The next part of this introductory chapter describes the guidelines we followed and the results we obtained in steps 1 through 4 in the construction of World3. Although these first steps appear to be simple and obvious, they are without question the most difficult and important stages of the modeling process. The essence of modeling is to simplify a system that is too complex to understand in full detail. This simplification requires the elimination of many real-world observations that are judged to be irrelevant to the problem being studied. It also calls for the aggregation, or grouping together, of elements that behave in a similar fashion. The decisions about which elements to include, which to omit, and which to aggregate are crucial to the eventual usefulness of the model, and they should be made only with reference to a carefully defined problem statement and time horizon.

The last part of this chapter describes only the guidelines employed in steps 5, 6, and 7, the specification and preliminary testing of the World3 model equations. The results of these steps are provided in Chapters 2 through 6, where the equations for each of the five major sectors in World3 are presented.

Step 8, experimentation with the model, is described in detail in Chapter 7 by means of numerous computer simulations. These simulations test the sensitivity of the model to changes in parameters and indicate the effects of alternative policies.

The final step, the communication of results, is carried out briefly in Chapter 8 and more extensively in the other two books of this series (Meadows et al. 1972, Meadows and Meadows 1973).

1.3 DESCRIPTION OF THE SYSTEM

In 1900 the human population numbered about 1.6 billion, and it was growing at about 0.6 percent per year (Carr-Saunders 1936). By 1970 the global population had more than doubled, and it was increasing at a rate of 2.0 percent per year, a rate of growth unprecedented in human history (PRB 1971). In the year 1900 about 9,000,000 people were added to the earth's population; in 1970 the net increase was 72,000,000. It is expected that the global population will rise to between 5.5 billion and 7 billion by the year 2000 (U.N. 1971).

To feed this growing population, agricultural output has also expanded. From 1951 to 1966 world food output rose by 34 percent. During the same period cultivated land was increased by 16 percent, grazing land by 35 percent, investment in tractors by 63 percent, and the annual use of nitrate fertilizers and pesticides by 146 percent and 300 percent, respectively (SCEP 1970, pp. 115, 118). Further increases in agricultural yield may be anticipated; for example, the new cereal grains of the Green Revolution promise to raise grain yields in selected regions by 300–400 percent.

The human use, displacement, and discard of resources are also increasing at record rates. The world consumption of minerals is currently growing by about 4 percent per year (NCMP 1972). Man-engendered release to the environment of at least thirteen major elements* exceeds natural rates of release by factors ranging from 3 to 100. World energy consumption has been increasing at 5–6 percent per year, which corresponds to a doubling time of 12–14 years. The growing use of materials and energy continues to be accompanied by increasing environmental pollution, as manifested by impure air and water supplies, diminished soil fertility, and the extinction of plant and animal species.

*Iron, nitrogen, manganese, copper, zinc, nickel, lead, phosphorus, molybdenum, silver, mercury, tin, and antimony (SCEP 1970, p. 116).

Although the world population has been growing rapidly, it has also, on the average, become richer and technologically more sophisticated. Global industrial output has grown even faster than population; it increased by 7 percent per year during the 1960s (U.N. 1970). The number of books published, the maximum speed of transportation, the capacity for computer data storage, and the productivity of an hour of labor have also grown exponentially (McHale 1972).

In summary, the complex system represented in World3 has historically exhibited increasing growth rates of population, industrial output, food production, and resource use. All this productive and reproductive activity is based on complex ecosystems that provide the maintenance functions necessary for human society. These ecosystems are governed by immutable physical laws and are vulnerable to degradation from misuse. The human social system is composed of political and economic institutions that respond to perceived shortages, primarily through the development of new technologies.

1.4 SPECIFICATION OF MODEL PURPOSE

To be useful to policy makers, a model must make some statement about the future, but information about the future may take several different forms. A model may provide, for example:

1. Absolute, precise predictions. (Exactly when and where will the next solar eclipse be visible?)
2. Conditional, precise predictions. (*If* the emergency core cooling system fails, what will be the maximum pressure on the nuclear reactor's containment vessel?)
3. Conditional, imprecise projections of dynamic behavior modes. (*If* corn prices are stabilized, will hog prices tend to fluctuate more or less strongly?)
4. Summary and communication of current trends, relationships, or constraints that may influence the future behavior of the system. (How do the paths of amino acid synthesis in a bacterial cell intersect? Where does the town zoning plan allow commercial construction?)
5. Philosophical explorations of the logical consequences of a set of assumptions, without any necessary regard for the real-world accuracy or usefulness of those assumptions. (On a curved surface, which theorems of Euclidean geometry still hold? How many angels can dance on the head of a pin?)

World3 was designed to provide information of the third sort. We had to limit ourselves to conditional and imprecise questions, rather than precise predictions, for two reasons. First, social systems are by their nature unpredictable in the absolute sense. Since any prediction made about the future of a social system becomes an