Executive Summary

Sustaining the freshwater resources of the Middle East presents a great challenge and opportunity for the region's scientific and technological communities. They must play a fundamental role in ensuring that this essential but scarce resource is available for present and future generations. The challenge has been heightened, as problems with freshwater quality and availability have multiplied and changed in response to growing population and economic activity over the past several decades.

Adequate water supplies to meet basic human needs are essential to maintain and enhance the welfare of all the inhabitants of the region. For the present generation, water-related concerns primarily focus on the distribution of the resource within society and the preservation and protection of water quality. For future generations, additional concerns will be to ensure adequate water supplies and preserve the quality of the environment, in addition to achieving greater equity in the distribution of water throughout the area.

In focusing on the contributions of science and technology to the sustainable use of the study area's water resources, this study was guided by five fundamental working criteria:

1. The view taken should be regional.
2. The demands and needs of both present and future generations must be taken into account.
3. All options should be considered for balancing water supplies and demand.

4. The maintenance of ecosystem services should be viewed as essential for achieving sustainability of water resources.
5. The close relationships of water quality and quantity should be clearly recognized.

There is an important concept embodied in the terms sustainability and intergenerational equity—the idea that the present generation's children and grandchildren should have at least as much ability to use a resource as does the present generation. Intergenerational equity includes the sustainable use of water resources.

THE STUDY AREA AND WATER USE

The committee's deliberations were limited to the area of the West Bank and Gaza Strip, Israel, and Jordan, referred to as "the study area" in this report. The study area has a hot, dry climate, and consists of a dry coast and strip of dry upland forest that grades into semidesert and desert. Most of the study area receives less than 250 millimeters (mm) of rainfall per year, about the same as or less than that received by Phoenix, Arizona, in the United States. The study area's highest rainfall amounts—those of more than 1,000 mm—fall in a small area of highlands in the northwestern part of the study area. By comparison, most of the United States east of the Mississippi River receives more than 800 mm of rainfall per year; much of the eastern United States and much of the Pacific Northwest west of the Cascades receive 1,000 mm or more. The landscape and hydrologic features of the study area are much like those of neighboring areas, which are sometimes included in definitions of the "Middle East," stretching as far south as Yemen, as far east as Pakistan, as far north as Turkey, and as far west as Morocco.

The study area has approximately 12 million inhabitants, with varying proportions in urban centers and holding a variety of occupations. In 1994, the study area's total average annual water use was estimated to be 3,183 million cubic meters (million m^3), ranging from almost 2,000 million m^3 in Israel to approximately 235 million m^3 in the West Bank and Gaza Strip. The average annual per capita use in the area, while highly variable, was approximately 260 cubic meters in 1994, and has been increasing. For the study area as a whole, agricultural irrigation accounts for more than half the water use, from an estimated 57 percent in Israel to 72 percent in Jordan, without considering wastewater that may be reused for irrigation. The several problems of water and the environment are similar to those in some neighboring areas and in some distant regions, such as arid sections of the United States and Australia.

Long experience in predicting water use and associated economic activity, population growth, and other variables of importance to water and economic planning shows that precise predictions are often incorrect. Many factors that influence water use have their origins outside the region, as described in Chapter 3, and even factors within the region can be unpredictable. However, although predictions, projections, and scenario building rarely provide an adequate basis for planning by themselves, they can be useful in identifying and analyzing different options.

The study area's inhabitants will almost assuredly live under conditions of significant water stress in the near future. Barring completely unforeseen events, the population is likely to grow, and very rapid growth is possible. The study area will probably continue to develop economically as well, and such growth could be substantial in Jordan and the West Bank and Gaza Strip. Because of the disparity between the economic progress of Israel compared to Jordan and the West Bank and Gaza Strip, some of the technical water-conservation and supply-augmentation options may be phased in over a long period of time. Chapter 2 provides a detailed discussion of the study area and its patterns of water use.

WATER AND THE ENVIRONMENT

The importance of ecosystem services to the sustainability of water supplies is often overlooked in the context of the region's water supplies. *Ecosystem services* refers to any functional attribute of natural systems that is beneficial to human society, nature, and wildlife. A biologically impoverished natural system produces services of poorer quality and reduced quantity.

The ecosystems of the study area, as elsewhere, provide services that are instrumental in achieving the sustainability of human water supplies. Vegetation helps to control runoff, and many plants, especially in wetlands, help to filter water and reduce the adverse effects of floods. Plants help to reduce erosion by reducing the rate of surface flows after heavy rains, thus reducing sediment input to water supplies as well. Surface water also provides important services. Streams help to assimilate wastewater, lakes provide storage for clean water, and surface waters provide habitat for many plants and animals important to humans and to ecosystem functioning.

At the same time, all the region's ecosystems, terrestrial as well as aquatic, require water for their own sustainability to continue to provide the many ecosystem goods and services that people rely on. The sustainability of water supplies requires that natural ecosystems be regarded as a critical legitimate user of the study area's water resources. Natural ecosystems are essential for maintaining adequate supplies of high-quality water.

Biodiversity is also important (see Chapter 4). Many peoples, including those in the Middle East, are committed to protecting biodiversity, as reflected in laws and international agreements. In future land-use planning, the benefits of water-related development should therefore be evaluated against the lost biodiversity and the cost of reduced ecosystem services. Applying this approach to the Jordan River basin as a whole would mean examining the effects of proposed measures on the biodiversity of wetlands, lakes, the lower river, and the Dead Sea coasts. Such an examination, lacking to date, should be an integral part of evaluating any proposed option that would affect water quantity or quality.

Chapter 4 discusses these evironmental issues in depth. In short, without the services provided by natural ecosystems, it will be extremely difficult and expensive—perhaps impossible—to sustain high-quality water supplies for the people in the study area. Thus, environmental considerations are not an adjunct to planning for sustainable water supplies, but a major and essential component of such planning.

HYDROLOGIC RELATIONSHIPS AND WATER RESOURCES PLANNING

Regardless of national boundaries, the waters of the study area are shared inasmuch as the region is hydrologically connected. Changes in the quantities and qualities of water available in one area will have impact on the quantities and qualities available in others. A good way to ensure that these consequential relationships are directly considered in water resources planning is to take a regional hydrologic viewpoint. For example, the failure to view water resources planning regionally could lead to indiscriminate ground-water development of the Mountain Aquifer that underlies both Israel and the West Bank. Systematic determination of well locations would maximize the yield of this aquifer. A comprehensive hydrologic database to inform and support regional water resources planning is clearly needed.

It is recommended that responsible national and international agencies take a regional approach to water resources planning in the following fundamental ways:

1. Acquire data on water availability and water use by employing consistent methods, techniques, and protocols.
2. Monitor both quantity and quality conditions of the area's water resources using these consistent techniques and units of measurement.
3. Encourage open exchange of scientific research relevant to these water resources and the conduct of scientific research on a regional and collaborative basis.

Any regional approach should be cognizant of human equity and established legal water rights of shared resources.

SELECTED OPTIONS FOR THE FUTURE

Achieving intergenerational fairness implies the need for a variety of management measures, some discussed in this report. These measures include monitoring the quality of water resources; scientific and technological research and development to make more efficient use of available resources without contaminating or degrading the resource; intergenerational assessments of the effects of particular water projects and uses; effective maintenance of capital investments, such as dams, municipal sewage treatment plants and water delivery systems; protection of watersheds and aquifer recharge areas by appropriate land use planning; and systems for sharing the resources equitably among communities.

This report assesses specific management options to shape the study area's future water resources and use, keeping in mind the criteria noted previously (see page 1). Some of these options have received close attention; others have been examined only in part. (The bibliography found at the end of the report indicates the wide range of evidence the committee consulted.)

Most of the options examined here relate to improving the efficiency of water use—that is, they involve conservation and better use of proven technologies. Although new technologies hold some promise for increasing water supplies, none currently appears to be cost-effective and ready for large-scale application. The committee did not consider options that involved water sources outside the study area because this examination was outside its charge outlined in Chapter 1.

The committee identified several basic questions to consider when choosing among various water resource planning options:

1. How effective will the option be in enhancing available water supplies? Options that produce large increments in available water supply will be more desirable than those that have modest effects.

2. Are the options technically feasible? In evaluating options, care should be taken to assess technical feasibility.

3. What is the environmental impact of the option? Will the option reduce or increase the quantities or qualities of water supply for other uses? Does the option have any other adverse environmental impacts? How will it affect aquatic and terrestrial habitats? Will the option lead to losses of biodiversity or of species that may be particularly valuable?

4. Is the option economically feasible? What factors affect its economic feasibility? Has the option proven economically feasible else-

where? It is important in answering these questions that all costs and benefits be reported together, with appropriate information about who bears the costs and who receives the benefits.

5. What are the implications for present and future generations? The quality of the environment must be maintained for future generations in a condition no worse than that of the current generation. Will the current generation's access to resources be conserved for future generations?

In examining the options the committee explicitly considered these questions. However, in assessing options for a particular case, it will become more critical to examine and compare the full range of options suitable for that case. All too often, a proposed solution is examined according to only one criterion, such as monetary cost, and is not compared with the other possible actions. Because sustaining high-quality water supplies in the area will be extremely difficult and expensive without the goods and services provided by natural ecosystems, environmental considerations are essential in planning for sustainable water supplies (see Chapter 4). Thus, attempting to meet future regional demands by simply increasing withdrawals of ground and surface water will result in unsustainable development characterized by widespread environmental degradation and depletion of freshwater resources.

Conservation

Given the rate of population growth, water quality and quantity will not be sustainable unless suitable conservation methods are used in all three major sectors of water use—urban, agricultural, and industrial. Some middle ground must be reached in which quality of life and economic development are brought into balance within the practical constraints imposed by the available water. Measures to reduce the demand for water are generally well established, but often require societal or economic incentives to implement. By reducing the demand for water, conservation measures can have a positive effect on water quality and the environment.

Examples of voluntary, domestic water conservation measures include adopting water-saving plumbing fixtures (toilets, showerheads, and washing machines); limiting outdoor uses of water, as by watering lawns and gardens only during the evening and early morning; adopting water-saving practices in commerce; repairing household leaks; and discouraging use of garbage disposal units. Chapter 5 compares the water savings of nonconventional over conventional appliances. Involuntary domestic water conservation measures can also be used, such as repairing leaking distribution and sewer systems; expanding central sewage systems; metering all water connections; and rationing, restricting, and recycling water use.

To the extent that the population grows or relocates in clusters, new water systems can be designed to reduce use and treatment costs, as by incorporating dual water systems to use nonpotable water for toilet flushing, garden irrigation, and similar applications. Dual systems reduce treatment costs and allow for recycling.

Agriculture

The agricultural sector is the largest user of water in the study area. Conservation measures have already helped to reduce the area's agricultural water use. The reduction of Israeli water use by more than 200 million m^3/yr between 1985 and 1993 was accomplished almost entirely in the agricultural sector through improved irrigation methods and water-delivery restrictions. Through rationing, research, and possibly through economic policies, agricultural water use may become even more efficient. However, as regional nonagricultural water demand increases and the cost of obtaining additional water supplies grows more expensive, the role of agriculture in the economy of the study area may need to be reevaluated (e.g., shifting from more to less water-intensive crops), so that water is used as efficiently as possible.

Harvesting local runoff and floodwaters can increase water supplies for dryland agriculture, and evaporative water loss can be reduced by cropping intensively within closed environments. Computer-controlled drip "fertigation" (application of fertilizer in the irrigation water) economizes on water and fertilizer use and prevents soil salinization and ground-water pollution if drainage water recycling is used. Brackish water, often abundant in the study area's dryland aquifers, can also be used for irrigating salinity-resistant crops, increasing the sugar contents of fruits such as tomatoes and melons and hence their market price. Brackish water is also useful for intensive aquaculture in deserts, but it may also cause problems by increasing soil salinization.

Finally, the use of treated local or transported wastewater for subsurface drip irrigation of orchards and forage can dramatically increase the production of the area's drylands in a sustainable manner. In any reevaluation of the role of agriculture in the study area, the socioeconomic impacts as well as the environmental impacts of changing agricultural practices should be considered.

Prices and Pricing Policies

Policies that subsidize the price of water or emphasize revenue recovery, to the exclusion of considerations of economic efficiency, are especially poorly suited to areas where water is scarce. On the other hand, pricing policies that emphasize economic efficiency and reducing overall water use are appropriate for regions of increasing water scarcity, such as the study area. Appropriate pricing ensures that appropriate signals are sent to consumers about the true cost of water, requiring each consumer to pay the marginal cost of the resources used, and—given some fixed level of benefits—ensures that the costs of providing the water are reduced. Pricing policies that encourage conservation, including marginal cost pricing, time-of-use pricing, and water surcharges generally work best where the quantity of water demanded is reasonably responsive to price.

Augmenting Supplies

Despite the best efforts to reduce water demand through conservation and economic policies, the available freshwater sources in the study area will probably have to be augmented by other sources to meet future needs. This is not at all to say that efforts at reducing demand are futile. Any alternate sources used will be expensive and, in some cases, will furnish lower quality water. Demand management in concert with supply augmentation will be needed to meet the future human and environmental water requirements of the area.

The rainfall of the region is not uniformly distributed over the year—hence there is a premium for storage of runoff when it occurs. In the north, where rainfall is relatively heavy, Lake Kinneret/Lake Tiberias/Sea of Galilee serves this purpose. In the more arid south, where surface reservoir sites are subject to large water losses from evaporation, subsurface storage has been used extensively. In ancient times, local cisterns were widely used, and this is still a valuable method for developing storage. Artificial recharge of ground water is another method which is currently in use in several places. As urban centers and their paved areas and infrastructure grow, there will be more opportunity to capture runoff from rainfall and use it to recharge ground water.

Additional regional water supplies can be obtained by using what little naturally occurring freshwater is currently unused (through watershed management and water harvesting[1]), by reusing water (wastewater reclamation), by developing sources of lower quality water (use of mar-

[1]Watershed management is defined as the art and science of managing the land, vegetation, and water resources of a drainage basin for the control of the quality, quantity, and timing of water, and for the purpose of enhancing and preserving human welfare and nature. Water harvesting is the collection of rainfall by rooftop cisterns.

ginal quality water and desalination of brackish water and seawater), by importing water from outside the study area, by transferring unused water within the study area (water imports and transfers are mentioned but not analyzed in this report), and by attempting to increase the renewable amount of water available (cloud seeding). Again, these options are discussed further in Chapter 5.

Applications and New Research

For each option it is desirable to ask at least two questions. Has an examination been made of all the available information on the option and the factors known to affect their adoption and use? And is it likely that new research might significantly change that assessment? For example, on the demand side no comprehensive study has been carried out of the range of social factors affecting domestic water withdrawal in the study area. At the same time, on the supply side a simpler technology for desalting or filtering water at domestic taps might be developed for arid land conditions. Research agencies have the challenge of deciding what new technology and what mix of technologies and management strategies deserve further exploration. Both kinds of initiatives—canvassing the effectiveness of existing options and exploring innovative technologies—need to be pursued.

Next Steps

This report offers a range of findings and observations on water resource management options. We believe that these options deserve careful examination by the many individuals and organizations who are concerned with the future of water and society in the Middle East. Thoughtful appraisal of experience to date is needed, along with discerning investigation of new relationships and technologies. The results will provide a solid basis for thoughtful, peaceful action to achieve the sustained use of crucial water resources. Rather than suggest a particular political plan, the committee has outlined a broad scope of concepts from which constructive action can emerge.