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WATER SCARCITY DRAFTING GROUP

DOCUMENT:

WATER SCARCITY MANAGEMENT IN THE CONTEXT OF WFD

Executive summary

Because of the increased frequency of drought events over recent years, the informal meeting of Water Directors of the European Union (EU) held in Roma (Italy) in November 2003, agreed to take an initiative on water scarcity issues. A core group led by France and Italy has prepared a technical document on drought management and long-term imbalances issues to be presented to the Water Directors meeting in June 2006.

The document represents a technical report, which has been prepared by the water scarcity drafting group. It describes water scarcity mitigation measures and practices implemented in Europe and Mediterranean non-EU countries in order to provide and share information. It is a living document that will need continuous input and improvements as application and experience build up in all countries of the European Union and beyond. The document consists of five parts. The introduction presents fundamental principles and approaches. In chapter I, the definitions and assessments of the different phenomena are described. Chapter II reports on planning and management of drought events. Chapter III deals with long-term imbalances in supply and demand. The conclusions and recommendations are presented in Chapter IV.

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INTRODUCTION

Freshwater is no longer taken for granted as a plentiful and always available resource. More and more people in more and more countries, among which EU is not an exception, are experiencing droughts – as individuals in their day-to-day lives and as communities and nations. Today, many European countries are subject to waves of water deficit that affect their inhabitants and the ecosystems they depend on. Events in 2003 have further demonstrated how socio-economic factors, driving the demand for water, have even made the wettest parts of Europe vulnerable to drought.

In addition to drought impacts, overexploitation of water resources in some European countries and in the Mediterranean in general, especially for agriculture, increases the risk of water deficit and, consequently, environmental hazards. With reference to water resources, the ongoing destruction and degradation of water ecosystems and aquifers has already led to dramatic social repercussions. Unsustainable consumption and production patterns are degrading ecosystems and reducing their ability to provide essential goods and services to humankind. Reversing this threat and achieving sustainability will require an integrated approach in order to manage water, land and ecosystems, one that takes into account socio-economic and environmental needs.

The problem of water deficit resulting from resource overexploitation is further exacerbated by global warming which is likely to increase the variability of precipitation patterns, thereby changing the patterns of water availability in Europe on a quantitative, temporal and/or regional basis. Alternative approaches have, therefore, to be found to meet water requirements for development activities. These new approaches are being driven by a growing awareness of the values brought by adequate water availability both in terms of quantity and quality.

This document represents a technical report, which has been prepared by the water scarcity drafting group. It describes water scarcity mitigation measures and practices implemented in Europe and Mediterranean non-EU countries in order to provide and share information.

This technical document refers to different types of definitions, issues and related actions treated through two phenomena leading to different actions and effects : drought events management and water scarcity resulting from supply/demand imbalances. It also deals with surface and groundwater resources. As noted above, this is a technical document, the accompanying summary document providing a more strategic view of the issues.

This introductory section highlights the concerns of applying, in a global perspective, Water Framework Directive (WFD) articles that target drought issues. Integrating an ecosystem approach, the many values of freshwater echoed in our life are underlined and the actions to deal with Europe’s vulnerability to water crises highlighted. The existing gaps in current drought mitigation measures are then brought into focus. This consequently leads to an identification of what remains to be done to achieve sustainable water management.

A - VALUES BROUGHT ABOUT BY WATER AVAILABILITY IN ADEQUATE QUANTITY AND QUALITY

Many of the services water provides are irreplaceable and thus invaluable. For centuries, humankind has enjoyed unlimited use of “ever available” freshwater. Those days are over, as reflected by the recurrent water shortages and their impacts on ecosystems all around the world and notably in Europe. It is time to recognize the value of all the services that water provides and to ensure that these services are sustainably enjoyed by humankind and ecosystems alike, based on a set of agreed values that should shape water institutions :

- Life-giving value : water may be well accepted as a basic human right, necessitating reliable water services for health, sanitation and ensuring life to everyone.
- Social value : water is central to socio-economic development and job creation. Good water resources development and management plus the establishment of sound water

supply and sanitation systems are nowadays considered as a key foundation for growth and social stability.

- Value to ecosystems : the irreplaceable services provided by the ecosystems through their use of water include producing food, decomposing organic waste, purifying air, storing and recycling nutrients, absorbing human and industrial wastes and converting them into beneficial uses.
- Economic value : water enables agriculture, fishing, navigation and hydropower generation and is an important input to industries.

B - LINK BETWEEN THE WFD AND WATER SCARCITY ISSUES

There is a Europe-wide awareness of the full range of values water offers for the population's well-being, from livelihoods to recreational, aesthetic and cultural points of view. This recognition is clearly reflected in the Water Framework Directive (WFD), adopted on October 23rd 2000, by the Council and the European Parliament. WFD defines a european framework for water management and protection at each hydrological basin level. Aiming to preserve and restore good water status to both surface and groundwater sources by 2015, the WFD gives priority to environment conservation through participatory and consultative programs. It raises the issue of water floods and droughts in its article 1 which emphasizes the need to :

- prevent further deterioration (articles 1.a and 4)
- promots sustainable water use based on a long-term protection of available water resources (article 1.b)
- contribute to mitigating the effects of floods and droughts (article 1.e)
- contribute to the provision of the sufficient supply of good quality surface water and groundwater as needed for sustainable balanced and equitable water use

In addition, the WFD requires that "good quantitative status" of groundwater bodies (balancing abstractions with recharge) is attained, thus supporting sustainable water abstraction regimes, even in water stress and shortage situations. Furthermore, groundwater levels should not be subject to anthropogenic alterations that might have impacts on surface waters. Water quantity can have a strong impact on water quality and therefore on the achievement of the ecological status.

It will also be essential to encourage participatory ecosystem-based management, to provide the minimum flow of water to ecosystems for conservation and protection and to ensure sustainable use of water resources.

In conformity with WFD regulations, member states are responsible for protecting, enhancing and restoring all bodies of surface water to achieve good status. In practice, this is carried out through the implementation of monitoring programs (article 8) which cover :

- the volume and water level or rate of flow to the relevant extent for ecological and chemical status and ecological potential.
- the ecological and chemical status and ecological potential properly speaking.

For groundwater, monitoring programs relate to chemical and quantitative status.

C - ACTIONS TO AVERT WATER SCARCITY IN EUROPE

There are many challenges for european water management but also many potential solutions. Much is happening at the community level to the extent that it seems that, for every water problem, someone on the continent has devised a solution or is developing one. Though not necessarily applicable in other environments, these solutions can demonstrate the capability of individuals to adapt to the rising challenges of drought and water allocation.

C.1 - European research policies

C.1.1 - Directorate General of Research

The Directorate General's mission is evolving as work on development of the European Research Area (ERA) progresses. It can be summarized as follows :

- to develop the European Union's policy in the field of research and technological development and thereby to contribute to the international competitiveness of European industry.
- to coordinate European research activities with those carried out at the level of the member States.
- to support the Union's policies in other fields such as environment, health, energy, regional development, etc.
- to promote a better understanding of the role of science in modern societies and stimulate a public debate about research-related issues at European level.

One of the instruments used for the implementation of this policy is the multi-annual Framework Programme which helps to organize and financially support cooperation between universities, research centres and industries - including small and medium sized enterprises.

C.1.2 - Directorate General Joint Research Centre

The Joint Research Centre (JRC) is a Directorate General and an integral part of the European Commission. The mission of JRC is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies. As a service of the European Commission, the JRC functions as a reference centre of science and technology for the Union. Close to the policy-making process, it serves the common interest of the member states, while being independent of special interests, whether private or national. The JRC provides scientific advice and technical know-how to support EU policies.

With regard to drought and water scarcity, the JRC is a leading European research partner with activities in the fields of forecasting and monitoring of weather-driven natural hazards such as floods, droughts and forest fires, in water quality research as well as in climate change and its impact. Policy support is provided – among others – by producing bulletins of agricultural yield forecasts and supporting the implementation of the Water Framework Directive.

C.1.3 - ARID cluster

ARID was a cluster of research projects funded by the European Commission, and is dealing with water resources use and management in arid and semi-arid regions. It operates by linking thematically complementary projects via :

- project web pages
- cross-representation
- exchange of data
- joint meetings
- workshops

The ARID cluster includes three research projects about integrated and sustainable Water Resources Management :

- Water Strategy Man : developing strategies to regulate and manage water resources and demand in water deficient regions.
- Medis : towards sustainable water use in Mediterranean islands ; addressing conflicting demands and varying hydrological, social and economic conditions.

- Aquadapt : strategic tools to support adaptive, integrated water resource management under changing utilisation conditions at catchment level, a coevolutionary approach.

ARID is supported by the European Commission under the Fifth Framework Programme and contributes to the implementation of the key action "Sustainable Management and Quality of Water" within the Energy, Environment and Sustainable Development.

C.1.4 - AquaStress

The AquaStress project is a EU funded research project that delivers enhanced interdisciplinary methodologies in selected test sites, enabling actors at different levels of involvement and at different stages of the planning process to mitigate water stress problems. AquaStress draws on both academic and practitioner skills to generate knowledge in technological, operational management, policy, socio-economic, and environmental domains. It is an Integrated Project (IP) funded by the European Commission in the frame of the 6^{th} R&D Framework Programme.

Aqua**S**tress will generate scientific innovations to improve the understanding of water stress from an integrated multisectoral perspective to support :

- diagnosis and characterization of sources and causes of water stress
- assessment of the effectiveness of water stress management measures and development of new tailored options
- development of supporting methods and tools to evaluate different mitigation options and their potential interactions
- development and dissemination of guidelines, protocols and policies
- development of a participatory process to implement solutions tailored to environmental, cultural, economic and institutional settings
- identification of barriers to policy mechanism implementation
- continuous involvement of citizens and institutions within a social learning process that promotes new forms of water culture and nurtures long-term change and social adaptivity

The IP adopts a Case Study stakeholder driven approach and is organised in three phases : (i) characterization of selected reference sites and relative water stress problems, (ii) collaborative identification of preferred solution options, (iii) testing of solutions according to stakeholder interests and expectations.

C.1.5 - European Environment Agency

The European Environment Agency (EEA), through its Eurowaternet Quantity Surveillance Network, complements the information related to freshwater resources and water availability across european countries. The main aim of such a network is to quantify pressures and impacts, to give answers to specific policy questions or mitigation measures, and to provide comparable and reliable information on the quantitative aspects of freshwater resources.

The EEA goals are achieved through the use of data on water flows and additional information from the gauging stations network. Data compilations on european water resources are provided by the WMO, the Unesco IHP, the FAO Aquastat, and the Statistical Office of the European Commission (Eurostat). Eurostat has the responsibility of providing the EU information based on a regular data collection on water statistics, eventually making recommendations for freshwater resources estimation.

C.2 - Regional policies towards Water Resources Management (WRM)

At the continental scale, Europe possesses abundant water resources, but they are very unevenly distributed. The european countries have realized that water, as a limited resource, must be carefully managed for the benefit of everybody and for the environment, in order to ensure water security now and in the future. This concept of water security, which considers the future of water in present-day planning, also implies the empowerment of different countries in order to represent their interests and share best practices. This is envisaged through a series of guidelines that will allow them to adopt a common policy regarding specific problems related to drought.

C.3 - International cooperation with mediterranean partners

The objective of the Mediterranean Water Framework Directive/ EU Water Initiative Joint Process is to facilitate the implementation of the WFD in EU Mediterranean countries and sound water resources management policies inspired by the WFD principles for Mediterranean non-EU countries. The principle is to use the EU water-related experience and the WFD approach and best practices and lessons learnt in the whole region. Therefore, the basis of the Mediterranean Joint Process is fostering exchanges of best practices between EU and non-EU countries. The initiative targets individuals working at technical levels (water managers, experts, etc) as well as political ones (water directors). The objective of these exchanges is to produce recommendations for water management based on the EU Water Framework Directive. For EU countries, these recommendations could be used as guidance when implementing the directive and as technical elements for convergence of legislation for non-EU countries. Indeed, the European Neighbourhood Policy, through the implementation of Actions Plans, agreed between the EU and partner countries[1], aims in particular at gradual approximation of policy, legislation and practice. Sustainable development and Environment are included in each of these Action Plans.

D - EXISTING GAPS

Even with the vast collection and availability of data, and the broad awareness of the many values of water, finding solutions remains very difficult when interests and associated values conflict. Therefore the water crisis has been called a crisis of governance (Initial contribution of HRH the Prince of Orange to the Panel of the UN Secretary General in preparation for the Johannesburg Summit, http://www.nowaternofuture.org/). In most european countries, reforms to improve the quality of management in the water sector are underway. The most visible change is towards better coordination of water concerns among sectors. Other significant changes include wider and more significant participation by water users, expansion of the range of service providers (from private sector to community-based organizations through public utilities) and more emphasis on river basin management and decentralization.

But much remains to be done. Successfully applying the principles of integrated water resources management is a top priority, because of the enormous impact water has on development. This requires strong institutions, sufficient know-how and commitment, and adequate financial resources. Among the outstanding issues that need attention are the strengthening of the institutional framework for drought forecasting and management, the enhancement of people’s capabilities to cope with drought, and the promotion and share of knowledge among all people concerned by water-related risks.

By adopting the WFD, the EU has thoroughly restructured its water protection policy. The directive requires that integrated management plans be developed for each river basin in order to achieve good ecological and chemical status. Although the WFD will contribute to the mitigation of the effects of droughts, it is not one of its principal objectives. In most cases, droughts are identified too late and emergency measures are undertaken in a hasty way. The latter are not, in general, sufficiently effective. Clear and consistent criteria for an early detection and warning of drought situations need therefore to be established. Such criteria would allow sufficient time, before and at

[1] Five Action Plans were agreed with Israel, Jordan, Morocco, Tunisia and the Palestinian Authority and work is starting for Egypt and Lebanon.

the beginning of a drought event, to look for suitable responses in the management of a water resource system.
The WFD additionally considers that prolonged droughts “cannot reasonably have been foreseen” (article 4.6). Prolonged droughts are therefore “grounds for exemptions from the requirement to prevent further deterioration or to achieve good status” (Preamble (32)) where “additional measures are not practicable” (article 11.5). The measures that directly relate to drought mitigation are left as optional supplementary measures (WFD Annex VI, Part 5).
The considerations behind the setting up of a common strategy on water stress in Europe are intimately linked to national and international social and economic policies. Additional driving forces arise from natural variability in water availability (rainfall) and the diversity of Europe’s climatic zones. Recent history has demonstrated that extreme hydrological events can create additional stress on water supplies allocated for human and ecosystem health. In 2003 for example, several european countries suffered an intensive summer heat preceded by a shortage in precipitation since the beginning of the year. These two climatic phenomena resulted in an extreme drought and water deficit, entailing various life and economic losses. The impact of an expected increase in climate variability will certainly lead to more extreme water-related hazards and consequently to large socio-economic losses.

E - LINKS WITH WFD ARTICLE 17 AND GROUNDWATER DAUGHTER DIRECTIVE

Groundwater systems are complex and considerably vary in different parts of the EU. The technical capacity of member states to assess and manage groundwater is limited. An overemphasis on testing compliance with regulations or attempting to derive complex standards would not therefore provide a satisfactory solution to the problem. Alternatively, focusing on measures and actions that effectively and reliably protect groundwater, as required by article 17 of the WFD, constitutes the resort to achieve most specific targets being locally derived. Such a practice would set basic minimum controls adopted everywhere but with additional controls applied depending on local vulnerability within specific parts of the aquifer boundary.
It is to be equally noted that the most important element of the Groundwater Daughter Directive relates to the requirement under article 17.1 for the Parliament and Council to adopt specific measures to “prevent and control groundwater pollution”. While it is important in this regard to derive criteria to assess groundwater status and identify significant upward trends, this should not preclude the early adoption of simple pragmatic measures to protect groundwater quality. This is even more valid considering that a groundwater protection regime against pollution is already mandatory under the directive 80/68/EEC.

I - DEFINITIONS AND ASSESSMENT OF THE DIFFERENT PHENOMENA

A - PREAMBLE

Water scarcity issues are becoming emergency issues and are going to play a key role in the near future for the definition of both environmental and development policies at a global scale.
Regarding Europe, the 2003 and 2005 drought events especially in Spain and France confirm definitely this trend and the urgent need of the implementation of common strategies facing the problem which involves the whole European Community and not only Mediterranean countries.
The 2005 drought in Spain, Portugal, and parts of France has been caused by a low precipitation rate on all the territory in 2004; in Spain the annual average precipitation has been lower than the minimum measured in the historical series from 1947 to 2003. This extreme reduction of rainfall (from 650 mm to 400 mm) resulted in significant impacts on water stored in reservoirs, drinking water availability, hydropower potential, water quality, environmental stress, and fire risk. This situation called for the execution of special plans for situations of alert and eventual drought, implementing respective management measures such as irrigation restrictions, and setting emergency measures.
With respect to France, from September 2004 to September 2005, drought involved a large part of national territory and was still real at the beginning of October 2005 in the Poitou-Charente and Loire departments. The annual precipitation of 2005 was lower than the last fifty years' average. Every year since 1997, at least twenty departments adopted water use restrictions. The Drought Action Plan adopted in 2004 after the 2003 drought crisis has been reactivated and updated in 2005 to face this new event. At the end of October 2005, mid-term action was still necessary to balance water supply and demand, and water scarcity has become a priority for strategies of the French Government.
However, droughts cannot be considered as local phenomena; according to recent studies (Appendix I, P.1 - NCAR-UCAR) drought episodes have occurred more frequently during the last decades at a global scale. Concretely, the percentage of Earth's land area stricken by serious drought more than doubled from the 1970's to the early 2000's. Based on this information, it is often reported by climate change watch organizations such as the Intergovernmental Panel on Climate Change (IPCC, 2002), that drought severity and frequency have increased in some of the Earth's regions in conjunction with climate change, although clear evidence for this is not yet conclusive.

B - DEFINITION AND ASSESSMENT OF DROUGHT

B.1 - Drought definitions

Drought is a normal, recurrent feature of climate, although often erroneously considered an unexpected and extraordinary event. It occurs in virtually all climatic zones, but its characteristics vary significantly from one region to another. Drought is a temporary aberration within the natural variability and can be considered an insidious hazard of nature; it differs from aridity which is a long-term, average feature of climate.
Droughts generally result from a combination of natural factors that can be enhanced by anthropogenic influences. The primary cause of any drought is a deficiency in rainfall, and, in particular, the timing, distribution, and intensity of this deficiency in relation to the existing water storage, demand, and use. This deficiency can result in a shortage of water necessary for the functioning of a natural (eco-)system, and / or necessary for a certain human activities.
High air temperatures and evapotranspiration rates may act in combination with lacking rainfall to aggravate the severity and duration of a drought event. High air temperatures in summer, when

associated with clear skies and sunshine, increase evapotranspiration to the extent that little or no rainfall is available for groundwater or river recharge. Winter droughts are caused by precipitation being stored in the catchment in the form of snow and ice, preventing any recharge of rivers or aquifers until air temperatures rise again and snow melting starts. Both precipitation and air temperature are, in turn, driven by the atmospheric circulation patterns. Consequently, any change in the position, duration, or intensity of high-pressure centres (anticyclones) would lead to changes in the prevailing circulation pattern, thus producing precipitation and air temperature anomalies. Drought is also related to the timing (i.e. principal season of occurrence, delays in the start of the rainy season, occurrence of rains in relation to principal crop growth stages) and the effectiveness (i.e. rainfall intensity, number of rainfall events) of the precipitation. Other climatic factors such as high wind velocities and low relative air humidity are often associated with a drought event in many regions of the world, and can significantly aggravate its severity.
It is important to differentiate between aridity, which is restricted to low rainfall regions as a long-term average feature, and a drought situation that indicates a deviation from the average situation, but still within the ecosystem's natural variability. It is very important to discern among transitory periods of water deficiency, a cause of exceptional droughts, and long-term imbalances of available water resources and demands, as reflected in figure 1.

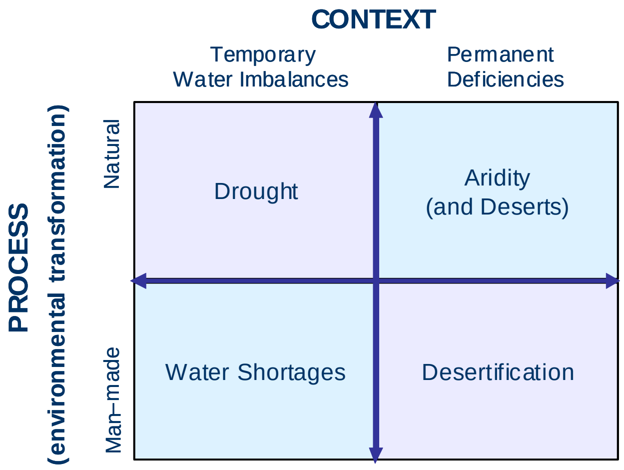


Figure 1: Typology of water stress condition (Vlachos, 1982).

B.1.1 - Operational Definitions of Drought

Operational definitions allow for the identification of onset and end as well as of the degree of severity of a drought. These definitions are categorized in terms of four basic approaches to identify and describe drought events: meteorological, hydrological, agricultural, and socio-economic droughts. The first three approaches consider a drought as a natural, physical phenomenon. The latter one regards a drought event in relation to anthropogenic supply and demand, thus tracking the effects of water shortfall as it passes through the socio-economic system.

Meteorological drought
Meteorological drought is usually an expression of precipitation's negative departure from normal over some periods of time. The exact definition is usually region-specific, and often based on a thorough understanding of regional climatology. The variety of meteorological definitions in different countries illustrates why it is not possible to apply a definition of drought developed in one part of the world to another without any modifications.

Agricultural drought

Agricultural drought occurs when there is not enough soil moisture to meet the needs of a particular crop at a particular time. Typically, agricultural drought happens after meteorological drought but before hydrological drought. Non-irrigated agriculture is usually the first economic sector to be affected by drought.
An operational definition for agricultural drought might compare daily precipitation values to evapotranspiration rates to determine the rate of soil moisture depletion, model soil moisture by a soil water balance model, or measure soil moisture directly, and then express these relationships in terms of drought effects on plant behaviour (i.e. growth and yield) at various stages of crop development. Such a definition could be used in an operational assessment of drought impact and severity by tracking meteorological variables, soil moisture, and crop conditions during the growing season, continually re-evaluating the potential impact of these conditions on final yield.

Hydrological drought
Hydrological drought refers to deficiencies in surface and subsurface water supplies. It is determined from measurements of stream-flows and lake, reservoir, and groundwater levels. There is a time lag between the lack of precipitation and decreased water levels in streams, rivers, lakes, and reservoirs; accordingly hydrological measurements are not the first indicators of a drought event. However, they reflect the consequences of reduced precipitation over an extended period of time, taking into account the effects of soil and vegetation. As another consequence, the end of a hydrological drought might be lagging behind the end of the corresponding meteorological drought, as considerable quantities of precipitation are required to restore river and lake levels back to their normal conditions.
Although climate is a primary contributor to hydrological drought, other factors such as changes in land use (e.g. deforestation), land degradation, or the construction of dams affect the hydrological characteristics of the basin. Because regions are interconnected by hydrologic systems, the impact of meteorological drought may extend well beyond the borders of the precipitation-deficient area and cause a hydrological drought where the local precipitation rate shows no large deficit.
Similarly, changes in land use upstream may alter hydrologic characteristics such as infiltration and runoff rates, resulting in more variable streamflow and a higher incidence of hydrologic drought downstream. Land use change is one of the ways human interventions alter the frequency of water shortage even when no change in the frequency of meteorological drought has been observed.

Socio-economic drought
Socio-economic drought definitions associate the supply and demand of some economic good with elements of meteorological, hydrological, and agricultural drought. It differs from the aforementioned types of drought because its occurrence depends on the time and space processes of supply and demand. Supply of many economic goods such as drinking, process, or cooling water, forage, food grains, fish, or hydroelectric power, depends on the climatic conditions. Because of the natural variability of climate, water supply can be ample in some years, but unable to meet human and environmental needs in other years. Socio-economic drought occurs when the demand for an economic good exceeds supply as a result of a weather-related shortfall in water supply.

To determine the onset of a drought event, operational definitions usually specify the degree of departure from average of the climatic variable under consideration over some time period. This is done by comparing the current situation to the historical average, often based on a 30-year period of record. The threshold identified as the beginning of a drought (e.g. 75 % of average precipitation over a specified time period) is usually established somewhat arbitrarily, rather than on the basis of its precise relationship to specific impacts.
Operational definitions can also be used to analyze drought frequency, severity, and duration for a given historical period. Such definitions, however, require detailed meteorological and corresponding impact data (e.g. crop yield), depending on the nature of the definition applied. Developing a climatology of drought for a region provides a greater understanding of its

characteristics and the probability of recurrence at various levels of severity. Information of this type is extremely beneficial in the development of response and mitigation strategies and preparedness plans.

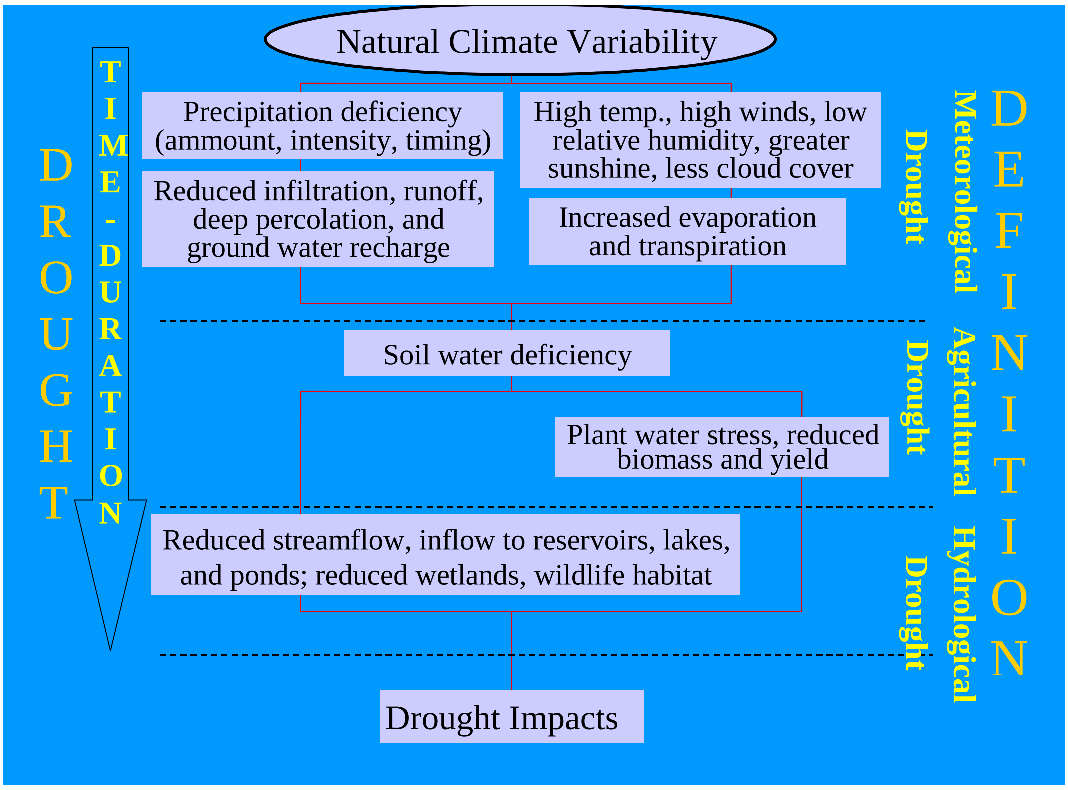


Figure 2: Sequence of drought due natural climate variability. Source: National Drought Mitigation Centre, USA, Drought Watch.

B.1.2 - Drought Management Definitions:

Drought management definitions help water resources managers and researchers to understand, clarify, and develop technical terms and concepts. Various definitions exist within the wide field of risk management, in which the natural hazards and disaster management community has a somewhat different approach than the perception of risk within the climate change community (e.g. Brooks 2003). Therefore it is important to agree upon a common terminology before using general expressions such as hazard, risk, or mitigation. The following terminology has been used within the MEDROPLAN project and can serve as a basis for drought risk management from the natural hazards point of view (Appendix I – P.2 MEDROPLAN).

Hazard
Hazard is the probability of occurrence of a potentially damaging event, phenomenon or activity, which may cause the loss of life, property damage, social and economic disruption or environmental degradation. In case of drought, it refers to the probability of a reduction in water supply that makes the supply of water inadequate to meet the demand.

Drought Impact
Drought impact is the specific effect of drought on the economy, on the social life and on the environment, which are symptoms of vulnerability.

Vulnerability
Vulnerability is the magnitude of losses resulting from a potentially damaging phenomenon. It comprises exposure – the values and lives present at the respective location – and their lacking

capability of resistance or defence to the threat. Vulnerability is an aggregate measure of human welfare that includes environmental, social and economic exposure to a range of harmful perturbations.

Risk
Risk is the result of imposing a hazard on something or someone that is vulnerable to that hazard. Risk may be quantified as the expected losses due to a particular hazard for a given area and reference period (i.e. hazard x vulnerability = risk).

Risk analysis and assessment
The process of identifying and understanding the relevant components associated with drought risk, as well the evaluation of alternative strategies to manage the associated risk resulting from the drought (i.e. risk management).

Capacity to face risk
Capacity is a combination of all the strengths and resources available within a community or organization that can reduce the level of risk, or the effects of a disaster.

Preparedness
Preparedness is the reduction of risk through activities and measures taken in advance to ensure effective response to a potential impact of damaging events.

Prevention
Prevention is the reduction of risk through the activities that provide outright avoidance of the adverse impacts of potentially damaging events.

Mitigation
Mitigation is the set of structural and non-structural measures undertaken to limit the adverse impact of potentially damaging events (i.e. adaptation).

Strategic reserves
Strategic reserves are those of restricted access, only to be made use of for the resolution of shortage or drought scenarios or for the prevention of similar situations in the near future.

Early warning
Early warning is the provision of timely and effective information, through identified institutions, that allows individuals at risk of a disaster, to take action to avoid or reduce their risk and prepare for effective response. It is an important element of preparedness.

Crisis management
Crisis management is the unplanned reactive approach that implies tactical measures to be implemented in order to meet problems after a disaster has started.

Proactive management
Proactive management are the strategic measures, actions planned in advance, which involve modification of infrastructures, and/or existing laws and institutional agreements.

B.2 - Drought causes

B.2.1 - Drought due to natural factors

When precipitation over a given region performs poorly and is accompanied by relatively high evaporation rates for prolonged periods, a drought occurs. Drought differs from other natural disasters in its slowness of onset and its commonly lengthy duration. In most cases, drought is caused by either a deficiency of precipitation or an inadequacy of inland water resources supplies for a prolonged period. “Inadequacy” in this context is a relative word, and is determined by the specific requirements in the sector or activity.

Before the rise of modern water-consuming cities, drought was predominantly an agricultural disaster. Now, with large urban agglomerations - especially in semi-arid regions - having expanded faster than water supplies can be made available, the spectre of drought faces both the farmer and the urban dweller. Since most inland water resources are usually sustained by precipitation, inadequate precipitation is usually the major cause of drought. This inadequacy is usually caused by an unfavourable performance of the factors which drive the climate system over the affected region. Precipitation anomalies are a naturally recurring feature of the global climate. These anomalies affect various components of the hydrologic cycle to produce a drought. Climatologies of precipitation, temperature, and atmospheric moisture provide an indication of the frequency and intensity of precipitation, the correlation of precipitation and temperature, and the atmospheric drying that occurs during droughts.

Shifts in atmospheric circulation, which cause drought, may extend for time scales of a month, a season, several years or even a century. The latter might be termed a climatic shift, but the effect on humans and their environment is equally great. Because of the economic and environmental importance of drought, determined efforts are being made to solve the problem of prediction of the atmospheric circulation patterns that produce droughts. Empirical studies conducted over the past century have shown that meteorological drought is never the result of a single cause but the result of many causes, often synergistic in nature (Appendix I-1.1).

B.2.2 - Anthropogenic factors enhancing drought impacts

The causes of water scarcity are manifold, and human activities contribute to the development of drought conditions. The current debate regards the causes as largely deterministic in that scarcity is a result of identifiable cause and effect. However, if water scarcity is the point at which water stress occurs (see C.1.3), then there are also less definable sociological and political causes. Many of the causes are inter-related and are not easy to distinguish. Some of the main causes are listed below. The list is not in order of priority although some causes have greater impact than others.

Population growth

The main cause of growing water scarcity is the growing demand resulting from population increase. The world's population is growing rapidly: in 2020 it is projected to be 7.9 billion, 50 % larger than in 1990 (Dyson, 1996). Most of this growth will be in countries whose inhabitants have low levels of household water consumption, and in which the use of water-intensive appliances is likely to grow. Many of these countries are also rapidly urbanising, and the task of obtaining sufficient water and distributing it to the newly urbanised households will be a major financial and environmental challenge to many authorities. The major increase in demand is due to the development needs of the growing population and, primarily, from the need to grow sufficient food to feed the increasing population.

Climatic change and variability

There is a great deal of debate regarding the issue of global climate change. Whilst there is a wide-spread view that global warming is happening, this is yet to be conclusively scientifically proven and the effect of this phenomenon on water resources is unknown. The consensus is that the effect will be to accentuate the extremes with more pronounced droughts and more severe flooding (Climate Change 2001: Impacts, Adaptation and Vulnerability - IPCC, 2001). If it persists, climatic zones are likely to migrate, leaving the climate of some regions dryer, others wetter, and all more variable and unpredictable (Schaer et al. 2004). Certain regions dependent on water (e.g. major farming areas, or large population centres) will experience more water scarcity, while others will become more humid. It is an open question what the net effect on water supply will be, but in any case there will be transitional and frictional costs in regions that become drier.

Land use

The degradation and land use conversion of watersheds and catchments may reduce the amount of usable water available downstream. While reduction of vegetation cover may result in higher runoff, it reduces groundwater infiltration and the storage capacity of dams and lakes through sedimentation. The draining of large scale wetlands or large scale deforestation may change the micro-climate of a region.

The consequences of poor land management and farming methods risk pushing communities ever closer to the point of vulnerability where even small changes in conditions can have disastrous effects.

Another issue related to land use is the development of "thirsty" crops, particularly in sensitive areas such as mountain catchments, surroundings of wetlands or already water stress facing regions.

With regards to Europe, it has been estimated that about 42 % of the total land area is farmland (comprising 24 % arable, 16 % permanent crops, and 2 % grassland), 33 % forest and 1 % urban (EEA, 1995). The European Union, as part of its reform of the Common Agricultural Policy, is committed to a policy of increasing afforestation. In Europe as a whole, forest cover has increased by about 10 % over the past 30 years and it is calculated that each decade 2 % of agricultural land is lost to urbanisation. Both these changes will have a significant effect on the hydrology of the local area. It is generally accepted that afforestation of a catchment reduces mean run-off, through increased interception and evapotraspiration, but is important to stress that this effect must be balanced with the important ecological functions played by a forested catchment in terms of protection from soil erosion and nature conservation. The precise impact on the streamflow will, however, vary depending on the type of forest, density of planting and land management practice.

Urbanisation has been shown to lead to increased surface run-off, reduced infiltration and reduced baseflows locally. In Mediterranean regions, the semi-arid climate coupled with poor land and crop management can lead to land degradation. It is estimated that about 44 % of Spain is affected by some kind of soil erosion. Soil erosion reduces the capacity of infiltration and increases the vulnerability of a region to drought.

Water quality

The pollution of water supplies reduces the availability of clean water for usage. This is particularly severe during times of water shortages. In normal conditions the capacity of a river to accept a given pollution load is determined by the average dilution factor. As water becomes scarcer, rivers and streams become increasingly sensitive to the effects of pollution, as do those human and other living organisms which depend on the water. This may happen to surface supplies (e.g. a river or lake used for drinking water supply) or groundwater, and the pollution may origin from industrial discharge, agro-chemical runoff from agricultural fields, the illegal disposal of civil discharges, or the release of insufficiently treated sewage from municipal works. Seen from the other point of view, the reduction of water pollution can increase the usable water supply.

Water demand

A growing and unmanaged demand for water will accelerate the arrival of conditions of scarcity. The widespread misconception that there is plenty of water and that the only problem is getting it to the right place at the right time still persists as a relict of the supply driven water resources management. Reducing and managing the demand for water, enforcing the efficiency of use and introducing water conservation measures requires policy and legislative attention.

Legislation and water resource management

Poor or inadequate legislation can exacerbate the effects of water scarcity. Legislation acts which give exclusive rights to some users are necessary to provide security for investment (usually in the agricultural sector), but they can result in serious jeopardy during times of scarcity. Water resources management and development policies can also have a direct effect on the capacity of some sectors to survive water scarcity periods. If these are inequitable, inefficient, or do not provide for at least the basic needs of all citizens, then a particular occurrence of water scarcity will result in conditions of drought.

International waters
The use of water in international rivers of cross-boundary catchment areas by upstream countries may lead to conditions of drought in downstream countries. This is a problem which is obviously exacerbated during times of scarcity. It is important that communication is maintained between riparian countries through a variety of mechanisms including special protocols, joint commissions, memoranda of agreement, treaties etc. It is important that these agreements are established during times of water abundance rather than in times of crisis.

Political realities
Politicians and decision-makers are the persons who have greatest influence on the allocation of scarce financial budgets and the adoption of policies. Unfortunately, the temporal perspective of many politicians does not coincide with the temporal dimension of a prudent water resources management, resulting in decisions being made on the basis of short term political benefits only.

B.2.3 - Drought perceptions in different climatic zones

The observed changes in precipitation rates over Europe in the 20th century follow the general hemispheric trend of increasing precipitation at mid and high latitudes and decreasing precipitation in the subtropics (Climate Change: the scientific basis – IPCC, 2001). The observations show a strong decadal variation in drought frequency.

Northern Europe
Annual precipitation over Northern Europe has increased by between 10 % and 40 % in the last century; the strongest increases are found in Scandinavia and Western Russia. The changes in Central Europe are less pronounced and include both increases (in the western part) and decreases (in the eastern part). The trend towards increasing precipitation in Northern Europe would continue at a rate of 1 % to 2 % per decade. An increasing trend is expected for the winter as well as the summer season. The projected changes for Western and Central Europe (e.g. France and Germany) are small or ambiguous (Appendix I – P.3 Project Acacia).

Southern Europe
Most of the Mediterranean basin has experienced up to 20 % reduction of precipitation during the last century. The projections for the 21st century show further decreases in precipitation over Southern Europe, but not by more than, at most, about 1 %. Contrary to Northern Europe, there is a marked difference between the seasons: apart from the Balkans and Turkey, Southern Europe can expect more precipitation in the winter while in the summer precipitation is projected to decrease by up to 5 % per decade. The effects of aerosol pollution over the Mediterranean, implying sea-surface cooling and heating of the atmosphere, are likely to contribute to the reduced summer precipitation in the region (Climate Change: the scientific basis – IPCC, 2001).

B.3 - Drought indices and indicators

Because there is no single definition for drought, its onset and termination are difficult to determine. In fact, as a drought does not begin with an extreme meteorological event, like a flood, its onset may be difficult to recognize for stakeholders. Rather, the onset of drought is gradual and drought usually hits different regions of a country, with varying levels of intensity and at different moments. A drought indicator is an objective measure of the system status that can help agencies identify the onset, increasing or decreasing severity, and end of a drought. But no single indicator or index alone can precisely describe the onset and severity of the event. As a consequence of these characteristics, effective early-warning systems for drought must be based on multiple indicators to fully describe a drought event development and severity (see chapter II.C).

Tracking various indicators provides crucial means to monitor drought. Common indicators of drought include meteorological variables such as precipitation and evaporation, as well as hydrological variables such as stream flow, groundwater levels, reservoirs and lakes levels, snow pack and soil moisture. Numerous climate and water supply indices are in widespread use to picture the severity of drought conditions and to represent it in a probabilistic perspective. Each index has strengths and weaknesses which need to be clearly understood before being applied.

Drought indices assimilate a large number of data into a comprehensible big picture. A drought index value is typically a single number, far more useful than raw data for decision making. There are several indices that measure how much precipitation for a given period of time has deviated from historically established norms. Although none of the major indices is inherently superior to the rest in all circumstances, some indices are better suited than others for certain uses. In the international publications different indices have been discussed and applied. Among those we mention (Appendix I-P.4, 1.2):

- Percent of Normal
- Deciles
- Palmer Drought Severity Index (PDSI)
- Surface Water Supply Index (SWSI)
- Standardized Precipitation Index (SPI)

The interest in developing indexes is represented in the scientific literature by new approaches such as PAI – Palfai Aridity Index (Palfai, 2002), or RDI - Reconnaissance Drought Index (Tsakiris, 2004), among others. Furthermore, plans generally call for certain measures to be initiated when a drought indicator reaches a predefined level. Trigger levels can be refined through computer modelling to strike an acceptable balance between the frequency of drought declarations and the effectiveness of an early response. The nature of the indicator and the level at which responses are triggered should be selected to reduce economic and environmental consequences.

B.4 - Drought impacts per sector

Drought should not be viewed as a merely physical phenomenon or natural event. Its impacts on society result from the interplay between a natural event (less precipitation than expected resulting from natural climatic variability) and the demand people place on water supply.

When a drought event begins, the agricultural sector is usually the first to be affected because of its heavy dependence on stored soil water. Soil water can be rapidly depleted during extended dry periods. If precipitation deficiencies continue, sectors dependent on other sources of water will begin to feel the effects of the shortage, too.

Sectors relying on surface water (i.e. reservoirs and lakes) and subsurface water (i.e. groundwater) are usually the last to be affected. A short-term drought that persists for 3 to 6 months may have little impact on these sectors, depending on the characteristics of the hydrologic system and water use requirements.

When precipitation returns to normal and meteorological drought conditions have abated, the sequence is repeated for the recovery of surface and subsurface water supplies. Soil water reserves are replenished first, followed by stream-flow, reservoirs, lakes, and groundwater. Drought impacts may diminish rapidly in the agricultural sector because of its reliance on soil water, but linger for months or even years in other sectors depending on stored surface or subsurface supplies. Groundwater users, often the last to be affected by drought during its onset, may be last to experience a return to normal water levels. The length of the recovery period is a function of the intensity of the drought, its duration, and the quantity of precipitation received as the episode terminates.

Drought produces a complex matrix of impacts that spans many sectors of the economy and reaches well beyond the area that is physically experiencing the drought.

Impacts are commonly differentiated into direct and indirect. Reduced crop, rangeland, and forest productivity, increased fire hazard, reduced water levels, increased livestock and wildlife mortality rates, or damage to wildlife and fish habitat are examples of direct impacts.
The consequences of the direct impacts lead to indirect impacts. For example, a reduction in crop, rangeland and forest productivity may result in reduced income for farmers and agro-industry, increased prices for food and timber, unemployment, reduced tax volume because of reduced expenditures, foreclosures on bank loans to farmers and businesses, migration, and disaster relief programs.
The impacts of drought can be categorized as economic, environmental and social (figure 3).

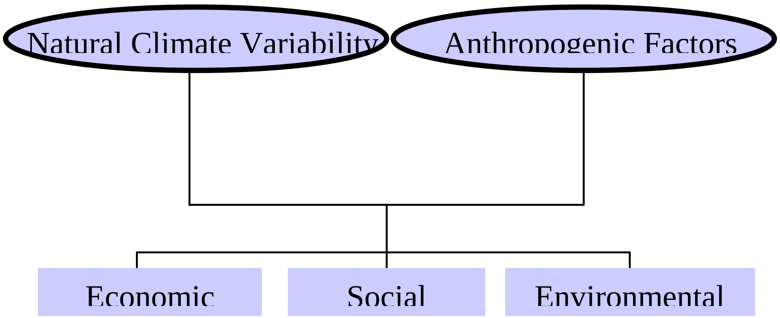


Figure 3: Sequence of drought impacts.

B.4.1 - Economic impacts

Many economic impacts occur in agriculture and related sectors, including forestry and fisheries, because of the reliance of these sectors on surface and subsurface water supplies. In addition to obvious losses in yields in both crop and livestock production, drought is associated to increases of insect infestations, plant diseases and wind erosion. The incidence of forest and range fires substantially augments during extended droughts, which in turn places both human and wildlife populations at higher levels of risk.
Income loss is another indicator used in assessing the impacts of drought because a lot of sectors are affected. Reduced income for farmers has a ripple effect. Retailers and others who provide goods and services to farmers face reduced business, leading to unemployment, increased credit risk for financial institutions, capital shortfalls and loss of tax revenue for government. Less discretionary income affects recreation and tourism industries. Prices of food, energy and other products increase as supplies are reduced. In some cases, local shortages of certain goods result in the need to import these goods from outside the stricken affected region. Reduced river discharge impairs the navigation on rivers and causes an increase of transportation costs, because products must be transported by rail or road. Hydropower production may also be curtailed significantly. For the 2003 summer drought in Europe, the MunichRe reinsurance company estimated economic losses of approximately US$ 13 billion, of which large parts were not insured (MunichRe 2004).

B.4.2 - Environmental impacts

Environmental losses are the result of damages to plant and animal species, wildlife habitat, air and water quality, forest and range fires, degradation of landscape quality, loss of biodiversity and soil erosion. Some of the effects are short-term and conditions quickly return to normal situation after the end of the drought. Other environmental effects linger for some time or may even become permanent. These effects are enhanced, if the management of water resources is permanently not sustainable at all, as often true for wetlands (Zacharias et al., 2003). Wildlife habitat, for example, may be degraded through the loss of wetlands, lakes and vegetation. This habitat change can have

negative impacts on species and, even more, their individuals. However, some species may recover from this temporary aberration. The degradation of landscape quality, including increased soil erosion, may lead to a more permanent loss of biological diversity and productivity of the landscape. Although environmental losses are difficult to quantify, growing public awareness and concern for environmental quality has forced public officials to focus greater attention and resources on these effects.
Often drought stress on plants and ecosystems is enhanced by a combination of stress factors; e.g. Matyssek et al. (2006) reviewed the interactions between drought and ozone stress in forest trees, finding a strongly reduced tolerance under exposure of the combined stress as well as a consequent reduced carbon fixation of forests. As for the 2003 summer drought in Europe, Ciais et al. (2005) found a reduction of up to 30 % in gross primary productivity over Europe, resulting in a strong anomalous net source of carbon dioxide to the atmosphere and hence a reversion of the carbon sequestration by European ecosystems of the previous years.
Environmental impacts from irrigation can be of different types: aquifer exhaustion from over abstraction, salinization of groundwater, increased erosion of cultivated soils on slopes and water pollution by nutrients and pesticides. These impacts are not well documented in many EU member states but different case studies show that over-abstraction and salinization of aquifers occur in many parts of the Mediterranean coastline (Portugal, Spain, Italy and Greece) and some localized areas in northern Europe (the Netherlands) (Digital Atlas of Global Water Quality, UN GEMS/Water Programme). Soil erosion is particularly severe in Spain, Portugal and Greece. The desiccation of former wetlands and the destruction of former high nature value habitats are significant in different regions of both southern and northern Europe (west France, inland Spain, Hungary and southeast England).

B.4.3 - Social impacts

Social impacts mainly involve public safety, health, conflicts between water users, reduced quality of life, and inequities in the distribution of impacts. Many of the impacts specified as economic and environmental have social components as well (see III-C.2).

C - DEFINITION AND ASSESSMENT OF SUPPLY/DEMAND IMBALANCES

An imbalance in water supply and demand is a situation where there is insufficient water to satisfy long-term average requirements. It is important, however, to underline the difference between imbalances, arising when water demand by society exceeds the supply capacity of the natural system, and aridity, which is a natural phenomenon, describing generally low water availability of an ecosystem due to low precipitation and/or high evaporation rates.

C.1 - Definition of imbalances in water supply and demand

C.1.1 - Water shortage

A water shortage can be described as any situation in which water supply is inadequate to meet demand. The term “water shortage” has the following specific meanings:

- a dearth, or absolute shortage,
- low levels of water supply relative to minimum levels necessary for basic needs.

It can be measured by annual renewable flows (in cubic meters) per head of population, or its reciprocal, i.e. the number of people dependent on each unit of water (e.g. millions of people per cubic kilometre).
The frequency and/or cause of a shortage may indicate the best way to overcome it. Droughts are temporary, but reoccurring. Thus, depending upon drought frequency, a solution to the problems

created by drought may be reducing demand and/or augmenting supply. On the other hand, water contamination can put a water supply out of commission permanently, or at least until treatment technology becomes affordable. The latter case is similar to developing a new source of supply. Water shortage caused by inadequate planning or equipment may be overcome by putting attention to design and capital improvements. Shortages resulting solely from increased demand for water resources may be best eliminated through long-term resources management.
A comparison of projected supply and demand indicates whether a utility faces a potential water shortage. Ideally, a utility should know not only whether it is likely to have a shortage, but how much of a shortage. This would enable the development of responses based on the projected magnitude of an impending shortage. In reality, it is very difficult to estimate the projected magnitude of a shortage because of the difficulty involved in estimating available supplies. Therefore, the primary objective is to determine whether a utility faces the possibility of a shortage. The secondary objective is to determine, if possible, the magnitude of this potential shortage.
Selected demand reduction options should be related to the degree of water shortage that exists. For example, imposing water rationing upon customers would be inadequate, if only a five percent deficit in your normal water supply occurred.

C.1.2 - Water scarcity

In popular usage, “scarcity” is a situation where there is insufficient water to satisfy normal requirements. However, this common-sense definition is of little use to policy makers and planners. There are degrees of scarcity - absolute, life-threatening, seasonal, temporary, cyclical, etc. Populations with normally high levels of consumption may experience temporary scarcity more severely than other societies who are accustomed to use much less water. Scarcity often arises because of socio-economic trends having little to do with basic needs. Defining scarcity for policy-making purposes is very difficult.
The term “water scarcity” has the following specific meanings:

- an imbalance of supply and demand under prevailing institutional arrangements and/or prices,
- an excess of demand over available supply,
- a high rate of utilization compared to available supply, especially if the remaining supply potentials are difficult or costly to tap.

Because this is a relative concept, it is difficult to capture in single indices. However, current utilization as a percentage of total available resources can illustrate the scale of the problem and the latitude for policymakers.
Some causes of water scarcity are natural, others are of anthropogenic. The impact of natural processes can be aggravated by human responses. Human behaviour can modify our physical environment in a way that the availability of usable water resources is reduced. The demand for water may be artificially stimulated, so that at a constant rate of supply the resource becomes “scarce”.

C.1.3 - Water stress

Water stress is generally related to an over-proportionate abstraction of water in relation to the resources available in a particular area. The ratio between total freshwater abstraction and total resources indicates in a general way the availability of water and the pressure on water resources.
Water stress occurs when the demand for water exceeds the available amount during a certain period or when poor quality restricts its use. It frequently occurs in areas with low rainfall and high population density or in areas where agricultural or industrial activities are intense. Even where sufficient long-term freshwater resources exist, seasonal or annual variations in the availability of freshwater may at times cause stress. Water stress induces deterioration of fresh water resources in terms of quantity (aquifer over-exploitation, dry rivers, etc) and quality (eutrophication, organic

matter pollution, saline intrusion, etc). Such deterioration can result in health problems and have a negative influence on ecosystems.
The Water Exploitation Index (WEI) in a country is the mean annual total demand for freshwater divided by the long-term average freshwater resources. It gives an indication of how the total water demand puts pressure on the water resource (figure 4). According to the European Environmental Agency (EEA, 2002), a total of 20 countries (50 % of Europe's population) can be considered as non-stressed, mainly in Central and Northern Europe. When not considering water abstraction for energy cooling, nine countries can be considered as having low water stress (15 % of european population). These include Belgium, Denmark, Romania and southern countries (Greece, Portugal and Turkey). Six countries (Germany, Belgium, Cyprus, Italy, Malta and Spain) are considered to be water stressed (35 % of European population).

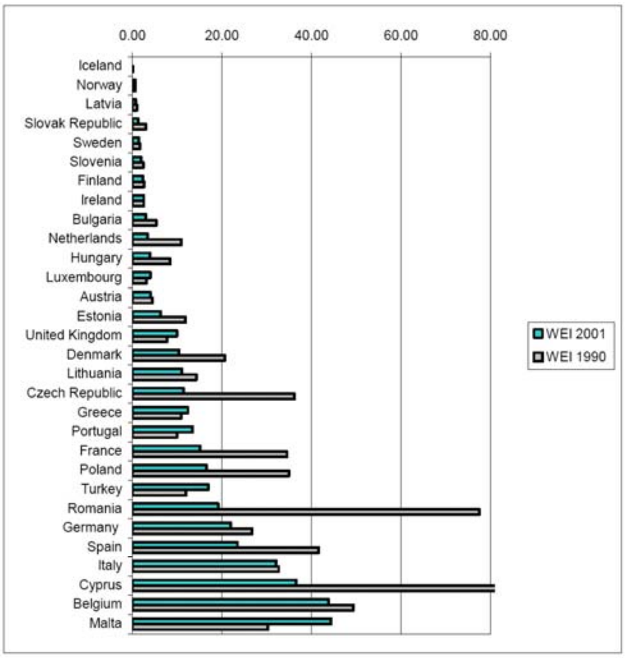


Figure 4: Water Exploitation Index (%). EEA 2002.

C.1.4 - Water demand management

Water demand management refers to the implementation of policies or measures which serve to control or influence the amount of water used (EEA Glossary).
The relationship between water abstraction and water availability has turned into a major stress factor in the exploitation of water resources in Europe. Therefore, it is logical that the investigation of sustainable water use is increasingly concentrating on the possibilities of influencing water demand in a favourable way for the water environment. Demand management includes initiatives having the objective of reducing the amount of water used (e.g. the introduction of economic instruments and metering), usually accompanied by information and educational programmes to encourage more rational use. According to the EEA, management can be considered as a part of water conservation policy, which is a more general concept, describing initiatives with the aim of protecting the aquatic environment and making a wiser use of water resources.

C.1.5 - Water conservation

While there is no universally accepted definition of water conservation, this term is often used in the sense of "saving water" through efficient or wise use. People do not always agree on the meaning of "efficiency" because there are various degrees of efficiency. For example, efficient residential water use can range from reducing toilet tank flows and turning the tap off when water is not in use (activities that do not require significant, if any, lifestyle changes), to planting low-water-use landscapes and car washing restrictions (activities that do require environmental or lifestyle changes).

In terms of utility management activities for dealing with water shortages, conservation can mean both short-term curtailment of demand and long-term resource management. Short-term curtailment of demand can be achieved through a vigorous public information programme, which can include both voluntary and enforced actions. The curtailment is temporary, and after a shortage is over consumers usually resume their former water use habits. Long-term resource management involves efficient use and resource protection strategies designed to achieve permanent changes in how water is managed and used, including policy changes like the removal of subsidies for thirsty crops in water-scarce areas. Water supply companies and authorities often undertake activities under normal circumstances to promote efficient use of water.

Today, water conservation has many meanings. It means storing, saving, reducing or recycling water. In detail it denotes:

for farmers who irrigate

- improving application practices via surge valves, special nozzles on sprinkler systems, soil moisture and crop water needs sensors
- increasing uniformity of application, thereby allowing less water to be used
- using meteorological data to balance water applications with available soil moisture and crop water needs
- lining diversion canals and ditches to minimize seepage and leaks
- irrigating with recycled water rather than freshwater that could be used after treatment for potable water

for municipalities

- encouraging residents to install and use high efficiency plumbing fixtures and educate them about water-saving habits
- reducing peak demands to avoid the extra-costs of investing in additional pumping and treatment plants
- metering water (customers pay for what they use)
- substituting recycled water for non potable application for urban irrigation of sports facilities and parks
- increasing water storage through aquifer recharge and recovery so that excess water in the winter can be stored for summer use.

for industry

- identifying other resource-conserving methods for the production processes
- reusing treated municipal wastewater instead of potable water for process and cooling
- reusing water used in manufacturing and cooling

C.2 - Background of water supply

The concept of water resources is multidimensional. It is not only limited to its physical measure (hydrological and hydrogeological), the "flows and stocks", but encompasses other more qualitative, environmental and socio-economic dimensions.

The water resources of a country are determined by a number of factors, including the amount of water received from precipitation, inflow and outflow in rivers and the amount lost by evaporation and transpiration (evaporation of water through plants). The potential for storage in aquifers and bodies of surface water is important in facilitating the exploitation of this resource by humans. These factors depend on geography, geology and climate.

Freshwater resources are continuously replenished by the natural processes of the hydrological cycle. Approximately 65 % of precipitation falling on land returns to the atmosphere through evaporation and transpiration; the remainder recharges aquifers, streams and lakes as it flows to the sea.
The average annual runoff for the member countries of the European Environment Agency (EEA) is estimated to be about 3100 km^3 per year (314 mm per year). This is equivalent to 4500 m^3 per capita per year for a population of 680 millions.

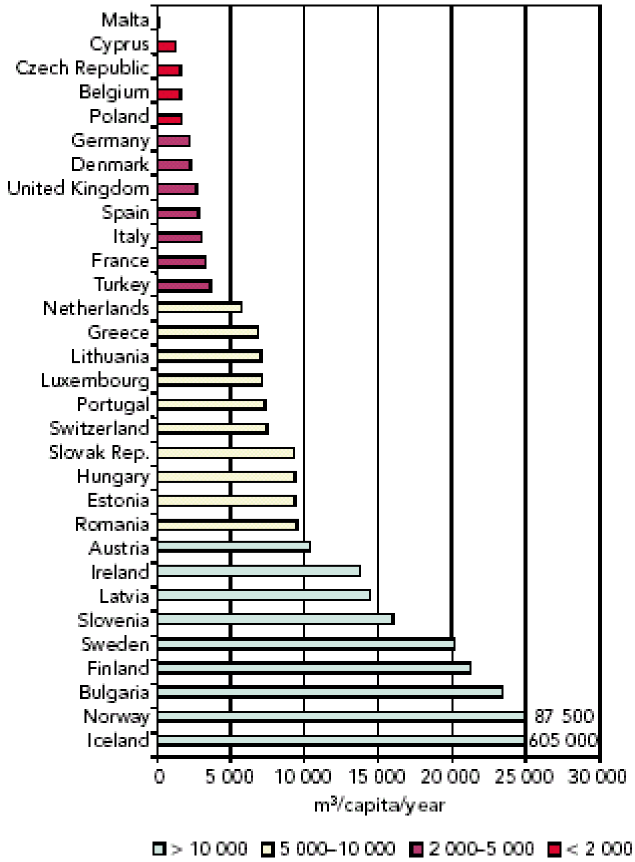


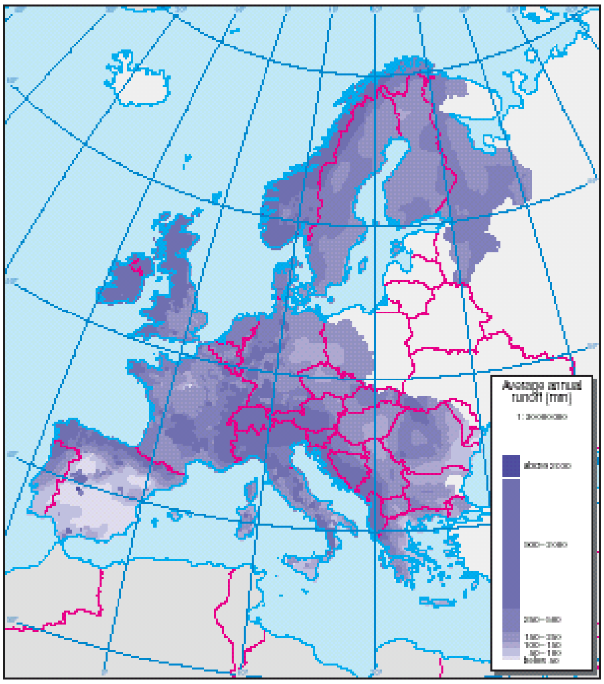
Figure 5: Annual Water availability per capita and country (Eurostat, 2001).

Sustainable use of the freshwater resources can only be assured if the rate of use does not exceed the rate of renewal. The total abstraction of a country or area must not exceed the net water balance (precipitation plus inflow minus evaporation and transpiration) and must guarantee a minimum river flow consistent with the Good Ecological Status (GES) that is supporting the typical biocoenosis of the water bodies.
Achieving the correct balance between use and renewal requires reliable quantitative assessment of the water resources and a thorough understanding of the hydrological regime. Available resources must be managed carefully to ensure that abstraction to satisfy the various demands for water does not threaten the long-term availability of water. Sustainability also implies management to protect the quality of the water resources, which may include measures such as preventing contaminants from entering the water, and maintaining river flows so that any discharges are sufficiently diluted to prevent adverse effects on water quality and ecological status.
At continental scale, Europe appears to have abundant water resources. However, these resources are unevenly distributed, both between and within countries. Once population density is taken into account, the unevenness in the distribution of water resources per inhabitant is striking.

A total of 12 countries have less than 4000 m^3/capita/year, while the Northern European countries and Bulgaria have the highest water resources per capita (figure 5).
Population density also determines the availability of water per person and widely varies across Europe, from fewer than 10 inhabitants per km^2 in Iceland to over 300 per km^2 in the Benelux countries and San Marino and over 1000 per km^2 in Malta.
The total renewable freshwater resource of a country is the total volume of river runoff and groundwater recharge annually generated by precipitation within the country, plus the total volume of actual flow of rivers coming from neighbouring territories (Brouwer and Falkenmark, 1989). This resource is supplemented by water stored in lakes, reservoirs, snow, icecaps and fossil groundwater.

C.2.1 - River runoff

In a long-term water balance, runoff is the amount of precipitation that does not evaporate, usually expressed as an equivalent depth of water across the area of the catchment. Stream-flow, in general terms, is the water within a river channel, usually expressed as a rate of flow passing a point, typically in m^3s^{-1}. A simple link between the two is that runoff can be regarded as stream-flow divided by catchment area, although in dry areas this does not necessarily hold, because runoff generated in one part of the catchment may infiltrate before reaching a channel and becoming stream-flow. Over short durations, the amount of water leaving a catchment outlet is usually expressed as stream-flow; over durations of a month or more, it is usually expressed as runoff.
Renewable water resources include waters replenished yearly in the process of the annual water cycle; they are defined as the total volume of river run-off and groundwater recharge generated annually by precipitation, plus the total volume of actual flow of rivers coming from neighbouring territories. Thus, river runoff represents renewable water resources and constitutes the dynamic component of the total water resource (figure 7).
Climatic and physical properties of the catchment, aggravated by human activities, such as river impoundment and landuse changes, may lead to significant variations in seasonal flow regimes.
In general, trends in hydrological data are consistent with those identified for precipitation: runoff tends to increase where precipitation has increased and decrease where it has fallen over the past few years. Variations in flow from year to year have been found to be much more strongly related to precipitation changes than to temperature changes (e.g. Krasovskaia, 1995; Risbey and Entekhabi, 1996). There are some more subtle patterns, however. In large parts of Eastern Europe (Westmacott and Burn, 1997), a major—and unprecedented—shift in streamflow from spring to winter has been associated not only with a change in precipitation totals but more particularly with a rise in temperature: precipitation has fallen as rain, rather than snow, and therefore has reached rivers more rapidly than before
There is also a considerable spatial variation in river flow across Europe. The average annual runoff in Europe very closely follows the pattern of average annual rainfall. Annual runoff is larger than 3000 mm in western Norway, and decreases to less than 25 mm in southern and central Spain and is about 100 mm over large part of Western Europe (Europe’s water: an indicator based assessment, EEA, 2003).



Source: European Environment Agency (1).

Figure 6: Long-term average annual runoff (in mm) in the European Union (EEA, 2003).

C.2.2 - Groundwater

Groundwater represents the largest single source of freshwater in the hydrological cycle (about 95 % globally), larger in volume than all water in rivers, lakes and wetlands together. In general, groundwater is of good quality because of natural purification processes and very little treatment is needed to make it suitable for human consumption unless in the case of high natural occurrence of toxic substances (table 1).
Natural underground reservoirs can have an enormous storage capacity, much greater than the largest man-made reservoirs; they can supply “buffer storage” during periods of drought. In addition, groundwater provides base flow to surface water systems, feeding them all through the year. Thus, groundwater quality has a direct impact on the quality of surface waters as well as on associated aquatic and terrestrial ecosystems.

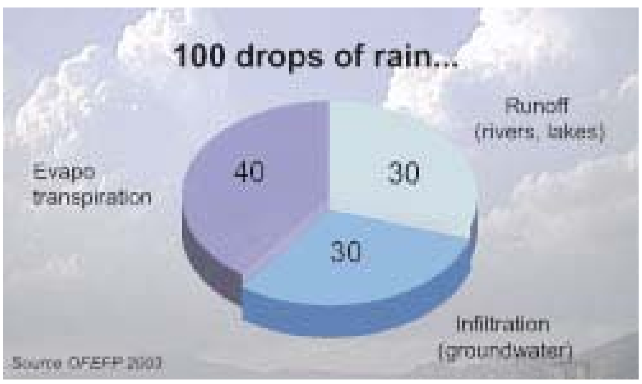


Figure 7: Precipitation and groundwater at the latitude of Switzerland (UNEP, 2004).

Region	**(%)**	**Population served (millions)**
Asia–Pacific	32	1 000 – 2 000
Europe	75	200 – 500
Central and South America	29	150
USA	51	135
Australia	15	3
Africa	NA	NA
World	-	1 500 – 2 750

Table 1: Estimated percentage of drinking water supply obtained from groundwater. Source: UNEP, 2004.

Groundwater represents the portion of precipitation that infiltrates into the land surface, entering the empty spaces between soil particles or fractured rocks; the larger the soil particles, the larger the empty spaces, and the greater the potential for water infiltration.

Groundwater systems are dynamic. Water is continuously in motion; its velocity is highly variable, ranging from a few meters per year to several meters per day. Many aquifer systems possess a natural capacity to attenuate and thereby mitigate the effects of pollution. The soil purifies the infiltrating water in three different ways. It serves as a physical filter retaining particles like a sieve. Secondly, pollutants undergo chemical conversion through contact with soil minerals. Furthermore, the surface layer of the soil supports intense microbial life; bacteria break down certain undesirable substances, neutralizing them.

Although groundwater is not easily contaminated, once this occurs, it is difficult to remediate. Therefore, it is important to identify which aquifer systems are most vulnerable to degradation. The replacement cost of a failing local aquifer will be high and its loss may stress other water resources serving as substitutes.

Groundwater abstraction

In some regions the extent of groundwater abstraction exceeds the recharge rate, thus leading to over-exploitation. In Europe, the share of groundwater needed at the country level to meet the total demand for freshwater ranges from 9 % up to 100 % (compare figure 8). In the majority of countries, however, total annual groundwater abstraction has been decreasing since 1990. The vulnerability of an aquifer to overexploitation depends on its type, the climate, the hydrological conditions, and the uses of water. The rapid expansion in groundwater abstraction over the past 30 to 40 years has supported new agricultural and socio-economic development in regions where alternative surface water resources are insufficient, uncertain or too costly.

Over-abstraction leads to groundwater depletion, with consequences like landscape desertification, deterioration of water quality (e.g. saltwater intrusion), loss of habitats (e.g. wetlands), modification of river/aquifer interactions, and ground subsidence (see chapter I.C.4 and Technical Report on Groundwater Management in the Mediterranean and the Water Framework Directive).

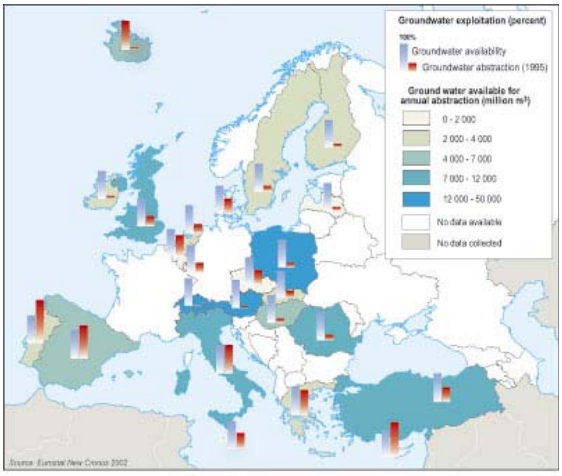


Figure 8: Groundwater resources and abstractions (Eurostat New Cronos, 2002). Data for groundwater resources are long term annual average; data for groundwater abstractions refer to year 1995 except for Cyprus 1998, Ireland 1994, Netherlands 1996, Portugal 1998, Italy 1985, and Turkey 2000.

Groundwater and Water Framework Directive

Due to the complexity in addressing groundwater, particularly when assessing its status, article 17 of the European Water Framework Directive (WFD) demands the creation of a so-called groundwater daughter directive to lay down specific measures for groundwater in order to prevent and control pollution and to achieve good chemical status of groundwater. It sets out criteria for assessing the chemical status and for identifying and reversing trends in pollution of groundwater bodies. The daughter directive must also provide controls on indirect discharges to groundwater that would be lost after the withdrawal of the current directive on the protection of groundwater of 1979 (Dir. 80/68/CEE) in 2013.

Currently, Working Group C of the WFD Common Implementation Strategy (WFD-CIS WG-C) is working on the clarification of groundwater issues that are covered by the WFD such as groundwater status assessment, groundwater-surface water interaction, overpumping and salinization. In its second mandate, WG-C is preparing technical guidance documents on some specific themes. At the moment three drafting groups are active: WG1 is defining general guidelines for the qualitative and quantitative monitoring so that the comparability of the results is ensured among Member States, WG2 is looking at the problems connected to the protected areas, and WG3 is producing a document to clarify issues about the prevention and limitation of pollutant inputs into groundwater.

Aquifer recharge

Natural aquifer recharge (from rain or surface water infiltration) is vital in order to maintain the groundwater and to replenish the discharges from the aquifer with a good quality water resource, but in many cases is quite impossible to grant a sustainable groundwater level only considering natural recharge. In many areas of the world, aquifers that supply drinking-water are being used faster than they recharge. Not only does this represent a water supply problem, it may also have serious health implications. Moreover, in coastal areas, aquifers containing potable water can become contaminated with saline water if water is withdrawn faster than it can naturally be replaced. The increasing salinity makes the water unfit for drinking and often also renders it unfit for irrigation. To remedy these problems, some authorities have chosen to recharge aquifers artificially with treated wastewater, using either infiltration or injection. Aquifers may also be passively recharged (intentionally or unintentionally) by septic tanks, wastewater applied to irrigation and other means. Artificial recharge is the planned, human activity of augmenting the amount of groundwater available through works designed to increase the natural replenishment or percolation of surface waters into the groundwater aquifers, resulting in a corresponding increase in the amount of groundwater available for abstraction.

C.2.3 - Reservoir stocks

The use of storage reservoirs helps to overcome the uneven distribution of natural water resources. Runoff in the wet season can be held back and used in the dry season (seasonal regulation), and water available in wet years can be stored and used in dry years (interannual regulation). The beneficial aspects of reservoirs in safeguarding water resources and supplies have to be balanced against the significant impacts that their construction and subsequent operations have on natural landscapes and ecosystems.

The predominant functions of reservoirs in Europe are storage for hydroelectric power production, public water supply, and irrigation. Water is not always available to meet demands. In particular, water for urban use must be guaranteed and irrigation demands often need to be met during the dry season, when river discharges are at their annual lowest level. Water storage by reservoirs helps to overcome this temporal unavailability of freshwater resources. In Europe, approximately 13 % of mean annual runoff is stored by dams. It represents a significant increase in the standing stock of natural river water, with residence times in individual reservoirs of less than one day to several years.

The countries with the highest percentage of stored water volume in relation to their annual renewable freshwater resources (over 20 %) are Turkey, Spain, and Cyprus. These countries also use the highest percentage of their resources for irrigation. This activity demands the largest water volumes in the driest seasons, requiring winter storage. Spain and Cyprus are considered to be water stressed, whilst Turkey has low water stress (see figure 4, Water Exploitation Index). In many countries such as Austria, Finland, France, Greece, Ireland, Italy, Norway, Portugal, and Sweden the majority of large reservoirs are used for hydropower production. In particular, the primary purpose of major reservoirs in Sweden and Norway is almost exclusively for hydroelectricity (EEA, 1999).

C.2.4 - Non-conventional resources

With increasing pressure on natural freshwater in parts of the world, other sources of water are growing in importance. These non-conventional sources of water represent complementary supply sources that may be substantial in regions affected by extreme scarcity of renewable water resources. Such sources are accounted for separately from natural renewable water resources. They include:

- the production of freshwater by desalinization of brackish or saltwater (mostly for domestic purposes),
- the reuse of urban or industrial wastewaters (with or without treatment), which increases the overall efficiency of use of water (extracted from primary sources), mostly in agriculture but increasingly also in industrial and domestic sectors. This category also includes agricultural drainage water.

Desalinization

Initially sea-water desalinization technologies were based on distillation; hence energy consumption was very high. The development of more efficient technologies (such as inverse osmosis) has reduced the cost of desalinization considerably (below 1 €/m^3). However, this technique still tends to be considerably more expensive than supply from conventional sources (surface water and groundwater). Desalinization of sea water or brackish groundwater is therefore mainly applied in places where no other sources are available. Sea-water desalinization in Spain accounts for about 0.22 km^3/year. Although this volume is small in comparison to total renewable water resources in the country (111 km^3/year), it represents a significant share of resources in the areas where this

technology is applied (mainly the Canary and Balearic Islands). In Greece, five desalinization plants are in operation, all of them on islands.
Desalinization can produce the degradation of coastal habitats like Posidonia sea-grass if the concentrated salt is not released adequately.

Water reuse
Water reuse is the use of wastewater or reclaimed water from one application such as municipal wastewater treatment for another application such as landscape watering. The reused water must be employed for a beneficial purpose and in accordance with applicable rules (such as local ordinances governing water reuse). Factors that should be considered in an industrial water reuse programme include (Brown and Caldwell, 1990):

- identification of water reuse opportunities,
- determination of the minimum water quality needed for the given use,
- identification of wastewater sources that satisfy the water quality requirements,
- determination of how the water can be transported to the new use.

In terms of quantitative water resources management, the reuse of wastewater or reclaimed water is beneficial because it reduces the demand for surface and groundwater. The greatest benefit of establishing water reuse programmes might be their contribution in delaying or eliminating the need to increase potable water supply and the capacity of water treatment facilities, and in reducing the costs of long sea outfall pipes to dispose of wastewater.
Main applications of this technique can be found for irrigation in agriculture, parks, recreational areas, golf courses, etc. Usually, simplified water treatment is carried out, in order to guarantee minimum quality standards of the water to be reused. Few studies and data about the reuse of wastewater are available, and further research is needed to assess the long-term effects of irrigation with treated wastewater on soils and agriculture.
In France, wastewater reuse has become a part of regional water resources management policies. It is practised mostly in the southern part of the country and in coastal areas, compensating local water deficiencies. In Portugal, it is estimated that the volume of treated wastewater is around 10 % of the water demand for irrigation in dry years, and that between 35’000 ha and 100’000 ha could be irrigated with treated wastewater. In Spain, the total volume of wastewater reclaimed amounts to 0.23 km^3/year, being used mainly for irrigation in agriculture (89 %), recreational areas and golf courses (6 %), municipal use (2 %), environmental uses (2 %), and industry (1 %).

Water recycling
Reuse of water for the same application for which it was originally used. Recycled water might require treatment before it can be used again.

Rainwater harvesting
For centuries, people have relied on rainwater harvesting to supply water for household, landscape, livestock, and agricultural uses. Before large centralized water supply systems were developed, rainwater was collected from roofs and stored on site in tanks known as cisterns. A renewed interest in this approach has emerged due to the escalating environmental and economic costs of providing water by centralized water systems or by well drilling, and the potential cost and energy savings associated to rainwater collection systems which are a source of water.

C.3 - Background of water demand

Various concepts are used to describe the diverse aspects of water use. Water abstraction is the quantity of water physically removed from its natural source. Water supply refers to the share of abstraction which is supplied to users (excluding losses in storage, conveyance and distribution), and water consumption means the share of supply which in terms of water balance is actually used (as evaporation) whilst the remainder is reintroduced into the source of abstraction.

The term "water demand" is defined as the volume of water requested by users to satisfy their needs. In a simplified way, it is often considered equal to water abstraction, although conceptually the two terms do not have the same meaning. Water demand estimations should be clearly associated to different prices of water.

C.3.1 - Agricultural water use

Over the past decades the trend in agricultural water use has, in general, been upwards, due to increasing use of water for irrigation. However, during recent years in several countries, the rate of growth has slowed down. The total water abstraction for irrigation in Europe is about 105'068 Hm^3/year (Hm^3 = cubic hectometre = 1 million cubic metres). The mean water allocation for agriculture decreased from 5499 to 5170 m^3/ha/year between 1990 and 2001.
Reforms of Common Agricultural Policy will lead to changes in types of crop being cultivated, the area irrigated, and the amount of water used. Two opposing trends can be distinguished. On the one hand, if production is reduced, the demand for production inputs such as water is bound to diminish. On the other hand, there might be a switch towards more profitable crops, which at least in southern Europe frequently require irrigation.

C.3.2 - Domestic use

The total water use for urban purposes in Europe is 53'294 Hm^3/year which amounts to 18 % of total abstraction and to 27 % of its consumptive uses. Between 1990 and 2001, urban use per capita has decreased and many changes have occurred, influencing the patterns of urban water use : increasing urbanization, changes of population habits, use of more efficient technologies and water saving devices, alternative sources of water (desalinization, indirect and direct wastewater reuse), increasing metering, and use of economic instruments such as water charges and tariffs. Connection of population to water supply systems has also increased, especially in Mediterranean countries.
The water required for drinking and other domestic purposes is a significant proportion of the total water demand. The proportion of water for abstracted urban use ranges from about 6.5 % in Germany to more than 50 % in United Kingdom.
Population distribution and density are key factors influencing the availability of water resources. Increased urbanization concentrates water demand and can lead to the overexploitation of local water resources. Higher standards of living are changing water demand patterns. This is mainly reflected in increased domestic water use, especially for personal hygiene. Most of the European population has indoor toilets, showers and/or baths for daily use. Most of the water use in households is for toilet flushing (33 %), bathing and showering (20 % - 32 %), and for washing machines and dishwashers (15 %). The proportion of water used for cooking and drinking (3 %) is minimal compared to the other uses.

C.3.3 - Industrial water use

The total water use for industry in Europe is 34'194 Hm^3/year which amounts for 18 % of its consumptive uses. Between 1990 and 2001, the industrial use has decreased consistently.
Over the period considered, different changes have occurred and have influenced the industrial water use: decline of industrial production, use of more efficient technologies with lower water requirements and use of economic instruments (charges on abstractions and effluents).
The biggest industrial water users are the chemical industry, the steel, iron and metallurgy industries, and the pulp and paper industry, although in most European countries industrial abstractions have been declining since 1980. In Western Europe this is due, primarily, to economic restructuring with closures in water-using industries such as textiles and steel, and a move towards less water-intensive industries. Technological improvements in water-using equipment and

increased recycling and re-use have also contributed to the decline. In Eastern Europe, abstractions seem to have diminished due to the serious decline in industrial activity across the whole sector.
Generally, pricing mechanisms have been used more intensively to encourage water use efficiencies in the industrial sector than in the household and agricultural sectors, as companies will adopt water-saving technologies faster, if costs can be reduced. Charges for the discharge of contaminated water into the sewerage network are also an important incentive for industries in order to improve process technologies and to reduce the amount of water used and discharged.

C.3.4 - Energy water use

Water abstracted for energy production is considered as a non-consumptive use and accounts for about 30 % of all the uses in Europe. Western European and Accession Countries are the largest users of water for energy production, in particular Belgium, Germany and Estonia where more than half of the abstracted water is used for energy production.
In general, the quantities of water abstracted for cooling by far excess those used by the rest of industry. However, cooling water is generally returned to the water cycle unchanged, except with an increase of temperature and some possible contamination by biocides.

C.3.5 - Tourism

In the Mediterranean region, about 135 million tourists (international and domestic) stayed along the coasts in 1990, representing more than half the total tourism in all Mediterranean countries and doubling the coastal population.
Tourism places a wide range of pressures on local environment. The impact on water quantity (total and peak) depends on water availability in relation to the particular timing and location of the water demand from tourism and on the capability of the water supply system to meet peak demands.
The intensity of the natural resources used by tourism can conflict with other needs, especially in regions where water resources are scarce in summer, and with other sectors of economic development such as agriculture and forestry. Uncontrolled tourism development, typically like in the past, has led to a degradation of the quality of the environment, particularly in coastal and mountainous zones.
Tourist water use is generally higher than water use by residents. A tourist consumes about 300 l/day; European household consumption is about 150 - 200 l/day. In addition, recreational activities such as swimming pools, golf and aquatic sports contribute to the pressure on water resources (focus available in Appendix 1.3).

C.3.6 - Network leakages

The reduction of leakage (both real and apparent) is an essential measure for water resources conservation and for the achievement of a good water balance at river basin scale.
Water losses due to network leakage include technical and economical aspects, and the importance of this issue is shared at international level. Accordingly, it is useful to agree upon a common terminology. The following definitions have been stated by the International Water Association (IWA Bluepages, 2000):

Water Losses
Water losses of a system are calculated as the difference between the system input volume and the authorised consumption. Water losses can be considered as a total volume for the whole system, or for partial systems such as raw water mains, transmission, or distribution. In each case the components of the calculation would be adjusted accordingly. Water losses consist of real and apparent losses.

Real Losses
Real losses are physical water losses from the pressurised system, up to the point of customer metering. The volume lost through all types of leaks, bursts, and overflows depends on frequencies, flow rates, and average durations of individual leaks.

Apparent Losses
Apparent losses consist of unauthorised consumption (theft or illegal use), and all types of inaccuracies associated with production metering and customer metering. Under-registration of production meters and over-registration of customer meters lead to under-estimation of real losses. Over-registration of production meters and under-registration of customer meters lead to over-estimation of real losses.

Non-revenue Water
Non-revenue water is the difference between the system input volume and billed authorised consumption.

Water leakage includes:
- losses due to pipeline breakage or damages,
- losses due to joints damages, especially in old and extended networks,
- losses in users connections,
- losses and surmounting in water reservoirs.

The main leakage indicators internationally used are:
- % of input volume: non-revenue water divided for the system input volume, multiplied by 100,
- specific water loss (m^3/day/km): the leakage volume divided by the length of mains and by the reference time,
- losses for number of service connection, referred to a specific reference time (day, hour, etc).

The IWA proposes also a new leakage indicator: the Infrastructure Leakage Index (ILI). This index can be used in order to provide additional insight into technical comparisons, as it takes into account many of the key influences on real losses (number of service connection, length of service connections, etc.) and separates aspects of infrastructure management from aspects of pressure management.

C.4 - Impact and assessment of imbalances

Driving Forces
Water quality and quantity are threatened by human activities that cause pressures on the environment, including urbanization, tourism, industry and agriculture (table 2).

Driving Forces	Impact
Urbanization	Increasing urban population causes substantial pressures on surface and groundwater. More than two-thirds of Europe's population lives in urban areas and the rate of urbanization is, in particular, increasing in Central and Eastern Europe, while in Western Europe it has stabilized.
Industry	Industrial pressures involve: high water demand for cooling and cleaning purposes; pollution with potentially toxic inorganic and organic substances (e.g. organic matter, metals, chlorinated hydrocarbons, nutrients…); disposal or dumping of sludge and waste, and inadequate containment of old industrial sites; accidents during production and transport. Further pollution arises from emissions to air, mainly from the combustion of fossil fuels, which initiate a process of acidification.
Tourism	Tourism causes very high pressures especially on groundwater, because of the additional water demand during seasons when the groundwater situation may already be rather critical. Waste and sewage from this sector represent another potential source of water pollution.
Agriculture	Agriculture causes high pressure and can produce its depletion due to over-abstraction. The legacy of the agricultural intensification of the post-war years is still present, and it is widely predicted that groundwater will continue to be contaminated with nitrate for several decades.

Table 2: Driving forces and impacts (UNEP - Freshwater in Europe, 2004).

Over-exploitation effects

- Groundwater quality:

  Continuous groundwater over-exploitation can cause isolated or widespread groundwater quality problems. Over-abstraction causes a decrease in groundwater level which can influence the movement of water within an aquifer. Significant draw-downs can cause serious quality problems. One of these changes is displacement of the freshwater/saltwater interface, causing active saltwater intrusion.

- Saltwater intrusion:

  Large areas of the Mediterranean coastline in Italy, Spain, and Turkey have been affected by saltwater intrusion. The main cause is groundwater over-abstraction for public water supply, followed by agricultural water demand and tourism-related abstractions. Irrigation is the main cause of groundwater overexploitation in agricultural areas. An example is the Greek Argolid plain of eastern Peloponnesus, where it is common to find boreholes 400 m deep contaminated by salt water intrusion.

- River-aquifer interactions:

  Aquifers can exert a strong influence on river flows. In summer, many rivers are dependent on the groundwater base flow contribution for their minimum flow. Lower groundwater levels due to over-exploitation may, therefore, endanger river dependent ecological and economic functions, including surface water abstractions, dilution of effluents, navigation and hydropower generation.

- Wetlands:

  Water abstraction in areas near wetlands can be a serious problem, as groundwater pumping usually lowers the groundwater table, causing an extended, deeper unsaturated zone. This can severely damage wetland ecosystems which are very sensitive to minor changes in water level.

- Ground subsidence:

Heavy draw-down has been identified as the cause of ground subsidence or soil compaction phenomena in some parts of Europe, notably along the Veneto and Emilia-Romagna coasts, the Po delta and particularly in Venice, Bologna and Ravenna in Italy.

Pollution effects on groundwater

Pollution of a water body occurs when an impurity (micro-organism or chemical) is introduced by or as a result of human activities, creating an actual or potential danger to human health or the environment when present at high concentrations. Europe's groundwater is polluted in several ways: nitrates, pesticides, hydrocarbons, chlorinated hydrocarbons, sulphate, phosphate and bacteria. Some of the most serious problems are caused by nitrates and pesticides (figures 9 and 10). As groundwater moves slowly through the ground, the impact of human activities can last for a relatively long time. This makes pollution prevention very important for addressing groundwater issues.

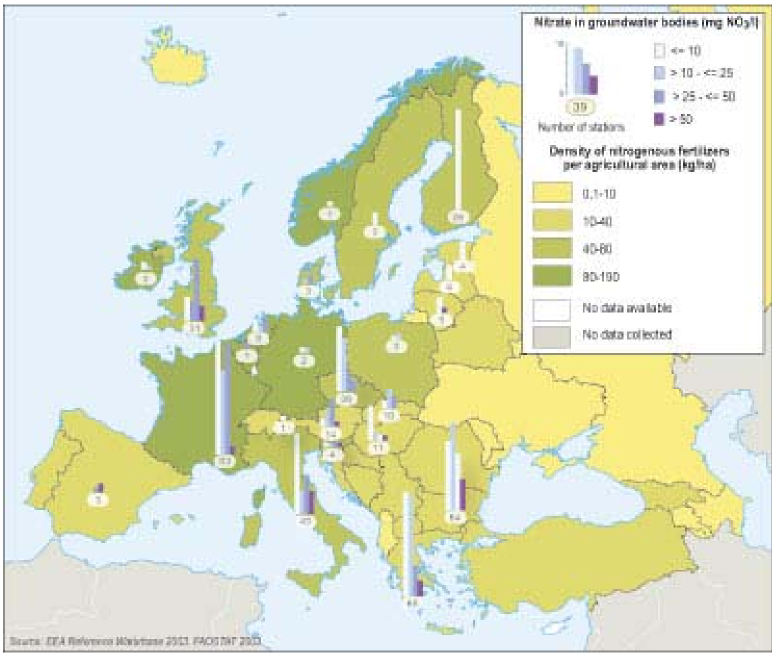


Figure 9: Nitrate in Groundwater Bodies (FAOSTAT – 2003).

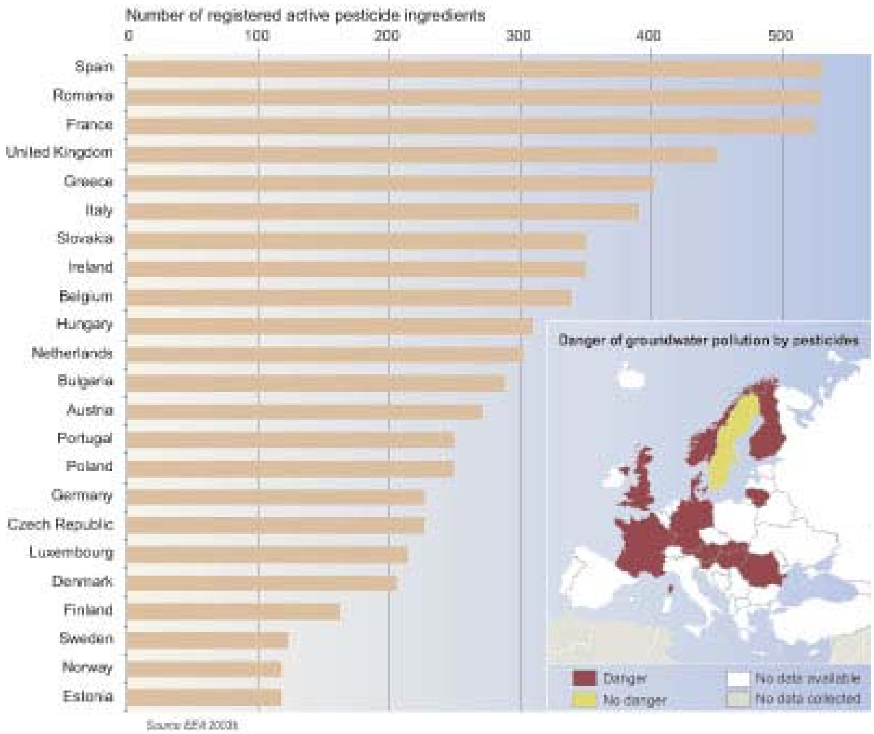


Figure 10: Number of registered active pesticide ingredients (EEA – 2000).

<u>APPENDIX 1</u>

- PROJECT BOX
- NATURAL FACTORS CAUSING DROUGHT
- INDEXES
- WATER USE BY SECTOR IN EUROPE

II - DROUGHT PLANNING AND MANAGEMENT

A - PREAMBLE

Drought is a naturally occurring phenomenon and a normal part of variability of the usual meteorological conditions, according to the climate characteristics. As a natural hazard, drought imposes differential vulnerability on the different countries depending on their degree of exposure to aridity and their drought management policies. The compounded effect of hazard and vulnerability generally represents the risk associated to drought events. Exposure to drought risk varies from country to country.
It is very important to discern among transitory periods of water deficiency, a cause of exceptional drought, and long term imbalances available resources/demands, as reflected in figure 11.

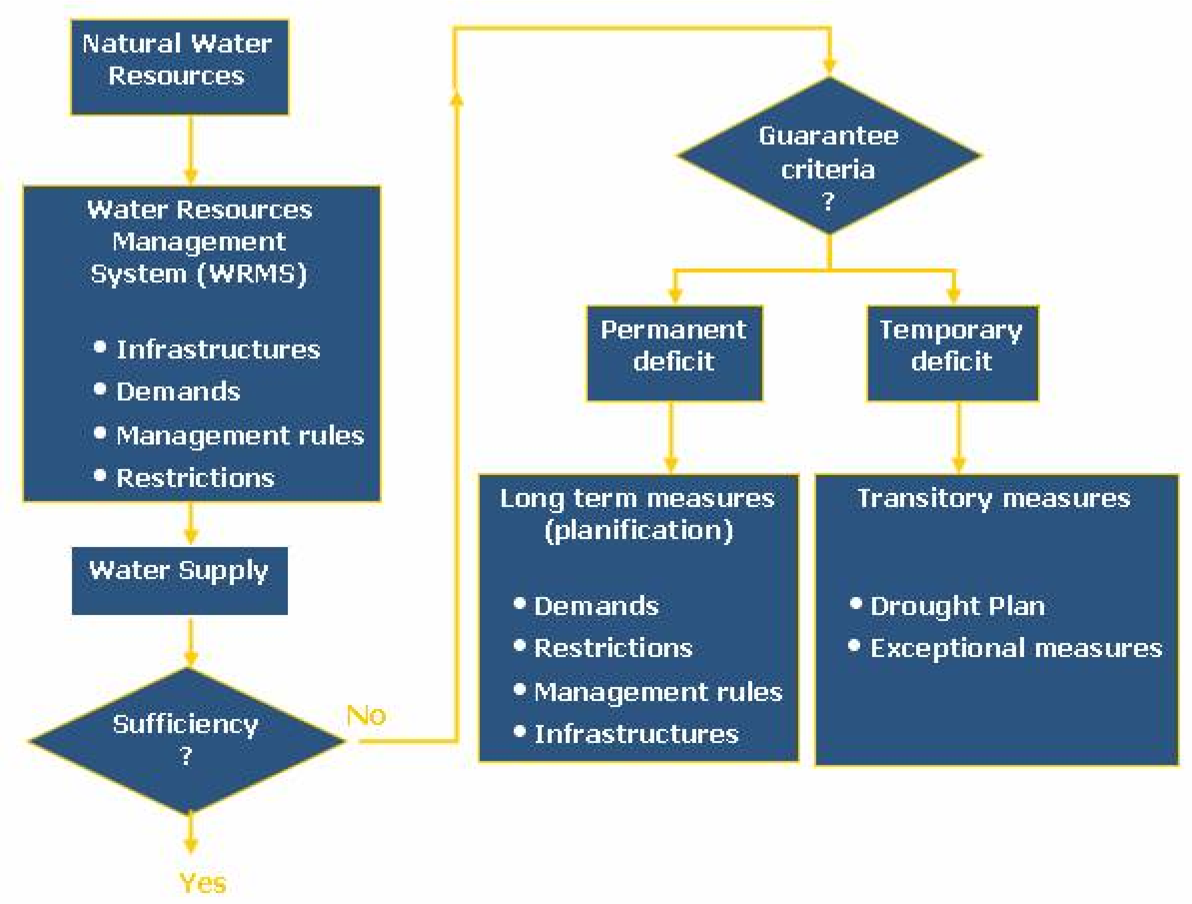


Figure 11 : Permanent or temporary deficit

When we say that a Water Resources Management System (WRMS) is able to meet a set of demands according to defined reliability criteria, we are implicitly accepting a certain probability of failure to satisfy fully the total water supply that is theoretically required.
The margin of accepted failure is limited by guarantee criteria. When it happens, it is necessary to carry out transitory measures as defined in drought management plans. In other cases, the WRMS cannot be considered as sufficient and produces a permanent deficit. Hence it is necessary to balance the offer of available resources and water demands on a medium- or long-term basis.
Nevertheless, nothing can be done to reduce the recurrence of climatological drought events. Therefore, drought management should not be regarded as managing a temporary crisis. It should rather be seen as a risk management process that places emphasis on monitoring and managing emerging stress conditions and other hazards associated to climate variability in the region under

consideration. Furthermore, drought management in terms of risk management rather than crisis management is now the agreed and practised form of drought management.

An important feature of drought as a natural hazard is that it is a complex, slow-onset phenomenon that is very difficult to predict and mainly only monitored. Weather forecasting does not mean automatically drought prediction, even in the case of meteorological drought, as the lead-time of a few days of standard weather forecasts is too short. While scientific advances such as seasonal climate prediction techniques have provided new opportunities in the tropical regions, the understanding in temperate regions for climate prediction remains at a lower level. However, latest developments in monthly and seasonal forecasting might allow for drought forecasting in the near future (compare chapter II.C). Our predictive capacity for agricultural, hydrological, and socio-economic droughts is limited too. However, as soil and groundwater systems show a slower response and temporal variability as compared to the highly fluctuating atmosphere, the prediction of changes should be generally less difficult. In any case one thing is certain: Drought is a recurring phenomenon that has strongly influenced environment, economy, and culture over the last millennium, especially in the Mediterranean countries.

Analysis of drought management policies in some countries today indicates that decision-makers mainly react to drought episodes through a crisis-management approach by declaring a national or regional drought emergency programme to alleviate drought impacts, rather than on developing comprehensive, long-term drought preparedness policies and plans of actions that may significantly reduce the risks and vulnerabilities to extreme weather events. Drought planning nowadays moves towards risk management rather than crisis management. Basic and applied references to drought can be found in Dracup et al. (1980), USACE (1994), National Drought Mitigation Center (http://drought.unl.edu), Wilhite (1983, 1991a and 1991b, 1993a, 1993b and 1993c, 1996), Wilhite et al. (1985, 1986, 1987, 1994a, 1994b), Tallaksen et al. (2004), EurAqua (2004).

Specific key issues such as the use of modelling tools for water resources management, rainfall harvesting, saline intrusions, increase of supply, reduction of demand, enforcement of metering, measures for impact mitigation, along with issues of integrated management methodologies and tools at catchment scale, as well as saline water intrusion prevention and mitigation have to be considered.

A drought plan representing the implementation of risk management will provide an action plan that provides a dynamic framework for an ongoing set of actions to be prepared for drought and to effectively respond to it. It typically includes periodic reviews of achievements and priorities, readjustment of goals, means and resources, strengthened institutional arrangements, and planning and policy making mechanisms for drought mitigation.

Effective information and early warning systems are the foundation of preparedness aspects in effective drought policies and plans, as well as effective network and coordination between central, regional and local levels.

In addition to an effective early warning system, the drought management strategy should include sufficient capacity for contingency planning before the onset of drought, and appropriate policies to reduce vulnerability and increase resilience to drought.

These are the basic elements of a drought preparedness and risk management strategies that need urgent development. Working towards a long-term drought management strategy, European Union countries need to establish the institutional capacity to assess the frequency, severity, and localisation of droughts and their various effects and impacts on crops, livestock, environment, and the wellbeing of drought-affected population.

Although drought is a complex phenomenon that involves social, economic and environmental aspects, this chapter is focused in drought management, specially in the context of water resources planning. The chapter deals with the following items :

- **Regional characterization of drought**. Drought is an anomaly or aberration regarding the habitual rainfall pattern in a certain region. It is, therefore, essential to characterize, in each geographical region, the drought pattern onset and the differences between normality and/or abnormality. The analysis of historical droughts and their management practices can provide substantial information for this characterization as well as a valuable source of experience about the effectiveness of the measures applied for their mitigation.

- **Drought mitigation approaches and long-term performance strategies to reduce the vulnerability of water resources systems to droughts.** These performances must be integrated in the hydrological planning process. In this framework, an anticipated elaboration of Drought Management Plans is only a part of the planning process.
- **The WFD as a useful instrument to drive the drought situations appropriately**. The River Basin Management Plans (RBMP), through their programs of specific measures, can facilitate their operative development. The planning of long-term measures guided to reduce the vulnerability to droughts should be integrated in the RBMP.
- **Guidelines on the content and development of Drought Management Plans**. Within this plans, the drought monitoring networks constitute an essential element of the process.
- **Drought Management Plans as part of the specific measures programs**. This approach can contribute to mitigate drought effects respecting WFD constraints. “Force majeure” situations should be characterized by the appropriate system of indicators, as integral part of Drought Management Plans.
- **Drought management experiences in EU member countries and in non EU Mediterranean countries**. A brief summary of remarkable examples of mitigation measures facing drought is given.

B - REGIONAL DROUGHT CHARACTERIZATION

Droughts are typically characterized by their duration, magnitude and intensity. They can be determined from the historical record alone by using non-parametric methods but, because the number of drought events that can be drawn from the historical sample is generally small, the "historical" drought characteristics have a large degree of uncertainty.
Other alternatives for finding drought characteristics include the application of stochastic models that can represent the underlying hydrologic quantities such as precipitation and streamflows, simulating long records of such hydrologic variables, and then deriving droughts characteristics from the simulated samples. Yet another approach may be based on modelling the underlying hydrologic quantities in such a way that drought characterization can be made analytically.
In addition, an important subject is the recurrence of drought events. While recurrence studies of other types of extreme events such as floods have given fruitful results, this is not the case with the recurrence characteristics of drought events, because the hypothesis of independence is not completed among episodes. Furthermore, most advances on drought characterization have been made for single site or for processes defined at a single point or averaged over an area, however a more complete drought characterization should involve both temporal and spatial variability of the hydrologic processes of concern.

B.1 - Historical droughts characterization

The usual way to try to understand drought patterns is to study the past documented history of events in the same region. To make this in a systematic and rigorous way, objective tools of comparison should be applied : drought indices that attempt to comprise the main drought features in order to facilitate comparisons. Numerous indices are found in the literature based on different drought features. Some of them have been described in the preceding chapter (see chapter I.B.4). Many of them were created for particular places and specific objectives, and therefore not suitable to generalize their results. However, there have been attempts to develop a general index, which would provide full characterization of drought events.

All of the indices (see Appendix 1.B.3 and 2.B.1) may provide a partial description of drought, but none of them define it completely. Attempts to correlate an indicator with a particular level of drought severity observed in a region have resulted in several multiple-parameter indicators. Some proposed composite indicators are the method of truncation (Chang and Kleopa, 1991), the Water Availability Index (Davis and Holler, 1987), and the Surface Water Supply Index (Dezman et al., 1982).

Each of them has particular advantages and disadvantages. No index includes a full representation of droughts in a single value, useful for all general application. The fact that droughts have a random nature prescribes the statistical theory for the foundation of a complete and generic index, which would meet this goal.

Furthermore, it is necessary to select or create the appropriate indicators adapted to specific regional circumstances in order to find out what sort of meteorological or hydrological patterns could be considered as a temporary aberration (drought) in a region, because usually they are different depending on the affected region. Developing a drought climatology analysis of a region provides a greater understanding of its characteristics and the probability of recurrence at various severity levels. Information of this type is extremely beneficial in the development of response and mitigation strategies and preparedness plans.

The historical context of droughts must be taken into account, considering the “no-repeatability” of the crisis phenomena connected to low water availability. Excluding the macroscopic low water availability situations, which result critical in any time and spatial context, a drought crisis is revealed by a socio-economical “perception”, often limited to a specific user or to a specific river basin area. Furthermore drought crisis may have different evolutions in the time scale.

Socio-economical context is a dynamic component which can modify its own sensitiveness and its own perception of water availability reduction ; this sensitiveness shall be considered in the definition of trigger value.

The influence of the socio-economical and historical context determines two different consequences. The first one is that crisis episodes do not constitute an homogeneous stochastically independent sample ; this utilization can be appropriate only when events are temporally close and consequently related to the same historical context. Anyway a statistical analysis on rare extreme events is not significative. The second consequence is that the analysis of consequences of water scarcity on users needs a reference condition related to socio-economical factors influencing water demand.

Therefore, the vulnerability of a water supply system related to critical drought events can be evaluated through simulation models able to reproduce different crisis scenarios. These scenarios, which should be statistically characterized, are a fundamental basis for the reference system testing.

This procedure will allow the simulation of the effects of drought events on users, enabling the choice of the most effective mitigation measures, through the use of technical – economical criteria and priority services guarantee criteria. The mitigation measures can be structural measures, in order to face high frequency crisis, or contingency measures, in order to face the rarest scenarios which cannot justify long-term financial investments.

B.2 - Historical drought analysis : What happened? What has been done?

Once the basic characteristics of meteorological and hydrological droughts of the basin or region have been established, effectiveness of management rules adopted in water resources systems must be audited (e.g. resources, consumptions and demands, infrastructures, adopted decisions) for past periods of drought, in order to assess the vulnerability of the water resources system, the impact of the drought, the effectiveness of adopted measures, as well as to identify possible future mitigation measures. In particular, the most recent severe drought with territorial- wide dimension must be analyzed. It is necessary to respond to the following questions at basin level :

- quantitative and qualitative evolution of resources

- evolution of consumptions and demands
- management rules adopted in the different exploitation systems
- degree of demand satisfaction for different uses and supply deficit
- evolution of reserves in surface and groundwater systems
- measures adopted to mitigate the effects of drought and assessment of their effects
- flows and environmental volumes reserved in hydrological planning and the degree of compliance in historical droughts
- impacts on water quality, environment and economy

B.3 - Drought diagnosis : What have we learnt?

In order to determine what we have learned during past severe drought events, a synthesis of the most outstanding conclusions is needed in order to establish the vulnerability of the water resources systems to droughts. This diagnosis will have to include the following topics: recurrence and severity of droughts, effects on aquatic and terrestrial ecosystems and wetlands, consequences on water status, fragility of water resources systems, identification of problematic water supplies, identification of mitigation measures adopted and their effects on demand management, identification of developed infrastructures for water resources increase, substitution to be activated under drought conditions, proposals to be developed in short term, identification of sensitive units of agricultural demand, and inventory of measures adopted for water conservation and their effects.
One of the most valuable sources of information about how to prepare for drought is the experience of those who have suffered a severe drought. The full value of these experiences, though, can be realized only if the lessons are recorded, critically analyzed, and communicated to others who can use the information. The reading of many drought experiences in different countries carries us to the following conclusions :

- The complexity of the impacts of a sustained drought demands more sophisticated planning; severe drought can change longstanding relationships and balances of power in the competition for water ; drought can force water supply solutions on a community that people would not have accepted otherwise.
- The success of drought response plans should be measured in terms of minimization and equitable redistribution of the impacts, but there is a lot to learn about the best ways of achieving this goal.
- Severe droughts can reveal inadequacies in the existing roles and performance of water institutions, causing significant institutional and legal changes. Increases in water prices should precede or accompany water restriction measures. Mass media can play a positive role in drought response, but only if water managers help design the message. Water banks could be an effective way of reallocating restricted water supplies.
- Groundwater continues to be the most effective strategic weapon against drought. During droughts, aquifers play an important role in meeting water demand, not only in terms of quality and quantity, but also in relation to space and time.
- The conjunctive use of surface waters and groundwater presents opportunities to use the natural buffering capacity of aquifers in dry periods, and to ensure recharge when water is abundantly available.
- Non-conventional resources, such as desalinization and treated wastewater reuse are additional alternatives with increasing potential to face drought. Water quality suffers during drought because low flows affect the ability to dilute effluents from wastewater treatment plants and sustain the aquatic ecosystem.

One of the fundamental advantages of water reuse is the fact that, in many cases, the resource employed is in the vicinity of its prospective new use, i.e. urban agglomerations and industrial sites. The treated water increases the fresh water quantity available for non potable applications and has been proven to be safe as long as appropriate water quality and well proven water management practice are adopted. The limiting factor for water reuse can be the quality of the reuse water and potential hazards for secondary users in a similar way to using river water or other non potable sources

The way to mitigate the adverse social, environmental, and economic impacts of a sustained drought is to ensure that a variety of management measures has been scheduled in advance. Early drought response actions and proper timing of tactical measures are essential in the short-term management of droughts.

It is necessary to take into account the public awareness and social perception of the shortage and to educate users to responsible behaviours towards water conservation. Governments and public authorities should take advantage of the abilities of the civil society to organize itself in order to face hardship.

C - EARLY WARNING : FORECASTING AND MONITORING SYSTEMS

A critical component within drought management is the continuous observation and evaluation of the development of a drought event. In fact, in order to detect the onset of a drought, crucial variables of the region's water balance must be permanently monitored, not only within a drought situation. In chapter I part B.1, the various facets and definitions of droughts have been introduced ; accordingly, meteorological parameters such as precipitation, air temperature and humidity, hydrological data such as water levels of lakes, reservoirs and groundwater, river discharge, but also information on the spatio-temporal development of the water demand must be continuously observed, collected and evaluated. The derivation of drought-relevant parameters, indices and indicators as shown in chapter I part B.3 from routinely collected data, and their comparison with past and expected values will allow a timely recognition of evolving water deficits, thus detecting the onset of a drought situation at an early stage of the event.

In addition to the monitoring of the current state, the exploitation of meteorological forecast products that become increasingly available in an operational mode opens the door to drought event forecasting and alerting, before the drought situation shows its first measurable impact. The European Centre for Medium-Range Weather Forecasts (ECMWF), but also several national meteorological services, are developing a suite of forecast products that will be of value for drought forecasting. As an immanent feature of meteorological forecasting, the uncertainty of such forecast products has to be taken into account. In order to derive information on the uncertainty, the current state-of-art ensemble forecasts comprise several (usually around 50) single forecasts. These forecasts start from a similar basis, but have slightly perturbed initial conditions, resulting in a variety of forecasting results. These results are equally valid and can be analyzed in a post-processing by statistical and probabilistic methods.

Besides monitoring and forecasting systems, simulation tools such as regional water balance models are very useful for drought management. Using collected data to define their initial state and meteorological forecasts to force the future development, various options of drought management measures can be examined and evaluated before actually being applied. Although models will always reflect only a limited portion of the entire natural and anthropogenic system of the water cycle, they can show the impact of single drought management measures under consideration and reveal unexpected consequences before they occur in reality.

Thus a monitoring and early-warning system will enable planners, water and natural resource managers, and other decision makers to make more informed and timely decisions. The relatively small investment required to develop and maintain such a system is justified given the large benefits that would accrue through a reduction of impacts associated to droughts events.

As the onset of drought is gradual, so should be the actions taken to face it. But this can only be achieved if a potential drought situation is regularly monitored through indices and indicators that have been established as part of the planning process. The monitoring and early-warning system

allows decision-makers to follow the development of drought before it becomes evident, to make the right decision regarding its onset and the type of mitigation measures to be launched. This is accomplished by linking the monitoring system to decision-making, through pre-established linkages between different levels of respective drought indices that trigger pre-defined drought mitigation measures.
Finally, monitoring mechanisms must be used to decide, if the drought response plan is having its intended effect. Monitoring also provides the required information needed to evaluate the performance of the drought management plan in alleviating the effects of drought. Such evaluation is normally performed as an ex-post analysis of every drought event in order to assess the achievements of the drought plan and to learn from the experience by recommending the necessary corrections for future plans.

D - INDICATORS AND WATER FRAMEWORK DIRECTIVE

Article 4.6 (WFD) points out specific events including droughts and the need for monitoring and forecasting : "a temporary deterioration in the status of water bodies shall not be in breach of the requirements of the directive if it is the result of circumstances of natural cause or force majeure which are exceptional or could not reasonably have been foreseen, in particular extreme floods and prolonged droughts, or the result of circumstances due to accidents which could not reasonably have been foreseen, (…) when all of the conditions established in WFD have been met".
The conditions under which circumstances that are exceptional or that could not reasonably have been foreseen may be declared, including the adoption of the appropriate indicators, are stated in the river basin management plan (see chapter II part F.3).

E - DROUGHT AWARENESS, PREPAREDNESS AND PROACTIVE MANAGEMENT. LONG-TERM DROUGHT PREPAREDNESS POLICIES

It is essential that people recognize drought as part of their environment. Drought must be considered as a natural part of a highly variable climate. Communities must be aware of being at risk. To be aware of a risk means to have recognized it, to know about it, not to forget or to repress it and to take it into account appropriately when acting. If there is no hazard awareness, even incentives will not be of any help. If persons concerned have not yet experienced severe drought periods, knowledge about the risk must be passed on with the help of information and education.
During the past decade in Europe, widespread and severe drought has resulted in an increased awareness of the nations continuing vulnerability to this creeping natural hazard. This experience has resulted in numerous initiatives by governments to improve the timeliness and effectiveness of response efforts. Although some progress has been made, much remains to be done. In most countries, governments continue to deal with drought in a reactive, rather than proactive, mode.
The demand for European water resources increased from 100 km^3/year in 1950 to 660 km^3/year by the end of the 20^{th} century. As the pressure on water resources continues to grow, Europe is becoming increasingly vulnerable to the effects of droughts.
The growing number of regions, watersheds or municipalities with drought plans in European Union is a positive sign that more emphasis is now being placed on drought preparedness, although most public response continues to stress emergency assistance. Many countries have developed and implemented a wide range of mitigation measures, but the shift from crisis management to risk management continues to be a difficult transition.
For this transition to be successful, the deficiencies of previous drought response attempts must be addressed and analyzed in a systematic way. Developing and implementing an integrated drought policy and plan would represent an important first step. This policy should promote the concept of risk management, although it cannot ignore the need for government assistance during extended periods of severe drought. However, this assistance must be consistent with national policy.

The policy should promote self-reliance while at the same time protecting the natural and agricultural resource base. There is also a need to coordinate drought-related activities (i.e. forecasting, monitoring, impact assessment, response and recovery, planning). This policy should also incorporate incentives for all drought-prone regions to develop plans that promote a more proactive, anticipatory approach to drought management. Lessons learned from previous drought response attempts need to be documented, evaluated and shared with all levels of government through post-drought audits.

Awareness of the necessity to move to a more proactive approach in drought management is growing, but the capacity to do so remains low. Some countries are in the need to establish programmes aimed for developing and implementing strategic water resources management plans that would make them less vulnerable to future droughts.

From the water resources perspective, a proactive approach to drought is equivalent to strategic planning of water resources management for drought preparation and mitigation. Such planning consists in two categories of measures, both planned in advance :

- Long-term actions, oriented to reduce the vulnerability of water supply systems to drought, i.e. to improve the reliability of each system to meet future demands under drought conditions by a set of appropriate structural and institutional measures.
- Short-term actions, which try to face an incoming particular drought event within the existing framework of infrastructures and management policies.

The overriding objective of the long-term actions is adjustment to drought conditions, even under normal situations, as a proactive and preparatory measure. This includes for instance the adoption of water saving technologies, the increase of groundwater recharge, water reuse, desalinization, among others, and at last the increase of water storage capacity. Depending on the severity of drought, long-term actions may or not completely eliminate the risks associated to it. They are supplemented by short-term measures which correspond to the actions taken during what is called a drought contingency plan. The plan is implemented during drought but the shift to it is usually gradual reflecting the progressive onset of drought.

A new conception about drought management is needed. A modern way to address this sort of situations is mainly based on developing comprehensive, long-term drought preparedness policies and action plans that may significantly decrease the risks associated to extreme weather events, reducing vulnerability and increasing resilience to drought. It should include prevention (in order to reduce the risk and effects of uncertainty) and mitigation (measures undertaken to limit the adverse impacts of hazards) strategies.

Proactive management involves modification of infrastructures and laws, institutional agreements and the improvement of public awareness.

The drought management strategy should include sufficient capacity for contingency planning before the onset of drought, and appropriate policies to reduce vulnerability and increase resilience to drought. An effective drought plan is one that has an optimal combination of both long and short-term measures.

E.1 - Long-term resource management

It involves efficient use and resource protection strategies designed to effective permanent change in how water is managed and used. Main management measures deal with water conservation. While there is no universally accepted definition of water conservation, this term is often used to mean “saving water” through efficient or wise use. In terms of utility management activities for dealing with water shortages, conservation can mean both short-term curtailment of demand and long-term resource management.

Long-term resource management involves efficient use and resource protection strategies designed to effective permanent change in how water is managed and used (see chapter I).

E.2 - Educational programs. Social awareness

A broad education program to raise awareness of short and long-term water supply issues will help ensure that people know how to respond to drought when it occurs and that drought planning does not lose ground during non-drought years.

It would be useful to tailor information to the needs of specific groups (e.g. elementary and secondary education, farmers, small business, industry, homeowners). Factual material and diagrams describing the local anthropogenic water cycle would help all concerned people to understand the issues about water availability and environmental protection.

Consumer's education is a must since any measures on facing drought must be accepted, adopted, and carried out in many instances by the consumer.

Since professionals are responsible to implement drought measures, they must be educated and trained accordingly. The responsible person for drought management should consider developing presentations and educational materials for public events such as water awareness days, relevant trade shows, specialised workshops, and other gatherings that focus on natural resources management.

E.3 - Research

Technological and social change is improving the ability to more effectively manage water and other shared natural resources during periods of drought. These changes can facilitate the shift to risk management because they will allow managers to address some of the more serious deficiencies of the crisis management approach. For example, our ability to monitor and disseminate critical drought-related information has been enhanced by new technologies such as automated weather stations, satellites, computers and improved communication techniques (e.g. Internet).

Previous drought response efforts have been hampered by a lack of adequate early warning systems and insufficient information flow within and between levels of decision makers.

Simultaneously, an improved understanding of complex atmospheric-oceanic systems and the development of new computer models have improved drought forecast skills for some regions. If they become part of a comprehensive early warning system, these advancements and others can provide decision makers with better and more timely data and information (compare chapter II.C).

Therefore research efforts must be considered as a valuable prevention tool and issues that could be addressed on drought preparedness include :

- Supporting and strengthening programmes for the systematic collection and processing of meteorological and hydrological observations.
- Building and strengthening scientific networks for the enhancement of scientific and technical capacities in meteorology, hydrology and other related fields to drought.
- Development of vulnerability assessment methodologies under different environmental conditions.
- Improved understanding of drought climatology (frequency, intensity and spatial extent) and of drought patterns.
- Development of standardized indicators for specific use, including hazards assessments.
- Development of decision support models for the dissemination of drought-related information to end users and appropriate methods to encourage feedback on climate and water supply assessment products.
- Improvement of the monitoring, modelling and prediction capacities and improved communication of how this information can be applied in decision support.

F . DROUGHT MANAGEMENT PLANS

Nowadays, there is more and more awareness and sensitizing among decision-makers about the necessity to move to a more proactive approach in drought management. The planning process takes place before the onset of drought whereas its implementation is partitioned over a long period of time, before drought starts until some time after it has passed. The planning process should never end in drought prone countries, but be continuous through evaluation of the plan and its amendments to adapt it to the dynamic changes. The most arduous part however is to get started.
As the primary concern of drought is water shortage, most of the planned activities aim at reducing the effect of such shortage, through measures that are taken before, during and after drought. The activities per se comprise a wide range of measures to reduce societal vulnerability that are not necessarily linked to water resources. In addition to planning, effective water resources management in drought prone areas hinges on the institutional and legal set-up established for addressing the interrelated issues of water conservation and planning for drought.
Because of the close relationship between water resources and drought, drought management is an essential element of national water resources policy and strategies.
Drought management plans must be prepared in advance before they are needed, based on specific legislation and after careful studies are carried out concerning the definition of the drought, its effect and the mitigation measures.

F.1 Drought plan basic questions

F.1.1 - Evaluation of drought effects

Drought effects may be environmental, social, economical, national, strategic, etc. These effects, direct or indirect, must be considered and evaluated and plans drawn to minimize their effects. For instance, drought may cause food shortage or may cause unemployment to farmers or to employees of an adversely affected industry.

F.1.2 - Legal framework

Law sometimes drives and sometimes constrains water management during drought. Therefore, the establishment of a legal framework to face drought must be developed in advance for success response. Explicit legal frameworks for managing water resources under drought circumstances are either lacking or fragmented in most countries.
Since droughts are considered as normal climatic phenomena, drought management plans should be part of the general water management plans. However, since in most countries the existing legislation on water management does not cover situations under water scarcity caused by droughts, water legislation should be revised and amended to help water management under drought conditions. The law should define drought beginning and termination and the degree of severity, the establishment of drought management committees, their responsibilities and powers in the exercise of their duties and the creation of drought management budget to be energized in cases of droughts.
Drought produces high environment damages as well as economic and social losses. Focus must be put on policy, legal and institutional aspects like funding mechanisms to mitigate extreme drought effects. Moreover, costs and efforts for implementation of other EU environmental policies and legislation will be strongly affected when droughts happen. Therefore, foresee financial support to prevent and mitigate drought consequences seems essential. As a result, it will be important to foresee financial support to support water management under these consequences. Appropriate funding under existing instruments may play a role in this respect

Legislation, giving extra power to government and to the authorities, which shall act in accordance to the drought mitigation plan, must be in force before drought occurs. This legislation should be clear as to its objectives and authorities granted to those in charge. It must be understood that the plan will be enforced under emergency conditions and there is no time for fooling around with legal matters.

F.1.3 - Water auditing

Efficient utilization of water by all consumers is necessary and for this purpose, each authority responsible for water distribution must carry out water auditing. This will reveal how much water, how and for what purpose the water is used and how efficient, and the authorities will use these conclusions to suggest or impose measures for reduction in water consumption under drought conditions.

F.1.4 - Water systems capabilities evaluation

Water conveyance and distribution systems are designed for the supply of water under normal supply conditions. Imposing water restrictions will necessarily require modifications to the systems to make them adaptable for new working conditions. More isolation valves, flow and pressure control valves, water meters, flow limiters, etc, are some of the many additions that may be needed to upgrade a main conveyor or a distribution system for efficient water restrictions. These improvements have to be made as early as possible.

F.1.5 - Establishment of drought management organisational structure

Drought mitigation plans should be realized with the establishment of a “Drought Committee” or similar organisational structure which shall appoint to carry out the special issues related to the drought impacts and measures to be taken and draw up the plan. This committee shall provide the appropriate coordination at the different administrative and territorial level, national/regional/local, and warrant the adequate transparency and user participation. A group of experts which should advise the process made up of engineers, hydrologists, groundwater hydrologists, sociologists, economists, etc, will continuously monitor the climatological behaviour and shall be responsible for proposing the implementation of the drought mitigation plan.

F.1.6 - Identify group of risk and its vulnerability to drought hazard

Water resources planning and management for drought preparedness and mitigation starts by an assessment of the potential and available water resources and the vulnerability of the existing supply systems to drought.
The risk associated to drought for any region is a product of the regions exposure to the natural hazard and the vulnerability of societies within the region to the event. Exposure to drought varies regionally and over time, and there is little, if anything, that can be done to alter its occurrence, because drought is a normal part of climate. Nowadays, it is an important issue for scientists to understand the probability of drought events at various levels of intensity and duration.
Vulnerability to drought is also strongly determined by social factors such as land use, population increases and migrations from one region to another or from rural to urban areas. Water use trends, environmental degradation, technological changes, and government policies can also alter vulnerability to drought. Vulnerability is dynamic and the factors mentioned above must be monitored to determine how changes in these factors may influence the impacts of future drought episodes.

In other words, the impacts that result from future drought occurrences will be determined not only by the frequency and intensity of meteorological drought but also by the number of people at risk and their degree of risk. If demand for water and other shared natural resources is increasing societal vulnerability to water supply interruptions caused by drought, then future droughts can be expected to produce greater impacts, with or without any increase in the frequency and intensity of meteorological drought.

F.1.7- Establishment of environmental flow regimes

The establishment of ecological flow regimes based on scientific studies and on the needs of the aquatic ecosystems to ensure their good ecological status is a key element for water management, especially during droughts. In many basins, flow regimes are still classified by only following simple hydrological criteria (eg. by establishing a % of the water flow) without attending requirements regarding temporal distribution and water quality. Scientific studies of flow regimes should include modelling for drought situations. Data on flow regimes and their fulfillment should be made public in a transparent and comprehensive way on a regular basis, similar to other data on water or drought management.

F.1.8 - Prepare drought plan

The distinction between planning, as a continuous and complex process, and a determinated plan drawn up is necessary. The preparation of plans is only a part of the whole planning process.

Drought management planning involves both long and short-term actions. Short-term actions are arranged through drought plans prepared in advance. The main objective of these drought plans is to limit the adverse impacts on the economy, social life and environment when drought appears, as well as to try to face an incoming particular drought event within the existing infrastructures and management policies. Drougt plans basically include mitigation measures.

A drought plan will provide a dynamic framework for an ongoing set of actions to prepare for, and effectively respond to drought, including : periodic reviews of the achievements and priorities; readjustment of goals, means and resources; as well as strengthening institutional arrangements, planning, and policy-making mechanisms for drought mitigation.

Effective information and early warning systems are the foundation for effective drought policies and plans, as well as effective network and coordination between central, regional and local levels.

In addition to an effective early warning system, the drought management strategy should include sufficient capacity for contingency planning before the onset of drought, and appropriate policies to reduce vulnerability and increase resilience to drought.

Since droughts are considered as recurrent natural events, drought management plans (figure 12) should be a part of general management plans which shall be put into effect when realized that water scarcity is to occur due to drought. The plan should be multi-annual assuming that droughts may last more than one year. Drought identification is very important so that implementation is enforced.

Drought plans nowadays tend to comply with the following characteristics:

- Completeness (all the elements required to make the plan work are included in the plan)
- Acceptability (the plan satisfies decision criteria and does not violate planning constraints)
- Effectiveness (the alternatives address the planning objectives)
- Efficiency (the plan addresses outputs to all inputs)

To be effective a plan must incorporate three primary components :

- a monitoring system
- an impact assessment system
- a response system

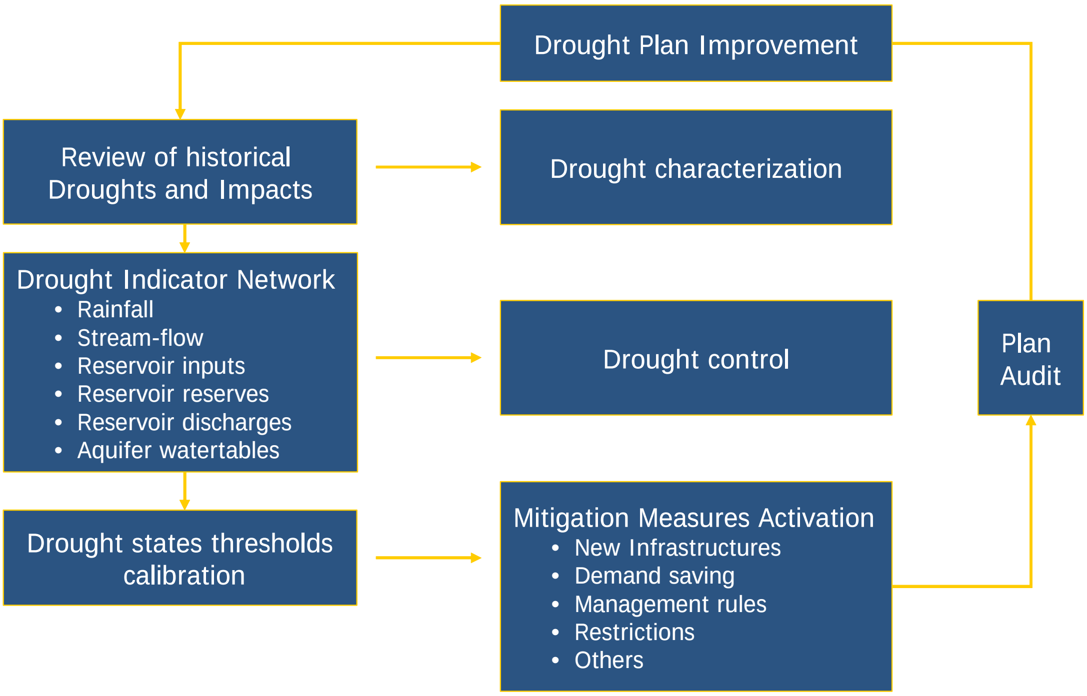


Figure 12 : Drought management plan process

An efficient plan must comply with some basic constraints. First, information on drought severity must be provided to decision makers and other users in a more timely manner. This requires better coordination of data collection efforts between responsible agencies, information sharing between and within levels of government, and improved delivery systems. Secondly, impact assessment procedures must be reliable and timely. Better indices are required to capture the severity of drought, particularly in the spring planting period. Improved estimates of drought impact on yield would help trigger assistance to the stricken area ; improved impact estimates are also important in other sectors such as energy, recreation and tourism. Third, objective and timely designation (and revocation) procedures are necessary to target assistance to drought areas.

F.2 - Drought mitigation measures

F.2.1 - Measures selection to mitigate drought impact

Drought responses can be classified as strategic, tactical and emergency measures. Strategic measures are long-term physical and institutional responses such as water supply infrastructures or law improvements. Tactical measures, like water rationing, are developed in advance to respond to expected short-term water deficits. Emergency measures are implemented as an ad hoc response to conditions that are too specific or rare to warrant the development of standing plans.

F.2.2 - Demand management

Drought could cause that the available quantities of water are less than the total normal demand. Therefore water conservation and restrictions on water supply shall be imposed to the three main sectors, i.e. irrigation, domestic and industry. The reductions shall be decided having in mind the economic, social, environmental, national, health, technical and other parameters.

Short-term curtailment of demand can be achieved through a vigorous public information program, which can include both voluntary and enforceable actions. The curtailment is temporary and after a shortage is over, consumers usually resume their former water use habits.
Main water demand management measures are the following :

- Policy changes
- Voluntary and mandatory use restrictions
- Allocation of priorities, compatibility and restrictions
- Pricing changes
- Public awareness
- Water ordinances with drought specialties
- Conservation credits
- Changes in irrigation methods
- Industrial conservation techniques
- Alternatives to water consuming activities

F.2.3 - Operational changes

Recently these kinds of measures have demonstrate their effectiveness :

- Conjunctive use management
- Water banking
- Water rights interchange
- Long-term changes in reservoir release rules
- Conditional reservoir operation
- Institutional changes
- Legal changes
- Operational coordination between systems

F.2.4 - Allocate strategic water reserves for drought conditions

Strategic water resources must be allocated as special water reserves, which shall be mobilized only under drought conditions.
The term "strategic use of groundwater" is frequently applied to the use of hydrogeological resources during drought periods, even arriving to its temporary overdraft. Concluded the crisis their employment ceases to allow its piezometric recovery so that they are under appropriate conditions for its application in future droughts. During droughts, a strict control of illegal wells drilling and pumping must be implemented in order to avoid worsening scenarios and not achieving the good quantitative status.
It is important to make an appropriate hydrogeological monitoring during the periods of normality in order to study the capacity of recovery of the aquifers and the possible affections to the quality of groundwater, so that the conclusions allow more efficient application in future crisis.
Certain strategic groundwater reserves have to be used under drought conditions. Overdraft and recovery must be monitored. Therefore an effective control is also required in periods of normality, avoiding these resources to be incorporated to the Water Management System like habitual resources, accounting them as extraordinary resources to confront situations of drought.
The Drought Plan must settle down, in accordance with the indicator system, the staggered start and stop of drought wells, their abstraction schedule and modifications due to quality water evolution.

F.2.5 - Water resources increase

Increasing water availability from existing sources is usually very difficult if not impossible. However water supply may be increased by :

- Strategic groundwater use ,drought strategic aquifers or aquifer recharge
- Treated wastewater reuse as an alternative to drinking water for non potable applications
- Desalinization
- Reallocation of supplies
- Water importation by barge
- Mobilizing lower quality water for specific uses
- Increasing water pumping from aquifers that can afford it besides drought strategic aquifers
- New storage in water distribution systems in order to increase regulation warranties
- New system interconnexions if the former measures are not enough to achieve the human necessities

F.2.6 - Environmental and water quality changes

According to WFD, temporary deterioration of the status of bodies of water shall not be in breach of the requirements if it is the result of circumstances of force majeure as extreme floods and prolonged droughts, under certain conditions (Article 4 paragraph 6). In these exceptional adverse circumstances, some relaxing must be applied to environmental constraints but preventing further deterioration in status of water bodies by :

- Reductions in required low flows
- Alternative means of achieving water quality such as most efficient water treatment, spill limitations, groundwater contribution to exhausted surface water bodies, etc.

Any reduction of the ecological minimum flow regimes have to be previously analyzed to determine the negative effect of these changes on the ecological status of water bodies as well as on the aquatic fauna and flora ecosystems, as they might have irreversible effects. Reductions of ecological minimum flow regimes should only be made effective if these flows are required for drinking water purposes.

F.2.7 - Timing

Water management plans under drought conditions should be well prepared before a drought occurs and in conditions which allow clarity in mind, not “management under crisis” and which will provide time to be prepared for the worse. Waiting for the last moment to act causes panic and despair, resulting in many cases to ineffective and uncoordinated actions. Most of all, the consumers are not conviced of the severity of the problem or do not give their total support. Plans made in advance shall provide the time to those involved to prepare them and take actions to minimize adverse effects.

F.3 - Measures to take under prolonged drought to be stated in the River Management Plan

Drought mitigation plan should be linked to WFD and incorporated to the River Management Plan as a supplementary plan, including at least :

- Indicators system and threshold establishing the level at which the exceptional circumstances appeared. Another level for pre-alert and alert should be defined.

- Measures to be taken in the pre-alert and alert phases in order to prevent deterioration in water status.
- All the reasonable measures to set up in case of prolonged drought in order to avoid further deterioration of water state.
- All practicable measures to be taken with the aim of restoring the body of water to its status prior to effects of those circumstances as soon as reasonably practicable.
- Summary of effects and measures.

F.4 - Drought monitoring and networks

F.4.1 - Continuous monitoring and control of the water consumed and water lost

Water consumed should be continuously recorded, stored and processed so that it is known on what uses the water is consumed, for domestic, industry, irrigation and environment. Control of the water consumption is necessary so that valuable water, in most cases heavily subsidized, is not wasted. Continuous monitoring and control of water lost in leakage, evaporation, etc, is a must to take the necessary measures to minimize losses and for water balance purposes.

F.4.2 - Continuous monitoring of water status

This method will provide collection, storing and processing of data related to precipitation, river flows, dam inflows, aquifer recharge, change of water levels in dams reservoirs and aquifers, losses (leakage, evaporation, breakage, etc). For this purpose, special information networks must be established for automatic collection of the information, involving groundwater and surface water, according to WFD criteria (in particular groundwater quantitative status).

F.4.3 - Continuous forecast of expected water resources

Forecasting of expected available water for the next few years for which a drought management plan must be prepared is not as easy as it sounds. Available actual data on river flows and precipitation have to be statistically analyzed and statistical models prepared so those estimates of inflows to dams connected with some probabilities can be made.

F.4.4 - Continuous evaluation of water demands, set normal and lower limits

Water demand for domestic, industrial, irrigation and other needs should be continuously recorded and evaluated to establish actual needs, the water lost or unaccounted and the wasted water. Minimum limits for each category of use should be agreed between the different users. Water supply priorities based on economic, environmental, population health needs, strategic, national and social criteria should be established.

F.4.5 - Improving the effectiveness of water use

Potential measures for the improvement of water use efficiency can be divided into those that aim to improve the performance of water distribution entities and those which aim to improve water use efficiency at stakeholder level. Measures can be further divided into those dealing with the improvement of existing infrastructure and those related to the non-structural aspects of water demand (e.g. improvement of organisation and management, improvement of knowledge about water losses, establishment of information systems, improvement in determination of crop demand and adjustment of water allocations, optimisation of timing, promotion of user initiatives for improvements, and tariff systems).

G - DROUGHT PLANNING EXAMPLES IN DIFFERENT COUNTRIES

G.1 - Water allocation during drought

A common way to face water allocation during drought is the french model. The French Water Act of 1992 seeks to guarantee a balanced management of water resources, allowing prefects to share these resources in case of crisis. Several tools are used to limit the impact of crisis situations when they occur: in the event of a proven crisis, i.e. as soon as the low flow-rate limits are exceeded, various measures may be taken to temporarily limit or suspend uses of water.
Framework decrees have been drawn up for watersheds, enabling the rules and thresholds for triggering restriction measures to be defined in advance. This approach greatly facilitates the exercising of regulations during crisis periods. It also makes possible to have greater transparency and better cooperation.
The document drawn up by the prefects indicates the warning levels (which may be gradual) and the measures to take when they are passed : uses to be suspended or scaled down, priority uses to be maintained – a definition of the priority of uses should ideally be drafted. The implementation of these measures if thresholds are passed is stipulated in a decree. Several incompressible needs have been identified and will need to be guaranteed for civil security, public health and national defense : regulated nuclear facilities, hospitals, fire-fighting facilities, etc.
The measures taken by the prefect must be appropriate. They must be sufficient in light of the severity of the situation and be in proportion. The prefects are also setting up contingency management offices with a view to organizing cooperation between users. They may bring together the various categories of users directly concerned as well as the fishing federations, nature protection associations and local water commissions when relevant.
Cooperation is the watchword for any water management system. Indeed, the law hallows it in the process of drawing up “Schéma Directeurs d’Aménagement et de Gestion de l’eau” (SDAGE), bringing together the water field players for development phases and monitoring.
The public authorities assess what measures need to be taken to combat drought in light of local circumstances (weakness of flow-rates for tables and watercourses, scale of withdrawals on the resource). Drinking water supplies remain a priority use, but it is also essential to protect and reconcile economic uses of water with efforts to safeguard aquatic environments.
Measures to limit uses of water may concern : the use of water for agricultural needs, the use of water for washing private vehicles or filling private swimming pools, the watering of public and private garden areas, the filling of man-made lakes, etc.
As water is a common resource, each person is responsible for preserving it. If they fail to comply with the restriction measures defined in the prefectoral decrees, they may be fined up to 1500 euros or even 3000 euros for repeating offenders.

G.2 - Water allocation priorities

All EU countries put first priority on drinking water during drought water allocation. Drinking water interests are considered as essential for public health and will get priority allocations, whereas optimal use will be made from the existing infrastructures such as reservoirs, and reductions in drinking water demands will be improved.

G.3 - Other priorities for safety reasons

A special issue in drought in the Netherlands is water-level control in the low-lying part of the country, where it is important to avoid irreversible land subsidence and to stabilise dykes and structures. This constitutes a top priority for safety reasons.

G.4 - Singular non conventional management measures for water conservation

Water scarcity is a reality in Cyprus. Presently, water demand for various uses exceeds the amount of water available, while in recent years, the problem has been exacerbated due to the observed prolonged periods of reduced precipitations.
In order to achieve minor water scarcity deficit, the Government of Cyprus has adopted novel actions for water conservation using second quality water or “grey waters”: establishment of subsidies for saving good quality domestic water through the connexion of private boreholes to toilet tanks or for the installation of grey water recycling systems in houses, schools, for watering gardens and toilet flushing, etc (see Appendix 2). Lightly polluted or “grey water” from baths, showers, hand or wash-basins and washing machines is kept separated from heavily polluted or “black water” from WC and kitchens. As a result, it is relatively easy to intercept each type of wastewater at household level for subsequent treatment and reuse. With this scheme, cypriots have achieved a drinking water conservation of 30 % to 65 %.

G.5 - Continuous monitoring, prevention and evaluation of drought consequences

In Hungary, the main drought problems and water scarcity are related to the decrease of surface water resources which support main economic uses and to drawdown of groundwater resources which furnish the most of drinking water supply systems. Ministry of Environment and Water recognized that the effective management of water scarcity requires a monitoring system. Therefore, a hydrometeorological monitoring system for the control of flood events, drought onset and water resource continuous evaluation has been developped. The hydrological conditions are continuously evaluated, making a Monthly Water Balance Report for the total area of the country, monthly submitted to the Agricultural Ministry, to the Water Boards, and published on a web page for general dissemination. This report includes the evolution of a state index (PAI-Index).
According to the Hungarian experience, it can be concluded that this report is very useful in awareness and adverse effects mitigation planning. It must be highlighted that continuous monitoring and forecasting are very important in circumstances of drought and water scarcity, because the activation of drought anticipation measures and real time management requires continuous monitoring.
Hungary has developed specific laws related to water issues. In case of drought, water service companies (most of them are represented by the Water Directorates) have the right to reduce water supply endowment to different users from surface and groudwater.
It is necessary to reduce negative effects of water scarcity in case of drought in a basin water resources management framework. This can be done with water resource increase or management measures. In order to increase available resources in Hungary, sluices in rivers, channels and reservoirs have been built with good results, particularly in case of reservoir vincrease with large basin.
As management measures, the Hungarian Drought Strategy was developed in 2003, based on own experiences. It follows two principles: prevention and integration of drought consequences. Experts are currently developing laws based on this strategy which follows twenty guidelines of which the most important are :

- necessity of data acquisition for forecasting
- necessity of continuous monitoring
- evaluation of drought consequences
- necessity of land use plans, especially in “drought-sensitive” areas
- necessity of drought mitigation measures such as building of reservoirs, or others solutions
- necessity of irrigation as the most effective application of drought damage reduction

- necessity of harmonization between forest deployment plans and drought strategy
- necessity of of water use costs re-evaluation
- necessity of evaluation of drought effects on tourism
- necessity of event communication with concerned inhabitants and water users and awareness dissemination to stakeholders.

G.6 - Drought planning legal framework

It is interesting, for instance, to have a look to the spanish legal framework which specifically refers to drought in a planning process. The spanish legal framework determines the way to face the problem for Public Administration and stakeholders. In the past, exceptional measures were applied during a crisis but few of them were dealing with preparedness, mitigation and previous planning. By the way, the former Water Act (1985) gave certain powers to Reservoir Committees of River Basin Authorities in case of water shortage, in agreement with water rights. Reservoir Committee submitted proposals to the Basin Authority Chairman with regard to filling and emptying reservoirs and aquifers, according to the rights of the different users and the current hydrological situation. In circumstances of unusual drought, the Government may adopt exceptional measures in order to address the situation, even if concessions (rights of water use under certain conditions) have been granted. Such measures may include the building of emergency infrastructures. Water Act also described a water use priority list, from first to last in order of importance : water supply in urban areas, irrigation, industrial uses for power generation, other industrial uses, fish farming, recreational uses and navigation.

The experience acquired during the last droughts suffered in the country have showed how this concept was inappropriate and demonstrated the necessity of new regulations and adequate drought risk management.

The new legal framework deals with drought planning and management through modifications introduced in the Water Act. For instance, Government may authorize the River Basin Authority to set up Water Interchange Centers (Water Bank) to enable user rights to be waved by voluntary agreement (Water Act, article 71). Specific legislation related to drought can be found in National Water Plan Act (Act 10/2001, article 27 “Droughts management”), which establishes that Ministry of Environment must establishe a global Hydrological Indicators System (HIS), and River Basin Authorities (Confederaciones Hidrográficas) must prepare Special Plans submit them to respective River Basin Councils and Environment Ministry for approval. A Special Plan includes water supply (for more than 20000 inhabitants) directives in case of drought or drought warning.

The process is as follows : River Basin Authority declares state of Drought or Drought Warning, according to the HIS threshold, initiating the measures included in the Special Plan. The institutions responsible for water supply (for more than 20000 inhabitants) have to draw up a Drought Emergency Plan and implement it when the state of drought or warning has been declared by the River Basin Authority.

The Water Directorate will have prepared a Guide in order to facilitate and coordinate de process with the River Basin Authorities. The process goes as in the following figure 13 :

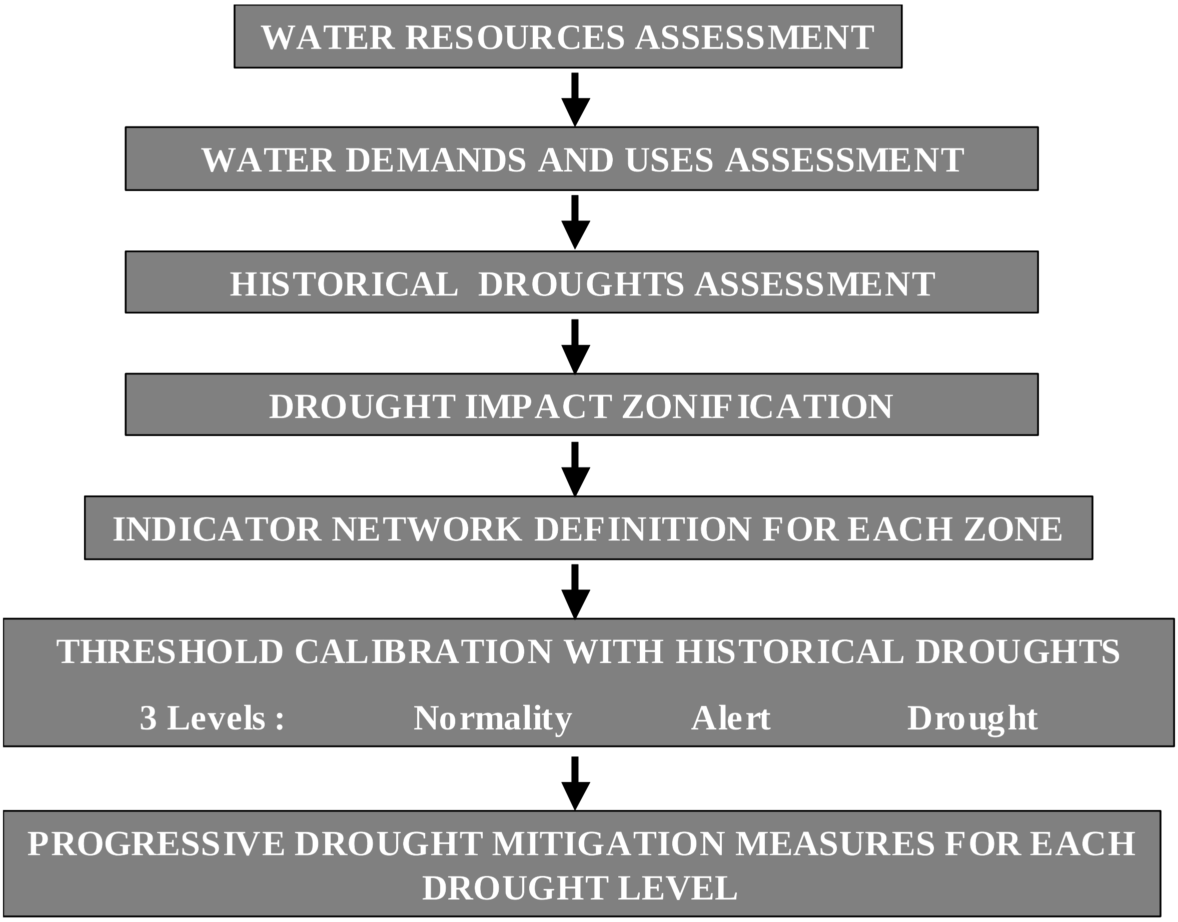


Figure 13 : Drought Special Plan drawing up Guide (Spanish Ministry of Environment)

G.7 - Other current practices and experiences in non EU countries

Many non EU countries within the Mediterranean region suffer effects from water scarcity and droughts. Thus, measures to face these problems have been proposed in several countries. Sometimes the selected solutions are usual practices which might have several ranges of impact. Therefore, it will be important to assess whether the solution proposed is the most adequate one.

Water harvesting with small dams and soil and water conservation in Tunisia

In Tunisia, there is an appraisal that about 29 billion m^3 of the rainfall is lost by evaporation and transpiration and 0,5 billion m^3 lost to the sea and to salty lakes. This water could be retained to improve the over-exploited water table. Non renewable water resources are very stressed in Tunisia due to the lack of capacity to retain the scarce renewable water resources.

Therefore in 1991, a long-term strategy stressing the necessity to conserve the national soil resources and to protect the existing infrastructures was set up. Until 2002, this strategy has permitted the construction of 580 mountain lakes (small dams with an average capacity of 100000 m^3), 2000 small check dams to trap sediments and 2000 diversion dams for water harvesting.

A new national plan was established for the period 2002-2011 to manage and maintain 1,5 million hectares in watersheds and to construct 1000 small dams, 3000 structures to recharge aquifers, 1500 diversion structures for water harvesting, 5500 protective structures for water ways and the management of 15000 ha by traditional techniques of soil and water conservation.

The construction of small dams at different points on the hydrological network attenuates the flood wave and reduces the erosion dynamics of the runoffs which are often violent in Tunisia (see Appendix 2).

H - COMMON PRINCIPLES

H.1 - Drought is not permanent water scarcity

Climate change, drought, and permanent water scarcity are interrelated, but these processes should not be confused, or interchangeably referred to, if the complex issues of drought and water management is to be addressed on a sound scientific basis.
Permanent water scarcity or permanent deficiencies are related to natural aridity, permanent over-exploitation of available resources and hence unsustainable water management, or desertification if aggravated by human footprint, while temporary water imbalances deal with the natural hazard event of drought, often in combination with human activities with increased water demand.

H.2 - Drought management instead of crisis management

The traditional mindset has been to react to drought with a crisis management approach, through the provision of emergency assistance to the affected areas or sectors. By following this approach, drought only receives the attention of decision makers when it is at peak levels of intensity and spatial extent and when water management options are quite limited. This approach is sometimes referred to as the "hydro-illogical cycle" where concern and panic lead to a reactive response to associated economic, social and environmental impacts, followed by apathy when precipitation restarts and water resources return to normal. This approach has been characterized as ineffective, poorly coordinated and untimely.
Drought planning tendencies nowadays develop towards moving from crisis to risk management. Developing comprehensive, long-term drought preparedness policies and action plans may significantly reduce the risks and vulnerabilities associated to extreme weather events.

H.3 - Need for drought preparedness

Droughts are natural recurrent components of the climate system but drought-related hazards are expected to increase in the future. This increase in drought hazard may result from an increased frequency and severity of meteorological drought, increased societal vulnerability to drought, or a combination of these two factors. Therefore, today there is a need for drought plans which should include prevention (in order to reduce the risk and effects of uncertainty) and mitigation measures (to limit the adverse impacts of hazards). Drought impact assessment involves, at least, the specific effects on economy, social life and environment that are vulnerable to drought events. The following issues have to be supported :

- Development of regional networks for drought preparedness that would enhance regional capacity to share lessons learned in drought monitoring, prediction, preparedness, and policy development.
- Development and implementation of early-warning systems on different spatial scales (e.g. regional, continental) in order to receive timely information on the possible onset and extent of an upcoming drought event and to launch early measures to mitigate the effects in time.
- Education and awareness rising of policy makers and the public regarding the importance of improved drought preparedness as a part of integrated water resources management.
- Enhancement of regional/international collaboration

H.4 - Need for advances in drought research related to effective measures development

Important issues that could be addressed on drought preparedness include:

- Developing effective indicators and indices to detect and assess drought situations throughout Europe.
- Development and dissemination of drought hazard, vulnerability and risk assessment tools.
- Development of vulnerability assessment methodologies under different environmental conditions, including the predicted climate change in Europe.
- Development of decision support models for the dissemination of drought-related information to end users.
- Appropriate methods to encourage feedback on climate and water supply assessment products.
- Development of decision support systems for the best exploitation of all information available, including drought forecasts, in order to optimize drought management and mitigation measures.
- Development of information systems to disseminate drought-related information to specifically various end user communities and to encourage their feedback on the usefulness of the presented products.
- Improvement of the monitoring, modelling and prediction capacities.
- Support of initiatives related to the development, improvement, promotion, and inter-linkage of early-warning systems.
- Development of national and regional drought and disaster management policies.
- Development of comprehensive drought reduction strategies that emphasize monitoring and early warning, risk assessment, mitigation and response as an essential part of drought preparedness.
- Assessment of the availability of skilled human resources to be involved in drought preparedness planning.
- Addressing the existing gaps and research needs for adequate risk methodologies in order to establish objective links between drought indicators and thresholds on one hand, and operational alarm levels necessary to perform decision making during drought situations for taking mitigation measures on the other hand.

H.5 - Need for drought planning

Basic elements of drought preparedness and risk management strategies that guide Drought Plans are the following :

- Effective information and early warning systems are the foundation for effective drought policies and plans, as well as effective network and coordination between central, regional and local levels.
- Drought management strategy should include sufficient capacity for contingency planning before the onset of drought, and appropriate policies to reduce vulnerability and increase resilience to drought.
- The problem of drought requires a proactive management developing actions planned in advance, which involve modification of infrastructures, laws, institutional agreements and the improvement of public awareness.
- Drought planning methodologies that could be adopted by drought-prone countries in the preparation of plans have to be disseminated.
- Information delivered to stakeholders has to be standardized.

Drought planning must be developed at different levels and linked to the River Basin Management Plan (RBMP) :

- <u>National level</u>
  At national level focus must be put in policy, legal and institutional aspects, as well as in funding aspects to mitigate extreme drought effects. These are strategic measures.
  General long-term measures are the focus of national level measures as well as transboundery measures, but not exclusively ; these types of measures must also be developed at RBMP level. In connection with river basin or local levels, national level measures must determine drought on-set conditions through a network of global indices and indicators at the national or regional level global basin indices/indicators network, which for instance can activate drought decrees for emergency measures with legal constraints or specific budget application.
- <u>River basin level</u>
  Drought Management Plans (DMP) at river basin level are contingency complementary management plans ro River Basin Management Plans. DMPs are mainly targeted to identify and schedule on-set activation tactical measures to delay and mitigate drought effects. Therefore, measures involved are mainly water demand or water conservation measures and, with the progressive application of WFD schedule, measures to achieve and comply with good a environmental status.
  In this sense, River Basin Management Plans have to include a summary of the programmes of measures in order to achieve the environmental objectives (article 4 of WFD) and may be supplemented by the production of more detailed programmes and management plans (e.g. DMPs) for issues dealing with particular aspects of water management.
  Regarding exceptions, “prolonged droughts” are introduced in the WFD as “force majeure” events. Therefore, clear definitions of what is understood by “prolonged droughts” will have to be established. The conditions under which exceptional circumstances are or could be considered have to be stated through the adoption of the appropriate indicators. Contingency drought plans must face these issues.
- <u>Local level</u>
  At local level, tactical and emergency measures to meet and guarantee urban water supply as well as awareness measures are the main issues.

<u>APPENDIX 2</u>

- Historical droughts characterization (B.1)
- Water management in drought periods in France
- Coping with Drought – The experience of Cyprus
- Water conservation in small dams in Tunisia

III- LONG-TERM IMBALANCES IN SUPPLY AND DEMAND

A - PREAMBLE

Recent assessments on trends and evolution of water demand in Europe have revealed a clear stabilization of the demand since the 1990's thanks to demand management measures to reduce leakages, the increasing use of water-efficient appliances that meter supplied water and the more efficient recycling of waste water.

However, this demand trend is not that clear when looking at regional scale. The total water drawing in Europe is about 353 km^3/year, which means that 10 % of Europe total freshwater resources are abstracted, leading to a situation of severe water stress in some areas. Because of local and seasonal variability of water demand even within a country, some areas are particularly vulnerable. Public water supply in northern Europe and irrigation in southern Europe exert the greatest pressure on water resources respectively. Since 1998, the irrigated land surface in the EU has continuously increased.

In these water stressed areas, the limited availability of water resources (depletion of some resources and loss of others due to pollution) and increased water demands (greater variety of uses and users) are the main causes of water scarcity problem. Remedial measures used to be based on the development of new water resources to offset the increasing demand. However, the ever increasing abstraction of the limited resource, in order to deal with a growing scope of multi-disciplinary uses and avert global heating hazards, have stimulated a new management strategy mainly economizing water rather than working out new water resources. To reach the goal of a sustainable water management, balance has to be achieved between abstractive uses of water (e.g. abstraction for public water supply, irrigation and industrials uses), in-stream uses (e.g. recreation, ecosystem maintenance), discharge of effluents and impact of diffuse sources.

This new concept is defined as an Integrated Water Resource Management (IWRM) approach that promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems (Global Water Partnership, 2004). This approach is not only about "managing physical resources" but also "reforming human systems to enable people to benefit from the resources".

WFD is a good first step towards this approach in terms of quantitative management of water. Throughout the program for the monitoring of surface water and groundwater status and protected areas (article 8) and throughout the programme of measures (article 11), WFD proposes an IWRM approach. Moreover, quantitative aspects are mentioned several times in these articles. WFD gives a framework for long-term changes on quantitative management in order to deal with long-term imbalances between supply and demand, recalling that "all practical steps are taken to prevent further deterioration in status" (article 4a).

These practical steps can be divided into two types of measures :

- Measures for fulfilling demands using available water
- Supply side measures

B - TYPE OF MANAGEMENT MEASURES FOR BALANCING DEMANDS USING AVAILABLE WATER

In the past, efforts to satisfy increasing demand have often been principally expended on increasing the supply of resources, which were available abundantly and at relatively low cost. However, the relationship between water abstraction and water availability has turned into a major stress factor in the exploitation of water resources in Europe. Therefore, it is logical that investigation on sustainable water use in application of WFD is now reoriented on the possibilities of influencing water demand in a favourable way for aquatic environment.

Integrated Water Management (IWM) is the new paradigm for a wish of efficient, sustainable and safe supply of water. IWM usually means *inter alia* the use of the best water quality for each demand, so different uses can be supplied with different qualities of water and consequently, and water have to be collectyed from different sources and retorted to their end-users as efficiently as possible. Nevertheless, in order to get real IWM from the demand side, it is also necessary to consider the Shadow Water (SW), the water that, as a consequence of best practices, we don't need to use. The water we don't have to produce, the water we prevent from leaking from the network, the water we avoid using and that we don't have to clean is Shadow Water, the best water we can achieve for our safe supply, for our environment and also for our economy.

Probably, many of these assertions would be discussed on a short-term and economic basis, but in a global and long-term prospect, they are unquestionable. Action towards a sustainable future has to be founded on the use of IWM based on raising the offer of SW versus Real Water. In fact, ratio between these two types of water is an indicator of the water supply quality.

Many experiences already exist in the "production" of SW. Some of them have been quantified in different situations and we are able to consider some of its advantages and difficulties. Cost estimations are time dependent, as many of them could be considered as long-term investments which clearly overcome company budgets.

B.1 - Demand-side measures

Demand-side management is already well developed in other economic sectors like electricity, gas or oil. Efficiency standards, product labelling and advice services to users are good examples of actions set up. For example, household appliances are now stamped by the EU Energy Label that rates appliances from A (most efficient) to G (least efficient). However, economic incentives are usually more efficient than these actions. They can intervene :

- on the price of a good. From example, in France, the electricity provider EDF (Electricité de France) proposes 3 different options : 1st option, a minimum subscription and a fixed price per kWh ; 2nd option, a higher subscription and a reduced price per kWh during 8 hours per day (usually at night) ; and finally 3rd option, the same as the 2nd one with a variability of the reduced price per kWh depending on the period of the year (higher in winter).
- on technology development financing. For example, in France, FIDEME (Fond d'Investissement de l'Environnement et de la Maîtrise de l'Energie) is a € 45 millions fund to promote and facilitate the financing of energy saving as well as control and waste improvement projects. The fund is used by subscribing bonds issued by enterprises that develop projects eligible to the fund.

The Plan of Implementation approved at the World Summit on Sustainable Development (WSSD), held in Johannesburg in 2002, included a specific directive calling for all countries to develop integrated water resources management (IWRM) and water efficiency plans by 2005. As Global Water Partnership technical committee stressed in a first version (April 2004) Paper on Guidance in preparing a national IWRM plan, advancing the WSSD plan of implementation inherent in an

IWRM approach is the recognition that truly sustainable water resources management involves managing demand, not just supply.

B.1.1 - Technological approaches

Water usages can be prioritized according to their ability to answer to human and aquatic environments' needs following the "human basic needs" or the "aquatic environments survival needs" to the "human being needs" or the "aquatic environments best conditions for life". Thus resource waters should be classified over periods of time referring to this prioritization. For example, groundwater, which is usually of high quality, should be reserved for drinking water or more generally for hygiene usages. Surface water collected by dams during winter should at least be used to maintain life conditions (temperature, oxygen,…) during summer and, at best, permit the good functioning of aquatic life cycle like fish migration or access to reproduction zone for example. Thus inter-usage water transfer can intervene in order to answer to this prioritization.

B.1.1.1 - Water saving devices

Water planning, efficiency of uses, quality of the supply, storm water and reuse of water are keystones to improve IWM (defined at the beginning of paragraph B). Many of the mistakes of any type of water management come from the non linear pressures on water demand : droughts are medium and long-term unpredictable events. For that reason, water supply pops up in the media just a few months from when a new shortage starts. Consequently, questions and promises of new investments just arise at this time. Many of them drive to quick answers that surely do not constitute the best possibilities for dealing with water scarcity.

Water planning has to be ready for these circumstances, defining what has been done and what is to do in each case by the appropriate person. The reality will probably be different whenever a new case comes up, but we avoid a lot of mistakes and save a lot of water and money if we put on top of the table different previously deemed possibilities.

Efficiency is not only a water managers question. Most people could expend less water just thinking about this objective. Moreover, we are able to use less water just by changing some of our habits while maintaining our standard of living. Water saving campaigns must inform citizens about how to use water and which level of efficiency we could obtain through already available technology. Pricing of water has to converge towards this objective : above the minimum of needed water, and for a normal standard of living (between 110 and 130 litres per person per day), the price of water has to achieve its full cost for industrial users and to be overtaxed for sumptuary users. Total recoveries have to reach the total cost of the water including external factors like the price we have to pay for aquatic system recovering.

Quality of the supply should agree with well-known standards and guarantee information to consumers. No supply could remain without metering : establishing an account with a minimum of reliability is an absolute requirement. Transparency is the key for a service that is considered as a monopoly for the consumer. In order to increase the quality of the supply, blame and shame policy, as well as an adequate financing, are necessary. A public water board must be considered to audit these services in a consistent way.

Storm water has a promising future as a urban supply complement. Like in the past, collecting water from the roof is a very good practice, especially in residential areas of the cities where family houses are easily prepared for this collection. New technologies for filtering and storing storm water will help end-users to implement these catchments.

Although urban water represents a small percentage of the water consumption around the world, regions that periodically suffer from drought episodes have developed different strategies to deal with supply shortages. Many of them come from the supply side but, as new sources of water

become scarce and more expensive year after year, demand policies gain their place in the centre of the debate.
Reuse of water is a common practice in dry regions of the world (figure 14). Europe reuses over 700 million m^3/year. The reuse is considered, in many cases, as the future trend. Indeed, we need to consider different qualities for different uses and to choose the best cleaning process for each purpose. Second quality water has the greatest possibilities for urban supply. A lack of infrastructures is usually a threshold for its development, but we need to establish standards for water reuse in order to include them to new developments.

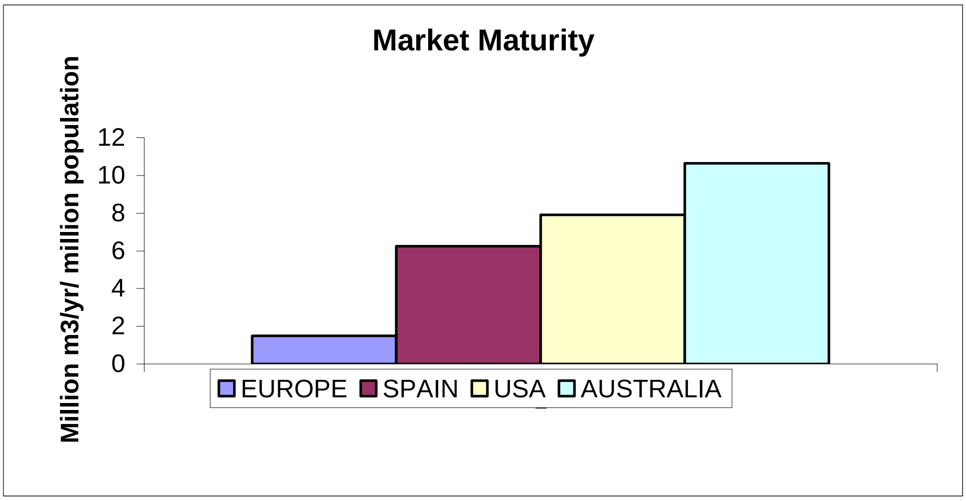


Figure 14 : Actual 2002 water reuse installed capacity vs population. European values include Spain. Australian value are for Mediterranean climate States only. Eureau water reuse working group, www.eureau.org

Water saving devices are often easily usable technologies in households, companies, farms and governmental communities :

- Air devices aim at saving water by pressuring it enough to use less water for the same result (high pressure coach cleaning or high pressure firemen device).
- Thermostats allow to avoid water losses to adjust temperature.
- Double command mechanisms permit to choose the amount of water necessary (double-command toilet, dishwasher cleaning options).
- Timed length of flow regulation system enables water saving with the same efficiency (drop by drop watering).

Water saving devices impact on water demand varies depending on the importance of water consumption of the activity sector considered. In agriculture, developing water saving devices can strongly impact water consumption especially during irrigation periods. In households, implementing water saving device would help developing people awareness of the necessity of considering water as a scarce resource. However, the impact on water scarcity problems would not be very significant for two reasons :

- Household consumption is usually not the biggest part of water consumption of a country where water scarcity problems occur.
- Because of the cost of these not widely spread technologies and the slow turnover of home appliances, water saving devices often have difficulties to penetrate the market. Long campaigns of information on their availability and advantages are required. Thus, water saving device should be seen as a solution to help economizing water but not as the main action of a management plan.

Most of the water use in households is for toilet flushing (20-33 %), bathing and showering (20-32%), laundry and dishwashing (table 3). The proportion of cooking and drinking water, compared to the other uses, is very small (3 %). Statistic studies show that the water efficiency can be improved in common household appliances such as toilets, taps and washing machines. Some appliances are adapted in a better way to collective buildings such as public toilets (taps which turn off automatically) ; nevertheless, most of water saving devices are not widely used because they are expensive. But recent research and development has refined these appliances and made them more accessible to the public.

Table 3 : Patterns of water use by households en England and Wales, Finland and Switzerland (Lallana et al., 2001).

Household uses	England and Wales (%)	Finland (%)	Switzerland (%)
Toilet flushing	33	14	33
Bathing and showering	20	29	32
Washing machines and dishwashing	14	30	16
Drinking and cooking	3	4	3
Miscellaneous	27	21	14
External Use	3	2	2

EU has recently established conditions required for dishwashers (Official Journal of the European Communities, 7th August 1993) and washing machines (Official Journal of the European Communities, 1st August 1996) "ecological labeling". Dishwashers must not use more than 1,85 L of water per cutlery item, washing machines more than 15 $L.kg^{-1}$ of clothes in a 60 ^{o}C cycle, and clear instructions have to be given about water and energy saving.

In addition to regulations, new technologies also have a positive impact on the use of water thanks to these domestic appliances and have achieved important water saving over the last 20 years.

However, the difficulty often consist with encouraging the use and increasing the market penetration of these devices. Initiatives can include the short or long-term renovation of the buildings, such as offices, sports facilities, schools or apartment blocks, when companies or local authorities decide to integrate water efficiency as a design criterion. Increasing the market penetration of appliances in the domestic field is the most difficult and requires information campaigns explaining the reasons and advantages of the new appliances, for example in terms of water bills reduction. This is obviously a long-term process, since the turnover of such appliances in individual homes is slow.

The impact of the use of water saving devices on water demand varies depending on the importance of household demand in relation to total urban water demand. For example, a 10-70% reduction in household water demand in the Netherlands, with a total demand of 1014 million m^3, 57% of which go to households, would result in a water reduction of 58 to 405 million m^3 (6 to 40% of the total urban demand). In the UK, with a total demand of 12117 million m^3 for urban use, of which 44% are for household demand, the water reduction would be 533 to 3732 million m^3 (4 to 31% of the total urban demand).

It would be necessary to encourage market penetration of these devices by increasing the information for users and seeking the cooperation of producers (better information to consumers about the available technologies).

B.1.1.2 - Water metering

Metering water can be the first step towards a succession of actions to reduce water consumption.

- Metering water at waterwork and households permits to localize leakages in the distribution network.

- Because price is often related to the consumed volume when water metering is introduced, water metering is a good way to develop people awareness in order to make them economize water resource.

However, it is difficult to estimate the effect of water metering on the decrease of consumption. A 10 to 25 % reduction is estimated as immediate savings from the introduction of water metering (Lallana et al., 2001). This effect certainly depends on the consumer's activity. Householders may not be very regardful whereas irrigants may surely pay attention because of the relative importance of this charge in its spending. This effect depends as well on the mode of pricing. Living standards must be taken into account otherwise numerous and low income families would have to pay more than wealthy families for the same volume per person and might try to economize that much that they would reduce their hygiene whereas high income family would not be aware of the necessity of saving water.

The impact of the introduction of metering of water consumption is difficult to separate from other factors effect, particularly the water charges applied. It is also essential to have a correct balance between real water consumption and unaccounted water. Water losses are better measured if a meter is installed at the waterworks as well as at the consumer's home.

However, immediate savings from the introduction of revenue-neutral metering are estimated to be about 10-25% of the consumption, because of the effects of information, publicity and leakage repair, as well as the non zero marginal pricing. Savings are also sustainable over time (waterstrategyman – 2005, Guidelines for integrated water management).

The introduction of metering, as part of water demand management, is usually accompanied by a revised charging system and regulation on leakage.

Water meters have usually been used to determine water consumption, but in some countries, such as Denmark, meter readings will be used to calculate a pollution tax, on the basis that water consumption indicates the discharge to the sewage treatment plant.

Introducing water metering to new regions would lead to effects to take into account (effects on socially disadvantaged households which are more vulnerable to water metering and pricing – large family, medical conditions ; waterstrategyman – 2005, Guidelines for integrated water management).

B.1.1.3 - Leakage reduction in distribution networks

The quantity of water lost is an important indicator of the positive or negative evolution of water distribution efficiency, both in individual years and as a trend over a period of years. High and increasing annual volumes of water losses, which are an indicator of ineffective planning and construction, and low operational maintenance activities, should be the trigger for initiating an active leakage control programme. However, a leak-free network is not a realisable technical or economic objective, and a low level of water losses cannot be avoided, even in the best operated and maintained systems, where water suppliers pay a lot of attention to water loss control. Particular problems and unnecessary misunderstandings arise because of differences in the definitions used by individual countries for describing and calculating losses (IWA, 2000). The problems of water and revenue losses are :

-Technical : not all the water supplied by a water utility reaches the customer.

- Financial and economic : not all the water supplied is paid for.
- Terminology : lack of standardized definitions of water and revenue losses.

Leakages are difficult to calculate. They can be involved in consumption that is sometimes defined as the abstracted volume of water not restored to water cycle. They cannot be calculated from the invoiced water because volume of invoiced water involves leakages at the consumers' place. They cannot be assumed as equal to losses because losses are not always due to leakages (evaporation in industrial water cooling for example).

Losses in the water distribution network can reach high percentages of the volume introduced. Leakage covers different aspects : losses in the network because of deficient sealing, losses in users' installations before the water is metered and sometimes the consumption differences between used (measured) and not measured quantities are also counted as losses. Leakage figures from different countries not only indicate the different aspects included in the calculations (e.g. Albania up to 75 %, Croatia 30-60 %, Czech Republic 20-30 %, France 30 %, and Spain 24-34 %).
It is possible to use different indices to express the efficiency of a distribution network. Many suppliers argue that a large number of factors should be taken into account in leakage performance and that the indicators described may not be comparable. IWA recommends the use of the Unavoidable Average Real Losses (UARL) index which recognizes separate influences of Real Losses from length of mains, number of service connections, total length of service connections from the edge of the street to customer meters and average pressure when the system is pressurized. In order to evaluate the maximum potential for further savings in Real Losses when the system is pressurised, the difference between the Technical Indicator for Real Losses (TIRL - to be intended as annual volume of real losses divided by the number of service connections) and the UARL must be calculated.
Anyway, network meters are generally considered as necessary to enable good network management.
In most rural municipalities, distribution network maintenance is not a priority (lack of regular monitoring, networks plans). This situation coincides with a lower price of water than the national average and a lack of a general use of domestic meters.
Tracing and repairing leakage can be very expensive. Increasing water production to feed leaks may prove cheaper in some systems. The consequence is that local authorities may decide not to trace leakage despite low efficiency ratios but continue their wasteful use of water (Waterstrategyman, 2005).
Even the systematic use of acoustic instruments such as correlators has its limitations too. The solution could be found in the application of the minimum optimum rehabilitation methods, in which the performance of the network is assessed according to standard of service requirements. Experience has shown that the most efficient and effective way of controlling leakage is to divide the network into a number of permanent districts by closing selected line valves and installing flow meters on the few remaining key supplying mains. In this way, leakage can be continuously monitored and the presence of a new leak identified immediately. In large and complex systems, the division of a network into districts represents quite a delicate operation which, if not undertaken with care, can create low pressure and water quality problems. In order to overcome such difficulties, a fully calibrated network analysis model should be constructed, allowing the design of the districts to be evaluated and optimized before the system is constructed in the field.
In England, the OFWAT and the Environment Agency succeeded in reduce leakages of about 6-700 Millions of cubic meters from 1996 to 2001. Since its peak in 1994-95, leakage has fallen by 1,869 ML/d (37%), enough to supply the daily needs of more than 12 million domestic customers (OFWAT, 2000-2001).
Despite the difficulties to identify the most effective measures for leakage reduction, these issues must be considered as a priority among demand-side interventions to be individuated in the programme of measures. Furthermore, the leakage reduction must support the achievement of the water balance at river basin scale.

B.1.1.4 - New technologies and changing processes in industry

Until now, a lot of emphasis has been put on reducing energy use in the industrial sector to reduce costs. It was only during the 1990's that improving water efficiency also began to be considered as a way of cutting costs. Actions to improve water efficiency are focused on the process and on the discharges.

In a study carried out between 1992 and 1997 in the industrial sector of Catalonia, the Institute of Energy (Catalonia, Spain) found that about 35 % of the proposed cost-saving measures were implemented in areas of management and control, 32 % in the process and only 18 % in the reuse of effluents. By implementing water saving measures, the amount of water saved varies depending on the industrial sector. Following a study carried out by the same institute in 1999, the range of potential water saving is 25 % to more than 50 %. The main findings for industry are as follows :

- The introduction of water saving technologies in the industrial sector is basically focused on the most common processes : cooling and washing.
- Water substitution means immediate savings for an industry (cost savings correspond to the drop in water charges, especially if the substitution did not imply additional investment).
- Improving the control of process conditions can reduce water consumption by about 50 %.
- Work in closed circuits can reduce water use by about 90 %.
- A reduction in the cost of the existing water saving technologies could encourage further extension to small industries.
- Better communication between industries with high water consumption may help to disseminate pilot project results on water saving technologies.

B.1.1.5 - New technologies and changing processes in agriculture (examples of irrigation methods in some countries)

Irrigation permits to increase culture production on one hand and partly prevent from climatic hazards on the other hand, obtaining a more stable output and a better quality. It also allows to decrease risks on agricultural income. Water withdrawals for agricultural irrigation have clearly increased since 50 years in southern Europe countries and mostly happen in summer (low water period) when water is not very available. They are thus conducive to create or enhance water shortage harmful for the other resource users and natural systems.
A reduction of agricultural withdrawals can be achieved through :

- A reasoning of irrigation with a precise adaptation of the amounts of supplied water : launching of irrigation from an irrigation balance, estimation of the existing cultivations needs, irrigation recording book, etc.
- Leakage limitation by drain, infiltration, evaporation or drift : gravity irrigation suppression, localized irrigation development (drop by drop) when possible, equipment adjustment, no irrigation during maximum sunshine or when wind blows over 7 km/h.
- Collective management of disposable resource for agriculture.
- Changing the type of cultivations : less consuming or differently distributed in time (winter cultivations instead of spring ones).

B.1.1.5.1 - Better control of irrigation

In order to achieve a balanced water resource management and a better knowledge of the pressions, removed water counting is necessary. It is an essential tool to pilot the irrigation and permits to know the actual amounts of withdrawals and consequently allows :

- An adaptation of water supplies according to actual needs for cultivations and soil specificities.
- The control of the good functionning of irrigation devices (leak spotting for example).
- To give the opportunity to local stakeholders to set up a planified and umpired management of the resource for all users.
- To make money savings by diminishing the removed volume.

But it is advisable to insure an as precise as possible counting, by means of maintenance and regular standardization of the counting devices.

Over the last decades, major efforts have also been made to adapt water consumption of irrigation to water needs of the crops, in relation to its variety and lifecycle. Traditionally, the UN FAO methodology was calculating the theoretical crop evapotranspiration. But water efficiency technologies have significantly improved over the last years and current methods are more precise to determine water requirements of the crop via analyzing soil humidity, plant and climate. Strategically placed control sensors measure humidity in the upper soil layers and the trunk at a high frequency. These data are transmitted to a central control station and combined to meteorological data from a climate station close to the plot.

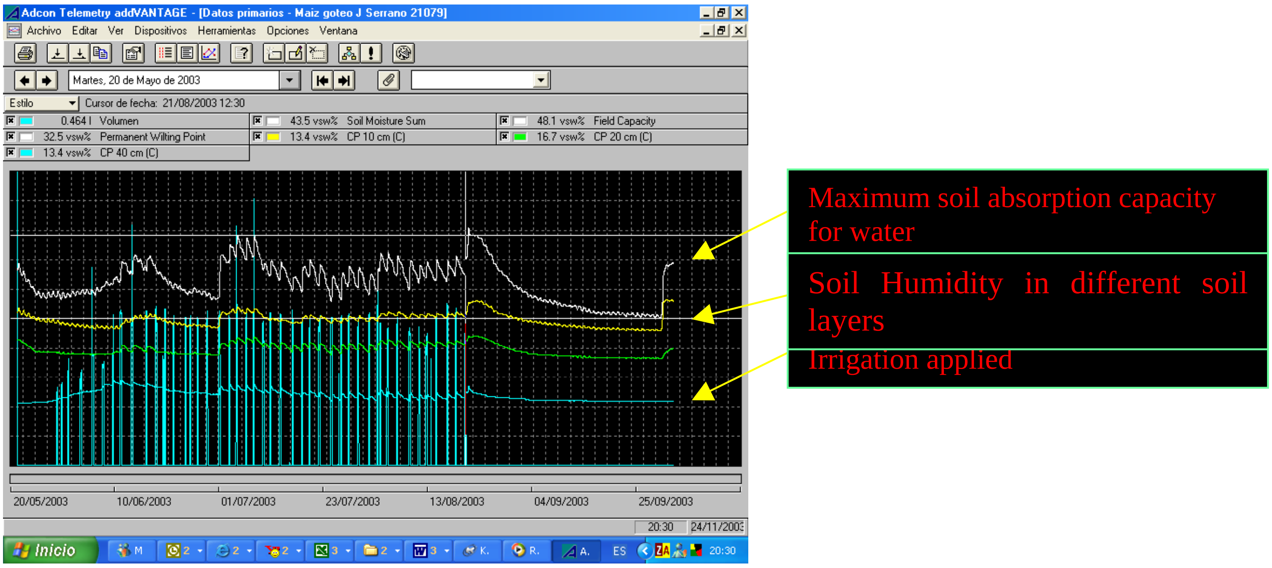


Figure 15 : Example of a register of irigation and soil humidity (WWF & Acciones Integradasde Desarrollo, 2005 : Proyecto LIFE Hagar. Madrid).

The resulting graphs show soil humidity and water absorption by the crop, facilitating the establishment of very adjusted irrigation recommendations (figure 15). The frequency of irrigation can permit to avoid water losses by infiltration and ensure that the soil is always partially humid. This control of the plant access to water is an ideal way to develop production objectives regarding a certain crop quality.

This method has been applied in different projects. In EU LIFE pilot project (www.life-hagar.com) in Castilla La Mancha (Spain), 12 plots of vineyard, onion, alfalfa, sugar beet and melon crops have been studied with soil humidity sensors (C-probes FDR), irrigation control, water meters, precise dendrometers and climate stations. The average water saving is 14 %, with a range of 4 to 30 % according to the crops. These savings are significant in an area with constant overexploitation (total deficit of 5500 Hm^3) and high water pumping costs. In the orange and mandarin Los Mimbrales estate (Huelva, Spain) immediately upstream the Doñana National Park, 30 % of water have been saved.

B.1.1.5.2 - Improvement of irrigation techniques : switching from gravity to pressurized irrigation and other technologies

The irrigation industry is rapidly developing new technologies to make irrigation more efficient. It is important to keep in mind that there is no one best irrigation method for all conditions. Any method can work efficiently if it is appropriate to the circumstances, well designed, and diligently maintained. In all cases, the proper application amount equals the water required by the crop, plus the water needed to prevent the build-up of harmful minerals in the soil through a process called leaching. It helps prevent waste, minimize run-off and lessens the effect of drought. "Smart" technologies, like systems with flow-control nozzles, climate-based controllers and automatic shutoffs are beneficial and even required for irrigation systems in some areas. More and more communities are moving toward rewarding or requiring new irrigation systems to include more water-wise features with irrigation systems that deliver exactly the right amount of water at the right time. The benefits of an automatic irrigation system include :

- reduced labor for watering
- convenience
- full landscape coverage
- easy control over irrigation timing for overnight or early-morning watering
- added value to home or business property
- minimized plant loss during drought

Traditional irrigation system controllers are really just timers. They turn the water on and off when they are told, regardless of weather conditions. Smart irrigation controllers, on the other hand, monitor and use information about environmental conditions for a specific location and landscape - information such as soil moisture, rain, wind, the plants evaporation and transpiration rates, and, in some cases, plant type and more - to decide for themselves when to water, and when not to, providing exactly the right amount of water to maintain lush, healthy growing conditions. Because smart irrigation controllers are more efficient than traditional, timer-based controllers, they also reduce overall water usage, typically by 30 %.

Gravity flow surface irrigation is the spreading of water over a basin or along furrows by gravity flow. Earthen borders check the spread. There may be pumps at the tail end of the field to recycle excess water (if there is any). Fields should be prepared so they are level or slightly and evenly sloped. A farmer can calculate the amount of water to apply (irrigation scheduling) by noting the field dimensions, crop, stage of growth, climate conditions, and soil dryness. The objective is to minimize the water lost beyond the reach of plant roots and the excess water pumped from the tail end of sloped fields. Farmers close to rivers can drain their excess tail water to the natural channel or let extra water percolate below the plant roots underground back to the river, thus helping to replenish the quantity of the river flow. However, the return water carries sediment, soil salts, chemicals and fertilizer, all of which diminish the water quality in the receiving stream. Careful water scheduling benefits the environment by reducing both diversions and runoff. Since less water is diverted, less power is required to pump water to the fields.

Pressurized sprinkler irrigation is the distribution of drops of water over the crop, imitating rain. For permanent installations, pipes can be laid on the ground or buried (solid set). For mobile installations, pipes may be moved by hand or supported by wheel structures that advance the sprinklers along a field (linear moves, wheel lines). Center pivot systems, similar to linear moves, rotate about well heads that supply water from underground rather than from canals. Sprinkler systems are well suited for uneven terrain. These systems apply water most uniformly when there is little wind ; windy conditions can spoil the application pattern. Careful monitoring and water scheduling reduce over-watering. For linear moves, downward oriented drop tubes deliver water closer to the crop with less wind scatter. The objective is to match the application rate to the infiltration rate, so that the soil is wetted without water pooling upon the surface where it evaporates or runs off the end of the field. Sprinkler irrigation can serve many purposes : frost protection, seed germination, leaf canopy cooling, delivery of agricultural chemicals mixed with the irrigation water and replenishing soil moisture during the off-season. But pressurized, elevated pipes also require expensive electrically powered pumping. The degree of application uniformity determines the efficiency of a sprinkler system. When water is unevenly distributed, supplying sufficient water to the least watered areas means that everywhere else is over-watered. Compared to surface irrigation methods, sprinklers permit better control over application amounts. Low pressure micro-irrigation delivers water drop-by-drop right to the root zone so the plants take up water gradually from their roots. Low pressure tubes allow water to seep through tiny perforations (emitters). Drip tapes and rigid drip tubes are rolled out over the surface, or buried under the soil surface. Mist sprayers are used to apply fine droplets beneath the leaf canopy, directly upon the soil. This method can be the most efficient crop watering method when the system is designed for :

- even application across the irrigated area
- careful timing to prevent over-watering
- water filtration to keep the emitters clean

The high cost of installing and maintaining a micro-system is justified for permanent high value crops such as vineyards and orchards. As technological innovation reduces the cost and as water prices rise, micro methods will find further application.

B.1.1.5.3 - Quota control

The water quota system is used to define the limit on water use or establishes how much to use, when, by whom, and for what purpose water can be augmented and used. When users' behavior is not very responsive to price changes, because of rigid price elasticity, or when uncertainty is involved in the computation of marginal cost and benefit, quota regulation is suggested as one of the measures for controlling water use (Tsur and Dinar, 1997; Mohamed and Sevenije, 2000). The difference between the quota and pricing system is that in the former case, the marginal social costs associated to each unit of abstraction are assumed to be minimal through the setting of some standards. Likewise, the basic difference between a quota and right allocation is that the former may have various attributes, including a pre-determined price, and be subject to modifications, based on external conditions and number of users, or participants (Tiwari and Dinar, 2001).

B.1.1.6 - Water reuse

Reclaimed water is an alternative water resource (see reuse european project, www.aquarec.org). Water reuse can be a tool in managing scarce water resources. Recycled water is being used as substitute for many traditional non potable uses and for sources that provide raw water for drinking water production (table 4). Such use can help conserving drinking water by replacing it or the water taken from drinking water sources, and by enhancing sources such as reservoirs and groundwater. The improvements in treatment of wastewater have opened new possibilities to reuse treated wastewater. Hence, the indirect recycling of water used in many parts of the world has been largely practiced for many years.

There are no formal european wide guidelines, best practice or regulations for water recycling and reuse other than the Urban Wastewater Directive which requires that "treated wastewater shall be reused whenever appropriate". Disposal routes shall minimize the adverse effects on the environment" (article 12**)**. The EU needs suitable guidelines and definition of "whenever appropriate". This should however be seen in the light of the objectives of the directive (article 1) : "…to protect the environment from the adverse effects of waste water discharges". Significant progress has been made through initiatives in some member states. To maintain the momentum gained, the valuable initiatives in Cyprus, Belgium, France, Spain, UK and other countries should be used as a base to develop water recycling and reuse guidelines and codes of best practice.

Table 4 : Water recycling and reuse definitions

	Definition
Reclaimed water	Treated wastewater suitable for beneficial purposes such as irrigation
Reuse	Utilization of appropriately treated wastewater (reclaimed water) for some further beneficial purpose
Recycling	Reuse of treated wastewater
Potable substitution	Reuse of appropriately treated reclaimed water instead of potable water for non potable applications
Non-potable reuse	Use of reclaimed water for other than drinking water, for example, irrigation
Indirect recycling or indirect potable reuse	Use of reclaimed water for potable supplies after a period of storage in surface or a groundwater
Direct potable reuse	conversion of wastewater directly into drinking water without any intermediate storage

The potential of reuse in Europe is high, especially in Spain, Italy, and to a lesser extent in France, Portugal, Greece, Poland and Belgium. For example in Spain, a maximum water reuse of 2000 Mm^3/year could be reached (Hochstrat et al., 2005).

B.1.1.6.1 - Applications

Although treated wastewater has been an important mean of replenishing river flows in many countries and the subsequent use of such water for a range of purposes (figure 16) constitutes indirect reuse of wastewater, it is becoming increasingly attractive to use reclaimed or treated wastewater more directly. In addition, reclamation of wastewater is attractive in terms of sustainability since wastewater requires disposal if it is not to be reclaimed (UKWIR et al., 2004).

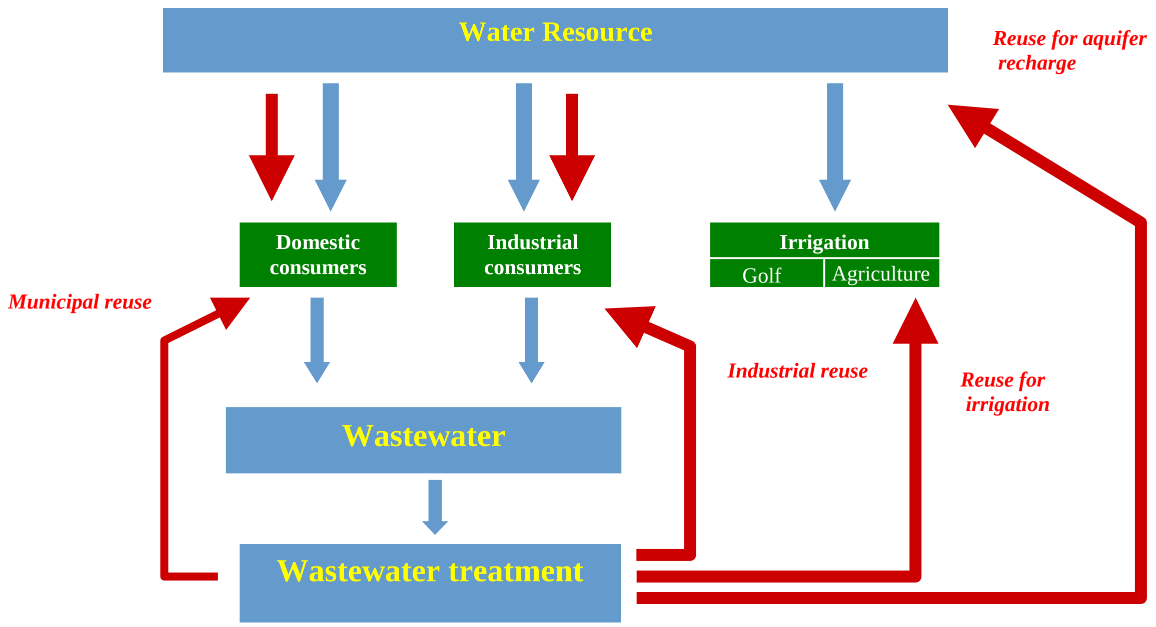


Figure 16 : Different applications of reuse

Treated wastewater may be used as an alternative source of water for agricultural irrigation. Agriculture represents up to 60 % of the global water demand while the requirements arising from increasing urbanization such as watering urban recreational landscapes and sports facilities, also creates a high demand : water scarcity in Mediterranean countries historically led these countries to

appropriately use treated wastewater in agriculture, irrigation of golf courses and other green spaces, including those used for recreation in which individuals may come into contact with the ground. It can be used to supplement artificially created recreational waters and for reclamation and maintenance of wetlands for which there can be a significant ecological benefit and a subsequent sense of profit to the community (see example of Costa Brava, Appendix 3). Concerns related to the reuse of treated wastewater are similar to the reuse of sludge, in particular the risks of contamination. Treatment plants are typically only equipped for biological treatment which does not eliminate the chemical substances in the waste water.
In urban environments, treated wastewater may also be used for fire-fighting purposes or street cleaning. In industry, the use of recycled or reclaimed water has extensively developed since the 1970's, for the dual purpose of decreasing the purchase of water and avoiding the discharge of treated wastewater under increasingly stringent emission regulations. This trend started with wash-water recycling but now incorporates the treatment of all types of process waters. Virtually, all industrial sectors are now recycling water, with examples in pulp and paper, oil refinery, etc. Consequently, together with overall shifts in the industrial sector, a 30 % reduction of industrial water consumption has been achieved in some european countries (website ref 1). Where water is scarce, industries also use reclaimed municipal water to reduce their production costs.
An additional use may be the direct supplementation of drinking water resources through groundwater infiltration and by adding it to surface water, with examples in northern Europe where several cities rely on indirect potable reuse for 70 % of their potable resource during dry summer conditions. It is even technically possible to use reclaimed water as a direct drinking water source, although acceptability of the public may not be achievable yet.
The first priority to consider, with regards to the benefit and the public acceptance, is the recharge of surface and groundwater bodies. This form of indirect reuse is a common practice : artificial recharge of groundwater for saline ingress control, or potable resource enhancement, such as in Flanders. Potable substitution is the second priority for any non potable application such as :

- reclaimed water for industry (for cooling water make up, process water to reduce manufacturing costs
- agricultural and urban irrigation, to increase productivity and increase the value of amenities such as parks, sports fields, golf courses as well as domestic gardens on new developments, and finally agriculture itself.

B.1.1.6.2 - Public health and environment protection

The protection of public health is the key issue associated to water reuse. In addition to public health risks, insufficiently treated effluent may have detrimental effects on the ability to grow irrigated crops. The main risk associated to reuse in irrigation is a short-term hazard associated to the presence of pathogens in the water. The World Health Organisation (WHO) has set guidelines for water reuse in irrigation, mainly based on fecal coliforms and helminth eggs counts, with quota adapted to the use for crops.
In Europe, a few member states (where reuse is necessary for irrigation, like in Spain, Belgium, Italy and France) had to overcome the absence of european guidelines or regulation by creating their own national regulation. These standards are based on the WHO guidelines and necessary conservative assumptions, the later leaving room for extremely severe requirements. It is worth noting that, in contrast with some other standards such as the Californian Title 22, member states standards for reused water are not based on technology.
For direct or indirect drinking water supply, the Directive 98/83 is applied with very strict standards for pathogens and chemical contaminants, therefore offering a high level of public health protection. There is however some concern that the current standards and guidelines were not designed to deal with the mixture and individual contaminants that are unique to wastewater sources and water catchments recharged with treated wastewater. Endocrine disruptors, pharmaceuticals,

disinfection byproducts and pathogenic bacteria, viruses and parasites, and genetically engineered products might be present at levels relevant to public health.
Hence, beyond the strict legal requirements for compliance with maxima designed for various types of uses, there is a shift towards water safety plans which are based on a risk assessment of the entire water cycle from source to final user. This incorporates a thorough analysis of the raw water quality parameters and protection measures, the individual treatment steps, their capability to remove the targeted pollutants, and the distribution system up to the point of use. This methodology uses the Hazard Analysis and Critical Control Points (HACCP) approach where the multiple barriers appear as the preferred approach to minimize risks to an acceptable level, in addition to the complementary water quality control.
The opportunities for water reuse should also avoid or minimize environmental impacts to biological, hydrogeological and cultural resources, and to land use due to the construction or operation of reuse facilities.

B.1.1.6.3 - Technologies

All types of technologies are used to reclaim wastewater, depending on the initial pollutant type and concentration, and treated water quality to be achieved. Stringent control of water quality and operational reliability are the main requirements which drive the technological choices. The most well-known example of reuse in Europe is the supply of drinking water through bank filtration, where the local geology (soil aquifer treatment) and land protection regimes authorize the use of surface water situated downstream of wastewater treatment plants. In such cases, the natural processes taking place in the bank safely remove the pollutants and pathogens. Whenever needed, these natural processes may be complemented by filtration on granular activated carbon for pesticides and ozonation for micro-pollutants removal.
One third of the water reclamation schemes relies on secondary treatment of municipal sewage. This level of treatment usually fulfils the requirement of cooling water in the industry, or irrigation water where the food crops are consumed after cooking. One has to mention the possibility offered by membrane bioreactors, which can replace the secondary treatment, while enabling to meet disinfection requirements. Other advanced treatment may replace traditional secondary treatment for reuse purposes.
More often, some kind of tertiary treatment is required to meet the industry or irrigation standards, especially in the later case where disinfection is needed. Disinfection may be achieved by oxidation with chlorine, ozone, or more recently ultraviolet irradiation. Granular activated carbon is used where micro-pollutants are likely to be present.
The last case involves a quaternary treatment with membranes. The most common processes involve either microfiltration (pore size of 0,1 µm) or ultrafiltation (pore size of 0,01 µm), which also removes viruses. These treatments are the favourite technologies on sewage for the removal of suspended solids, particles, bacteria and parasites. In addition, nanofiltration (pore size of 0,001 µm) or reverse osmose membranes (pore size of 0,0001 µm) are used when soluble materials such as salts or dissolved organic matter have to be removed, in order to achieve drinking water quality or ultra pure water quality for industry.
A combination or hybridization of different centralized or decentralized technical solutions is needed to reach the specific objectives when considering the local water cycle. The issue is not the availability of technology but the vision, experience and institutional infrastructure needed to recognize and implement reuse solutions. These needs to build on the synergy between natural and technological solutions that protect public health and the environment, reduce costs and energy demand to treat and transport water.
In the interest of managing both known and unknown risks, advanced water treatment processes are increasingly being deployed in recycled water projects to provide added assurance that unknown risks are mitigated.

B.1.1.6.4 - Water reuse benefits

Water reuse benefits all segments of the anthropogenic water cycle and should be considered as an horizontal application that pulls together the normally segregated disciplines of potable water and wastewater treatment for economic development, public health and environmental protection. Water reuse reduces the competition for water between agriculture, public and industrial supplies by increasing the available water resource and can be used as an effective cohesion tool across Europe. Water reuse benefits are :
1 - Decrease of net water demand and value addition to water
2 - Potable substitution : keep potable water for drinking and reclaimed water for non potable use
3 - Lower energy costs compared to deep groundwater, importation or desalinization
4 - Reduction of manufacturing industries costs by using high quality reclaimed water
5 - Valuable and drought proof alternative water for industry and irrigation
6 - Reduction of nutrient removal costs to protect the surface waters through irrigation
7 - Reduction of nutrient discharge to the environment and loss of freshwater to the sea
8 - Increase of land value when developing brown field sites and with drought proof irrigation
9 - Increase of local ecological benefits, flood protection and tourism through the creation of wetlands, urban irrigation, bathing beach protection and reduction of the need and cost of long sea outfalls
10 - Control of the problems of over-abstraction of surface and groundwater
11 - Management of the recharge of surface and groundwaters to optimize quality and quantity
12 - Integration of all parts of the anthropogenic water cycle to enable cohesion between all regulators and industries across Europe.

B.1.1.6.5 - Enabling the growth of water recycling and reuse

It is essential that the development of water recycling and reuse in agriculture and other sectors be based on scientific evidence of effects on environment and public health. The EU needs a regulatory and institutional framework tailored to suit local needs to take advantage of the water recycling and reuse opportunities, and to help overcome the water shortage problems regarding cost-effectiveness. It appears necessary to provide a comprehensive guidance document to ensure that any risk is minimized and that valuable knowledge is available for any organisation considering the implementation of a water reuse project.
In line with the Water Framework Directive 2000/60/EC, the civil society and the stakeholders must be involved so that they understand and fully contribute to the decisions. The consultation required by directive 2000/60/EC creates a momentum for a better understanding of water cycle, upon which local projects should be built. For any project, the safety of the product and the systems has to be proven, and the solutions must be justified and sustainable from environmental, economic and social points of view. This can be achieved by the publication of clear and accurate documents on the anthropogenic water cycle to overcome the lack of understanding of drinking water, wastewater, water resource planners, environmental fraternities, politicians and the public.
The promotion of water reuse would benefit from clear guidance and best practice documents from the European Union authorities (Durham et al., 2005).
DG Environment of the European Commission recognizes that wastewater reuse has a potential role to play in the efficient and integrated use of water resources and is one of the actions that has to be undertaken for a more effective water management. A preliminary discussion on this issue took place at the EU Water Directors' meeting in Luxembourg (June 2005).
Several research projects[2] (UKWIR, 2004) provide the initial material for such a work, and workshops[3] have already been organized in Europe on the various aspects earlier described in this

[2] In particular: AQUAREC, CORETECH, MEDWATER

document. In the drafting of the guidelines, several points need to be precisely addressed. Beyond an accurate description of the anthropogenic water cycle, the benefits and risks of water reuse for different purposes need to be clearly explained. Moreover, the guidelines should provide a framework for new projects implementation, since local authorities and stakeholders normally do not have the experience to handle the various tasks involved. Consideration should also be given as to some new legal requirements or financial incentives to allow Water Districts to encourage or favour water reuse projects.

In addition to the appreciable amount of experience gained in Europe, the realizations and institutional set-up in other water stressed regions of the world such as the USA, Australia and Singapore, could provide some useful complementary concepts. As an example in Australia, an achievable target of 20 % reuse of wastewater by 2012 has been set in some territories to highlight the importance of reuse and focus regional strategies (Durham et al., 2005).

Finally, water scarcity solutions need to include economically justifiable water saving and demand management techniques rather than immediately searching for new water resources. Water reuse is one of a large number of alternative solutions but is important when considering the objectives of the Water Framework Directive as water reuse is proven to increase water availability and reduces surface water eutrophication. Agenda 21 and the widely agreed need to recycle waste materials are dynamically being promoted and implemented across Europe. It can be argued that water recycling has a higher impact on european sustainability than paper, glass and metals recycling and Europe does not have guidelines yet to help innovators to sustainably recycle water.

See example of Cyprus and Sogesid case study (the reuse of treated urban wastewater : case studies in southern Italy), Appendix 3.

B.1.2 - Economic approaches

Demand-side management efficiency is rather due to economic actions (research financement, subsidies for efficient products, regulatory price controls, price incentives) and legal obligation than to public awareness actions. Economic actions are often the result of public intervention in the sector and public intervention policy depends on the sector and the country. Thus, the mode of intervention, direct incentives (taxes) or indirect incentives (fiscality), must be adapted.

Economic actions are often a way of promoting one technology more than another. Distorsion in prices, taxes or subsidies leads to competitive advantage of a service or a product to the detriment of another one. The consequences for non beneficiary companies have to be foreseen. These incentives can be proposed not only for alternative technologies but, as well, for programs that could be developed by non beneficiary companies to reduce their clients' consumption, for process evolution or for activity diversification of these same companies. Attention must be paid on the choice of the technology that receives economic help because the cost of a technology is often difficult to estimate and some technologies are already helped through undirect incentives.

B.1.2.1 - Impact of agricultural policies

The increased water demand in agriculture has been stimulated by numerous causes, including farmers' response to market demands or in certain cases agricultural subsidies - often under the CAP frame - that support certain production.

The EU and National agricultural policies orientate water consumption in several ways :

- by differentiating subsidies for irrigated and non-irrigated crops
- by investing into irrigation systems through rural development funds
- by paying export subsidies, often used as means to deal with European over-production, and often in sectors in which volumes of production are directly linked to irrigation (e.g. tomatoes)

[3] By UKWIR, EUREAU, AEAS Spain among others.

There have been CAP reforms in the past few years, and these have -in part- diminished the direct link between subsidies and volume of production (and therefore irrigation). The direct payments for arable areas are now fully decoupled except for only two member states (France and Spain), which have decided to keep these payments coupled at the level of 25 % allowed by the Community framework. Indeed majority of MS didn't follow fully the Commission's ideas on de-coupling.
In order to reduce the effects of droughts and water scarcity, measures to promote adapted agricultural production such as low water requiring crops (WFD appendix VI) are needed. Furthermore, and in order to minimise drought impacts on water bodies, the cross-compliance review in 2007 must include WFD standards as a baseline for cross-compliance.
Furthermore, some of the water-demanding agricultures still have to be reformed within the framework of CAP, including the wine and horticultural sector. Reform proposals will be tabled in due course. Although there are no direct subsidies in the Fruits & Vegetables sector, there are payments to help producer organisations operate and also to place products on the market, as well as export subsidies (but there are many other measures possible, e.g. similar to agri-environment).
The planned reforms should take into account the effects of the agricultural subsidies on water consumption, especially in water-stressed areas. Here again the issue of respect of water (abstraction) standards comes in.

B.1.2.2 - Examples of pricing methods for irrigation in different countries

Irrigation has a different purpose in different geographic and climatic areas of Europe. In southern European countries, irrigation is necessary to secure crop growth each year, whereas, in central and western Europe, it is used to maintain production during dry summers. These different roles are important when analyzing water pricing policies in the agricultural sector because these policies are often derived from more general policies (economic and social development in rural areas). This difference is also important when comparing agricultural pricing policies between countries or regions (see Table A, Appendix 3).
The situation regarding water tariffs for irrigation is often very different from other sectors :
• irrigation tariffs can be extremely low and there is significant lobbying pressure to resist any increase
• water use in the sector has been subsidized in most of the countries (subsidies as a tool for developing irrigation for food production and/or social development)
• tariffs can be based on forfeits
• meters may not be installed on many abstractions or uses
• public pressure concerning the environmental image of agriculture is much less than for industry for example

Most agricultural water prices distinguish between charges for water resources and charges to cover part or all of the cost of water supply for irrigation. The aim of the former component is to ration water use (especially if it is scarce), while that of the latter is to guarantee that the supply system is financially self-sufficient. Nevertheless, it is only in the regions where water is scarce, and as a consequence is a tradable good, that water prices tend to reflect their scarcity values, as distinct from supply cost (OECD, 1999). The cost of irrigation water supply consists of the variable costs of processing and delivering the water to end-users and of the fixed cost of capital depreciation, operation and maintenance. Variable costs depend on the amount of water delivered, while fixed costs do not. In most countries, fixed costs are heavily subsidized (UN, 1980).
The method by which irrigation water is delivered affects the variable cost, as well as the irrigation technology applied and the feasible pricing schemes. The irrigation water in a region is often delivered by more than one method, depending on tradition, physical conditions, water facilities and institutions (UN, 1980). The most common pricing methods for irrigation are described in Table B

(Appendix 3). The most common system for irrigation charges is based on the irrigated surface, followed by a combination of per unit area and volume used.
The adoption of more efficient irrigation technologies is accelerated by higher water charges but also other factors such as land quality, well depths, and agricultural prices, are just as important, if not more so, than the price effect of water itself.
Subsidies for the rehabilitation of irrigation districts and for new irrigation technologies might end up increasing farm water consumption. Although water productivity could increase, total water consumption at the level of the basin might also increase, unless allocations are simultaneously revised downwards.

Examples of pricing methods for irrigation
Cyprus: *Water for irrigation purposes is supplied through government and non-government schemes. Irrigation water in government schemes is delivered directly to individual farmers (retail supplies) and in isolated cases is also provided on a bulk basis to irrigation divisions. Non – government schemes consist of small irrigation schemes, which are managed by committees chaired by the District Officer. For irrigation provision through the government schemes, charges are established on a volumetric basis and are uniform for all schemes covering a high proportion of the total financial cost.*
England and Wales: *Multi-rate volumetric pricing is common. Water authorities greatly vary in the complexity of their charging systems. For example, in 1984/85, the Wessex Water Authority had 9 different rates and the Yorkshire Water Authority 45 rates (OECD, 1987).*
France: *Irrigation water is commonly priced by a two-part tariff method, which consists of a combination of a volumetric and a flat rate. In 1970, the Société du Canal de Provence et d'Aménagement de la Région Provencale, which supplies 60000 ha of farmland and nearly 120 communes, introduced a pricing scheme in which rates vary between peak demand and off-peak periods. The peak period rate is set to cover long-run capital and operating costs. The off-peak rate is set to cover only the operating costs of water delivery. About 50 % of total supply costs (variable and fixed) are subsidized by the State (OECD, 1987).*
Greece: *Per area charges are common. The proceeds usually cover only the administrative costs of the irrigation network. The irrigation projects are categorized as of basic, local and private importance and the project areas are also classified as areas of national, public or private interest. The proportions of the capital costs of an irrigation project paid by farmers are 30, 50, and 40 % for projects classified as of national, public and private interest, respectively (Gole et al., 1977).*
Spain: *The water charges are established per agricultural area and not per volume consumed. This means that the user pays the same amount despite the amount of water used and there is no real incentive for saving water (MMA, 1998).*

In general, the amount of water used for irrigation moderately responds to water price levels but is more influenced by factors such as climate variations, agricultural policies, product prices or structural factors. Cross-sectional studies of irrigation districts, at both national and international levels, have found conflicting evidence of the influence of water price levels on water management efficiencies (OECD, 1999).

B.1.2.3 - Economic incentives/fines

Essential elements of water demand management programmes in the urban context are measures dealing with economic incentives. Price structures are generally fixed at municipal level and can widely vary within a country. The differences, in general, take into account different types of users (e.g. domestic, industrial and agricultural) and tend to reflect differences in cost structures.
There is a huge variety in the types of metered tariff which can be used (Pezzey and Mill, 1998).
The main types of tariff structure (excluding the initial connexion charge) are :
• flat-rate tariff

• uniform volumetric tariff
• two-part or binomial tariff (sum of a flat-rate tariff and a uniform volumetric tariff)
• block tariffs, which also usually incorporate a flat-rate charge, plus declining block tariffs and rising block tariffs

Frequently, tariffs include a basic allowance (charged at zero or a low rate) to allow equity concerns. A minimum charge for a volume consumed can also be applied. The same or different tariffs may apply to different types of users. Rates and thresholds may vary over time, according to customer characteristics (property value or income) or location. Two-part, rising block and declining block tariffs are widespread. The two former types are gaining ground due to a general shift of opinion away from consideration of water supply as a public service to its use as a commodity with a correct price. Seasonal tariffs (summer/winter) are uncommon, but are becoming more widespread. Peak tariffs (hourly or daily) have only been tested in experiments.

Tariffs may be designed with several aims, which may in some cases be in conflict:
• efficiency (maximum net benefit for society)
• raising revenue to cover the costs of supply in a fair and equitable way
• reducing environmental costs (abstraction and pollution)
• understandable for customers and applicable for administration purposes

In fact, improving the fairness or efficiency of a tariff often makes it more complex and more difficult to understand.

Economic incentives (water charges and taxes) have mainly been introduced with the aim of generating revenue to partially cover the cost of supplies.

Maximum economic efficiency is attained when the price is set at the level where marginal costs equal marginal benefits. Volumetric pricing is a mechanism through which tariffs can be designed to achieve efficiency and to account for equity (access of the poor) without involving high transaction costs due to monitoring, measuring and collecting water charges. The effectiveness of direct water charges on volumetric basis in changing the users' behavior will mainly depend on the price elasticity of demand. Pricing of water can also reflect the quality of water. The higher the amount used, the higher the price per unit. Users, both residential and agricultural, will adjust their use behavior to the structure of the tariff, and respond by improving their water use practices. One caveat is that in many countries, and especially in the case of irrigation water, the effectiveness of price increase is affected by the difference between the value of unit of water to the user (the shadow price of water) and the actual price charged per unit of water. In many countries, that difference is so big that for any price increase to be effective, it has to be so high, that political considerations may arise that will prohibit it from happening.

Irrigation water can also be priced on the basis of output per area, i.e. irrigators pay a certain water fee for each unit of output they produce. The basic concept is that farmers should pay the charge according to the crop productivity or the value of output, or the marginal value product of water per unit of water used.

Subsidies can be provided either directly to users of water or for a water use technology. The adoption of subsidy measures for promoting efficient water use is often practiced for promoting environmentally friendly technologies, but it is also used to promote water savings, from which society as a whole may benefit. Different types of subsidies such as grants or payments to farmers, budgetary subsidies (e.g. tax credits), provision of extension services, preference loans, debt relief, etc, could be implemented depending on their effectiveness and suitability to a particular country.

Tax incentives are designed to modify behavior by encouraging particular groups or activities, and could be implemented in the form of preferential tax treatment to certain producers or residential consumers through tax credits, exemption or deductions, or through tax benefits provided to investors. Taxes are relevant in the case of negative externalities resulting from water use. For example, the excess pumping of groundwater lowers the water table, increases salinity of the aquifer and creates negative regional externalities. The excess withdrawal of water also results in degradation of ecosystems because the minimum water requirement of the ecosystem is not met due to the lowering of the water table and the reduction of the regional water balance. A tax incentive, equal to the marginal environmental damage cost, could be designed and implemented so that the water charge also addresses these ecological concerns. Indirectly, environmental taxes can also be imposed on the water-related inputs such as energy inputs and chemical fertilizers, which also partly influence the level of water use and the level of externality. Energy usually used in water abstraction is highly subsidized and encourages farmers to use more water at a relatively lower cost of extraction (Tiwari and Dinar A., 2001). Such taxes can be designed so that individuals internalize the externalities by improving water use efficiency and gradually adopt efficiency measures.

B.1.2.4 - Water banks and markets

Water banks or markets are mechanisms to sell or rent water use rights. They exist in the USA, Chile, Canada and Australia. In Europe, water banks are a new concept and the only fully developed experience is the one of the Canary Islands in Spain (Aguilera-Klink et al., 2000). In order to tackle water scarcity problems, the Spanish government is currently implementing "Centers for the Exchange of Water Rights" in the Segura, Júcar and Guadiana river basins and developing legal regulations for water banks.

Water bank regulations have to ensure a difficult balance that stimulates the exchange of water rights and, at the same time, protects the environment and every water user.

Water banks offer several opportunities to tackle drought problems : as water user acquires a "value", current water users save water in order to sell their rights on the unused amount of water. At the same time, new water users (e.g. tourism) in water stressed areas with limited water permit to have a legal way of acquiring water rights and would not illegally abstract it. Water banks can furthermore support the establishment of environmental stream flows in certain river stretches, either by establishing a percentage of sold water for environmental purposes or by acquiring water rights. This measure can directly support the establishment of a good ecological status, as requested by WFD.

However, water banks have some inherent risks:

- Upstream concentration of water rights can reduce stream flows in river stretches.
- Changes in water use can produce higher pollution.
- In water stressed areas, "virtual" water might be sold because legally established water rights might exceed the existing resources.
- If a public water bank does not work adequately, a "black" water market might appear.

For all these reasons, it seems appropriate to introduce water banks in a step-by-step approach, avoiding illegal water sellings and fixing a baseline water price that ensures that resource and environmental costs are taken into account.

B.1.3 - Social approach

B.1.3.1 - Users education and information

Dialogue with users and participation of citizens is essential for an efficient water management, permitting a demand regulation and a better use of amenities. Information and educational campaigns in all sectors are always part of a wider plan to use water more efficiently by encouraging more rational water use and changing habits. For this purpose, public awareness has to be motivated. As a user, the citizen gives financial support (taxes) to mobilize and distribute the resource as well as rectifying quality and quantity variations. Civic pression has to be as constructive as possible, so it is necessary to inform people about roles and means of water managers. Information campaigns as well as promoting water-saving devices, raising prices to pay for leakages, are important initiatives.

In the agricultural sector for instance, farmers must be helped to optimize irrigation by means of training (on irrigation techniques), regular information on climatic conditions, adaptation of the irrigation volume and period according to the type of crop, rainfall level and type of soil.
In the industrial sector, water savings are just part of a wider programme which includes measures to reduce water pollution and implement environmental management systems.
It is difficult to quantify the effect of a public educational campaign because it is always part of a wider water-saving programme which includes other measures.

B.1.3.2 - Institutional aspects : conflict resolution and administrative settings

The administrative setting of river basin authorities is a key factor to adequately implement drought mitigation measures, especially those regarding law enforcement. Two recent NGO reports (WWF, 2003a ; WWF and EEB, 2005) show that administrative setting of competent authorities for water management and implementation of the WFD are still a pending issue in many EU countries.
"Unpopularity" or concern for social consequences of drastic alleviating measures such as the closure of illegal boreholes, make their practical application very rare. This fact does not help respect the corresponding law and also explains why, for example, the Guadalquivir river basin authority (Spain) waited 18 years to start mapping illegal boreholes in the Doñana National Park, finding 100 % of completely or partially illegal water users in the first studies (CHG, 2003).
Lack of incentives to comply with the law is also due to the fact that suiting infringements through administrative and legal procedures takes years and frauds can even expire before the suiting process is completed.
In other cases, the existing legislative text is the result of a long negociation which has weakened and altered the original objective of the law. For instance, the Spanish 1985 Water Act converted water from private to public good, with the objective of improving the manageability of this resource. However, during the negotiation of the legislative text, it was decided to maintain property rights for all those that could prove to be water users before the entrance into force of the act. This has caused a huge administrative overload. 20 years after, the filing of all the application forms for the recognition of private rights is still unfinished. Frauds still exist, for example in the hydrogeological unit 04.04 of the Guadiana river basin, the water volume associated to registered rights currently doubles the unit renewable water resources. It becomes practically impossible for some river basin authorities to manage this public good. In the Alicante province, on the Mediterranean coast, almost 80 % of water rights are private.
A part of these shortcomings is due to a lack of human resources in water administration, both in terms of staff number technical competences needed to deal with increasingly complex legal requirements. Water policy actions should strengthen river basin authorities role and the capacity to enforce the existing law. Moreover, the speeding up of judicial procedures against frauds would help making the river basin authorities' control action more effective than it is for the moment.

B.1.3.3 - Wider user participation

To keep a permanent dialogue, the user must be associated to the decision process and participate at the most upstream level as possible to the different steps of the establishment of fixtures. The adaptation of fittings to the demand is the condition for their acceptance by the public.
The place given to users in water management has been increasing with the passing of years. Water services are developped for users but they have only been beneficiaries of those services for a long time. Their place have gradually been recognized by the mean of organisations such as consultative commissions of local public services where users are represented and can officially share their positions.
A lot of associations have developped in water sector. Many of them deal with environmental protection. They provide information to the public, education, actions in law, environmental

maintenance and management of specific systems. Recently, a new type of (often local) associations is developing in water services management and sanitation (management modes, price of water, etc) in connexion with specialized consumers' associations.
In France, a particular water services management have been developed : delegation of services. A collectivity confide to an enterprise (after competition) the service exploitation and eventually the investments charge. They are linked by a contract. Since the middle of the 19th century, this device have permitted the development of big industrial groups like the Compagnie Générale des Eaux and Lyonnaise des Eaux. Other smaller groups have risen these last years, often at a regional scale. These societies distribute water to 80 % of the subscribers and assure collect and treatment of waste water of 50 % of french subscribers.

B.1.3.4 - Education and awareness campaigns

The financing of educational and sensitisation campaigns must not be considered as a brake for action but as a tool for promotion and profitability of this action. The message has to be adapted to specific publics according to their interests. The size of the operative organism (global or local), the width of the action zone and the level of information determine the accomplishment of the actions vis-à-vis users and beneficiaries of a given project. A big organism will provide information at a large scale about comprehension of the water cycle, the fragility of the resource and the impact of the problems on health and daily life. This kind of information sets general public's sight. A local operator, directly concerned by a specific project in a reduced perimeter of action, will explain the advantage of the project to the users, the correct and efficient utilization and the importance of maintaining this fixture. The users targeted are the direct users and beneficiaries of the installation.
Useful information has to be selected in order to sensitize users and point their behavior toward a better use of water and get their endorsement for the projects they are concerned with. The acting informators must be aware of the needs and demands of the target public (as well as his link with water) and use the field knowledge in order to be more efficient.
Dialogue and participation of the users can be achieved by two means :

- Meetings of different users categories and beneficiaries as well as their representatives
- Moderators visiting users for a more direct and individual contact

B.1.4 - Conclusion : integrated water management approaches on demand side measures

The management of water is very different accross Europe. A range of regional and decentralized policies is existing. The WFD is an important step towards integrated management of water resources at a river basin scale and towards harmonisation of water policies among member states.

B.2 - Supply-side measures

B.2.1 - Natural catchment storage

Water naturally stored in a catchment as lakes, rivers, aquifers and wetlands is globally abundant in Europe with seasonal and regional variability.
Wetlands are usually considered as patches in catchments, isolated from other functional elements. Hydrologically spoken, wetlands are discharge areas with many economic, social, natural, environmental values and services as a source of drinking water, water for irrigation, fishing, wildlife, biodiversity, etc. However, wetlands can behave like recharge areas to aquifers in many parts of the world, generally in arid and semiarid zones. Streambeds in the catchment and floodplains usually recharge aquifers during periods of floods or when high discharges occur. It is especially important in arid and semiarid areas where rainfalls are usually scarce and successions of dry years are unpredictable.

Although the relationship between groundwater and wetlands is very complicated and not well known, it is accepted that aquifers are the best manner to store water in these semiarid regions where evapotranspiration exceeds the rainfalls and water deficit may be significant during many months along the year. Moreover, storage water in aquifers decreases seasonally following the characteristic natural variability of water resources in arid and semiarid regions, not suffering from drought impacts as dams do (website ref 2). Some aspects regarding the role of wetlands in the water cycle at river basin scale are tackled in the CIS Guidance Document N°12 "The role of wetlands in the Water Framework Directive".

Some experiences show us the importance of good management of natural storage water in catchments during drought periods. For example, in Messana Valley in Crete, about 50 % of recharge to the aquifer occur through catchment streambeds. During a wet year, the aquifer can store 19 million m^3 of water. Each year, about 22 million m^3 are withdrawn to irrigate olive trees and vines. In southeast of Spain, an alluvial aquifer (Sinclinal de Calasparra) is used during drought periods to supply drinking water to 76 Segura river basin villages. Sebkhet Kelbia, located in central Tunisia, is a big flood-plain wetlands of 1 300 ha and one of the 16 Natural Reserves of Tunisia, designated for strict nature protection. It receives water from three rivers (Nebhana, Merguellil and Zeroud) that rise in the near mountains (website ref 3). During floods, these rivers recharge alluvial aquifers although outside this period the rivers are dry. Water from aquifer is then used for irrigation (websites ref 4 and 5).

The ecological integrity of wetlands maintenance, especially for those located in arid and semiarid regions, is not a simple technical question, but increases the supply of groundwater that may be essential for many human activities survival during drought years.

B.2.2 - Aquifer recharge

Natural aquifer recharge (from rain or surface water infiltration) is vital in order to maintain the groundwater and to replenish the discharges from the aquifer with a good quality water resource, but in many cases is quite impossible to grant a sustainable groundwater level only considering natural recharge.

In many areas of the world, aquifers that supply drinking-water are being used faster than they recharge. Not only does this represent a water supply problem, it may also have serious health implications. Moreover, in coastal areas, aquifers containing potable water can become contaminated with saline water if water is withdrawn faster than it can naturally be replaced. The increasing salinity makes the water unfit for drinking and often also renders it unfit for irrigation.

To remedy these problems, some authorities have chosen to recharge aquifers artificially with treated wastewater, using either infiltration or injection. Aquifers may also be passively recharged (intentionally or unintentionally) by septic tanks, wastewater applied to irrigation and other means.

Artificial recharge is the planned, human activity of augmenting the amount of groundwater available through works designed to increase the natural replenishment or percolation of surface waters into the groundwater aquifers, resulting in a corresponding increase in the amount of groundwater available for abstraction. Before deciding on aquifer recharge as a measure to solve water scarcity problems, an analysis needs to be undertaken if and how it affects other water bodies, such as surface, transitional or coastal waters. Aquifer recharge cannot be made independently from an understanding of the whole water cycle. Furthermore, previous to aquifer recharge, it is necessary to identify the water services that benefit from this measure and how and in which proportion they would be required to recover the costs of the measure. In this sense, artificial aquifer recharge must be considered as part of a wider approach to water resource management which addresses demand and quality issues as well as supply aspects. Although the primary objective of this technology is to preserve or enhance groundwater resources, artificial recharge has been used for many other beneficial purposes. Some of these purposes include conservation or disposal of floodwaters, control of saltwater intrusion, storage of water to reduce pumping and piping costs, temporary regulation of groundwater abstraction, and water quality improvement by removal of suspended solids by filtration through the ground or by dilution by mixing with naturally-occurring groundwaters (Asano, 1985). Artificial recharge also has application in wastewater disposal, waste treatment, secondary oil recovery, prevention of land subsidence, storage of freshwater within saline aquifers, crop development, and streamflow augmentation (Oaksford, 1985).

Aquifer recharge with treated wastewater is likely to increase in future because it can :

- restore depleted groundwater levels
- provide a barrier to saline intrusion in coastal zones
- facilitate water storage during times of high water availability.

If aquifer recharge is haphazard or poorly planned, chemical or microbial contaminants in the water could harm the health of consumers, particularly when reclaimed water is being used. Wastewater may contain numerous contaminants (many of them poorly characterized) that could have health implications if introduced to drinking-water sources. Ensuring that the use of treated wastewater for aquifer recharge does not result in adverse health effects, a systematic science-based approach is needed, designed around critical control points, as used in the hazard analysis critical control point (HACCP) approach. Such an approach to potable aquifer recharge requires a thorough evaluation of the best practices that will protect public health, and consideration of environmental and sociocultural concerns.

A variety of methods have been developed and applied to artificially recharge groundwater reservoirs in various parts of the world. The methods may be generally classified in the following four categories (Oaksford, 1985) :

- Direct Surface Recharge Technique (Asano, 1985).
- Direct Subsurface Recharge Technique.
- Combination surface-subsurface methods, including subsurface drainage (collectors with wells), basins with pits, shafts, and wells.
- Indirect Recharge Techniques.

Direct surface recharge techniques are among the simplest and most widely applied methods. In this method, water moves from the land surface to the aquifer by means of percolation through the soil. Most of the existing large scale artificial recharge schemes in western countries make use of this technique which typically employs infiltration basins to enhance the natural percolation of water into the subsurface. Field studies of spreading techniques have shown that, of the many factors governing the amount of water that will enter the aquifer, the area of recharge and length of time that water is in contact with soil are the most important (Todd, 1980). In general, these methods have relatively low construction costs and are easy to operate and maintain. Direct subsurface recharge techniques convey water directly into an aquifer. In all the methods of subsurface recharge, the quality of the recharged water is of primary concern. Recharged water enters the aquifer without the filtration and oxidation that occurs when water percolates naturally through the unsaturated zone.

Direct subsurface recharge methods access deeper aquifers and require less land than the direct surface recharge methods, but are more expensive to construct and maintain. Recharge wells, commonly called injection wells, are generally used to replenish groundwater when aquifers are deep and separated from the land surface by materials of low permeability. All the subsurface methods are susceptible to clogging by suspended solids, biological activity or chemical impurities.

Combinations of several direct surface and subsurface techniques can be used in conjunction with one another to meet specific recharge needs.

Indirect methods of artificial recharge include the installation of groundwater pumping facilities or infiltration galleries near hydraulically-connected surface waterbodies (such as streams or lakes) to lower groundwater levels and induce infiltration elsewhere in the drainage basin, and modification of aquifers or construction of new aquifers to enhance or create groundwater reserves. The effectiveness of the former, induced recharge method depends upon the number and proximity of

surface waterbodies, the hydraulic conductivity (or transmissivity) of the aquifer, the area and permeability of the streambed or lake bottom, and the hydraulic gradient created by pumping. Using the latter technique, aquifers can be modified by structures that impede groundwater outflow or that create additional storage capacity. Indirect methods generally provide less control over the quantity and quality of the water than do the direct methods.
For example, Managed Aquifer Recharge (MAR) is a method of adding a water source such as recycled water to underground aquifers under controlled conditions using infiltration galleries. Treated effluent flows via an inflow pipe, then flows down through a chamber into covered galleries (engineered trenches that facilitate the infiltration of water into the ground and consisting of parallel slotted pipes containing either gravel or open plastic structures). The top and sides of the galleries are covered in geotextile material to prevent topsoil from entering the galleries, while the base is open to the *in situ* soil. The trenches are about 10 metres above the water table to allow water quality improvements to occur in the *in situ* soil before recharging the aquifer. As the treated water infiltrates the soil natural biological, chemical and physical processes occur to remove pathogens, chemicals and nutrients from the water. This “filtering” process continues whilst the water infiltrates and resides in the aquifer. The following water quality improvements occur during the process : removal of nutrients such as phosphates and organics, degradation of chemicals such as disinfection by-products, pathogen die-off. This significantly reduces the health and environmental risks that may be associated with secondary treated wastewater, leaving the reclaimed water in similar quality to that of the surrounding groundwater. This method costs less to treat and use reclaimed water using MAR than desalination ; however should high quality water be required the reclaimed water may still need to be desalinated. As there is much less salt in reclaimed water than seawater, significantly less energy is required to desalinate reclaimed water. (websites ref 6 to 8)

B.2.3 - Dams

Reservoirs play an important role in public water supply, irrigation and industrial uses. The construction of dams, however, can have serious implications for the functioning of freshwater ecosystems in a river basin and ultimately impact livelihoods.
Dams disconnect rivers from their floodplains and wetlands and reduce river flows. They act on the migratory patterns of fish and flood riparian habitats, such as waterfalls, rapids, riverbanks and wetlands, which are essential feeding and breeding areas for many aquatic and terrestrial species. Dams also disrupt the ecosystem services provided by rivers and wetlands, such as water purification. By slowing the movement of water, dams prevent from natural downstream movement of sediments to deltas, estuaries, flooded forests, wetlands, and inland seas, affecting species composition and productivity.
The World Commission on Dams found that the technical and economic performance of many water supply dams, both irrigation and bulk water supply, have failed to reach the intended targets. The survey showed that, except 29 dams with a water supply component (excluding irrigation), 70 % of dams did not reach their targets over time, and a quarter of dams delivered less than 50 % of the target. Equally, irrigation components of large dams studied by the WCD fell short on targets, including the areas irrigated. However, dams with heights inferior to 30 m and reservoirs of less than 10 km^2 tended to be closer to predicted targets (World Commission on Dams, 2000).
When considering dams as a structural solution to water scarcity, the decision making process must be realistic about the dam technical and economic performance, as well as about the environmental and economic cost associated to the disturbance and loss of ecosystems and the services they provide.
The construction of new water supply dams and the management of existing dams in Europe are subject to EU legislation, especially WFD, which aims to ensure the environmental quality of water bodies. The directive applies to all surface waters (rivers, lakes and coastal waters) and groundwater in a river basin. Its objective is to achieve at least a “good ecological and chemical status” of all

waters by 2015, as well as preventing from the deterioration of current status. Volume of water flow is included in the definition of ecological status. This is of particular relevance to dams which tend to interrupt streamflow. This has implications on new dams construction, which inevitably modify water bodies status. According to article 4 (7) derogation provision, WFD allows the development of new water infrastructure, even if it prevents from reaching good status. However, this provision comes with a number of strict conditions, including :

- conditions for mitigation measures
- proof that there are no better alternative options in environmental terms
- condition that the project is either of "overriding public interest" or that the provision of benefits to human health and safety (e.g. flood control) or sustainable development outweight the benefits of achieving the directive environmental objectives. Furthermore, articles 4.8 and 4.9 are mandatory as conditions for these derogations.

WFD implications for existing dams depend on whether or not the water body is classified as heavily modified, fulfilling article 4.3 criteria and respecting those of articles 4.8 and 4.9. In other cases, dam sites may be subject to extensive mitigation measures implementation in order to reach good ecological potential, particularly regarding minimum flow regimes, aquatic fauna migration and sediment management. In addition, the fact that these water bodies also need to reach good chemical status should be taken into account (Barreira, 2004).

B.2.4 - Use of basin-external water resources

B.2.4.1 – Alternative sources

DESALINIZATION

This techic is used when technically and economically feasible. There are more than 7500 desalting plants in operation worldwide producing several billion gallons of water per day. 57 % are in the Middle East and 12 % of the world capacity is produced in the Americas, with most of the plants located in the Caribbean and Florida regions. However, as drought conditions continue and concerns over water availability increase, desalinization projects are being proposed at numerous locations.

A number of technologies have been developed for desalinization which include distillation, reverse osmosis, electrodialysis, and vacuum freezing. Two of these technologies, distillation and reverse osmosis, are being considered by municipalities, water districts and private companies for the development of sea water desalinization (website ref 9).

Desalinization costs are very sensitive to the salinity of the feed water. Desalinization of brackish waters and waters that are mildly saline can be economically justified for some high valued uses. Seawater desalinization remains enormously expensive when all costs are fairly accounted for. There is a tendency to promote seawater conversion projects that are joint with power plants. The resulting costs are almost always understated because the power is subsidized and all of the joint costs are allocated to power production. Seawater conversion is unlikely to be the solution to water problems except in a few instances where there are no alternative sources of supply and there is considerable wealth to defray the costs of seawater desalinization (Vaux H. Jr., 2004).

Water treatment costs vary by the amount of salt removal, cost of energy, size of plant, as well as the type of treatment technology. Desalinization costs are dominated by capital investment, energy and maintenance costs. Reverse osmosis systems, which utilize membrane technology for water treatment, have the lowest cost of operations, especially in areas with high power cost. While membrane technology advances have resulted in significant cost reductions, energy still accounts for up to 60 % of the operating cost. Further improvements in energy efficiency will deliver sustainable reductions in operating cost. Along with improvements in energy efficiency, improvements in membrane performance and membrane life through integrated treatment systems can reduce capital cost and life cycle cost. Membrane-based treatment solutions are essential to create new water sources such as brackish water aquifers, seawater, and even wastewater. Membrane-based desalinization and reuse is a proven solution, but a broader application of these technologies to create meaningful new water sources requires investment to further reduce the energy consumption associated to the operation of membrane systems. The long-term, sustainable solution to produce economical sources of new water lies in developing more advanced, energy-efficient technologies to treat multiple water sources. As a practical matter, substantial incremental funding for research and development would significantly accelerate the development of economical sources of new water (website ref 10).

RAIN WATER HARVESTING

To help meet water demand, rainwater harvesting and grey water practices are commonly used in several European countries. Traditional regulatory practices prohibiting rainwater harvesting or grey water reuse as substitutes for potable water supply are changing. Applications of these practices are supported by commercially available technologies. Where these practices and technologies are encouraged by regulations, they are increasingly being used. The incentive may be a lack of alternative water supply, or where available water is not an issue, the cost of publicly supplied water may be encouraging acceptance (website ref 11).

Rainwater harvesting involves the use of captured rainwater, usually from a roof catchment, which otherwise would have soaked into the ground, evaporated or entered the drainage system. Once captured, the water can be drawn on for a variety of uses from irrigating crops or gardens, as toilet flush water, in water features and occasionally as a source of drinking water. Watering a garden with rainwater collected in a water butt is a rudimentary form of rainwater harvesting.

Where there is negligible potential human contact, the rainwater will usually only require coarse filtration to prevent leaf litter, debris and small animals entering the system. If the rainwater is to provide a potable water supply, thorough treatment is required, which makes this use uncommon.

During rainfall events, the first flush of water usually has the lowest water quality due to contamination from leaf litter, bird droppings and wind-blown pollutants that have adhered to the roof surface or guttering. For this reason, many rainwater harvesting systems divert the first flush of water so that it is not used.

The amount of rainwater that can be harvested is a function of the rainfall received and plan roof area. For example, in Northern Ireland, where 2004 annual rainfalls were just over 1000 mm/year, a home with a $100m^2$ plan roof area could harvest 60 m^3 of rainwater, assuming that 60 % of rain that falls on a roof catchment is collected and used.

Legislation in France permits the use of rainwater for certain purposes and under certain conditions. Untreated, the water can only be used for external utilisations such as irrigation and automobile washing, or where there is suitable plumbing construction preventing cross-contamination or cross-connexions, it can be used inside homes for toilet flushing. A number of experimental buildings that incorporate rainwater harvesting systems have been constructed in France. Studies have unequivocally demonstrated that such systems can be designed, constructed and implemented with due regard to public and environmental health. It is claimed that an average residential rainwater harvesting system can be fully amortized in less than three years.

National legislation in Belgium requires all new constructions to have rainwater harvesting systems for the purposes of flushing toilets and external water uses. The aim of this legislation is twofold : 1) to reduce demand for treated water and the expansion of the water supply infrastructure ; and 2) to collect and use rainwater instead of surcharging stormwater management systems.

DOMESTIC GREY WATER REUSE

Conventional toilet flush water is supplied water unnecessarily treated to drinking water quality standard, an expensive and energy intensive process. Greywater recycling is an innovative alternative whereby treated greywater is principally used for toilet flushing but also for gardens watering. Greywater is wastewater from showers, baths, wash basins, washing machines and kitchen sinks although for recycling purposes kitchen sink and washing machine water is normally excluded because it is too greasy and/or contains too many detergents to allow cost effective treatment (website ref 12).

Unlike rainwater, greywater requires filtration to remove hair, skin and soap products from the water and chemical or biological treatment prior to reuse. The potential level of human contact with the water in its end use will determine what level of treatment is required. For example, greywater used for hosing down vehicles will require a high water quality because the risk of human contact with the water is greater in highly pressurized systems. Similarly, black water (toilet effluent diluted by flushing water) is not recycled because of the even higher level of treatment needed before it is safe for human contact. Public acceptance is also a major barrier here.

Perhaps the two biggest barriers to widespread uptake of greywater recycling are public concern about the risk to health and system maintenance requirements. The health concerns are twofold : firstly the health risk from contact with greywater in the normal operation of the system and secondly the health risk posed by the breakdown or ineffective operation of the treatment system. Greywater recycling systems are designed for minimal user contact with the greywater. Aerosols from toilet flushing are the only potential contact most users will have with the water and this is unlikely to have health implications if the water has been properly treated. It can be minimized even further by closing the toilet lid prior to flushing.

There is a health risk however where treatment systems have broken down or not been maintained correctly so that untreated water (which may have been stored for long periods) comes into contact with users. Where untreated greywater has a long residence time in the system, the risk is greater. If there are pathogens such as enteric viruses, giardia, cryptosporidium, salmonella and campylobacter present in the wastewater from affected individuals, lengthy periods of poor storage could result in the water turning septic and posing a health risk. The untreated greywater awaiting treatment should instead be stored in a dark, cool container and continually stirred to prevent anaerobic conditions. Despite these risks, there are numerous safeguards which together diminish the health risks almost completely :

- Ultraviolet, chemical and/or biological disinfection
- Periodic inspection and cleaning of the system to ensure the water is being adequately disinfected
- Clear identification of pipework as carrying greywater and incompatibility with main pipework
- Pale colouring added to the recycled water to differentiate it from potable water
- User training covering how the system works and good practice to adopt to minimise potential risks
- A manual “divert” option whereby excessively contaminated water does not have to enter the recycling system
- Multi-occupancy buildings are likely to have greater water circulation ensuring the greywater used is fresh rather than having had a long storage residence time in the system.

USE OF ALTERNATIVE WATER RESOURCES IN INDUSTRIAL CYCLE

Industry is one of the largest consumers of water. Water is used for processes as diverse as mixing, cooling, boiler feed and plant wash-down as well as for washrooms and other sanitary uses.

Unlike most residential properties, industry and business in the UK are subject to compulsory metering. With the cost of mains water, sewerage and trade effluent rising, businesses are increasingly conscious of the substantial water, and therefore cost, savings that water reuse and water conservation can achieve. For example the five finalists in the Industry category of the 2005 Water Efficiency Awards were able to cut water consumption by between 25 and 98 % by adopting a combination of water reuse and conservation strategies. Enhanced Capital Allowances, a UK Government initiative, promotes this sustainable solution and provides tax incentives for water saving and rainwater devices and water reuse with membranes as well from September 2005 (website ref 13). In addition to these water cost savings other potential benefits to industry include (website ref 14) :

- avoiding water restrictions imposed during periods of drought
- reduced energy and chemical costs through recycling
- removing the need for discharge consents
- good publicity opportunity
- improved company image and reputation amongst the public, customers and own workforce
- helping to achieve certified environmental accreditation (e.g. ISO 14001)
- fulfilling corporate social responsibility commitments

SUSTAINABLE DRAINAGE SYSTEMS

Sustainable Drainage Systems (SUDS) is an approach to drainage which seeks to decrease the amount of surface runoff, decrease the velocity of surface runoff, or divert it for other useful purposes, thereby reducing the contribution it makes to sewer discharge and flooding.

As well as controlling the quantity of runoff, SUDS can also improve the quality of runoff, preventing pollutants from entering the drainage system. SUDS will also “green” the urban environment and should provide landscape, amenity and biodiversity benefits too.

Techniques that come under the SUDS umbrella vary enormously but usually involve some of the following components :

- Permeable and porous surfaces to reduce surface runoff
- Ponds/basins for temporary storage during high magnitude rainfall events (detention basins) or longer term storage (retention basins)
- Pipework and channeling to divert water from undesirable locations
- Structures that increase the lag between a rainfall event and discharge of water to the drainage system by increasing infiltration.

The SUDS approach is particularly valuable in urban areas where high density development and impermeable surfaces mean surface runoff can easily cause flooding, either directly or indirectly through sewer flooding (website ref 15).

DIRECT AND INDIRECT POTABLE REUSE

Direct potable reuse (i.e. treated wastewater directly reused for drinking water) is very rare because of the increased potential risk to public health and the negative public perception. Even though the technology is well proven, direct potable reuse is only justifiable when there is no other option for example in the desert or outer space. Currently, the only place where direct potable reuse takes place on a municipal scale is in Windhoek, Namibia where treated wastewater combined with surface runoff is treated to provide potable water. Direct reuse is common practice for non potable applications in industry and irrigation.

Indirect potable reuse can be planned or unplanned. Conventional water treatment in many countries involves unplanned indirect potable reuse of treated wastewater. Water abstracted from rivers to provide drinking water includes treated wastewater that has been discharged upstream. It is unplanned in the sense that it is not an intentional part of the wastewater discharge policy that the water will be reused downstream for potable water supply. The abstracted water will still need to meet potable water standards if it is to supply drinking water. River water may go through several abstraction/treatment/use/treatment/discharge cycles before reaching the sea. The pursuit of economies of scale has led to a tendency for large down-catchment wastewater treatment plants. Planned use by relocating treatment and shortening the use/reuse cycle could increase water availability for both environmental and other purposes.

The reason why indirect water reuse is not considered to pose a health risk is that the treated wastewater benefits from natural treatment from storage in surface water and aquifers and is diluted with “ordinary” river/ground water before abstraction to ensure good drinking water quality (part of a multi-barrier approach in the water safety plan). The storage time provides a valuable buffer to measure and control quality. Direct potable reuse, however, is almost a closed loop system with limited storage and a shorter buffer time therefore increasing the risk (website ref 16).

USE OF ALTERNATIVE WATER RESOURCES FOR IRRIGATION

Irrigation is the artificial application of water to the ground surface in addition to what falls naturally as rainfall. Unlike energy production that gives back the majority of the removed water to the environment, irrigation consumes half the water deducted from the environment because of absorption and evapotranspiration (website ref 17).

Since the mid-1990's, irrigation has consistently been the largest use for freshwater globally. In France, a 66 % increase of the irrigated surface has been observed between 1988 and 1997. The use of recycled water for irrigation is widespread because water quality standards are less stringent where water is not for potable use or direct human contact. Irrigating land uses extensive amounts of water so there may be cost savings associated to using recycled water too. The two main irrigated environments are agricultural land (horticulture, crop production and grazing pasture for livestock) and amenity/recreation areas (e.g. golf courses, public parks, and commercial landscaped gardens). The quality of water required for irrigation of agricultural land will depend on the crop type and whether the crop is eaten raw or cooked (website ref 18).

B.2.4.2 - Increasing availability of water resources

The creation of new resources is rarely a sustainable solution for environmental management, considering the heavy cost and the impact on natural systems. But the creation of a new resource, when ecologically feasible and within rational economic conditions, is conceivable, when the imbalance is so great that other imaginable management measures seem to be insufficient. But this approach mustn't become an escape ahead. For that reason, withdrawals have to be stabilized in order to keep the advantage of the resource creation in terms of restoration, because an increase can contribute to the imbalance. For this purpose, collective commitments for withdrawals limitation have to be made, leading to results with the height of the stakes, by the mean of existing collective structures or creating organisms that gather the concerned irrigants when they do not exist.

Nevertheless and generally, the cost in capital of collective infrastructures for storage and transfer is not affordable for the majority of the irrigants. These collective infrastructures have mostly been funded par public collectivities within development planning general policy. The Water Framework Directive compels to take into account the cost recovery from beneficiaries.

Therefore, it seems important for new resources projects to be preliminary analyzed macroeconomically, so all merchant and non-merchant users can think in terms of cost/advantages and notably taking into account the perspectives evolution of water demand in agricultural sector.

In the strong imbalance zones, a solution can be seen in the creation of small water dammings of substitution of which the filling is made during winter with little impact on natural systems and under the same conditions as cited before. In France for instance, the development of irrigation since the 60's has led to a correlative development of this kind of dammings at a superior rate than the constitution of multi-usage and structuring resources.

The generally private status and the importance of those small dammings deserve to be the object of an environmental examination. Indeed, the cumulative impact of these dammings at a basin scale has to be taken into account and can be equivalent or even superior to the impact of a big unique work.

B.2.4.3 - Inter-basin water transfers

The main objective of inter-basin water transfer is water security. In some arid regions, this transfer is not a question of choice but a necessary act. Inter-basin water transfers are often seen as a fast and easy solution to face drought and water stress situations. Transfers require a specific derogation and justification adjusted to the criteria established in WFD articles 4.7, 4.8 and 4.9. If these criteria are met, transfers can be considered as the "last option" to address water problems. They often provoke social and political conflicts between donor and receiving basins.

In their initial planning stages, expectations towards water transfers have often been overestimated, as shown by a recent review of three different transfer projects in Spain (Tagus-Segura - WWF, 2003b- Ebro and Júcar-Vinalopó). Some particular aspects require special attention :

- water availability in donor basin, including water consumption expectations in the proper basin and variations in rainfalls and evaporation due to climate changes.
- environmental and social effects of the transfer on the donor basin.
- effects of the transfer on the receiving basin.
- costs of water transfer projects.
- respect of the derogation criteria established in WFD articles 4.7, 4.8 and 4.9.

Considering water availability, the initial Júcar-Vinalopó transfer project studies demonstrated that there were enough available resources. Nonetheless, after reviewing streamflows and environmental needs of the Júcar basin, current plans for the Vinalopó transfer consider the pumping of up to 62 Hm^3/y of groundwater from the Valencia aquifer.

Regarding the environmental effects, transfers usually worsen water bodies ecological status. For example, transfers from the Tagus basin suppose a significant reduction of stream flows in the Middle Tagus so the river currently has problems to dissolve urban and industrial pollution. Furthermore, ecological processes dynamics such as erosion/sedimentation are crucial for the maintenance of downstream ecosystems, as observed in the Ebro delta, and of the coastal waters nutritional chains (Ibáñez et al., 1999).

In receiving basins, inter-basin water transfers often promote an increased land-use and stimulate the increase of long-term water demand, as seen in the Segura basin for instance. The difference of water quality between the basins can affect freshwater ecosystems and even provoke inadequacy for potential water users, as the Ebro transfer project analysis have shown. Furthermore, aquatic species translocation is an additional risk of transfers : the Tagus-Segura transfer has transported four fish species (*Carassius auratus, Gobio gobio, Chondrostoma polylepis* and *Rutilus arcasii*) between basins and promoted hybridizing with *Chondrostoma arrigonis* in the Júcar basin (Oró, 2003).

The costs of water transfer projects do not often fully reflect all the transfer and associated works, infringing WFD cost recovery obligations. During the Ebro transfer project, different economic reviews of the initial studies doubled the expected price of water from 0,31€/m^3 up to 0,72€/m^3 (WWF, 2003c).

Considering the upcoming new data, the Spanish Government is currently reviewing all major transfer projects. The lessons learnt from this process should be taken into account in future projects in all countries at an early planning stage, additionally to WFD mandatory requirements, an option assessment, including non-constructive alternatives, is highly recommended.

B.2.5 - Conclusion : integrated water management approaches on supply side measures

Water Conservation and water demand management in Emilia-Romagna is a good case study to illustrate integrated water management approach. Emilia-Romagna (44° latitude) is situated in northern Italy in the valley of the Po river, bounded by Apennine Mountains to the south and the Adriatic Sea to the east. The climatic conditions of the region are related to the climatic general conditions of the Po valley (surrounded by the Alps and the Apennine) and are mostly influenced by the mountains and the sea, leading to a high spatial variability of the precipitation fields. For the region, but also for the Mediterranean zone, the water uses for irrigation are generally predominant. In December 2005, the Regional Legislative Assembly approved the Regional Water Protection Plan anticipating the WFD someway. The Water Saving and Conservation Programme is an integral part of the Water Protection Plan. The Region, together with Basin Authorities, has established the Plan objectives for each drainage basin with reference to the WFD. By 2016, every significant surface and ground water body must reach the “good” ecological quality status. In order to assure the fulfilment of this objective, each classified surface water body, or a portion of it, must acquire at least the requisites of “sufficient” status by 31st December 2008. For quantitative aspects, priority objectives are eliminating water deficit in groundwater and maintaining a minimum flow in rivers.

- WATER SAVING AND CONSERVATION PROGRAM

The structure of such a program is presented in figure 21.
In Emilia-Romagna, the withdrawals (in million m^3) in the 70’s, the 80’s and in year 2000 were estimated as presented in tables 5, 6 and 7 .

Table 5 : Total withdrawals in the middle of the 70’s.

	Civil Uses	**Industrial Uses**	**Agriculture Uses**	**Total**
Groundwater	350	240	150	740
Surface water	negligible	290	852	1142
Total	350	530	1002	1882

Table 6 : Total withdrawals in the middle of the 80’s.

	Civil Uses	**Industrial Uses**	**Agriculture Uses**	**Total**
Groundwater	310	227	193	730
Surface water	170	337	681	1188
Total	480	564	874	1918

Table 7 : Total withdrawals in the year 2000.

	Civil Uses	**Industrial Uses**	**Agriculture Uses**	**Total**
Groundwater	282	171	222	675
Surface water	205	62	1183	1450
Total	487	233	1405	2125

There is a modest increase of the total withdrawals, with a strong replacement from the industrial uses to the irrigation uses and, partially, to the civil uses. An important decrease in the groundwater withdrawals is observed. It is also interesting to note that the civil withdrawals are stable since the 80’s. The increase in surface water withdrawals depends on the regional policies developed to answer the subsidence problems posed by the unsustainable uses of groundwater in the south-eastern part of the region (Bologna, Ravenna and the coastal zone), using a canal (Canale Emiliano Romagnolo, CER), which can take about 60 m^3/sec from the Po river for agricultural uses, the Ridracoli Dam builded at the end of the 80’s for civil uses and a stronger regulation of groundwater withdrawals. Nowadays the groundwater annual deficit is estimated to be around 25 Mm^3/y, with the worst problems in Bologna and also in Parma. Considering the surface water, the estimated deficit due to the future application of the Minimum Flow (MF) is around 47 Mm^3/y. The average regional consumption for domestic uses is 170 L/capita/day (L/c/d). The estimated overall (real and apparent) leakage from the civil networks is 123 Mm^3/y, which means about 26 % of the civil withdrawals.
The application of MF is the most demanding task. The need to keep a higher volume of water in the rivers impacts the actual use of resources with particular significance during summer when the water flow is low while the water demand is at the highest level. In most of the cases, it is needed to revise “historical” water withdrawal, that were already present in the last centuries for irrigation and

old mills, and in the 20th century for drinking purposes. The level of the conflicts is therefore pretty high.
The regional strategy is based on a twin track approach and, considering the regional situation and water balance, is firstly based on the development of new regional policies for water conservation and the demand management, not forgetting the infrastructural development where necessary (for instance the local connexions with the Canale Emiliano Romagnolo. The Conservation Program also includes a need to define a Regional Drought Contingency Programme. The main Conservation Program actions are as shown in figure 17.

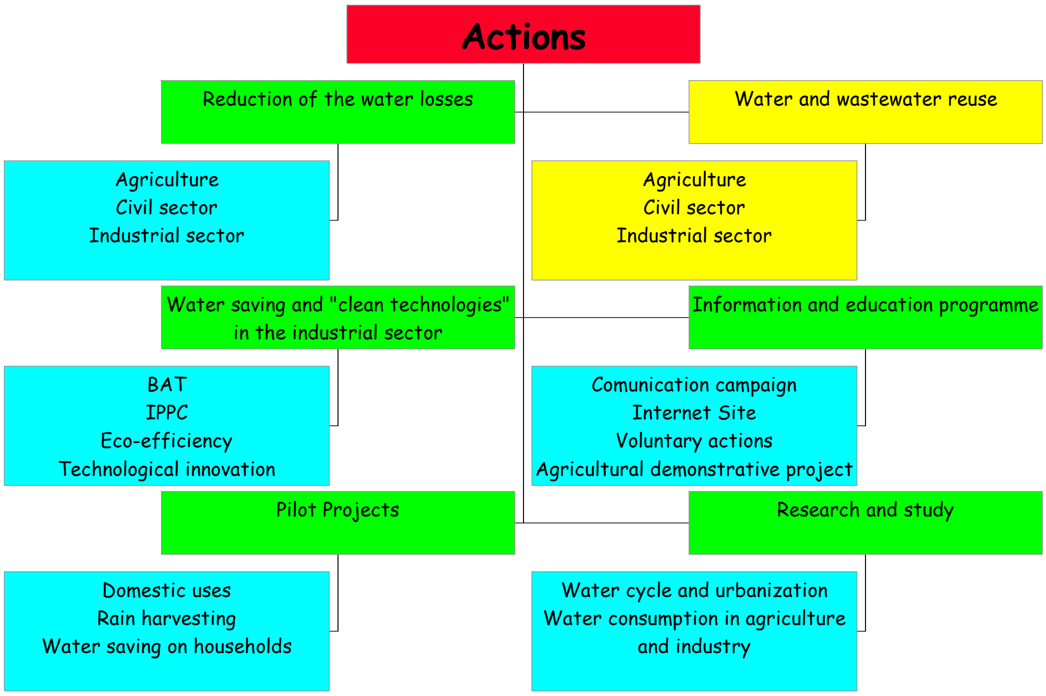


Figure 17 : Water saving and conservation program.

- WATER AND ENERGY SAVING

Energy production and use are responsible for the bulk of greenhouse gas emissions. Europe has committed itself in the Kyoto Protocol to reduce those emissions which come from fossil fuels burning, mainly coal, oil and gas. In its 2005 Green Paper on energy efficiency “Doing more with less”, the European Commission set out a strategy to improve energy efficiency and to encourage greater use of new, renewable sources of energy. The total final energy consumption in the EU in 1997 was about 930 Mtoe. A simplified breakdown of this demand shows the importance of buildings in this context : 40,7 % of total energy demand is used in the residential and tertiary sectors, most of it for building-related energy services. Space heating is by far the largest energy end-use of households in member states (57 %), followed by water heating (25 %). The planned water savings in Emilia-Romagna will directly bring an energy saving for the domestic water heating of about 12 %, which means 3 % of all the energy needed in the residential sector (2,7 Mtoe/year in Emilia-Romagna region), which is about 1/6 of Kyoto commitment in the residential sector of the region.

- RESULTS OF THE REGIONAL CONSERVATION PLANNING

The demand scenarios “business as usual” show an 8 % population growth for civil water uses, stability in the unitary consumption and a “natural” reduction of water losses (26 to 20 %). The industry is declining since the 70's. For agriculture, irrigated surface is still growing, but technological efficiency at the field is increasing with an almost stable demand (no clear indication from CAP). With the above conservation measures and assumptions, which must lead to a reduction of domestic consumption of 170 L/capita/day (L/c/d) to 150 L/c/d by 2016, plan measures would allow, in 2016, groundwater abstraction levels essentially depending on recharge capacity, also enabling to progressively offset current piezometric anomalies. As for surface waters, critical aspects are linked to irrigation uses of Apennine waters ; plan measures will foster resource deficit reduction in view of MF application.

- REGIONAL PLAN FOR DROUGHT MANAGEMENT

The plan also outlines the first elements pertaining to the Regional Plan for Drought Management. The report presented by IPCC predicts changes in the regional distribution of precipitations, leading to drought and floods, changes in the occurrence frequency of climatic extreme events, particularly heat events. Climate changes that were observed during the last decades in the region seem to be consistent with the predictions and have social impacts even at a local scale. The Water Regional Plan takes care about those aspects in order to define, for the first time in the Emilia-Romagna region, a Drought Contingency Program at the regional and local scales. Studies realized for the planning, using indicators like Standard Precipitation Index (SPI), showed that the last 15-20 years were years of growing drought. Anyway this specific risk must be afforded as in other sectors (floods, etc) with a planning strategy which shall be implemented after the plan adoption and asking the local actors to define their Contingency Programs following the regional guidelines within 2006.

C – LONG-TERM IMBALANCES IMPLICATIONS

C.1 - Environmental concerns (quantitative aspects in the WFD)

The Water Framework Directive establishes that member states, in implementing the program of measures specified in the River Basin Management Plans (RBMP), shall protect, enhance and restore all surface water bodies and groundwater bodies with the aim of achieving good ecological status (good ecological potential for artificial and heavily modified water bodies) within 2015. Good status is defined, for surface water bodies, according to the ecological and chemical status, while, as regards groundwaters, the good status refers to the quantitative and chemical status. So for surface waters, the Directive is more focused on quality aspects than on quantitative ones ; nevertheless, quantitative aspects are addressed through an indirect approach.

Drought Management Plan at national level is linked to RBMP at river basin scale by the fact that there is a need of coherence between actions per basin. National strategy and instruments constitute the doctrine whereas measures are the actions at river basin level.

Moreover, RBMP must be linked to other land management plans (town-planning, public roads), especially soils management plans, in order to take into account the other management and planning instruments that can influence the quantitative management, notably in arid environments .

C.1.1 - Integration of qualitative and quantitative aspects

Quantitative protection of water resources is closely linked to qualitative aspects. Reaching the objectives for good ecological status would be very difficult or nearly impossible without properly considering quantitative aspects. On one hand, quantitative actions are essential in order to guarantee ecosystems (typical habitats, dilution, prevention of extreme situations) and on the other hand, pollution diminishes available resources creating imbalances within the hydrological cycle and causing conditions of water stress. But in term of compliance regimes, the good quantitative status only concerns groundwater bodies.

In this sense, an integrated protection of water resources is needed to achieve the good ecological status. This approach is fully taken up by the Directive which considers the key role of quantitative aspects in the recitals and especially in the following ones :
- RECITAL 19: …*control of quantity is an ancillary element in securing good water quality and therefore measures on quantity, serving the objectives of ensuring good quality, should also be established.*
- RECITAL 20 : *The quantitative status of a groundwater body may have an impact on the ecological quality of surface waters and terrestrial ecosystems associated to that groundwater body.*
- RECITAL 34 : *For the purposes of environmental protection, there is a need for a greater integration of qualitative and quantitative aspects of both surface waters and groundwaters, taking into account the natural flow conditions of water within the hydrological cycle.*
- RECITAL 41 : *For water quantity, overall principles should be laid down for control on abstraction and impoundment in order to ensure the environmental sustainability of the affected water systems.*
Even if the above mentioned recitals clearly show the need for a greater integration of qualitative and quantitative aspects of both surface and groundwaters, the Directive doesn't talk about specific questions addressing quantitative aspects for surface networks.
The quantitative status of surface waters is considered in the WFD through the inclusion of the hydrological characteristics of water bodies in the provisions for the definition of ecological status (table 8).

Table 8 : Hydrological elements supporting biological composants

WATER BODY	HYDROMORPHOLOGICAL ELEMENTS SUPPORTING BIOLOGICAL COMPOSANTS
Rivers	Hydrological regime: - connexion to groundwater bodies - quantity and dynamics of water flow
Lakes	Hydrological regime: - quantity and dynamics of water flow - residence time - connexion to groundwater bodies

Regarding good status of inland water (rivers and lakes), the Directive says that "the hydrological regime must be consistent with the achievement of the values specified for the biological quality elements".
As mentioned above quantitative aspects are directly and fully considered in the assessment of groundwater status. A good status is achieved when the water level in the groundwater body is such that the available groundwater resource is not exceeded by the long-term annual average rate of abstraction. Accordingly, the level of groundwater is not sensible to anthropogenic alterations such as what would result from :

- failure to achieve the environmental objectives specified in article 4 for associated surface waters
- any significant diminution of the status of such waters
- any significant damage to terrestrial ecosystems which directly depend on the groundwater body

Alterations of flow direction resulting from level changes may occur temporarily or continuously in a spatially limited area, but such reversals do not cause saltwater or other intrusion and do not indicate a sustained and clearly identified anthropogenically induced trend in flow direction likely to result in such intrusions.

In conclusion, even if the WFD focuses on the qualitative aspects, it stresses that the quantitative aspects are essential for the achievement of good ecological status.

C.1.2 - Quality and quantity in RBMP

The Directive provides some clear indications about the way to approach the need to integrate quantity/quality aspects. These indications are both included in RBMP and in the program of measures.
As regards the RBMP, the Directive sets out that they consider the water bodies quantitative status in the river basin general characterisation and in the evaluation (table 9). Moreover, quantitative status considerations can play a role in other aspects covered by RBMP as the economic analysis or the applications of exemptions in article 4.

Table 9 : River basin management plans

RIVER BASIN MANAGEMENT PLANS

River basin management plans shall comprise the following elements :

1.1 A general description of the characteristics of the river basin district which includes an identification of reference conditions for the surface water body types.

2. A summary of significant pressures and impact of human activity on the status of surface water and groundwater, including an estimation of pressures on the quantitative status of water including abstractions.

4.2 A map presentation of the results of the monitoring programmes carried out under those provisions for the status of groundwater (chemical and quantitative).

5. A list of the environmental objectives established under article 4 for surface waters, groundwaters and protected areas, including identification instances where use has been made of articles 4(4), (5), (6) and (7), and the associated information required under that Article.

6. A summary of the economic analysis of water use as required by article 5 and Annex 3.

7.4 A summary of the programme or programmes of measures adopted under article 11, including a summary of the controls on abstraction and impoundment of water, and reference to the registers and identifications of the cases where exemptions have been made under article 11(3)(e).

C.1.3 - Quality and quantity and reference conditions

The definition of these elements, recognized by the Directive as essential for RBMP arrangements, implies the evaluation of water resource availability and the consideration of quantitative aspects in the definition of the reference conditions. For each surface water body type, the WFD requires that type-specific hydromorphological and physicochemical conditions shall be established representing the values of those elements for surface water bodies at high ecological status.
It is imperative to fully take into account quantitative aspects associated to the hydromorphological elements supporting the biological ones. In other words, in certain circumstances (e.g. arid climates, highly permeable soils, etc), quantitative aspects could play a crucial role in establishing the reference conditions and in achieving the environmental objectives.

C.1.4 - Quality and quantity and river basin balance

The integrated quali-quantitative approach is fully coherent with the logic of the hydrological balance and the protection of a flow consistent with the GES (Good Ecological Status). The definition of a balance, in fact, requires the assessment of inflow (natural flow and anthropic discharges) and of the outflow (for civil, agricultural, industrial uses, etc) : the difference between inflow and outflow must guarantee, on each homogenous stretch, a flow which protects the typical biocoenosis of the water body considered.

C.1.5 - Quality and quantity in the programme of measures

As regards the measures, the WFD defines a programme of measures which includes “basic measures” (minimum requirements to be complied with) and “supplementary measures” (designed and implemented in addition to the basic measures).
For both, measures of quantitative protection of the water bodies are introduced. In article 11.3 (basic measures, table 10), controls are established over abstractions and impoundment, artificial recharge of water bodies and measures to ensure that the hydromorphological conditions of the water bodies are consistent with the achievement of the required ecological status.
The Directive defines a “non–exclusive list” of supplementary measures which aim to protect water quantity both on supply and demand side.

Table 10 : measures of quantitative protection of the water bodies in article 11.3

Article 11.3
Basic measures are the minimum requirement to comply with and shall consist of : (…)
(e) control over the abstraction of fresh surface water and groundwater, and impoundment of fresh surface water, including a register or registers of water abstractions and a requirement of prior authorization for abstraction and impoundment. (…)
(f) controls, including a requirement for prior authorization of artificial recharge or augmentation of groundwater bodies. The water used may be derived from any surface water or groundwater, provided that the use of the source does not compromise the achievement of the environmental objectives established for the source or the recharged or augmented body of groundwater. (…)
(i) for any other significant adverse impacts on the status of water identified under article 5 and Annex II, in particular measures to ensure that the hydromorphological conditions of the bodies of water are consistent with the achievement of the required ecological status or good ecological potential for bodies of water designated as artificial or heavily modified. Controls for this purpose may take the form of a requirement for prior authorization or registration based on general binding rules (…)

LIST OF MEASURES TO BE INCLUDED WITHIN THE PROGRAMMES OF MEASURES : PART B
The following enumeration is a non-exclusive list of supplementary measures which member states within each river basin district may adopt as part of the programme of measures required under article 11(4): (…)
(viii) abstraction controls
(ix) demand management measures, *inter alia*, promotion of adapted agricultural production such as low water requiring crops in areas affected by drought
(x) efficiency and reuse measures, *inter alia*, promotion of water-efficient technologies in industry and water-saving irrigation techniques
(xi) construction projects
(xii) desalinization plants
(xiii) rehabilitation projects
(xiv) artificial recharge of aquifers (…)

Basic and supplementary measures must be selected with the aim to ensure a sustainable water balance and the minimum flow supporting the ecosystems.

C.2 - Social concerns

C.2.1 - Socio-natural dynamics in the context of water scarcity

Under conditions of any type of resource scarcity, economically and politically disadvantaged social groups usually meet difficulties to sustain their livelihoods, their quality of life, and even their very existence. The objective of this section of the document is to explore the undesirable social impacts of water scarcity and the effect of its mitigation on our communities. By inference, this specification embraces the concept of livelihoods as well as lives and therefore includes threats to the economic viability of individuals and communities.

The number of citizens exposed to drought within the European Union is increasing. Figure 18 shows the relevant data for 2002.

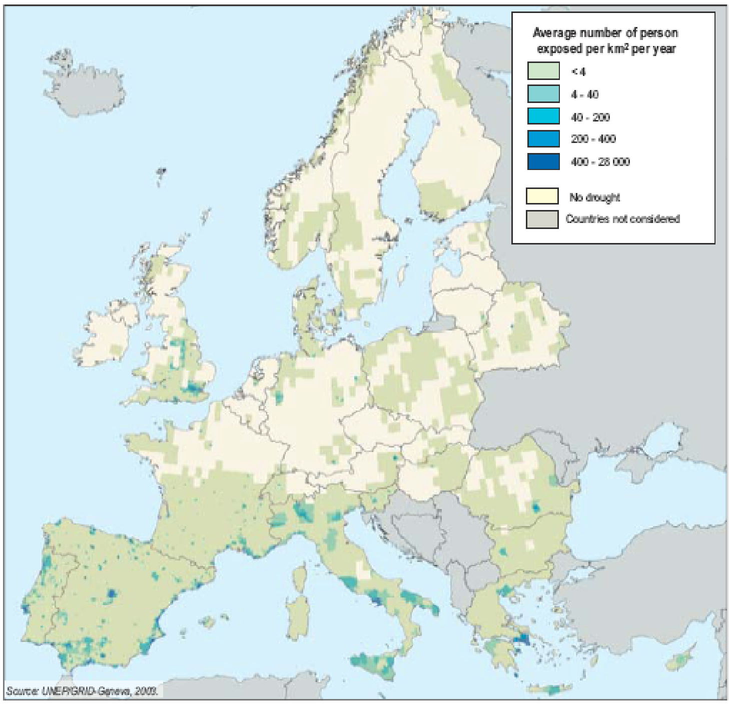


Figure 18: Average number of people per km exposed to drought (UNEP)

Scarcity of water resources can affect a wide range of social indicators, perhaps the most significant of which are:

- the affordability of water
- the public health
- the community cohesion

Recent and current EC funded research on the human and social dimensions to water stress and water management is represented by the projects (many of which are members of the Human Dimensions Cluster coordinated by the Harmoni-COP project) listed in the end of chapter III references.

<u>*C.2.1.1 - Affordability of water*</u>

As resource managers seek to raise extra-capital for investment in new supply sources or improve the efficiency of current systems, the delivered price of water can dramatically rise. The issue of affordability, whilst of obvious concern to those working in the developing nations, has latterly attracted increasing interest in Europe and the developed world (OECD, 2003). The literature on the affordability of water in the context of privatisation (Rodriguez, 2004) and willingness/ability to

pay (Merrett, 2002) has been full of lively deliberations in recent years and has also prompted a wider debate on the human right to water (Bluemel, 2005).
Tariff structures in the developed world tend to reflect a desire that the basic human needs of water and sanitation should be accessible to all members of society regardless of financial circumstances. Where government has detached itself from influence over water pricing, or has set other performance criteria above this social imperative, affordability is under threat and needs to be regularly monitored although the phenomenon is not exclusively a problem for the water sector as it is also clearly related to low incomes.

C.2.1.2 - Public health

Where water scarcity is driven by climate change, there can be significant impacts on human health. Warmer, sunnier climates also encourage more recreational water use, leading to the increased exposure of leisure users to waterborne pathogens. The additional risks to human health from water stress mainly results from changes in the spread and activity patterns of pathogens and their intermediate hosts. For example, drought can induce malaria outbreaks following drought years (Chase et al., 2002) and recent research suggests that hemorrhagic fever may probably be associated to drought events (Acuña-Soto et al., 2005).

C.2.1.3 - The community cohesion

At higher scales of social organization, water stress can give rise to economic disruption and mass migration as agricultural systems fail. Loss of income (due either to the increased costs of securing access to water or of lower crop prices) and loss of land value (perhaps due to desertification) are obvious consequences of increasing water stress. However, this reduction in farming community wealth has consequences for other businesses which rely on the trade and patronage of farmers. The social, and often psychological, damage caused to farming families may well take several years to materialize as they struggle to adapt to changing climatic, environmental and production pressures. Working longer hours, delaying investment, selling stock, and taking on extra work off the farm (sometimes leading to the involuntary separation of families), are all well recognized adaptation mechanisms.
Scarcity conditions are also likely to raise new, or exacerbate existing, social tensions. Young people develop very negative impressions of farming as a livelihood. The strain placed on farming communities by water scarcity is often long-term and the end of a drought period rarely presages a sudden return to full production and the restoration of income levels.

C.2.2 - Social impact of supply side responses

Supply side responses to water scarcity involve the increase of the volume of water available for use (though not necessarily potable use). The social impacts of supply side measures are unlikely to be as significant as those for demand side mechanisms, simply because consumers are largely unaware of any change in the supply regime. There are, however, three exceptions to this situation :

- Firstly, the beneficiaries of projects which augment provision to an existing supply network are those who already have access to the network. The social costs and benefits of such schemes can be poorly distributed amongst communities. For example, urban communities may benefit from a large inland desalinization scheme whilst rural communities are blighted by distillate treatment and disposal sites.
- Secondly, although there are excellent european examples of reuse projects for irrigation, industry and indirect potable uses through river and groundwater bodies, there is a wide variety of social (and institutional) issues surrounding the recovery, recycling and reuse of wastewaters. Whilst the technologies are well tested and

economic conditions often favourable, societal concerns about the use of non-potable water can hamper attempts to implement reuse schemes. In summary, studies have identified that :

- Communities across Europe are sensitive to water reuse issues unless they understand their urban water cycle and have confidence in quality control. This is more evident in the northern part of the continent than in the south even though many large cities in northern Europe depend on indirect reuse for their freshwater resource for potable treatment especially during dry weather flow.
- Many corporate stakeholders are nervous about supporting reuse projects in the absence of clear and legally binding water quality guidelines.
- Use of a water recycling system where the source and application are located within their own household is acceptable to the vast majority of the population as long as they trust the organization which sets standards for water reuse. Using recycled water from second party or public sources is less acceptable, although half the population shows no concern, irrespective of the water source. This situation is different for reuse in industry.
- Water recycling is generally more acceptable in non-urban areas than in urban areas. This disparity is more pronounced for systems where source and use are not within the respondent's own residence.
- Willingness to use recycled water, particularly from communal sources, is higher amongst metered households than non-metered ones, and higher amongst households which take water conservation measures than those that do not.
- The use of recycled water for irrigation is widely accepted by farmers who believe them to be safer than river waters.
- There are strong concerns about the sale of products which have been irrigated with recovered wastewater, especially vegetables. Farmers can overcome resistance through positive evidence from the consumers and the retailers that there will be a market for the products cultivated with the recovered water.
- The establishment of standards for the reuse and management of monitoring programmes promotes confidence in reuse schemes.

- Thirdly, increasing water scarcity often leads to attempts to re-negotiate access or distribution rights to water resources. Stakeholder requirements and claims to legitimacy for those requirements will change as the resource becomes scarcer. Where existing rights are threatened, the very definition of an equitable distribution may be challenged and the spread of costs and benefits resulting from mitigation actions questioned. Existing management structures are not always capable of supporting such re-negotiation, particularly where there are competing uses.

C.2.3 - Social impact of demand side responses

Encouraging water conservation is perhaps the most obvious policy instrument available to help professionals in their efforts to balance supply and demand. National and pan-national bodies tend to favour approaches or mixes of instruments they promote (often informed by local cultural and development considerations), although the overall effect of many strategies is that of a "carrot and stick" approach. Such demand side approaches rely on a range of instruments and techniques which can be divided into four broad categories :

- economic
- regulatory
- technological
- educational

A recent review of societal responses to these policy mechanisms can be found in Gearey and Jeffrey (2005).

C.2.3.1 - Economic category

Design and implementation of economic policy instruments in the water sector requires awareness of the implications of such instruments and the impacts they may have on particular groups of users. The essential role of water in the lives of humans and its cultural status in many societies need to be respectively recognized and valued. Ability to pay for water, either as a commodity, a social good, or an environmental resource, varies across communities and through time. This fact, when combined to the nature of water as a primary good, raises issues of equity and fairness in water allocation (Herbert et al., 1995) ; particularly as the volumes consumed by some types of water use, such as drinking, are relatively inelastic to price. Availability of a reasonably priced supply of water has also been linked to regional and national economic growth, particularly in the agricultural and primary industrial sectors (Schama, 1995).
Evidence to support the view that economic instruments are effective in modifying water consumption behaviour is variable. Although the application of simple pricing instruments such as block rates has generated expected gross responses from domestic consumers, more detailed pictures of response envelopes have been difficult to construct. Different groups of water users clearly respond to economic instruments in different ways and at different times. Although many studies have demonstrated a link between water price and consumption, results from a study carried out in the Netherlands reported by Achttienribbe (1998) recently raised serious doubts about the price elasticity of water consumption in different sectors. The motivation to save money (a financial incentive) rather than to save water (an environmental incentive) has been demonstrated to be the dominant driver for reactions to many conservation initiatives.

C.2.3.2 - Regulatory category

Regulatory based demand side measures can include mandatory and enabling legislation, regulations, policies, standards and guidelines. They can be used to reduce institutional, legal or economic barriers for a more efficient water use or to create barriers against unnecessary or wasteful water consumption. Whilst the use of regulatory measures can generate a more predictable and immediate effect on consumption patterns, there are a number of considerations to be taken into account :

- Firstly, the perceived legitimacy of a regulatory measure can significantly influence its impact. Communities will ask questions about whether the regulation is based on a sound and broadly accepted understanding of the problem, and the credibility/ competence of the regulating body in setting the measure. They will also be concerned about the fact that any price increase is not being used to take advantage of the situation to increase profits.
- Secondly, many regulatory measures rely on effective monitoring and enforcement, activities which in themselves are resource consuming.
- Finally, and as it is the case for any regulatory measure, evasion, deception, and abuse will adversely impact the effectiveness of the instrument and challenge its credibility as an effective policy instrument.

C.2.3.3 - Technological category

Technological instruments include structural or physical improvements to water supply and use systems and installation of water efficient devices or processes (such as low flush toilets or low flow showers, etc). Difficulties associated to technology based policy instruments typically concern the availability of complimentary knowledge and skills required for effective deployment. In addition, new technologies cannot simply be located in our houses, streets and utility infrastructures without some understanding of how they impact existing system performance. Public responses to retrofit programmes (eg. supply and fitting of low volume cisterns) has been shown to be positive if the equipment is offered for free and if the programme is high-profile and aggressively managed (Sarac et al., 2002). However, initiatives may be rejected on aesthetic and practical reasons, particularly if bathrooms or kitchens have recently been refurbished.

C.2.3.4 - Educational category

The education of water users through different contact routes and media is largely utilized to modify water use behaviour and encourage voluntary water conservation actions. Often seen as the core instrument for use in long-term conservation strategies (Grisham et al., 1989), educational programmes make use of printed, video, and audio media as well as face-to-face methods. Developments in the fields of participative planning and social learning have influenced the design and execution of this type of water policy instrument as more consensual and community informed approaches to water management have been developed. Indeed, although the term “education” has traditionally been used to characterize this form of water policy instrument, there is increasing impetus to use a term which better reflects the collaborative nature of the process (e.g. “communication”, or “dialogue”; the latter of which being the preferred term here).

Dialogue, as noted above, is an instrument which encourages behavioural change. Consequently its effectiveness is posited on the assumption that beliefs determine values, values determine attitudes, and attitudes determine behaviour. However, the ability of attitudes to predict behavioural intentions and overt behaviour continues to be a major focus of theory and research in psychology and it is now generally recognized that although attitudes are relevant for understanding and predicting social behaviour, many important questions remain unanswered. Indeed, many studies, such as that conducted with specific reference to the water sector by De Oliver (1999) tell us that none of these links can be taken for granted, and that measuring the causal process is itself a non-trivial activity. These limitations to managing water use behaviour through dialogue have led to calls for more targeted campaigns, greater public participation during the early stages of programme design, best practice exemplarity to demonstrate the benefits of conservation and programmes which generate a commitment to act.

C.2.4 - Social vulnerability and adaptation

Social vulnerability to natural hazards such as drought and water stress is a function of the ability to predict the occurrence of the hazard, the resources available to cope with the hazard, the particular features of the existing economic system, and the ability to adjust and adapt to changing conditions. Whilst the resilience of social networks is often challenged by conditions of water stress, social resilience can work to prevent degradation resulting from overexploitation of land in response to drought. Recent advances in the theory of social adaptation has emphasized the ability (or inability) of a social entity to cope with the increasing demands caused by water scarcity, describing a second-order scarcity (Turton et al., 1999) of social resources which acts as a barrier to adaptive change.

Before a solution can be offered to the problems of increasing water stress, we need to begin to define what is individually and communally acceptable as response options and what the barriers are to adaptation. One barrier may be convenience. Given that water supply in the many parts of the world is universal and that there are few barriers to delivery, access couldn’t be easier. Low levels of water metering and relatively low pricing, signal to the market that the product is cheap and abundant. Asking people to change their consumption patterns needs to be correlated with an

explanation about why a change is needed. Another barrier to adaptation may be awareness : although people are aware of global warming, the uncertainty of predictions means that a guaranteed prognosis cannot be delivered. A third problem might be the cultural significance of water ; hygiene, health and prosperity are all linked to access to water – for some it represents modernity at its highest apex. The goal is to identify what triggers need to be put in place before individuals and communities accept their responsibility in cutting water demand. Without this shift in attitude, policy targeted on individual and community consumption will face legitimacy problems. The key to tackling individual and community consumption will be to recognize that consumers are not homogenous groups : in the same way that market consumption is heterogeneous, so is water use.
Indeed, the extent to which communities are able to adapt to increasing water scarcity has been represented in a Social Water Stress Index (Ohlsson, 1999). This SWSI represents a society's social adaptive capacity in facing the challenges of physical water scarcity. It is calculated as the ratio of :

- A standard measure of water stress/scarcity, arrived at by dividing the amount of annually available renewable water by population size, to
- the Human Development Index for each country. A higher value indicates a greater degree of water stress.

C.2.5 - The cultural significance of water

Any discourse on water consumption is predicated on cultural understandings of water and its institutional framework. In many countries the institutional framework is based on private property rights – access to water "belongs" to a person or institution, whether private or public. There is no universal access to water and the rights to water are not based on the needs but on legal entitlement. This is not the place to review water rights but this brief outline helps to select the type of literature that could inform further research. The work conducted by Aguilera-Klink et al. (2000) is exemplary in this area : deconstructing concepts of water scarcity, the authors are able to build a strong argument about what explains the development of a society's water structure, what shapes attitudes towards water and examine how consumption patterns become engrained within an institutional framework. It does not only cover the way water is accessed and priced but also highlights that perceptions of scarcity can create "panic consumption" leading to more acute conditions of scarcity. By linking progress with water, consumption creates its own dynamism cemented within power structures in society. This paper is one of the few to emphasize how power relations and water have a direct effect on consumption levels. What is also made clear is how those with a direct dependency on access to water have specific local knowledges (seasonal water flow, depth of aquifer) but limited understanding of the holistic hydraulic process.
Water use, perceptions and attitudes to water and water governance adaptivity must include a perspective on how water acts as a conductor of power and gender relations, how it becomes representative of forms of knowledge and means of operating power/knowledge discourses. We cannot talk about human behaviour without recognizing that we also need to talk about power. Behaviour is learnt and is socio-cultural, we learn to adapt to our environment. Part of that process is gaining knowledge and as a consequence, our actions help us move through the various networks of power that exist in our society. Using power as a theoretical underpinning enables us to analyze water as a vehicle of control rather than just as a social or economic good.

C.2.6 - Concluding comments

Although research into the social dimensions of water scarcity has increased (and its quality improved) over recent years, effective knowledge exploitation is beset by two problems :

- Firstly, the knowledge base itself is dispersed and typically located within the confines of a disciplinary community such as sociology or anthropology rather than with water management per se. It is thus difficult for water sector professionals to locate relevant knowledge (in both terms of research findings and knowledgeable individuals). Possible responses to this issue are difficult to envisage although dedicated publications or events which provide an opportunity for commercial concerns to access contributions on the human dimensions of water management would be of benefit.

- A second problem is that many organizations in the water sector are poorly equiped to recognize and exploit the potential contributions of the “softer” sciences. Decades of emphasis on engineering, technology and infrastructures has left its imprint on water supply and management institutions to the extent that the only incentives to understanding any human association with water is in terms of marketing (selling people the products of engineering) and public relations (convincing people of the benefits of engineering). However, the issues here go deeper than the educational background of individuals. Studies of human behaviour or attitudes typically produce results of low predictive power. However, this does not mean that they are of no value. Research contractors need to identify the contribution of such studies before they are executed and accept that they are more likely to ‘inform’ than ‘resolve’ a particular problem.

The role the Water Framework Directive (WFD) could play in facilitating socially just and equitable responses to water scarcity is worth noting. The simple fact that River Basin Management Plans are to be prepared through a transparent and consultative process is important in this context. Such forms of planning provide opportunities to anticipate scarcity conditions, scope possible responses, rehearse arguments to support specific options and learn about other stakeholders perspectives, concerns, constraints and policy preferences. Consequently, some of the tensions discussed in earlier parts of this chapter will not happen.

The WFD, whilst inviting member states to “take into account the principle of recovery of the water services costs”, avoids imposing full cost recovery as an economic principal for water services provision. This will empower governance bodies by enabling them to support vulnerable groups without compromising their commitment to the WFD ; a potential social safety net which could be very useful under conditions of water scarcity – as discussed above.

Finally, article 14 of the WFD provides a mechanism for addressing social learning, participative planning and gender issues. By extending the consultation franchise to previously unengaged groups, article 14 facilitates inclusion and will give a voice to social concerns. The extent to which such concerns will be acted on remains an open question. However, there is little excuse for social concerns not to be registered and brought to the attention of decision takers.

The economic, environmental and social development of our communities co-evolves with the availability and quality of water, and we need to enrich and deepen our understanding of these relationships. Sustainable development is fundamentally about the adaptive capacity of the human race. In relation to water, the broad objective should be to enhance adaptive potential in the context of safeguarding water supplies, not only for human consumption but also in support of viable ecosystems. People adapt and change at a faster rate than policies, technologies and infrastructures. The challenge is to understand this potential as it impacts on water supply, and exploit it as a beneficial tool for adaptive response.

C.3 - Economic profitability

With growing water scarcity and increasing competition between water-using sectors, the need for water savings and more efficient water use has raised in importance in water resources management. Improvement in the physical efficiency of water use is related to water conservation through increasing the fraction of water beneficially used over water applied, while enhancing

economic efficiency is a broader concept seeking the highest economic value of water use through both physical and managerial measures.
Economic efficiency of irrigation water use refers to the economic benefits and costs of water use in agricultural production. As such, it includes the cost of water delivery, the opportunity cost of irrigation and drainage activities, and potential third-party effects or negative (and positive) externalities (Dinar, 1993). Economic efficiency can be expressed in various forms, for example, as total net benefit, as net benefit per unit of water, or per unit of crop area and its broader approach compared to physical efficiency allows an analysis of private and social costs and benefits.
Economic efficiency at the basin scale seeks to maximize the net benefits of water uses in the whole basin. The concept can take positive and negative externalities in water use, for example, among upstream and downstream demand sites (irrigation systems), water productivity (output per unit of water consumption), as well as physical efficiencies at the system level into account. In addition, the concept can relate water uses across water-using sectors. However, this issue is not addressed here (website ref 19).
Several writers (Kolderie, 1989 ; Wunsch, 1991 ; Ostrom et al., 1993) distinguish between the responsability for "provision", which might be government's concern, and "production", which might be done by private or community actors. A clearer distinction is made between (a) "direct provision", which is the act of physical producing (constructing, creating, maintaining) and delivering a service, and (b) "indirect provision", ensuring that a service is available by setting policy and service standards, coordinating, financing, enabling and regulating producers. As water is a basic need for life, direct and indirect provision have to be realized with efficiency and equity for a good allocation and management of water. Then the question of which type of service, public or private, is the most adapted is very important. There is no universal answer to this question. Every water system that proposes an efficient and equitable service can be performant. The choice between a public and a private service has to be done by taking into account the advantages and disadvantages of the service in accordance with the local context. However, co-management between public and private sectors can be a good solution for "direct" and "indirect" provision. Table 11 sums up the advantages and disadvantages of different water allocation mechanisms.

Table 11 : Water allocation mecanisms (Lallana et al., 2001).

Allocation mechanism	Definition	Advantages	Disadvantages	Example
Marginal cost pricing	Targets a water price equal to the marginal cost of supplying the last unit of that water. Water supply charges typically include • collection • transport to treatment plant • water treatment to meet quality standards • distribution to customers • monitoring and enforcement. Water charges may also include any social costs (or benefits), although they may be more difficult to calculate.	• Avoids the tendency to underprice water • Could avert overuse because prices would rise to reflect the relative scarcity of water supplied • Can also be combined with pollution charges or taxes	• Difficulties in defining marginal cost itself as a result of problems in collecting sufficient information to estimate benefits and costs • Tends to neglect equity issues • Requires volumetric monitoring which is not always in place	Irrigation in France Water is sold on the 'binomial tariff' basis. The Société du Canal de Provence designs tariffs with the objective that they reflect long-run marginal capital costs in the peak period, operating costs only in the off-peak period, and possible discharge reduction in the form of pollution fees. Thus the State subsidies 50 % of all elements of the tariff.
Public/admi-nistrative allocation	The government decides which water resources can be used by the system as a whole, and allocates and distributes water within different parts of that system. The State's role is particularly strong in intersectoral allocation, as it is often the only institution	• Tends to promote equity objectives, ensuring water supply to areas of insufficient quantity; the physical allocation of water among the users is independent of the charge	• Prices do not represent either the cost of water supply or its value to the user • Often leads to waste and misallocation of water • Often does not support	

	that includes all users of water resources, and has jurisdiction over all sectors of water use.		user participation. • The dominant incentive to comply is enforcement by law. • The structures or fees for water often do not create incentives for users to save and use it more efficiently.	
Water markets	The allocation of water is referred to as an exchange of water use rights, compared to a temporary exchange of a given quantity of water between neighbouring users. Sometimes it requires the intervention of government to create the conditions necessary for markets to operate (defining water rights, creating the institutional and legal framework, investing in infrastructure to allow water transfers)	• The seller has the opportunity to increase profitability • The buyer benefits because water market encourages increasing water availability • Empowerment of water users by requiring their consent to any reallocation of water and compensation for any water transferred • Provision of water rights tenure to the water users • Induces a shift towards improved water management and efficiency in agriculture	• Difficulties for establishing the market: measuring water, defining water rights when flows are variable, enforcing withdrawal rules, investing in conveyance systems, environmental degradation • Third-party effects have to be identified and quantified to take into account the associated costs in the exchange process (pollution, overdraft of water tables, etc.)	
User-based allocation	Irrigation: farmer-managed irrigation (by time rotation, depth of water, area of land, shares of the flow). Domestic-water supply: community wells and hand-pump systems. User-based allocation requires collective action institutions with authority to make decisions on water rights. The effect of user-based allocation depends on the content of local norms and the strength of local institutions.	• Potential flexibility to adapt water delivery patterns to meet local needs • Administrative feasibility, sustainability and political acceptability	• Requires a very transparent institutional structure • Local user-based institutions can be limited in their effectiveness for intersectoral allocation of water because they do not include all sectors of users	Communal irrigation system In Portugal (Vila Cova village), issues such as beginning and ending of the irrigation period, losses in canals, travel time of water, user sequence, and night turns are addressed via various arrangements that involve different community institutions.

APPENDIX 3

- Water reuse (B.1.1.6)
- Examples of pricing methods for irrigation in different countries (B.1.2.2)
- Cecina PRB : measures adressing water imbalances management

IV- COMMON PRINCIPLES (CONCLUSIONS AND RECOMMENDATIONS)

In November 2003, the European Water Directors recognized water scarcity as a major issue for water management and environmental protection. At the same time, they decided to establish a drafting group within the WFD Common Implementation Strategy (CIS) in order to tackle this topic.
The group has been working on a document providing definitions, exchange of experiences, and possible actions in order to react on scarcity issues. This document will be submitted for endorsement to the Water Directors by June 2006. In the context of recent drought events in Europe during summer 2003 and the western Mediterranean region in 2004/05, the drafting group is presenting key issues on drought and water scarcity for countries prone to such phenomena and for consideration and discussion at the Water Directors meeting of november 2005 held in London.

A - THE LINK BETWEEN WATER SCARCITY AND ENVIRONMENTAL PROTECTION ISSUES

Unsustainable water management including water over-consumption and water pollution as well as possible climate change effects in a water scarcity situation could result in severe impacts on nature and society.
Inefficient drought and water resources management put aquatic ecosystems under higher stress. Indeed, the lack of adequate water use planning leads to heavy overexploitation of rivers and reservoirs in case of drought, which jeopardizes the survival of the associated fauna and flora. For example, aquifer over-pumping to meet an increasing water demand or to mitigate drought effects causes drops of the water table levels, affects wetlands, and, in coastal zones, dramatically increases groundwater salinization. These issues also have an impact on water quality.
Therefore, measures to prevent and alleviate drought and water scarcity should be developed and implemented in the context of WFD, as WFD places the integrity of freshwater ecosystems at the core of water management.

B - THE LINK BETWEEN WFD IMPLEMENTATION AND WATER SCARCITY MANAGEMENT

The WFD is not directly designed to tackle quantitative issues ; however, the directive can be an instrument for addressing drought and water scarcity management. Indeed :
- the directive is a “framework for the protection of waters which prevents further deterioration” (articles 1.a and 4)
- the directive contributes to mitigate the effects of droughts (article 1.e).
- water quantity can have a strong impact on water quality and therefore on the achievement of good ecological status.
- a “good quantitative status” is required for groundwater ; a balance between abstraction and recharge must be ensured. Furthermore, groundwater levels should not be subject to anthropogenic alterations that might have impacts on surface waters.

For these reasons:

- When developing the WFD Programmes of Measures (POM) and associated River Basin Management Plans (RBMP) (articles 11 and 13), quantitative and qualitative aspects should be jointly considered for the plans and programmes to be coherent and to create synergies where possible. Quantitative issues should, in particular, be taken into account when setting the objective of “no further deterioration” of current status (articles 4.1, 4.5, 4.6 and 4.7).

- Actions to manage water quantity (e.g. water scarcity) should be considered as “measures” (basic/supplementary) when developing the WFD POM and associated RBMP (articles 11 and 13).
- When and where needed, a specific “drought management (sub)plan” should be included in the WFD RBMP (article 13.5).
- Public participation (article 14) should also be organized around water scarcity management issues, as required by the WFD.

Regarding derogations, “prolonged droughts” are introduced in the directive as force majeure events. Therefore, clear definitions of what is understood by “prolonged droughts” will have to be established.

C - FIRST ELEMENTS FOR A DROUGHT MANAGEMENT PLAN

The WFD aims to raise the standard of water quality and prevent further deterioration in quality across all waters and wetlands. Member states shall implement the necessary measures to prevent deterioration of the status of all bodies of surface and ground waters.

Realizing that the mitigation of the adverse effects of drought is an important objective of WFD is also very important.

Analysis of the drought management policies in some countries today indicates that decision-makers usually react to drought episodes through a crisis-management approach by declaring a national or regional drought emergency programme to alleviate drought impacts, rather than developing comprehensive, long-term drought preparedness policies and plans of actions that may significantly reduce the vulnerabilities to extreme weather events. Drought planning evolves to risk management.

A new conception of drought management is needed. A modern way to address these kind of situations is mainly based on the following principles:

- Developing comprehensive long-term drought preparedness policies and action plans may significantly decrease the risks associated to extreme weather events, reducing vulnerability and increasing resilience to drought.
- It should include prevention – in order to reduce the risk and effects of uncertainty- and mitigation – measures undertaken to limit the adverse impacts of hazards- strategies.
- The problem of drought requires a proactive management developing actions planned in advance, which involve modification of infrastructures, laws and institutional agreements and the improvement of public awareness.
- The drought management strategy should include sufficient capacity for contingency planning before the onset of drought, and appropriate policies to reduce vulnerability and increase resilience to drought. Effective information and early warning systems are the foundation for effective drought plans, as well as effective networking and coordination between central, regional, and local levels.

There is also a need to coordinate the drought-related activities, such as forecasting, monitoring, impact assessment, response and recovery estimation and planning. This policy should also incorporate incentives for all drought-prone regions to develop plans that promote a more proactive, anticipatory approach to drought management. Lessons learnt from previous drought response attempts need to be documented, evaluated and shared at all levels of government through post-drought audits.

The drought is a complex phenomenon that involves social, economic, and environmental aspects. From the water resources perspective, a proactive approach to drought is equivalent to strategic planning of water resources management for drought preparation and mitigation. Such planning consists of these two categories of measures, both planned in advance :

a) Long-term actions, oriented to reduce the vulnerability of water supply systems to drought, i.e. to improve the reliability of each system to meet future demands under drought conditions by a set of appropriate structural and institutional measures. Alternative actions are :
   - Water conservation and demand management, involving efficient use and resource protection
   - Educational programs
   - Public information and awareness
   - Research

b) Short-term actions, which try to face an incoming particular drought event within the existing framework of infrastructures and management policies. They basically consist in contingent plans. The objective is to limit the adverse impacts on economy, social life and environment when a drought situation is developing. The primary components of short-term actions are :
   - Data and continuous monitoring system (Drought Management Plan Monitoring)
   - Impact assessment system
   - Response system, requiring appropriate :
      - Legal framework
      - Organisational structure
      - Measures and infrastructures

These policies must be linked to WFD. Therefore, contingency drought plans must face these issues and establish clear, objective thresholds to implement these exceptional circumstances related to an indicator system.
Temporary deterioration in the status of bodies of water shall not be in breach of the requirements of the WFD (article 4 paragraph 6) when resulting from natural or force majeure cause, or in case of a reasonably unpredictable event ("exceptional floods", "prolonged droughts"), or due to reasonably unforeseeable accidents, when all of the established WFD conditions have been met.
The conditions under which circumstances are exceptional or could not reasonably have been foreseen, have to be stated including the adoption of the appropriate indicators and included in the river basin management plan.
Summarizing the most remarkable conclusions, it is necessary to develop comprehensive, long-term drought preparedness policies and action plans that may significantly reduce risk and vulnerability to such extreme events. Key elements of this approach comprise :

- To build a long-term strategy to prepare for extreme events within water policies, including public awareness, educational programs and research. It could be reached by reinforcing coordination at European level to seek a transnational and transdisciplinary approach to drought research, monitoring, forecasting and joint mitigation strategies.
- To prepare Drought Management Plans with pre-planned measures, as a strategy to mitigate negative drought effects. The plan must include appropriate indicators and establish thresholds to progressively initiate the actions.
- Drought Management Plans linked to WFD and incorporated into River Basin Management Plans as supplementary plan, including :
  - Indicators and thresholds establishing onset, ending, and severity levels of the exceptional circumstances. In addition, thresholds of pre-alert and alert levels should be defined too.
  - Measures to be taken in the pre-alert and alert phases in order to prevent deterioration of water status.
  - All the reasonable measures to be taken in case of prolonged drought in order to avoid further deterioration of water status.
  - All practicable measures to proceed with the aim of restoring the body of water to its status prior to the drought event as soon as reasonably practicable.
  - Summary of effects and measures taken and subsequent revision and updating of the existing drought management plan.

D - FIRST ELEMENTS OF ACTIONS FOR LONG-TERM IMBALANCES MANAGEMENT

EU institutions, member states, and stakeholders should play a leading role in the implementation of a new vision for the water resources management. This vision could be summarized as considering that fresh water is a scarce and valuable resource that should be carefully managed in the long-term perspective by respecting the following conditions. In more details, this implies :

- For functioning freshwater ecosystems to fulfil basic socio-economic and environmental needs. Indeed, prioritizing the uses, including the environmental "use", is a necessity in order to achieve sustainable water management on a multi-criteria basis (usefulness, quantities consumed, season, etc). The important point is to affirm the principle that drinking water supply is the priority usage.
- Promotion of participation, partnership and active cooperation for sustainable water management at local, national, and international scale :
  - Water management should be defined at a local scale in order to be adapted to local environmental, social and economic context. This local scale is proposed to be the river basin scale of the WFD.
  - Involvement of the concerned local actors in water management projects should be considered as a key issue for the sustainability of the projects.
- Knowledge is a key aspect for a sustainable management of water resources within River Basin Management Plans. Sound knowledge about water availability and quality as well as its real use by different users is required. Water management must be realistic and produce sound estimates of water needs by aquatic ecosystems and human activities that depend on water.
- Where necessary (in case of resources overexploitation), authorities should implement a combination of measures for both demand and supply sides for all users in a coherent river basin programme to restore the equilibrium. The role of administrative institutions should be stressed to improve the equilibrium between supply and demand management. Thus institutions should deal with the human and economic resources to effectively cope with this challenge.

In the core of possible measures to be set up, some are emerging due to their important impact on the biggest water consumers and to their short-term effects :

- For demand-side measures :

  -Changes in water consumption promoting subsidies, especially of the CAP.

  -Reduction of leakages in the distribution networks.

  -Improvement of irrigation technologies by improving agricultural management, optimizing soil water utilisation and irrigation, and setting up new programmes of practical research in order to reduce water consumption (e.g. crop rotation, genetic variety).

  -Identification and implementation of potable substitution opportunities where appropriate quality of reclaimed water can be used for non drinkable applications to increase drinkable water availability.

  -Evaluation of the advantage of setting up water banks and quota systems.

  -Setting up an adapted tax and price policy system to encourage investments or demand approach management development, and to develop financial mechanisms to internalize external costs and anticipate profits on water savings.

  -Development of education and awareness campaigns
- For supply-side measures :

-Preservation of the functioning of natural catchments and restoration.

-Improvement of an efficient use of existing water infrastructures such as dams or inter-basin water transfers.

-Setting up an obligation for using a costs / needs / advantages / alternative solutions analysis for every project of new water resource creation.

- Evaluation of effectiveness and efficiency of the proposed measures.

Cost-effectiveness analysis has a role in the prioritization of the measures addressing water scarcity and drought. Demand-side measures have to be prioritized except if the cost-analysis indicates the contrary.

There is a need for a deeper analysis of some measures mentioned above to be implemented in the RBMP / Drought Management Plan, in the status of DMP (supplementary plan along the line of article 11) and specific requirements of the WFD in term of "appropriate" indicators and measures. The analysis of specific measures (such as wastewater reuse and desalination) and of the link with climate change has to be developed. There is also a need for further development of coordination at EU level and for development of knowledge on specific issues, among which :

- Alternative and saving water technologies should be promoted and further explored ; guidelines and standards should be required in order to improve and promote coordination and information exchanges.
- Links with other EU instruments for agriculture should be deepened.
- Communication about the socio-economic benefits of achieving the WFD "good status", also for regions and/or countries affected by drought and water scarcity.
- Need for further research in the harmonization of methods for the estimation of water resources and future water demand development in space and time, as well as research in environmental impact assessment ; finally coordination of activities among researchers, experts and agencies.

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HarmoniCOP - http://www.harmonicop.info/index.php
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MantraEast - http://www.mantraeast.org/
Merit - http://merit-eu.net/
Mulino - http://siti.feem.it/mulino/
Prinwass - http://users.ox.ac.uk/~prinwass/index.shtml
RiverDialogue - http://www.riverdialogue.org/
Slim - http://slim.open.ac.uk/page.cfm
WaterStrategyMan - http://environ.chemeng.ntua.gr/wsm/
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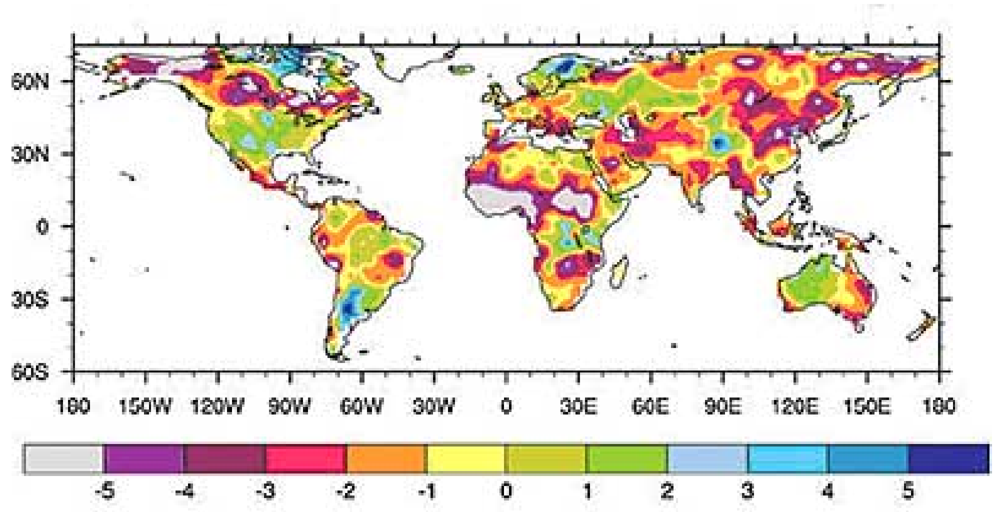
APPENDIX

APPENDIX 1 - DEFINITIONS AND ASSESSMENT OF THE DIFFERENT PHENOMENA (Chapter I)

PROJECT BOX

P.1 - NCAR-UCAR

Linear trends in the Palmer Drought Severity Index from 1948 to 2002 show drying (reds and pinks) across much of Canada, Europe, Asia, and Africa and moistening (green) across parts of USA, Argentina, Scandinavia, and western Australia (NCAR-UCAR, 2005)



P.2.- MEDROPLAN

In August 2003 the Mediterranean Drought Preparedness and Mitigation Planning (MEDROPLAN) proposed a glossary of technical terms in order to create a common set of concepts and definitions to be used for all MEDROPLAN team members. MEDROPLAN defines drought-related technical terms.

P.3 PROJECT ACACIA

The projected precipitation in the 21st century was evaluated within the ACACIA project in the modelling exercise mentioned above. The result showed that the trend towards increasing precipitation in Northern Europe would continue at a rate of 1 to 2% per decade. An increasing trend is expected for the winter as well as for the summer season. The projected changes for Central Europe (e.g. France and Germany) are small or ambiguous.

P.4 INTERREG PROGRAMMES

In the context of INTERREG initiatives a specific programme about drought was promoted in the 1994-99 programming after the severe drought events occurring from 1988 in the Mediterranean area. Drought indexes have been applied for a bulletin prototype within the INTERREG II C Programme " Territorial planning and coping with the effects of drought" in1999-2000 and the activities have been implemented during these last years in the frame of the Programme INTERREG III B with the projects SEDEMED and SEDEMED II "Sécheresse et desertification dans le Bassin Méditerranéen" financed by the European Fund for Regional Development in the section dedicated to the spatial cohesion and integration of the EU Western Mediterranean area (MEDOCC).

1.1 –NATURAL FACTORS CAUSING DROUGHT

Global Weather Patterns
A great deal of research has been conducted in recent years on the role of interacting systems, or teleconnections, in explaining regional and even global patterns of climatic variability. These patterns tend to recur periodically with enough frequency and with similar characteristics over a sufficient length of time that they offer opportunities to improve our ability for long-range climate prediction, particularly in the tropics. One such teleconnection is the El Nino/Southern Oscillation (ENSO).

High Pressure
The immediate cause of drought is the predominant sinking motion of air (subsidence), high-pressure systems can be stalled by jet streams, wide bands of fast-moving air (up to 335 miles per hour) in the upper atmosphere. Masses of air that usually move from place to place can be locked in one area by jet streams, that results in compressional warming or high pressure, which inhibits cloud formation and results in lower relative humidity and less precipitation.
Regions under the influence of semi permanent high pressure during all or a major portion of the year are usually deserts. Most climatic regions experience varying degrees of dominance by high pressure, often depending on the season. Prolonged droughts occur when large-scale anomalies in atmospheric circulation patterns persist for months or seasons (or longer).

Localized subsidence
Induced by mountain barriers or other physiographic features. Most such areas lie in the lee of mountains. The dryness is caused by the warming of air currents which allows to hold moisture and carry it away. As air is moving past a mountain range, it is forced to rise in order to pass over the peaks. However, as the air rises, it becomes colder and the vapour condenses into rain or snow. The rain then falls on that side of the mountain, known as the windward side (the side that is turned toward the wind). When the air mass finally makes it over the mountain, it has lost much of its vapour. This is another reason why many deserts are found on the side of a mountain facing away from the ocean. This phenomenon is known as the rain shadow effect.

Absence of rainmaking disturbances
In general, rain is caused by the travel of organized disturbances across a region--i.e., systems that involve actual uplift of humid air. Thus the aridity of the Mediterranean summer, though in part due to subsidence, arises mainly from the absence of cyclonic disturbances that bring the rains of winter. There is plenty of water in the air, but nothing to bring it down as rain.

Absence of humid airstreams
The relationship between the water available for precipitation (precipitable water) and the precipitation that actually falls is by no means simple. Dry weather may be prolonged in areas of high humidity. In addition to rainmaking atmospheric disturbances, regions of abundant rainfall must have access to humid airstreams. Some intercontinental regions are quite remote from such sources.

1.2 - INDEXES

Percent of Normal
This index is computed by dividing the actual precipitation by the "normal" precipitation (typically considered to be a 30-year mean) and multiplying by 100. This index can be calculated for a variety of time scales. Usually these time scales range from a single month to

a group of months. One problem is that the distribution of the precipitation, on time scales less than one year, is not gaussian. For this reason the mean usually differs from the median. This introduces an error in the evaluation of the deviation from the values of the cumulated precipitation considered "normal" for a specific time-space scale. Values of the index less than 100 means drought conditions exist.

Deciles

The distribution of the time series of the cumulated precipitation for a given period is divided into intervals each corresponding to 10% of the total distribution (decile). Gibbs and al. (***Gibbs and al., 1967***) proposed to group the deciles into classes of events as listed in figure 1.

Class	Percent	Period
Decile 1-2	20 % lower	Much below normal
Decile 3-4	20 % following	Below normal
Decile 5-6	20 % medium	Near normal
Decile 7-8	20 % following	Above normal
Decile 9-10	20 % higher	Much above normal

Fig.-1: Classes of events *(Gibbs and al. 1967)*

Palmer Drought Severity Index (PDSI)

Palmer (***Palmer, 1965***) developed this index based on the supply-and-demand concept of the water balance equation. The objective of the index is to measure the departure of the moisture supply for normal condition at a specific location. The PDSI is based on precipitation and temperature data, on the local Available Water Content (AWC) of the soil and other meteorological parameters. The Palmer Index has been widely used but it has some limitations. Among these we mention: the index is highly sensitive to the AWC of a soil type and that there are some difficulties in comparing the results obtained in regions with a different water balances. The Palmer Index varies between -6.0 and +6.0. The index classification is shown in Fig. 2.

PDSI	Class
4.0 or more	Extremely wet
3.0 to 3.99	Very wet
2.0 to 2.99	Moderately wet
1.0 to 1.99	Slightly wet
0.5 to 0.99	Incipient wet spell
0.49 to 0.49	Near normal
-0.5 to 0.99	Incipient dry spell
- 1.9 to 1.99	Mild Drought
- 2.0 to 2.99	Moderate drought
- 3.0 to 3.99	Severe drought
- 4.0 or less	Extreme drought

Fig. 2: Palmer index classification *(Palmer, 1965)*

Surface Water Supply Index (SWSI)

The Surface Water Supply Index (SWSI) was developed by Shafer and Dezman (***Shafer and al., 1982***) to complement the Palmer Index. It is designed for large topographic variations across a region and it accounts for snow accumulation and subsequent runoff. The procedure to determine the SWSI for a particular basin is as follows: monthly data are collected and summed for all the precipitation stations, reservoirs, and snowpack/streamflow measuring

stations over the basin. Each summed component is normalized using a long-term mean. Each component has a weight assigned to it depending on its typical contribution to the surface water within that basin.
Like the Palmer Index, the SWSI is centered on zero and has a range between -4.2 and +4.2. The SWSI suffers the same limitations discussed for the PSDI.

Standardized Precipitation Index (SPI)
The SPI was developed by McKee et al (***McKee and al., 1993***). It was designed to quantify the precipitation deficit for multiple time scales. These time scales reflect the impact of a drought on the availability of the different water resources. Soil moisture conditions respond to precipitation anomalies on a relatively short scale. Groundwater, streamflow, and reservoir storage reflect the longer-term precipitation anomalies. For these reasons, McKee et al. (1993) originally calculated the SPI for 3, 6, 12, 24, and 48 month time scales. The calculation of the index needs only precipitation record. It is computed by considering the precipitation anomaly with respect to the mean value for a given time scale, divided by its standard deviation. The precipitation is not a normal distribution, at least for time-scales less than one year. Therefore, the variable is adjusted so that the SPI is a gaussian distribution with zero mean and unit variance. A so adjusted index allows to compare values related to different regions. Moreover, because the SPI is normalized, wet and dry climates can be monitored in the same way. The classification shown in figure 3 is used to define drought intensities resulting from the SPI computation.

SPI values	Class
> 2	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
- 0.99 to 0.99	Near normal
- 1 to – 1.49	Moderate dry
- 1.5 to – 1.99	Severely dry
< - 2	Extreme dry

Fig. 3 - SPI classification (McKee and al., 1993)

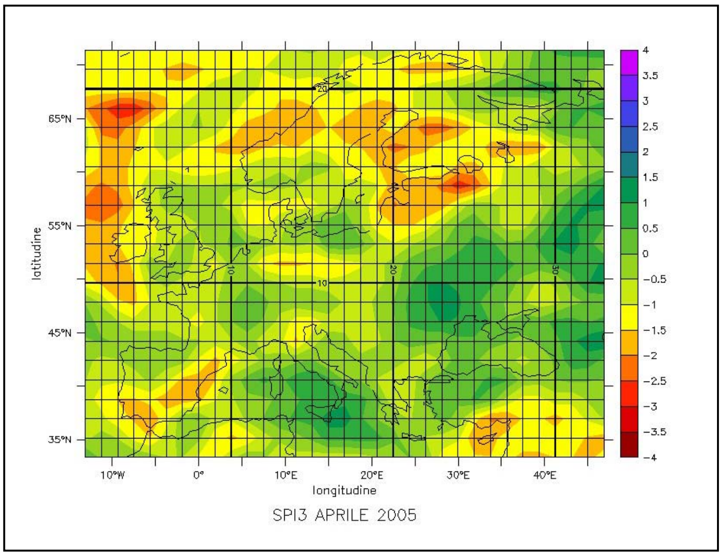
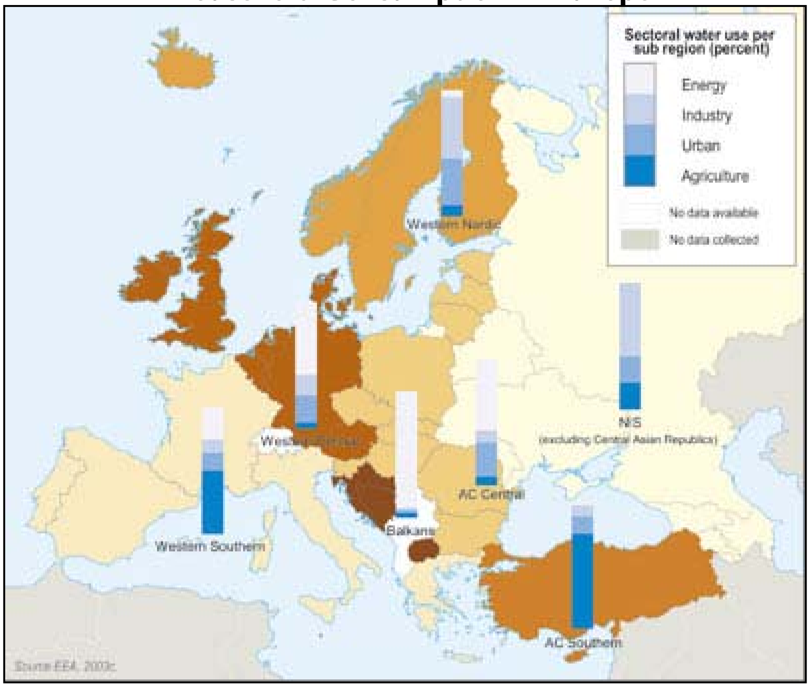


Fig. 4 - APAT drought bulletin

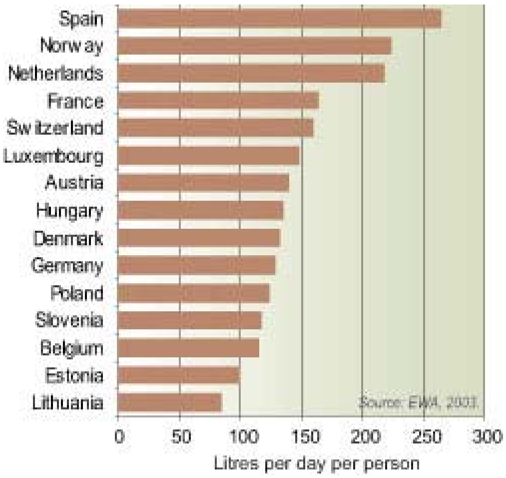
1.3 - WATER USE BY SECTOR IN EUROPE

On average, 42% of total water abstraction in Europe is used for agriculture, 23% for industry, 18 % for urban use and 18% for energy production. The breakdown of water consumption between the various economic sectors varies considerably from one region to another, depending on natural conditions and economic and demographic structures.
In France (64%), Germany (64%) and the Netherlands (55%), for example, most of the water abstracted is used to produce electricity. In Greece (88%), Spain (72%) and Portugal (59%), water is mostly used for irrigation. In Northern European countries such as Finland and Sweden, little water is used in agriculture. In contrast, cellulose and paper production, both highly intensive water-consuming industries, are significant activities and water is abstracted mainly for industrial purposes (66% and 28% respectively of total abstractions).
The role of irrigation differs between countries and regions because of climatic conditions. In Southern Europe, it is an essential element of agricultural production, whereas in Central and Northern Europe, irrigation is generally used to improve production in dry summers.
Southern European countries account for 74 % of the total irrigated area in Europe. This is expected to increase further following new irrigation development in some countries. In the central EU Accession Countries, changes in the economic structure and land ownership, and the consequent collapse of large-scale irrigation and drainage systems and agriculture production have been the main drivers for agriculture changes over the past 10 years.
Industrial water demand is especially pertinent to urban areas with high populations, as industries are usually located in these areas. The amount of water used by industry and the proportion of total abstraction accounted for by industry vary greatly between countries. Abstraction for industrial purposes in Europe has been decreasing since 1980.
The urban water use per capita in the Nordic countries is higher than in central Europe, varying between 104 m^3/inhabitant/y in Sweden to 262 m^3/inhabitant/y in Iceland. Some studies suggest that this high use is related to personal washing and dishwasher use. In central Europe, variations are between 68 m^3/inhabitant/y in Germany to 147, 122 and 106 m^3/inhabitant/y in Switzerland, Ireland and UK respectively. These variations reflect differences between the structure of water supply systems and water saving measures applied.
The relative high use per capita in Mediterranean countries, around 120 m^3/inhabitant/y in 2001, reflects their hot climate (increase in water for showering, garden use, public services), and the trend reflects changes in lifestyle derived from increasing urbanization
The southern Accession Countries use 11% of their abstraction for urban purposes and the same percentage of their consumptive uses. Urban water use, from freshwater resources has declined sharply in the last two years. Desalination plants provide water to main cities and the coastal tourist areas to avoid water shortages and rationing water to population.

Household Consumption in Europe



[Source: EEA - 2003]



[Source: EWA - 2003]

The northern Accession Countries use 21% of their abstraction for urban purposes which accounts for 54% of their consumptive uses. Bulgaria, Romania and Slovenia, with 136, 110 and 110 m^3/inhabitant/y respectively, have the highest urban water use per capita. The high levels of use in Romania and Bulgaria can be explained by the number of breakdowns in water-supply networks, lack of water metering, water losses and water wastage. Structural reforms are taking place slowly.

The share of urban water in southern Europe is 16% of its total abstraction and 21% of its consumptive uses, the lowest in Europe together with the southern Accession Countries.

Spanish data express total water production for household consumption, not net consumption; comparisons can give a wrong perception of excessive water consumption.

APPENDIX 2 - DROUGHT PLANNING AND MANAGEMENT (Chapter II)

- ## Historical droughts characterization (B.1)

Meteorologic indicators are based on measures of this kind of variables, including precipitation, air temperature or evaporation. Since hydrologic indices, like streamflow, are a function of meteorological conditions, such as rainfall, measuring precipitation may provide a more direct indication of drought. Since rainfall measurements alone do not indicate the antecedent conditions of moistness or dryness, some indicators make use of mean air temperature to reflect this “climatic moisture demand”.
Agricultural indicators typically consider soil water and crop parameters, such as soil moisture in the top 100 cm of soil, crop yields, or cumulative precipitation and temperature since the beginning of spring. Perhaps the best known of these indices is the Palmer Index, which refers to either the Palmer Drought Severity Index (PDSI) or the Palmer Hydrologic Drought Index (PHDI). The PDSI attempts to track weather patterns and the PHDI tracks hydrologic factors such as soil moisture, lake level or streamflow. Fundamentally, the index provides monthly values corresponding to degrees of wetness or dryness, where drought is a function of the weighted differences between actual precipitation and precipitation requirement. The precipitation requirement is a function of water balance terms : potential evapotranspiration, soil recharge, surface runoff and soil moisture loss.
Hydrologic indicators generally used to define triggers are physical measures of a system, such as reservoir storage, streamflow levels or groundwater supply. Reservoir storage is useful because it is relatively easy to determine. However, drought severity can be underestimated for several reasons : reservoir levels may not reflect increased demands associated to dry periods, may be inappropriate for small reservoirs, and many reservoirs are operated on a rule curve which may disguise early drought indications.
Streamflow levels are often used as drought indicators. Streamflow can be related to the total moisture of a basin as well, since it is a function of soil moisture, groundwater levels, runoff and precipitation. However, streamflow may not be appropriate in some instances. Small streams may respond too quickly to short periods of dryness, large streams may react too slowly to the onset of drought, and streamflow can be strongly influenced by basin characteristics, such as the natural topography and geology and the man-made development.
Groundwater is a major source of water in many parts of the country, and its elevation or drawdown level is often used as a drought indicator. As an indicator, groundwater level may be limited by a poor understanding of the aquifer stratigraphy and recharge rates, as well as other factors that may influence groundwater level.

- ## WATER MANAGEMENT IN DROUGHT PERIODS IN FRANCE

1 - BALANCE OF NEEDS – RESOURCES

1.1 - Quantities of water available in France

On the whole, based on the annual average for the whole country, there is not a shortage of water in France. Indeed, it is estimated that 450 billion m^3 of water are contributed through rainfall each year (this represents an average of 330 billion m^3 rainfall in a ten-year dry year). Out of this total, 270 billion m^3 are withdrawn through evaporation or by vegetation: this is evapotranspiration. The balance, which should be considered in addition to ten billion m^3

imported by cross-border rivers, representing a total of 190 billion m^3, drains away through surface runoffs or infiltration. Out of this total, nearly 70 billion m^3 run off in high water-level periods and can only be used very partially. As such, the most regular portion of these flows, which is available for human activity, comes to only 110 billion m3, falling to 60 billion m^3 in ten-year dry years.
The value of this stock of water, which varies considerably from one year to the next, also sees significant changes from one season to another and from one region to another. In addition to this unequal breakdown in space and over time, it is important to note the unequal distribution of natural water collection structures: the four main rivers in France collect nearly 63% of the water in the territory.
In light of such variability, it is easy to see how the use of the resource required to fulfil needs varies considerably from one region to the next. All the more so because these needs vary significantly in terms of geographic and temporal factors.

1.2 - Water withdrawals in France

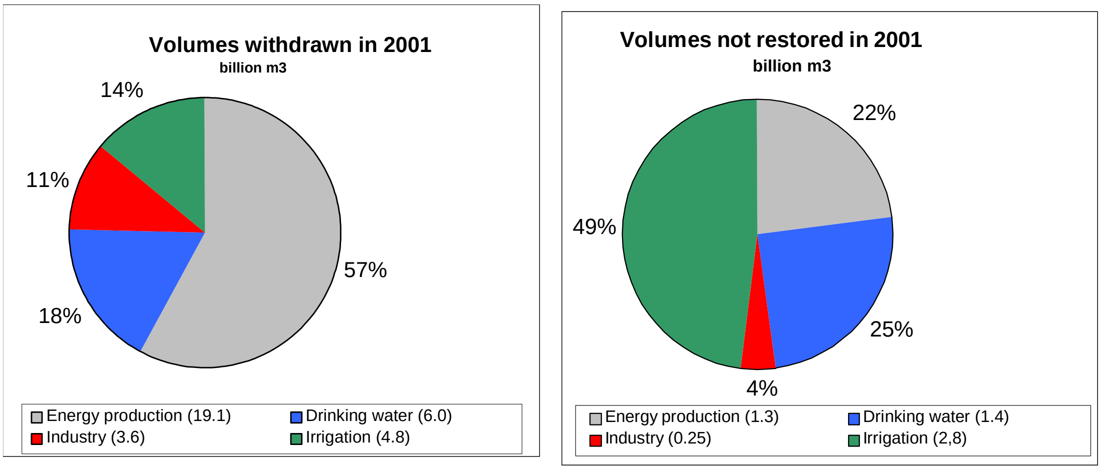


Figure E: breakdown of volumes of water withdrawn and consumed per use in 2001 in Metropolitan France. Source: Agences de l'Eau.

Each year, around 34 billion m^3 of soft water are withdrawn in Metropolitan France for human activities (drinking water production, industry, irrigation, and cooling of thermal power production plants, figure E), excluding withdrawals carried out to supply navigation channels and hydroelectric facilities. This assessment, which appears to be favourable, must be qualified. Indeed, it masks a wide range of situations that vary from one region, season and year to the next.
The production of electricity in thermal plants (flame and nuclear) is by far the sector that uses the largest quantities of water. In 2001, 57 % of the volumes withdrawn were used for cooling thermal plants, but a large percentage of this water (94 %) is put back into the watercourses after being used for cooling the plants. The water not returned to watercourses accounts for 23 % of consumption in France. This consumption is spread over the year.
The irrigation of crops represents 14 % of volumes withdrawn, although this figure masks the importance of the pressure of this use on resources. Indeed, irrigation, excluding gravity irrigation, does not allow any of the resource to be returned and the portion of unreturned volumes used for irrigation purposes represents 49 % of the volumes consumed each year in France over a very short period (four months from June to September). During these periods, in regions with high levels of irrigation, the water consumed by agriculture accounts for over 80% of water consumption for human activities.

Withdrawals for the production of drinking water represent 18 % of the volumes withdrawn and around 24 % of unreturned volumes. They are spread over the twelve months of the year. Lastly, the industrial sector withdraws relatively low quantities of water each year (11 % of the total national volume). Furthermore, this sector, as with the power production sector, does not consume large volumes of water.
Water withdrawals increased through to the end of the 80's, but on the whole, have tended to remain the same over the last fifteen years. In 1955, these volumes were estimated at 18,5 billion m^3 compared to 34 in 1990. A significant percentage of this increase is due to the development of thermal plants as of the 70's.
The volumes withdrawn for the irrigation of crops have also increased in light of the growth in irrigated surface areas. Indeed, these have grown from 400000 hectares in 1955 to 1,1 million hectares in 1988 and 1,6 million hectares in 2000. However, the last figure has changed relatively little since 1992. This strong development of irrigation reflects the combination of particularly dry climatic episodes (1976,1989-1991), and has been consolidated by the common agricultural policy, which introduced specific measures to directly support irrigated crops, and more generally the tendentious development of agricultural production methods. Indeed, irrigation makes it possible to increase yields and ensure that they vary less.

1.3 - Balance of demands - resources

In light of the very high variability of water resources and needs over time and in space, a simple comparison between annual inputs (450 billion m^3) and annual needs (34 billion m^3) is not particularly significant. It can even give a false sense of security.
The drought in 2003 illustrates this statement: the combination of a lasting period of very low pluviometry and high temperatures, and their significant needs, resulted in a general breakdown in the balance of supply and demand in several French regions.

2 - CRISIS MANAGEMENT BY THE PUBLIC AUTHORITIES

2.1 - 1992 water law – objectives and means

The principles set forth in article 1 of the 1992 Water Law enable the french state to intervene in the field of water management to make general interests prevail over specific interests: water is promoted to the position of the nation's common heritage and protecting, valuing and developing this usable resource in accordance with natural balances is of general interest. The law seeks to guarantee a balanced management of water resources, making it possible for prefects to share these resources in the event of a crisis.
Several tools are used to take into consideration agricultural demand for water and the impact of agricultural activities on water resources, i.e. on the flow-rates of watercourses and on levels of groundwater. Certain tools are designed to encourage water savings, prevent crisis situations and plan for withdrawals of resources in order to balance demand and availabilities for the resource, while others aim to limit the impact of crisis situations when they occur:

- Procedures for the authorisation and declaration of activities likely to have negative consequences on the natural environment, notably "reducing water resources" and "seriously affecting the quality or diversity of aquatic environments".
- The ranking of certain basins in which frequent imbalances affect the resource as water sharing zones (structural deficit zones), ensuring that almost all withdrawals are covered by the authorisation procedure and enabling the authorities to manage demand for water.

- The implementation of water management and development blueprints (Schéma Directeurs d'Aménagement et de Gestion de l'eau, SDAGE), defining notably, at specific points on key watercourses, two flow-rate values to be incorporated into management procedures. The first is the target low-water level flow-rate (débit objectif d'étiage, DOE), which represents the flow-rate above which all uses and the correct functioning of the aquatic environment are guaranteed. The second is the crisis flow-rate (débit de crise, DCR) below which the environment and drinking water supplies are at risk. Healthy management must guarantee the target low-water level flow-rate. However, whatever the circumstances, the crisis flow-rate must be safeguarded. To achieve this, various tools are made available to the public authorities.
- In the event of a proven crisis, i.e. as soon as the abovementioned flow-rate limits are exceeded, various measures may be taken to temporarily limit or suspend uses of water.

French law does not task the State to share out the resource using its policing powers, but rather seeks to ensure that the resource – common heritage – is managed by all stakeholders, with the State intervening to provide support or act as a safeguard.

2.2 - Implementation

The departmental nature of exercising regulations in the event of a crisis should not go against the principle of fairness between users and the necessary upstream–downstream solidarity for river basins in line with the catchment logic. Indeed, the State has set up an organisation for each sub-basin, with prefect-coordinators responsible for each catchment basin, working with their colleagues concerned to steer moves to draft and formalise contingency plans.

In this way, framework decrees have been drawn up for catchment basins, enabling the rules and thresholds for triggering restriction measures to be defined in advance. This approach greatly facilitates the exercising of regulations during crisis periods. It also makes it possible to have greater transparency and better cooperation.

The document drawn up by the prefects indicates the warning levels (which may be gradual) and the measures to be taken when they are passed: uses to be suspended or scaled down, priority uses to be maintained – a definition of the priority of uses should ideally be drafted. The implementation of these measures in cases when thresholds are passed is stipulated in a decree. Several incompressible needs have been identified, and these will need to be guaranteed for civil security, public health and national defence: regulated nuclear facilities, hospitals, fire-fighting facilities, etc.

The measures taken by the prefect must be appropriate. This means that they must be sufficient in light of the severity of the situation and must be in proportion.

The prefects are also setting up contingency management offices with a view to organising cooperation between users. They may bring together the various categories of users directly concerned as well as the fishing federations, nature protection associations, and local water commissions when relevant.

Cooperation is the watchword for any water management system. Indeed, the law sanctions cooperation in the process for drawing up SDAGE, bringing together the players from the water field for their development and monitoring phases.

2.3 - Which uses are concerned by restriction measures?

The public authorities assess what measures need to be taken to combat drought in light of local circumstances (weakness of flow-rates for tables and watercourses, scale of withdrawals

on the resource). Drinking water supplies remain a priority use, but it is also essential to protect and reconcile economic uses of water with efforts to safeguard aquatic environments.
Measures to limit uses of water may concern: the use of water for agricultural needs, the use of water for washing private vehicles or filling private swimming pools, the watering of public and private garden areas, the filling of man-made lakes, etc.
As water is a common resource, each person is responsible for preserving it. If they fail to comply with the restriction measures defined in the prefectoral decrees, they may be fined up to 1500 euros or even 3000 euros for repeating offenders.

3- DROUGHT ACTION PLAN IMPLEMENTED AS OF 2004

The drought of 2003 led to a high level of involvement by the public authorities: in Metropolitan France, prefects from 77 departments took measures to limit water use, an unprecedented figure. Several difficulties or shortcomings were identified, highlighting the need to improve the organisation and implementation of the system for managing drought situations.
Indeed, the summer of 2003 will remain in the minds of the French in the same way as the summer of 1976 in the past. Nevertheless, it is important to note that the 2003 drought, although it began as of February, following a very wet period with high levels of groundwater, started relatively late compared with that of 1976. Against a backdrop of global warming, we are not safe from periods of drought that could be more serious in terms of not only their duration but also the occurrence of several dry years one after the other as at the end of the 80’s, which means that it is essential to have suitable drought management tools and procedures and remain attentive to the hydrologic situation at all times.
It is vital to plan ahead for crises for the measures limiting water withdrawals to be effective. Anticipating drought and heat-wave periods more effectively involves a more effective monitoring of water resources, advance planning of measures and a strengthening of coordination for each river basin in order to guarantee upstream–downstream solidarity. It should be possible to meet these challenges by bolstering the principle of framework decrees and setting up forecasting indicators and scenarios.
Despite the intensity of this drought, France has failed to conduct a complete quantified appraisal of the consequences on aquatic environments. One lesson to be learned from the experience of 2003 is that the monitoring tools need to be enhanced, working with the various national partners, focusing on aquatic environments and the monitoring of temperatures and dissolved oxygen in watercourses. Under the water framework directive, it is necessary to know the status of aquatic environments and ramp up surveillance in problem areas. As such, by 2006, the surface water surveillance networks will need to have been adapted to the various issues and more importantly the piezometric monitoring of groundwater will need to have been strengthened. This upgrading must take into consideration the needs for monitoring droughts in addition to the issue of flooding, notably at basin heads.
It is necessary to plan ahead for crises in order to be prepared to cope with new periods of dry weather. A hydrological tracking system has been in place since 1989, enabling weekly or monthly reports on the hydrological situation to be published for water players at the national level and in the basins, regions and departments. A report on the national hydrological situation is published each month by the water division, based on these local reports.
It also seemed necessary to set up a monitoring committee to coordinate key communications actions, assess the management of crises and their consequences on the environments. This committee groups together all the players whose activities are linked to aquatic environments and who may be concerned by any measures taken.
The quantitative management of water cannot focus solely on the management of crises, at the risk of crises occurring again each year. The situation for numerous water resources –

surface or ground water – represents a chronic imbalance: the withdrawals made every year prevent a sustainable renewal of the resource and a sufficient contribution to supplies for aquatic environments (marshes, rivers) that depend on it. In these degraded situations, the compatibility between the different uses, including in first place drinking water, is no longer guaranteed, and the effects on the ecological status of aquatic environments may be serious. The framework directive on water makes it obligatory to achieve the good ecological status of watercourses and the good quantitative status of groundwater.
The return to a sustainable balance between withdrawals and resources represents one of the key objectives of the reform of the water policy, reflected in a bill submitted to the French council of ministers at the end of 2004 with new measures to ensure the sustainable management of water resources.

• COPING WITH DROUGHT – THE EXPERIENCE OF CYPRUS

ABSTRACT
This example illustrates (in a simplified way) how Cyprus manages water scarcity resulting from supply/demand imbalances and presents the measures taken during drought conditions. A brief overview of water balance and use of water in Cyprus provides the necessary background for the presentation of Cyprus experience.

1 - INTRODUCTION

Water scarcity is a reality in Cyprus. Like other Mediterranean countries, Cyprus has a semi-arid climate and limited water resources which depend almost entirely on rainfall.
Precipitations are highly variable with considerable regional variations and often two or three, or sometimes up to six consecutive dry years, are observed. Statistical analysis of rainfalls in Cyprus reveals a stepped drop in the early 70's, which persists. Furthermore, Cyprus has numerous small but of great importance catchments, none of which provide perennial flow.
The limited availability of water resources and increasing water demand are the principal causes of water scarcity problem. Presently, water demand for various uses exceeds the amount of water available, while in recent years, the problem has been exacerbated due to the observed prolonged periods of reduced precipitations.

2- WATER BALANCE

The mean annual precipitations over the first 70 years of the last century amount to approximately 500 millimetres, whereas during the last thirty years (1971-2000) it has dropped to 460 millimetres. The quantity of water, which corresponds to the total surface of the Government controlled area, is 2670 million cubic metres (Mm^3), but only 14 % (370 Mm^3) are available for development since the remaining 86% return to atmosphere through evapotranspiration (figure F). The mean annual quantity of 370 Mm^3 of water is distributed between surface and groundwater (ratio 1,75:1).

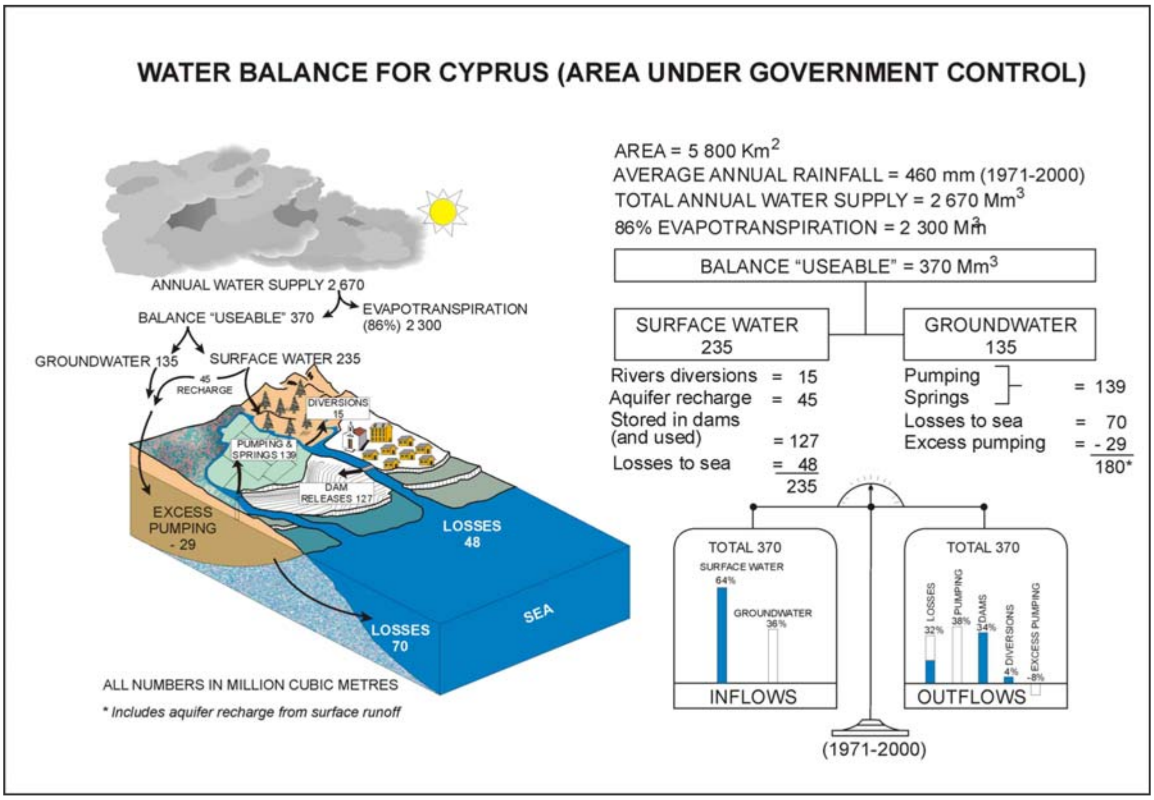


Figure F : Water balance

3 - WATER USE

Domestic use and irrigation are the two main water-consuming sectors in Cyprus (figure G). Irrigated agriculture accounts for about 69 % of total water demand and the domestic sector which includes the tourist and industrial sector for 25%. The remaining 6% are used for industrial (1 %) and environmental purposes (5%). The tourist demand accounts for about 5%.

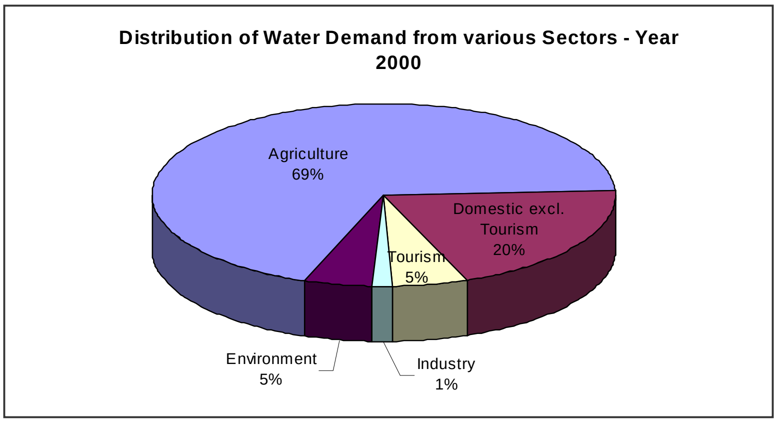


Figure G : Water demand by sector (Source: WDD - FAO, 2002)

4 - LONG-TERM WATER SCARCITY MANAGEMENT IN CYPRUS

The Republic of Cyprus, recognizing the need for effective and efficient utilization of its limited water resources, began the implementation of a Water Master Plan during the late sixties, with the objective to satisfy, in a sustainable way, the different users of water and to safeguard human and other forms of life.

Several measures were used to increase availability of water and decrease water demand. On the supply side the dams capacity was increased from 6 Mm^3 in 1960 to 307,5 Mm^3 today (figures H and I). Boreholes were drilled for domestic and irrigation purposes, and water treatment plants and recharge works were constructed. On the demand side, the installation of improved farm irrigation systems was encouraged, the construction of modern efficient conveyance and distribution systems with minor losses was promoted and water charges were imposed both for domestic water supply and for irrigation water. Leakage detection methods are applied on water distribution systems to reduce water losses and real time telemonitoring and telecontrol are now used in the most important projects to optimize operation and maintenance.

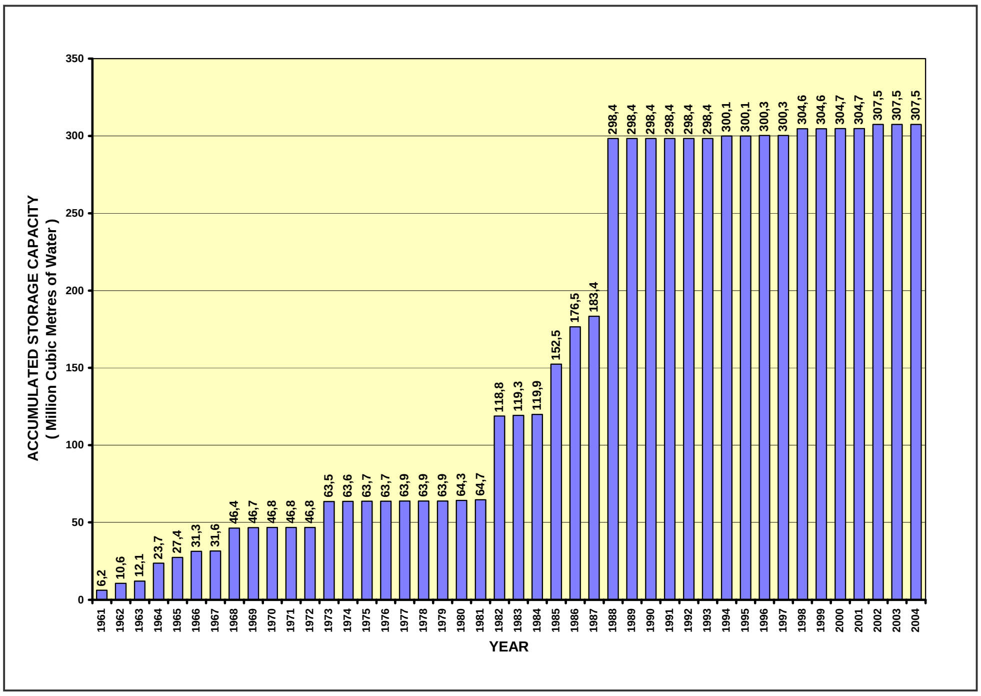


Figure H : Dam construction 1961 - 2004

After substantially completing the implementation of the Master Plan, the available water was still not enough to satisfy the water demand for domestic and irrigation needs. An analysis of the situation indicated that water shortage was due to a great extent to the climatic change, which caused a reduction of approximately 20 % in the precipitation and resulted in a 40 % reduction in surface runoff. In addition, more frequent occurrence of extreme drought events is experienced. Furthermore, there was also a rapid increase in the number of tourist arrivals in Cyprus, which placed additional seasonal demands for water.

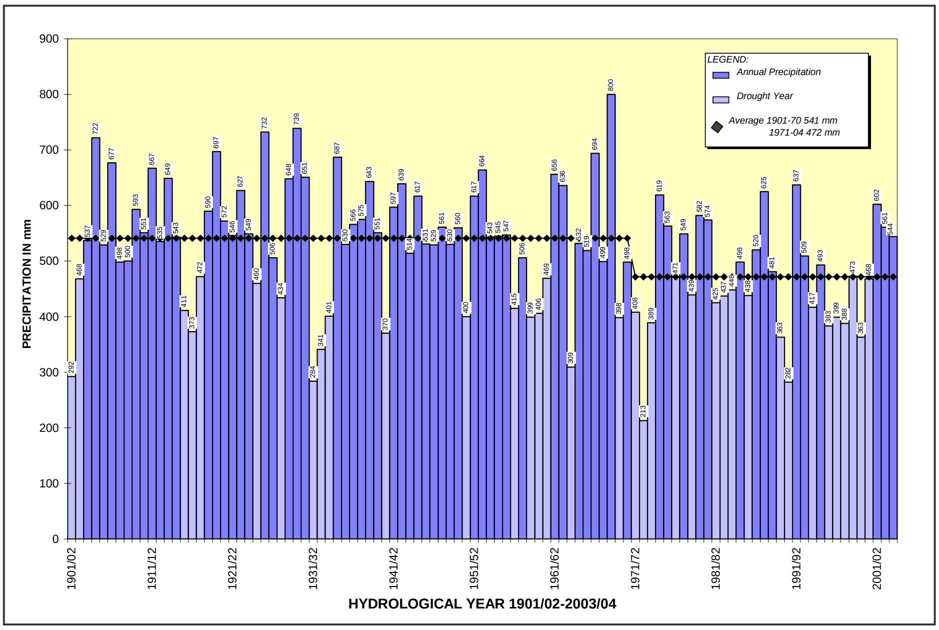


Figure I : Inflow of water to the dams 1987 – 2004

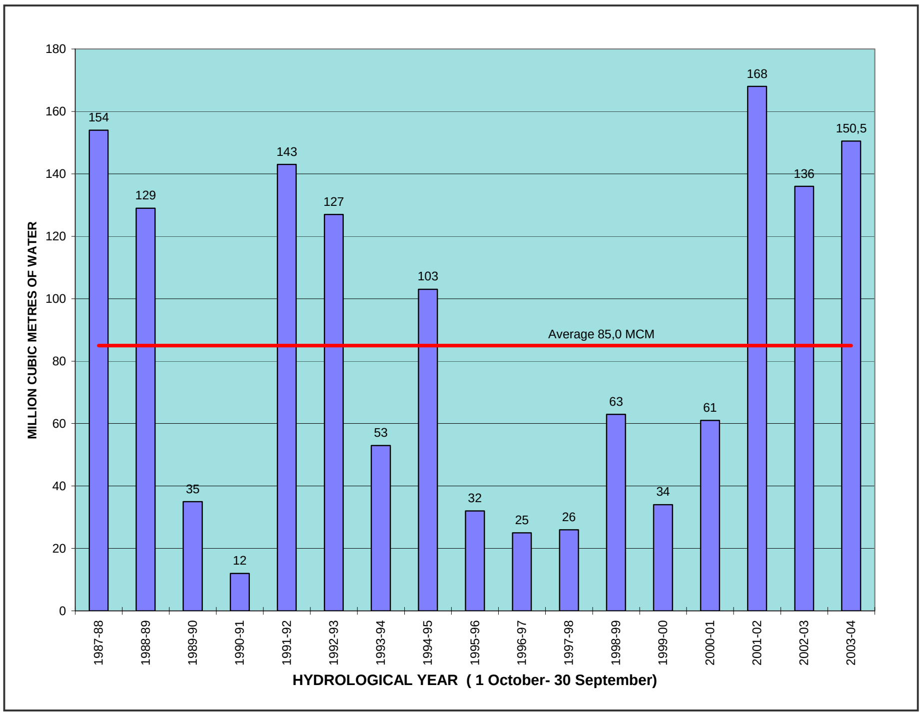


Figure J : Cyprus annual precipitation and average 1901/1970 – 1971/2004
(Area under government control)

The construction of surface water reservoirs was meant to provide a certain amount of resilience to the water resources system during low rainfall years by creating multi-year storage. However, several consecutive years of rainfall, which are significantly below normal, can lead to drought conditions (figure J).
The groundwater resources of the island have been the most obvious and easily accessible sources of water for many years and, as a result, they have been heavily over pumped especially during periods of drought. This has led to seawater intrusion in many coastal aquifers and deterioration of both quality and quantity of groundwater.

Consequently, the Government of Cyprus had to revise its general water policy in order to promote effective water governance and to provide water security so that every person can access safe water. The revised policy objective is to increase the water security by making the water supply for domestic needs independent from the climatic behavior, to increase the reliability of water supply and to reduce water demand. To achieve this purpose, Cyprus had to turn to non-conventional water resources such as seawater desalinization for securing drinking water supply and recycling treated municipal effluents for irrigation and groundwater recharge purposes. Reuse schemes using treated domestic effluents are now in operation and many more are under study or construction. By these means, water supply for irrigation and groundwater recharge will increase.
The introduction of desalinization has enabled the Government to lift the water restrictions for domestic water supply and, since January 2001, the supply of drinking water to towns and villages is continuous and without any restrictions.
Furthermore, the Government decided to revise the existing legal and institutional framework in order to create an enabling environment for promoting effective water governance, allowing all stakeholders to work together for effective water management. In this context, efforts are now focusing on establishing a new Directorate for Integrated Water Management, which is proposed to manage the island water resources within the framework of the national water policy in a holistic way.
At the same time, water demand management has always been an integral part of the Government's policy about water. The current Government policy also provides demand management measures such as the restructuration of agricultural cultivations and the promotion of cultivations which require less water, promotes water saving measures and awareness of public for proper use of water, establishes subsidies to keep good quality domestic water, the metering of water services and use of rising block-tariffs for domestic water supply, the application of a quota system for the allocation of government irrigation water in combination with penalty charges for over consumption, etc.

5 - MEASURES IN PERIODS OF DROUGHT

Most recently, low rainfall in the years from 1996 to 2000 has produced drought conditions in Cyprus creating an even bigger gap between supply and demand (figure K).

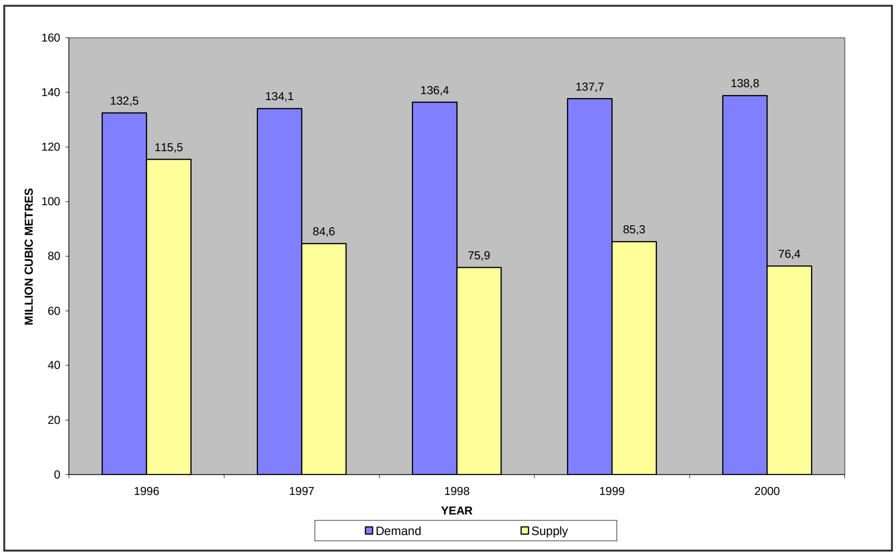


Figure K : Government Water Works – Water demand and supply balance 1996 – 2000. It has been estimated that the available supplies of water during the period 1996 - 2000 from all the sources in the areas covered by the Government Water Works were of 87,5 Mm^3 on average. The water demand in the years 1996 to 2000 was calculated to be on average 136 Mm^3, of which 56 Mm^3 were dedicated to towns and villages and 80 Mm^3 to irrigation.

Drought has caused a variety of socio-economic problems in Cyprus and various measures were implemented to face the situation :

- Water supply restrictions
- Demand management measures
- Supply enhancement measures

Furthermore a Drought Committee was set up with mandate to examine and assess the measures proposed by the Water Development Department in consultation with other public or private bodies and to monitor and coordinate without bureaucratic procedures the implementation of the measures finally approved by the Council of Ministers.

5.1 - Water supply restrictions

Water rationing measures were introduced. Water was supplied to households for as little as two or three days per week and only a few hours each time. Irrigation water to seasonal crops was almost completely restricted and water allocated to permanent crops was reduced to the absolute minimum needed for survival. Furthermore, greenhouses were only receiving water for one plantation period instead of two normally, while animal husbandry and industry suffered a reduction in supply of about 28 %. In general, water supply restrictions amounted to over 20 % for domestic uses and 30 to 70 % for irrigation purposes.
It is true that in the selection of these restrictions, there was no unanimity in the discussions between the different socio-economic partners. The most severe objections or reservations were raised by :

- Agricultural organisations who demanded that the farmers be compensated by the Government for the lost income due to the unavailability or shortage of water.
- Hotel owners who demanded that the tourist industry be given either a zero or a very small reduction in the water supply. The same line of action was supported by the mayors of the coastal tourist towns.
- Environmental organisations who argued that reducing quantity and timing of supply of water may not be an effective measure especially when compared to the hardships and dangers these measures inherently have.

5.2 - Demand management measures

Measures adopted were addressed to the two main uses of water, domestic and irrigation sectors.

5.2.1 - Domestic sector

- Establishment of subsidies for saving good quality domestic water. For example, a subsidy was granted for the drilling of private boreholes within the Water Boards and Municipalities areas which are served by the Government Water Works and for the connection of private boreholes to toilet tanks (figure L). Subsidies were also granted for the installation of grey water recycling systems (figure M) in houses, schools, etc.
- Distribution of sealed plastic water bags, free of charge, to be used in the toilet flush tanks as displacers, thus reducing the volume of flush.

- Reduction of the "unaccounted for water" in the distribution systems of the Water Boards, Municipalities and Villages.
- Amendment and strict implementation of the Law 1/91 which prohibits the use of a hosepipe for the washing of cars and pavements (increase of fine of approximately 26 to € 52).
- Education and Awareness Campaign about the need for water conservation.

5.2.2 - Irrigation sector

- Subsidy for the installation of a system to collect rain water from the roofs of the greenhouses; subsidies were also envisaged for the use of improved irrigation systems.
- Application of a quota system for the allocation of government irrigation water in combination with penalty charges for over consumption.
- No supply of water to new irrigation areas.
- Education of farmers for a better use of water and the adoption of new low water demand crops.

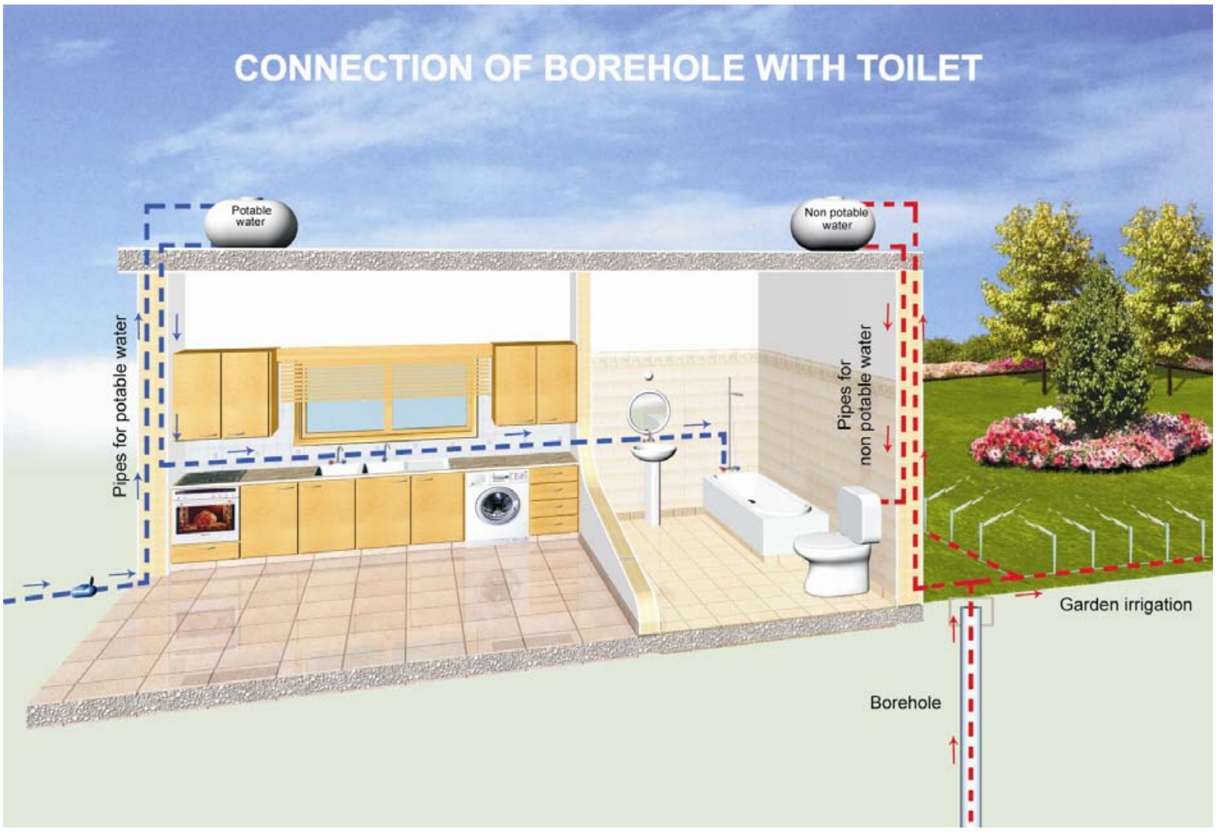


Figure L : Boreholes connection with toilet

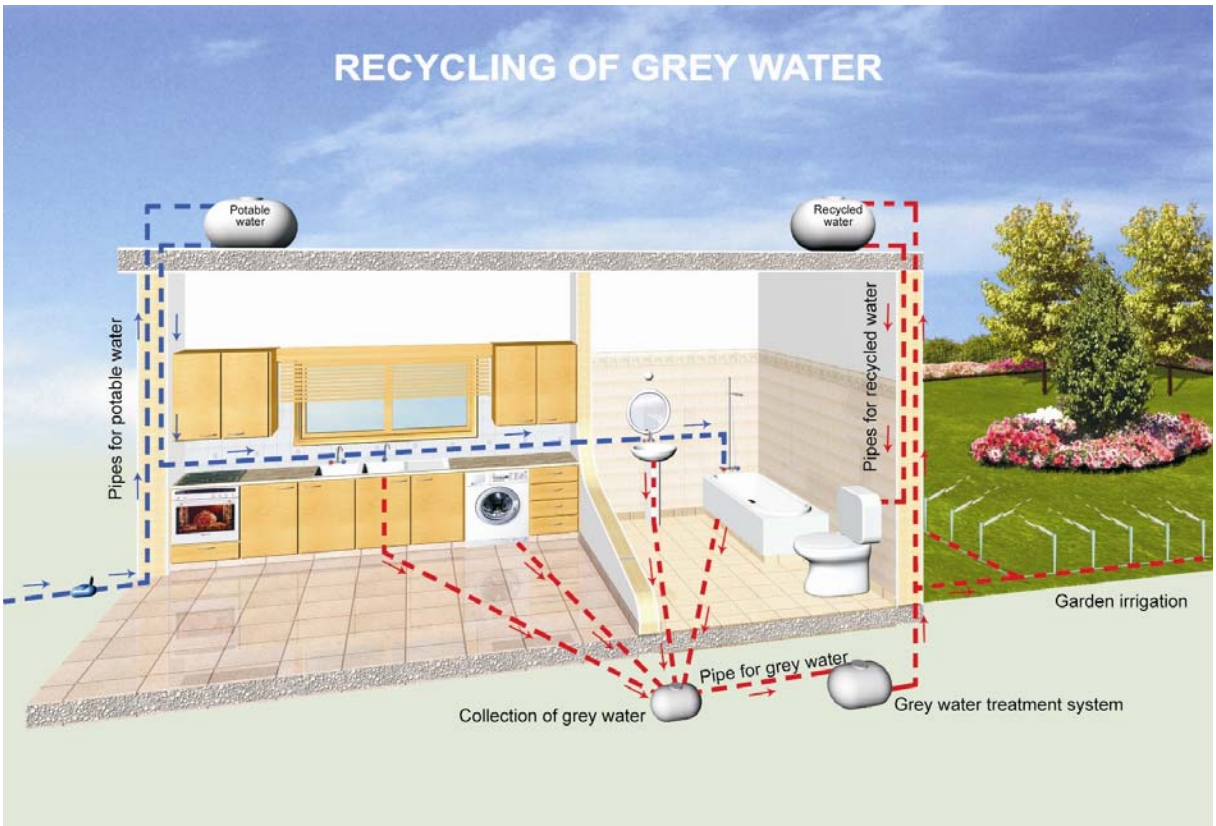


Figure M : Grey water recycling systems

5.3 - Supply enhancement measures

The immediate measures to enhance water supply were :

- Expansion of the existing desalinization plant (at Dhekelia) from 25000 to 40000 m^3/day.
- Acceleration of the process for a new desalinization plant (west of Larnaca) with a capacity of 52000 m^3/day. The main aim of the desalinization plants policy was to eliminate the dependency of towns and tourist areas on the unpredictability of climate and rainfalls and thus ensure that water is provided on a continuous basis to households. Environmental organisations, however, were against this measure because of its high cost and because of environmental concerns.
- Use of recycled water : farmers were apprehensive in using recycled water for irrigation as it was the first time that recycled water was commercially used at such a large scale. Water scarcity, however, has faded out the reluctance of the farmers in using recycled water.
- Emergency measures to temporarily increase the water supply for drinking purposes to both urban and rural areas (sinking of wells, requisition of private boreholes, transfers of water using pipes or trucks).

5.4 - Efficiency of measures

The restrictions in the water supply were generally well accepted by the public. Almost everybody realized the necessity of imposing such restrictions due to the existing large gap between supply and demand. During the application of the restriction measures, the consumption decreased in every economic sector. The results were deemed as satisfactory.

The demand management measures announced by the Government were readily accepted by water consumers as evidenced by the large number of applications filed, especially for those measures bearing governmental subsidies. The largest numbers of applications were filed in Nicosia, which faced the most acute water shortage.
The third and last bundle of actions in combating the prevailing drought, i.e. increase in water supply via the erection of a new desalinization plant and use of recycled water, found approval by the majority of people.
The emergency plan for combating lasting drought was quite successful. The objectives of the plan were fully met. The “water consciousness” of the public towards this scarce resource was high and vivid, making the introduction of measures rather easy.

6 - CONCLUSIONS

The key conclusions are :

- In Cyprus, water is a commodity facing depletion. Droughts are a very usual phenomenon and often two or three consecutive dry years are observed.
- In view of the possible future increases in drought frequency, not only in the Mediterranean region but across Europe as well, as a consequence of climate change, Cyprus vulnerability to drought may increase.
- Water availability is affected by climate changes. Cyprus has experienced a rainfall reduction of about 20%, which resulted in a 40% reduction in surface runoff.
- The use of storage reservoirs helps overcome the uneven distribution of natural water resources over time and reduces vulnerability to short-term droughts. Nevertheless, when several dry winters cluster together, severe drought conditions may develop. Such infrastructure measures, however, can have negative environmental effects and are nowadays considered with extreme caution.
- In certain semi-arid areas, wastewater reuse and seawater desalinization may constitute vital alternative sources of supply. Wastewater reuse is best applied during drought conditions.
- The recent drought has increased public awareness of the water resources fragility and has clearly showed the economic, social and environmental consequences of a drought.
- A suitable response to a drought largely depends on adequate management of the water resource system.
- The adopted measures have significantly increased capabilities to withstand the impact of drought episodes.
- Demand management measures such as the use of economic instruments, leakage control, public education programmes, water reuse, etc, offer the potential to ensure that limited water resources are used in a sustainable way.

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• WATER CONSERVATION AND SMALL DAMS IN TUNISIA

A major critical problem of agriculture in much of Tunisia is the recurring deficiency of soil moisture for crops and range production. The central farming regions (200-400 mm) and the intermountain plains (400-550mm) in the north-western part of country are particularly affected. Because of non-uniformity of precipitation patterns, many sub-humid region areas (400-550 mm) are also influenced by moisture shortage during certain periods in the growing season.
The enormity of the problem is particularly evident in the annual variation of cereal yields. The total national production fluctuates commonly in a ratio of 1 to 5 depending on the amount and timing of rainfall. The soil moisture during the planting season affects also the hectares used for cereals.

1 - WATER RESOURCES PROBLEMS

There is an estimate that about 29 billion m^3 of rainfall are lost by evaporation and transpiration and 0,5 billion m^3 lost to the sea and salty lakes. This water could be retained to improve the over-exploited water table. Furthermore some 10000 hectares of arable land are annually sterilized in these reservoirs. Consequently, the dams lose this same volume of their storage capacity.

2 - STRATEGY OF SOIL AND WATER CONSERVATION

A long-term strategy stressing the necessity to conserve the national soil resources and to protect the existing infrastructure was set up. A national programme to invest in soil and water conservation was established, and an estimated budget of almost 500 million dinars was used to cover the cost of all needed interventions from 1991 to the year 2002. The introduction of new farming policies based on the use of technology and adequate water harvesting practices are adopted.
This national wide project gave the opportunity to manage one million hectares and to maintain and rehabilitate 440000 ha in watersheds and cereal production regions. It has permit also to construct 580 mountain lakes (small dams with an average of capacity of 100000 m^3), 2000 small check dams to trap sediments and 2000 diversion dams for water harvesting.
After the evaluation and the success of this program, A new national plan was established for the period 2002-2011. An estimated budget of 780 million dinars was proposed to manage and maintain 1,5 million hectares in watersheds and to construct 1000 small dams, 3000 structures to recharge aquifers, 1500 diversion structures for water harvesting, 5500 protective structures for water ways and the management of 15000 ha by traditional techniques of soil and water conservation. The objectives of soil and water conservation plan are:
1- To reduce the loss arable land estimated to 10.000 ha/year.
2- To maintain soil fertility in order to avoid the decrease in soil productivity.
3- To retain the 500 million cubic meters of run-off water (which are actually lost in the sea and salty lakes), by carrying out water and soil conservation works.
4- To recover arable land by establishing structures (jessours) in the south of Tunisia.
5- To improve the life span of dams, which are threatened by sedimentation at the rate of 25.8 million cubic meter/year.
6- To reduce damages caused in valleys and plains by floods.
7- To implement a new farming policy, which aims at utilizing anti erosion in order to increase production.

8- To create job opportunities and to improve revenues of rural population in the marginal areas.

The water harvesting interventions, as planned for in the management plan have covered different regions and proposed to reach an ambitious objective, particularity due to the fact that the anti-erosive interventions call not only for mechanical and physical measures such as (bank construction, waterway lying, drop structures, farm ponds...) but also agricultural developing interventions (fruit tree planting, forage crop, range management, change in crop production) with an effective farmer's participation.
Water and soil conservation division in collaboration with other technical institutions is aiming at increasing production to reach food self sufficiency, improving revenues and standards of living of the rural population, creating job opportunities and reducing the rural urban migration.

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3- AN INTEGRATED WATER AND CONSERVATION APPROACH

In order to reach the objectives of an adequate land management, an integrated approach, based on a methodological study and a planning, which permit to find practical and rational solutions to the problems encountered in water scarcity, will be adopted
The approach is to protect the downstream of watersheds from sedimentation, and floods, and to improve revenues of farmers and livestock herders established in the upper parts of the watersheds. The integrated conservation management will be considered at three levels:
- ***Technical and environmental:*** It is fundamental to define guidelines to help prevent and fight against water scarcity, and to consider the watershed management techniques which aim at maintaining the fertility of the soil in the watershed and reducing the transport of sediment to the dam reservoirs taking in care environmental aspects.
- ***Economical:*** In order to make the best micro and macro economical return of the conservation work, it is crucially important to count on the participation of the land-user. It is not expected that this one will change his usual practices unless he perceives that the change is directed towards his interests, that it will minimise his risks and increase his income.
At the macro level, the aim consists of meeting the government objectives of controlling the critical soil erosion situation, moving towards food self sufficiency, and ensuring the best global ratio cost-benefit of the government's investments.
- ***Social level:*** concern must be given to the support of the local population, as the objective is not only to fight against soil erosion and promote economic growth but is also related to the improvement of the public's conditions especially in the most seriously affected areas where misery, unemployment and under-development are present.

Successful land resource management involves the introduction of changes in farmers' behavioural patterns. Therefore the principal benefit of this approach is to give small and medium scale farmers the opportunity to breakout of the vicious circle of abusive cereal cultivation which decline production yields and accelerate soil erosion by adopting an improved farming system based on animal production.

4- WATER AND SOIL CONSERVATION MEASURES

The conservation measures applied are of different types and tend to be site specific and tailored to fit in with the local farming systems, customs and environmental conditions. They can be directly productive measures: tree Plantation, Pastures and range land improvement, crop rotation, contour farming, or indirectly productive measures: contour banks, elements of banks, terraces, small dams, stone cordon, water management.

5- SMALL DAMS : AN ORIGINAL EXPERIENCE IN TUNISIA

The construction of small dams at different points on the hydrological network attenuates the flood wave and reduces the erosion dynamics on the runoffs, which are often violent in the Mediterranean region. Many countries have carried or are carrying now programs to build small reservoirs, particularly in hilly semiarid regions, in the aim to collect surface water resources and to reduce siltation in downstream dams. In Tunisia 580 small dams are already built.

In the semiarid dorsal region that extends from the Cap Bon to the Algerian border, 32 artificial reservoirs were chosen to constitute a network of hydrological observations. These lakes have highly diverse intake areas ranging from somewhat uninhabited semi-forests to areas that are devoted entirely to agriculture. Their watershed areas vary from a few hectares to several dozen square kilometers. They are also representative of the rainfall gradient of the semiarid region, which is 250 to 500 mm of rainfall annually.

These reservoirs have highly diverse intake areas ranging from somewhat uninhabited semi-forest to areas that are devoted entirely to agriculture. Their watershed areas vary from few hectares to several dozen square kilometres. They are also representative of the rainfall gradient of the Mediterranean area (250 to 700 mm annually rainfall). Different geologies of the Mediterranean basin are also represented.

Within the program of collaboration between the Ministry of agriculture and water resources (ACTA in Tunisia) and the research institute for development (IRD France) it is planned to assess hydrological variables describing the water balance of small dams. Each reservoir is equipped with level gauge, an evaporation pan, and two stations for automatic data collection. The first station connected to a tipping bucket rain gauge (resolution of 0.5 mm rainfall), while the second is connected to a submerged probe that measures the water leve, within 1 cm, and temperature each 5 minutes. The spillway is designed in such a way that the discharge can be estimated.

The bathymetry of each reservoir is recorded at least once every hydrological year, and is compared with a detailed ground survey, making it possible to determine the silting rate of each reservoir, and to create level-volume and level-surface relationships. The water abstraction for main users around the reservoirs is observed daily.

A software package allows to take the data directly and store it in a single hydrological data bank :

- rainfall and evaporation,
- level-volume and level-surface curves for the reservoir,
- level-spillway discharge curves,
- water level, spillway discharge, volume and surface area of water in the reservoir,
- water abstraction

The software allows editing tables of data and curves. Many different times steps can be chosen and various ways to present the data are possible.

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The software allows editing tables of data and curves. Many different times steps can be chosen and various ways to present the data are possible.
For a certain time period, the general water balance equation for a reservoir can be applied by using the principles of water volume conservation. The variation of the water volume stored in the reservoir is equal to the sum of water volumes entering minus water volumes exiting the system.The instantaneous flow entering in the reservoir can be assessed at a time step of 5 min. Water balances can be computed at a daily time step.
Different types of hydrological models have been implemented to predict sediment budget. A first empirical model bases on volume of the flow and maximum discharge during five minutes was calibrated and validated for computing the sediment transport flood by flood between two bathymetric measurements on 24 catchments. A distributed model bases on RUSLE was implemented to simulate the sediment budget resulting from different scenarios of land uses. KINEROS MODEL 5 (Woolhiser et al., 1990) was applied on two sites to test the efficiency of a distributed physically based model and discuss the values given to different parameters.

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APPENDIX 3 - LONG TERM IMBALANCES IN SUPPLY AND DEMAND (Chapter III)

- **Water reuse (B.1.1.6)**

- Applications (B.1.1.6.1)

Example of Costa Brava

The Costa Brava Water Agency (Consorci de la Costa Brava, CCB) is a supra-municipal institution formed by the 27 coastal municipalities of the province of Girona, in NE of Spain. CCB was created in 1971 and is considered to be a pioneering organization of its kind in Spain because of the early (for Spain) construction of wastewater treatment plants (WWTP) and for its understanding of the water cycle as a whole. This vision led to the implementation of the first planned water reuse project in 1989, which consisted to the supply of disinfected secondary effluent from the Castell-Platja d'Aro WWTP to the Mas Nou golf course. The creation of the Catalan Water Agency (ACA) in 2000 has also given a new boost to the construction of tertiary treatment structures in the Costa Brava area, adding three facilities of this kind to the nine already existing. Reclaimed water volumes are increasing every passing year, reaching 5,7 hm^3 in year 2004 out of 37 hm^3 or 15 % of wastewater treated in the area. The applications include irrigation for agriculture, golf and landscape, restoration of wetlands for flood protection, enhancement of the local environment and aquifer recharge (Sala et al., 2004).

- Enabling the growth of water recycling and reuse (B.1.1.6.5)

- **Example of Cyprus : Two practical measures for the conservation of drinking water**

Conservation of drinking water has been initiated as a practical mean of assisting water demand management where, for instance, capital expenditure on water resource development (new dams, main conveyors, water treatment, etc) might be reduced or deferred. "Water saved is exactly the same as water supplied" and "One person´s reduction in water use makes water available for someone else".
As a practical measure to save drinking water, a scheme has been put into practice during the last few years, for subsidizing the drilling of private boreholes or the recycling of "grey water" for garden watering and/or for toilets in individual households. For the moment, these two practical measures have permitted to save 2 million cubic meters of drinking water per year. Only about a half of the average annual supply of domestic water in Cyprus needs to be of drinking water quality. Over 50 % of water demand could be met with a lower grade quality water (processed water for example).

- *Second quality water from boreholes in the built-up areas*

In Cyprus, existing aquifers are shallow with a depth of about 60 m from ground level. Such aquifers are found in some areas of towns and villages. These aquifers are recharged by the onsite wastewater systems, such as septic tanks/absorption pits in addition to natural recharge from precipitations and river flows.

The Government of Cyprus through the Department of Water Development is subsidizing this scheme to encourage consumers to use this second quality water for watering their gardens and for toilets. Each consumer can drill his own borehole outside his house. The cost of drilling such a borehole with the installation of a small electro-submersible pump is approximately €1500 of which the Government subsidizes € 350. The connexion of the borehole to the toilets is easy, and the cost is approximately € 550 of which € 350 are given by the government as a subsidy. With this scheme, 30 % to 65 % of drinking water are saved.

- *Grey water recycling*

Lightly polluted or grey water from baths, showers, hand or wash-basins and washing machines, is kept separately from heavily polluted or black water from toilets and kitchens. As a result, the interception of each type of wastewater at household level for subsequent treatment and reuse is quite easy. This reuse is novel in Cyprus.

After five years of research and two years (1997-1998) of experimental work at a pilot scale, the Government of Cyprus has decided to give a € 700 subsidy for the installation of a grey water treatment plant costing € 1400 for a household with a production of 1 m^3 per day. With this scheme, a conservation of 30 % to 45 % of the per capita drinking water consumption is reached. Consequently, the conservation of drinking water for two persons covers the needs of a third person.

- **The reuse of treated urban wastewater : case studies in southern Italy (Sogesid case study)**

The problem of water supply in southern Italy, and particularly in Apulia, has been addressed since the end of the eighteenth century when water scarcity begin to affect the region constraining social and economic development. The fast development of the region, the changes in traditional agriculture practices and land use, the groundwater over-abstraction (causing saltwater intrusion) together with the climate changes, led to frequent water shortages in Apulia and in the coastal areas of Basilicata, causing conflict between the two regions.

Over the last four decades, the response to these problems has included improvements of water infrastructures and the construction of large reservoirs aimed at the regulation of resources allocated for agricultural, hydro-electrical an and industrial sectors.. The present stress on the groundwater resources in Apulia, requires an optimization of the water demand management, also considering the use of non-conventional water in order to reduce fresh water demand.

In this context the study “Definition of technical, economic and operational optimization of wastewater treatment finalized to be reused in Apulia” has been commissioned by the Italian Ministry of Environment to Sogesid S.p.A.[1], in order to support the water resources conservation policy in regions stressed by a water scarcity emergency. The study has been based on the following phases: identification of non-conventional water demand and treated wastewater sources; analysis of best advanced treatment technologies available for wastewater reuse; economic analysis of additional treatment costs; evaluation of case studies.

The scenarios for treated wastewater reuse in the region depend not only on the definition of the effluents quality, and consequently on the advanced treatment process required, but also on the costs involved and the environmental risks and benefits connected.

[1] Sogesid S.p.A. is a public company fully controlled by the Ministry of Economy and Finance.

The results obtained in the study and particularly in the case studies, underline the advantages of reutilization projects in areas with existing water scarcity or water stress, with special regards to areas where environmental benefits are also generated.
The definition of non-conventional water demand was carried out for the whole region, giving priority to the areas with already stressed water resources, identifying the water treatment plants as well as the potential users and other possible benefits deriving from the reuse (environmental, social, etc…). Twenty-two case studies have been identified and analyzed; for each case study it has been developed a preliminary plan considering: additional process required, treatment techniques and operational costs, water conveyance systems and distribution infrastructures, social and environmental benefits and any other element interesting the project feasibility.
The analysis was finalized to the identification of an economic threshold below which the expected advantages justify the additional investments needed for advanced treatment.
Benefits can also be increased at local level through different forms of incentives and, above all, by quantifying the value of water resources that will be available when substituted by treated wastewater.
It has been therefore crucial to define benefits and environmental risks connected to wastewater reuse policies.
The following basic criteria have been considered for the economic analysis:

- -Type of reuse (irrigation, integrated irrigation, industrial);
- -Improvement works required in the plant, with or without primary treatment;
- -Additional advanced process treatment;
- -Estimated costs, with regard to plant dimensions and population equivalent (p.e.) served.

All the economic evaluations have been based on the Italian national legislation on water reuse and water protection.
The result of the analysis can be summarized as follows :

A. The required costs for advanced wastewater treatment in order to respect the quality limits required for water disposal in surface water bodies, range between a maximum of 79 € per capita for plants of 2,000 p.e. and a minimum of 20 € per capita for plants of 500,000 p.e.

B. The additional costs for improving the effluent quality, in order to respect the limits for disposal over soil, are negligible.

C. The difference between the additional costs in cases A and B is dramatically reduced with the economy of scale obtained in large treatment plants (above 100,000 p.e.)

D. The cost-benefit evaluation depends on the size of the treatment plant and on the tariff policy (incentives and income from additional fresh water made available).

E. Any project in arid or semiarid regions with demand for non-conventional water (agriculture, industry, environment), presents considerable benefits from the implementation of a wastewater reutilization policy.

F. The environmental benefit (e.g.: groundwater abstraction reduction) has a central role in a comprehensive evaluation of a reuse project.

G. The suitability of reuse project change in relation to treatment plant size and the typology of disposal (into a river or on the soil) of the treated effluent.

It follows a synthesized description of one of the twenty-two case studies analyzed in the project.

Reuse of effluents from the Carovigno Treatment Plant
The project is located close to “Torre Guaceto Reserve”. The reserve is a wetland of international interest being included into the Ramsar Convention, being a Special Protection

Area (79/409/CEE Directive) as well as a marine reserve and Site of Community Importance (92/43/CEE Directive).
The extensive agricultural activity represents one of the major components of the local economy. The agricultural production is oriented to water intensive crops and consequently to a high water demand. The agricultural area included in the reserve represents approximately 864 ha (78%) and the naturalistic area 250 ha (22%).
The inadequate management of the aquifer, with a consequent over-abstraction, is the principal cause of the environmental deterioration affecting the "Wetland" of "Torre Guaceto Reserve". The very high concentration of salt in the groundwater has led to the reduction and even extinction of some very particular and rare macro-invertebrate species.
Carovigno Treatment Plant represents a potential source of non-conventional water which could be used in the agriculture zone in spite of groundwater. The treated effluent is planned to be disposed into a channel which is a "sensitive water body" and so (the advanced treatment processes required are designed to fulfill the limits foreseen by Directive 91/271/CEE.
The annual volume of treated wastewater in the Carovigno Treatment Plant is approximately 3.7 million m^3/year, the available volume during the irrigation period is estimated to some 2.8 million m^3 /year.
The total demand for irrigation water in the "Torre Guaceto Reserve" is estimated to be 0.7 million m^3/year, while the estimated total water demand for the environmental rehabilitation of the Natural Reserve is estimated to some 2,9 million m^3/year.
In order to reach the required effluent quality, the project foresees additional treatment, and other interventions like rehabilitation/extension of the irrigation network and pumping stations, monitoring systems, storage tanks, emergency marine pipeline for disposal of untreated effluent in case of plant failure etc.
The effluent supplied to the Wetland Area will be conveyed into a disposal area with an overland flow treatment technique, using vegetative biotypes like *Phragmites australis*. The total estimated cost of about 1.8 million € has a very high cost – effectiveness ratio, taking into consideration the benefits from the environmental rehabilitation of the Natural Reserve Area.
Expected effects of the project :

- reduction of water abstraction from stressed aquifers
- limitation of saltwater intrusion into the wetland
- habitat protection
- recharge of wetland through a controlled effluent disposal
- reduction of the nutrients load on the Sensitive Area

- **Examples of pricing methods for irrigation in different countries (B.1.2.2)**

Table A : Agricultural pricing policies of different EU countries (Lallana et al., 2001)

Country	Water rights	Water pricing	Other economic instruments
Austria	GW: licensed	Irrigation: GW free of charge.Livestock: from PWS at household rates.	
Belgium	SW: user rights	Agricultural water from PWS at household rates, from GW and SW a levy on declared volumes (from 1998).	Pollution charges
France	SW: user rights	Charges have a catchment component and a consumption component. The prices are established by the regional development companies.	Quotas depending on water availability
Germany	SW: user rights GW: licensed	Water prices are the responsibility of the Länder Water tax (from 1998).	Tax exemptions for farmers
Greece	SW: user rights GW: licensed	Pricing from agreements between local land improvement boards and private suppliers. Water fees, in general, are dependent on extraction costs.	Agricultural policies; rural development policies
Italy	SW: licensed	Irrigation boards are responsible for irrigation projects.	Quotas; progressive pricing in the south
Netherlands	SW: user rights GW: licensed	Water control boards (66 in total) are in charge of water management; the costs are covered by water users. Farmers pay the full supply cost and the full drainage cost.	Pollution levies and flood control levies
Portugal	SW: public and private rights	Agricultural water prices are levied by user associations. From 1999, all licensed water has been subject to a water levy, depending on the amount of water used, returns generated by each type of user, and the region's relative scarcity of water.	Agricultural policies; rural development policies
Spain	SW: user rights GW: licensed	The irrigation water price has two components: the regulation levy (to cover capital investments for water works) and a tariff to cover the operational and maintenance cost of storage and transportation. The river basin agencies and the irrigation districts are in charge of the prices.	Quotas; occasional markets
Sweden	GW: permits when shortage of water in given regions (10 % of irrigation farmers)	Water for irrigation can be abstracted freely by farmers.	
UK	SW: licensed GW: licensed	National river authorities and water companies are in charge of water pricing. Only direct abstractions for spray irrigation require an abstraction licence. Licences are based on volume, nature of water resource, season in which abstraction is allowed and on the water returned directly to water resources; 25-50 % of the annual charge is based on actual recorded consumption. Where mains are used for agriculture, the tariff is fixed by the official regulator (OFWAT).	Quotas

Table B : Most common pricing methods for irrigation (Lallana et al., 2001)

Volumetric	Water charge is based on the direct measurement of volume of water used. Variations of the volumetric approach include: (a) indirect calculation based on measurement of minutes of known flow; and (b) a charge for a given minimal volume to be paid for, even if not used.
Output	Irrigation water is charged on per output basis (users pay a certain water fee for each unit of output they produce).
Input	Water is charged by taxing inputs (users pay a water fee for each unit of a certain input used).
Per unit area	Water is charged per irrigated area, depending on the kind and extent of crop irrigated, irrigation method, the season of the year, etc. In many countries, the water rates are higher when there are storage works than for diversions directly from streams. The rates for pumped water are usually higher than those for water delivered by gravity. In some cases, farmers are also required to pay per ha charges for non-irrigated ha.
Tiered pricing	This is a multi-rate volumetric method, in which water rates vary as the amount of water consumed exceeds certain threshold values.
Two-part tariff	Users are charged a constant marginal price per unit of water purchased (volumetric marginal cost pricing) and a fixed annual (or admission) charge for the right to purchase the water. The admission charge is the same for all users.
Betterment levy	Water fees are charged per unit area, based on the increase in land value accruing from the provision of irrigation.
Water market	In some developed economies, markets for water or water rights have been formed and determine water prices.

- **CECINA PRB : MEASURES ADDRESSING WATER IMBALANCES MANAGEMENT**

In the context of PRB exercise, water resources availability issues came out immediately, and became priority issues.
Testing activities stressed the relevant pressures of industrial and civil water demand on river basin water resources which cause lack of water during the summer months.
Cecina river has always had an unstable stream flow, causing flood during winter months and dry out during summer months.
From the hydrogeologic point of view, the river basin is characterized by variable precipitation strictly dependent by seasonal fluctuation, with an high rainfall level in wintertime and dry climate in summertime.
From the orographic and lithologic point of view, the high and middle river basin is characterized by steep slopes and clay outcrops and, consequently, middle-low permeability ground. The alluvial mattress of the river bed is made of gravel and present high permeability, but its thickness is very limited. Gravel and sand pits, which have been closed since few years, caused, in some parts of the river, geomorphologic modifications and a reduction of the alluvial mattress.
Ultimately, Cecina river Basin is characterised by a seasonal, torrential flow. The orography determines low “corrivation time”, causing fast water recharge but also fast water drainage in the alluvial soil. This effect is much more emphasized by anthropogenic pressures.
Due to its natural characteristics, Cecina River Basins is stressed by high water unbalances in summertime, especially from June to the first days of October, worsened by a relevant gap

between anthropogenic demand (for industrial, civil and agricultural uses) and a limited water resources availability.

Water scarcity on Cecina River Basin must be intended as recurrent seasonal imbalance between water demand and supply which causes groundwater resources depletion and compromises the minimum vital flow.

During the PRB exercise, a Water Balance has been drawn up, in order to quantify the river flow deficit.

The balance has the following formula: R = F + E ± X

R = rainwater
F = river flow
E = evapotranspiration
X = flow deficit

The final result of the water balance is that the flow deficit is estimated between 17,6 and 20,6 Mmc/year in front of a total flow of 131,435 Mmc/year (table 1).

	R	**F**	**E Turc**	**X = R-(F+E)**
mm	830,67	207,05	595,78	27,84
Mmc	527,311	131,435	378,203	17,672
			E Thornthwite	
mm	830,67	207,05	591,08	32,54
Mmc	527,311	131,435	375,215	20,661

Table 1

As regard the Minimum natural flow, it can be defined as the minimum river flow under undisturbed conditions; it has been evaluated by calculating the $Q_{7,10}$ [2] (= 7,8 L/sec). The minimum natural flow results from the sum of $Q_{7,10}$ and the water abstractions (=84,7 L/sec) and it has been evaluated in 93,5 L/sec.

This information confirms the strong impact of the abstractions on the water flow and constitutes an important basis for the definition of effective answers. These answers consist of a series of coordinated measures coherent with a common integrated water resources government.

First of all, a telemeter net has been installed in order to control the main industrial water users. This measure is a fundamental basis for the water users control and government.

Secondly, Tuscany Region (Cecina river basin authority) endorsed a water quantity preservation measure for the reduction of water abstraction: new authorisations shall grant a reduction of abstractions at least of 17 % on total consumptions.

This administrative/planning measure has been defined together with a strategic programme of actions concerning the integrated river basin environmental protection. These actions are included in a “Framework Agreement” endorsed by the competent institutional authorities (both national and local) on water and soil protection.

In this context, it has been implemented the Aretusa Project which aims to reduce the water stress due to industrial abstractions on the coastal aquifer. The project consists of a reclamation plant for industrial reuse of wastewaters from the WWTP of Cecina and Rosignano municipalities. The water services manager (ASA) together with the Solvay group (the most important industry on the river basin), has considered the possibility to reduce abstractions through waste waster re-use technologies. According to the ASA estimate, on the basis of the capacity of the two treatment plants, the Cecina plant must supply about

[2]$Q_{7,10}$ is the minimum average flow for seven consecutive days with a ten years recurrence time

2.400.000 m^3 and the Solvay plant 2.453.000 m^3 of water per year. At the moment the project implementation grants a water abstraction reduction of about 4 million m^3/year. Solvay grants a reduction of the withdrawals from the river bed aquifer of the same quantity (4 Mm^3): 2 Mm^3 of the 4 Mm^3 not abstracted are made available for potable use.

ENVIRONMENTAL BENEFITS OF ARETUSA PROJECT

<table>
<tr><th>WATER ABSTRACTIONS REDUCTION</th><th>POLLUTANT REDUCTION FROM WWTPs DISCHARGES</th><th>REDUCTION OF THE POTABLE WATER DEFICIT</th></tr>
<tr><td>INDUSTRIAL ABSTRATIONS
(Jan-2002)
<u>m3/year</u>
- Cecina wells:……………..800.000
- Riparbella wells:……….1.200.000

- wells and surface waters:

<u>Montescudaio: ……..…..3.700.000</u>
TOT …………………6.700.000</td><td>EXISTING LOADS
<table>
<tr><th></th><th>CECINA</th><th></th><th>ROSIGNANO</th><th></th></tr>
<tr><td>LOADS</td><td>m3/year</td><td>2,400,000</td><td>m3/year</td><td>2,453,000</td></tr>
<tr><td></td><td>mg/l</td><td>t/year</td><td>mg/l</td><td>t/year</td></tr>
<tr><td>COD</td><td>100</td><td>240</td><td>100</td><td>245</td></tr>
<tr><td>BOD5</td><td>30</td><td>72</td><td>30</td><td>74</td></tr>
<tr><td>N</td><td>35</td><td>84</td><td>60</td><td>147</td></tr>
<tr><td>P</td><td>10</td><td>24</td><td>10</td><td>25</td></tr>
</table></td><td>Current deficit in Cecina e Rosignano municipalities: 1.500.000 m3/year (data from ASA)</td></tr>
<tr><td>REDUCTION OF ABSTRACTIONS
TOT:………………4.000.000 [m3/year]
% on total:……………………60%
%groundwaters…….nearly 100%</td><td></td><td>ARETUSA CONTRIBUTE: 2.000.000 [m3/year] available for potable uses</td></tr>
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