

The Quality of Our Nation's Waters

Ecological Health in the Nation's Streams, 1993–2005



National Water-Quality Assessment Program

Circular 1391



COVER

Background: Lake Fork River, Utah (U.S. Geological Survey photo by Daren Carlisle); upper photo: damselflies (photo courtesy of Jeremy Monroe, Freshwaters Illustrated); lower photo: mottled sculpin (*Cottus bairdii*) (photo courtesy of Ben Holcomb, Utah Department of Environmental Quality).

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By Daren M. Carlisle, Michael R. Meador, Terry M. Short, Cathy M. Tate, Martin E. Gurtz, Wade L. Bryant, James A. Falcone, and Michael D. Woodside

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FOREWORD

The United States has made major investments in assessing, managing, regulating, and conserving natural resources such as water, minerals, soils, and timber. Sustaining the quality of the Nation's water resources and the health of our ecosystems depends on the availability of sound water-resources data and information to develop effective, science-based policies. Effective management of water resources also brings more certainty and efficiency to important economic sectors. Taken together, these actions lead to immediate and long-term economic, social, and environmental benefits that make a difference to the lives of millions of people (<http://water.usgs.gov/nawqa/applications/>).

Two decades ago, Congress established the U.S. Geological Survey's National Water-Quality Assessment Program (NAWQA) to meet this need. Since then, it has served as a primary source of nationally consistent information on the quality of the Nation's streams and groundwater; how water quality changes over time; and how natural features and human activities affect the quality of streams and groundwater. Objective and reliable data, water-quality models and related decision support tools, and systematic scientific studies characterize where, when, and why the Nation's water quality is degraded—and what can be done to improve and protect it for human and ecosystem needs. This information is crucial to our future because the Nation faces an increasingly complex and growing need for clean water to support population, economic growth, and healthy ecosystems. For example, two-thirds of estuaries in the United States are impacted by nutrients and dead zones that no longer fully support healthy fish and other aquatic communities. Forty-two percent of the Nation's streams are in poor or degraded condition compared to reference conditions. Eighty percent of urban streams have at least one pesticide that exceeds criteria to protect aquatic life. Groundwater from about 20 percent of public and domestic wells—which serve about 150 million people—contains at least one contaminant at a level of potential health concern.

This report presents a national assessment of stream health based on the condition of biological communities in relation to important physical and chemical factors, such as the degree of hydrologic alteration and concentrations of nutrients and other dissolved contaminants. Algae, macroinvertebrates, and fish provide a direct measure of stream health because they live within streams for weeks to years, therefore integrating through time the effects of changes to their chemical and physical environment. This report is one of a series of publications, *The Quality of Our Nation's Waters*, which describes major findings of NAWQA on water-quality issues of regional and national concern. Other reports in this series focus on the occurrence and distribution of nutrients, pesticides, and volatile organic compounds in streams and groundwater; the effects of contaminants and streamflow alteration on the condition of aquatic communities in streams; and the quality of untreated water from private domestic and public supply wells. Each report builds toward a more comprehensive understanding of the quality of regional and national water resources (http://water.usgs.gov/nawqa/nawqa_sumr.html). All NAWQA reports are available online at <http://water.usgs.gov/nawqa/bib/>.

The information in this series is intended primarily for those interested or involved in resource management and protection, conservation, regulation, and policymaking at regional and national levels. In addition, the information should be of interest to those at a local level who wish to know more about the general quality of streams and groundwater in areas near where they live and how that quality compares with other areas across the Nation. We hope this publication will provide you with insights and information to meet your needs, and will foster increased citizen awareness and involvement in the protection and restoration of our Nation's waters.

William H. Werkheiser
Acting Deputy Director,
U.S. Geological Survey



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Glossary

agricultural stream A stream draining a watershed covered by more than 25 percent agricultural land.

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

algal bloom A surge of algal growth typically caused by excessive nutrients in water. Dissolved oxygen in the water is consumed when algae grows and decomposes, which can lead to death of aquatic animals if the oxygen deficit is severe.

aquatic Pertaining to water. Plant and animal life living in water.

Aquatic-Life Benchmark A threshold value established by the U.S. Environmental Protection Agency above which the concentrations of a chemical in water or sediment may have adverse effects on aquatic organisms. Benchmarks for water are established to address either acute (short-term) or long-term (*see* chronic effect) exposures.

Aquatic-Life Criteria Water-quality guidelines established by the U.S. Environmental Protection Agency (EPA) for protection of aquatic life. Often refers to EPA water-quality criteria for protection of aquatic organisms.

atrazine A herbicide that is used to control weeds in major crops. It is widely used around the world.

baseline A standard by which things are measured or compared. In water-quality assessments, generally defined as the conditions before human intervention. For example, among a set of streams in an assessment, those with minimal manmade modifications to hydrology, chemistry, and biology would be considered representative of baseline conditions.

basin *See* drainage basin.

bed sediment Sediment particles, including eroded soil and organic matter, deposited at the bottom of a stream, lake, or ocean.

beneficial-use attainment The status of a water body relative to its ability to meet its designated beneficial use, as defined by the Clean Water Act. Typical beneficial uses include the protection of aquatic life and recreation.

benthic Refers to organisms that live on the bottoms of lakes, streams, or oceans.

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 toxic substance enters organisms through the gills and tissues or from dietary or other sources at a rate greater than that at which the substance is lost.

biodiversity *See* species diversity.

biological alteration The condition of a biological community that has been changed, relative to communities at regional reference sites, primarily due to human influences. These changes are typified by a loss of native species or changes in the relative abundance of species.

biological assessment An assessment of environmental quality by means of sampling and analyzing the characteristics of biological communities.

biological community A collection of species that inhabit a particular ecosystem or place. Distinctions among communities are typically arbitrary and reflect convenient categories of general types of organisms, such as algal, macroinvertebrate, and fish communities that inhabit a particular stream.

biological condition A measure of the degree to which biological communities differ from a natural (undisturbed or reference) state; generally, biological indicators at a site are compared with those at relatively natural sites to assess status of, or change in, condition.

biomass The total weight or volume of living material or type of organism within a given area and at a particular time.

carbon dioxide A naturally occurring chemical compound that is composed of two atoms of oxygen and one atom of carbon. It most often occurs in nature as a gas. Carbon dioxide is an important ingredient of photosynthesis by plants and is a product of respiration in animals.

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

chloride A chemical ion most familiar as a component of common salt (sodium chloride). Chloride can enter streams from leaking sewage lines and septic tanks, road salt application, fertilizer use, and the use of water softeners, bleach, and swimming pool chemicals. Chloride may be transported to streams through groundwater and wastewater-treatment plant discharges.

chlorophyll A green, photosynthetic pigment common to plants.

chlorpyrifos An insecticide introduced in 1965 and widely used for pest control on corn, cotton, and fruit trees.

chronic effect Physiological response (such as death or impaired reproduction) resulting from long-term exposure to elevated concentrations of one or more chemicals or other changes in the physical or chemical characteristics of the environment.

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 micrograms per liter (water sample) or micrograms per kilogram (sediment or tissue sample).

confidence limit The upper or lower value of the range in the estimate of a specific quantity. Used to express the reliability of the estimate, where a larger range indicates less reliability and smaller ranges indicate greater reliability.

consumptive water use Water removed from a particular water supply or water body that is not returned to it.

crustacean Any of a large group (Crustacea) of arthropods (invertebrate animals, including insects, with an external skeleton, segmented body, and jointed appendages). Familiar

species such as crabs, lobsters, crayfish, and shrimp are crustaceans. (*See also* invertebrate.)

cubic foot per second Rate of water discharge within a stream channel representing a volume of 1 cubic foot passing a given point during 1 second, equivalent to approximately 7.48 gallons per second or 0.02832 cubic meter per second.

cyanobacteria A group of microorganisms that are related to bacteria but are capable of photosynthesis.

daily streamflow The average of stream discharge measurements recorded over a 24-hour period.

DDT (dichlorodiphenyltrichloroethane) A synthetic organic chemical whose insecticidal properties were not discovered until 1939. DDT was widely used as an antimalarial insecticide and in agriculture before being banned in the United States and other countries due to its tendency to persist in the environment and cause harm to wildlife, particularly birds.

diatom Single-celled, colonial, or filamentous algae with cell walls constructed of silica and having two overlapping parts.

diazinon An insecticide developed in 1952 and heavily used for general purpose indoor and outdoor pest control in lawns, gardens, and agricultural crops. Since the early 2000s, diazinon use has been phased out in the United States.

discharge Rate of fluid flow passing a given point at a given moment of time (*see* cubic foot per second), expressed as a volume per unit time.

diversion A turning aside or alteration of the natural course of a flow of water, normally considered physically to leave the natural channel. In some U.S. States, this can be a consumptive use direct from another stream, such as by livestock watering. In other States, a diversion may consist of such actions as taking water through a canal, pipe, or conduit.

drainage area The drainage area of a stream at a specified location is that area, measured in a horizontal plane, which is enclosed by a drainage divide.

drainage basin The part of the surface of the Earth that contributes water to a stream

through overland runoff, including tributaries and impoundments.

drainage divide The line or ridge of high ground that separates neighboring drainage basins (*see also* watershed).

ecoregion A geographic area of similar climate, landform, soil, potential natural vegetation, and hydrology.

ecosystem The interacting populations of plants, animals, and microorganisms occupying an area, plus their physical environment.

electrofishing A common method to survey fish populations. This method uses electricity to temporarily stun fish. After the fish are caught, identified, and measured, they are typically returned to the stream unharmed.

eutrophic Aquatic ecosystems that are highly enriched with plant nutrients, most commonly phosphorus and nitrogen. Also said of organisms that thrive in such conditions.

floodplain The low-lying area adjacent to streams and rivers that periodically (or historically) is inundated during extreme high flows.

food web An interconnected network of feeding linkages among organisms in an ecosystem.

gaging station A particular site on a stream, canal, lake, or reservoir where systematic observations of discharge are obtained.

groundwater Water beneath the ground surface in pore spaces, fractures, and other voids in geologic formations.

habitat The living space and environmental setting of a particular organism.

headwater The source or most upstream parts of a river basin.

high flow Streamflow that is created by runoff from precipitation or melting snow and is typically much higher than the long-term average flows.

hydrocarbon A compound composed solely of hydrogen and carbon. Most naturally occurring hydrocarbons on Earth are in the form of crude oil and natural gas. Most hydrocarbon contamination in the environment is from petroleum products refined from such oil and gas.

hydrologic system The assemblage of pathways by which water travels as it circulates beneath, at, and above the Earth's surface through various processes such as precipitation (rain and snow), runoff, evaporation, infiltration, transpiration (loss of water vapor from parts of plants, especially in leaves), and groundwater discharge.

impermeable surface Hard surfaces that block the infiltration of rain and snowmelt into the ground, including rooftops and paved surfaces, such as roads, parking lots, and driveways.

impoundment A body of water, such as a pond or reservoir, created by a dam or other natural or manmade obstruction to water flow (*see also* reservoir).

index of biological integrity (IBI) An aggregated number, or index, based on several attributes or metrics (such as species diversity and relative abundance) of a biological community that provides an assessment of the community's health and therefore helps identify issues with that community's surrounding environment.

insecticides Pesticides that are used to kill unwanted insects.

invertebrate An animal having no backbone or spinal column (*see also* benthic invertebrate).

kelp Kelps are a group of brown algae (Phaeophyceae) that typically can grow to more than 100 feet tall and are found in underwater "forests" in shallow oceans.

low flow Streamflow that is derived entirely by groundwater discharge and is typically much lower than the long-term average flows.

macroinvertebrate Animals that do not have backbones, such as worms, clams, crustaceans, and insects; "macro" refers to those animals that can be easily seen without magnification.

maximum annual streamflow The highest recorded daily streamflow value over a period of 1 year.

mean The average of a set of observations.

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 ($\mu\text{g/L}$) A unit expressing the concentration of constituents in solution as weight (micrograms, μg) of solute per unit volume (liter, L) of water; equivalent to one part per billion in most stream water and groundwater. One thousand micrograms per liter equals 1 milligram per liter (1 mg/L).

minimum annual streamflow The lowest recorded daily streamflow value over a period of 1 year. In this report, minimum flow was calculated on a 7-day moving average rather than using daily values.

mixed-use streams Streams draining watersheds with a mixture of agriculture and urban land cover or relatively natural watersheds with substantial amounts of mining or water-management activities, such as dams and diversions. This is an operational definition used by NAWQA.

natural streamflow The natural patterns of flowing water in streams and rivers, including daily, seasonal, and annual variability and magnitudes.

NAWQA National Water-Quality Assessment Program of the U.S. Geological Survey. NAWQA was started in 1991 to develop long-term consistent and comparable information on streams, rivers, groundwater, and aquatic systems in support of national, regional, State, and local information needs and decisions related to water-quality management and policy.

nitrogen A naturally occurring chemical element and an important ingredient in many organic chemicals and proteins. It is also an important nutrient for plants.

non-native species Any organism found to be living outside its natural range (*see also* range).

nonpoint source A pollution source that cannot be defined as originating from discrete points such as pipe discharges. Areas of fertilizer and pesticide applications, atmospheric deposition of pollutants, and manure generation are types of nonpoint source pollution.

nutrient An element or compound essential for animal and plant growth. Common nutrients in fertilizer include nitrogen, phosphorus, and potassium.

oxygen A naturally occurring element, most frequently present as a gas. Dissolved oxygen in water is an important component of

water quality because many aquatic animals respire by passing water over gill structures, which allows the transport of oxygen into the organism.

peak flow The largest magnitude stream discharge measured over a period of time, typically a year.

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

pesticide toxicity index (PTI) A numeric score or index that accounts for the concentration of each pesticide compound measured in a water sample, the toxicity of each compound measured, and the possibility that multiple compounds have additive effects on aquatic organisms. The PTI does not measure actual toxicity of a water sample but assesses potential for toxicity relative to other samples. The PTI is computed separately for different taxonomic groups, such as fish or invertebrates (Munn and others, 2006).

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

photosynthesis Synthesis of chemical compounds by organisms with the aid of light. Carbon dioxide is used as raw material for photosynthesis, and oxygen is a product.

point source A source of something, such as pollution, at a discrete, identifiable location such as a discharge pipe, drainage ditch, tunnel, well, concentrated livestock operation, or fixed watercraft.

polychlorinated biphenyls (PCBs) Widely used as dielectric and coolant fluids, for example in transformers, capacitors, and electric motors before being banned by the United States Congress in 1979. PCBs have been shown to cause cancer in animals, and there is also evidence that they can cause cancer in humans.

polycyclic aromatic hydrocarbons (PAHs) Also known as poly-aromatic hydrocarbons or polynuclear hydrocarbons, PAHs are complex organic molecules that occur in the environment as by-products of natural (for example, forest fires or volcanic activity) and human-caused (for example, fossil fuels) combustion. PAHs

are a concern as a pollutant because some have been identified as damaging to DNA (deoxyribonucleic acid) and causing cancer. In aquatic systems, PAHs typically aggregate and are usually associated with sediments, but they can also occur in the dissolved phase in water at low concentrations.

potential toxicity Relative potential for toxicity of a water sample, as based on the pesticide toxicity index (*see also* pesticide toxicity index).

primary producer Organisms—typically plants—that produce their own energy through photosynthesis.

range (species range) A geographic boundary that encompasses the area in which a species is found.

reach A short, usually about 500 foot (~150 meter) section of a stream or river where organisms are sampled as part of a biological assessment (*see also* biological assessment).

reference The least-disturbed condition available in an ecoregion; determined based on specific criteria and used as a benchmark for comparison with other sampled sites in the region (*see also* baseline).

relative abundance The number of organisms of a particular kind present in a sample relative to the total number of organisms in the sample.

reservoir A body of water created by a dam and used to store water for various uses.

riffle A section of stream that is typically relatively shallow and fast moving.

riparian zone The land area adjacent to rivers and streams populated by plants and animals that rely on water from the stream for survival.

river mile The distance between any given point on a river and the river's mouth.

runoff [spring or seasonal] A period of time when water flows into streams as a result of rainfall or the melting of a snowpack.

runoff [surface] Water, generally from rain fall, that travels over the ground surface to the nearest surface stream.

salinity An indication of the amount of dissolved salt in water.

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

sediment quality guideline (SQG) A threshold value above which the concentrations of a chemical in sediment may have adverse effects on aquatic organisms, similar in concept to U.S. Environmental Protection Agency Aquatic-Life Benchmark.

sessile An organism that is fixed in one place or is generally immobile.

species diversity An ecological concept that incorporates both the number of species (taxa) in a particular sampling area and the evenness with which individuals are distributed among the various species.

species richness The number of species (taxa) present in a defined area or sampling unit.

species traits Descriptive features of a species that define its way of life, body shape, role in the ecosystem, and vulnerability to manmade environmental change.

statistical model A formalization, in the form of mathematical equations, of relations among a variable of interest and other variables that are related to it.

stormflow Flow in a stream that is largely derived from a storm event.

streamflow A type of channel flow, applied to that part of surface runoff in a stream whether or not it is affected by diversion or regulation (*see also* minimum and maximum annual streamflow).

streamflow modification Human-caused changes to natural variation and magnitudes of natural streamflows.

suspended sediment Particles of rock, sand, soil, and organic detritus carried in suspension in the water column in a stream, in contrast to sediment that moves on or near the streambed (*see also* turbidity).

suspended-sediment concentration The concentration of suspended sediment in water expressed as milligrams of dry sediment per liter of water-sediment mixture (mg/L).

taxa richness *See* species richness.

taxon [plural taxa] A grouping of organisms given a formal name such as species, genus, or family.

taxonomic A system of grouping organisms based on their characteristics and theorized evolutionary origin.

temperate climate The climate that is present in the middle latitudes between the tropics and the polar regions. Temperate climates typically have a wider range of temperature and precipitation than other regions.

terrestrial Pertaining to land. Organisms that live or grow on land.

tile drain Perforated pipes that are buried to shallow depths in the ground to reduce the water content of poorly drained soils and divert shallow groundwater to nearby streams.

tolerant [for example, tolerant taxa]

Organisms that have characteristics that make them able to thrive in polluted environments.

total nitrogen The sum of inorganic (nitrate, nitrite, ammonia) and organic forms of nitrogen.

total phosphorus The sum of inorganic and organic forms of phosphorus.

toxicity The degree to which the presence of a chemical substance at a particular concentration may be harmful to the health of humans and other organisms.

trace metal Elements that are metals and typically occur in the environment in small amounts.

turbidity Reduced clarity of surface water because of suspended particles, usually

sediment (*see also* suspended sediment and suspended-sediment concentration).

urban stream A stream draining a watershed with at least 5 percent coverage of residential, commercial, industrial, or other urban lands and less than 25 percent agricultural land.

vascular plants A large group of plants that are defined as those land plants that have tissues for conducting water and minerals throughout the plant. They also have tissue to conduct products of photosynthesis. Most visible terrestrial plants are vascular.

vertebrate Any animal with a backbone.

water-quality criteria Specific levels of water quality which, if reached, are expected to render a body of water unsuitable for its designated use. Commonly refers to water-quality criteria established by the U.S. Environmental Protection Agency. Water-quality criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes.

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.

watershed A region bounded by a drainage divide that is drained by, or contributes water to, a stream, lake, or other body of water.



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