

Chapter 1

HAND OUT 1:
Importance of water resources
From Mays, L. (2001)

Introduction

1.1 BACKGROUND

Water resources engineering (and management) as defined for the purposes of this book includes engineering for both *water supply management* and *water excess management* (see Figure 1.1.1). This book does not cover the *water quality management (or environmental restoration)* aspect of water resources engineering. The two major processes that are engineered are the *hydrologic processes* and the *hydraulic processes*. The common threads that relate to the explanation of the hydrologic and hydraulic processes are the fundamentals of fluid mechanics. The hydraulic processes include three types of flow: pipe (pressurized) flow, open-channel flow, and groundwater flow.

The broad topic of *water resources* includes areas of study in the biological sciences, engineering, physical sciences, and social sciences, as illustrated in Figure 1.1.1. The areas in biological sciences range from ecology to zoology, those in the physical sciences range from chemistry to meteorology to physics, and those in the social sciences range from economics to sociology. Water resources engineering as used in this book focuses on the engineering aspects of hydrology and hydraulics for water supply management and water excess management.

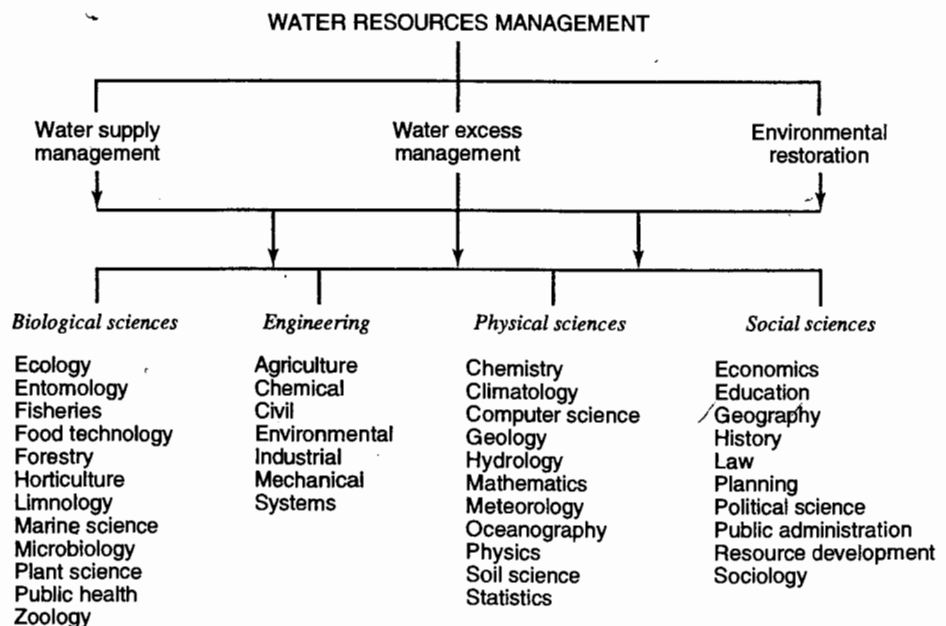


Figure 1.1.1 Ingredients of water resources management (from Mays (1996)).

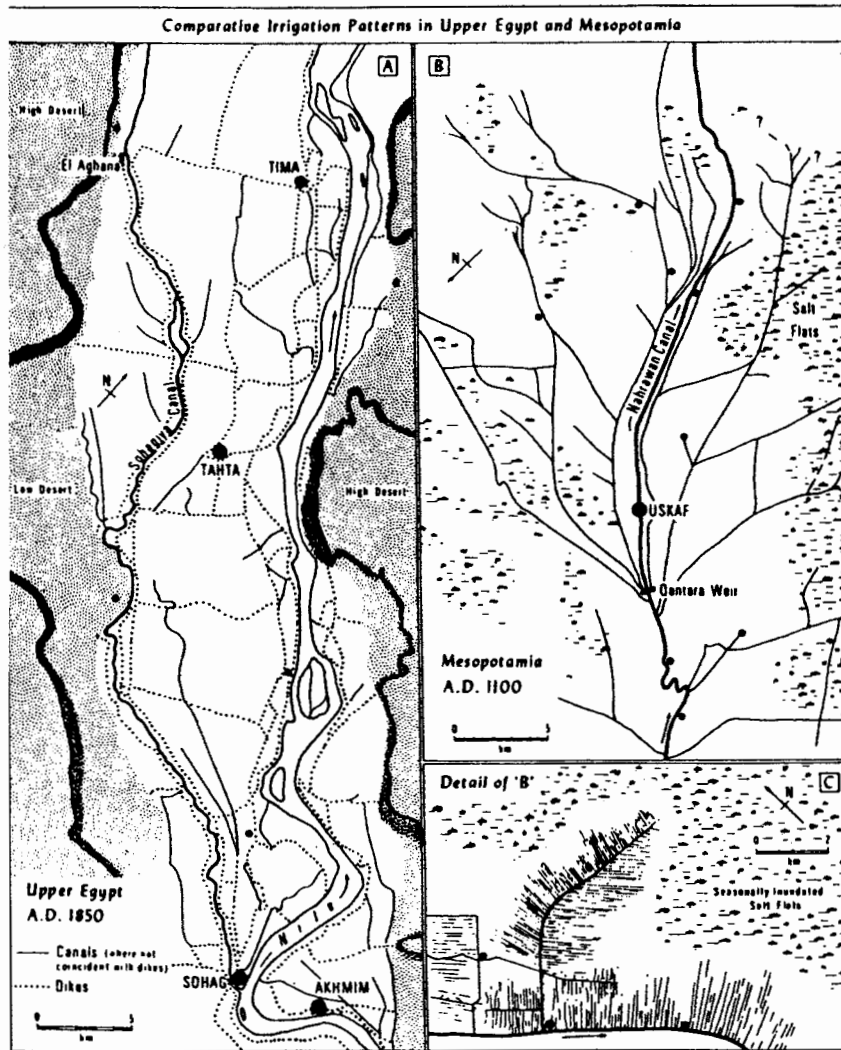


Figure 1.1.2 Comparative irrigation networks in Upper Egypt and Mesopotamia. (a) Example of linear, basin irrigation in Sohag province, ca. AD 1850; (b) Example of radial canalization system in the lower Nasharawan region southeast of Baghdad, Abbasid (A.D. 883–1150). (Modified from R. M. Adams (1965), Fig. 9. Same scale as Egyptian counterpart). (c) Detail of field canal layout in b. (Simplified from R. M. Adams (1965), Fig. 10. Figure as presented in Butzer (1976)).

Water resources engineering not only includes the analysis and synthesis of various water problems through the use of the many analytical tools in hydrologic engineering and hydraulic engineering but also extends to the design aspects.

Water resources engineering has evolved over the past 9,000 to 10,000 years as humans have developed the knowledge and techniques for building hydraulic structures to convey and store water. Early examples include irrigation networks built by the Egyptians and Mesopotamians (see Figure 1.1.2) and by the Hohokam in North America (see Figure 1.1.3). The world's oldest large dam was the Sadd-el-kafara dam built in Egypt between 2950 and 2690 B.C. The oldest known pressurized water distribution (approximately 2000 B.C.) was in the ancient city of Knossos on Crete (see Mays, 1999, 2000, for further details). There are many examples of ancient water systems throughout the world.

1.2 THE WORLD'S FRESHWATER RESOURCES

Among today's most acute and complex problems are water problems related to the rational use and protection of water resources (see Gleick, 1993). Associated with water problems is the need to supply humankind with adequate clean freshwater. Data collected on global water resources by Soviet scientists are listed in Table 1.2.1. These obviously are only approximations and should not be considered as accurate (Shiklomanov, 1993). Table 1.2.2 presents the dynamics of actual water availability in different regions of the world. Table 1.2.3 presents the dynamics of water use in the world by human activity. Table 1.2.4 presents the annual runoff and water consumption by continents and by physiographic and economic regions of the world.

Table 1.2.1 Water Reserves on the Earth

	Distribution area (10 ³ km ²)	Volume (10 ³ km ³)	Layer (m)	Percentage of global reserves	
				Of total water	Of fresh- water
World ocean	361,300	1,338,000	3,700	96.5	—
Groundwater	134,800	23,400	174	1.7	—
Freshwater		10,530	78	0.76	30.1
Soil moisture		16.5	0.2	0.001	0.05
Glaciers and permanent snow cover	16,227	24,064	1,463	1.74	68.7
Antarctic	13,980	21,600	1,546	1.56	61.7
Greenland	1,802	2,340	1,298	0.17	6.68
Arctic islands	226	83.5	369	0.006	0.24
Mountainous regions	224	40.6	181	0.003	0.12
Ground ice/permafrost	21,000	300	14	0.022	0.86
Water reserves in lakes	2,058.7	176.4	85.7	0.013	—
Fresh	1,236.4	91	73.6	0.007	0.26
Saline	822.3	85.4	103.8	0.006	—
Swamp water	2,682.6	11.47	4.28	0.0008	0.03
River flows	148,800	2.12	0.014	0.0002	0.006
Biological water	510,000	1.12	0.002	0.0001	0.003
Atmospheric water	510,000	12.9	0.025	0.001	0.04
Total water reserves	510,000	1,385,984	2,718	100	—
Total freshwater reserves	148,800	35,029	235	2.53	100

Source: Shiklomanov (1993).

Table 1.2.2 Dynamics of Actual Water Availability in Different Regions of the World

Continent and region	Area (10 ⁶ km ²)	Actual water availability (10 ³ m ³ per year per capita)				
		1950	1960	1970	1980	2000
<i>Europe</i>	10.28	5.9	5.4	4.9	4.6	4.1
North	1.32	39.2	36.5	33.9	32.7	30.9
Central	1.86	3.0	2.8	2.6	2.4	2.3
South	1.76	3.8	3.5	3.1	2.8	2.5
European USSR (North)	1.82	33.8	29.2	26.3	24.1	20.9
European USSR (South)	3.52	4.4	4	3.6	3.2	2.4
<i>North America</i>	24.16	37.2	30.2	25.2	21.3	17.5
Canada and Alaska	13.67	384	294	246	219	189
United States	7.83	10.6	8.8	7.6	6.8	5.6
Central America	2.67	22.7	17.2	12.5	9.4	7.1

Table 1.2.2 Dynamics of Actual Water Availability in Different Regions of the World (continued)

Continent and region	Area (10 ⁶ km ²)	Actual water availability (10 ³ m ³ per year per capita)				
		1950	1960	1970	1980	2000
<i>Africa</i>	30.10	20.6	16.5	12.7	9.4	5.1
North	8.78	2.3	1.6	1.1	0.69	0.21
South	5.11	12.2	10.3	7.6	5.7	3.0
East	5.17	15.0	12	9.2	6.9	3.7
West	6.96	20.5	16.2	12.4	9.2	4.9
Central	4.08	92.7	79.5	59.1	46.0	25.4
<i>Asia</i>	44.56	9.6	7.9	6.1	5.1	3.3
North China and Mongolia	9.14	3.8	3.0	2.3	1.9	1.2
South	4.49	4.1	3.4	2.5	2.1	1.1
West	6.82	6.3	4.2	3.3	2.3	1.3
South-east	7.17	13.2	11.1	8.6	7.1	4.9
Central Asia and Kazakhstan	2.43	7.5	5.5	3.3	2.0	0.7
Siberia and Far East	14.32	124	112	102	96.2	95.3
Trans-Caucasus	0.19	8.8	6.9	5.4	4.5	3.0
<i>South America</i>	17.85	105	80.2	61.7	48.8	28.3
North	2.55	179	128	94.8	72.9	37.4
Brazil	8.51	115	86	64.5	50.3	32.2
West	2.33	97.9	77.1	58.6	45.8	25.7
Central	4.46	34	27	23.9	20.5	10.4
<i>Australia and Oceania</i>	8.59	112	91.3	74.6	64.0	50.0
Australia	7.62	35.7	28.4	23	19.8	15.0
Oceania	1.34	161	132	108	92.4	73.5

Source: Shiklomanov (1993).

Table 1.2.3 Dynamics of Water Use in the World by Human Activity

Water users ^a	1900	1940	1950	1960	1970	1975	1980		1990 ^b		2000 ^b	
	(km ³ per year)	(km ³ per year)	(km ³ per year)	(km ³ per year)	(km ³ per year)	(km ³ per year)	(km ³ per year)	(%)	(km ³ per year)	(%)	(km ³ per year)	(%)
Agriculture												
Withdrawal	525	893	1,130	1,550	1,850	2,050	2,290	69.0	2,680	64.9	3,250	62.6
Consumption	409	679	859	1,180	1,400	1,570	1,730	88.7	2,050	86.9	2,500	86.2
Industry												
Withdrawal	37.2	124	178	330	540	612	710	21.4	973	23.6	1,280	24.7
Consumption	3.5	9.7	14.5	24.9	38.0	47.2	61.9	3.2	88.5	3.8	117	4.0
Municipal supply												
Withdrawal	16.1	36.3	52.0	82.0	130	161	200	6.0	300	7.3	441	8.5
Consumption	4.0	9.0	14	20.3	29.2	34.3	41.1	2.1	52.4	2.2	64.5	2.2
Reservoirs												
Withdrawal	0.3	3.7	6.5	23.0	66.0	103	120	3.6	170	4.1	220	4.2
Consumption	0.3	3.7	6.5	23.0	66.0	103	120	6.2	170	7.2	220	7.6
Total (rounded off)												
Withdrawal	579	1,060	1,360	1,990	2,590	2,930	3,320	100	4,130	100	5,190	100
Consumption	417	701	894	1,250	1,540	1,760	1,950	100	2,360	100	2,900	100

^a Total water withdrawal is shown in the first line of each category, consumptive use (irretrievable water loss) is shown in the second line.^b Estimated.

Source: Shiklomanov (1993).

Table 1.2.4 Annual Runoff and Water Consumption by Continents and by Physiographic and Economic Regions of the World

Continent and region	Mean annual runoff		Aridity index (R/LP)	Total	Water consumption (km ³ per year)					
	(mm)	(km ³ per year)			1980		1990		2000	
					Irretrievable	Total	Irretrievable	Total	Irretrievable	Total
<i>Europe</i>	310	3,210	—	435	127	555	178	673	222	
North	480	737	0.6	9.9	1.6	12	2.0	13	2.3	
Central	380	705	0.7	141	22	176	28	205	33	
South	320	564	1.4	132	51	184	64	226	73	
European USSR (North)	330	601	0.7	18	2.1	24	3.4	29	5.2	
European USSR (South)	150	525	1.5	134	50	159	81	200	108	
<i>North America</i>	340	8,200	—	663	224	724	255	796	302	
Canada and Alaska	390	5,300	0.8	41	8	57	11	97	15	
United States	220	1,700	1.5	527	155	546	171	531	194	
Central America	450	1,200	1.2	95	61	120	73	168	93	
<i>Africa</i>	150	4,570	—	168	129	232	165	317	211	
North	17	154	8.1	100	79	125	97	150	112	
South	68	349	2.5	23	16	36	20	63	34	
East	160	809	2.2	23	18	32	23	45	28	
West	190	1,350	2.5	19	14	33	23	51	34	
Central	470	1,909	0.8	2.8	1.3	4.8	2.1	8.4	3.4	
<i>Asia</i>	330	14,410	—	1,910	1,380	2,440	1,660	3,140	2,020	
North China and Mongolia	160	1,470	2.2	395	270	527	314	677	360	
South	490	2,200	1.3	668	518	857	638	1,200	865	
West	72	490	2.7	192	147	220	165	262	190	
South-east	1,090	6,650	0.7	461	337	609	399	741	435	
Central Asia and Kazakhstan	70	170	3.1	135	87	157	109	174	128	
Siberia and Far East	230	3,350	0.9	34	11	40	17	49	25	
Trans-Caucasus	410	77	1.2	24	14	26	18	33	21	
<i>South America</i>	660	11,760	—	111	71	150	86	216	116	
Northern area	1,230	3,126	0.6	15	11	23	16	33	20	
Brazil	720	6,148	0.7	23	10	33	14	48	21	
West	740	1,714	1.3	40	30	45	32	64	44	
Central	170	812	2.0	33	20	48	24	70	31	
<i>Australia and Oceania</i>	270	2,390	—	29	15	38	17	47	22	
Australia	39	301	4.0	27	13	34	16	42	20	
Oceania	1,560	2,090	0.6	2.4	1.5	3.3	1.8	4.5	2.3	
Land area (rounded off)	—	44,500	—	3,320	1,450	4,130	2,360	5,190	2,900	

Source: Shiklomanov (1993).

1.3 WATER USE IN THE UNITED STATES

Dziegielewski et al. (1996) define *water use* from a hydrologic perspective as all water flows that are a result of human intervention in the hydrologic cycle. The National Water Use Information Program (NWUI Program), conducted by the United States Geological Survey (USGS), used this perspective on water use in establishing a national system of water-use accounting. This accounting system distinguishes the following water-use flows: (1) water withdrawals for off-stream purposes, (2) water deliveries at point of use or quantities released after use, (3) consumptive use, (4) conveyance loss, (5) reclaimed wastewater, (6) return flow, and (7) in-stream flow (Solley et al., 1993). The relationships among these human-made flows at various points of measurement are illustrated in Figure 1.3.1. Figure 1.3.2 illustrates the estimated water use by tracking the sources,

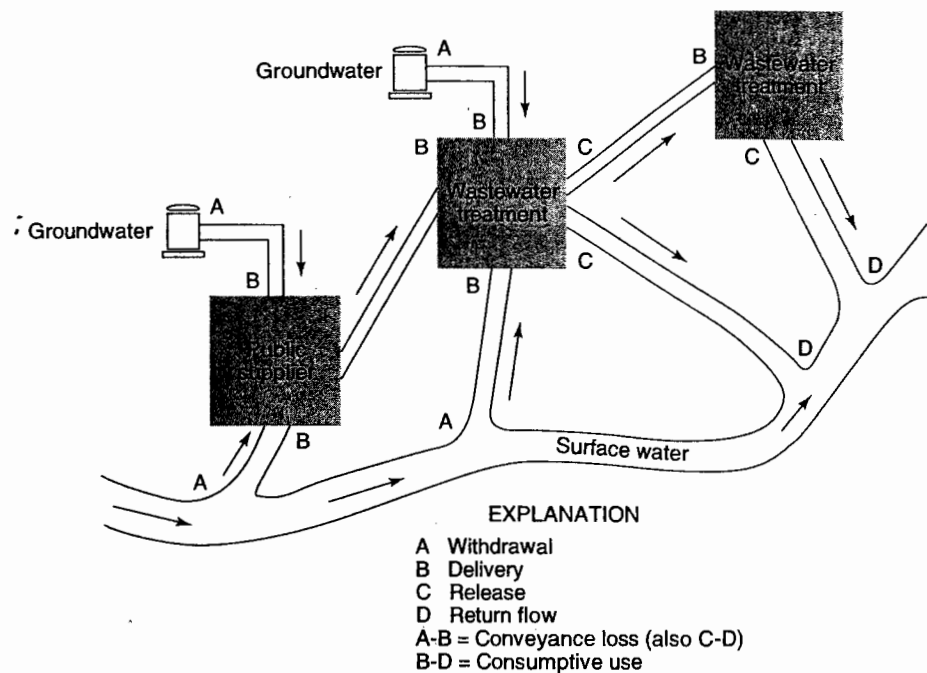


Figure 1.3.1 Definition of water-use flows and losses (from Solley et al. (1993)).

uses, and disposition of freshwater using the hydrologic accounting system given in Figure 1.3.1. Table 1.3.1 defines the major purposes of water use.

Table 1.3.1 Major Purposes of Water Use

Water-use purpose	Definition
Domestic use	Water for household needs such as drinking, food preparation, bathing, washing clothes and dishes, flushing toilets, and watering lawns and gardens (also called residential water use).
Commercial use	Water for motels, hotels, restaurants, office buildings, and other commercial facilities and institutions.
Irrigation use	Artificial application of water on lands to assist in the growing of crops and pastures or to maintain vegetative growth in recreational lands such as parks and golf courses.
Industrial use	Water for industrial purposes such as fabrication, processing, washing, and cooling.
Livestock use	Water for livestock watering, feed lots, dairy operations, fish farming, and other on-farm needs.
Mining use	Water for the extraction of minerals occurring naturally and associated with quarrying, well operations, milling, and other preparations customarily done at the mine site or as part of a mining activity.
Public use	Water supplied from a public water supply and used for such purposes as firefighting, street washing, municipal parks, and swimming pools.
Rural use	Water for suburban or farm areas for domestic and livestock needs, which is generally self-supplied.
Thermoelectric power use	Water for the process of the generation of thermoelectric power.

Source: Solley et al. (1993).

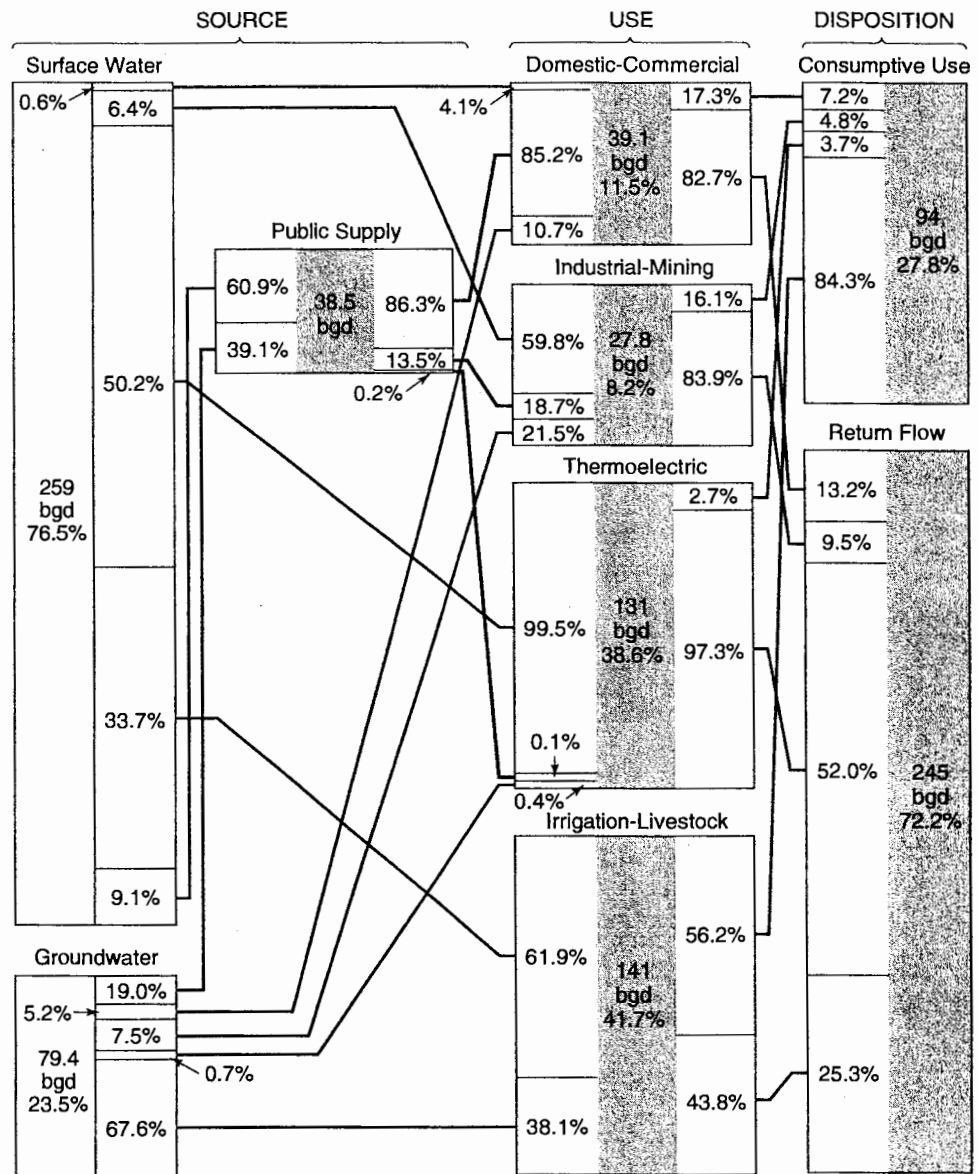


Figure 1.3.2 Estimated water use in the United States, 1990. Freshwater withdrawals and disposition of water in billion gallons per day (bgd). For each water use category, this diagram shows the relative proportion of water source and disposition and the general distribution of water from source to disposition. The lines and arrows indicate the distribution of water from source to disposition for each category; for example, surface water was 76.5 percent of total freshwater withdrawn, and, going from "Source" to "Use" columns, the line from the surface water block to the domestic and commercial block indicates that 0.6 percent of all surface water withdrawn was the source for 4.1 percent of total water (self-supplied withdrawals, public supply deliveries) for domestic and commercial purposes (from Solley, Pierce, and Perlman, (1993)).

1.4 SYSTEMS OF UNITS

The analysis of pressurized (conduit) flow, open-channel flow, and groundwater flows requires an understanding of the elements of fluid mechanics (presented in Chapter 2). A review of the mechanics of materials is a prerequisite to the examination of fluid mechanics principles. Table