metamorphic rocks, which can contain uranium-bearing minerals, are common rock types in these areas.



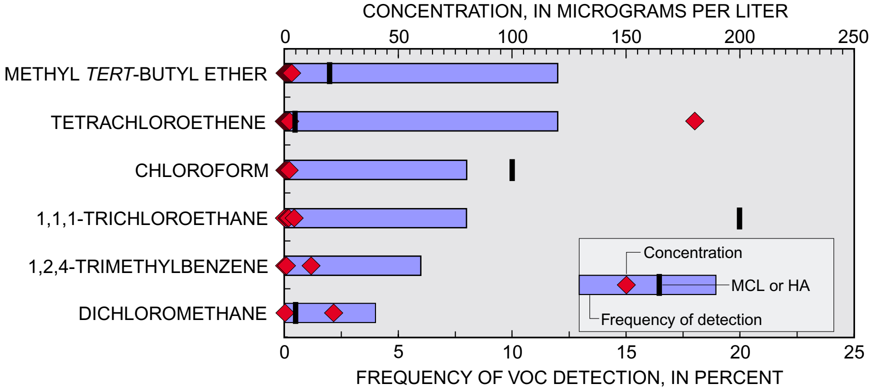


Figure 10. Volatile organic compounds were detected at low frequencies in monitoring and drinking-water wells sampled in the Southern Rocky Mountains. With a few exceptions (2 samples), concentrations of VOCs were substantially less than water-quality standards. All concentrations shown are greater than 0 µg/L. (MCL, maximum contaminant level; HA, health advisory.)

MTBE was detected in water from one municipal well. MTBE concentrations greater than the drinking-water lifetime health advisory of 20–40 µg/L (U.S. Environmental Protection Agency, 1997) were not detected. However, once MTBE enters the ground water, it is less vulnerable to decomposition and travels farther than other gasoline compounds (Squillace and others, 1996).

Tetrachloroethene is present in solvents for adhesives and is also a by-product of dry cleaning. Chloroform can occur naturally or result from the chlorination of drinking water. 1,1,1-Trichloroethane is present in solvents and cleaning agents. 1,2,4-Trimethylbenzene is present in petroleum by-products.

Dichloromethane is predominantly used as a solvent in paint strippers and removers. Concentrations of dichloromethane and tetrachloroethene were greater than the USEPA drinking-water standard of 5 µg/L at one site in Silverthorne.

Total coliform bacteria were detected in 21 percent of the ground-water samples collected in urban areas. Total coliform bacteria were detected only in samples collected from the shallow monitoring wells and in none of the water samples from drinking-water wells. Bacteria in ground water may occur naturally in soils or may be related to human or animal waste and, therefore, may be an indication of the sanitary quality of the water (Myers and Sylvester, 1997). However, the presence of total coliform bacteria does not necessarily indicate the presence of potentially pathogenic bacteria such as *Escherichia coli (E. coli)*, which was not detected in any of the samples.

Urban land use in the Southern Rocky Mountains, near Fraser, Colorado. (Photograph by Jeffrey B. Bails, U.S. Geological Survey.)

Chlorofluorocarbons (CFCs) were used to determine the age of ground water

Shallow ground water, which is used for drinking water in part of the Southern Rocky Mountains, is generally young (less than 10 years old) and is more susceptible to contamination as a result of land-use practices. The age of the ground water refers to the time from when the water recharged, or entered, the aquifer to the time it was withdrawn from the aquifer. The presence of contaminants, if any, in ground water can reflect land-use conditions at the time of recharge. The age of the ground water was determined in five urban areas where water-quality samples were collected from shallow alluvial aquifers. The age of ground water at most of the sites sampled ranged from 0 to 10 years old. Ground-water ages of greater than 10 years were found in 7 of 25 wells.

In the samples where CFC dates were obtained, four of the five nitrate concentrations greater than 2.0 mg/L were from recently recharged ground water (10 years or younger). This is an indication that current land use may be affecting water quality. Increasing urban development may add nitrate to the ground water from different sources, such as septic systems, application of fertilizers, and domestic animal wastes. Effects of increased urban development on ground-water resources are not extensive in the study area at present.

The Quality of Streams and Rivers is Affected by Historical Mining Activities

Streams affected by mine drainage, from abandoned/inactive mines, are present throughout much of the Rocky Mountains of Colorado. Metal mining in the UCOL has been an important part of the economy of Colorado since the late 1800s. As a result, many streams in the upper part of the basin contain heavy metals and other toxic elements that affect stream-water quality. Knowledge of mine-drainage effects on a body of water is essential for assessing water quality with regard to human consumption, recreation, and aquatic life.

Because of the potential exposure of aquatic organisms to trace elements in streambed sediment, trace-element concentrations in streambed sediment serve as an indicator of potential toxicity to aquatic life. Sampling trace elements in streambed sediment can be used to identify stream reaches affected by mining and can be used to determine sources of trace elements. The occurrence and distribution of trace elements were characterized by collecting streambed-sediment samples at 29 sites in mining districts (fig. 6 and table 1) and at 8 background (non-mining) sites in the Southern Rocky Mountains.

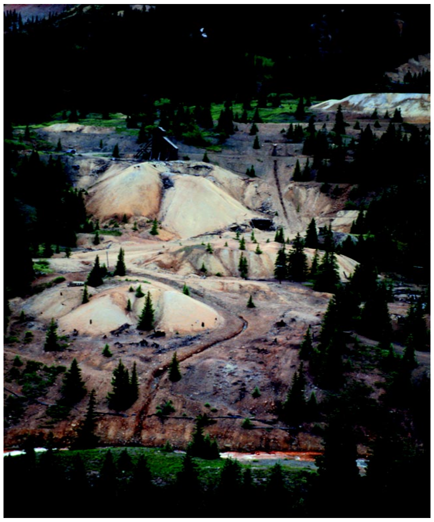
Concentrations of cadmium, copper, lead, and zinc in streambed sediment were high at some sites downstream from mining areas (Deacon and Driver, 1999)**.** Median concentrations of cadmium (Cd) and zinc (Zn) in samples from most mining districts exceeded the Canadian Sediment Quality Guidelines Probable Effect Level (PEL), which is a sediment guideline (fig. 11). The PEL defines the concentration level above which adverse effects to aquatic biota are predicted to occur frequently (Canadian Council of Ministers of the Environment, 1999). National sediment concentration guidelines have not been established for the United States. Concentrations of copper and lead were also elevated and exceeded the PEL in several mining districts. The mining and mineralized areas of the UCOL generally result in higher trace-element concentrations in streambed sediment than are detected in other areas studied within the NAWQA Program (p. 12).

Table 1. Mining districts and sampling sites in the Southern Rocky Mountains

Mining district[1]	River/Stream [site number(s) in figure 6][2]
Aspen	Hunter Creek (24)
Breckenridge	Blue River, French Gulch, Swan River (7, 10, 11, 12, 13, 14, 15, 16, 17)
Climax	Tenmile Creek (18)
Crested Butte	Oh-Be-Joyful Creek, Coal Creek, Slate, East Rivers (25, 26, 27, 28)
Gilman	Cross Creek, Eagle River (22, 23)
Lake City (Carson, Burrows, Sherman Districts)	Lake Fork of the Gunnison River, Hensen Creek (31, 32)
Montezuma	Peru Creek, Snake River (4, 5, 6)
Ouray (Red Mountain, Sneffels, Uncompahgre Districts)	Canyon Creek, Red Mountain Creek, Uncompahgre River (33, 34, 35, 36, 37)
Urad-Henderson	South Fork of Williams Fork, Williams Fork (2, 3)

[1] Information from Davis and Streufert (1990).

[2] Background (non-mining) sites 1, 8, 9, 19, 20, 21, 29, 30.



Mining land use in the Southern Rocky Mountains. (Photograph by Jeffrey Deacon, U.S. Geological Survey.)

Collecting samples from several types of media provides a better understanding of trace elements in the environment. In addition to streambed sediment, which can store trace elements, the overlying stream water can also be a source of trace-element exposure to aquatic organisms. Because invertebrates are continuously exposed to water-quality conditions, these organisms integrate effects of contaminants over time and provide a measurement of water quality. Invertebrate indicators of streams contaminated by trace elements include reduced abundance and a shift in commu-

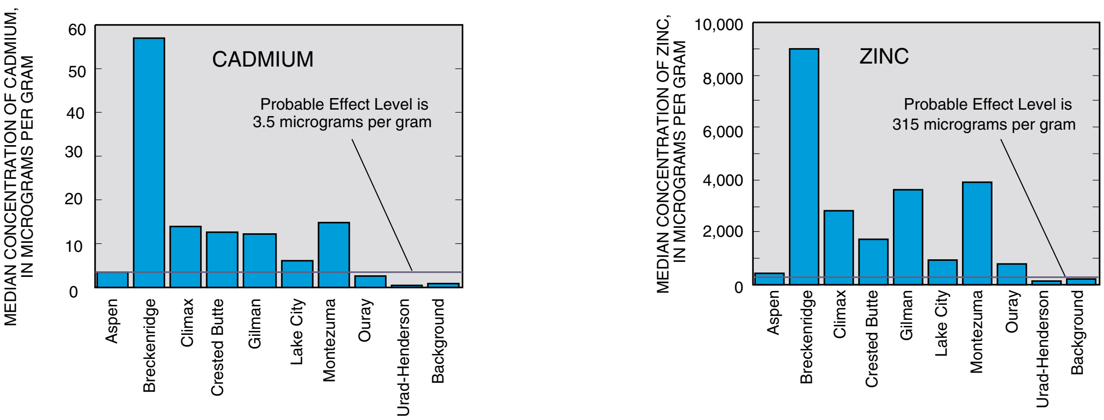
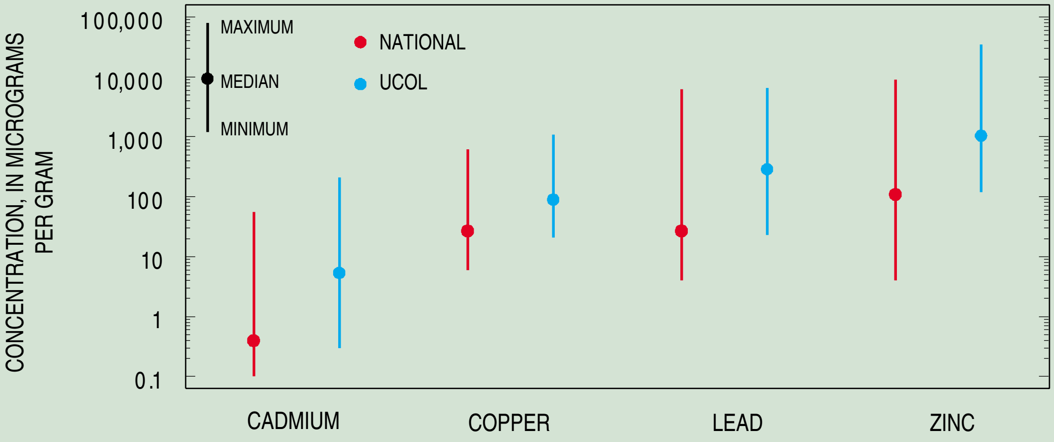


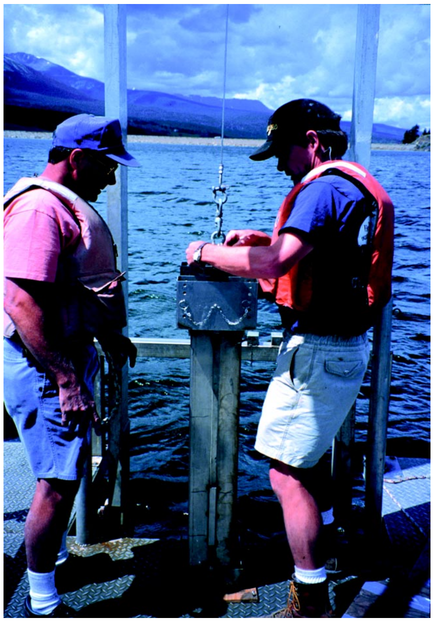
Figure 11. Median concentrations of cadmium and zinc in streambed sediments were greater than the Canadian Probable Effect Level in most mining districts of the UCOL.

nity composition from sensitive insects, such as mayflies, to more tolerant insects, such as midges. Lower mayfly abundance can be related to increased trace-element concentrations (Clements and Kiffney, 1995; Clements, 1994; Kiffney and Clements, 1994). Concentrations of trace elements in transplanted aquatic moss also provide information about the occurrence and bioavailability of trace elements (Carter and Porter, 1997). In order to assess the source(s) and environmental effects of trace elements, a more detailed study was conducted in the Blue River Basin; this study included the collection of water, streambed sediments, reservoir sediments, and aquatic moss samples and an assessment of the habitat and invertebrate communities.

TRACE ELEMENTS IN STREAMBED SEDIMENTS OF THE UCOL WERE OFTEN GREATER THAN CONCENTRATIONS DETECTED AT OTHER SITES NATIONALLY



The median concentrations for cadmium, copper, lead, and zinc in streambed sediment from sites in the UCOL were higher than the median concentrations of the same trace elements sampled in other Study Units of the national NAWQA Program. The data available on trace elements include 541 samples from the NAWQA Study Units (Rice, 1999) and 37 samples from the UCOL. Mineralized areas and historical mining activities in the UCOL have resulted in higher concentrations of some trace elements in streams than those concentrations that typically are found in other parts of the United States.



Collecting sediment core samples on Dillon Reservoir. (Photograph by Norman Spahr, U.S. Geological Survey.)

Mining activities have affected trace-element concentrations and aquatic invertebrates in French Gulch and the Blue River. Samples from different media were used to investigate the effects of mining activities on the water quality and associated biota at 10 sites along the Blue River and French Gulch, a tributary of the Blue River (fig. 12). Sites 2 and 3 (fig. 12) are background sites on French Gulch and are minimally affected by mining activities. Zinc concentrations in water and streambed sediment and zinc accumulated by aquatic moss at these background sites were lower than those from sites downstream from the mined areas. The invertebrate community structure (as indicated by mayfly abundance and percent midges) was minimally affected at the background sites.

Although habitat conditions at site 4 were degraded and zinc concentrations were greater than those upstream, the invertebrate community was not found to be significantly degraded. Farther downstream, where underground mine seepage contributes to surface runoff (site 6), zinc concentrations in the water, streambed sediment, and aquatic moss were high and the invertebrate communities were degraded. The most affected site along French Gulch was site 7, located near the confluence with the Blue River.

Site 1, upstream from French Gulch on the Blue River, was characterized by lower zinc concentrations in water, moss, and sediment than downstream sites, indicating that the French Gulch basin is contributing zinc to the Blue River. Downstream from the confluence of French Gulch with the Blue River (site 8), concentrations of zinc in water, moss, and streambed sediment were higher than background levels but slightly lower than in French Gulch. Also at site 8, brown trout livers had the highest concentrations of zinc of any sites sampled in the Southern Rocky Mountains (Deacon and Stephens, 1998). The invertebrate community in the Blue River downstream from French Gulch was degraded (site 8). The site conditions remain moderately affected downstream to Dillon Reservoir (site 10).

Mining activities have affected trace-element concentrations in the bottom sediment of Dillon Reservoir. Dillon Reservoir was constructed in 1963 in an area with a long history of mining activity. Sources of trace elements in Dillon Reservoir, a drinking-water supply for the city of Denver, are located in the Blue River, Snake River, and Tenmile Creek Basins. The reservoir is accumulating some trace elements. For example, loads calculated using streamflow and water concentration indicate that only 37 percent of the zinc that enters Dillon Reservoir leaves the reservoir (fig. 12, top left graph).

Sediment cores were collected at several locations in Dillon Reservoir. Concentrations of lead and zinc throughout the core collected near the dam exceeded the PEL. Cadmium, lead, and zinc concentrations in sediment cores from the Blue River, Snake River, and Tenmile Creek arms of the reservoir also were above the PEL (values for zinc are shown in the top of fig. 12).

Although bottom sediment concentrations of some trace elements exceeded the PEL, concentrations in the water column were not high. The concentrations of trace elements in the reservoir water column did not exceed the Colorado surface-water-quality standards.

Sediment core from Dillon Reservoir. (Photograph by Norman Spahr, U.S. Geological Survey.)

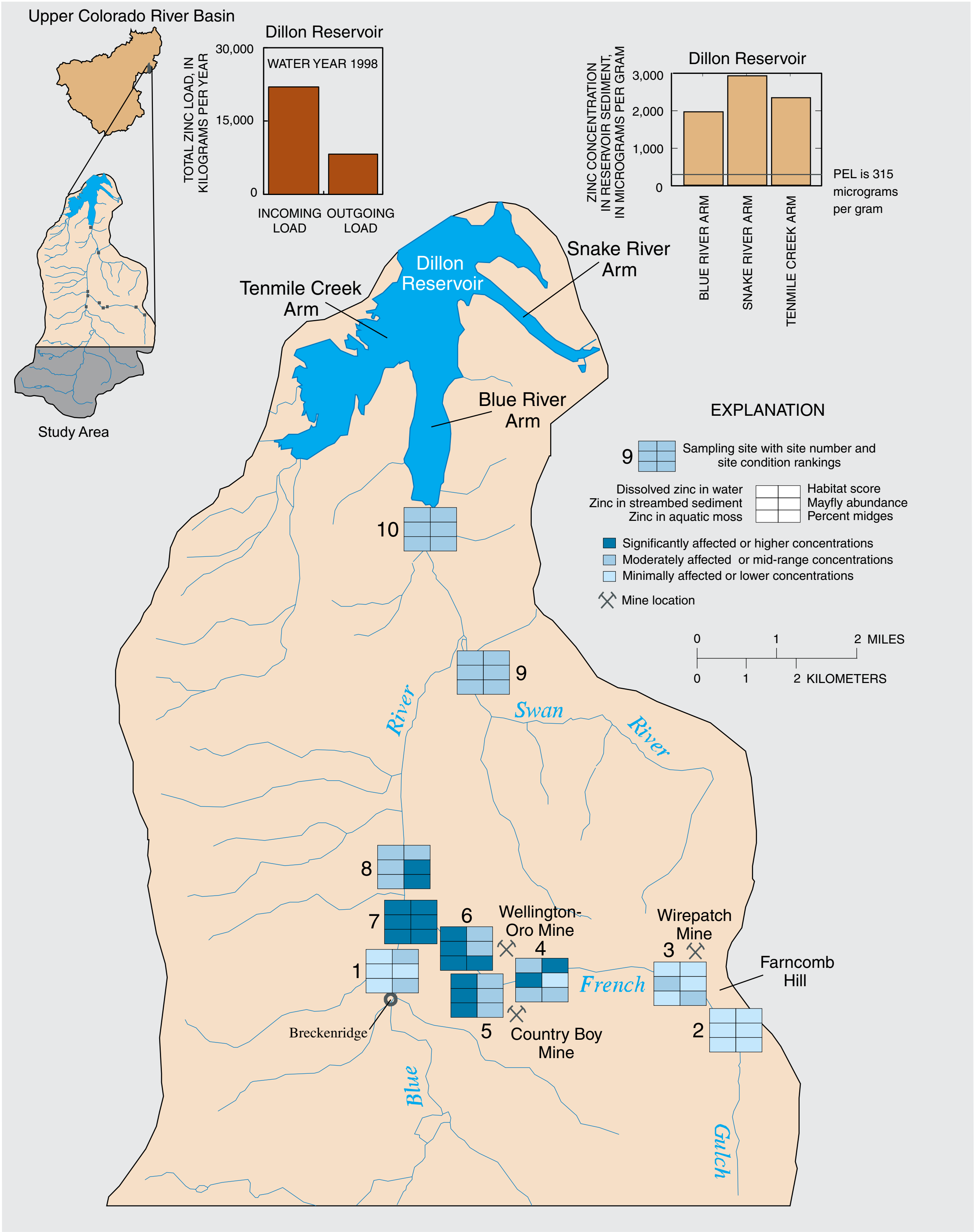
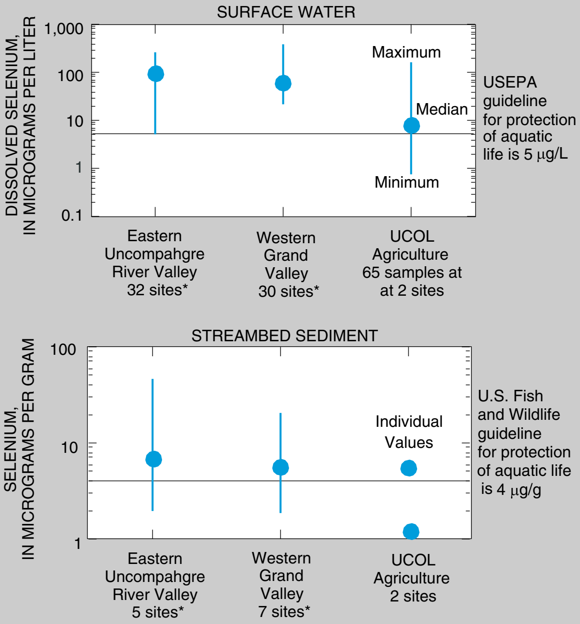


Figure 12. Different types of sampling media provide a better understanding of conditions at sites sampled in the Blue River Basin. Dillon Reservoir sediments are accumulating some trace elements originating from mining areas.

Selenium in Western Colorado

Selenium, a naturally occurring trace element, is common throughout the Western United States in marine sedimentary rocks. It is an essential micronutrient for birds, fish, and animals (Mayland, 1994) but at high concentrations can be highly toxic to fish and wildlife. Selenium can be very mobile in the environment and the mobility can be accelerated by irrigation. As irrigation water is applied to soils containing selenium, the selenium is leached out of the soils and into surface and ground water. Selenium in wetlands, ponds, and lakes is incorporated into bed sediment and can be bioaccumulated by wildlife, including fish and birds (Ohlendorf and others, 1986). Areas of the Western United States susceptible to selenium contamination from irrigation, which include the Grand and Uncompahgre Valleys in western Colorado, have been identified by Seiler and others (1999). Extensive irrigated agriculture is present in the Grand and Uncompahgre Valleys of the Colorado Plateau in western Colorado (fig. 6). Irrigation drainage from these areas may account for as much as 75 percent of the selenium load in the Colorado River near the Colorado-Utah State line (Butler and others, 1996). It is estimated that 61 percent of the selenium load to Lake Powell in Utah originates from these agricultural areas in the UCOL (Engberg, 1999). Primary source areas of selenium in western Colorado are the western one-half of the Grand Valley and the eastern side of the Uncompahgre River Valley where the residual soils and alluvium are derived primarily from the Mancos Shale, a marine shale containing selenium.



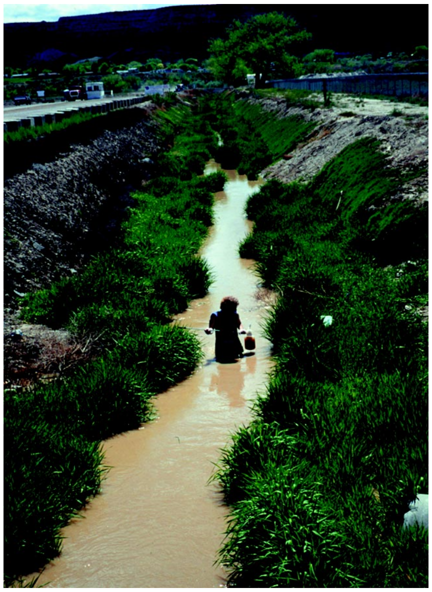
* Data from Butler and others, 1996.

A study in 1991–93 of irrigation drainage in the Grand and Uncompahgre River Valleys detected relatively high concentrations of selenium in many surface-water and streambed-sediment samples (Butler and others, 1996). Concentrations of selenium greater than the aquatic-life guidelines were also detected in the UCOL surface-water sampling in agricultural areas during 1995–98 and at one streambed-sediment sampling site in 1995. Investigations of selenium in western Colorado for remediation planning are continuing through the U.S. Department of the Interior National Irrigation Water Quality Program and the Gunnison Basin Selenium Task Force.

Water-Quality Characteristics of Agricultural Areas

Agricultural land use constitutes about 5 percent of the Study Unit area (fig. 6). Within the Southern Rocky Mountains, agricultural land is almost exclusively hay meadows. The agricultural areas of the Colorado Plateau (principally the Grand Valley near Grand Junction in Mesa County and the Uncompahgre Valley near Delta and Montrose in Delta and Montrose Counties, fig. 6) produce hay, corn, small grains, dry beans, onions, melons, fruit, and grapes. The Grand Valley has about 70,000 acres of irrigated land, and the Uncompahgre Valley contains about 86,000 irrigated acres (Butler and others, 1996). The market value of agricultural products produced in Delta, Mesa, and Montrose Counties was about 145 million dollars in 1992 (Bureau of the Census, 1994). Pesticides, nutrients, and sediment are water-quality issues commonly associated with agricultural land use.

Pesticides were sampled in different media. Pesticides were investigated in surface water by periodic monitoring at 2 agricultural sites and a one-time synoptic sampling at 43 agricultural sites. Fish were collected once at three agricultural sites and the tissues analyzed for organochlorine pesticides. Organochlorine pesticides in streambed sediments were sampled once at six agricultural sites. Ground-water samples were not collected in the agricultural areas of the UCOL because ground water is generally not used for public water supply in these areas.



Collecting water samples at an agricultural drain in the Grand Valley. (Photograph by Norman Spahr, U.S. Geological Survey.)

Pesticides were commonly detected in agricultural areas of the UCOL, but concentrations were generally low. Most pesticide detections in surface water were not at concentrations of concern. Freshwater aquatic-life guidelines were exceeded occasionally; however, guidelines have not been established for all compounds. Only 5 of the 90 samples collected in the agricultural areas contained pesticides that exceeded established guidelines. The pesticides that exceeded guidelines for protection of freshwater aquatic life are azinphos-methyl, 1 of 24 samples at Reed Wash; carbaryl, 2 synoptic sites, Indian Wash and Orchard Mesa Drain in the Grand Valley; diazinon, 1 synoptic site, Indian Wash; diuron, 1 synoptic site, Indian Wash; and *gamma*-HCH, 1 synoptic site, the drain at Blossom Road in the Uncompahgre Valley.

Pesticide detections and concentrations showed seasonal patterns. Periodic sampling at two agricultural streams showed that the total number of pesticides detected was greatest during April through August (Bauch and Spahr, 2000). Pesticide detections per month for Dry Creek are shown in figure 13. Concentrations of atrazine were found to be greater from May through August than during other periods of the year (fig. 13). The seasonal pattern of concentrations was similar for other pesticides and reflects the growing season for the Grand and Uncompahgre Valleys.

Pesticides were detected in 40 of 43 agricultural streams. Thirty-one pesticides (21 herbicides and 10 insecticides) were detected at least once during a May 1998 agricultural stream synoptic study in the Grand Valley and Uncompahgre Valley areas. Atrazine and alachlor were detected in more than 50 percent of the samples. Concentrations of atrazine did not exceed aquatic-life guidelines. Guidelines are not available for alachlor.

Some insecticides have persisted in streambed sediment and fish tissue, although their use has been banned or restricted. DDT was banned in 1972, but DDT or its breakdown products, DDE and DDD, were detected in streambed sediments at five of the six agricultural sites sampled and in fish tissue at all three of the agricultural sites where fish tissue samples were collected (Stephens and Deacon, 1998). Concentrations of DDT and DDE in streambed sediment at two sites exceeded the Canadian Sediment Quality Guidelines PEL (Canadian Council of Ministers of the Environment, 1999). The DDD concentration at one site exceeded the PEL. Dieldrin (a restricted use insecticide since 1974) was detected in streambed sediments at two of the six sites and in fish tissue at all three sites. Insecticides detected in fish tissue and streambed sediments were generally not detected in

Agriculture and the San Juan Mountains near Montrose. (Photograph by Norman Spahr, U.S. Geological Survey.)

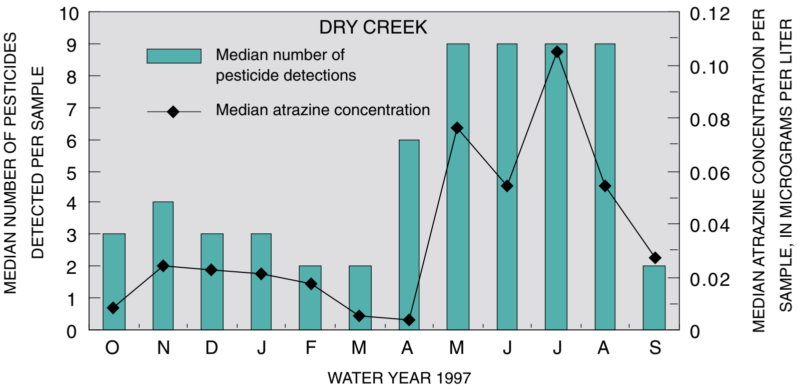
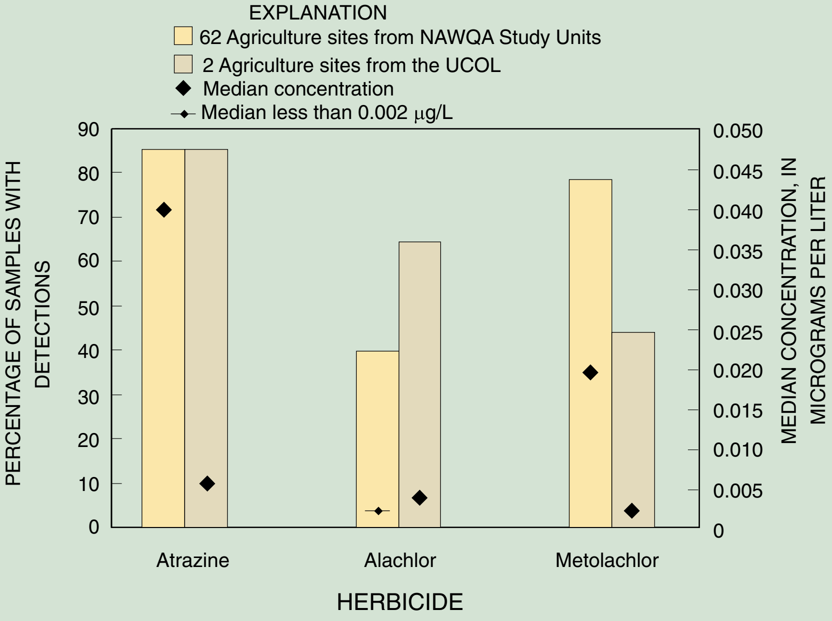


Figure 13. The number of pesticide detections and median atrazine concentrations in surface water are greater during the spring and summer months. Atrazine is commonly used for season-long weed control in corn.

HERBICIDES COMMONLY DETECTED IN THE UCOL WERE ALSO COMMONLY DETECTED IN OTHER AGRICULTURAL AREAS NATIONALLY

The three most commonly detected herbicides at the two agricultural monitoring sites in the UCOL (one site each in the Grand and Uncompahgre Valleys) also were among the top 10 herbicides detected in surface-water samples at 62 agricultural sites in 35 nationally distributed NAWQA Study Units. The percentages of samples with detections for atrazine, alachlor, and metolachlor are shown below and are based on more than 1,550 samples for the national sites and 39 samples at the UCOL sites. Atrazine, alachlor, and metolachlor are commonly used for weed control in corn. Alachlor and metolachlor are also used for weed control in dry beans. Other herbicides that were frequently detected (present in over one-third of the samples) in the UCOL but not shown in the graph include trifluralin, DCPA, 2,4-D, cyanazine, and deethylatrazine (a breakdown product of atrazine). These herbicides also were commonly detected at other agricultural sites across the Nation. Median concentrations of the commonly detected herbicides in the UCOL were less than or similar to the median concentrations for the national sites. Concentrations of atrazine and metolachlor were less than the Canadian guidelines for the protection of aquatic life [1.8 µg/L for atrazine and 7.8 µg/L for metolachlor (Environment Canada, 1999)]. Guidelines have not been established for alachlor.



water samples from the same site, probably because these compounds are relatively insoluble in water. Occurrence of organochlorine pesticides, even at low concentrations, is becoming increasingly relevant because of recent evidence linking these compounds to endocrine disruption (Goodbred and others, 1997).

Nutrient concentrations in streams and rivers reflect point and nonpoint sources. National background concentrations have been determined for some forms of nutrients: total nitrogen in streams (1.0 mg/L), nitrate in streams (0.6 mg/L), and total phosphorus in streams (0.1 mg/L) (U.S. Geological Survey, 1999). Relative concentrations of nutrients in surface water are linked to the amounts and types of substances used and discharged in different land-use settings. These substances can then reach the stream through point sources (such as wastewater discharge) or nonpoint sources (such as precipitation or runoff from agricultural areas). Estimated amounts of fertilizer applied during 1997 in Delta, Mesa, and Montrose Counties were about 14,100,000 pounds of nitrogen and 1,800,000 pounds of phosphorus (Jeffrey Stoner, U.S. Geological Survey, written commun., 2000). Fertilizer use in these counties accounted for about 77 percent of the total estimated fertilizer usage for the UCOL.

Nutrient concentrations in areas of agricultural land use were generally greater than in areas of other land uses. Median concentrations of ammonia, nitrite plus nitrate, total phosphorus, dissolved phosphorus, and orthophosphate were greater at agriculture sites than at the Colorado Plateau reference and mixed land-use sites (fig. 14). The Colorado Plateau reference site has some limited agriculture upstream (livestock/ hay meadows), so is not represen-

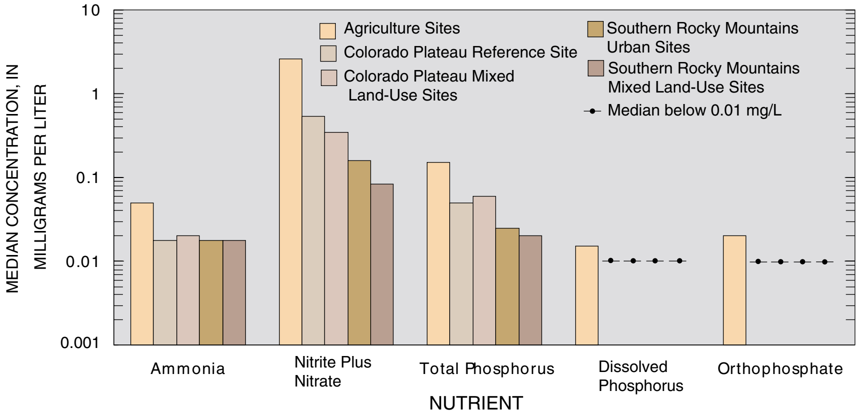


Figure 14. Concentrations of nutrients in agricultural areas of the UCOL were greater than concentrations in other land-use settings. A log scale is used due to the large range of concentrations.

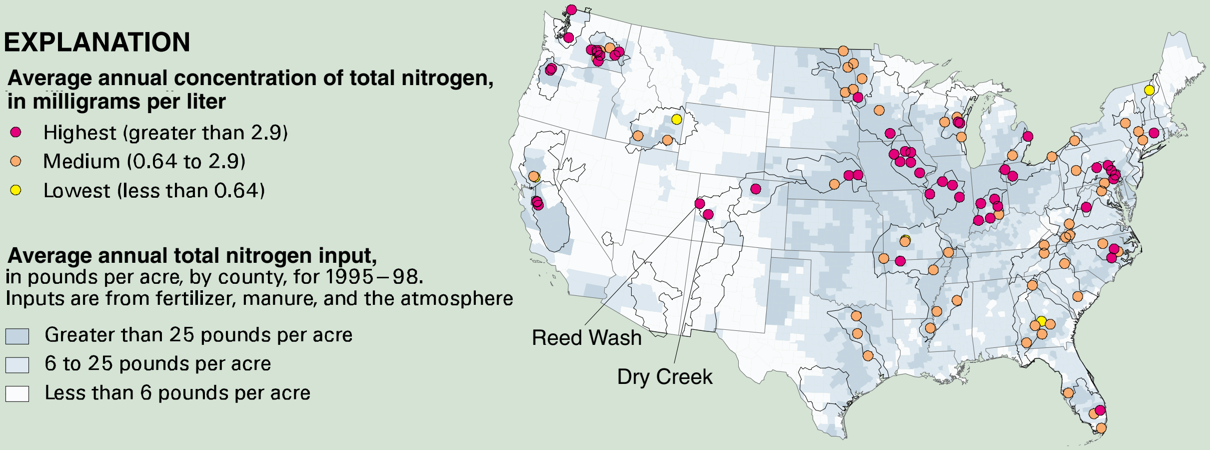
tative of natural conditions but is probably representative of small streams in the Colorado Plateau. Median concentrations of nutrients at agricultural sites also were greater than median concentrations at mixed land-use and urban sites within the Southern Rocky Mountains. The urban areas shown in the bar chart are downstream from Vail and Crested Butte, Colorado (fig. 6), and are streams that are not dominated by wastewater effluent such as might be found in large metropolitan areas. Concentrations of nitrite and nitrate were within State standards for agricultural water use. Water from the agricultural streams is not commonly used for domestic supply.

Geology and agriculture contribute to elevated suspended-sediment concentrations in the Colorado Plateau. Suspended-sediment concentrations in the streams and rivers of the Colorado Plateau were much greater than concentrations in the Southern Rocky Mountains (fig. 15), due in large part to differences between the sedimentary geology of the

NITROGEN CONCENTRATIONS AT THE UCOL AGRICULTURAL SITES WERE GREATER THAN CONCENTRATIONS FOR MANY AGRICULTURAL SITES NATIONWIDE

Total nitrogen (the sum of nitrite, nitrate, ammonia, and organic nitrogen) concentrations at the UCOL agricultural monitoring sites (Reed Wash and Dry Creek) were ranked in the group of national agricultural sites with the highest concentrations. The map below shows a comparison of average annual total nitrogen concentrations at the two UCOL agricultural sites with agricultural sites in other NAWQA Study Units. The average concentrations for the UCOL sites were 3.8 milligrams per liter for Reed Wash and 3.2 milligrams per liter for Dry Creek and are less than State instream standards. Average annual total phosphorus concentrations at the two agricultural sites in the UCOL also ranked among the group of national agricultural sites with the highest total phosphorus concentrations.

TOTAL NITROGEN IN STREAMS—AGRICULTURAL AREAS



Colorado Plateau and the igneous-metamorphic geology of the Southern Rocky Mountains. Agricultural return flows also contribute to the greater sediment concentrations measured at the agricultural sites.

The reference site in the Colorado Plateau also had elevated sediment concentrations. Any rain or snowmelt event in these areas tends to substantially increase the sediment concentrations of streams and rivers because of the high erodibility of the soils.

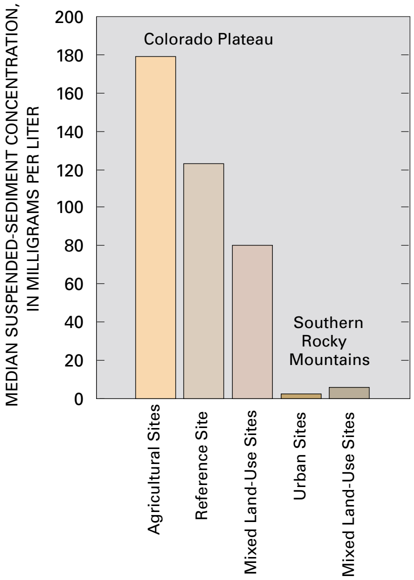


Figure 15. Suspended-sediment concentrations were greatest in the agricultural areas of the Colorado Plateau.

Sediment and water-quality sampling at Reed Wash. (Photograph by Norman Spahr, U.S. Geological Survey.)

BIOLOGICAL MEASURES INDICATE THAT UCOL AGRICULTURAL AND COLORADO PLATEAU MIXED LAND-USE SITES RANK AMONG THE MORE DEGRADED SITES NATIONALLY

The elevated nutrient and sediment concentrations found in the agricultural and surrounding areas of the Colorado Plateau help to explain the prevalence of more tolerant biological species. Algal, invertebrate, and fish communities in the Colorado Plateau generally consist of species more tolerant to nutrients and sediments. These result in higher degradation rankings for all three biological measures. The biological measures in the Colorado Plateau indicate that agricultural and mixed land-use sites in the UCOL are above the national average in terms of degradation. These rankings compare UCOL agricultural sites to other NAWQA agricultural sites and UCOL mixed land-use sites to other NAWQA mixed land-use sites nationally.

Site name	Biological indicator		
	Algal status	Invertebrate status	Fish status
Dry Creek (agricultural site)	🟨	🟧	🟧
Reed Wash (agricultural site)	🟧	🟧	🟧
Colorado River near Cameo (Colorado Plateau mixed land use)	🟧	🟨	🟨
Gunnison River near Grand Junction (Colorado Plateau mixed land use)	🟧	🟧	🟧
Colorado River at State line (Colorado Plateau mixed land use)	🟧	🟧	🟨

EXPLANATION

🟨 Middle 50 percent nationally

🟧 Highest 25 percent nationally, most degraded sites

Explanation of Biological Rankings

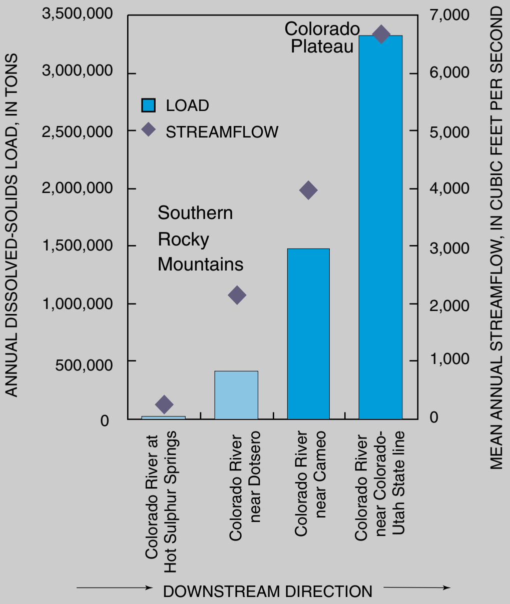
The three selected biological indicators respond to changes in stream degradation. Degradation can result from a variety of factors that modify habitat or other environmental features such as land use, water chemistry, and flow. Algal status focuses on the changes in the percentage of certain algae in response to increasing siltation and often is positively correlated with higher nutrient concentrations in many regions of the Nation. Invertebrate status is the average of 11 invertebrate metrics that summarize changes in richness, tolerance, trophic conditions, and dominance associated with water-quality degradation. Fish status focuses on changes in the percentage of tolerant fish species that make up the total number of fish. "Tolerant" fish are reported to thrive in degraded water quality. For all indicators, higher values indicate degraded water quality.

Salinity in the Colorado River Basin

A serious water-quality issue in the Colorado River Basin is salinity defined as the concentration of dissolved mineral salts or total dissolved solids in water. Salinity increases in the Colorado River in a downstream direction; the dissolved-solids concentration is about 50 mg/L in the upstream mountain areas and averages about 850 mg/L at Imperial Dam, Arizona (Kircher, 1984). In the UCOL, annual dissolved-solids loads in the Colorado River ranged from about 17,700 tons at Hot Sulphur Springs in the Southern Rocky Mountains to more than 3,300,000 tons near the Colorado-Utah State line.

Major sources of salinity in the Colorado River Basin are mineral springs and nonpoint-source runoff. The major human influence is irrigated agriculture. About 11 percent of the salt load in the Colorado River near the U.S.–Mexico border is contributed from the Grand Valley and Uncompahgre Valley (lower Gunnison River Basin) agricultural areas (U.S. Department of the Interior, 1999). Much of the soil in these areas is derived from and overlies the Mancos Shale, a saline marine deposit. Deep percolation of irrigation water and seepage losses from irrigation systems leach salt from the soil and shale, increasing the salinity of return flows. Salinity-control projects have been constructed throughout the Colorado River Basin, including two projects in the UCOL—the Grand Valley Unit and the Lower Gunnison Basin Unit.

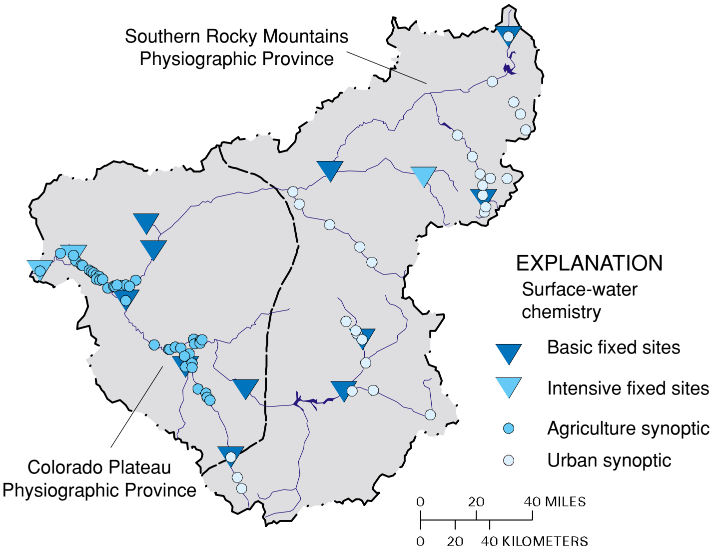
As part of the study of salinity in the Colorado River Basin, trends in dissolved-solids concentrations in the basin have been investigated in numerous studies (Vaill and Butler, 1999; Bauch and Spahr, 1998; Butler, 1996; Liebermann and others, 1989; Kircher, 1984). The most recent study (Vaill and Butler, 1999) determined that since the 1960s there have been, in general, downward trends in flow-adjusted annual and monthly dissolved-solids concentrations and loads in the Colorado River Basin upstream from Lake Powell in Utah, except in the Yampa River Basin. In the UCOL, there were downward trends both upstream and downstream from the salinity-control projects in the Grand Valley and the lower Gunnison River Basin. With the downward trends as evidence, it appears that both natural processes and human efforts such as salinity-control projects may be decreasing salinity loading in the Colorado River Basin.

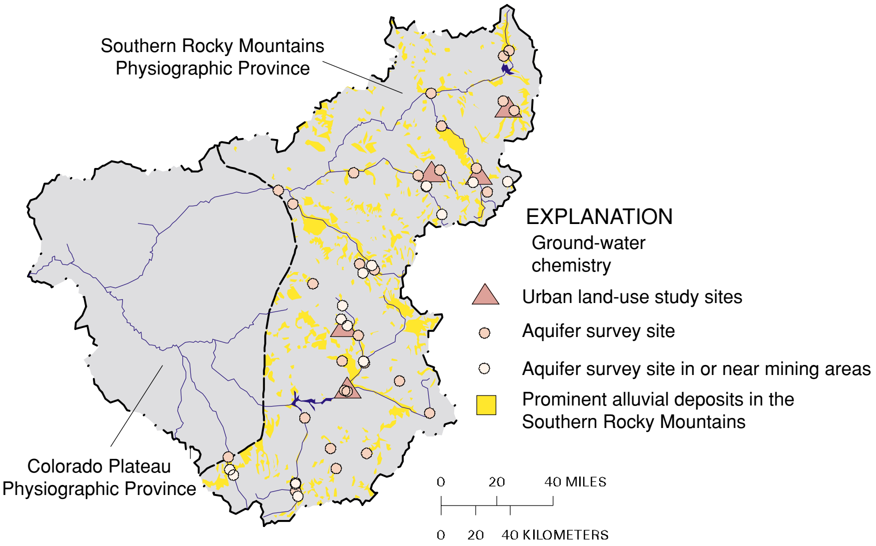


Mean annual dissolved-solids loads increase greatly between sites in the Southern Rocky Mountains and sites in the Colorado Plateau. Data based on water years 1970 to 1993. (Butler,1996; Bauch and Spahr, 1998)

SURFACE-WATER CHEMISTRY

The basic fixed site network was established to investigate the differences in stream-water quality associated with land use and environmental settings within the UCOL. Basic fixed sites were sampled monthly to determine temporal variability of water-quality constituents. The three intensive fixed sites (a subset of the basic fixed site network) were sampled weekly to monthly to further define temporal variability. Synoptic studies were designed to investigate agriculture and urban development effects on water quality. Synoptic sites were sampled one or two times to determine spatial influences of land use on water chemistry.



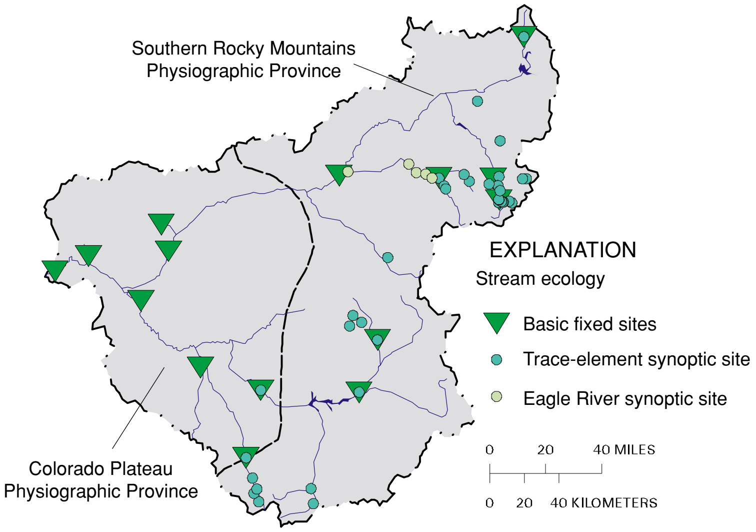


GROUND-WATER CHEMISTRY

To evaluate the effects of urban land use on shallow ground-water quality, five areas within the Southern Rocky Mountains that are undergoing urban development and use ground water as a primary drinking-water source, were studied. An overall assessment of water quality in predominantly alluvial aquifers of the Southern Rocky Mountains was also completed. In addition to the overall assessment, wells were selected in or near mining areas. Alluvial aquifers were selected for these studies because they are generally productive and can be susceptible to land-use practices.

STREAM ECOLOGY

Ecological assessments were done at all basic fixed sites plus one additional site on the Blue River. A synoptic study in mining areas of the Southern Rocky Mountains investigated trace elements in streambed sediment, aquatic moss, and surface water. A characterization of the algal and invertebrate communities and nutrient concentrations in surface water was completed at five sites on the Eagle River.



SUMMARY OF DATA COLLECTION IN THE UPPER COLORADO RIVER BASIN, 1996–98

Study component	What data were collected and why	Types of sites sampled	Number of sites	Sampling frequency and period
Surface-Water Chemistry				
Basic fixed sites–general water chemistry	Monthly samples collected for major ions, nutrients, organic carbon, and suspended sediment to describe concentration variability and loads. Daily streamflow also collected or computed.	Streams and rivers representing urban development, mining, agricultural, and mixed land use.	14	Monthly plus additional high- or low-flow samples for water years 1996–98
Intensive fixed sites	All constituents collected for the fixed sites. Weekly to monthly samples collected to describe temporal variability in pesticide and volatile organic compounds concentrations.	A subset of the fixed site network. One site representing urban development, one site representing agricultural land use, and the outlet of the Study Unit.	3	Weekly to monthly plus additional high- or low-flow samples for water year 1997
Synoptic sites–agriculture	One time sample to describe the spatial variability of pesticides and nutrients in agricultural areas.	Agricultural drains, streams and rivers in the Grand and Uncompahgre Valleys. Outlet of the Study Unit.	43	May 1998
Synoptic sites–urban development	Nutrient and algae samples along an upstream to downstream profile in areas of urban development to investigate influences of urban development.	Upstream to downstream sites along seven tributary rivers.	30	March and September 1998
Ground-Water Chemistry				
Land-use effects–Urban	Samples collected for major ions, nutrients, 18 trace elements, radon, dissolved organic carbon, 87 pesticides, 86 volatile organic compounds, bacteria (total coliform and *E. coli*), and chlorofluorocarbons to describe the effects of urban development on the shallow ground water in five urban areas of the Southern Rocky Mountains.	Shallow monitoring wells	25	Spring and Fall 1997
Aquifer survey–Southern Rocky Mountains	Samples collected for major ions, nutrients, 18 trace elements, radon, dissolved organic carbon, 47 pesticides, 86 volatile organic compounds, and bacteria (total coliform and *E. coli*) to describe the water-quality conditions in selected alluvial aquifers throughout the Southern Rocky Mountains Physiographic Province.	Private and municipal drinking-water wells Monitoring well Spring	28 1 1	Once in 1997
Aquifer survey–Southern Rocky Mountains in or near mining areas	Samples collected for same as above (except that 13 of these sites were not sampled for pesticides or volatile organic compounds) to describe the water-quality conditions in selected alluvial aquifers throughout the Southern Rocky Mountains Physiographic Province for wells located in or near mining areas.	Private and municipal drinking-water wells Spring	14 1	Once in 1997
Stream Ecology				
Basic fixed sites	Fish, invertebrate, and algae communities, trace elements, and organics in streambed sediment and fish tissue, and habitat data were collected to assess the occurrence and distribution within the UCOL.	Streams and rivers representing urban development, mining, agricultural, and mixed land use.	15	Fish community, invertebrate community, and algae August, 1996–98; Habitat August 1996; Streambed sediment and fish tissue August-October 1995
Synoptic sites–trace elements	Trace-element concentrations in streambed sediment, aquatic moss, and water; and invertebrate community structure to assess the spatial extent and magnitude of trace-element contamination from mining areas.	Areas of mining land use and background sites in areas of no mining.	32	August 1998
Synoptic sites–Eagle River	Invertebrates, algae, and nutrients in water to characterize current conditions in an area of extensive urban development.	Sites within and downstream from developed areas. Additional sites in areas that may be developed in the future.	5	February and September 1997

GLOSSARY

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.

Alluvium—Deposits of clay, silt, sand, gravel or other particulate rock material left by a river in a streambed, on a flood plain, delta, or at the base of a mountain.

Alluvial aquifer—A water-bearing deposit of unconsolidated material (sand and gravel) left behind by a river or other flowing water.

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.

Aquatic-life guideline— Water-quality guidelines for protection of aquatic life. Often refers to U.S. Environmental Protection Agency water-quality criteria for protection of aquatic organisms. See also Water-quality guidelines.

Basin— See Drainage basin.

Benthic invertebrates— Insects, mollusks, crustaceans, worms, and other organisms without a backbone that live in, on, or near the bottom of lakes, streams, or oceans.

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.

Breakdown product— A compound derived by chemical, biological, or physical action upon a pesticide. The breakdown is a natural process which may result in a more toxic or a less toxic compound and a more persistent or less persistent compound.

Chlorofluorocarbons— A class of volatile compounds consisting of carbon, chlorine, and fluorine. Commonly called freons, which have been used in refrigeration mechanisms, as blowing agents in the fabrication of flexible and rigid foams, and, until several years ago, as propellants in spray cans.

Community— In ecology, the species that interact in a common area.

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

Confluence— The flowing together of two or more streams; the place where a tributary joins the main stream.

Constituent— A chemical or biological substance in water, sediment, or biota that can be measured by an analytical method.

Cubic foot per second (ft^3/s, or cfs)— Rate of water discharge representing a volume of 1 cubic foot passing a given point during 1 second, equivalent to approximately 7.48 gallons per second or 448.8 gallons per minute or 0.02832 cubic meter per second.

Detect— To determine the presence of a compound.

DDT— Dichloro-diphenyl-trichloroethane. An organochlorine insecticide no longer registered for use in the United States.

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.

Drainage basin— The portion of the surface of the Earth that contributes water to a stream through overland runoff, including tributaries and impoundments.

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

Health advisory— Nonregulatory levels of contaminants in drinking water that may be used as guidance in the absence of regulatory limits. Advisories 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.

Instream standards— See Water-quality standards.

Invertebrate— An animal having no backbone or spinal column. See also Benthic invertebrates.

Load— General term that refers to a material or constituent in solution, in suspension, or in transport; usually expressed in terms of mass or volume.

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.

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

Micrograms per liter (μg/L)— A unit expressing the concentration of constituents in solution as weight (micrograms) of solute per unit volume (liter) of water; equivalent to one part per billion in most streamwater and ground water. One thousand micrograms per liter equals 1 mg/L.

Midge— A small fly in the family Chironomidae. The larval (juvenile) life stages are aquatic.

Milligrams per liter (mg/L)— A unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water; equivalent to one part per million in most streamwater and ground water. One thousand micrograms per liter equals 1 mg/L.

Monitoring well— A well designed for measuring water levels and testing ground-water quality.

Mouth— The place where a stream discharges to a larger stream, a lake, or the sea.

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 pesticide— A class of organic insecticides containing a high percentage of chlorine. Includes dichlorodiphenylethanes (such as DDT), chlorinated cyclodienes (such as chlordane), and chlorinated benzenes (such as lindane). Most organochlorine insecticides were 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".

Phosphorus— A nutrient essential for growth that can play a key role in stimulating aquatic growth in lakes and streams.

Picocurie (pCi)— One trillionth (10^{-12}) of the amount of radioactivity represented by a curie (Ci). A curie is the amount of radioactivity that yields 3.7×10^{10} radioactive disintegrations per second (dps). A picocurie yields 2.22 disintegrations per minute (dpm) or 0.037 dps.

Radon— A naturally occurring, colorless, odorless, radioactive gas formed by the disintegration of the element radium; damaging to human lungs when inhaled.

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

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

Species— Populations of organisms that may interbreed and produce fertile offspring having similar structure, habits, and functions.

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

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.

Surface water— An open body of water, such as a lake, river, or stream.

Suspended sediment—Particles of rock, sand, soil, and organic detritus carried in suspension in the water column, in contrast to sediment that moves on or near the streambed.

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.

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, zinc and selenium.

Un-ionized ammonia— The neutral form of ammonia-nitrogen in water, usually occurring as NH_4OH. Un-ionized ammonia is the principal form of ammonia that is toxic to aquatic life. The relative proportion of un-ionized to ionized ammonia (NH_4^+) is controlled by water temperature and pH. At temperatures and pH values typical of most natural waters, the ionized form is dominant.

Volatile organic compounds (VOCs)— Organic chemicals that have a high vapor pressure relative to their 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.

Water-quality guidelines— Specific levels of water quality which, if reached, may adversely affect human health or aquatic life. These are nonenforceable guidelines issued by a governmental agency or other institution.

Water-quality standards— State-adopted and U.S. Environmental Protection Agency-approved ambient standards for water bodies. Standards include the use of the water body and the water-quality criteria that must be met to protect the designated use or uses.

Water year— The continuous 12-month period, October 1 through September 30, in U.S. Geological Survey reports dealing with the surface-water supply. The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months. Thus, the year ending September 30, 1980, is referred to as water year 1980.

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APPENDIX—WATER-QUALITY DATA FROM THE UPPER COLORADO RIVER BASIN IN A NATIONAL CONTEXT

For a complete view of Upper Colorado River Basin data and for additional information about specific benchmarks used, visit our Web site at http://water.usgs.gov/nawqa/. Also visit the NAWQA Data Warehouse for access to NAWQA data sets at http://water.usgs.gov/nawqa/data.

This appendix is a summary of chemical concentrations and biological indicators assessed in the Upper Colorado River Basin. Selected results for this Basin are graphically compared to results from as many as 36 NAWQA Study Units investigated from 1991 to 1998 and to national water-quality benchmarks for human health, aquatic life, or fish-eating wildlife. The chemical and biological indicators shown were selected on the basis of frequent detection, detection at concentrations above a national benchmark, or regulatory or scientific importance. The graphs illustrate how conditions associated with each land use sampled in the Upper Colorado River Basin compare to results from across the Nation, and how conditions compare among the several land uses. Graphs for chemicals show only detected concentrations and, thus, care must be taken to evaluate detection frequencies in addition to concentrations when comparing study-unit and national results. For example, simazine concentrations in Upper Colorado River Basin agricultural streams were similar to the national distribution, but the detection frequency was much higher (72 percent compared to 18 percent).

CHEMICALS IN WATER

Concentrations and detection frequencies, Upper Colorado River Basin, 1996–98—Detection sensitivity varies among chemicals and, thus, frequencies are not directly comparable among chemicals

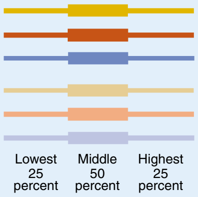
◆ Detected concentration in Study Unit

66 38 Frequencies of detection, in percent. Detection frequencies were not censored at any common reporting limit. The left-hand column is the study-unit frequency and the right-hand column is the national frequency

- - Not measured or sample size less than two

12 Study-unit sample size. For ground water, the number of samples is equal to the number of wells sampled

National ranges of detected concentrations, by land use, in 36 NAWQA Study Units, 1991–98—Ranges include only samples in which a chemical was detected



Streams in agricultural areas
Streams in urban areas
Streams and rivers draining mixed land uses
Shallow ground water in agricultural areas
Shallow ground water in urban areas
Major aquifers

National water-quality benchmarks

National benchmarks include standards and guidelines related to drinking-water quality, criteria for protecting the health of aquatic life, and a goal for preventing stream eutrophication due to phosphorus. Sources include the U.S. Environmental Protection Agency and the Canadian Council of Ministers of the Environment

| Drinking-water quality (applies to ground water and surface water)

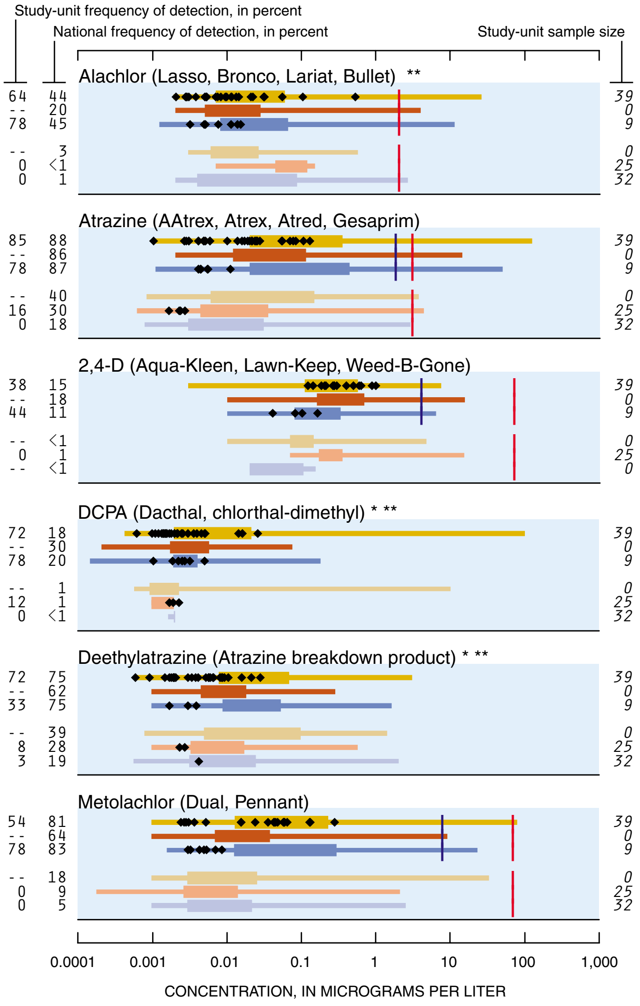
| Protection of aquatic life (applies to surface water only)

| Prevention of eutrophication in streams not flowing directly into lakes or impoundments

* No benchmark for drinking-water quality

** No benchmark for protection of aquatic life

Pesticides in water—Herbicides

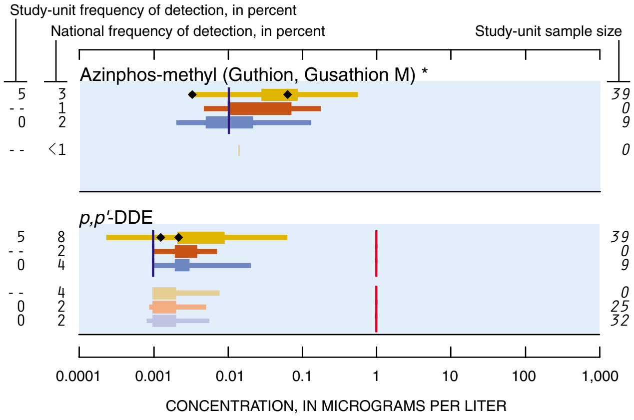


Other herbicides detected
Acetochlor (Harness Plus, Surpass) * **
Benfluralin (Balan, Benefin, Bonalan) * **
Bentazon (Basagran, Bentazone) **
Bromacil (Hyvar X, Urox B, Bromax)
Cyanazine (Bladex, Fortrol)
2,4-DB (Butyrac, Butoxone, Embutox Plus, Embutone) * **
Dicamba (Banvel, Dianat, Scotts Proturf)
EPTC (Eptam, Farmarox, Alirox) * **
Ethalfluralin (Sonalan, Curbit) * **
Oryzalin (Surflan, Dirimal) * **
Prometon (Pramitol, Princep) **
Simazine (Princep, Caliber 90)
Tebuthiuron (Spike, Tebusan)
Trifluralin (Treflan, Gowan, Tri-4, Trific)

Herbicides not detected
Acifluorfen (Blazer, Tackle 2S) **
Bromoxynil (Buctril, Brominal) *
Butylate (Sutan +, Genate Plus, Butilate) **
Chloramben (Amiben, Amilon-WP, Vegiben) **
Clopyralid (Stinger, Lontrel, Transline) * **
Dacthal mono-acid (Dacthal breakdown product) * **
Dichlorprop (2,4-DP, Seritox 50, Lentemul) * **
2,6-Diethylaniline (Alachlor breakdown product) * **
Dinoseb (Dinosebe)
Diuron (Crisuron, Karmex, Diurex) **

Fenuron (Fenulon, Fenidim) * **
Fluometuron (Flo-Met, Cotoran) **
Linuron (Lorox, Linex, Sarclex, Linurex, Afalon) *
MCPA (Rhomene, Rhonox, Chiptox)
MCPB (Thistrol) * **
Metribuzin (Lexone, Sencor)
Molinate (Ordram) * **
Napropamide (Devrinol) * **
Neburon (Neburea, Neburyl, Noruben) * **
Norflurazon (Evital, Predict, Solicam, Zorial) * **
Pebulate (Tillam, PEBC) * **
Pendimethalin (Pre-M, Prowl, Stomp) * **
Picloram (Grazon, Tordon)
Pronamide (Kerb, Propyzamid) **
Propachlor (Ramrod, Satecid) **
Propanil (Stam, Stampede, Wham) * **
Propham (Tuberite) **
2,4,5-T **
2,4,5-TP (Silvex, Fenoprop) **
Terbacil (Sinbar) **
Thiobencarb (Bolero, Saturn, Benthiocarb) * **
Triallate (Far-Go, Avadex BW, Tri-allate) *
Triclopyr (Garlon, Grandstand, Redeem, Remedy) * **

Pesticides in water—Insecticides

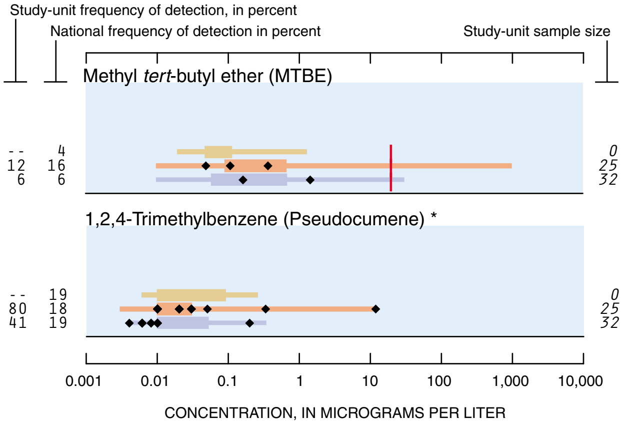


Other insecticides detected
Carbaryl (Carbamine, Denapon, Sevin)
Carbofuran (Furadan, Curaterr, Yaltox)
Chlorpyrifos (Brodan, Dursban, Lorsban)
Diazinon (Basudin, Diazatol, Neocidol, Knox Out)
gamma-HCH (Lindane, gamma-BHC)
Malathion (Malathion)
cis-Permethrin (Ambush, Astro, Pounce) * **
Phorate (Thimet, Granutox, Geomet, Rampart) * **
Propargite (Comite, Omite, Ornamite) * **
Terbufos (Contraven, Counter, Pilarfox) **

Insecticides not detected
Aldicarb (Temik, Ambush, Pounce)
Aldicarb sulfone (Standak, aldoxycarb)
Aldicarb sulfoxide (Aldicarb breakdown product)
Dieldrin (Panoram D-31, Octalox, Compound 497)
Disulfoton (Disyston, Di-Syston) **
Ethoprop (Mocap, Ethoprophos) * **
Fonofos (Dyfonate, Capfos, Cudgel, Tycap) **
alpha-HCH (alpha-BHC, alpha-lindane) **
3-Hydroxycarbofuran (Carbofuran breakdown product) * **
Methiocarb (Slug-Geta, Grandslam, Mesurol) * **
Methomyl (Lanox, Lannate, Acinate) **
Methyl parathion (Penncap-M, Folidol-M) **
Oxamyl (Vydate L, Pratt) **
Parathion (Roethyl-P, Alkron, Panthion, Phoskil) *
Propoxur (Baygon, Blattanex, Unden, Proprotox) * **

Volatile organic compounds (VOCs) in ground water

These graphs represent data from 16 Study Units, sampled from 1996 to 1998

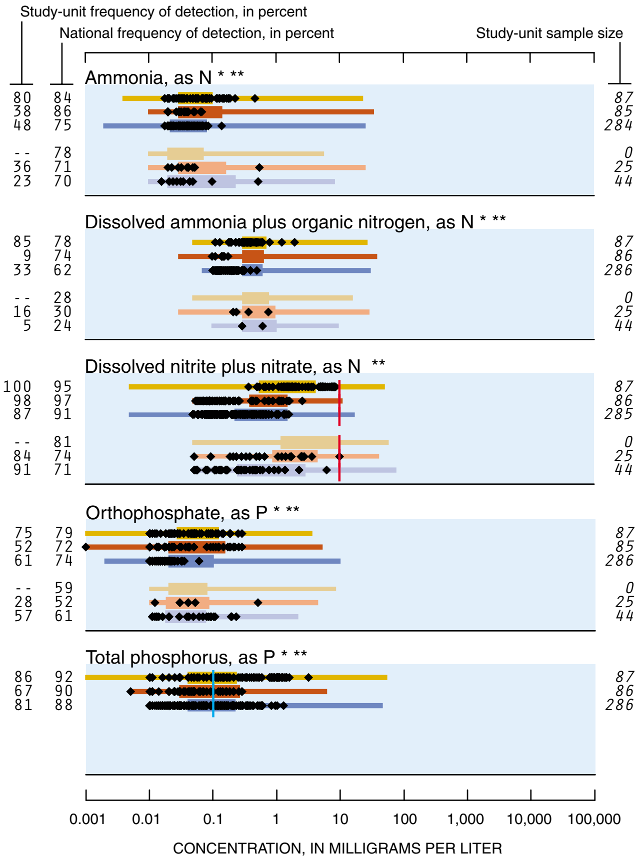


Other VOCs detected
Benzene
Bromodichloromethane (Dichlorobromomethane)
2-Butanone (Methyl ethyl ketone (MEK)) *
n-Butylbenzene (1-Phenylbutane) *
sec-Butylbenzene *
Carbon disulfide *
Chloroethane (Ethyl chloride) *
Chloromethane (Methyl chloride)
1,3-Dichlorobenzene (*m*-Dichlorobenzene)
Dichlorodifluoromethane (CFC 12, Freon 12)
Dichloromethane (Methylene chloride)
Diethyl ether (Ethyl ether) *
1,2-Dimethylbenzene (*o*-Xylene)
1,3 & 1,4-Dimethylbenzene (*m*-&*p*-Xylene)
1-4-Epoxy butane (Tetrahydrofuran, Diethylene oxide) *
Ethenylbenzene (Styrene)
1-Ethyl-2-methylbenzene (2-Ethyltoluene) *
Ethylbenzene (Phenylethane)
Iodomethane (Methyl iodide) *
Isopropylbenzene (Cumene) *
p-Isopropyltoluene (*p*-Cymene) *
4-Methyl-2-pentanone (Methyl isobutyl ketone (MIBK)) *
Methylbenzene (Toluene)
Naphthalene
2-Propanone (Acetone) *
n-Propylbenzene (Isocumene) *
Tetrachloroethene (Perchloroethene)
Tetrachloromethane (Carbon tetrachloride)
1,2,3,5-Tetramethylbenzene (Isodurene) *
1,1,1-Trichloroethane (Methylchloroform)
Trichloroethene (TCE)
Trichloromethane (Chloroform)
1,2,3-Trimethylbenzene (Hemimellitene) *
1,3,5-Trimethylbenzene (Mesitylene) *

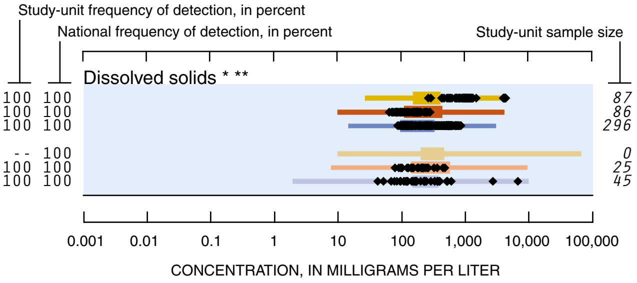
VOCs not detected
tert-Amylmethylether (*tert*-amyl methyl ether (TAME)) *
Bromobenzene (Phenyl bromide) *
Bromochloromethane (Methylene chlorobromide)
Bromoethene (Vinyl bromide) *
Bromomethane (Methyl bromide)
tert-Butylbenzene *
3-Chloro-1-propene (3-Chloropropene) *
1-Chloro-2-methylbenzene (*o*-Chlorotoluene)
1-Chloro-4-methylbenzene (*p*-Chlorotoluene)
Chlorobenzene (Monochlorobenzene)
Chlorodibromomethane (Dibromochloromethane)
Chloroethene (Vinyl chloride)
1,2-Dibromo-3-chloropropane (DBCP, Nemagon)
1,2-Dibromoethane (Ethylene dibromide, EDB)
Dibromomethane (Methylene dibromide) *
trans-1,4-Dichloro-2-butene ((Z)-1,4-Dichloro-2-butene) *
1,2-Dichlorobenzene (*o*-Dichlorobenzene)
1,4-Dichlorobenzene (*p*-Dichlorobenzene)

1,2-Dichloroethane (Ethylene dichloride)
1,1-Dichloroethane (Ethylidene dichloride) *
1,1-Dichloroethene (Vinylidene chloride)
trans-1,2-Dichloroethene ((E)-1,2-Dichlorothene)
cis-1,2-Dichloroethene ((Z)-1,2-Dichloroethene)
1,2-Dichloropropane (Propylene dichloride)
2,2-Dichloropropane *
1,3-Dichloropropane (Trimethylene dichloride) *
trans-1,3-Dichloropropene ((E)-1,3-Dichloropropene)
cis-1,3-Dichloropropene ((Z)-1,3-Dichloropropene)
1,1-Dichloropropene *
Diisopropyl ether (Diisopropylether (DIPE)) *
Ethyl methacrylate *
Ethyl *tert*-butyl ether (Ethyl-*t*-butyl ether (ETBE)) *
Hexachlorobutadiene
1,1,1,2,2,2-Hexachloroethane (Hexachloroethane)
2-Hexanone (Methyl butyl ketone (MBK)) *
Methyl acrylonitrile *
Methyl-2-methacrylate (Methyl methacrylate) *
Methyl-2-propenoate (Methyl acrylate) *
2-Propenenitrile (Acrylonitrile)
1,1,2,2-Tetrachloroethane *
1,1,1,2-Tetrachloroethane
1,2,3,4-Tetramethylbenzene (Prehnitene) *
Tribromomethane (Bromoform)
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113) *
1,2,4-Trichlorobenzene
1,2,3-Trichlorobenzene *
1,1,2-Trichloroethane (Vinyl trichloride)
Trichlorofluoromethane (CFC 11, Freon 11)
1,2,3-Trichloropropane (Allyl trichloride)

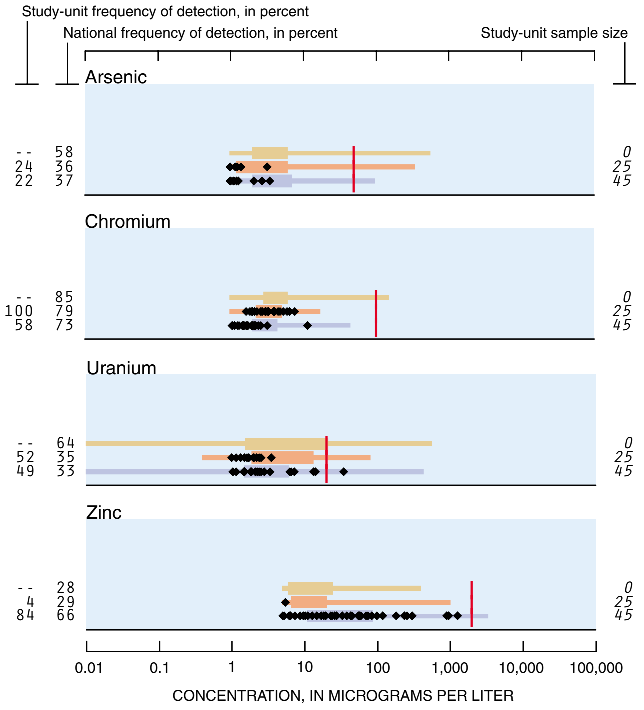
Nutrients in water

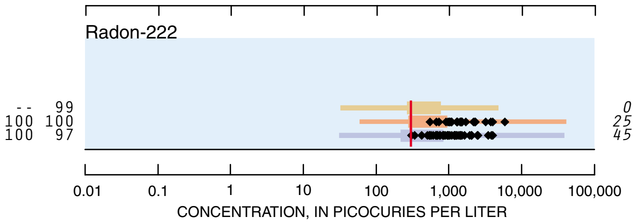


Dissolved solids in water



Trace elements in ground water





Other trace elements detected
Lead
Selenium

Trace elements not detected
Cadmium

CHEMICALS IN FISH TISSUE AND BED SEDIMENT

Concentrations and detection frequencies, Upper Colorado River Basin, 1996–98—Detection sensitivity varies among chemicals and, thus, frequencies are not directly comparable among chemicals. Study-unit frequencies of detection are based on small sample sizes; the applicable sample size is specified in each graph

◆ Detected concentration in Study Unit

66 38 Frequencies of detection, in percent. Detection frequencies were not censored at any common reporting limit. The left-hand column is the study-unit frequency and the right-hand column is the national frequency

- - Not measured or sample size less than two

12 Study-unit sample size

National ranges of concentrations detected, by land use, in 36 NAWQA Study Units, 1991–98—Ranges include only samples in which a chemical was detected

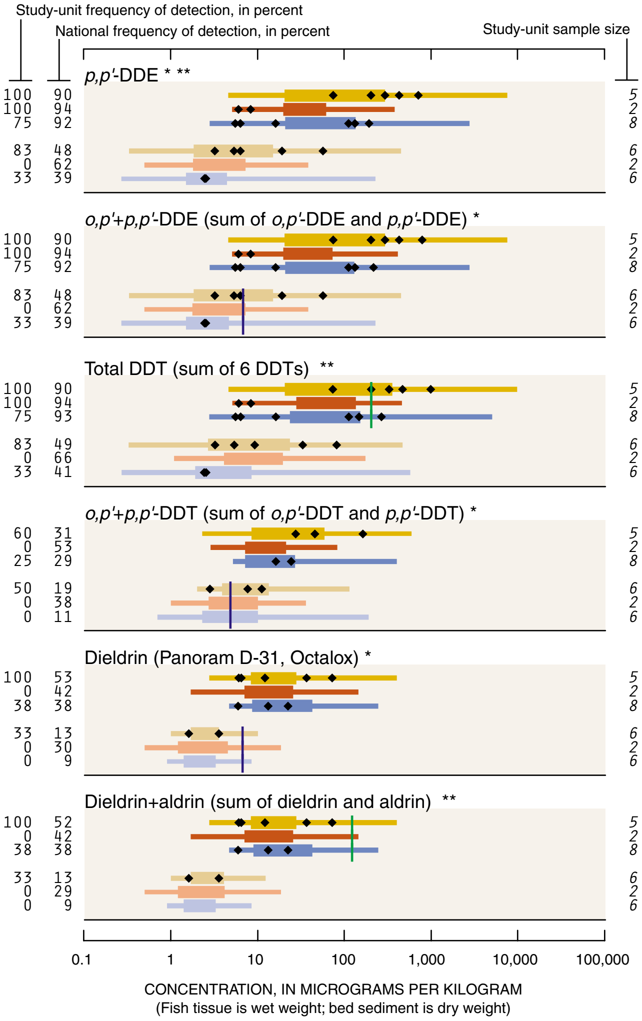
Fish tissue from streams in agricultural areas
Fish tissue from streams in urban areas
Fish tissue from streams draining mixed land uses
Sediment from streams in agricultural areas
Sediment from streams in urban areas
Sediment from streams draining mixed land uses

Lowest 25 percent | Middle 50 percent | Highest 25 percent

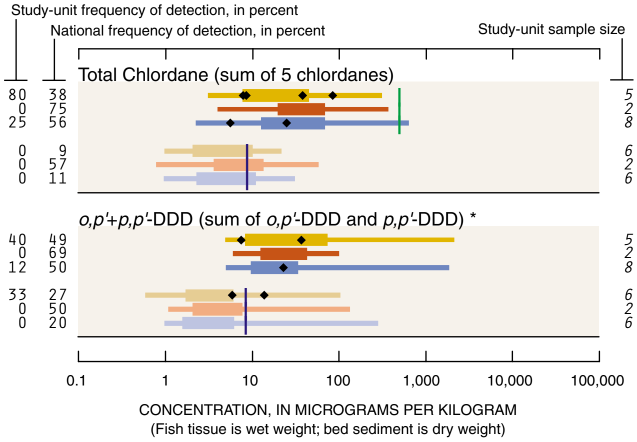
National benchmarks for fish tissue and bed sediment

National benchmarks include standards and guidelines related to criteria for protection of the health of fish-eating wildlife and aquatic organisms. Sources include the U.S. Environmental Protection Agency, other Federal and State agencies, and the Canadian Council of Ministers of the Environment

| Protection of fish-eating wildlife (applies to fish tissue)
| Protection of aquatic life (applies to bed sediment)
* No benchmark for protection of fish-eating wildlife
** No benchmark for protection of aquatic life



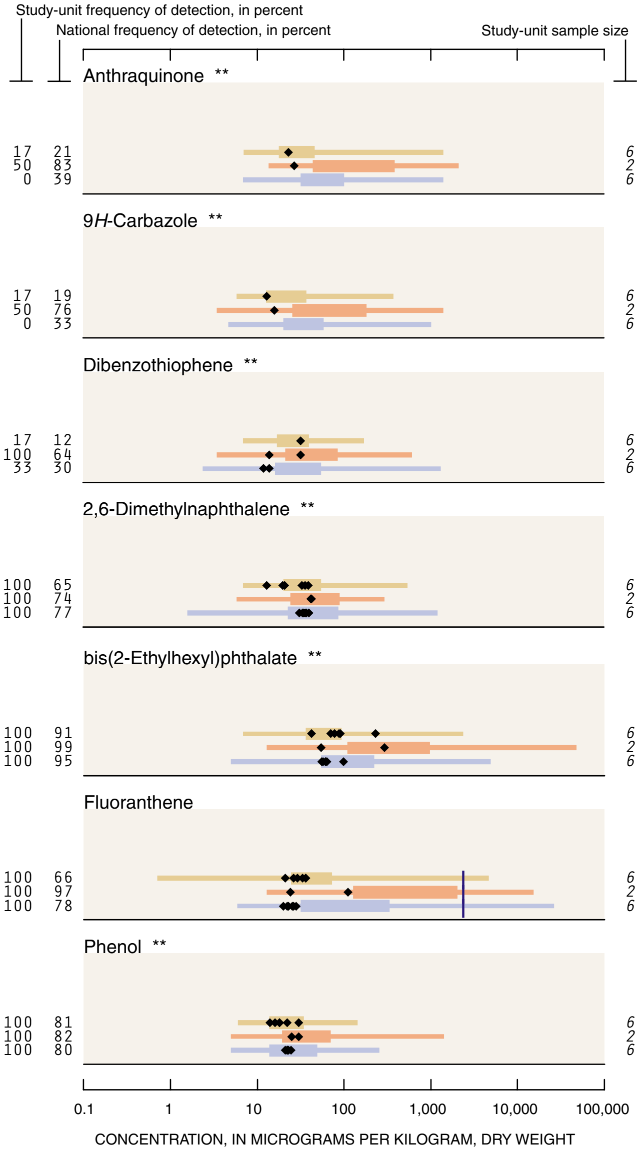
Organochlorines in fish tissue (whole body) and bed sediment



Other organochlorines detected
DCPA (Dacthal, chlorthal-dimethyl) * **
Heptachlor epoxide (Heptachlor breakdown product) *
Heptachlor+heptachlor epoxide (sum of heptachlor and heptachlor epoxide) **
Hexachlorobenzene (HCB) **
Toxaphene (Camphechlor, Hercules 3956) * **

Organochlorines not detected
Chloroneb (Chloronebe, Demosan) * **
Endosulfan I (alpha-Endosulfan, Thiodan) * **
Endrin (Endrine)
gamma-HCH (Lindane, gamma-BHC, Gammexane) *
Total-HCH (sum of alpha-HCH, beta-HCH, gamma-HCH, and delta-HCH) **
Isodrin (Isodrine, Compound 711) * **
p,p′-Methoxychlor (Marlate, methoxychlore) * **
o,p′-Methoxychlor * **
Mirex (Dechlorane) **
Total PCB
Pentachloroanisole (PCA) * **
cis-Permethrin (Ambush, Astro, Pounce) * **
trans-Permethrin (Ambush, Astro, Pounce) * **

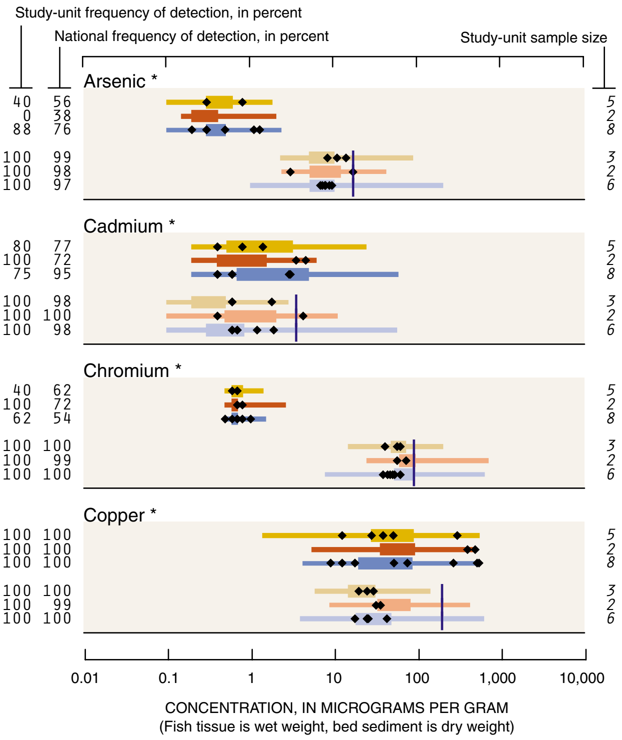
Semivolatile organic compounds (SVOCs) in bed sediment

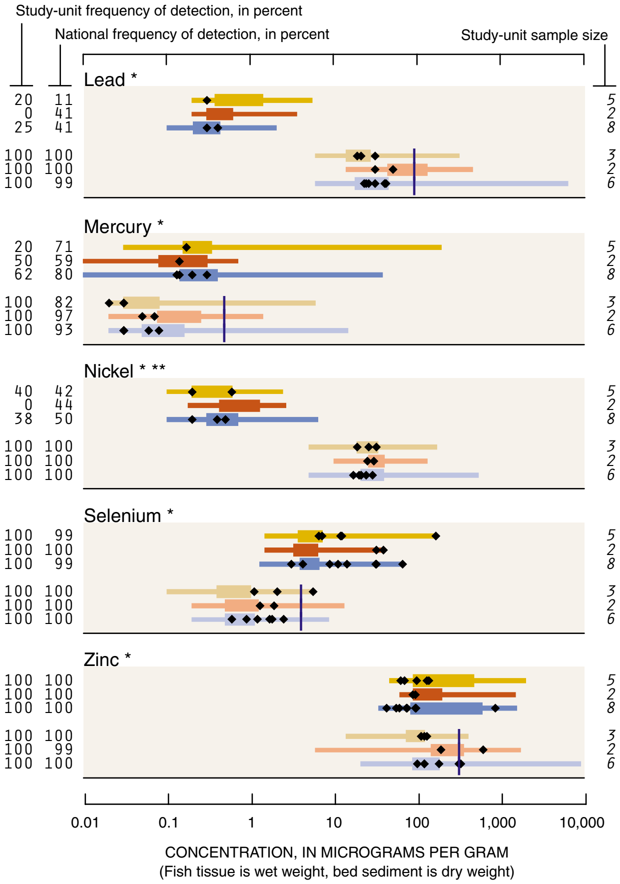


Other SVOCs detected
Acridine **
Anthracene
Benz[*a*]anthracene
Benzo[*a*]pyrene
Benzo[*b*]fluoranthene **
Benzo[*ghi*]perylene **
Benzo[*k*]fluoranthene **
Butylbenzylphthalate **
Chrysene
p-Cresol **
Di-*n*-butylphthalate **
Di-*n*-octylphthalate **
Dibenz[*a,h*]anthracene
Diethylphthalate **
1,2-Dimethylnaphthalene **
1,6-Dimethylnaphthalene **
Dimethylphthalate **
2-Ethylnaphthalene **
9*H*-Fluorene (Fluorene)
Indeno[1,2,3-*cd*]pyrene **
1-Methyl-9*H*-fluorene **
2-Methylanthracene **
4,5-Methylenephenanthrene **
1-Methylphenanthrene **
1-Methylpyrene **
Naphthalene
Pentachloronitrobenzene **
Phenanthrene
Pyrene
2,3,6-Trimethylnaphthalene **

SVOCs not detected
Acenaphthene
Acenaphthylene
C8-Alkylphenol **
Azobenzene **
Benzo[*c*]cinnoline **
2,2-Biquinoline **
4-Bromophenyl-phenylether **
4-Chloro-3-methylphenol **
bis(2-Chloroethoxy)methane **
2-Chloronaphthalene **
2-Chlorophenol **
4-Chlorophenyl-phenylether **
1,2-Dichlorobenzene (*o*-Dichlorobenzene) **
1,3-Dichlorobenzene (*m*-Dichlorobenzene) **
1,4-Dichlorobenzene (*p*-Dichlorobenzene) **
3,5-Dimethylphenol **
2,4-Dinitrotoluene **
Isophorone **
Isoquinoline **
Nitrobenzene **
N-Nitrosodi-*n*-propylamine **
N-Nitrosodiphenylamine **
Phenanthridine **
Quinoline **
1,2,4-Trichlorobenzene **

Trace elements in fish tissue (livers) and bed sediment





BIOLOGICAL INDICATORS

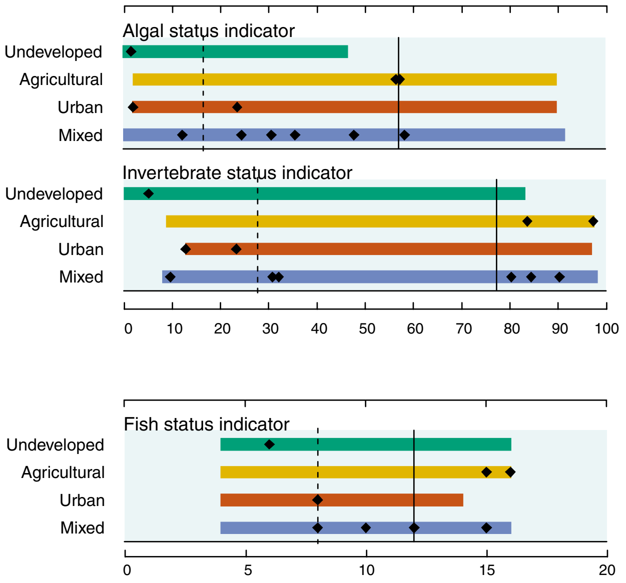
Higher national scores suggest habitat disturbance, water-quality degradation, or naturally harsh conditions. The status of algae, invertebrates (insects, worms, and clams), and fish provide a record of water-quality and stream conditions that water-chemistry indicators may not reveal. **Algal status** focuses on the changes in the percentage of certain algae in response to increasing siltation, and it often correlates with higher nutrient concentrations in some regions. **Invertebrate status** averages 11 metrics that summarize changes in richness, tolerance, trophic conditions, and dominance associated with water-quality degradation. **Fish status** sums the scores of four fish metrics (percent tolerant, omnivorous, non-native individuals, and percent individuals with external anomalies) that increase in association with water-quality degradation

Biological indicator value, Upper Colorado River Basin, by land use, 1996–98

◆ Biological status assessed at a site

National ranges of biological indicators, in 16 NAWQA Study Units, 1994–98

🟩 Streams in undeveloped areas
🟨 Streams in agricultural areas
🟥 Streams in urban areas
🟦 Streams in mixed-land-use areas
— 75th percentile
- - 25th percentile



A COORDINATED EFFORT

Coordination with agencies and organizations in the Upper Colorado River Basin Study Unit was integral to the success of this water-quality assessment. We thank those who served as members of our liaison committee.

Federal Agencies

Bureau of Land Management
Bureau of Reclamation
National Park Service-Curecanti National Recreation Area
National Park Service
Natural Resources Conservation Service
U.S. Bureau of Mines
U.S. Environmental Protection Agency
U.S. Fish and Wildlife Service
U.S. Forest Service

State Agencies

Colorado Department of Public Health and Environment
Colorado Division of Minerals and Geology
Colorado Division of Wildlife
Colorado Geological Survey
Colorado River Basin Salinity Control Forum
Colorado River Water Conservation District
Colorado Water Conservation Board
Eagle County
Eagle River Water and Sanitation District
East Grand Water Quality Board
Grand County Water & Sanitation District
Grand Junction Drainage District
Grand County Commissioners
Denver Water

Local Agencies

City of Aurora
City of Gunnison
City of Grand Junction
Clifton Water District
Crested Butte South Metropolitan District
Gunnison County
Mesa County Water Association
Mt. Crested Butte Water and Sanitation District
Northern Colorado Water Conservancy District
Northwest Colorado Council of Governments
Silvercreek Water and Sanitation District
Summit County Water Quality Committee
Town of Crested Butte
Town of Fraser
Town of Granby
Town of Silverthorne
Town of Winter Park
Town of Vail
Uncompahgre Valley Water Users Association
Upper Gunnison River Water Conservancy District

Universities

Colorado State University Cooperative Extension

Other public and private organizations

Colorado Water Resources Research Institute
Gunnison Basin POWER
Sierra Club
Vail Associates

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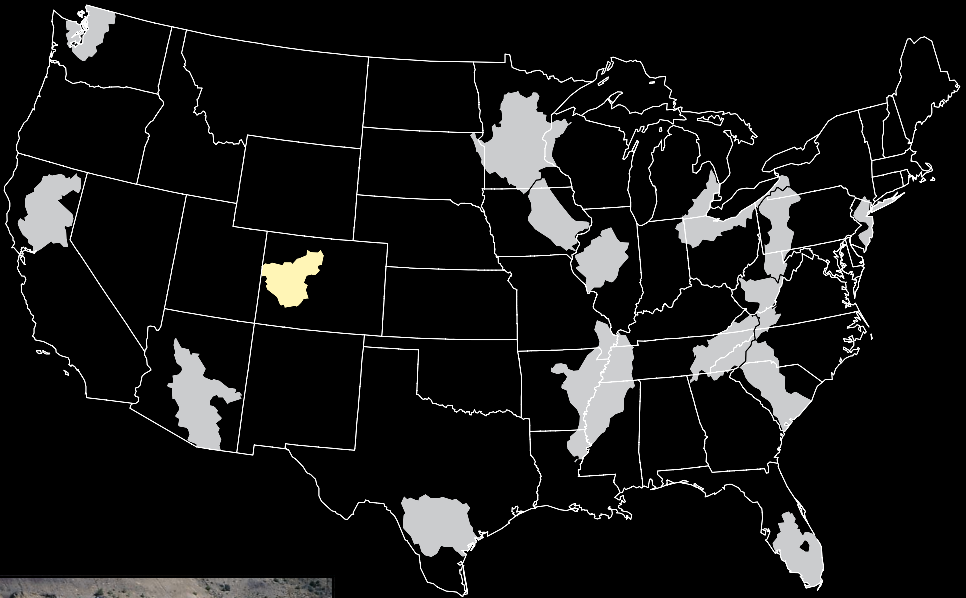
NAWQA

National Water-Quality Assessment (NAWQA) Program
Upper Colorado River Basin



Spahr and others—Water Quality in the Upper Colorado River Basin
U.S. Geological Survey Circular 1214

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