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INTRODUCTION

Originally, all pollution was of nonpoint (diffuse) nature. It became "point" pollution when years ago people in urban and industrial areas collected urban runoff and wastewater and brought it, at great expense, to one point for disposal.

—Paraphrase of a statement made a by a well-known urban environmental economist (Gaffney, 1988), which serves to introduce the topics to be presented in this chapter.

HISTORICAL PERSPECTIVES AND TRENDS IN ENVIRONMENTAL DEGRADATION AND ABATEMENT

From Romans to Earth Day (1970)

It is an irony of history that semi-desert conditions now prevail in much of the region known as the Fertile Crescent. . . . Moreover, the earlier peoples had on the whole a higher standard of living than most of the present inhabitants. The degradation of the region came about almost entirely because of human discord and neglect. The ancient people had ingeniously developed the lands of the Fertile Crescent by intelligent use of meager water resources. . . . Then invaders laid waste to the region and a long decline set in. A succession of indolent and mutually intolerant people allowed the cisterns and reservoirs to fall into ruin, the irrigation channels and terraces to crumble, the trees to be cut down, the low vegetation to be destroyed by sheep and goats and the land to be scoured by erosion.

This statement is a portion of the introduction by Maurice A. Garbell (1965) to a discussion of the the Jordan Valley Plan. The history of the Middle East shows that if land stewardship is absent, the well-being of the people who misuse the water resources declines. At some point these adverse effects and deterioration become irreversible. However, in the eighteenth century, when the first settlers from Europe arrived in the Piedmont area of the American southeast, they found rivers and lakes "crystal clean," without visible pollution—the water transparent and abundant with fish (Clark et al., 1985). Throughout the Middle Ages, salmon migrated during the spawning season far into headwater streams in central Europe such as to Prague on the Moldau River (a tributary of the Elbe River), several hundred kilometers from the North Sea, into which the river flows.

One would be greatly mistaken if these statements about the cleanliness of the rural, mostly uninhabited environment were taken as a general rule about the environment of the ancient world and during the Middle Ages. The clean state of rural areas centuries ago was in contrast to the uncleanliness of urban centers. The streets of medieval cities (and probably of large urban centers in ancient Rome and other great historical centers) were covered with garbage, manure, and human excreta. In medieval Paris and other cities, piles of garbage and manure in the streets were often a meter or more high. The smell would have been strong and nauseating. Terrible epidemics plagued medieval cities, and even the rural population was not spared. In one medieval epidemic, 25% of the entire European population vanished. However, water use and water supplies used by urban dwellers were much smaller than they are today, and most human excreta disposal was on site in latrines and outhouses. Consequently, there was less pollution generation from households reaching the receiving bodies of water. On the other hand, rainfall and urban surface runoff were the primary and sometimes the only means of disposal of accumulated street surface pollution. Problems with urban runoff are not new, and concerns regarding polluted runoff date back to ancient Rome, where sewers were built, primarily for stormwater disposal. The main ancient Roman sewer, the *cloaka maxima,* is still in use (Figure 1.1).

In the mid-nineteenth century in the middle of the industrial revolution, it was realized that the filth of the cities and urban contamination of the water supplies, mostly diffuse in type, were the major reasons for waterborne epidemics of such killers as cholera and typhoid fever. As a result, the first major period of environmental awareness arose. It was born because life in growing industrialized urban centers with medieval drainage became unbearable to the population and its governments. The population migration after the feudal system (slavery in the United States) was broken increased the pollution in cities dramatically. The first urban sewer system in the United States was planned in Chicago in 1885, although sewers had been built in Europe decades before and in ancient Rome thousands of years earlier. The mixture of urban runoff and wastewater was brought by sewer to the nearest watercourse, and dilution of the polluting substances through the flow of the receiving water body was considered satisfactory for controlling pollution. It is interesting to note that until the 1950s, many European receiving water standards were based on dilution. (For example, according to British water quality standards, no treatment was required if 1 part of untreated sewage discharge was diluted by 500 parts of receiving water flow.) As a result of building sewers without treatment, many rivers soon became heavily overloaded and gave off an obnoxious stench, which was caused by anoxic decomposition of sewage and garbage in streamwater and muds. The stench of the Milwaukee River

Figure 1.1. Stormwater inlet into the ancient Roman sewer *cloaka maxima* at the Forum Romanum in Rome.

in Milwaukee was so bad that in 1880 the city government authorized the building of two flushing tunnels by which clean Lake Michigan water was delivered to two discharge points on the river and its tributary upstream from the city. The large quantity of pumped flow diluted the sewage discharged from the city into its rivers and flushed the impurities quickly into Lake Michigan. One of the first cases of water quality management, the Milwaukee system is still in use. (The pumping stations and tunnels have been declared a national engineering landmark by the American Society of Civil Engineers; Figure 1.2). At the same time, in nearby Chicago, a terrible cholera epidemic in the 1880s, caused by sewage discharges into Lake Michigan and contamination of the intake of the city's water supply, led to building an engineering marvel, the Chicago Sanitary and Ship Canal. The canal reversed the flow of the Chicago River, which had originally flowed into Lake Michigan, diverting it into the Des Plaines River, which flows into the Mississippi River. This kept the sewage and urban runoff carried by the city's combined sewers from contaminating the city's water supply (Figure 1.3).

The period between 1880 and 1920 marks the beginning of major concerns about water quality, especially drinking water. Water pollution control efforts focused on the

Figure 1.2. Intake to the flushing tunnel and pumping station are the national civil engineering landmark in Milwaukee, Wisconsin. The pumping station is more than 100 years old. A large quantity of flow is pumped into the Milwaukee River upstream from the harbor during periods of dissolved oxygen deficiency.

removal of objectionable solids, disease-causing organisms, and oxygen-demanding substances that were turning urban receiving water bodies into unsightly, oxygen-deprived, black-colored, smelly streams. Many cities gave up on some streams that transected them and simply covered them. In 1910, in Essen, Germany, one of the most industrialized areas of the world at the time, the first water quality management agency was established to provide safe urban runoff and wastewater disposal and safe drinking water. Karl Imhoff (see Box 1.1) was the first director of the first water qual-

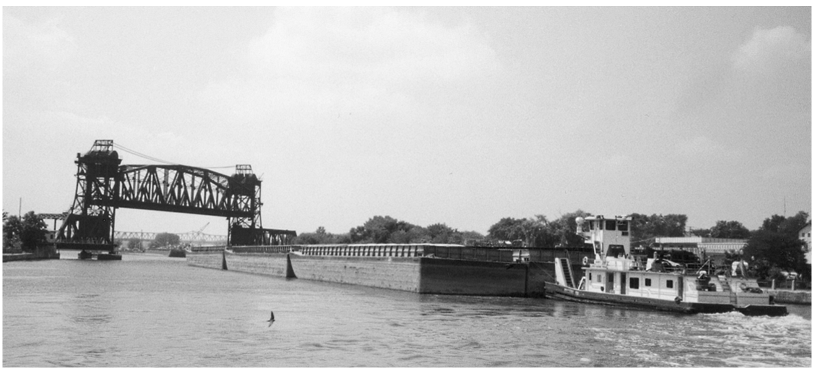

Figure 1.3. The Des Plaines River in Illinois. The effluent-dominated river carries almost all wastewater and diffuse pollution (wet weather) flows from the Chicago metropolitan area (population of about 9.5 million). In the early twenty-first century, the status of the river has improved to such a degree that fish and aquatic biota have returned and the river quality is meeting the majority of water quality standards for aquatic life protection.

BOX 1.1: KARL IMHOFF (1876–1965), FOUNDER OF WATER QUALITY MANAGEMENT

Karl Imhoff (front) and Gordon M. Fair. Photo taken in 1956 by Klaus R. Imhoff. (Courtesy of Klaus R. Imhoff, Essen, Germany.)

Karl Imhoff was a pioneer in urban drainage and wastewater disposal engineering in Germany. He studied civil engineering at the Technical University in Munich, where he received his engineering diploma in 1899. In his first professional year practicing engineering he designed wastewater disposal facilities in Berlin, but shortly thereafter he took an assignment with the just-founded Emsher River Association *(Emschergenossenschaft),* a wastewater disposal and watershed management agency in the industrialized Ruhr district (an area that includes the industrial cities of Dortmund and Essen), which was the center of German coal, steel, and other heavy industries, with a population of about 8 million. Later he became its first director. In the 1920s, other multiobjective river management associations were formed in the district. Small rivers were used for water supply, power production, wastewater disposal, and later, for recreation. Karl Imhoff soon realized that the rivers, watersheds and wastewater disposal must be managed in a coordinated way, and the association was made responsible for multiobjective river management. In 1907, Imhoff published his famous *Pocketbook of Urban Sewerage (Taschenbuch der Stadtentwässerung)*. This book is still published in Germany (Imhoff and Imhoff, 1990) and in translations worldwide.

In 1926, Karl Imhoff met Gordon M. Fair, a prominent U.S. sanitary (environmental) engineer who later became a professor of sanitary engineering at Harvard University and one of the founders of modern environmental engineering in the United States. They became lifelong friends and co-workers. Fair introduced Imhoff to the concept of oxygen balance and stream self-purification, developed earlier in the United States by Streeter and Phelps. This model and concept is a foundation of waste assimilative capacity determination and waste load allocation. Both engineers developed and perfected this concept further and included it their work. Fair translated the *Pocketbook* into English in 1929 and later published jointly with Imhoff a U.S. adaptation under the title *Sewage Treatment* (Imhoff and Fair, 1940, 1956). The latest adaptation of Karl Imhoff's work is Novotny et al. (1989).

ity management agency in the Ruhr district. A few communities added treatment plants at the end of their sewer system to purify the sewage discharged. Most treatment facilities built in this period provided only primary treatment: the removal of solids. Almost all sewer systems carried a mixture of sewage and urban runoff. These systems, called *combined sewers,* contrast with newer, more expensive *separate sewer systems,* which employ dual sewers, one for sanitary sewage and a second for urban runoff. (See Chapter 8 for a discussion of urban drainage and its water quality impact.) Even though the sewer systems were called "combined," they were designed to carry primarily sewage and industrial wastewater, called *dry weather flow.* A typical design capacity for combined sewers was six to eight times the dry weather flow. However, this design capacity was totally insufficient for conveyance of rainfall-generated runoff. Similarly, treatment plants were designed mostly for dry weather flow (a typical design capacity was about four times the dry weather flow). When, as a result of rainfall events, the capacity of the sewers or of the treatment plant was exceeded, an untreated mixture of sewage and rainwater was discharged into the nearest watercourse. Such discharges of untreated wastewater from *combined sewer overflows* into the receiving waters occurred many times throughout the year.

After the epidemics of the Middle Ages and early industrial revolution had been largely eliminated public interest in the environment subsided until the late 1960s. World events were dominated by World War I, the Depression era, World War II, and the Cold War. Meanwhile, however, pollution of the environment was increasing rapidly. Pollution in many urban rivers was again becoming unbearable. For example, every summer from the nineteenth century to the middle of the twentieth century, the stench of the Thames River in London became so unbearable that the British Parliament recessed during the affected periods. In 1950s, flammable waste discharges from the greater Cleveland–Akron industrial area caused the Cayahoga River in Ohio to catch on fire.

In the agricultural sector, until the 1950s most farming was done on smaller family farms where organic fertilizers (manure) were used, and the waste production was generally easily assimilated by soils and receiving water bodies. Despite its appearance and (sometimes) odor, this type of farming causes less harm to surface and

Figure 1.4. Approaching dust storm in Prowers County, Colorado, in the 1930s. (Photo by Thomas Meier, USDA, courtesy of Natural Resources Conservation Service.)

groundwater resources, although localized pollution problems from barnyard wastes were common. However, due to poor farming practices on marginal lands in drier regions, erosion of agricultural soils became a serious problem, culminating in catastrophic "dust bowl" soil losses (Figure 1.4). The Dust Bowl was an ecological disaster that took place in the southwestern Great Plains and Oklahoma in the 1930s. It was caused by misuse of land and years of drought. As the topsoil was blown away, thousands of farmers left their homes and millions of hectares of farmland were lost. Dust and sand brought by wind covered farms. A well-known scientist and land steward, Aldo Leopold (see Box 1.2), a professor at the University of Wisconsin, became concerned with the problem of agricultural erosion before the Dust Bowl era, and in 1923 published the first manual on erosion control. His book "explained the importance of watersheds, the nature of erosion in the Southwest, and the causes of erosion and relating factors; it detailed natural and artificial erosion; it listed problems and remedies; and it suggested organization that might be able to work cooperatively in the erosion control effort" (Lorbiecki, 1996). Aldo Leopold's efforts and the Dust Bowl catastrophes gave an impetus to the U.S. Congress to establish the Soil Conservation Service (presently the Natural Resources Conservation Service) of the U.S. Department of Agriculture, with the stated goal of combating agricultural erosion and promoting soil conservation.

The post-1950s period has seen a worldwide shift from small family farms to large monocultural, intensively operated farm units. Farm yields have increased dramatically; however, to sustain the increasing yields and productivity, farmers began to use large quantities of chemical fertilizers and pesticides. At the same time, deforestation was occurring on a large scale with most of the deforested land converted

BOX 1.2: ALDO LEOPOLD (1887–1949), LAND STEWARD AND CONSERVATIONIST

Aldo Leopold in the mid-1940s. (Courtesy of Aldo Leopold Foundation, Baraboo, Wisconsin.)

Aldo Leopold received his master's degree from the Yale Forest School, the first graduate school of forestry in the United States. In his early career he was a forest ranger in the southwestern United States, planning campgrounds, and sanitation facilities and writing promotional literature. He came to Wisconsin in 1924, and in 1933 the University of Wisconsin offered him a teaching position in the nation's first program on game management. He was devoted to protecting wilderness and wildlife and argued for the preservation of wilderness on the grounds that the "highest use" was not always an industrial or commercial use but rather, leaving the land its natural state. He treated earth and land as living beings that must be respected and cherished. His posthumously published book (Leopold, 1949, 2001) is one of the best works available on environmental ethics, land stewardship, conservation, and watershed management.

to agricultural uses (mostly in developing countries) and urban uses (in both developed and developing countries).

Manufactured chemicals were introduced in the mid-twentieth century, many of them originally resulting from toxins developed for warfare or as industrial chemicals. Later, some chemicals were also found to be toxic to insects (insecticides) and weeds (herbicides), and the second half of the twentieth century found wide use of these in agriculture and urban/suburban settings. Spraying entire cities and landscapes (e.g., wetlands) with DDT (dichlorodiphenyltrichloroethane) to control mosquitoes was common in many countries in the 1950s. Some persistent chemicals found their way into the environment, where they caused great, almost irreparable harm. Such was the case with DDT, heralded originally as a way to prevent malaria and to eliminate every obnoxious insect, including lice, and PCBs (polychlorinated biphenyls), a group of very useful industrial chemicals. Both chemicals were later found to be greatly damaging, persistent, bioaccumulating environmental contaminants. Many other chemicals and radioactive substances were developed during and after World War II, which have contaminated soils, water, and air. This period was also marked by the rapid expansion of personal and commercial vehicular traffic, spurred by the building of freeways. Automobile and truck traffic is a major source of toxic chemicals and is related to other polluting activities associated with expansion of the freeway system and suburban development (urban sprawl).

The spread of toxic chemicals from many sources and their potential danger led to the second environmental activist period, the impetus of which was the book *Silent Spring* by Rachel Carson (1962) (see Box 1.3). In 1970, a senator from Wisconsin, Gaylord Nelson, founded Earth Day, which became a culmination of widespread protests: by population and environmental activists. The Earth Day celebration emphasized public concerns about the state of the environment and initiated calls for action. Rachel Carson did not see the fruits of her efforts; she died in 1964 at the age of 56.

BOX 1.3: RACHEL CARSON (1907–1964), FOUNDER OF ENVIRONMENTALISM

Rachel Carson was an extraordinary writer, scientist, and ecologist who introduced the world to the study of ecology and environmentalism. Combining her talent as a writer and a scientist, she warned society of the dangers of human activities on ecology and human and animal health. Carson recognized, based on her own experience with cancer and other illnesses, the danger of wide and indiscriminate use of chemicals. She perceived the dangers of DDT and other pesticides and chemicals as destroying the ecology as well as the cells in her own body. She wrote *Silent Spring* (Carson, 1962) to warn people about the dangers inherent in the misuse of toxic chemicals that spread throughout the environment, affecting the ecology of the entire earth. She challenged the practices of the agricultural and chemical industries and was attacked by them and some in the government as an alarmist. In his introduction to *Silent Spring,* Albert Schweitzer said: “Man has lost the capacity to foresee and forestall. He will end by destroying the earth.” Based on the wide public response to the book and against the opposition of chemical giants, government began to investigate chemical pollution of the environment and its impact on organisms. Public opinion changed, and by the mid-1960s more than 40 bills were in state legislatures for the regulation of pesticides.

Figure 1.5. Lincoln Creek in Milwaukee lined with concrete, resulting in a loss of habitat. Early in the 2000s, the lining was removed and creek habitat was restored.

In addition to pollution, activities that lead to habitat destruction should be considered and remedied. Typically in the past, in the jargon of water resource developers, *channel improvement* meant lining a stream with concrete and cutting down streambank vegetation (Figure 1.5), and *beneficial use of water* meant diverting flows from streams and lakes to the point that no flow was left during some periods. As mentioned earlier, an ultimate conversion of an urban stream was to cover it and convert it to a sewer. Those activities caused severe damage, if not elimination, of the aquatic habitat. For example, there are almost no natural streams in Los Angeles. Many streams in this community were converted into concrete-lined flood conveyance channels. Their hydrology was changed to the point where the only dry weather low flow existing in some (not all) sections of the streams is the flow generated by treatment plant effluents. Streams that carry mostly effluent discharges and reduced natural flow between rainfalls are called *effluent dominated* (Figure 1.3).

Post–Earth Day Period to the Third Millennium

An excellent review on the trends in urban wet weather pollution in the period 1970–present is included in Field et al. (2000).

Proliferation of Automobiles and Urban Sprawl. In the last 30 to 40 years, we have seen dramatic changes in urban habitation, caused by a great increase in automobile use. Building freeways and four-lane highways causes a demise of downtown and higher-density urban living and urban neighborhoods in the United States. Between 1960 and 2000, the number of vehicle miles (kilometers) driven by the U.S. population increased almost fourfold, from about 1.15×10^{12} km (0.71×10^{12} miles) in 1960 to about 4.2×10^{12} km (2.6×10^{12} miles) in 2000 (Tetra Tech, 1996). The average U.S. citizen drives twice as much as the average European or Japanese citizen (Kunstler, 1996).

As a result of the combined effect of population increase and increase in automobile use in the United States, most urban people have become suburbanites, driving ever-longer distances to their work. More and more agricultural and pristine land is being converted to subdivisions. This phenomenon, called *urban sprawl,* is responsible for increases in diffuse pollution and adverse hydrological changes in watersheds, and causing flooding. For example, between 1960 and 1990, the population of the Baltimore metropolitan area has increased by 33%, yet the amount of land used for urban and suburban living has increased five times faster, by 170% (Katz, 1997).

Progress in Point-Source Abatement: The Clean Water Act. Some progress in the abatement of municipal wastewater collected by sewers was made between 1920 and 1970, when in the United States and elsewhere, treatment plants were built at a rapid pace. By 1977 in the United States, 95% of the 156 million people residing in sewered communities received some form of treatment of their wastewater, while 70% received secondary biological treatment predominantly of dry weather sewage and wastewater flows (Schroepfer, 1978). By 1970, the Thames River in London was alive again, and fish have been caught there since.

In 1972, the U.S. Congress enacted the Water Pollution Control Act Amendments (the Clean Water Act, PL 92–500), which was the most far-reaching environmental legislative act to solve environmental problems. Section 101(a) of the act states: “The objective of the Act is to restore and maintain the chemical, physical, and biological integrity of the Nation’s waters.” Major advances and accomplishments in the control of pollution discharged by urban sewer and industrial effluents were made in the United States in the 1980s and 1990s. However, the record of the rest of the world, including some industrialized countries, was mixed at best and the major environmental actions (with the exceptions of Germany, United Kingdom, and Sweden) did not take place until at least a decade later. Even at the beginning of this millennium, neither Brussels, Belgium, a major European center and seat of the North Atlantic Treaty Organization (NATO), nor Milan, Italy, had functioning treatment plants throughout the metropolitan areas, and streams transecting the cities were simply covered to put them out of sight. However, in Europe, the period of the 1970s to 1990s saw an emergence of environmental activism similar to that in the United States before 1970. Political “green” parties emerged in several countries, including Germany and Italy. These parties were relatively small but active and often represented a balance of power between larger governing political parties. Presently, the European Union has developed ambitious plans for environmental control that are comparable or even surpass U.S. plans. The European approach to watershed management, if fully implemented, could serve as an example to the world.

At the beginning of the 1970s in the United States, and especially in Europe, many rivers and lakes could still not support a viable fishery (a major goal of the Clean Water Act), being so polluted that fish were absent and the river and lake bottoms were covered with mud contaminated with toxic substances of unnatural, human-made origin. Lake Erie in the Great Lakes system was dying. Even where fish were present, carcinogenic compounds discharged into the receiving waters in the post–World War II period had stressed the aquatic population, fish had become unfit for human consumption, and water recreational activities had been reduced or had ceased.

Since passage of the Water Pollution Control Act Amendments in 1972, hundreds of billions of dollars have been spent on the cleanup of pollution, primarily that caused by sewage and industrial wastewater discharges. But at the same time as money was beginning to be spent on this type of cleanup, it was realized that these efforts might be insufficient. In addition to pollution from sewage and industrial wastes, pollution from land and from human activities occurring on the land caused the cleanup goals not to be met, despite vast expenditures of money.

In the 1970s, most of the emphasis of actions derived from the Clean Water Act was still on cleanup of traditional municipal and industrial *point sources.* The tool for implementation of the cleanup programs is the *National Pollution Discharge Elimination System* (NPDES) permit system, which requires point source dischargers to obtain waste water discharge permits that limit the quantity of pollution that can be discharged into the receiving water. The limit, in most cases, was based on *effluent standards* and was unrelated to the *waste assimilative capacity* of the receiving water body. The notion of *nonpoint pollution* was not known to the majority of the population and environmental professionals. Many farmers argued that farming does not pollute.

The Clean Water Act took into account the fact that pollution from land is different from that of effluents from municipal and industrial sewers, so pollution sources were classified into two categories. The first category, *point sources,* included most of the traditional pipe effluents, plus several sources that were identifiable as to their point of discharge. A broad definition of point sources (see the section "Definitions" below) was included in the Clean Water Act. *Nonpoint sources* were everything else: land, atmospheric, and subterrain sources that were difficult to measure and identify, with loads mostly driven by meteorological events (see "Definitions"). Because some point sources under present classification (e.g., urban runoff, runoff from animal feedlots) are also driven by meteorological events, a new category, *diffuse sources,* was introduced in the first edition of this book (Novotny and Olem, 1994), which encompasses land sources of pollution that can legally be categorized as either point or nonpoint. In section "Definitions" we outline differences among various categories of sources and types of pollution.

Great Lakes Studies. In 1972, the Pollution from Land Use Activities—Reference Group (PLUARG) of the International Joint Commission (IJC) was established for the purpose of determining the levels and causes of pollution from land-use activities. This was the first time that a large multinational (U.S.–Canadian) agency recognized that a significant portion of pollution reaching and polluting the Great Lakes may originate from land, is addition to the effluents. From 1972 through 1978, a large group of scientists in Canada and the United States studied the pollution of surface runoff and atmospheric deposition and found that indeed the land runoff and the atmosphere were a significant and often major source of pollutant loads to the Great Lakes, in addition to the traditional municipal and industrial point sources. Agriculture was recognized as a major source of nutrients (nitrogen and phosphorus) stimulating excessive algal growths in the lakes. The resulting studies provided the most exhaustive review conducted up to that time, and to date it remains the most definite database and reference source of diffuse pollution (Novotny and Chesters, 1981; Nonpoint; Source Control Task Force, 1983).

As a result of these studies, the states surrounding the Great Lakes adopted a detergent phosphorus ban and established phosphorus effluent limits. Intensive nonpoint pollution studies were initiated by some Great Lakes states, and some states went a step further and created funding mechanisms and processes for watershed-wide nonpoint pollution control programs. Wisconsin's Priority Watershed Program, created in 1978, is an example of an early successful approach to the control of nonpoint/diffuse pollution (Gayan and D'Antuono, 1988). The program was designed to deal with the varying nature of nonpoint pollution problems throughout the state. These problems include pollution from cropland, construction sites, streambank erosion, and nutrient loads from barnyard runoff, cropland erosion, manure spreading on croplands, and runoff from city lawns and streets (Konrad, 1985).

The Wisconsin program concentrated available funds into selected hydrological units (watersheds) that exhibit large problems due to diffuse pollution inputs, called *priority watersheds.* Specific areas within a priority watershed that contribute significant amounts of pollutants to lakes and streams are collectively called *priority management areas.* This was one of the first implementations of *targeting* watersheds and areas for management, and was later incorporated (see the section "Definitions") into present watershed management programs.

The state of Wisconsin provides financial support in three major areas: (1) cost sharing (50 to 70%) with landowners and municipalities to install management practices; (2) aids for local governments to fund additional technical assistance, education and information, and financial and project management; and (3) administrative and planning funds for state administration and the preparation of priority watershed plans. In the late 1990s, several urban communities in Wisconsin successfully combined flood drainage plans with diffuse pollution control priority watershed programs because some components of the plans, such as detention–retention ponds (see Chapters 4 and 9), stream and streambank restoration (see Chapter 13), and other plan components received cost sharing from the priority watershed program. At the beginning of this century, the priority watershed program was modified to include grants to communities for diffuse pollution control outside priority watersheds.

Section 208 Planning Efforts. Section 208 of the original Clean Water Act had a far-reaching impact because it enacted a land-use planning process. For the first time it was realized that control of point sources would not have solved all the pollution problems in the United States. Section 208 called for area-wide water pollution control planning in areas designated by the governor of each state that would include both point and nonpoint sources and pollution abatement programs. Section 208 activities had two major outcomes:

1. Many excellent planning reports were produced by designated planning agencies that identified the extent of point and nonpoint pollution and suggested solutions.
2. To provide tools for these planning reports, the Environmental Protection Agency (EPA) funded several research efforts that resulted in development of hydrological/water quality watershed models, including several that are still used today (HSP-F, STORM, SWMM, CREAMS; see Chapter 13 for a description of the models).

However, incentives for treatment and penalties for noncompliance with the plan were included only for point sources (which at that time excluded urban stormwater and other sources that are currently defined as point sources), with no enforcement tools available for nonpoint sources. After the plans were completed, no mechanism for implementation and maintenance of nonpoint pollution abatement programs were in place.

Significant developments regarding nonpoint pollution abatement occurred in the 1980s. One notable development was the *National Urban Runoff Project* (NURP), a four-year research effort carried out at 28 sites throughout the United States which established that urban runoff is unacceptably polluted by toxic compounds and other pollutants. The NURP program had the following objectives:

- To investigate and establish quality characteristics of urban runoff and of similarities or differences at different urban locations.
- To identify the extent to which urban runoff is a significant contributor to water quality problems across the nation.
- To establish performance characteristics and the overall effectiveness and utility of management practices for control of pollutant loads from urban runoff.

From its findings, the NURP report to the Congress (U.S. Environmental Protection Agency 1983a) concluded that:

- Urban runoff contains high concentrations of toxic metals, and *priority pollutants* (toxic, mostly organic chemicals) were also detected in significant quantities.
- Urban runoff is contaminated by coliform and pathogenic (disease-causing) bacteria and viruses.
- Urban runoff carries high quantities of sediment.

Congress and the EPA then enacted an urban stormwater permitting program for urban and industrial runoff sources. In a sense, urban and industrial runoff sources were reclassified as point sources requiring a NPDES permit. Most permit application and control efforts were not initiated until the mid-1990s.

The *Chesapeake Bay Program of the EPA* was established in 1976 (U.S. EPA, 1983b, 1988). The Chesapeake Bay is the largest estuary on the east coast of the United States. It has been one of the world's most productive water bodies, providing habitat to fish and shellfish. However, water and habitat quality in this relatively shallow water body has been declining. Submerged aquatic vegetation has been disappearing, fishers have been landing fewer of certain spawning fish, and oyster harvests have declined. These problems were traced to excess nutrients and toxic pollutants in the bay system. These contaminants were also causing depressed dissolved oxygen concentrations, algal blooms, increased turbidity, and high concentrations of heavy metals in sediments. The U.S. EPA (1983b) found that diffuse (nonpoint) sources of pollution were among the chief causes of the bay's decline.

In 1983, the governors of Pennsylvania, Maryland, and Virginia, the mayor of the District of Columbia, and the administrator of the Environmental Protection Agency signed the Chesapeake Bay Agreement, which established a framework for cooperation and pledged to address the problem of nonpoint pollution as well as other sources of pollution in order to restore and protect the Chesapeake Bay. The project is continuing.

In the 1980s a watershed model using the BASINS approach (see Chapter 13) was developed. The watershed model, along with other information, provided the basis for understanding the relative contributions of point and nonpoint sources by major river basins, and linked the nutrient loading with specific areas where nutrients and dissolved oxygen concentrations potentially limited the aquatic resources. Federal support for the program provided implementation funds to each state and to Washington, DC. The bay states and the District of Columbia have developed a variety of approaches to address the nonpoint pollution problem. In the agricultural sector, the Chesapeake Bay states have been relying primarily on voluntary cost-sharing programs to carry out their program objectives. These programs are helping farmers to reduce soil and associated nutrient losses into the bay. All states target the diffuse sources at several levels:

1. The states target general geographic areas where each will emphasize implementation of agricultural diffuse pollution controls.
2. Once a general area has been identified, all the states have procedures to target the critical areas and management needs within that area.
3. State and local staff identify cost-effective, site-specific management practices for individual landowners and users.

Urban programs to control diffuse sources within the bay watershed lean more toward regulation where the stormwater NPDES permits are the tool.

Implementation of Voluntary Soil Conservation Practices. In many states, farmers received education and incentives to implement soil conservation. These efforts are carried out by the Natural Resources Conservation Service of the U.S. Department of Agriculture.

Continuing Research Efforts. The EPA, U.S. Department of Agriculture (USDA), Federal Highway Administration of the U.S. Department of Transportation, and other federal and state agencies sponsor numerous research projects that contribute to recognition of the nonpoint pollution problem and have developed *best management practices* for its solution. For example, the Rural Clean Water Program of the USDA, which began in 1980, has funded 21 long-term (10- to 15-years) watershed projects whose objectives are to improve water quality, help agricultural homeowners and operators use pollution control practices, and develop programs, policies, and procedures for the control of agricultural nonpoint pollution. The program has a much greater water quality emphasis than previous programs that focused primarily on soil conservation. Approved management practices include water management systems, animal waste management systems, and fertilizer and pesticide management, in addition to erosion control and soil conservation.

There has been a growing awareness of the importance and severity of nonpoint source pollutants in European and U.S. legislation. New environmental directives for water quality by the European Union impose strict limitations for a variety of nonpoint source pollutants. In the United States, nonpoint sources were recognized in the 1987 reauthorization of the federal Clean Water Act. Section 319 of the act requires the EPA and the individual states to assemble information and report to the U.S. Congress on the nature of nonpoint source pollutant impacts on receiving water quality and to present a plan to address nonpoint sources.

The importance of diffuse sources on water quality has been confirmed by studies in Europe and North America. A report on the Danube River basin found that nonpoint sources contributed 60% of the nitrogen and 44% of the phosphorus load to the entire river basin (Commission for European Communities, 1994). According to Cunningham (1988), nonpoint sources were the principal contributors of pollutants to 76% of U.S. lakes and reservoirs that failed to meet streamwater quality standards. Nonpoint sources similarly impaired 65% of U.S. streams failing to meet standards and 45% of estuaries (U.S. EPA, 1997). These statistics show that diffuse sources are significant in those water bodies where pollution problems persist.

In the 1990s, more comprehensive diffuse pollution programs emerged in some parts of the United States and Europe (e.g., the Lagoon of Venice in Italy) and events begun to move in the right direction. At one site, major progress was made by implementing regulations requiring NPDES permits for urban stormwater discharges; however, at another site, the public (represented by many environmental organization, e.g., Sierra Club, Natural Resources Defense Council) was disappointed by the lack of progress and the inefficiency of rural diffuse pollution controls. This resulted in much litigation aimed at forcing federal and state pollution control agencies to begin to act on the remaining pollution problems. In the mid-1990s, there were almost 40 lawsuits in which the EPA and states were sued to implement an original but forgotten statutory requirement of the Clean Water Act, the *total maximum daily load* (TMDL) process.

TMDL is embedded in the Clean Water Act [Section 303(d)] and EPA's water quality regulations (40 CFR 130). This regulation, dormant and unused between 1972 and almost the end of the twentieth century, requires states to develop and implement pollution abatement plans for all water bodies for which the standing water quality standards are not met and cannot be met by enforcing the technology-based standards for point sources. The plans must address point and nonpoint source control (see Chapter 11). Until the end of the century, very few states had developed any TMDL, and environmental groups became impatient with this inaction. The groups realized that TMDL could be an effective tool to implement nonpoint pollution programs and went to court to force implementation. A leading editorial by the *New York Times* (March 1, 1998) described the lawsuits and related activities as "opening a new front to the struggle over pollution and requiring the Government to make a new assessment of whether water quality standards are being met."

Other problems with implementation of watershed management were due to the inadequacy of procedures, models, and methodologies caused by previous insufficient focus of the research community on watershed-wide diffuse source management, past mistakes, and sole attention being given by states to control of regulated point sources. In a sense, in many states water quality management was limited to issuing point source discharge permits, and very few watershed-wide managements have been implemented. As pointed out, watershed planning under Section 208 of the CWA carried out in the late 1970s contributed to knowledge of the problem, but no implementation of diffuse source controls and watershed management followed. It was not until 1991 that the EPA finally published its first guidelines for state implementation of Section 303(d). At the end of the millennium, most cases were settled, resulting in a fast track initiation of TMDL planning and implementation in some states. A court ruling by the U.S. District Court for the Northern District of California (*Pronsolino et al. v. Marcus and Brower,* 2000) reaffirmed the fact that TMDL procedures are indeed a tool to implement nonpoint pollution abatement programs and that such programs are a responsibility of the states: "The 1972 Act was clear that states should finally decide whether, and to what extent, land management practices should be adopted to mitigate runoff. To assist the states in gathering information, the statutory role of the TMDL was to identify the load necessary, as a matter of engineering, to implement the water quality standards." The history of TMDL and other environmental lawsuits document the powerful role the U.S. judicial system has in shaping and implementing environmental policies. However, the enormous scope of TMDL efforts required by both the courts and pollution control agencies (about 40,000 TMDL studies were to be developed and implemented in a relatively short time) brought the entire effort to an abrupt halt in 2000. Congress has asked the National Academy of Sciences to look at the scientific basis for TMDL before the new regulations were implemented. The Committee to Assess the Scientific Basis of the TMDL Approach to Water Pollution Reduction (2001) reaffirmed the importance of the TMDL process and suggested corrective measures (see Chapter 11). Diffuse pollution was again recognized as the major contributor to impairment of the nation's waters.

A grass-roots movement to support sustainable green development of cities and agricultural areas also emerged in the 1990s. People realized that urban sprawl is not what they wanted when they moved into "clean" suburbs. This is a dichotomy to begin with, because the land-use conversion process itself—from forest, idle land, or agriculture to suburban use—creates pollution (see Chapter 2). However, there is great difference in pollution loads and flood-flow contributions between a standard development with curb-and-gutter paved roads with storm sewers and more ecologically friendly "smart growth" and "ecovillages" that incorporate wetlands, ponds, and infiltration (see Chapter 9). Such developments also educate homeowners about reducing or eliminating use of fertilizers and pesticides by growing less grass and planting more native plants that do not require watering and fertilization.

In the agricultural sector, two different trends are evident today. One approach, in addition to implementing best management practices to retain and remove pollutants from farms, is to use modern computerized techniques of fertilizer and pesticide application. Some large industrialized farmers developed GISs (geographical information systems; see Chapter 10), mapping their fields, crops, and soils, and distributing exact amounts of fertilizers and pesticides using a satellite-based global positioning system (GPS) based on the point location of soil and crop requirements. Runoff from feedlots is contained and used as a fertilizer after winter freezing.

A trend in the opposite direction is the emergence of organic farming, mostly on small family farms. In organic farming, no chemicals are used, manure and compost are the fertilizers of choice, and animals are raised unconfined using progressive grazing practices and careful manure management. The agricultural products are then certified as organic and sold as such. The movement that in the early 1990s started as a few farms is growing rapidly.

Most of the best management practices developed in the twentieth century focused on management of symptoms of the problem: reduction in soil erosion, street sweeping, and capture of polluted flows in ponds and other storage basins, and provide treatment. There is a trend now to focus and remedy the *root causes* of pollution, such as reduction of fertilizer use and/or monocultural farming, clean–green cities, smart growth, and clean industries

Developing World. In developing countries most pollution generated in large urban centers (megacities), from farms, deforestation, and land and wetland conversion could be classified as diffuse. Diffuse pollution can be local, regional, and transboundary. The UN Economic and Social Council in the report to the UN secretary general (Commission on Sustainable Development, 1997) has noted that 80 countries comprising more than 40% of the world's population are already suffering from serious water shortages, and in many cases, the scarcity of water resources has become a limiting factor to economic and social development. Ever-increasing water pollution has become a major problem throughout the world, including in coastal zones. The UN Commission of Sustainable Development noted that in many countries, rapid deterioration of water quality, serious water shortages, and reduced availability of fresh water were severely affecting human health, ecosystems, and economic development.

Developing countries are very susceptible to the effects of diffuse pollution, even to a larger degree than are developed countries. The following are the major reasons (Novotny, 2000):

1. Many urban megacenters have poorly functioning or nonexistent sewer systems, making urban surface runoff the major means of transporting pollutants in a diffuse manner to receiving water bodies. Some cities have only poorly functioning open surface channels for transmission of both rainfall runoff and sullage (Figure 1.6). A UN study found that in Latin America, virtually all domestic sewage and industrial waste is discharged untreated, mostly in a diffuse manner, into the nearest streams (Commission on Sustainable Development, 1997). Because of a lack of emission controls, air pollution in many megacities in developing countries is excessive. Measurements of diffuse loads in developed countries document a direct relationship between urban air pollution and pollution from runoff. Consequently, wet and dry deposition and runoff in megacities could be highly polluted by toxic compounds.

2. Population increase and pressures are largest in developing tropical and subtropical countries.

3. In humid tropical countries, a great part of the population lives on water, uses water for transportation and boats for living, and deposits wastes directly into surface waters (Figure 1.7). Historic Venice in Italy is the ultimate “living on water” community (Figure 1.8).

Figure 1.6. Urban diffuse pollution in shanty towns of developing countries.

Figure 1.7. Living on water in the tropical country of Thailand. (Courtesy of N. Tonmanee, Land Development Department, Bangkok.)

Figure 1.8. The famous jail bridge canal in Venice.

4. Water from surface sources contaminated by diffuse pollution is a source of potable and household water in shanty towns that developed in many urban centers and in rural villages without an adequate water supply.

5. In many countries, rivers have religious significance and the population, in large numbers, engages in religious bathing and other ceremonies in and near the rivers.

6. In many tropical and subtropical countries, high flows and surface runoff are major contributors to flow and pollution only during the regular wet seasons (monsoon). During most of the year, smaller rivers receive flow from groundwater, irrigation return flows, and urban dry weather flows.

Eutrophication (excessive growths of algae driven by increased inputs of phosphorus and nitrogen; see Chapter 12) of surface and coastal waters is one of the prime examples of a global diffuse pollution problem strongly affecting both developed and developing countries. It has recently emerged as a major problem, following the intensification of industrial agricultural practices, the "green revolution" of the late 1960s. The problem is not getting better. The increase in use of fertilizers and intensive animal husbandry has resulted in order-of-magnitude increases in nutrient inputs into surface and coastal waters. As a result, many aquifers and drinking water reservoirs have been contaminated by nitrates and surface waters by algae and trihalomethane precursors. The areas affected by eutrophication often involve very large water bodies and coastal zones that may be remote from the sources of nutrients that promote the eutrophication process.

Present Situation

The Black Sea, Adriatic Sea, Chesapeake Bay, and Gulf of Mexico are examples of large water bodies affected by transboundary and/or global inputs of diffuse pollution. These bodies have one symptom in common—they suffer from excessive inputs of nutrients from farming operations and cities located thousands of kilometers upstream and brought in by large tributaries (the Danube and Volga Rivers for the Black Sea, the Po River for the Adriatic Sea, the Susquehanna and Potomac Rivers for the Chesapeake Bay, and the Mississippi River for the Gulf of Mexico). The result is the same: excessive algal developments in the upper zone of the water body and anoxia (lack of oxygen) in the deeper zone. The consequences are also the same: loss of fishery and recreation values. The information contained in the Harmful Algal Bloom and Hypoxia Research and Control Act of 1998 (PL 105-383) specifies that according to the National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Interior, 53% of U.S. estuaries experience hypoxia (reduced oxygen levels) or anoxia for at least part of a year; 19,000 km^2 (7000 square miles) in the Gulf of Mexico off Louisiana and Texas suffers from hypoxia. Harmful marine algal blooms caused primarily by increased nutrient discharges have been responsible for an estimated $1 billion in economic losses during in the 1990s alone. Thus, diffuse pollution problems have now reached global proportions.

In the 1970s and 1980s, the focus of diffuse pollution abatement was primarily on control of flows and pollutants contained in surface flows. In an attempt to draw public attention to the diffuse pollution problem, a publication by the Natural Resources Defense Council (Thompson et al., 1989) used the term *poison runoff* to describe the level of contamination of urban and rural runoff. Today, however, the focus is on all three components of the hydrologic process: (1) atmospheric transport and deposition, (2) surface flow generations and movement, and (3) subsurface water and flow in groundwater zones. These three process are interconnected and integrated in the flow of streams and rivers. Because of this need for an integrated analysis and solutions, *watershed approaches and management* are now promoted and implemented. The present policy is to address all pollution sources in the watershed context (see Chapter 11). The TMDL process is now the most important legal tool toward a possible final solution of the diffuse pollution problem in the first quarter of this century. (Most states were given 15 years to prepare and implement the TMDL studies.) The TMDL process also initiates the *watershed management process.*

At the end of the twentieth century in the United States, over 50% of receiving water bodies were not meeting their designated water uses and water quality goals specified by the Clean Water Act. In addition, many shallow aquifers are contaminated by nitrates and organic chemicals (pesticides and solvents). Because past cleanup efforts focused primarily on point sources and removed pollutants dangerous to human health (raw sewage and industrial wastewater, pathogenic microorganisms), at present, aquatic life is more at risk than human health. Thus present water quality problems include excessive contamination of surface (water and sediment) and ground waters by nutrients and toxic chemicals (Figure 1.9). Some problems have been caused by past discharges that have either been reduced or have ceased, but their legacy is in sediments and contaminated soils of floodplains and watersheds.

A comprehensive study by the U.S. Geological Survey (1999), focusing on the

Figure 1.9. Milwaukee River in the 1980s, suffering from nutrient enrichment, resulting in excessive algal and macrophyte growth.

Table 1.1 Relative Level of Contamination of Streams

	Urban Areas	Agricultural Areas	Undeveloped Areas
Nitrogen	Medium	Medium-high	Low
Phosphorus	Medium-high	Medium-high	Low
Herbicides	Medium	Low-high	No data
Currently used insecticides	Medium-high	Low-medium	No data
Historically used herbicides	Medium-high	Low-high	Low
Metals and other toxic organics	High	Medium-high	Very low

Source: Adapted from U.S. Geological Survey (1999).

status of the U.S. waters and the extent of diffuse pollution, made the following findings (Table 1.1):

- The highest levels of nitrogen occur in streams and groundwater in agricultural areas. Fifteen percent of samples from streams affected exceeded the drinking water standard for nitrate nitrogen, 10 mg/L as N. Somewhat less than 50% of nitrogen fertilizer and manure applied on fields was lost to receiving waters.
- Elevated levels of phosphorus originating from fertilizers and livestock were also measured. Phosphorus loss amounted to less than 20% of phosphorus applied to land.
- Pesticides (primarily herbicides) are found frequently in agricultural streams and shallow groundwater. Pesticides found most frequently include atrazine, metachlor, alochlor, and cyanazine.
- Concentrations of insecticides can sometimes be found in urban streams that exceed the guidelines for protection of aquatic life.
- Urban streams have the highest frequencies of occurrence of DDT, chlordane, and dieldrin in fish and sediments. Complex mixtures of pesticides commonly can be found in urban streams.
- Concentrations of phosphorus are elevated in urban streams. These concentrations commonly exceed 0.1 mg/L.
- Hydrology and land use are the major factors controlling nutrient and pesticide concentrations in major rivers. Concentrations are proportional to the extent of urban and agricultural land use throughout a watershed. Key factors are soils and slope of the land.
- Groundwater (base flow in rivers originating from groundwater sources) can be a major source of nutrients and pesticides to streams.

In his essay on TMDL, Houck (1999) concluded that every state and every region has a distinct diffuse pollution problem. In Wisconsin, waters are polluted by dairy and cranberry farms, in North Carolina by hogs, in Maryland by chickens, in South Florida by sugar, in Wyoming by beef cattle, in Oregon by clear-cutting, in California by irrigation return flows, and across the United States by urban runoff and urbanization (urban sprawl).

On April 22, 2000, more than 500 million people in 170 countries celebrated the thirtieth anniversary of Earth Day with a worldwide drive for clean energy, clean air, clean transportation, and clean investments in clean industries. However, a comparison of worldwide trends is still not encouraging. According to World Watch, in the last 30 years of the twentieth century:

- The world population almost doubled, from 3.7 billion to 6 billion, although the rate of the increase was reduced from 2.04% per year to 1.3%.
- The average area of cropland per person was reduced from 0.18 ha (0.4 acre) to 0.11 ha (0.26 acre).
- The original forest area was reduced from 64% to 53% of the forest remaining.
- Consumption of oil, coal, and natural gas increased from 4.8 billion tons to 7.6 billion tons in equivalent oil.
- The number of automobiles increased from 193 million to 520 million. Most automobiles driven in developing and industrialized countries do not have air pollution devices and emit lead, nitric oxides, and other pollutant in much larger quantities than do automobiles in some developed countries.

A $4 million study by 175 scientists from around the globe commissioned by the UN (2001) and summarized in *Time*'s special Earth Day issue (Spring 2000) lists the following troubling issues and trends related to diffuse pollution:

- Half of the world's wetlands have been drained, destroying habitat.
- The United States has lost almost all of its original grasslands (prairies). Elsewhere, soil erosion and desertification are reducing the ability of systems to support livestock.
- Except for Russia and Canada, industrial nations have cleared almost all their original forest. Rain forests are also shrinking rapidly. In developing countries, logging rates are faster than tree growth.
- More than 40% of agricultural land has been badly degraded by erosion, nutrient depletion, and water stresses.
- So much water is taken from rivers such as the Colorado, Yellow River (China), and Ganges (India) that they sometimes dry up before reaching the sea.

Work on solving the diffuse pollution problems on a worldwide scale has only began.

DEFINITIONS

Any treatise dealing with water quality and pollution needs definitions. In the minds of the public, water quality is often synonymous with pollution, and similarly, water quality or watershed management, including that related to diffuse sources, is equated with pollution control. Actually, these terms have different definitions, as shown below.

Water Quality and Pollution

Water quality reflects the composition of water as affected by nature and human cultural activities, expressed in terms of both measurable quantities and narrative statements. In the United States the descriptive water quality parameters are related to intended water use. For each intended use and water quality benefit, there may be different parameters best expressing water quality. Both single compound (e.g., BOD_5, ammonia, nitrate, dissolved oxygen, phenols, etc.) and multiple compound parameters (oil and grease, whole effluent toxicity, coliforms, etc.) are used.

The term *pollution* is derived from a Latin word (*pollu'ere*) that means "to soil" or "to defile." The terms *pollution, contamination, nuisance,* and *water (air, soil) degradation* have often been used synonymously to describe faulty conditions of surface and ground waters. Various definitions have been offered to define pollution and related terms (Vesilind, 1975; Krenkel and Novotny, 1980; Henry and Heinke, 1989). These definitions are not identical and, in a legal sense, not even similar. In most early simple interpretations, if the water quality expressed by the measured parameters exceeded some accepted threshold value of nuisance or interference with a beneficial use of the water body, the water body was considered as being polluted. In 1970s the definition most accepted by scientist was "unreasonable interference of water quality with the beneficial uses of the resources." However, the perception of beneficial use was different to different people, which was a problem. For example, from the economic standpoint, the greatest beneficial use of water and resource was to provide an inexpensive way to dispose of wastes, in which case, fishing and swimming might have been perceived by these economic users as interfering with their beneficial use. Indeed, during discussions of the implications of the Water Pollution Control Act Amendments of 1972, some people with good intentions tried to compare the cost of reducing pollution with the market value of fish in the receiving water body. Fortunately, such interpretations are not acceptable today, but they show the possible problems with simple definitions and preceptions. Today's interpretations put a high value on the protection of the environment and supersede any economic savings that might be achieved by allowing injurious discharges of pollutants.

Today, the quality status of receiving water bodies and their pollution is understood in a more comprehensive manner, expressed as *integrity* (Figure 1.10). Consequently, the statutory definition of pollution included in the Clean Water Act, Section 502-19 (U.S. Congress, 1987) is: "The term 'pollution' means the man-made or man-induced alteration of chemical, physical, biological, and radiological integrity of water." Based on linguistic definition, *integrity* means "being unimpaired"; therefore, *alteration of integrity* means impairment or injury. In ecological interpretation, integrity of a water body implies the ability of its ecological system to support and

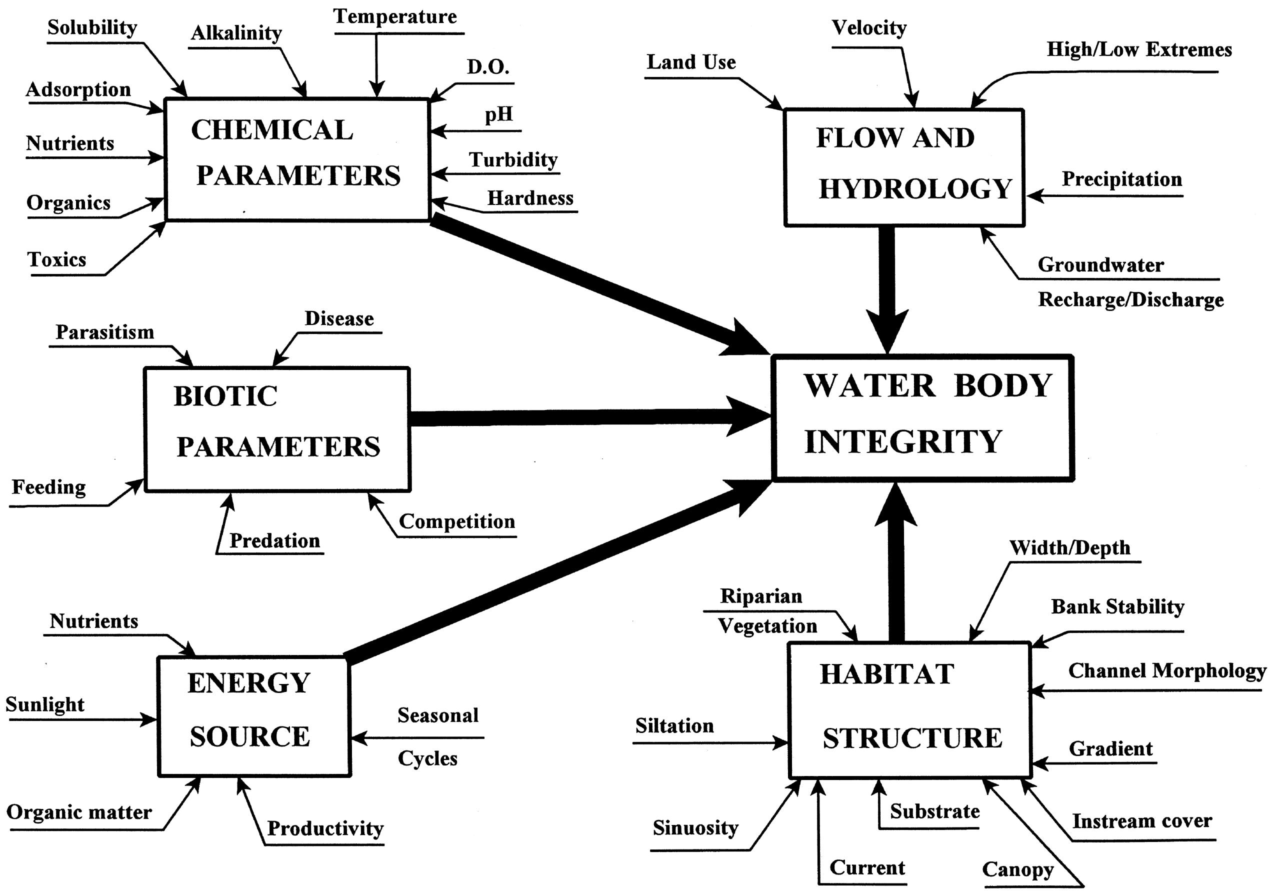

Figure 1.10. Five principal factors and their components that comprise the integrity of surface waters. (Adapted from Karr et al., 1986.)

maintain “a balanced, integrated, adaptive community of organisms having a species composition, diversity and functional organisms comparable to that of natural biota of the region” (Karr and Dudley, 1981). *Physical integrity* implies habitat conditions of the water body that would support a balanced biological community. *Chemical integrity* would mean a chemical composition of water and sediments that would not be injurious to the aquatic biota. A composition of aquatic organisms resembling or approaching that of unaffected similar water bodies in the same *ecoregion* without invasive species represents the biological integrity.

According to this definition, pollution is caused by human beings or their actions and is differentiated from changes in the quality of the environment due to natural causes such as natural erosion, weathering of rocks and natural elutriation of minerals, natural processes occurring in water bodies and sediments, and as a result to natural disasters such as volcanic eruptions or deposition of fly ash from (natural) forest fires. If the water composition is steady, reflecting the natural environment, the water quality would be characterized as *background* or *natural water quality.* Abrupt and transient changes caused by natural disasters could be considered as a *nuisance* or as *undesirable water quality modifications* or even as an *act of God* by the legal profession, but in a technical engineering sense they generally do not require abatement, or abatement is not technically or economically feasible.

The Clean Water Act and ensuing regulations on watershed management (U.S. EPA, 1999) consider pollution in a more comprehensive context than in previous interpretations. Pollution not only implies addition of harmful substances, but any human action or alteration of a receiving water body that impairs its integrity could be considered pollution. Under this definition, cutting down trees along rivers, which increases temperature and impairs the habitat, straightening of channels and channel linings, hydraulic modifications, and reducing low flows below tolerable levels by excessive withdrawals would be pollution. Therefore, the EPA classifies water bodies with impaired integrity as those that are affected by pollution and those affected by identifiable pollutants (U.S. EPA, 1999). Uncontrollable atmospheric deposition that adversely affects the quality and integrity of surface waters would also be considered as pollution.

Background Water Quality. Water draining the forest is clean and pristine; however, it contains chemicals, microorganisms, and sediments. The origin of such chemicals is the contact of rainwater with vegetation (tree canopy throughfall), soils, decaying vegetation, and animal and insect droppings, among others. These water quality constituents constitute *background or natural water quality* (see Chapter 3). In most cases, background/natural water quality represents the purest state of surface water. However, there are cases where natural water quality is not as good and can diminish the beneficial uses of the receiving water. For example, streams draining natural wetlands in temperate regions often have very low dissolved oxygen concentrations, which may preclude a healthy fish population. Anaerobic decomposition and evolution of methane from highly organic wetland sediment that consumes oxygen are common. Other examples of undesirable natural water contamination, but not human pollution, include the high carbon dioxide content of some groundwater, which is injurious to building materials, and elutriation of humic organics from decaying aquatic vegetation, which impairs the suitability of water for use as a water supply.

Knowledge of natural water quality is important in diffuse pollution abatement. The same meteorological processes, rain, surface erosion, and elutriation of chemicals that form the natural chemical and biological composition of surface waters also generate pollution. The difference in some cases is the intensity at which the key water quality constituents are elutriated from the land surface of soils into the receiving waters. Natural water quality does provide a *reference* on the most desirable water quality in a region. Hence, water quality composition contains both constituents that can be of both human and natural origin. Even when the composition contains contributions from humans, the definition of pollution specifies that to be considered pollution, the integrity of the water must be downgraded or threatened.

Pollutant. Although *pollution* and *impairment* refer to a state of the water body and impairment of its integrity, the term *pollutant* is defined as (U.S. EPA, 1999): "dredged spoil, solid waste, incineration residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal and agricultural waste discharged into water. Excluded from this definition (within the meaning of appropriate sections of the CWA) are: (A) sewage from vessels or (B) water, gas, or other material that is injected into a well to facilitate production of oil or gas or water derived in association with oil or gas production and disposed in a well. Included also are drinking water contaminants regulated under the Safe Drinking Water Act."

Evidently, a pollutant is identifiable and is mostly *allochthonous* [discharged from outside the water body; dredged spoil is *autochthonous* (originates from within the water body)].* Water quality, water body integrity, and pollution are determined and measured by comparing physical, chemical, biological, microbiological, and radiological quantities and parameters to a set of standards and criteria. The difference between the *standards* and *criteria* should be explained.

Criteria and Standards. A *criterion* is basically a scientific quantity upon which a judgment is based. It is usually developed from scientific experiments and observations. Water quality criteria are expressed as constituent concentrations, levels, or narrative statements representing a quality of water that supports a particular desig-

*This semantic division between *pollution* and *pollutant* creates a problem in U.S. water quality abatement programs. Section 303(d) of the Clean Water Act, the legal foundation of the TMDL process, deals with pollutants and not pollution. Thus, a TMDL process, as understood in the twentieth century, could remove and control pollutants in point and nonpoint sources but could not fix problems caused by pollution, such as habitat impairment. A remedy was suggested in the report by the NRC Committee to Assess the Scientific Basis of the TMDL Approach to Water Pollution Reduction (2001).

nated use. They are typically based on morbidity or chronic toxicity of various substances to human life (human health protection criteria) or aquatic life (aquatic life protection criteria), or can be related to technical methods of removing substances from water or wastewater. A *standard* applies to a definite rule, principle, or measure established by an authority. Based on the Clean Water Act, in the United States, the Environmental Protection Agency, a federal agency, has responsibility for issuing scientifically developed water and sediment quality criteria and effluent limitations. Because of the division of the governance between federal and state governments, the states only can issue legally binding standards, using the federal criteria as guidance.

The water quality criteria and standards currently used throughout the world are either *stream (ambient)* or *effluent (emission)*. The effluent standards determine how much pollution can be discharged from municipal and industrial wastewater sources and by some diffuse pollution sources. These standards are unrelated to the beneficial use of the water body into which the regulated source discharges. *Performance standards,* which are equivalent to effluent standards for the control of pollution from lands, are used to control pollution from subdivisions, construction sites, and mining. The *receiving water body standards* can be related to the beneficial uses of the water body, such as protection of people using the water body as a source of potable water or for contact recreation or protection of aquatic habitat. The fundamentals of water quality standards are described in Chapters 11 and 12. The designated use of the water body (water supply, aquatic life protection, contact and noncontact recreation, and others) should be attainable. (See Chapter 11 for a discussion of use attainability.) Standards and criteria may be numerical, chemical based, or narrative, or based on the toxicity of the entire water body or effluent. Criteria (standards) are *nationwide* or *site specific.*

In water quality planning and evaluation, exceeding the water quality parameters over one or more standards (criteria) implies an injury to the water use for which the standard was issued. Consequently, a wastewater discharge or diffuse pollution load that does not result in a violation of a standard may be considered noninjurious, as it does not cause pollution. The quantity of potential pollutants that can be discharged into the environment (receiving water body, atmosphere, or soil/groundwater) without altering its integrity is then called *waste assimilative capacity.* A sum of the waste assimilative capacity and the background load has been defined in the TMDL guidelines (U.S. EPA, 1991) as the *loading capacity* (see Chapters 11 and 12). Determining the waste assimilative capacity (loading capacity) of the receiving water body is one of the most important steps in any environmental protection effort. It is a key step in the TMDL study and the decision on watershed management. Not taking the waste assimilative capacity into consideration would lead to uneconomical wasteful approaches or even ineffective solutions. The concept of waste assimilation capacity and its determination are shown in Figure 1.11. Typically, the waste assimilative capacity of surface water bodies might be higher for decomposable organic matter, but it is very low to nil for some toxic chemicals that bioaccumulate in tissues of organic organisms and become injurious to animals and people that use fish and shellfish as

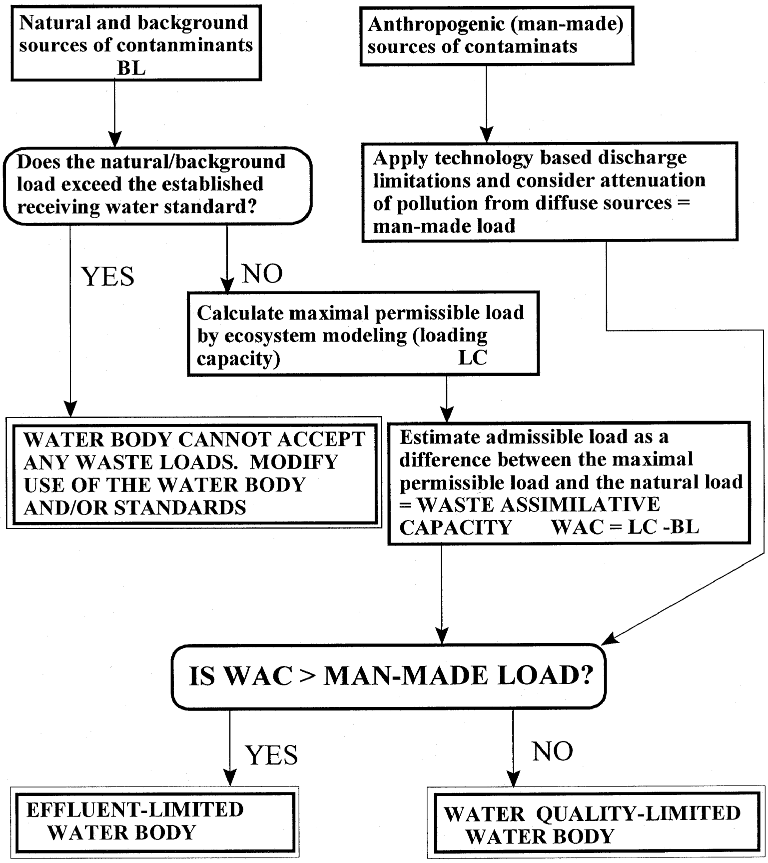

Figure 1.11. Waste assimilative capacity concept.

food. Waste assimilative capacity is not always fixed. It can be increased by water body restoration and other measures (see Chapters 13 and 14).

Best Management Practices. Best management practices (BMPs) are methods, measures, or practices selected and implemented to meet the needs of nonpoint (diffuse) source control, BMPs include, but are not limited to, structural and nonstructural controls and operations and maintenance procedures. BMPs can be applied before, during, and after pollution, producing activities to reduce or eliminate the introduction of pollutants from diffuse sources into receiving waters.

Regulated and Protected Water Bodies: Waters of the United States

The jurisdiction of federally mandated program and regulations extends over all navigable waters. This right of the U.S. federal government to regulate and protect navigable waters is derived from the commerce clause of U.S. Constitution, which requires the government to protect and maintain the commerce on land and water between states, foreign nations, and native American tribes. Such waters are called *waters of the United States.* Since at the time the first laws were written a major part of commerce was done by small boats and on water, the courts and statutes have interpreted *navigable waters* as waters on which a canoe can be floated at some time or season or throughout the year. A navigable water that would be classified as water of the United States must be an established natural water body. Box 1.4 includes a legal definition of the waters of the United States.

Pollution Sources

From the previous discussion it follows that pollution is caused by people and results in an undesirable or harmful change of the quality of the resource—water, soil, or air. The sources or causes of pollution can be classified as:

1. Human alteration of the status of a water body and its habitat that downgrades its integrity and creates pollution
2. Addition of allochthonous (originating from outside the water body) pollutant loads to the water body

Group 1 includes pollution and polluting activities that are more difficult to control. The causes of such alteration include:

- Hydraulic modification of water bodies
  - Channel lining and straightening that downgrade habitat
  - Building dams and impoundments that change water quality adversely by creating anoxic portions of the impoundment, accumulate contaminated sediment, or prevent fish migration
  - Flow diversion from the stream
- Invasion of foreign species that were brought to the water bodies by people (e.g., water hyacinth, zebra mussels, sea lamprey)
- Drainage of riparian (water body bordering) wetlands to accommodate agricultural and urban development
- Urban development that changes the hydrology of a stream or stream corridor and causes stream bank erosion and reduces channel stability
- In situ sediments that are contaminated by past human activities that are difficult to identify and discharges or sediments causing increased sediment oxygen demand that can be attributed to anthropogenic (humanmade) sources

Today, activities on navigable water bodies that would alter their integrity and character (channel construction, building of dams, drainage of riparian wetlands)

BOX 1.4: WATERS OF THE UNITED STATES

1. All waters that are used that are or can be used in interstate or foreign commerce, including waters that are subject to the ebb and flow of the tide.
2. All interstate waters, including interstate wetlands.
3. All other waters (lakes, wetlands, river, ephemeral and perennial streams, mudflats, sandflats, prairie potholes, wet meadows, natural ponds) whose use or degradation would or could affect interstate or foreign commerce, including any such waters:
   a. Which are or could be used by interstate or foreign travelers for recreational or other purposes
   b. From which fish or shellfish are or could be taken and sold in interstate or foreign commerce
   c. Which are or could be used for industrial purposes by industries in interstate or foreign commerce
4. All impoundments of waters otherwise defined as water of the United States under this definition.
5. Tributaries of waters of water bodies defined above as water of the United States.
6. The territorial seas.
7. Wetlands adjacent to water (other than waters that are themselves wetlands) identified in paragraphs 1 to 6 of this definition. *Wetlands* are defined as those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marches, bogs, and similar areas.

Ponds and lagoons that are used and have been built for wastewater treatment or cooling, artificial drainage ditches, stormwater conveyance, open channels that are not natural streams, abandoned quarries and surface mines filled with groundwater, outdoor swimming pools, and similar water bodies are not waters of the United States. The simple fact that a canoe can be floated on them does not make them eligible for classification as waters of the United States.

Source: U.S. EPA (1994).

cannot proceed until the U.S. Army Corps of Engineers has issued the necessary permits, which, considering the present public attitudes to such projects, is difficult to obtain. As a matter of fact, successful grass-roots efforts to remove such in-stream structures and bring the water bodies back to a more natural state have been emerging since the 1990s (see Chapter 13).

Allochthonous sources of pollution in category 2 are classified as either point or nonpoint sources. Originally, the term *diffuse pollution* was synonymous with *nonpoint pollution.* After passage of the Clean Water Act in 1977 and Water Quality Act of 1987 by the U.S. Congress, redefinition of these characterizations is necessary.

Point sources of pollution were defined originally as pollution that enters the transport routes at discrete, identifiable locations and can usually be measured. Major point sources under this definition included sewered municipal and industrial wastewater sources and effluents from solid waste disposal sites. Nonpoint sources were simply "everything else" and included diffuse, difficult-to-identify, intermittent sources of pollutants, usually associated with land or use of land. These definitions led to some legal ramifications for abatement efforts. According to the U.S. Constitution, the government could mandate control of point sources that enter navigable waters while private use of land was considered sacred and enforcement of nonpoint pollution control was impossible. Hence the new definitions broadened the category of *point* sources. The current statutory definition of point sources is as follows (Clean Water Act, Section 502-14, U.S. Congress, 1987): "The term 'point source' means any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft from which pollutants are or may be discharged. This term does not include agricultural stormwater and return flows from irrigated agriculture." This definition does not leave much space for "everything else" being nonpoint sources. The last sentence in the definition is a reflection of an impact of lobbying and not of a true pollution impact or character of pollution from agricultural sources.

The common characteristic of these point sources is that they discharge pollutants into the receiving water bodies at an identifiable single- or multiple-point location. The second common characteristic of these point sources is that in the United States and most other countries, these sources are regulated, their control is mandated, and a permit is required for waste discharge from these sources.

According to the latest definitions, the statutory point source category includes the following sources:

- Municipal and industrial wastewater effluents
- Runoff and leachate from solid waste disposal sites
- Runoff and infiltrated water from concentrated animal feeding and raising operations
- Runoff from industrial sites
- Storm sewer outfalls from larger urban centers

- Combined sewer overflows
- Runoff and drainage water from active mines, both surface and underground, and from oil fields
- Other sources, such as discharges from vessels, damaged storage tanks, and storage piles of chemicals
- Runoff from construction sites
- Bypasses of untreated sewage form sanitary sewers and treatment plants (these are not allowed by law and hence cannot be considered as a legal source of pollution)
- Winter runoff and snowmelt from airports, especially during aircraft deicing and anti-icing operations

Two common characteristics of these statutory point sources are that (1) they do, indeed, enter the receiving water bodies at some identifiable single or multiple locations and (2) they carry pollutants.

Statutory nonpoint sources ("everything else") then include:

- Return flow from irrigated agriculture and orchards
- Agricultural runoff and infiltration from sources other than confined concentrated animal operations
- Silvicultural runoff and runoff from logging operations, including logging roads and transportation
- Runoff from unconfined pasture- and rangelands
- Urban runoff from small communities with storm sewers
- Urban runoff from unsewered settlement areas
- Septic tank surfacing in areas of failing septic tanks systems and leaching of septic tank effluents
- Wet and dry atmospheric deposition over a water surface (including acid rainfall)
- Flow from abandoned mines (surface and underground), including inactive mining roads
- Runoff and snowmelt (with or without deicing chemicals) from roads and highways outside urban areas
- Activities on land that generate wastes and contaminants, such as:
  - Wetland drainage
  - Mass outdoor recreation and gathering
  - Land development other than construction
  - Military training, maneuvers, shooting ranges

Some of these nonpoint sources are either locally or federally regulated. They should also be included in TMDL and broader watershed management plans. In many states, developers are required to implement erosion control practices, wetland protection laws regulate drainage of wetlands, and septic tank installations and failures are typically considered a health problem and are regulated by county or state public health agencies.

From our previous discussion and definition of pollution, one may conclude that not all lands and land-use activities are polluting. Pollutants emitted from some disturbed land located far from the water course are attenuated between the source and the recipient; hence, the land may not cause impairment of water quality (pollution). For this reason, some soil conservation practices far from a watercourse may not have a significant water quality improvement benefit. The lands that are most polluting within a watershed are called *hazardous* or *critical lands.* Determination and location of such lands is one of the most important tasks in planning watershed management and TMDLs. Table 1.2 shows the most important sources of pollution of U.S. surface water bodies.

The statutory definition of point and nonpoint sources has very important regulatory ramifications. However, it leaves ambiguity as to the selection and design of abatement. The fact remains that "traditional" point sources of wastewater—municipal, industrial, and agricultural (farm) discharges—are different from *diffuse* sources, which according to the statutory definition, may be both point and nonpoint. The traditional point sources strictly include wastewater effluents from municipal and industrial sites, from indoor farm operations (e.g., confined chicken production, greenhouses), and from deep mines. The flow and pollution from these sources may vary; however, in most cases they are continuous uninterrupted discharges, variability is not greatly related to meteorological factors, and the variability is not great (within one order of magnitude). The prevalent method of control is collection and treatment.

Runoff from storm sewers, concentrated animal feeding operations, and construction sites have the characteristics of both nonpoint and point source pollution. Pollution from these sites is intermittent, occurs mostly during meteorological events, and originates from land-use activities, which are characteristics of nonpoint sources, yet the discharge is usually through an identifiable outlet or overflow point. In the United States such sources are legally point. Thus the expanded definition of *diffuse sources* may include both point and nonpoint sources. A practical definition of *diffuse sources and pollution* has been proposed in the United Kingdom as follows (D'Arcy et al., 2000): "Pollution arising from land-use activities (urban and

Table 1.2 Leading Sources of Water Quality Impairment

Rank	Rivers	Lakes	Estuaries
1	Agriculture	Agriculture	Urban runoff
2	Municipal point sources	Municipal point sources	Municipal point sources
3	Stream/habitat changes	Urban runoff	Agriculture

Source: U.S. EPA water quality inventory.

rural) that are dispersed across a catchment, or subcatchement, and do not arise as a process industrial effluent, municipal sewage effluent, deep mine or farm effluent discharge."

Diffuse sources can be characterized as follows (Novotny and Olem, 1994):

- Diffuse discharges enter receiving surface waters in a diffuse manner at intermittent intervals that are related primarily to the occurrence of meteorological events.
- Waste generation (pollution) arises over an extensive area of land and is in transit overland before it reaches surface waters or infiltrates shallow aquifers.
- Diffuse sources are difficult or impossible to monitor at the point of origin.
- Unlike traditional point sources, where treatment is the most effective method of pollution control, abatement of diffuse land is focused on land and runoff management practices.
- Compliance monitoring is carried on on land rather than in water.
- Waste emissions and discharges cannot be measured in terms of effluent limitations.
- The extent of diffuse waste emissions (pollution) is related to certain uncontrollable climatic events, as well as geographic and geologic conditions, and may differ greatly from place to place and from year to year.
- The most important waste constituents from diffuse sources subject to management and control are suspended solids, nutrients, and toxic compounds.

Pollutants of Concern

Traditional point source pollutants include suspended solids and their organic (volatile) content, biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), pathogenic microorganisms, nutrients (nitrogen and phosphorus), and toxic compounds, both organic and inorganic. The biodegradable organics reduce dissolved oxygen levels in the receiving water bodies and cause other nuisance problems, such as accumulation of organic sludge, sediment oxygen demand, and promotion of nuisance algal growths.

Pollutants of concern, originating from diffuse sources, are presented in Table 1.3. Toxic chemicals, both inorganic (metals and salts) and organic [polyaromatic hydrocarbons (PAHs) and solvents], are the most serious pollutants in runoff from urban areas and highways, while sediment, nutrients, and pesticide loads are most troublesome in agricultural runoff and subsurface flows. Heavy salt use and receiving water loads during winter from municipalities and roads are serious water quality problems in snowbelt areas of North America and Europe. In addition to salt (sodium and calcium chloride), winter salt-laden snowmelt also contains higher concentrations of toxic compounds and complex cyanide (an anticaking additive to salt) that can break down to toxic hydrogen cyanide (Novotny et al., 1999; see also Chapter 8).

Table 1.3 Diffuse Pollution Concerns

Pollutant	Example Source	Environmental Problem
Oil and other hydrocarbons, including:	Car maintenance; disposal of water oils; spills from storage and handling; traffic emissions and road runoff; industrial emissions	Toxicity; contamination of urban stream sediments; groundwater contamination; nuisance (surface waters), taste (potable supplies)
Solvents	Cleaning of industrial yards, illegal connections of industrial effluents to surface waters	Toxicity; contamination of potable supplies (rivers and groundwater)
Pesticides	Municipal application to control roadside weeds; agriculture; private lawn care	Toxicity; contamination of potable supplies
Suspended solids	Runoff from arable land; upland erosion; accumulation of solids on impervious urban surfaces; construction	Destruction of gravel riffles; embeddedness; sedimentation in natural pools and ponds; carrier of nutrients and toxic compounds
Biodegradable organic wastes	Agricultural wastes (feedlots, silage liquor, surplus crops); sewage sludge; land application of effluents	Oxygen demand; nutrient enrichment
Fecal pathogenic microorganisms	Septic tank system failures; animal feces in towns and cities; illegal cross-connections of separate sewer systems; applications of organic wastes to land	Health risk; noncompliance with recreational standards (beach closings)
Nitrogen	Agricultural fertilizers; traffic emissions; atmospheric deposition	Eutrophication (especially of coastal waters); contamination of potable supplies; acidification
Phosphorus	Soil erosion; agricultural fertilizers; Contamination of urban runoff (detergents, organic materials)	Eutrophication of fresh waters: Ecological degradation Increased potable water treatment cost Nuisance algal growths
Toxic metals	Urban runoff; land application of industrial and sewage sludge	Toxicity
Acidity of atmospheric precipitation	Car emissions; power plant emissions	Toxicity; aesthetic nuisance
Sodium and cyanide	Deicing chemicals for winter road traffic safety	Toxicity

Source: D'Arcy et al. (2000).

IMPORTANT REGULATIONS FOR DIFFUSE POLLUTION CONTROL

Federal Laws

The Clean Water Act reauthorized in 1987 (PL 100-24) has several sections dealing with diffuse (nonpoint) pollution. Sections 208, 303, and 319 of the act are most important. Section 303, which has the title "Water Quality Standards and Implementation Plans," is covered in detail in Chapter 11. In essence, Section 208, which requires states to prepare watershed-wide plans for point and nonpoint source abatement, identifies the problem in the watershed; plans and analyses under Section 303 set into motion and identify solutions for watersheds where mandated point source controls will not achieve the goals of the Clean Water Act; and Section 319 develops solutions and provides funds for nonpoint pollution abatement.

To address nonpoint pollution problems, Congress amended the CWA in 1987 and established in Section 319 the NPS pollution management program, which encourages the states and native American nations to prepare state (tribal) nonpoint source assessment reports to develop and implement management programs in order to be eligible for federal funds. Most states and tribes have complied. Since 1991, recipients of Section 319 grants have directed approximately 40% of the funds toward controlling nonpoint pollution from agricultural lands. Efforts to control runoff from urban sources, septic systems, and construction also received significant funding, as did projects to manage wetlands and NPS pollution from forestry, habitat degradation, and changes to stream channels. The Northern California District Court (*Pronsolino et al. v. Marcus and Brower,* 2000) has asserted the EPA's right to withdraw federal funds from the state if the nonpoint source management required by the TMDL is not incorporated in the plans and implemented by the state. Thus, eligibility of funding is now tied to the TMDL limitation and achievement of the water quality goals specified by the Clean Water Act.

Section 402 establishes the permit program for discharges of pollutants from point sources. More specifically, Section 402(p) requires a NPFES permit for separate storm sewers. The permits for point discharges under Section 402 are issued by states.

Section 404 regulates the discharges of dredged and fill materials into waters of the United States and establishes a permit program to ensure that such discharges comply with federal regulations. The permits are issued by the U.S. Army Corps of Engineers. Other provisions of the act, such as the national estuary program (Section 320), clean lakes program (Section 414), and Great Lakes basin and Chesapeake Bay programs, also deal with diffuse source pollution management.

Control of Combined Sewer Overflows. The EPA published its control strategy for controlling combined sewer overflows (CSOs) in 1989 (*Federal Register,* August 10, 1989). The strategy relies on the NPDES permit system. The permit system is aimed at bringing all CSO into compliance with the technology-based requirements of the Clean Water Act and applicable state standards, and to minimize water quality, aquatic biota, and human health impacts from wet weather combined sewer overflows. CSOs have always been regulated legally as point sources; hydrologically, they are in a wet weather diffuse source category. The marked difference between CSOs and stormwater obviously are (see Chapter 8 for technical definitions):

- CSOs contain a large proportion of untreated sewage, while entry of raw sewage is excluded from stormwater discharges.
- Small rains do not trigger CSOs since some rainwater–sewage mixture is directed toward the treatment plan (provided that the urban sewerage includes a treatment facility, which may not be the case in many developing countries and even some developed countries). Separate storm sewer overflows discharge polluted runoff during all rain and snowmelt events. Most urban snowmelt may not result in a CSO (Novotny et al., 1999).

All permits for CSO discharges should require the following technology-based limitation as a minimum: (1) proper operation and regular maintenance programs for sewer systems and combined sewer overflow points, (2) maximum use of the collection system for storage, (3) review and modifications of pretreatment programs to assure that CSO impacts are minimized, (4) maximization of flows to the treatment plant for treatment, (5) prohibition of dry weather overflows, and (6) control of solid and floatable materials in CSO discharges.

Additional CSO control measures are based on the potential impact on receiving water bodies that would bring discharges in compliance with state standards. This is a task of TMDL studies (see Chapter 11), which must consider under the *seasonality* requirement both wet and dry weather discharges. Additional controls measures include improved operation, best management practices, supplemental pretreatment, local limits programs, specific pollutant limitations, compliance schemes, direct treatment of overflows, sewer rehabilitation, in-line and off-line storage with subsequent treatment, reduction of tidewater intrusions, construction of CSO controls within the sewer system or at the discharge point, sewer separation, and new or modified treatment facilities. The compliance monitoring program should be described and included in the permit.

The strategy does not cover sanitary sewer overflows (SSOs) and treatment plant bypasses, which are considered to be "an intentional diversion of waste streams from any portion of the treatment facility" that begins at the headwork of the facility. Bypasses are not allowed unless (1) they are unavoidable to prevent loss of life, and (2) there is no other feasible alternative to the bypass. Similar prohibitions apply to the bypasses and overflows from sanitary sewers. These bypasses constitute a discharge of untreated and insufficiently diluted waste that represent a threat to pubic health.

Storm Water (Separate Sewer) Permit Regulation. The EPA rules define *stormwater* as follows: Storm water means storm water runoff, snow melt runoff, surface runoff, street wash water related to street cleaning or maintenance, infiltration (other than infiltration contaminated by seepage from sanitary sewers or by other discharges) and drainage. The stormwater control rules by the EPA seek to establish NPDES permit application requirements for (1) stormwater discharges associated with industrial activity, (2) discharges from urban separate sewer systems, and (3) discharges from construction sites. To accomplish the goal, urban stormwater that originally was considered by many as a nonpoint source of pollution was declared a point source. Originally, in a phased-in approach (phase I), industrial dischargers, large urban centers (greater than 100,000) and construction sites greater than 2 ha (5 acres) were required to file for a permit, but soon after that cities used their prerogative to extend the permits to entire urban areas (i.e., most suburban and nearby small urban centers). Today, most cities and urban areas with density greater than 385 people/km^2 (1000 people/square mile) are required to apply for a permit to discharge the stormwater, and many use this requirement to prepare comprehensive drainage plans that would address both pollution and flood control. Some cities have created stormwater management utilities that are responsible for collecting fees and managing systems to minimize pollution and provide flood control.

Stormwater from industrial areas that are required to file for and receive a permit must comply with Sections 301 and 402 of the Clean Water Act, which require application of best available treatment technology (BAT). Permits for municipal storm sewer systems include controls that reduce the discharge of pollutants to the maximum extent practicable (MET) as well as requirements to effectively prohibit discharging nonstormwater (cross-connections) into the storm sewer.

The permit system requires industrial facilities that discharge stormwater associated with industrial activity to submit sampling data, a description of stormwater management practices, and certification that the discharge does not contain processed water, domestic sewage, or hazardous wastes. Group applications, industry category by category, are permitted and sometimes encouraged. Permits are issued on a systemwide basis for municipal separate storm sewers. Municipalities are first required to describe their existing stormwater management program, identify all known outfalls, and conduct field screening for illicit connections. (See Chapter 8 for schematics of separate storm sewer systems, pollution inputs, and illicit connections.) The municipalities are then required to verify illicit connections, conduct representative sampling, and describe priorities for stormwater management during the five-year permit term. The data collected during these phased tasks will allow the permit to be developed for site-specific conditions. As stated, stormwater management may have the dual objectives of also providing flood control and best management practices that would provide such dual benefits should be included in the plan.

Relation to Groundwater Quality. In Section 319, the Clean Water Act (1987) strengthens the regulatory link between diffuse (nonpoint) pollution and groundwater quality. The CWA specifically requires states to select best management practices, taking into account the impact of the practice on groundwater quality. The U.S. Senate report explained (Thompson et al., 1989): "States are required to consider impact of management on groundwater quality. Because of the intimate hydrologic relationship that often exists between surface and ground-water, it is possible that measures taken to reduce runoff of surface water containing contaminants may increase transport of these contaminants to groundwater. The State should be aware of this possibility, when defining best management practices, especially in aquifer recharge areas."

Coastal Zone Management Act (PL 92-583 and PL 104-150). The Coastal Zone Management Act was originally passed by the 92nd Congress in 1972. In 1990, the act was reauthorized and included specific provisions to tackle nonpoint pollution problems of coastal area. This act was developed in response to the high rate of development in coastal states and out of concern about the environmental effects of this growth. It is expected that early in this century, about one-half of the U.S. population will be living near coastal waters in regions that make up only 10% of the U.S. land area.

Section 6217 of the 1990 reauthorization requires that the 29 states and territories with approved coastal zone management programs develop coastal nonpoint pollution control programs. If these original management measures fail to produce the necessary coastal water quality improvements, a state or territory must then implement additional management measures to address remaining water quality problems. The programs will update or expand the state programs developed under Section 319 of the Clean Water Act. There should also be an assurance that the implementation of management measures will ensure. Mechanisms of implementation may include permit programs, zoning, bad actor laws, enforceable water quality standards, and general environmental laws and prohibitions. States may also use voluntary approaches such as economic incentives if they are backed by appropriate regulations (U.S. EPA, 1996).

Federal Agriculture Improvement and Reform Act (the Farm Bill, 1996). Originally, the Clean Water Act was perceived as being weak on agricultural nonpoint sources, and the programs had to rely on voluntary participation of farmers and incentives. However, by the judicial process (*Pronsolino et al. v. Marcus and Brower,* 2000), Section 303 of the Clean Water Act and the authority of the EPA was also affirmed to include nonpoint pollution abatement in agricultural and forested watersheds. The farm bill of 1996 then provides the tools to achieve the water quality goals in agricultural watersheds.

The conservation provisions of the 1966 farm bill simplified existing conservation programs that were practiced in the agricultural sector since the Dust Bowl devastation and improved their flexibility and efficiency. Three major programs represent the key conservation features of the farm bill: the conservation reserve program, the environmental quality incentives program, and the wetland conservation program.

Conservation Reserve Program (CRP). The CRP gives the Natural Resources Conservation Service the authority to make annual rental payments for 10 years to farmers who retire highly erodible land and land bordering bodies of water from farming and plant it with such permanent cover crops as grasses, legumes, and trees. The CRP stream buffers can idle cropland for up to 30 m (100 ft) from the water's edge. Under the "sodbuster" provisions (Subchapter II), to retain the benefits, farmers must follow an approved conservation system when plowing fields that were not previously in use for crop production. The farm bill allows up to 15.2 million hectares (36.4 million acres) to be enrolled at any one time. New enrollments can replace expired or terminated contracts.

Environmental Quality Incentives Program (EQIP). This program sets priority areas where significant water, soil, and related natural resource problems exist. It establishes five- to 10-year contracts that provide technical assistance and pay up to 75% of the costs of conservation practices such as manure management systems, pest management, and erosion control. It defines land eligible for EQIP contracts as agricultural land that poses a serious problem to soil, water, or related resource.

Wetland Conservation and Wetland Reserve Programs (Swampbuster). Swampbuster programs envision having an enrollment of 406,000 ha (975,000 acres). The goal of the program is no net loss of wetlands. It encourages protection and restoration of wetlands and provides 75 to 100% cost sharing for permanent easements and 50 to 75% for 30-year easements. Cost sharing will help pay for restoration of wetlands. Of interest are compliance provisions incorporated in the act. To qualify for *market transition payments,* which replace traditional farm subsidies, farm operators must agree to abide by the conservation compliance and wetland conservation (swampbuster) provision in the 1996 farm bill. This is a powerful incentive to farmers to enter and carry out the provisions of the act [including those that will transpire from the Section 303(d) TMDL provisions of the Clean Water Act].

Other Federal Laws That Affect Diffuse Pollution and Water Quality Management. Among the most complicating factors in diffuse pollution abatement and water quality management are the plethora of laws affecting the decision-making process and specifying various sometimes-conflicting environmental policies. For example, water quality standards are derived from both the Clean Water Act and the Safe Drinking Water Act. The statutory federal laws affecting diffuse pollution, in addition to the laws mentioned above, include:

Environmental Laws

1. National Environmental Policy Act
2. Clean Air Act Amendments
3. Safe Drinking Water Act
4. Federal Insecticide, Fungicide and Rodenticide Act
5. Oil Pollution Act of 1990
6. Pollution Prevention Act
7. Toxic Substances Control Act
8. Superfund Amendments and Reauthorization Act
9. Wild and Scenic Rivers Act

10. North American Wetlands Conservation Act
11. Endangered Species Act
12. Harmful Algal Bloom and Hypoxia Research and Control Act of 1998

Floodplain Control and Water Resources Management

13. Flood Control Act and Amendments
14. National Flood Insurance Program
15. Flood Disaster Protection Act
16. Water Resources Development Act and Amendments
17. Watershed Protection and Flood Prevention

Mining

18. Surface Mining Control and Reclamation Act
19. Federal Land Policy and Management Act

State Laws and Local Ordinances

Many states have enacted effective diffuse pollution control laws, and local communities have followed with local ordinances. It is beyond the scope of this book to describe the programs in each state or community. Readers should follow up-to-date descriptions of hundreds of programs and initiatives published by the EPA's Web sites (*www.epa.gov/owow/npsw* or *www.epa.gov.owow.tmdl*) that have state-by-state links to the state programs. These programs are carried in addition, or as a supplement, to federally mandated programs. Sections 303(d) and 319 of the Clean Water Act provide impetus and partial funding to state and local programs. Most state programs provide cost sharing for installation of best management practices. Some states (e.g., Wisconsin, Florida, Maryland) have developed their own programs and authorized creation of state funds for nonpoint pollution and/or stormwater management. Other states rely on obtaining most of their support through federal assistance.

Local Natural Resources Conservation Service offices of the USDA are responsible for implementing programs based on the Federal Agriculture Improvement and Reform Act. NRCS specialist work with individual farmers and provide site-specific assistance in development of their nonpoint pollution control measures and contracting with them to enroll in conservation reserve and wetland reserve programs.

European Union Water Framework Directive

The EU Water Framework Directive was adopted by the EU parliament in December 2000. Similar to the shift from effluent base controls to water quality–based controls and total maximum daily load that occurred in the United States during the 1990s, this directive puts emphasis on river basin management plans. The following are the key aims of the directive taken from the Web site *http://europa.eu.int/water/water-framework* and other sources (McCann, 2001):

- Expanding the scope of water protection to all waters, surface waters, and groundwater
- Achieving "good status" for all waters by a set deadline
- Applying water management based on river basins
- Employing a combined approach of emission limit values and quality standards
- Getting the prices right
- Getting the citizen involved more closely
- Streamlining legislation

The directive emphasizes that the best model for a single system of water management is management by river basin—the natural geographical and hydrological unit—instead of according to administrative or political boundaries. Initiatives moved forward by the states on the Maas, Schelde, or Rhine river basins have served as positive examples of this approach, with their cooperation and joint objective setting across member state borders, and in the case of the Rhine, beyond EU territory. Although several member states already take a river basin approach, this is at present not the case everywhere. For each river basin district, some of which will traverse national frontiers, a river basin management plan will need to be established and updated every six years.

Objectives of the Water Framework Directive. The key objectives of water quality in a European context are general protection of the aquatic ecology, specific protection of unique and valuable habitats, protection of drinking water resources, and protection of bathing water. All these objectives must be integrated for each river basin. It is clear that the last three—special habitats, drinking water areas, and bathing water—apply only to specific bodies of water (e.g., those supporting special wetlands; those identified for drinking water abstraction, those generally used as bathing areas). In contrast, ecological protection should apply to all waters: The central requirement of the treaty is that the environment be protected in its entirety to a high level.

Ecological Protection. For this reason, a general requirement for ecological protection and a general minimum chemical standard were introduced to cover all surface waters. These are the two elements "good ecological status" and "good chemical status." *Good ecological status* is defined in terms of the quality of the biological community, the hydrological characteristics, and the chemical characteristics. As no absolute standards for biological quality can be set that apply across the EU, because of ecological variability, the controls are specified as allowing only a slight departure from the biological community, which would be expected in conditions of minimal anthropogenic impact. A set of procedures for identifying that point for a given body of water, and establishing particular chemical or hydromorphological standards to achieve it, is provided, together with a system for ensuring that each member state interprets the procedure in a consistent way (to ensure comparability). The system is somewhat complicated, but this is inevitable given the extent of ecological variability and the large number of parameters that must be dealt with.

Chemical Protection. *Good chemical status* is defined in terms of compliance with all the quality standards established for chemical substances at the European level. The directive also provides a mechanism for renewing these standards and establishing new ones by means of a prioritization mechanism for hazardous chemicals. This will ensure at least a minimum chemical quality, particularly in relation to very toxic substances, everywhere in the EU.

Other Uses. As mentioned above, the other uses or objectives for which water is protected apply in specific areas, not everywhere. Therefore, the obvious way to incorporate them is to designate specific protection zones within the river basin which must meet these different objectives. The overall plan of objectives for the river basin will then require ecological and chemical protection everywhere as a minimum, but where more stringent requirements are needed for particular uses, zones will be established and higher objectives set within them.

Combining Ecological Goals with Flood Protection and Water Supply Objectives. There is one other category of uses that does not fit into this picture. It is the set of uses which adversely affect the status of water but which are considered essential on their own terms—they are overriding policy objectives. The key examples are flood protection and essential drinking water supply, and the problem is dealt with by providing derogations from the requirement to achieve good status for these cases as long as all appropriate mitigation measures are taken. Less clear-cut cases are navigation and power generation, where the activity is open to alternative approaches (transport can be switched to land; other means of power generation can be used). Derogations are provided for those cases also, but subject to three tests: that the alternatives are technically impossible, that they are prohibitively expensive, or that they produce a worse overall environmental result.

Groundwater Protection. The presumption in relation to groundwater should broadly be that it should not be polluted at all. For this reason, setting chemical quality standards may not be the best approach, as it gives the impression of an allowed level of pollution that member states are not being encouraged to decrease. A few such standards have been established at the European level for particular pollutants (nitrates, pesticides, and biocides), and these must always be adhered to. But for general protection, the EU has taken a precautionary approach. It comprises a prohibition on direct discharges to groundwater, and (to cover indirect discharges) a requirement to monitor groundwater bodies so as to detect changes in chemical composition and to reverse any anthropogenically induced upward pollution trend. Taken together, these should ensure the protection of groundwater from all contamination, according to the principle of minimum anthropogenic impact.

Quantity is also a major issue for groundwater. Briefly, the issue can be put as follows: There is only a certain amount of recharge into a groundwater each year, and of this recharge, some is needed to support connected ecosystems (whether they be surface water bodies or terrestrial systems such as wetlands). For good management, only that portion of the overall recharge not needed by the ecology can be abstracted—this is the sustainable resource, and the directive limits abstraction to that quantity. One of the innovations of the directive is that it provides a framework for integrated management of groundwater and surface water for the first time at the European level.

River Basin Management Plan. All the elements of this analysis must be set out in a plan for the river basin. The plan is detailed account of how the objectives set for the river basin (ecological status, quantitative status, chemical status, and protected area objectives) are to be reached within the time scale required. The plan includes all the results of the foregoing analysis: the river basin's characteristics, a review of the impact of human activity on the status of waters in the basin, estimation of the effect of existing legislation and the remaining gap to meeting these objectives; and a set of measures designed to fill the gap. One additional component is that an economic analysis of water use within the river basin must be carried out. This is to enable a rational discussion of the cost-effectiveness of the various measures possible. It is essential that all interested parties are fully involved in this discussion and, indeed, in the preparation of the river basin management plan as a whole, which brings the final major element of the proposal, the public participation requirements.

Public Participation. In getting waters clean, the role of citizens and citizens' groups will be crucial. There are two main reasons for an extension of public participation. The first is that the decisions on the most appropriate measures to achieve the objectives in the river basin management plan will involve balancing the interests of various groups. The economic analysis requirement is intended to provide a rational basis for this, but it is essential that the process is open to the scrutiny of those who will be affected.

The second reason concerns enforceability. The greater the transparency in the establishment of objectives, the imposition of measures, and the reporting of standards, the greater the care that Member states will take to implement the legislation in good faith, and the greater the power of the citizens to influence the direction of environmental protection, whether through consultation or, if disagreement persists, through the complaints procedures and the courts. Caring for Europe's waters will require more involvement of citizens, interested parties, and nongovernmental organizations (NGOs). To that end, the water framework directive will require information and consultation when river basin management plans are established: The river basin management plan must be issued in draft, and the background documentation on which the decisions are based must be made accessible. Furthermore, a biannual conference will be organized to provide for a regular exchange of views and experiences in implementation. Too often in the past, implementation has been left unexamined until it is too late—until member states are already woefully behind schedule and out of compliance. By establishing very early on a network for the exchange of information and experience between water professionals throughout the EU, the framework directive will ensure that this does not happen.

Water Pricing and Fees to Pay for the Plan. The need to conserve adequate supplies of a resource for which demand is increasing continuously is also one of the drivers behind what is arguably one of the directives's most important innovations—the introduction of pricing. Adequate water pricing acts as an incentive for the sustainable use of water resources and thus helps to achieve the environmental objectives under the directive. Member states will be required to ensure that the price charged to water consumers—such as for the abstraction and distribution of fresh water and the collection and treatment of waste water—reflects the true costs. Whereas this principle has a long tradition in some countries, this is currently not the case in others. However, derogations will be possible: as in less-favored areas or to provide basic services at an affordable price.

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