CHAPTER 1

INTRODUCTION

概 论

1-1 WHAT IS ENVIRONMENTAL ENGINEERING?

Professions, Learned and Otherwise

Webster's dictionary defines the learned professions as law, medicine, and theology. It has been suggested that engineers may not be learned enough to rank among these because the study of law, medicine, or theology requires considerably more than four years of undergraduate work. There was a time, some hundred years ago, when the four-year engineering program was two years longer than those of the learned professions! At any rate, *Webster's* is willing to concede that engineering, along with teaching and writing, is a profession even if it is not "learned." At a minimum, a profession is an occupation that requires advanced training in the liberal arts or sciences and mental rather than manual work.

But being a professional is more than being in or of a profession. True professionals are those who pursue their learned art in a spirit of public service (ASCE, 1973). True professionalism is defined by the following seven characteristics:

1. Professional decisions are made by means of general principles, theories, or propositions that are independent of the particular case under consideration.
2. Professional decisions imply knowledge in a specific area in which the person is expert. The professional is an expert only in his or her profession and not an expert at everything.
3. The professional's relations with his or her clients are objective and independent of particular sentiments about them.
4. A professional achieves status and financial reward by accomplishment, not by inherent qualities such as birth order, race, religion, sex, or age or by membership in a union.
5. A professional's decisions are assumed to be on behalf of the client and to be independent of self-interest.
6. The professional relates to a voluntary association of professionals and accepts only the authority of those colleagues as a sanction on his or her own behavior.
7. A professional is someone who knows better what is good for clients than do the clients. The professional's expertise puts the client into a very vulnerable position. This vulnerability has necessitated the development of strong professional codes and ethics, which serve to protect the client. Such codes are enforced through the colleague peer group (Schein, 1968).

The branch of engineering called civil engineering, from which environmental engineering is primarily, but not exclusively, derived, has an established code of ethics that embodies these principles. The code is summarized in Figure 1-1.

And What Is Engineering?

Engineering is a profession that applies mathematics and science to utilize the properties of matter and sources of energy to create useful structures, machines, products, systems, and processes.

AMERICAN SOCIETY OF CIVIL ENGINEERS
CODE OF ETHICS

Fundamental Principles

Engineers uphold and advance the integrity, honor and dignity of the engineering profession by:

1. using their knowledge and skill for the enhancement of human welfare and the environment;
2. being honest and impartial and serving with fidelity the public, their employers and clients;
3. striving to increase the competence and prestige of the engineering profession; and
4. supporting the professional and technical societies of their disciplines.

Fundamental Canons

1. Engineers shall hold paramount the safety, health and welfare of the public and shall strive to comply with the principles of sustainable development in the performance of their professional duties.
2. Engineers shall perform services only in areas of their competence.
3. Engineers shall issue public statements only in an objective and truthful manner.
4. Engineers shall act in professional matters for each employer or client as faithful agents or trustees, and shall avoid conflicts of interest.
5. Engineers shall build their professional reputation on the merit of their services and shall not compete unfairly with others.
6. Engineers shall act in such a manner as to uphold and enhance the honor, integrity, and dignity of the engineering profession.
7. Engineers shall continue their professional development throughout their careers, and shall provide opportunities for the professional development of those engineers under their supervision.

FIGURE 1-1
American Society of Civil Engineers code of ethics. (ASCE, 2005)

This implies that there are fundamental differences between scientists and engineers. The key is not so much in the individual parts of the definition, but rather in the integration of the parts. It is inherent in the professional development of the engineer that he or she must attain experience, practice, and judgment under the tutelage of an experienced engineer. Engineering has at least this much in common with the learned professions!

Engineers are frequently pressed to explain why they are different from scientists. Consider the following distinction: "Scientists discover things. Engineers make them work" (MacVicar, 1983).

On to Environmental Engineering

The Environmental Engineering Division of the American Society of Civil Engineers (ASCE) has published the following statement of purpose:

> Environmental engineering is manifest by sound engineering thought and practice in the solution of problems of environmental sanitation, notably in the provision of safe, palatable, and ample public water supplies; the proper disposal of or recycle of wastewater and solid wastes; the adequate drainage of urban and rural areas for proper sanitation; and the control of water,

> soil, and atmospheric pollution, and the social and environmental impact of these solutions. Furthermore it is concerned with engineering problems in the field of public health, such as control of arthropod-borne diseases, the elimination of industrial health hazards, and the provision of adequate sanitation in urban, rural, and recreational areas, and the effect of technological advances on the environment (ASCE, 1977).

Thus, we may consider what environmental engineering is not. It is not concerned primarily with heating, ventilating, or air conditioning (HVAC), nor is it concerned primarily with landscape architecture. Neither should it be confused with the architectural and structural engineering functions associated with built environments, such as homes, offices, and other workplaces.

1-2 INTRODUCTION TO ENVIRONMENTAL ENGINEERING

Where Do We Start?

We have used the ASCE definition of an environmental engineer as a basis for this book. Given the constraints of time and space, we have limited ourselves to the following topics from the definition:

1. Provision of safe, palatable, and ample public water supplies
2. Proper disposal of or recycling of wastewater and solid wastes
3. Control of water, soil, and atmospheric pollution (including noise as an atmospheric pollutant)

A Short Outline of This Book

This short outline provides an overview of the book. It is derived from the ASCE definition of environmental engineering.

Chapter 2, Materials and Energy Balances, introduces tools that are used in environmental engineering. These tools will be applied throughout the book to develop a fundamental understanding of the subject matter and as a method for developing equations to analyze and describe the behavior of environmental processes.

Hydrology is the subject of Chapter 3. In that chapter we discuss the hydrologic cycle and the analyses used to ensure an ample supply of water from either surface water or groundwater. Because hydrology is concerned with flooding as well as with droughts, we also touch on the "adequate drainage" portion of the environmental engineering definition. The discussion of the physics of groundwater movement will give you the tools you need to understand problems of groundwater pollution.

In Chapter 4 we turn from water quantity to water quality. First, we review some basic chemistry concepts and calculations; then we examine some characteristics of water that affect its quality. Finally, we explain how to treat water for public consumption.

In Chapter 5 we consider the effects of various materials on water quality. In particular, we spend a good deal of time examining the effects of organic pollution on the levels of dissolved oxygen in the water. Dissolved oxygen is required for higher forms of aquatic life, such as fish, to survive.

Wastewater treatment is the subject of Chapter 6. Here, we look at how we can remove pollutants that reduce the quality of the lake or stream. Our emphasis is on municipal wastewater treatment.

In Chapters 7 and 8, we turn to the control of atmospheric pollution and noise control. After a brief introduction to the health effects and other environmental impacts of air pollutants and noise, we examine transport processes that carry pollutants from their source to people, as well as some methods of control.

Solid waste is the topic of Chapter 9. Collection, disposal, and recycling of solid waste are fundamental needs of our complex urban society. This chapter will present some of the tools for understanding and solving problems in solid waste management.

Hazardous waste is the topic of Chapter 10. Methods of dealing with abandoned hazardous waste sites and managing the wastes we are continually generating are discussed. We examine some alternatives for treatment of these wastes as an application of the technologies addressed in earlier chapters.

The final chapter is a brief examination of ionizing radiation. A brief introduction to health effects of radiation is followed by a discussion of management techniques for both radioactive waste and x-rays.

The appendices provide tables of the properties of air, water, and selected chemicals.

Tables at the inside front and back covers provide a list of atomic masses, the periodic table, conversion factors, and the International System of Units (SI) naming convention for factors of 10.

1-3 ENVIRONMENTAL SYSTEMS OVERVIEW

Systems as Such

Before we begin in earnest, we thought it worth taking a look at the problems to be discussed in this text in a larger perspective. Engineers like to call this the "systems approach," that is, looking at all the interrelated parts and their effects on one another. In environmental systems it is doubtful that mere mortals can ever hope to identify all the interrelated parts, to say nothing of trying to establish their effects on one another. The first thing the systems engineer does, then, is to simplify the system to a tractable size that behaves in a fashion similar to the real system. The simplified model does not behave in detail as the system does, but it gives a fair approximation of what is going on.

We have followed this pattern of simplification in our description of three environmental systems: the water resource management system, the air resource management system, and the solid waste management system. Pollution problems that are confined to one of these systems are called single-medium problems if the medium is either air, water, or soil. Many important environmental problems are not confined to one of these simple systems but cross the boundaries from one to the other. These problems are referred to as *multimedia* pollution problems.

Water Resource Management System

Water Supply Subsystem. The nature of the water source commonly determines the planning, design, and operation of the collection, purification, transmission, and distribution works. The two major sources used to supply community and industrial needs

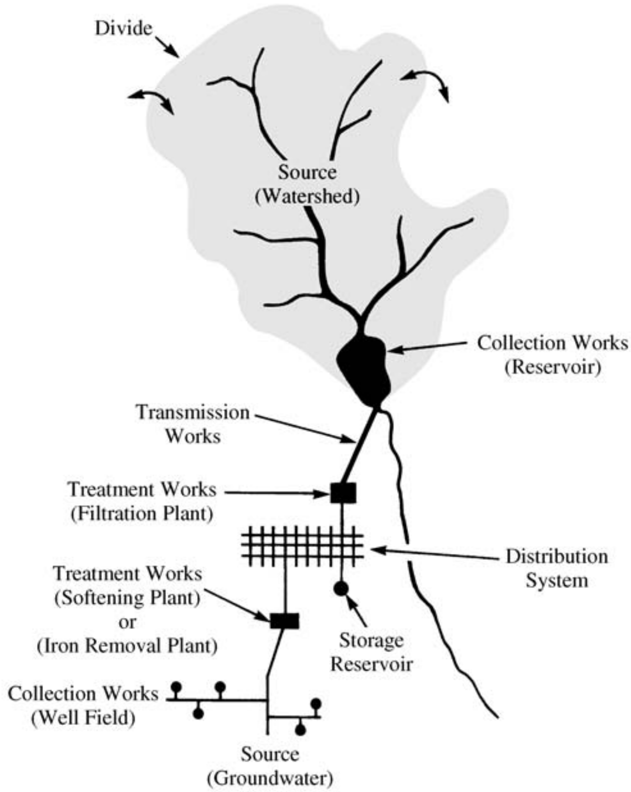

FIGURE 1-2
An extension of the water supply resource system.

are referred to as *surface water* and *groundwater*. Streams, lakes, and rivers are the surface water sources. Groundwater sources are those pumped from wells.

Figure 1-2 depicts an extension of the water resource system to serve a small community. The source in each case determines the type of collection works and the type of treatment works.* The pipe network in the city is called the distribution system. The pipes themselves are often referred to as *water mains*. Water in the mains generally is kept at a pressure between 200 and 860 kilopascals (kPa). Excess water produced by the treatment plant during periods of low *demand*† (usually the nighttime hours) is held in a storage reservoir. The storage reservoir may be elevated (the ubiquitous water tower), or it may be at ground level. The stored water is used to meet high demand during the day. Storage compensates for changes in demand and allows a smaller treatment plant to be built. It also provides emergency backup in case of a fire.

Population and water-consumption patterns are the prime factors that govern the quantity of water required and hence the source and the whole composition of the water

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***Works* is a noun used in the plural to mean "engineering structures." It is used in the same sense as *art works.*

†*Demand* is the use of water by consumers. This use of the word derives from the economic term meaning "the desire for a commodity." The consumers express their desire by opening the faucet or flushing the water closet (W.C.).

resource system. One of the first steps in the selection of a suitable water-supply source is determining the demand that will be placed on it. The essential elements of water demand include average daily water consumption and peak rate of demand. Average daily water consumption must be estimated for two reasons: (1) to determine the ability of the water source to meet continuing demands over critical periods when surface flows are low or groundwater tables are at minimum elevations, and (2) for purposes of estimating quantities of stored water that would satisfy demands during these critical periods. The peak demand rates must be estimated in order to determine plumbing and pipe sizing, pressure losses, and storage requirements necessary to supply sufficient water during periods of peak water demand.

Many factors influence water use for a given system. For example, the mere fact that water under pressure is available stimulates its use, often excessively, for watering lawns and gardens, for washing automobiles, for operating air-conditioning equipment, and for performing many other activities at home and in industry. The following factors have been found to influence water consumption in a major way:

1. Climate
2. Industrial activity
3. Meterage
4. System management
5. Standard of living

The following factors also influence water consumption but to a lesser degree: extent of sewerage, system pressure, water price, and availability of private wells.

If the demand for water is measured on a *per capita** basis, climate is the most important factor influencing demand. This is shown dramatically in Table 1-1. The average annual precipitation for the "wet" states is about 100 cm per year while the average annual precipitation for the "dry" states is only about 25 cm per year. Of course, the "dry" states are also considerably warmer than the "wet" states.

The influence of industry is to increase per capita water demand. Small rural and suburban communities will use less water per person than industrialized communities.

The third most important factor in water use is whether individual consumers have water meters. Meterage imposes a sense of responsibility not found in unmetered residences and businesses. This sense of responsibility reduces per capita water consumption because customers repair leaks and make more conservative water-use decisions almost regardless of price. Because water is so inexpensive, price is not much of a factor.

Following meterage closely is the aspect called system management. If the water distribution system is well managed, per capita water consumption is less than if it is not well managed. Well-managed systems are those in which the managers know when and where leaks in the water main occur and have them repaired promptly.

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*Per capita is a Latin term that means "by heads." Here it means "per person." This assumes that each person has one head (on the average).

TABLE 1-1
Total fresh water withdrawals for public supply[a]

State	Withdrawal (Lpcd)[b]
"Wet"	
Connecticut	471
Michigan	434
New Jersey	473
Ohio	488
Pennsylvania	449
Average	463
"Dry"	
Nevada	1,190
New Mexico	797
Utah	1,083
Average	963

[a]Compiled from Hutson et al. (2001).
[b]Lpcd = liters per capita per day.

Climate, industrial activity, meterage, and system management are more significant factors controlling water consumption than the standard of living. The rationale for the last factor is straightforward. Per capita water use increases with an increased standard of living. Highly developed countries use much more water than the less developed nations. Likewise, higher socioeconomic status implies greater per capita water use than lower socioeconomic status.

The total U.S. water withdrawal for all uses (agricultural, commercial, domestic, mining, and thermoelectric power), including both fresh and saline water, was estimated to be approximately 5,400 liters per capita per day (Lpcd) in 2000 (Hutson, et al., 2001). The amount for U.S. public supply (domestic, commercial and industrial use) was estimated to be 580 Lpcd in 2000 (Hutson, et al., 2001). The American Water Works Association estimated that the average daily household water use in the United States was 1,320 liters per day in 1999 (AWWA, 1999). For a family of three, this would amount to about 440 Lpcd. The variation in demand is normally reported as a factor of the average day. For metered dwellings the factors are as follows: maximum day = 2.2 $\times$ average day; peak hour = 5.3 $\times$ average day (Linaweaver et al., 1967). Some mid-Michigan average daily use figures and the contribution of various sectors to demand are shown in Table 1-2.

International per capita domestic water use has been estimated by the Pacific Institute for Studies in Development, Environment, and Security (Pacific Institute, 2000). For example, they report the following (all in Lpcd): Australia, 1,400; Canada, 430; China, 60; Ecuador, 85; Egypt, 130; Germany, 270; India, 30; Mexico, 130; Nigeria, 25.

Wastewater Disposal Subsystem. Safe disposal of all human wastes is necessary to protect the health of the individual, the family, and the community, and also to prevent

TABLE 1-2
Examples of variation in per capita water consumption

		Percent of per capita consumption		
Location	Lpcd	Industry	Commercial	Residential
Lansing, MI	512	14	32	54
East Lansing, MI	310	0	10	90
Michigan State University	271	0	1	99

Data from local treatment plants, 2004.

the occurrence of certain nuisances. To accomplish satisfactory results, human wastes must be disposed of so that:

1. They will not contaminate any drinking water supply.
2. They will not give rise to a public health hazard by being accessible to *vectors* (insects, rodents, or other possible carriers) that may come into contact with food or drinking water.
3. They will not give rise to a public health hazard by being accessible to children.
4. They will not cause violation of laws or regulations governing water pollution or sewage disposal.
5. They will not pollute or contaminate the waters of any bathing beach, shellfish-breeding ground, or stream used for public or domestic water-supply purposes, or for recreational purposes.
6. They will not give rise to a nuisance due to odor or unsightly appearance.

These criteria can best be met by the discharge of domestic sewage to an adequate public or community sewerage system (U.S. PHS, 1970). Where no community sewer system exists, on-site disposal by an approved method is mandatory.

In its simplest form the wastewater management subsystem is composed of six parts (Figure 1-3). The source of wastewater may be either industrial wastewater or domestic sewage or both.* Industrial wastewater may be subject to some pretreatment on site if it has the potential to upset the municipal wastewater treatment plant (WWTP). Federal regulations refer to municipal wastewater treatment systems as publicly owned treatment works, or POTWs.

The quantity of sewage flowing to the WWTP varies widely throughout the day in response to water usage. A typical daily variation is shown in Figure 1-4. Most of the water used in a community will end up in the sewer. Between 5 and 15 percent of the water is lost in lawn watering, car washing, and other consumptive uses. Consumptive use may be thought of as the difference between the average rate that water

*Domestic sewage is sometimes called sanitary sewage, although it is far from being sanitary!