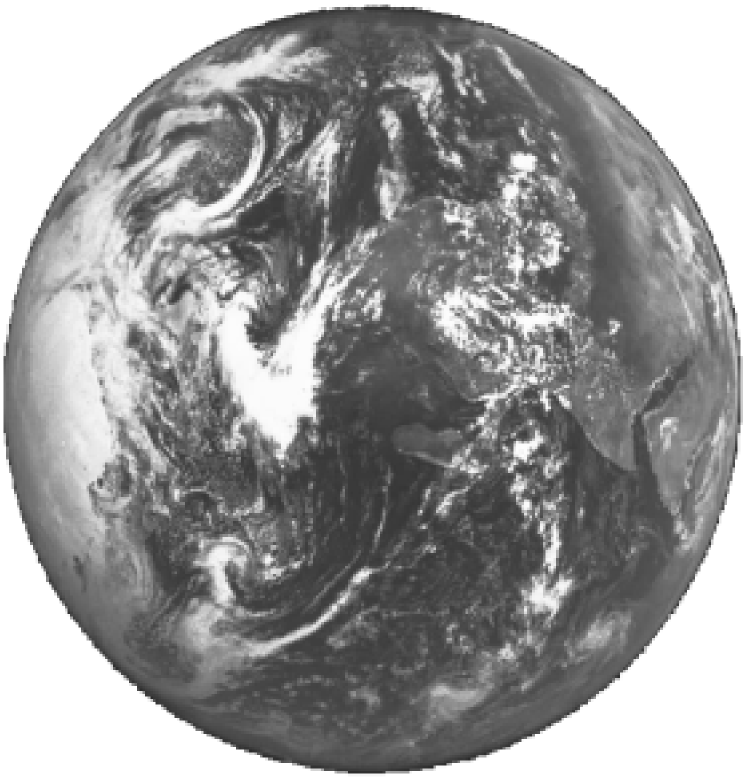
Part I

Sustainability and Water Management

WATER RESOURCES ON EARTH



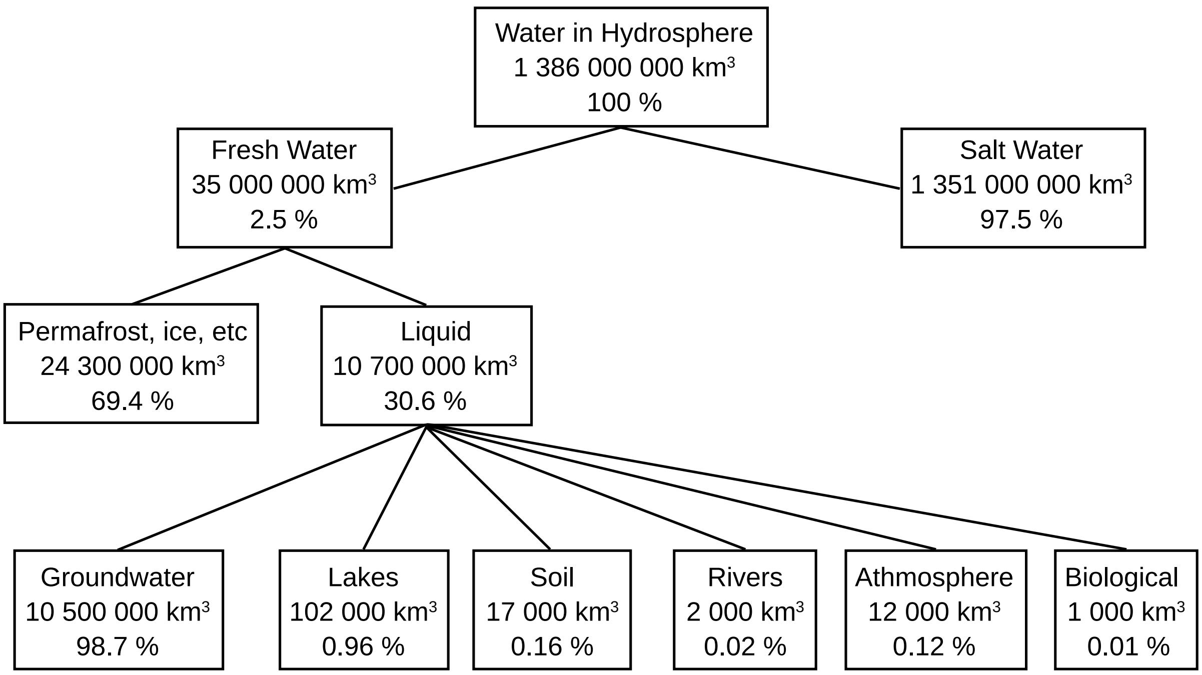


Figure 1.1. Water resources on Earth ($\cdot 10^6$ km^3) (Saiejs & van Berkel, 1995).

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WATER RESOURCES AND WATER SUPPLY

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Green and blue water

The Earth is abundantly supplied with water. However 97.5 % of it consists of saltwater in the oceans and only 2.5 % of the water supply on Earth is freshwater. This water is contained in the ground or in rivers and lakes and in the permafrost of the polar caps or in glaciers high in the mountains. Of the fresh water 69.4 % exists in the form of ice, snow or permafrost and is not directly available for use. Almost 99 % of the remainder is groundwater. The amount of fresh water in lakes is not more than 1 % of the liquid water available on Earth (Saiejs & van Berkel, 1995; see Figure 1.1).

A global water balance is shown in Figure 1.2. The average annual rainfall over the continents amounts to 110 000 km^3 (Saiejs & van Berkel, 1995). Of this, 63 000 km^3 returns to the atmosphere in the form of evaporation and transpiration from forests, grasslands, farm crops and other plant communities. This portion of the water, utilised by natural vegetation and rain-fed agricultural crops, is sometimes called green water.

The difference between annual rainfall and evapotranspiration, referred to as the effective runoff, is approximately 47 000 km^3. This is the sustainable, annually renewable, freshwater in lakes, reservoirs, streams and aquifers. In theory this so-called blue water is available for human use. A sustainability rule is thus: The water demand should be met from effective runoff only (Pearce, 1994). Water however is unevenly distributed over space and time. A large part of the runoff is floodwater that is hard to contain. Reliable annual flow that is realistically accessible for human use is estimated to be at least 9 000 km^3. To this some 3 500 km^3 of runoff regulated by existing reservoirs is added. Thus the total runoff accessible for annual human use is 12 500 km^3. However, some of the available surface water must be left in streams and rivers to

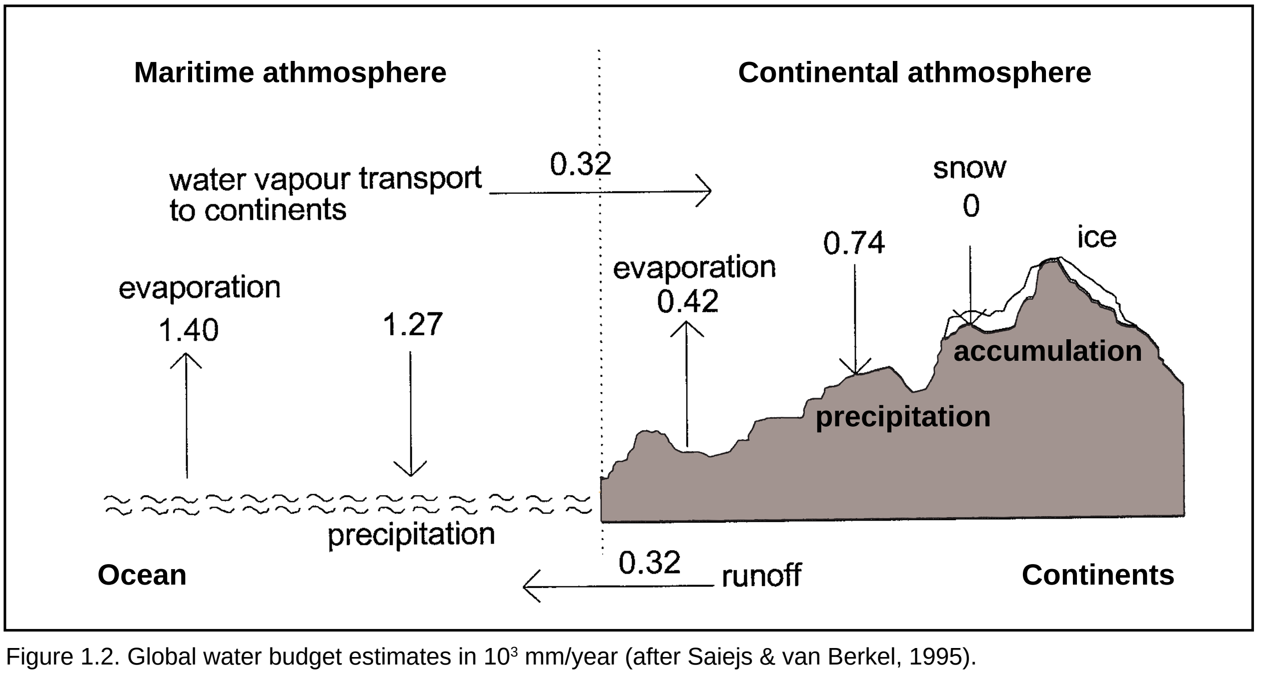

Figure 1.2. Global water budget estimates in 10^3 mm/year (after Saiejs & van Berkel, 1995).

[1] Responsible for Concepts of Water quality

safeguard conservation of the aquatic ecosystems and ensure effluent dilution, which in practise further reduces the amount of available water.

The remaining 34 500 km^3 of blue water is difficult and costly to utilise because of topography, long distances from population centres and social and environmental consequences.

More than half of the easily accessible freshwater resources are already utilised and in many regions of the world water supply is a critical issue. An increasing number of countries suffer from freshwater shortages and competition between different users is on the rise. More than 25 countries are already classified as water deficient and the number of countries facing severe water shortages during next decade is likely to increase dramatically.

In the Baltic drainage basin the annual volume of freshwater runoff is about 450 km^3. Due to relatively high precipitation and low evapotranspiration the water resources are much greater in the northern and western part of the region (Figure 1.3) than in the southern part, where water is a limiting factor in agricultural production.

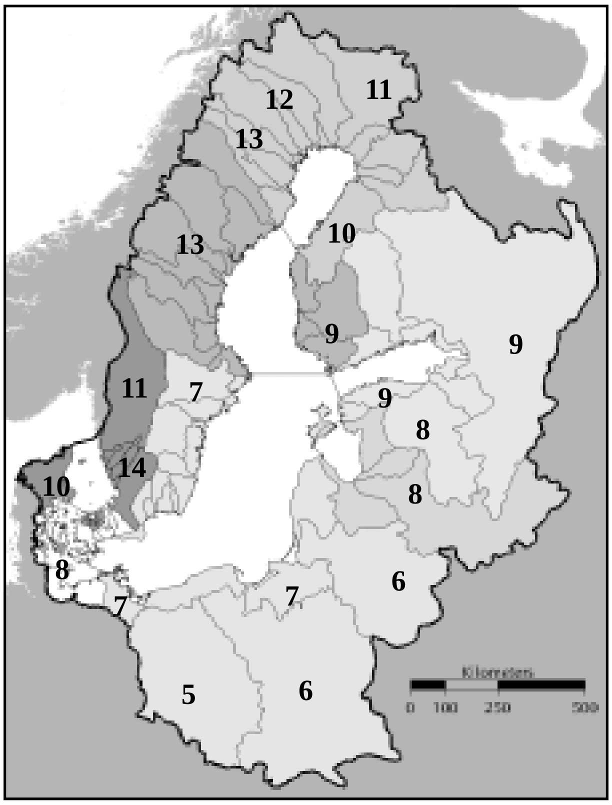

Figure 1.3. Mean annual specific runoff. (l/s km^2). Ballerina database at URL: http://www.baltic-region.net/

In general, the Baltic region has good water resources compared to most regions of the world, although they are much more limited in the south than in the north. The region's agriculture is seldom subject to severe droughts or floods, natural rainfall normally gives good yields, rainfall intensity does not cause severe soil erosion, and salinity is not a problem. Likewise, a safe supply of water to urban centres is not, especially in the northern part of the region, a great problem, nor is industrial water supply a limiting factor. Norway's share of hydropower is one of the largest of all the national energy budgets of the world, and hydropower is important in Sweden and Finland as well. Instead, the water problems of the Baltic region are foremost connected to water quality.

Water as a natural resource

Water resources have probably influenced humans more than any other natural resource and are still one of the most important prerequisites for civilisation. Since human beings first settled, easy access to drinking water and water as a transport medium has been necessary to stable and lasting settlements. A quick glance at a map still shows a concentration of villages and cities to coastlines and rivers. In areas where freshwater is scarce the inhabitants spend a considerable amount of time every day collecting water, and development of such societies has been slow.

In the developing countries, at least one fifth of the people living in cities and three quarters of the rural population lack access to reasonably safe supplies of water, while many of the industrialised countries are experiencing serious problems regarding water pollution, scarcity and wasteful use.

The availability of freshwater in terms of location and quantity is essential to all societies and consequently there are few natural resources of which our knowledge is more advanced (Table 1.1). Despite this extensive knowledge, the exploitation of water resources is done on such scales, ranging from individual households to cities of several million inhabitants, that even more detailed knowledge, especially concerning interaction between the different users, is called for.

A further complication is the variability of water availability, not only spatially but also temporally. In many areas of the world freshwater is scarce, which creates a problem if the population demand is not in harmony with the available resources, even if these areas normally have spots of high water availability, e.g. oases. Availability is also an issue in areas where water is plentiful, but where the quality is low because of pollution, or where the demand is extremely high. To a certain extent engineering solutions can be applied, but this is often at a considerable cost. The temporal variation consists of a seasonal variation, which is often quite predictable, and a variation between years that is more problematic. Most human activities have been adapted to, or made independent of, the seasonal variation, farming perhaps being the best example. However, if, e.g. the expected

Table 1.1. The availability of fresh water. Internal renewable water resources are domestically generated runoff. Note that all countries in the very-low category are dependent on withdrawing runoff generated in neighbouring countries (World Resources Institute, 2003)

Category Country	Per capita internal renewable water resources, m^3/yr (2001)	Annual withdrawals per capita, m^3/yr	(year)
Very low:	**1 000 or less**		
Egypt	26	1 055	(1996)
Israel	119	287	(1997)
Jordan	131	255	(1993)
The Netherlands	688	519	(1991)
Low:	**1 000 - 5 000**		
South Africa	1 014	366	(1990)
Denmark	1 123	233	(1990)
India	1 211	592	(1990)
Germany	1 305	579	(1991)
Poland	1 391	321	(1991)
China	2 173	439	(1993)
United Kingdom	2 431	204	(1991)
Japan	3 372	735	(1992)
Medium:	**5 000 - 10 000**		
Switzerland	5 637	172	(1991)
United States	6 932	1 834	(1991)
High:	**10 000 and more**		
Sweden	19 391	340	(1991)
Finland	20 645	439	(1991)
Norway	84 787	489	(1985)
Canada	91 147	1 607	(1991)
Iceland	671 940	622	(1991)

summer precipitation does not occur at all or is considerably less than expected, a draught situation is immediately at hand. If this is repeated several years in a row, extremely severe situations with starvation, desertification and population migration may ensue. Note the use of the word 'expected,' because sometimes we expect more than the normal or mean value.

Sustainable water management must thus be a long-term undertaking, remembering that the variability of the water resources is such that what seems sustainable over a few years may not be sustainable over a ten- or thirty-year period. We should also bear this in mind in our humid part of the world when we expand our populated areas too close to rivers. Even if we experience it as a surprise that a river suddenly rises to a level that is much higher than anyone can remember, this is probably a situation that normally occurs every 30 years or so.

It should be noted that even in the humid conditions of the Baltic region, it is normal to experience a certain draught, or rather a water deficit, in early summer. At that time, the vegetation normally demands more water than there is at hand during this period. However, adaptation of the vegetation and, if the crop is valuable, irrigation keep the problem at a reasonable level.

Table 1.2. Water use by continent (See below).

Continent	Agriculture (%)	Domestic (%)	Industrial (%)	Total (km^3/yr)
Africa[1]	85	9	6	128
Asia1	84	6	10	1 444
Former USSR[1]	62	10	28	270
Europe[2]	30	14	62	551
N&C America[3]	43	11	46	686
Oceania&Australia[3]	51	11	38	30
South America[3]	62	17	21	167
World[1]	71	9	20	3 253

[1] FAO, 2004 (data from 1988)
[2] Krinner et al., 1999 (data from 1997)
[3] Shiklomanov, 1999 (data from 1995)

Water use for food production

Water is used for all life, including the farming that supplies us all with food. The basis is production of grain and other crops. Here water supply is the main limiting factor, along with e.g. temperature and soil conditions. The total world area of arable land is about 1 500 million hectares which means approximately 0.25 hectare per person. It is estimated that rain-fed farm crops and grasslands transpire about 18 000 km^3 of green water annually.

About 250 million hectares, or 17 % of all farmland, are irrigated. Global estimates indicate that irrigated farmlands produce nearly 40 % of the food on 17 % of the land. Half of the expansion of food production in the last thirty years has come from the expansion of irrigated farming. Half or even two thirds of future gains in crop production are expected to come from irrigated land.

The amount of water needed to produce the annual food requirement for one person is about 2 000 m^3 for a balanced diet with meat. This explains why agriculture is the major user of water globally. Almost 70 % of the water withdrawn from rivers, lakes and aquifers goes to the agricultural sector and mainly for irrigation purposes (Table 1.2). Domestic and industrial users account for the remaining 30 %. There are significant differences between different parts of the world. In developing countries in arid zones farming often claims more than 90 % of the water. In humid temperate industrial countries the figure is often less than 30 %. Most of the data in the table are from the 1980s. The total water use today is almost 50 % higher.

In the Baltic drainage basin the total land area is about 175 million hectares. About 20 % of the total land, or 35 million hectares, is arable. Some 10 million hectares are land for pasture. If we assume that the average annual evapotranspiration from farm crops and grassland is 400 mm (= 4 000 m^3/ha) the total use of green water in agriculture approaches a magnitude of 180 km^3.

Only 3-4 % of the arable land in the region is under irrigation. A rough estimate shows that the total water use for agriculture is approximately 3 km^3. The sectorial water use for the different countries in the Baltic region is shown in Table 1.3.

The agricultural sector contributes significantly to the pollution of the Baltic Sea. The total input of nutrients has been estimated at 1 600 000 tonnes of nitrogen and 60 000 tonnes of phosphorus per year. The major source of the nitrogen and phosphorus load is agricultural runoff, which accounts for about half. About 10 % of the phosphorus comes from agriculture itself.

The most important sources of nutrients related to agriculture in the Baltic Sea region are:

- leaching of nitrogen and phosphorus from arable land;
- leaching of nitrogen and phosphorus caused by inappropriate storage of manure from animal production;
- atmospheric emissions of ammonia from animal production and field application of manure; and
- inadequate treatment of wastewater in rural areas.

Water resources in a systems perspective

The healthy development of human domiciles, societies and human affairs is critically dependent on water supplies. Safe water provision is needed in households, agriculture and industries. As a rule of thumb we use 200 l/capita and day in households, and twice as much in industries in the Baltic region. In addition some agricultural productions depend not only on the natural water supply but also on irrigation. This book deals with many aspects of water use in these sectors. The overall intention is to describe how we can manage this resource so that society has a safe supply of water for all its various needs.

In this introductory chapter we will point out three perspectives on water use in society:

The systems perspective, whereby the individual components are all part of the same system, or are even using the same water.

The recirculation perspective, how the water we use is part of one or several hydrological cycles.

The 'downstreamer perspective', whereby the water that leaves one user is the water provided for the next.

Water is considered to be a renewable resource. This is of cause true in a regional sense but in a global perspective water resources are confined to a closed system. On a global scale there are no water incomes, except possibly the chemically bound water in meteorites, and there are no water expenses, either, except for the occasional water molecule entering free space.

There is a danger in viewing water resources from a narrow regional perspective. Since water is circulated globally in the hydrological cycle, all the water we use has a history and a past. If we pollute the water regionally, for example, the effects may show up in a totally different region with unforeseeable environmental effects. Pesticides used intentionally in farming in one region may cause the death of birds elsewhere, e.g. in the Baltic Sea. Another example is when sulphuric smoke pollution and the humidity in the air in coal-burning industrial regions kill the coniferous trees in forest regions. These causes and effects are well known today but were either not foreseen or were ignored at the time when the practise was initiated.

Table 1.3. Water resources and water use in the Baltic drainage basin (Source World Resources, 1994)

Country	Population[1] 2004 (millions)	Annual renewable water resources[2] (km^3)	Annual withdrawals (km^3)		Sectorial water withdrawals Agric. (%)	Domestic (%)	Industry (%)
Belarus	10.3	37	2.7	1990	35	22	43
Czech Republic	10.2	13	2.7	1991	2	41	57
Denmark	5.4	6	1.2	1990	43	30	27
Estonia	1.4	13	0.2	1995	5	56	39
Finland	5.2	110	3	1991	3	12	85
Germany	82.4	107	46.3	1991	20	11	69
Latvia	2.3	17	0.3	1994	13	55	32
Lithuania	3.6	16	0.3	1995	3	81	16
Poland	38.6	54	12.3	1991	11	13	76
Russia	144	4 313	77.1	1994	20	19	62
Slovakia	5.4	13	1.8	1991	0	-	-
Sweden	8.9	171	2.9	1991	9	36	55
Ukraine	47.7	53	26	1992	30	18	52

[1] PopulationData.net, 2004
[2] Mean of 1977-2001

The systems approach can also be taken when studying the main users of water resources: agriculture, industry, and urban areas.

In agriculture, the incomes are precipitation and irrigation. The expenses are evapotranspiration, drainage and groundwater formation. The strategy of water management is twofold: to deliver an appropriate amount of water to the growing plants and to distribute nutrients to the plant's roots using water as the transport medium. If there is a problem of water shortage, irrigation is applied using groundwater or a nearby river, while if there is too much water the field is drained. The principal action in both these respects is to divert the natural flow paths of the water. The second objective, increasing the nutrient status of the field, adds another dimension to water management, i.e. water quality. High nutrient content means high quality for plants but low quality for humans and animals. The 'good life' of the aquatic plants also causes lake eutrophication. Further issues are erosion and salinisation but these problems are minor in the Baltic region. The environmental issues in this system can thus be defined as i) minimising the harmful effects of the diversion of the natural flow paths and ii) keeping the nutrient-rich water inside the system, where it constitutes a resource.

In industry, water incomes and expenses are defined by the system of pipes entering and leaving the plant. The objective means using water either as a part, e.g. transport or cooling medium, or as an ingredient in the industrial process. The main problem is the addition of dissolved substances to the water, caused by the process. Another issue is the increased water temperature caused by some industrial processes, such as energy plants. If the water is exported to the same body of water from which it was imported, no significant diversion of the pathways has been made. However, used groundwater or surface water is normally redistributed via the municipal sewage treatment plant into a surface water body, often a different one that the one where the water originated. The main environmental issue is thus to i) minimise the impact of the industrial processes on the water and ii) minimise the water volumes handled. The optimal solution is of course to close the system totally, avoiding strain on water resources and export of polluted water.

Urbanised areas, i.e. cities and towns, have properties that constitute a mixture of agricultural and industrial systems. The water incomes are precipitation, discharge and water from local or municipal wells or waterworks. Expenses are evapotranspiration, sewage and stormflow from sewage treatment plants or individual houses, water lost in the distribution system, locally infiltrated precipitation and losses of groundwater. Note that the system can be defined in different ways, depending on the problem studied. If the problem is the damage to buildings caused by the lowered groundwater level, then locally infiltrated stormwater constitutes a systems income and a potential solution to the specific problem.

Several objectives can be identified. To deliver high quality drinking water and to treat sewage water are the main objectives, but to get stormwater off the streets, to avoid inundation by regulating surface water levels and in most cities preserving the groundwater level are also important objectives. Urban water planning and management is complex, involving the administration of both waterworks and sewage treatment plants as well as city and road planning. This area is of special importance since it interfaces directly with citizens and their need of household water for everyday activities. The environmental issues involved are those of supplying domestic water of sufficient quality and quantity, sanitation and the proper treatment of sewage water, handling of storm flows and prevention of inundation and lowering of the groundwater table.

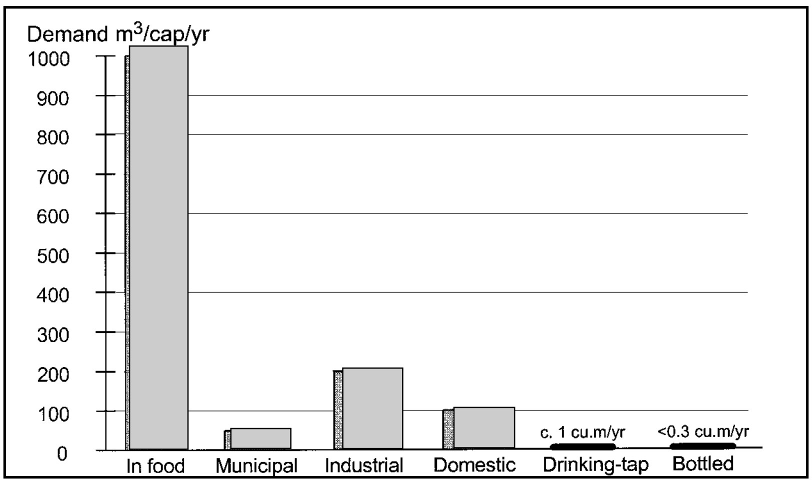

Figure 1.4. Demand for water (indicative for semi-arid circumstances) in cubic metres per capita per year (Allan, 1995b).

An individual person needs only one cubic metre of water per year for drinking, approximately 100 cubic metres for his or her household needs and roughly 1 000 cubic metres per year to produce the food he or she needs to eat. In addition an average of about 50 cubic metres are needed for municipal water used for general purposes and 200 cubic metres on average for industrial water (see Figure 1.4). These figures are indicative for semi-arid conditions and vary considerably in different regions. For an individual use of 1 300 cubic metres per year and a population of 6 billion, the total water need in the world is about 7.8 cubic kilometres or about 17 % of the sustainably available water. Many countries have a much smaller supply of sustainable water per capita than 1 300 cubic metres (see Table 1.1) and the situation will become worse in the future, especially in developing countries with their high population growth rates.

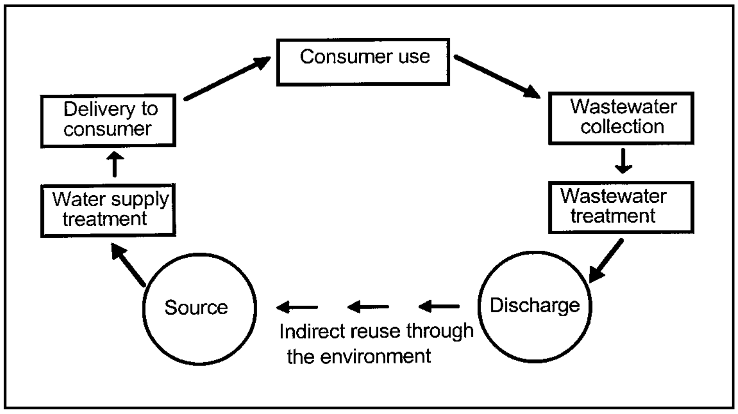

Figure 1.5. The hydrological cycle in society.

An important feature of water provision is the reuse of water inherent to the nature of the hydrological cycle. E.g. villages throughout a river stretch use water from the same stream, or water transpired by the plants is released as precipitation useful to plants in neighbouring fields. The runoff water into a river in a farm area might be used later for preparing drinking water for the city downstream. Groundwater used for domestic purposes is released to a river and reused downstream or is infiltrated to the benefit of the vegetation.

What this implies is that, with a systems view of water resources, the outflow in the system always constitutes someone else's inflow. Among the creative ideas stemming from this implication is the suggestion that industrial water intake should be put downstream of the industry's outlet, creating a self-regulating system in which the industry would be highly motivated to keep water quality high. The rational realisation of the idea is, of course, to create closed-system processes.

Another perspective is illustrated by the 'urban' or 'societal' water cycle which points out that water used for one purpose may soon be reused for another (Figure 1.5). After treatment, freshwater is normally transported into urban areas via water pipes in order to secure a high water quality. Treated wastewater is typically discharged into large receiving waters in order to avoid severe local pollution problems. However, in some regions, the wastewater quantity should instead be regarded as a possible resource for increasing the groundwater level, for irrigation use or other purposes. Obviously, this requires even more efficient wastewater treatment (Ødegaard et al., 1996). If water is scarce the water might have to be 're-used,' which means going through several rounds in an ever narrowing water cycle requiring more and more refined methods of treatment. In urban water management this might be quite expensive. In industry it is taken to the extreme in the closed factory, where the same water is used indefinitely.

Concepts of water quality

The quality of the water is related to the specific purpose of the water use, while the value and usefulness of a water source is dependent on this particular use. Water quality is thus a consumer term. Water quality depends on the chemistry, physical appearance (colour, taste and smell) and biological properties of the water. There are numerous ways of utilising water – as drinking water, for washing and bathing, as a carrier of domestic waste, for irrigation, in various industrial processes and as an object of recreation.

It is thus obvious that there is no universal, or even general, requirement on water quality. Each use requires its own set of standards. These standards are usually formulated as critical values of specific properties, which should not be exceeded. Water that is considered harmful as, e.g. drinking water, may be excellent for irrigation or even swimming. Examples of categories of use, some of which have been discussed above, are

- domestic use
- use in irrigation
- use in industry
- use in recreation

In all of these categories there is always the possibility of treating the water to make it acceptable for its particular use. This is well in line with the concept of sustainable use of water. Naturally, it should not be carried to the extreme that water must be saved, because it is a natural resource. Water is, after all, a renewable resource and it is the rate of natural renewal that sets the upper limit for its rate of use.

The need for adjusting water to its use has now been practised for decades within the category labelled recreational use. Surface water is allowed to carry a certain load of waste as long as this does not depreciate its recreational value. Monitoring is set up to make sure that all functions are as they should be. Recreational use is mainly a surface water concern. But surface water is not independent of groundwater, often being the source of the surface water.

The discussion in this introduction will be limited to water quality standards for domestic and irrigation water. Further treatment of industrial water use issues will be presented in later chapters.

Table 1.4 illustrates the work done in the past to create standards of guidance to society. It also shows some of the difficulties encountered in the effort to draw up an internationally unified set of standards for domestic use.

The table lists three categories of concern: toxic effects, human health and general use. A number of existing standards are also listed, first the one developed by the international WHO (World Health Organisation), then the one set by the European Community and lastly standards adopted by the U. S., Sweden, France, and Tanzania.

For toxic effects from various elements that normally occur in low concentrations, the differences between the different standards are small. As regards human health only fluoride and nitrate are listed. High fluoride concentrations occur in parts of the Mount Kilimanjaro complex due to old lava flows, which are very rich in sodium and poor in calcium, which normally counteracts the fluoride concentrations in water. It can be seen that Tanzania uses a concentration limit that is about eight times higher than other countries, which can be easily explained. If a limit of 1 mg/l were to be used, a large part of the population would simply have no drinking water.

The table has no standard values for biological variables. These would probably be difficult to apply in some of the countries.

High salinity in soil water restricts the growth of crops. Sensitivity to salt varies widely from crop to

Table 1.4. Water quality standards for domestic water

Substance	**Unit**	**WHO**[1]	**EU**[2]	**USA**[3]	**Sweden**[4]	**France**[5]	**Tanzania**[6]
Toxic effects							
Lead	μg/l	10	10	0	10	50	100
Arsenic	μg/l	10	10	0	10	50	50
Selenium	μg/l	10	10	50	10	10	50
Chromium	μg/l	50	50	100	50	50	100
Cyanide	μg/l	70	50	200	50	50	50
Cadmium	μg/l	3	5	5	5	5	30
Barium	μg/l	700	-	2 000	-	100	1 000
Mercury	μg/l	1	1	0	1	1	1
Silver	μg/l	-	-	100	-	10	50
Human health							
Fluoride	mg/l	1.5	1.5	4	1.5	1.5	8
Nitrate	mg/l	50	50	10	50	50	50
General use							
Colour	mg Pt/l	50	-	15	30	15	-
Turbidity		5[7]	-	5[8]	1.5[9]	2[7]	-
pH		-	6.5-9.5	6.5-8.5	6-8	6.5-9	6.5-8.5
Total dissolved matter	mg/l	-	-	500	-	1 500	2 000
Total hardness	mg_qv/l	-	12	-	-	-	-
Calcium	mg/l	-	150	-	-	100	-
Magnesium	mg/l	-	80	-	20	50	-
Sulphate	mg/l	500	250	250	100	250	-
Chloride	mg/l	-	250	250	100	200	200
Iron	mg/l	-	0.2	0.3	0.2	0.2	1[10]
Manganese	mg/l	0.5	0.05	0.05	0.05	0.05	0.5
Copper	mg/l	2	2	1	2	1	3
Zinc	mg/l	3	5	5	-	5	0.2
Phenolic substances as phenol	_g/l	2	-	1	-	0.5	2

[1] WHO (1998)
[2] EC (1998). These standards were also adopted by Bulgaria (that appeared in previous editions of this textbook) in 2001. A difference is the value for cupper where the Bulgarian source (Ministry of Health et al, 2001) reads 2.0 "_g/l" instead of "mg/l"; most likely a printing mistake.
[3] EPA (2002)
[4] SLV (2001)
[5] Ministère de la solidarité, de la santé et de la protection sociale (1989; 1990)
[6] The United Republic of Tanzania (1981)
[7] JTU (Jackson turbidity units)
[8] NTU (Nephelometric turbidity units)
[9] FNU (Formazin nephelometric units)
[10] The source reads "110" but it should most like be 1.0

crop. Of greater concern is often the effect that the salts can have on soil structure. A high fraction of sodium in irrigation water may decrease the exchangeable calcium, replacing it with sodium. This will turn the soil into mud when wetted and starve the plants due to oxygen deficiency. There is, however, a rather simple way of predicting this if the sodium/calcium ratio in irrigation water is known. The sodium adsorption ratio (SAR) can be computed according to the following:

$$SAR = [Na^{+}] ([Ca^{2+}] + [Mg^{2+}]) - 0.5$$

According to Bolt & Bruggenwert (1978) the following SAR values are valid:

safe water	EC < 25 mS/m and	SAR < 7
marginal	EC < 75 mS/m and	SAR < 13
unsuitable	EC < 225 mS/m and	SAR < 20

where EC is electric conductivity and SAR is the sodium adsorption ratio.

The functions of water management

A system for safe water provision should:

- provide water for a variety of uses, such as in agriculture, households, factories, offices and schools
- remove wastewater from users in order to prevent unhygienic conditions and treat this to remove environmentally harmful substances
- remove excess water from fields and other non-built areas, and storm water from urban areas to avoid damage from flooding

The essential function is thus to secure sufficient water of adequate quality to the various users without harming the environment. Further requirements may be related to other, very special demands, such as delivery security for hospitals, high flow rates in fire fighting etc.

In urban areas water use in buildings is the key issue. The choice of water-consuming devices (toilets, showers, washing machines and dishwashers) has great impact on water and sewage handling. Other technical factors, which could be influential in domestic use, include separation of grey water from black water and the use of garbage disposers. In addition, consumer behaviour has a major impact on domestic water and wastewater handling.

As a rule, industries in the Western world use efficient methods of water saving and recycling. However outdated technologies that require massive volumes of water are still in use in many places.

The challenge to managers of water systems is to find the best way to satisfy the demands of the water users and of those expressed in the political arena. Earlier, the choice of water, wastewater and runoff water handling was mainly determined by function efficiency and acceptability of cost. This choice was affected by factors such as climatic and topographical conditions, population density and convenience. Today, the choice of system must also take the long-term environmental impact and conservation of resources into consideration.