Chapter 1 Introduction

1.3 What is Environmental Engineering?

Engineering involves the application of fundamental scientific principles to the development and implementation of technologies needed to satisfy human needs. For environmental engineering the body of knowledge whose application defines the discipline is environmental science.

What is environmental science?

Environmental science deals with the study of the processes in water, air, and soil and organisms which lead to pollution or environmental damage, and the scientific basis for the establishment of a standard which can be considered acceptably clean, safe and healthy for human beings and the natural ecosystem (physical and natural sciences).

Whereas the disciplines of biology, chemistry, and physics are focused on a particular aspect of natural science, environmental science in its broadest sense encompasses all the fields of natural science. The historical focus of study for environmental scientists has been, of course, the natural environment. By this, we mean the atmosphere, the land, the water and their inhabitants as differentiated from the built environment.

Quantitative environmental science is an organized collection of mathematical theories that may be used to describe and explore environmental relationships, while environmental science is an organized body of knowledge about environmental relationships.

What is Environmental Engineering?

Environmental engineering is concerned with the design, manufacture, installation and operation of the engineering systems that sustain and control the environments required by people and processes. It impacts on all aspects of everyday life. Environmental engineers achieve their aims by the utilization and conversion of the many energy resources that surround us - the fossil fuels and the renewable energies. There is a growing awareness that the quality of life must be balanced by the conservation of these resources and the protection of the environment. Environmental engineers understand this balance and seek to harness energy resources in an environmentally friendly manner.

The Environmental Engineering Division of the American Society of Civil Engineers (ASCE) has published the following statement of purpose that may be used to show the relationship between environmental science and environmental engineering:

> 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.

The protection of the environment thus involves social, political, economic, and legal issues far beyond the domain of any single scientific or engineering discipline. These issues are broader in scope than environmental engineering, but they are issues about which an environmental engineer should be knowledgeable and are issues which are likely to be a component of the work of the environmental engineer.

However, this course remains largely directed toward the more narrow issues of the technical basis for assessing and eliminating the effects of pollutants in the environment. The engineering science which underpins this effort represents the fundamental knowledge base required of environmental engineers. *Environmental pollution is the contamination of the environment with substances that are potentially injurious to human, plant, and animal life or the quality of that life*. The term *contaminant* is sometimes interchangeably used with pollution, but generally we will reserve the term pollutant for a substance that has a demonstrated adverse effect on human or ecological health. A contaminant is a substance that is not a component of the natural or “clean” system, but it may not pose a hazard. One task of an environmental engineer is to help differentiate between harmless contaminants and pollutants. Regardless of the form of pollution environmental pollution involves three important components.

Pollutant Release ⇒ Environmental Processes ⇒ Receptors/ Effects

The most important of these components is the receptors, i.e., plants, animals, and/or people. Pollution only occurs when adverse receptor effects exit. Pollution emissions, at the opposite end, are the source of the problem and generally the most convenient element to control. Linking the source to be controlled and the receptors are the mixing and transformation processes that occur in the environment.

The identification, evaluation, and resolution of a particular pollution problem typically evolves in the reverse direction implied by the above, that is

1. Identification of an adverse receptor effect.
2. Determination of the substance of substances causing that effect and estimation of the threshold concentration below which the effect is no longer important.
3. Identification of the source of the polluting substances between source and receptor so that the threshold receptor levels (the no-effects or acceptable effects level) can be translated into a safe emission level.
4. Control of the source to achieve the safe emission level.

An environmental engineer is the type of engineer that must work with each of these problems and assist in their evaluation and resolution along with other professionals like: physicians, life scientists, chemical engineer and others.

An environmental engineer would be expected to have a greater understanding of the environmental impact of engineering activities than traditionally trained engineers. In addition environmental engineer should exhibit a greater understanding of the availability and feasibility of control and waste minimization technologies than environmental scientist. Thus an environmental engineer serves in an integrated role, meshing traditional engineering activity with environmental concerns. This is depicted in Figure 1.1 where the environmental engineer is seen to hold a central position between the environmental scientist with a traditional focus on the ecosystem and the impacts of development and the industry engineer with a traditional focus within the fenceline of such a development. It is from this perspective that the environmental engineer may be best able to resolve environmental issues while balancing all external constraints, whether they are technical, economic, or societal constraints such as moral, social, political, or legal constraints.

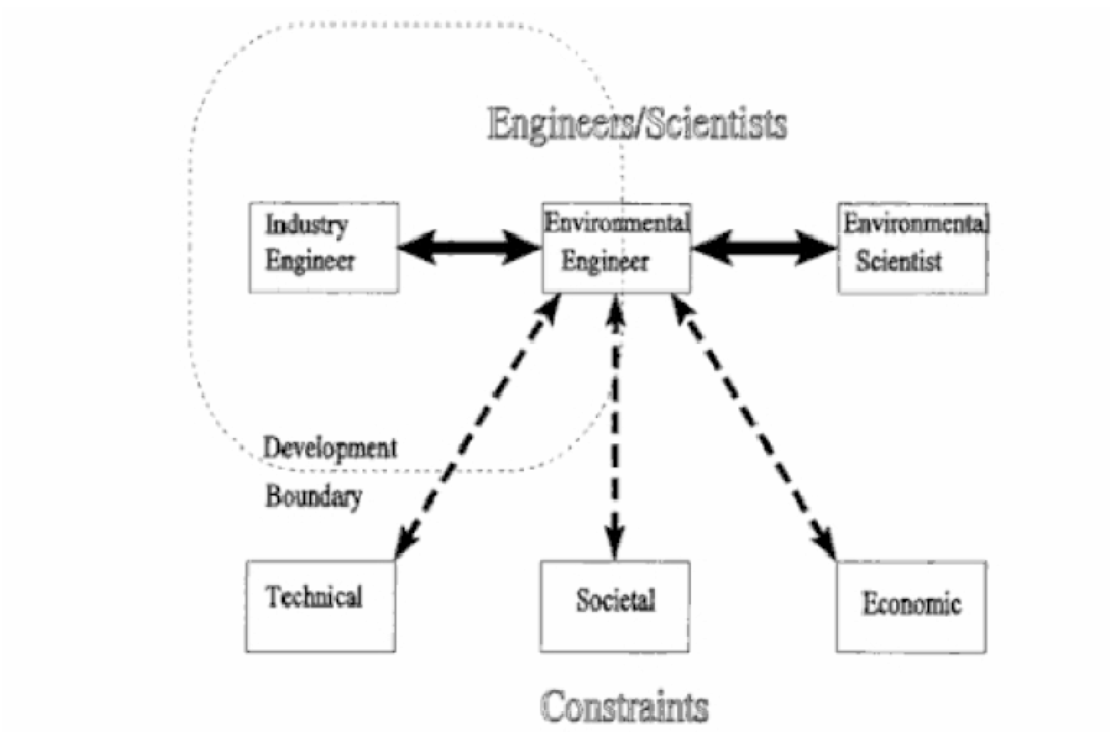

Figure 1-1 Relationship between an environmental engineering and other disciplines and constraints.

The defining activity of an environmental engineer is thus the application of engineering science to the analysis of environmental processes and effects and the design of control systems designed to minimize adverse effects on those processes.

Environmental Systems Overview

At large scale we introduce the ecosystem. On the large scale shown in Figure 1-2, system of natural science called ecosystem is the framework for all environmental systems. *Ecosystem is the relationships and interactions of plants and animals with the water, air, and soil that makes up their environment.* From this large scale, we have three environmental systems that serve as the focus of this course: *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 another. Such problems are referred to as *multimedia* pollution problems.

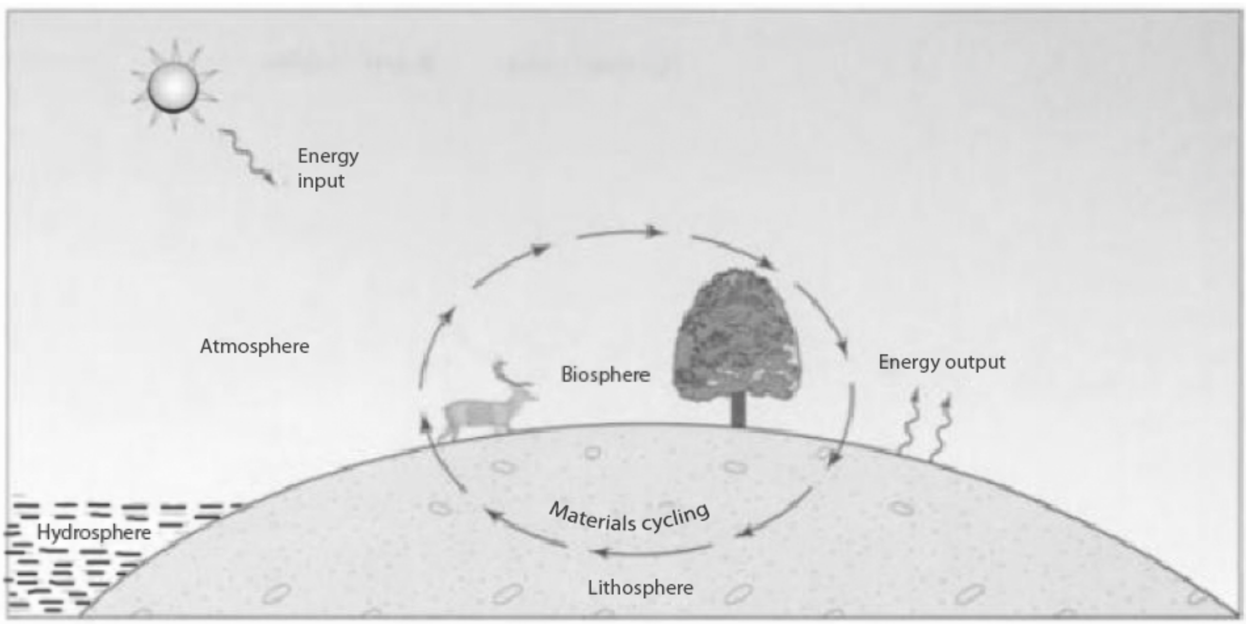

Figure 1-2 The earth as an ecosystem

A. Water Resource Management System

Water Supply Subsystem. The mature 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 are referred to as surface water and groundwater.

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 the occurrence of certain nuisances. In its simplest form the wastewater management subsystem is composed of six parts shown in figure 1-3.

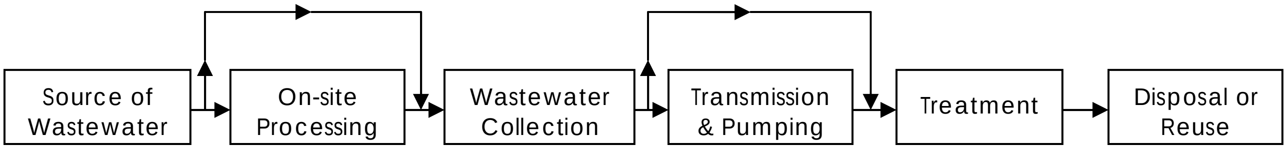

Figure 1-3 Wastewater management subsystem.

B. Air Resource Management System

Our air resource differs from our water resource in two important aspects. The first is in regard to quantity. Whereas engineering structures are required to provide an adequate water supply, air is delivered free of charge in whatever quantity we desire. The second aspect is in regard to quantity. Unlike water which can be treated before we use it, it is impractical to go about treating the air we consume. The balance of cost and benefit to obtain a desired quality of air is termed *air resource management*.

Air resource management programs are instituted for a variety of reasons. The most defensive reasons are that (1) air quality has deteriorated and there is a need for correction, and (2) the potential for a future problem is strong.

C. Solid Waste Management

A simplified block diagram of a solid waste management system is shown in Figure 1-4.

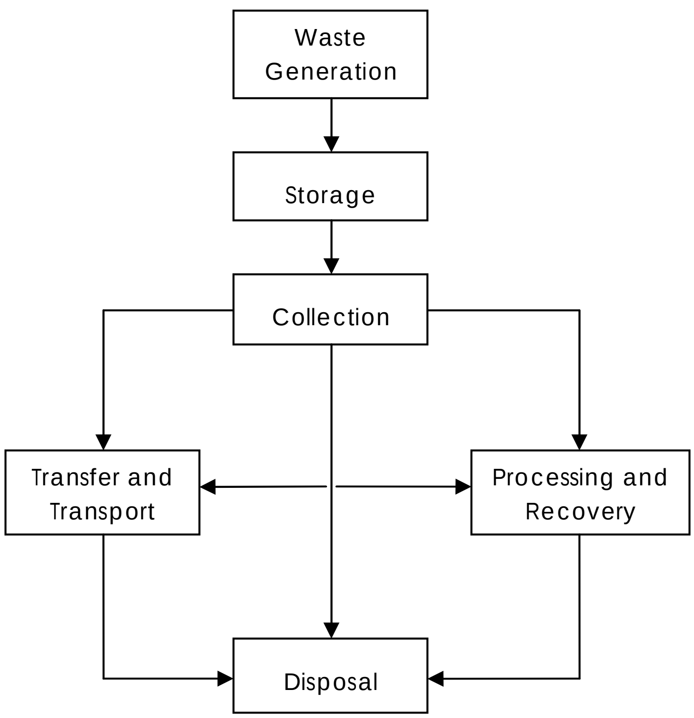

Figure 1-4

A simplified block diagram of solid waste management system

D. Multimedia Systems

Many environmental problems cross the air-water-soil boundary as illustrated in Figure 1-5 below. An example is acid rain that results from the emission of sulfur oxides and nitrogen oxides into the atmosphere. These pollutants are washed out of the atmosphere, thus cleansing it, but in turn polluting water and changing the soil chemistry, which ultimately results in the death of fish and trees

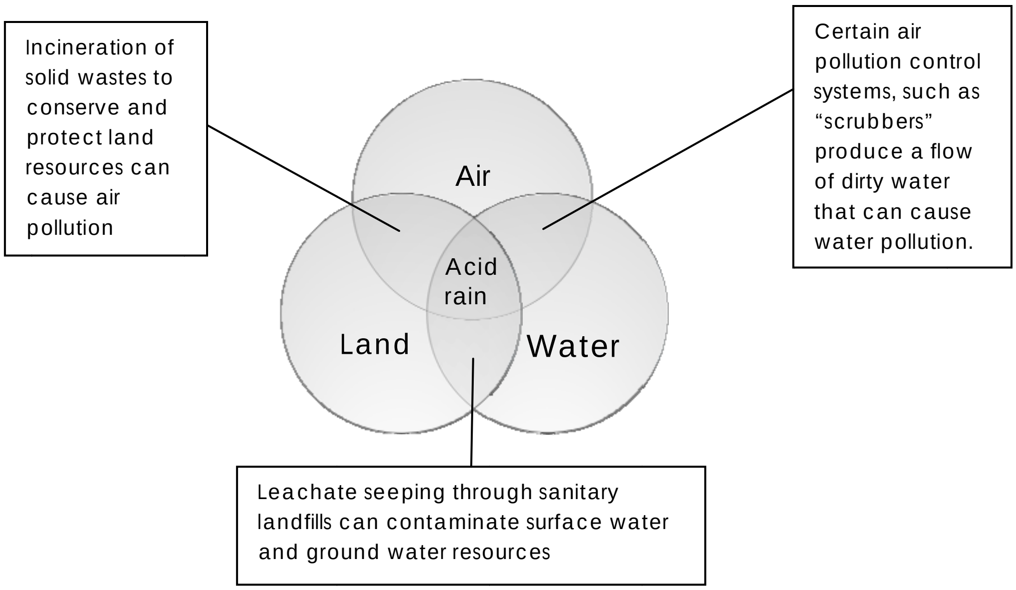

Figure 1-5 Multimedia system problems

In general, three lessons have come to view from past experience with multimedia problems. First, it is dangerous to develop models that are too simplistic. Second, environmental engineers must use a multimedia approach and, in particular, work with a multidisciplinary team to solve environmental problems. Third, the best solution to environmental pollution is waste minimization-if waste is not produced, it does not need to be treated or disposed of.

1.2 Example Activities of Environmental Engineers

It is perhaps easiest to illustrate the activities of an environmental engineer through examples. A few such examples are given below. They are presented both illustrations of tasks that an environmental engineer might be asked to perform and to provoke thought about common environmental problems and their solutions.

Example 1.1: Remediation of soil contaminated by a gasoline leak

Soil may become contaminated with gasoline as a result of a transportation accident. Often the first response is removal of some of the contaminated soil. Even after soil removal, however, it is possible that some portion of the spilled gasoline will remain. Gasoline can move rapidly through soils and any soil that contacts the gasoline will likely retain a residual equal to 10 to 20 % of the soil volume. The major health concern is often the aromatic compounds benzene, toluene, ethyl benzene, and xylene (the BTEX fraction), which may compose 10 to 20% of the gasoline. These compounds are relatively mobile in soils and even very low concentrations can render drinking water unstable.

The technology used to remediate the soil may be selected, designed, and operated by an environmental engineer. Because these compounds are relatively volatile, a popular means of remediating or cleaning near-surface soils not saturated with water is by applying a vacuum and forcing air through the soil. A vapor extraction system, and required above-ground treatment of the withdraw air, and the in-ground (or in situ) transport processes might be modeled by the environment

Example 1.2: Permit application based on atmospheric dispersion estimates

Industrial facilities are normally required to receive permission from a regulatory body before releasing contaminants into the air or water. The permission is given in the form of a license or permit that defines the amount of pollutant that can be released. And environmental engineer might be asked to support and application for such a permit by estimating or measuring the amount that needs to be released, assessing the ability to reduce that amount through some on-site treatment, and finally by modeling the impact of released material on the surrounding environment. Only by making a convincing case for the need for the pollutant releases and demonstrating that the impact on the environment is minimal will the facility be likely to receive permission for the emissions.

Example 1.3: Improving environmental performance after an audit

Often industrial firms identify potential environmental problems and solutions by conducting an environmental audit. This is similar to an accounting audit in that individuals, usually external to the company or facility, examine and evaluate the company's performance, in this case their environmental performance. External review and evaluation is an excellent wat to identify problems or solutions that might otherwise be missed. An environmental engineer might be expected to conduct such an audit, especially in cooperation with an engineer or other professional that has intimate knowledge of the individual industry or process. With the assistance of such an expert, it should be possible to identify potential problems as well as their solution by revising on-site activities.

Example 1.4: Site assessment after plant decommissioning

An industrial facility removed from service is often a potential problem because of spills or leaks of environmental pollutants during the plant operation. This is especially true for older facilities where stewardship of the environment improved over time. Practices considered quite appropriate even 5 to 10 years ago may now be considered environmentally unsound. As a result, an industrial facility is likely to require site assessment including on-site sampling after decommissioning. The range of subsequent uses available to the facility will depend on the degree of contamination and the ease of returning the site to more pristine conditions. An environmental engineer may be involved in both the assessment of the site and the design and operation of any subsequent remediation process.

Example 1.5: Estimation of volatile emissions from surface impoundment

Trace quantities of volatile contaminants may be found in industrial process waters. Often, these are treated by using the contaminated water stream as feed for bacteria in a biological treatment system. Volatile contaminants, however, may not be degraded and instead released by evaporation. It is often important to estimate the quantity of any such losses, especially in areas where such compounds (typically volatile organic compounds) may contribute to other air pollution problems such as photochemical smog and ozone pollution. An environmental engineer may be asked to estimate the fate of ant of the variety of compounds that might pass through such a system and, if necessary, design an alternative control process that reduces the evaporation rate of the volatile compounds. Often such an effort would involve a combination of direct measurements and modeling to help interpret those measurements.

Example 1.6: Mediator between industry and citizen groups

Local citizens are often concerned about environmental problems in their community. Often as a result of questionable past activities, there is very limited trust of the polluting individual or firm. The issues are often complex and not fully understood by the community and in some cases by the polluter, an environmental engineer may be asked to provide an assessment of the conditions and help the community understand the real risks associated with the environmental problems.

Example 1.7: Preparation of an environmental impact assessment

Any planned development whether commercial or industrial, is increasingly being asked to assess the environmental impact of the facility during construction and upon completion. An environmental engineer has to assess also possible impacts on the environment due the proposed development and report the extent (both in time and severity) of each actions involved in the project plan, and he is also expected to come up with the mitigation measures that have to be taken to reduce the anticipated impacts.

1.3 Environmental policies and legislations

In the 1960s, a broad awareness of environmental pollution problems developed among the general public. Many people came to realize the value and importance of protecting environmental quality. In addition to stopping air and water pollution solving problems related to refuse disposal, radiation, noise, pesticides, and wildlife conservation became important in the modern quest for environmental quality.

The emergence of an environmental awareness on the part of the public gave a genuine concern to politicians, lawmakers, and governmental agencies on the need for an appropriate legal and regulatory frame work for environmental quality control. As a result, different environmental laws and regulations have been issued by different agencies through the world.

Environmental law consists of all legal guidelines that are intended to protect our environment. In practice, the terms *law, statute,* and *regulation* are often used interchangeably. Regulations are generally more volatile than laws (statutes), of more applicability in determining compliance.
Environmental law as a distinct system arose in the 1960s in the major industrial economies. While many countries worldwide have since accumulated impressive sets of environmental laws, their implementation has often been woeful. In recent years, environmental law has become seen as a critical means of promoting sustainable development (or "sustainability"). Policy concepts such as the precautionary principle, public participation, environmental justice, and the polluter pays principle have informed many environmental law reforms in this respect (see further Richardson and Wood, 2006). There has been considerable experimentation in the search for more effective methods of environmental control beyond traditional "command-and-control"

style regulation. Eco-taxes, tradable emission allowances, voluntary standards such as ISO 14000 and negotiated agreements are some of these innovations.

In the years since 1970, many laws were passed by US Congress and other European countries to establish and implement standards of environmental quality for water, land, and air. Many of these laws have been revised and amended several times since their enactment, and some remain under review. A few of the key environmental laws are listed below.

International environmental law is the body of international law that concerns the protection of the global environment.

Originally associated with the principle that states must not permit the use of their territory in such a way as to injure the territory of other states, international environmental law has since been expanded by a plethora of legally-binding international agreements. These encompass a wide variety of issue-areas, from terrestrial, marine and atmospheric pollution through to wildlife and biodiversity protection.

The key constitutional moments in the development of international environmental law are:

- the 1972 United Nations Convention on the Human Environment (UNCHE), held in Stockholm, Sweden;
- the 1987 Brundtland Report, *Our Common Future*, which coined the phrase 'sustainable development';
- the 1992 United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro, Brazil

Table 1-1 Key Environmental Laws.

Year	Title	Purpose
1963	Clean Air Act (CAA)	Legislation to restrict emission levels of air pollutants from automobiles.
1974	Safe Drinking Water Act (SDWA)	Drinking water regulation to protect public health which specified the MCLs.
1976	Resource Conservation and Recovery Act (RCRA)	To protect the public from harm caused by waste disposal, to encourage reuse, reduction, and recycling, and to clean up spilled or improperly stored wastes.
1977	Clean Water Act (CWA)	Legislation for BAT requirement for toxic substances and BCT requirement for conventional pollutants.
1980	Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)	Created to protect public health from heavily contaminated toxic waste sites that have been abandoned.

Legend: BPT = Best Practical Treatment, BAT = Best Available Treatment, MCL = Maximum Contaminant Level

1.4 Environmental Ethics

Ethics is the systematic analysis of morality. Morality, in turn, is the perceptions we have of what is right and wrong, good or bad, or just or unjust. We all live by various moral values such as truth and honesty. Some, for example, find it very easy to tell lies, while others will almost always tell the truth. If all life situations required nothing more than deciding when to tell the truth or when to lie, there would be no need for ethics. Very often, however, we find ourselves in situations when some of our moral values conflict. Do we tell our friend the truth, and risk hurting his feelings, or do we lie and be disloyal? How do we decide what to do? Ethics makes it possible to analyze such moral conflicts, and people whose actions are governed by reflective ethical reasoning, taking into account moral values, are said to be ethical people.

The birth of environmental ethics as a force is partly a result of concern for our long-term survival, as well as our realization that humans are but one form of life, and that we share our earth forms of life.

TABLE 1-2 An Environmental Code of Ethics

1. Use knowledge and skill for the enhancement and protection of the environment.
2. Hold paramount the health, safety and welfare of the environment.
3. Perform services only in areas of personal expertise.
4. Be honest and impartial in serving the public, your employers, your clients and the environment.
5. Issue public statements only in an objective and truthful manner.

Discussion point

What do you think is the root of our environmental problems? Consider it from the view of religion, social and economic structure, and technology.

The public, your employers, and your client believe that dredging a lake to remove weed and sediment will enhance the lake. However, the dredging will destroy the habitat for muskrats. How can you be impartial to all these constituencies?

Reading assignment

Read about historical perspective of environmental engineering and environmental awareness.