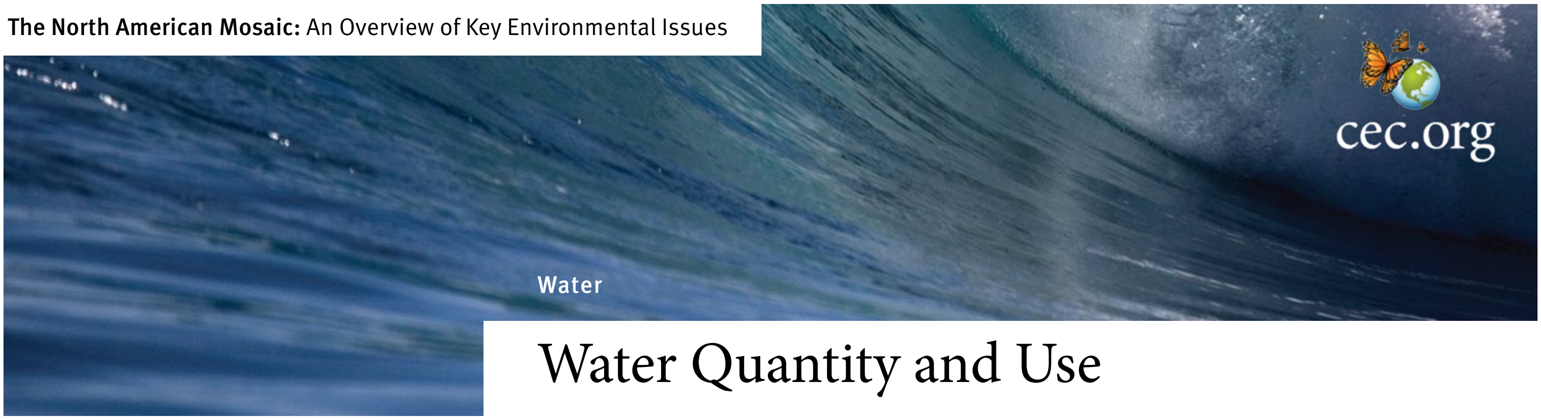


Water Quantity and Use

Key Findings

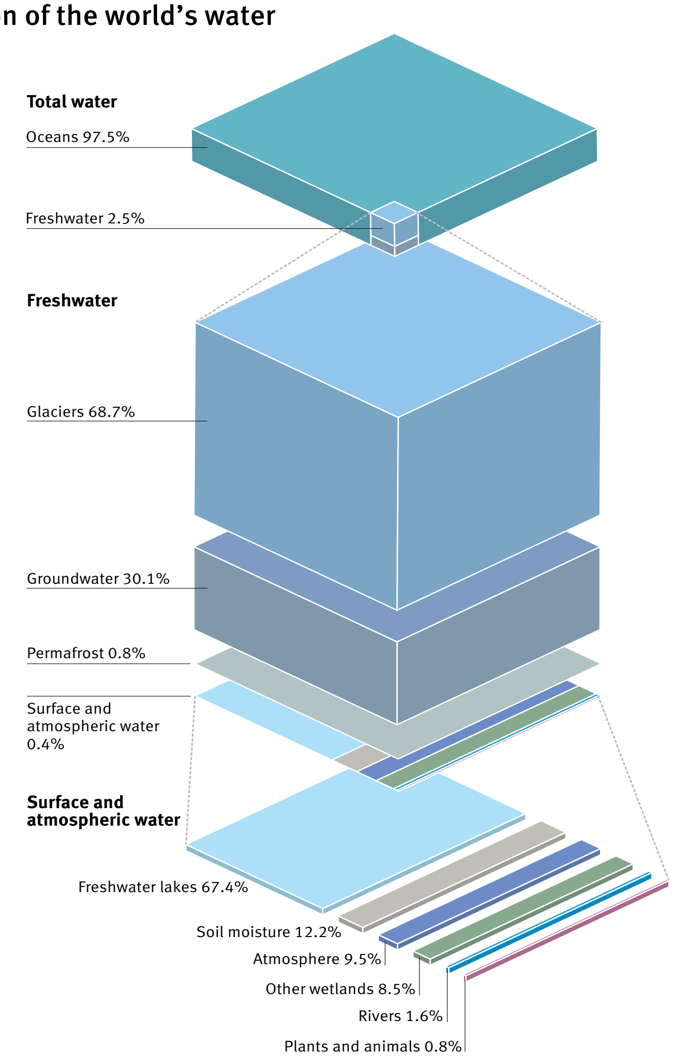
- Fresh surface water and groundwater are a common denominator for life. Continued access to freshwater is a concern in several areas across North America.
- The distribution of freshwater varies widely across North America. Industrial and agricultural uses account for the majority of North American water withdrawals, and in some areas human use competes with ecological requirements.
- Total water withdrawals in the United States grew from 1970 until 1990, but since then they have been relatively constant despite continued population growth. In Canada and Mexico, total water withdrawals have continued to rise.
- Climate change, land use and population growth affect the availability of freshwater throughout North America. As climate changes, patterns of precipitation and runoff are also likely to change. In response to expected population growth and patterns of development, heightened competition among water users is anticipated.

Water quantity and use **are directly related to a variety of human and ecological needs: agricultural, industrial, domestic and environmental. Human development and the environment depend on adequate supplies of clean water.**

What Is the Environmental Issue?

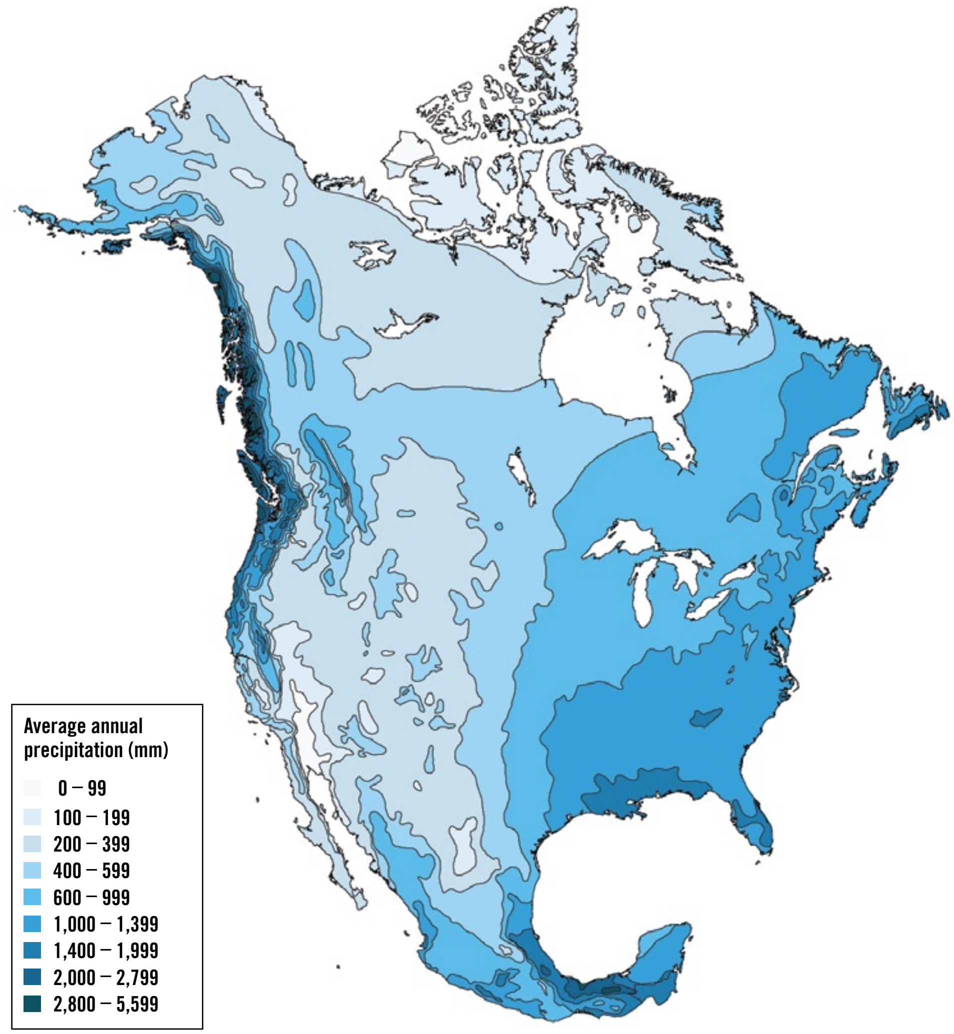
Water—a finite but renewable resource—is essential to sustain life, development and the environment. Although over 70 percent of the earth's surface is covered by water, 97 percent is salty ocean water and less than 3 percent is freshwater (see figure). Of the freshwater, 69 percent is frozen in glaciers and permanent snow, and an additional 30 percent is "hidden"

Global distribution of the world's water



Source: United Nations Environment Programme.

Average annual precipitation in North America



Source: ESRI.

Freshwater withdrawals for domestic, industrial and agricultural uses in North America (2000)

Use	Canada	Mexico	United States
Total withdrawal (km³/yr)	46	78	479
Domestic	19%	17%	13%
Industrial	69%	6%	46%
Agricultural	12%	77%	41%

Source: Food and Agriculture Organization.

groundwater. Thus less than 1 percent of the earth's water is present as fresh surface water and atmospheric vapor.

Fresh surface water and groundwater are a common denominator for life in all countries. Not only does water sustain all life, but there are no substitutes for it in many commercial and industrial processes, and especially in growing agricultural crops. The use of freshwater for public water supplies, irrigation, industrial processes and cooling of electric power plants exerts pressure on water resources. Meanwhile, the patterns of freshwater use affect public water supplies, the salinization of freshwater bodies in coastal areas, food production and competition among various end uses. Another factor is that aquatic ecosystems typically need both minimum and maximum flows at specific times of the year to sustain their various communities of aquatic organisms.

Why Is This Issue Important to North America?

Freshwater resources are of major environmental and economic importance to North America, but the distribution of these resources varies widely. Canada has some 20 percent of the world's total freshwater resources. Much of it, however, is in remote locations or retained in lakes, underground aquifers and glaciers. By contrast, Mexico is primarily an arid country in which freshwater is abundant in some local areas only. Not just the amount of freshwater is important, but also how rapidly this water is replenished through rainfall and runoff. In many parts of North America, humans' needs and uses for water compete with the need for water to sustain aquatic life.

Distribution of Water Resources

North America's internal renewable water resources include the average annual flow of rivers and the recharge of groundwater (aquifers) by precipitation within a country's borders (see table). Surface water produced internally represents the average annual flow of rivers generated from internal precipitation and the base flow generated by aquifers. Groundwater recharge is estimated by measuring rainfall in arid areas where rainfall is assumed to infiltrate aquifers, although the uncertainties about these estimates are considerable. The total of the two accounts for any overlap occurring when surface waters recharge aquifers, or when aquifers release to surface flow. Natural incoming flows originating outside a country's borders are not included in the total in the table.

Freshwater resources are not distributed uniformly across North America (see map). In

North America's internal renewable water resources (km³/yr)

	Canada	Mexico	United States	North America
Surface water produced internally	2,840	361	2,662	5,863
Groundwater recharge	370	139	1,300	1,809
Total (adjusted for overlap)	2,850	409	2,800	6,059

Source: Food and Agriculture Organization.

general, the eastern regions of North America are considered water-rich or precipitation-dominated, although droughts can significantly affect water availability on a periodic basis. Annual normal precipitation values of 800 millimeters or greater are generally associated with water-rich areas in Canada, southeastern Mexico and the eastern United States. Annual normal precipitation values of less than 600 millimeters are associated with arid and semiarid regions, including the Great Plains regions of Canada and the United States and much of Mexico. This distribution plays a role in the withdrawal of surface versus groundwater for use.

Uses of Water Resources

In North America, about 85 percent of water withdrawals are by industry and agriculture combined, but the distribution among uses varies by country (see table). In Canada, 69 percent of withdrawals are used by industry and 12 percent by agriculture, whereas in Mexico agriculture uses about 77 percent and industry only 6 percent. In the United States, agricultural and industrial withdrawals are roughly similar.

Not all freshwater withdrawals have the same implications for the water supply. Agriculture is a highly consumptive use, returning only a small portion of water withdrawn back to the source. The rest is lost to evaporation or used for irrigation and livestock watering. Industrial uses are often much less consumptive because water is recycled internally and eventually returned in part downstream. An example is electric thermal power generation, which accounts for a large proportion of industrial withdrawals. Some of the water is converted to steam to drive the generator producing the electricity, but most of the water is used for condenser cooling and later released. In domestic water use, returns are largely via sewage, which is treated in most areas before being returned to surface waters. Other human uses of freshwater—such as those for hydroelectric power generation, shipping and recreation—are in-stream uses that are not counted as withdrawals.

Withdrawals can also be expressed on a per capita basis (see graph). The United States and Canada are the highest per capita water users in the world when withdrawals for all uses are considered. Per person usage is more than two and a half times that in Asia or Europe and over six times that in Africa. One reason is the low cost of water relative to that in other industrialized countries. Per capita water use in Mexico is more comparable to that in other areas of the world, although it is still slightly higher.

Total water withdrawals in the United States grew from 1970 until 1990, but since then they have been relatively constant, even though the population has grown by about 16 percent. In Canada and Mexico, total water withdrawals have continued to rise. Between 1972 and 1996, Canada's rate of water withdrawals increased by almost 90 percent, although its population rose by only 34 percent over the same period. Mexico has also experienced higher water withdrawals over the last 30 years.

Irrigation is partly responsible. Land under irrigation has increased since 1960, doubling in Canada and Mexico and increasing by more than 50 percent in the United States. Much of this increase has occurred in arid or semiarid regions, where groundwater is the primary water source. Slightly over a tenth of North America's cultivated area is irrigated, of which over 75 percent is in the United States and slightly more than 20 percent in Mexico. In the United States, areas equipped for irrigation account for about 12 percent of cultivated land. In Mexico, almost a quarter of cultivated land is irrigated. By contrast, less than 2 percent of Canada's cultivated area is under irrigation.

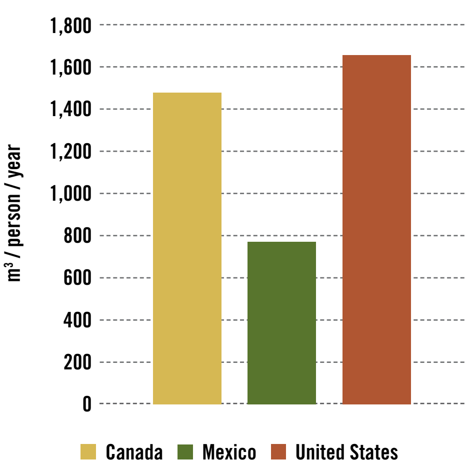
The majority of withdrawals in North America are from surface water, but ground-

Case Study – The Pitfalls of Groundwater Mining

Subsidence in San Joaquin Valley, California
Photo: US Geological Survey.

Land subsidence, or even collapse, can occur when groundwater withdrawal exceeds recharge and a void is created in the underground aquifer. One example is the San Joaquin Valley, one of the most productive agricultural areas in the United States. The California Central Valley, which includes the San Joaquin Valley, produces about 25 percent of US table food on only 1 percent of US farmland. From 1900 until the 1970s, groundwater was mined to irrigate and grow this food. But eventually groundwater withdrawals significantly exceeded recharge, and the over 75 years of pumping groundwater for irrigation caused the land to drop (subside) by over 8 meters. In this photo of a site near Mendota in the San Joaquin Valley, the top sign on the pole indicates the level of the land surface in 1925 compared with the level when the photo was taken, about 1977.

Per capita water use in North America based on all withdrawals (2000)



Source: Food and Agriculture Organization.

water withdrawals also serve many uses, from domestic supply to irrigation. Although globally the amount of groundwater exceeds that of surface water (i.e., about 30 percent groundwater to less than 1 percent surface water), surface water is much more rapidly replenished (through precipitation) than groundwater. Some groundwater is called "fossil water," because its rate of recharge or renewal is measured in geologic time (millions of years), whereas the renewal of surface waters is measured in days or weeks.

In many areas of North America, the groundwater table is declining; withdrawals are simply outweighing recharge. In some areas of Mexico and the United States, the ground overlying these declining aquifers has collapsed or subsided. Mexico City has experienced up to 18 meters of subsidence over the past 100 years because of groundwater withdrawal. Since the late 1980s, authorities in Mexico City have managed groundwater use in an effort to reduce subsidence, and yet the observed rate of subsidence during the last 20 years has been on the order of 20–30 centimeters per year. In the United States, more than 43,500 square kilometers in 45 states have been directly affected by subsidence (see case study).

What Are the Linkages to Other North American Environmental Issues?

Water is a pervasive factor in all aspects of the environment, but linkages with certain issues merit further consideration.

Climate Change

Water vapor is not only the most important greenhouse gas, but also a major influence on the earth's climate. Water patterns are both affected by and influence climate change. Patterns of increased rainfall and drought have been linked with El Niño and La Niña events in North America, based on changes in the sea surface temperature. As climate patterns change, precipitation and runoff patterns are also likely to change, with more drought in some areas and more flooding in others. Scientists may not be able to predict the precise patterns of change with certainty, but they do understand that climate change will lead to changes in water availability in North America.

Land Use

Like climate change, changes in land use, particularly those stemming from population growth, are linked to water quantity and use. In general, population growth and land use changes are expected to play a greater role than climate change in the scarcity of water resources over the next 25 years. Certain areas of North America are likely to have greater water shortages than others, however, because of the spatial differences in the distribution of renewable and available water within countries and across geographic areas. In some areas, the trends in climate change, population change and land use are occurring simultaneously. Land use can also affect water supply by expanding the impervious surfaces that limit the extent of groundwater recharge.

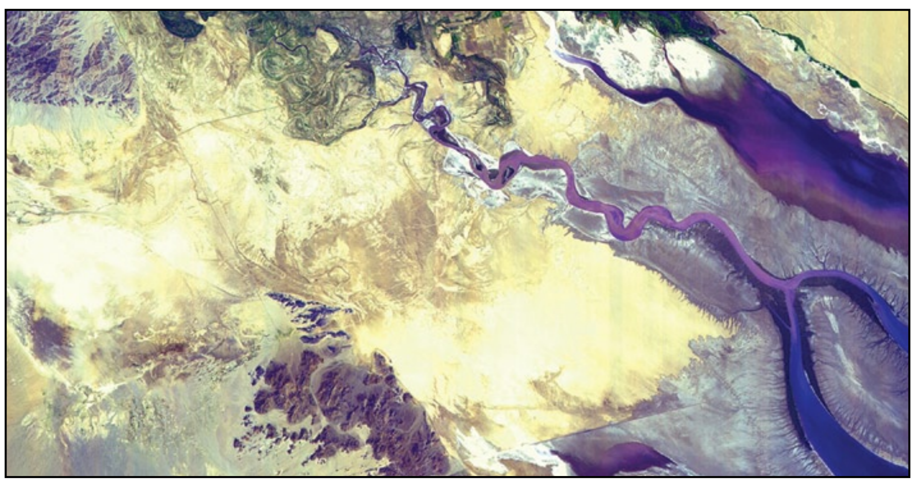
Biodiversity and Ecosystems

Precipitation and runoff sustain both terrestrial and aquatic ecosystems, as well as provide the freshwater required to sustain estuarine ecosystems. Competition for water between humans and aquatic ecosystems can significantly alter flow regimes—that is, as water is withdrawn for other uses, the lowered flow no longer supports aquatic communities. Aquatic ecosystems require more than just a minimum amount of water for maintenance; they also require flooding with the right frequency and magnitude to sustain the system. Dams and other flow impediments can alter both the timing of flows and the amount of water that flows in streams, significantly affecting the downstream biodiversity (see case study).

Pollutants

Runoff is usually accompanied by increased loading of sediments, nutrients, toxic contaminants and other pollutants—all of which affect the quality of drinking water supplies and aquatic ecosystems. As land is converted to urban or suburban uses, point source pollution increases as additional wastewater treatment facilities are constructed to treat the waste from an expanding population. Impervious surfaces in developed areas also promote additional runoff that may not have an opportunity to be filtered through natural processes. The cumulative influence of increased point and nonpoint sources can affect the suitability of water to support aquatic ecosystems and to meet other desired water uses.

Case Study – Colorado River Delta



An image of the Colorado River Delta taken September 2000 by the Spaceborne Thermal Emission and Reflection Radiometer (ASTER). Photo: National Aeronautics and Space Administration.

The Colorado River Delta is located in the region below the California-Mexico border, where the Colorado River has historically flowed into the Gulf of California (Sea of Cortez). This oasis of 7,800 square kilometers used to be one of the largest desert estuaries in the world. In the 1920s, naturalist Aldo Leopold commented on the rich diversity of waterfowl, freshwater and brackish aquatic life, jaguar, deer, beaver and other wildlife found in the Colorado River Delta. Today, the Delta is only about 5 percent of its original size, and it no longer supports this rich biodiversity because its historical inflow no longer consistently reaches this estuary. Upstream dams and diversion canals have significantly reduced and altered flow in the Colorado River. Even though estuaries such as the Delta are naturally brackish, these ecosystems must have freshwater inflows to sustain their biodiversity and productivity.