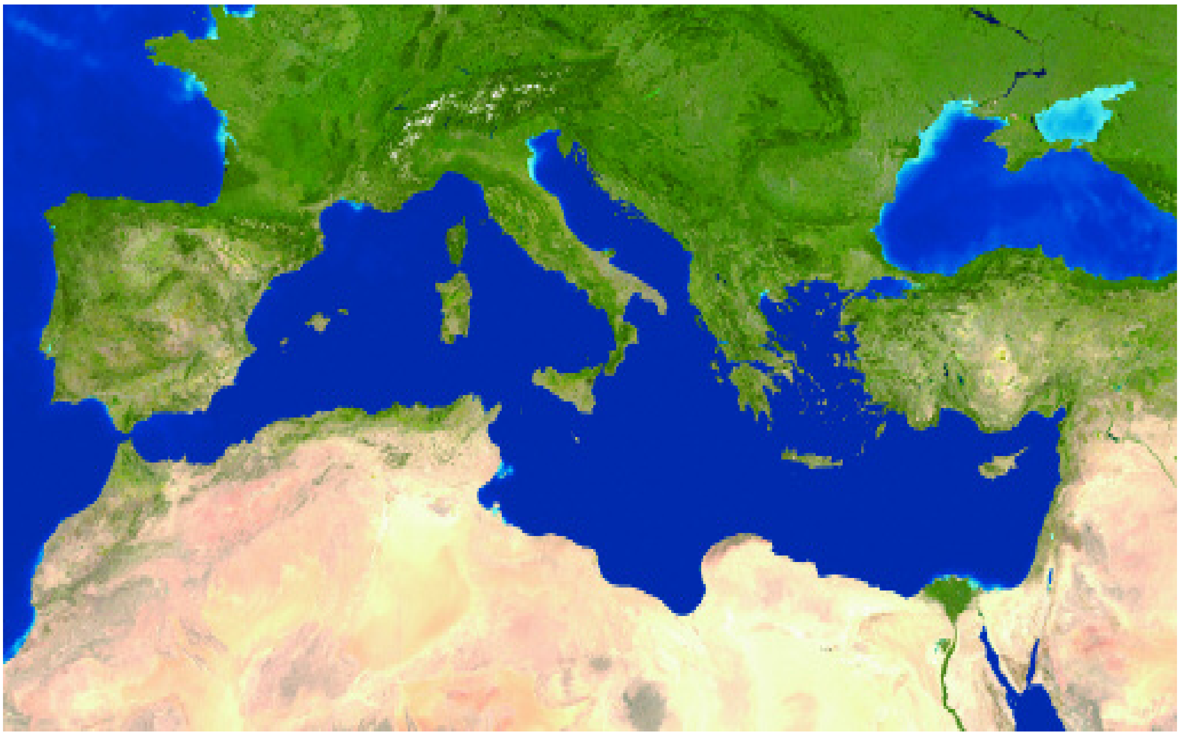
JOINT MEDITERRANEAN EUWI/WFD PROCESS



MEDITERRANEAN GROUNDWATER REPORT

Technical report on groundwater management in the Mediterranean and the Water Framework Directive

Produced by the

MEDITERRANEAN GROUNDWATER WORKING GROUP (MED-EUWI WG ON GROUNDWATER)

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http://www.semide.net/initiatives/medeuwi/JP/GroundWater

PREFACE

Mediterranean countries share many common features in terms of climate, water and land resources and development issues. These include arid and semi-arid climate, limited water resources, agricultural development limited by water availability and high economic and social value of water.

In the Mediterranean region, water is a scarce and fragile resource, unequally distributed in space and time both at regional level and within each country, and widely exploited. The problem has been aggravated due to the rapid population growth, socio-economic development, and mass Mediterranean tourism (Mediterranean is the world's first tourist destination) which have strained the natural resources of this region to the limit. However, regarding water availability there is an obvious contrast between the northern coast of the Mediterranean where resources quantity vary from average to high and the southern and south-eastern coasts that are adjacent to dry and desert areas with very limited water resources (except of Egypt with its Nile river feed from the tropics).

The groundwater resources of the Mediterranean region are either the main sources of freshwater or are vitally needed to supplement surface-water sources. Groundwater represents more than 50% of the available water resources in Mediterranean islands and it is practically the only water resource in the Sahara region extending from Egypt to Morocco. However, they are under threat from problems that affect both the quantity and the quality of water that the aquifers provide.

Groundwater exploitation in the region has increased dramatically during the last decades mainly due to an increase in irrigated agriculture, tourism and industry. Thus, many groundwater resources are at risk of being exhausted through overpumping. With withdrawal exceeding the internally renewable water resources, the resulting groundwater scarcity is rapidly becoming a major concern in most countries of the Mediterranean. The pressures on natural groundwater resources are higher in the summer period, when natural supply is minimal, while water demands are maximum (irrigation, tourism). Furthermore, some considerable water volumes stored in large deep aquifers in Libya, Tunisia, Egypt and Algeria are non-renewable resources and their use is consequently not sustainable.

Groundwater scarcity is in many cases accompanied by poor groundwater quality, especially in coastal aquifers, where water is often highly saline, reducing its utility. A general groundwater quality deterioration occurs in many parts of the Mediterranean region, due to contamination in recharge areas, mismanagement during irrigation practice, overexploitation of coastal aquifers and other reasons.

With growing groundwater scarcity and quality deterioration in many parts of the Mediterranean, the contribution and role of internationally shared aquifers in meeting the growing water demand is likely to increase. Cooperative arrangements to jointly develop, manage and protect shared aquifers will become a necessity, not only to avoid conflict but also to optimise utilization and to achieve water security.

The Mediterranean Groundwater WG (MED-EUWI Working Group on Groundwater)

Sharing of experiences, methodologies and common challenges and developing synergies between the EU and non-EU countries of the Mediterranean on groundwater issues could facilitate the development of good groundwater management practices in the region as well as the promotion and implementation of sound water resources management policies.

In the EU side, these practices should be guided by approaches and criteria included in the Water Framework Directive (2000/60/EC) - WFD - and the experience already gained by the Mediterranean Pilot River Basins (PRBs) and national institutions responsible for groundwater resources management from the Member States. Similarly, well developed and long tested practices and valuable experiences exist in non-EU countries, as well as in regional and international organisations with experience in the region.

The Mediterranean Component of the EUWI has already tackled issues relating to groundwater resources management in the region, and in particular in the area of North Africa. The MED EUWI, provides an overall umbrella for the promotion of specific cooperation initiatives, experience transfer and synergies between EU and non-EU Mediterranean countries on groundwater management.

The **Mediterranean Groundwater WG (MED-EUWI Working Group on Groundwater)** is one of the three thematic groups of the Mediterranean Joint Process between the EU Water Framework Directive and the Mediterranean Component of the EU Water Initiative (Med EUWI/WFD Joint Process) and in parallel, a Drafting Group (GW5) of the WG C (WG on Groundwater), which is part of the EU Common Implementation Strategy of the Water Framework Directive (2000/60/EC).

The objective of the Mediterranean Groundwater WG is to exchange experiences, share common challenges and develop synergies between EU and non EU countries, basin authorities, institutions and stakeholders of the Mediterranean region, aiming at the adoption of a common vision on groundwater resources management, based on the Water Framework Directive (WFD) approaches and objectives and the regional conditions.

In particular, the development of partnership on groundwater issues between the EU and non EU countries of the Mediterranean region, in the framework of the Mediterranean Groundwater WG, aims to:

1. identify the most significant problems, pressing needs and challenges for the Mediterranean region relating to groundwater resources management,
2. list on-going regional and national processes, initiatives and projects developed to respond to groundwater issues in the region, and then create the basis for the development of additional joint initiatives and projects relevant to groundwater issues,
3. develop common approach methodologies and management strategies on groundwater resources based on the concept of integrated management of all available resources and develop adequate recommendations and technical specifications on priority issues,
4. transfer, exchange and demonstration of know-how on strategies, criteria, methodologies and tools used in the Mediterranean region on various groundwater management issues, such as inter-State cooperation regarding shared aquifers, remedial actions practised to recover salinized resources, management of data on shared aquifers, etc., and by then improve the awareness raising on issues relating to the groundwater protection and sustainable management.

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INTRODUCTION

1 FACTS AND TRENDS IN THE MEDITERRANEAN REGION

The Mediterranean countries have an area around 8.82 million km^2 and population of about 420 millions (2000). Of these, about 37% live in the coastal strip which represents only 17% of the total area. This means that the coastal population density is more than double the average population density. This situation is reinforced by a seasonal, tourist and migratory flow of more than 100 million people.

The arid and semi-arid regions of the Mediterranean combine a low rate of rainfall and a high rate of evapotranspiration and are subject to extreme recurrent droughts (*Figure 1*). The Mediterranean climate is characterized by a yearly precipitation, comprised of between more than 1000 mm for the northern countries (more than 2540 mm near Dalmatian) and less than 400 mm for some of the southern countries (less than 255 mm in parts of North Africa) and by a potential evapotranspiration often higher than 1200 mm implying a hydro deficit which is often high.

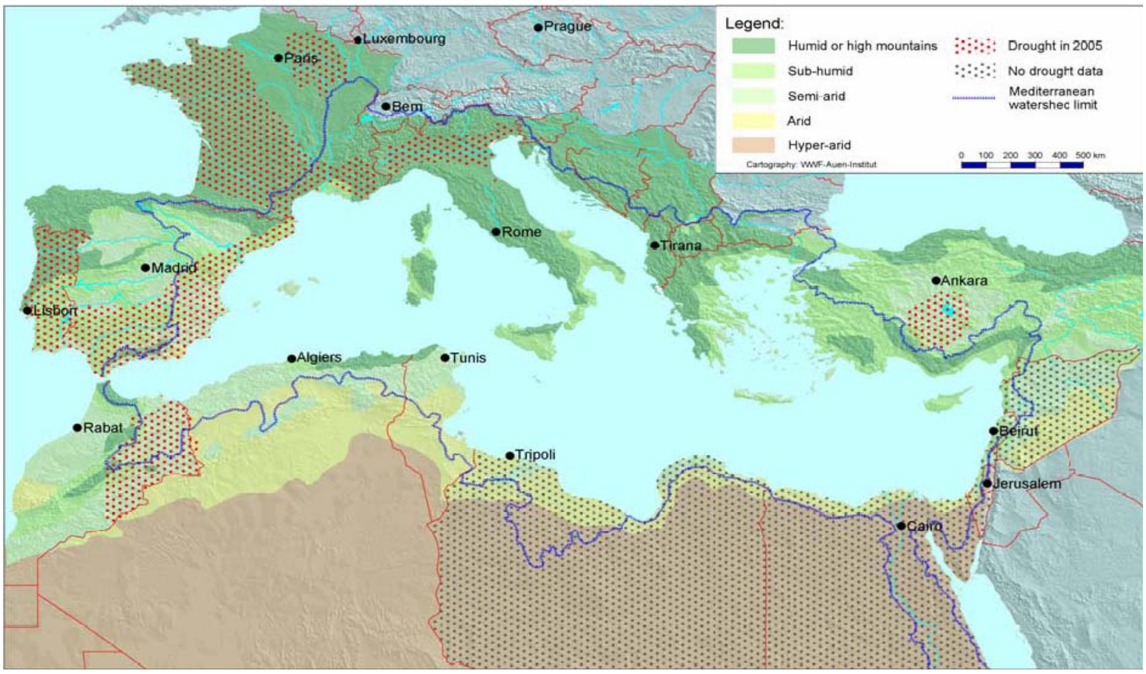


Figure 1: *Arid and semi-arid areas of the Mediterranean region, with the places affected by the drought of 2005 (one of the worst for the region)*
(WWF Auen-Institut, Germany)

Due to the low rate of rainfall and the high rate of evapotranspiration, only a small amount of water flows into rivers or percolates to aquifers. The water resources of the Mediterranean region are estimated at around 1.060 km^3 compared to 41.000 km^3 of the planet. This quantity represents only 2.6% of the world total with a population representing 7.4% of the world population.

The varying climate from north to south and east creates different conditions for water resources availability. Water resources are relatively plentiful in the north countries and scarce in the south and east. Of the total water resources of the region, 107.4 km^3 (10% of the total) are in the south, 62.4 km^3 (5.8% of the total) in the east and the remaining 894.6 km^3 (84.2% of the total) in the north. The availability of water may also significantly vary during the different seasons of the year, and from year to year.

The per capita available water is 2691 m^3/year compared to 7176 m^3/year for the planet or 37.5% of the global average. The per capita available water is also varying, from 4733 m^3/yr in the north Mediterranean countries to 810 m^3/year in the south Mediterranean countries and 2585 m^3/year in the east Mediterranean countries (*Figure 2*).

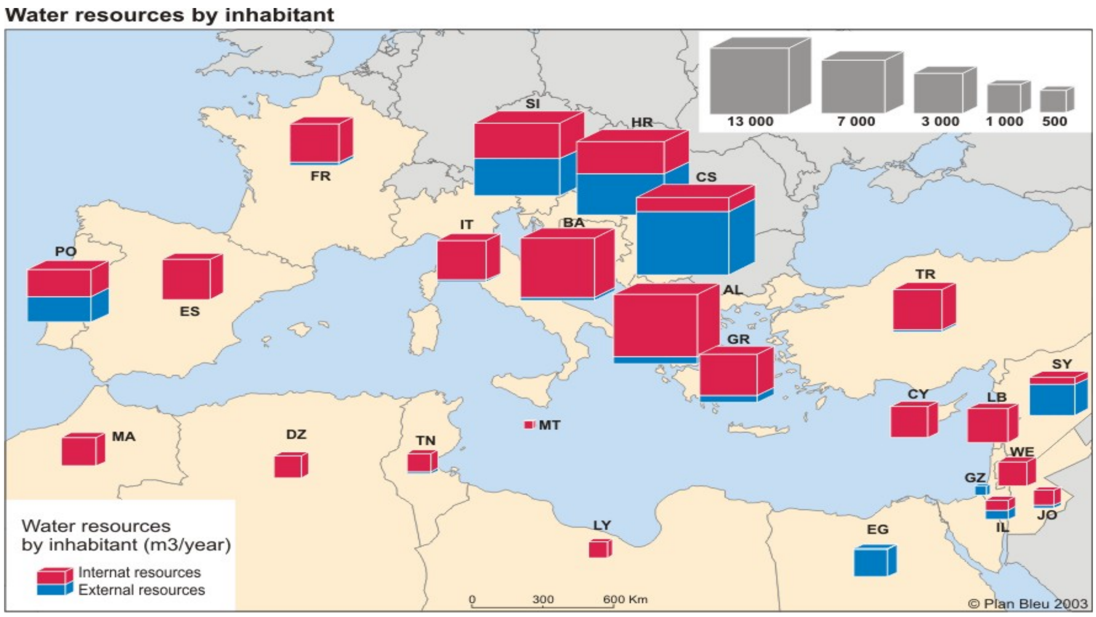


Figure 2: *Water resources per capita in Mediterranean countries*
(Mediterranean Vision on water, population and the environment for the XXIst century
by Jean Margat and Domitille Vallee MEDTAC/Blue Plan December 1999)

The per capita available water ranges from overabundance in Albania and in the countries of the former Yugoslavia (over 10.000 m^3/year per inhabitant) to extreme water-poverty in the Palestinian Territories-Gaza and in Malta (less than 100 m^3/year per inhabitant).

Thus, today more than 160 million of the about 420 million Mediterranean people (United Nations estimate) live in countries with less than 1.000 m^3/year per inhabitant (annual average). Of these 160 million persons, 30 million are living below the line of absolute water-poverty of 500 m^3/year per inhabitant: in the Palestinian Territories, Israel, Jordan, Libya, Malta and Tunisia (*Figure 3*).

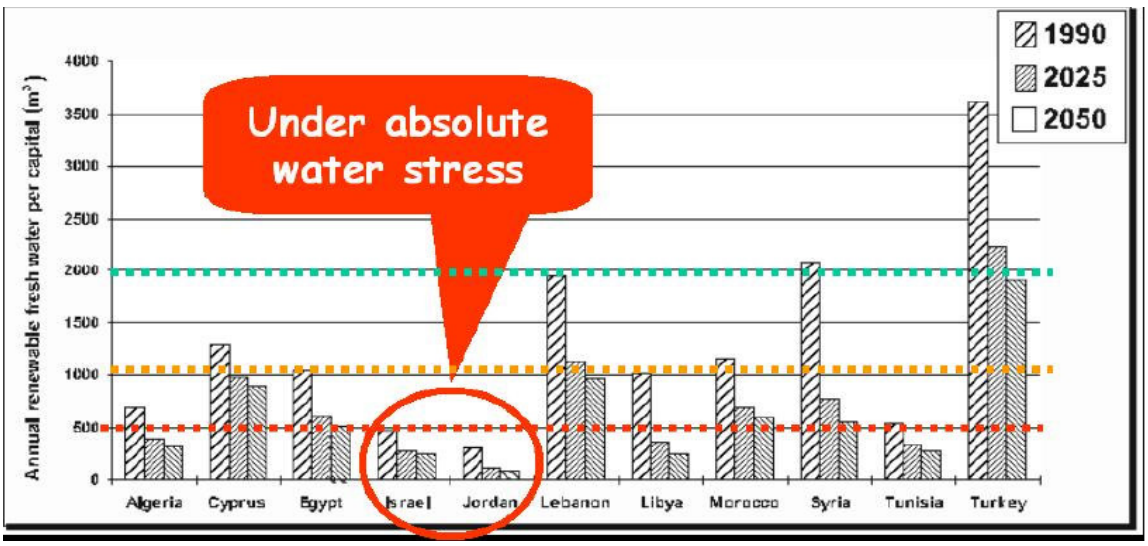


Figure 3: *Available fresh water per capita in southern Mediterranean countries, 1990–2050*
1700 m^3 = periodic water stress, 1000 m^3 = chronic water stress, 500 m^3 = absolute water stress
(UN–PD 1994)

Water consumption in the Mediterranean area is high, especially in the hot and dry regions where less water is available. The agricultural sector constitutes the highest consumption of water but tourism also produces huge problems in peak seasons in specific, mostly coastal, areas. In summer, pressure on water resources escalates when the demand for water from tourists and agriculture is at its peak. Drinking water has priority for water use in all Mediterranean countries.

Water demand in Mediterranean countries has doubled in the second half of the last century and has now reached about 290 km³ per year. The countries experiencing the greatest growth (more than 2% per year) are Turkey, Syria and France. Italy is among the few Mediterranean countries that reduced its water consumption over the past decade (*Figure 4*). However, it had already reached one of the top levels of water consumption in the Mediterranean. The overall water demand in the Mediterranean region continues to increase, even more in the light of the effects of climate change.

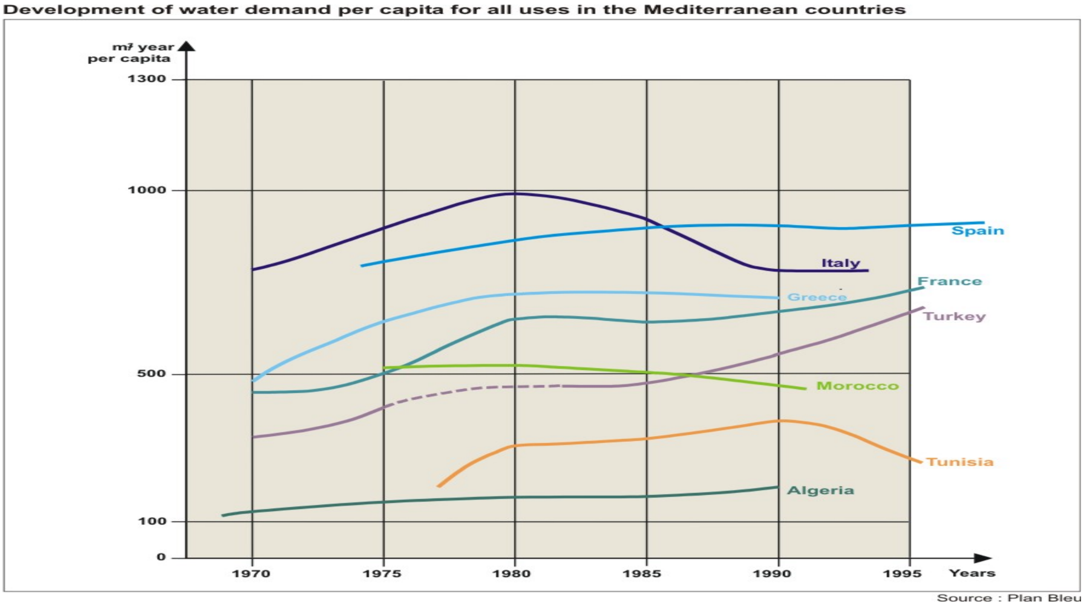


***Figure 4:** Development of water demand per capita for all uses in the Mediterranean countries*
(Plan Bleu, 2004)

Future estimations forecast a rise of consumption by 25% by 2025 in the Southern and Eastern Mediterranean, particularly in Turkey, Syria and Egypt. Turkey expects a severe decline in the available amount of water per year/per capita due to population growth.

With an average of 65% (*Figure 5*), irrigated agriculture constitutes the biggest bulk of water consumption in the Mediterranean, except for France and the Eastern Adriatic countries. However, the range of water consumption in agriculture is wide, reaching from around 14% of the total water extracted in France to more than 80% in most of the South-European countries as well as in Northern Africa. Water demand for irrigation is likely to go on increasing with the rise of temperature.

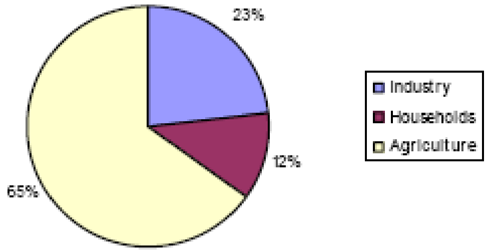


***Figure 5:** Average water consumption in the Mediterranean region by sector*

The share of households in water consumption is similar in all Mediterranean countries with 9 to 15%. In the Northern Mediterranean region, this trend appears to be stabilizing. This trend is different to the North African countries where urban water demand is expected to continue increasing.

In the industrial sector there are again huge differences: France shows the highest water use with around 70%, the biggest problem being a sufficient amount of water to cool power plants. Spain, Portugal and Turkey show much lower industrial shares with around 15%, and almost negligible are Greece, Morocco and Tunisia with around 2%.

Water demand for tourism is clearly increasing. In Tunisia, for instance, tourist water demand has doubled between 1977 and 1996. On the Balearic Islands, tourist water consumption likewise multiplied 15 times between 1980 and 1995.

Water scarce countries in the Mediterranean have made different options for the development of their water resources, determined to a greater extent by the characteristics of the natural availability:

- In the East of the Mediterranean groundwater comprises a major part of the internal renewable water resources in the region. In general it can be stated that most of the groundwater resources in this region are fully exploited and some aquifers are overexploited, particularly in Jordan and the Palestinian Authority.
- In the North of Africa, Egypt and Morocco rely mostly on surface water, other countries use both surface and groundwater resources (Algeria and Tunisia).
- Full exploitation of water resources is generalised in the Mediterranean islands. Most islands use all renewable groundwater and over-abstract their resources at an increasing cost as the water table goes down. Some islands are dependent on expensive transportation of water from mainland to deal with structural shortages (Greek islands, Croatian islands) or during droughts.

2 GROUNDWATER RESOURCES: ABUNDANT OR RARE RESOURCES, UNEVELY DISTRIBUTED

The countries of the Mediterranean are unequally endowed with renewable groundwater. This is first of all due to the climate, but also due to the differences in geologic conditions and relief which are unequally conducive to groundwater infiltration and accumulation.

Overall, subterranean drainage in the Mediterranean countries totals about 300 billion m³ on average per year, of which 71% in the North (in Europe), 24% in the Middle East and only 5% in the South, on the African shore. This imbalance is further accentuated in years of drought.

Broken down by country, these average renewable flows of groundwater vary, depending on their extent and the climate situation in each case, from 50 million m³ (Gaza, Malta) to 100 billion m³ a year (France). These quantities represent slightly more than a quarter of the total natural water resources in the region, varying between the countries from less than 5% to almost 100%.

Some salient facts:

- Four types of aquifers are most frequently encountered in the Mediterranean region (*Figure 6*):
  - Aquifers of large sedimentary basins, which may be confined or unconfined and may locally be artesian, either in the North (Paris Basin, Danube margins of the Pannonic Basin) or in the South, mostly located in the Maghreb and more extensive in the Saharan region where there are deep aquifers with considerable reserves which, however, are currently hardly replenished (“fossil waters”) and are relatively independent of surface waters.

- ➢ Karstic carbonated aquifers, major water towers with perennial drainage which are maintained by their often abundant sources, which however vary considerably in volume and regulatory function.
- ➢ Mainly detrital sedimentary aquifers in coastal plains in contact with the sea.
- ➢ Alluvial aquifers, located in the valleys and deltas of major rivers which have strong links with watercourses with which they often exchange water; those in the Nile valley and delta and in the Po plain are the most extensive and contain deep captive groundwater.

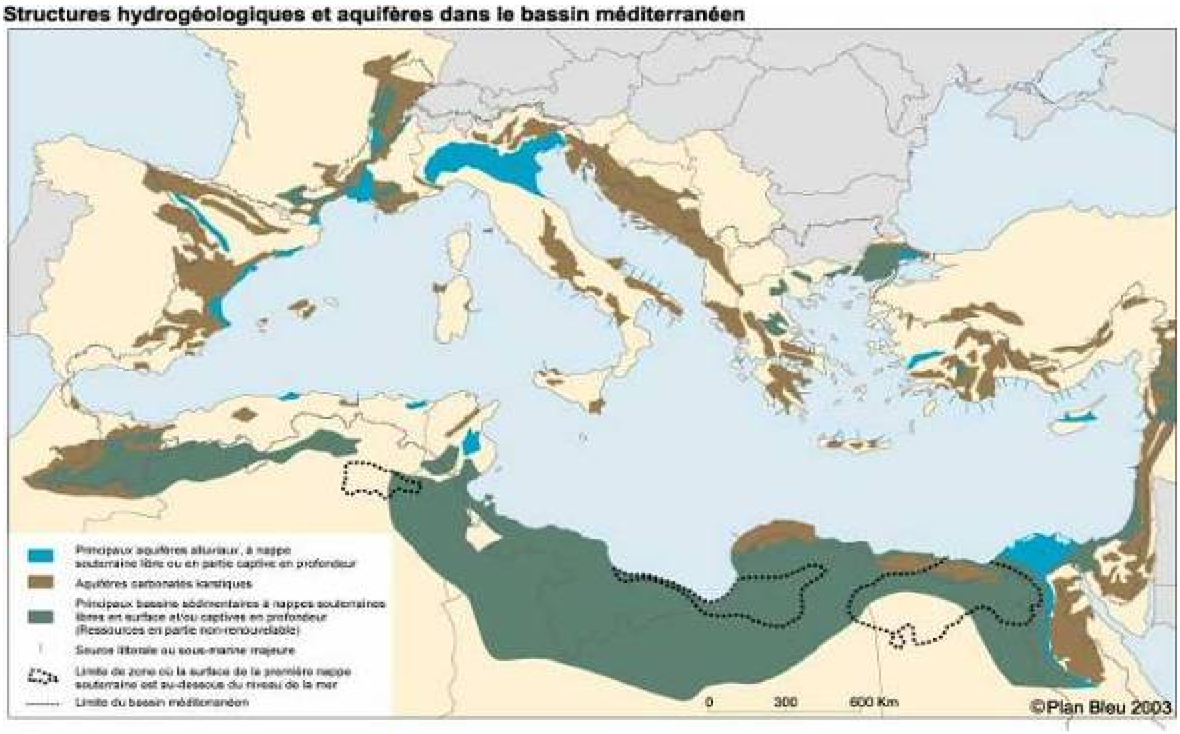


Figure 6: *Hydrogeological structures and aquifers in the Mediterranean*
(Blue Plan, 2003)

- There are strong links between groundwater and surface water. Three-quarters of underground drainage is collected in watercourses, thus ensuring their permanent flow, though more in Europe (85%) than in the Middle East (42%) and the South (30% only). On the other hand, in the South, in particular in the semi-arid area, groundwater levels are replenished through flooding of surface watercourses, which are mostly temporary, with most water - unless captured earlier – flowing into evaporation fields, in particular in closed depressions (*Figure 7*).

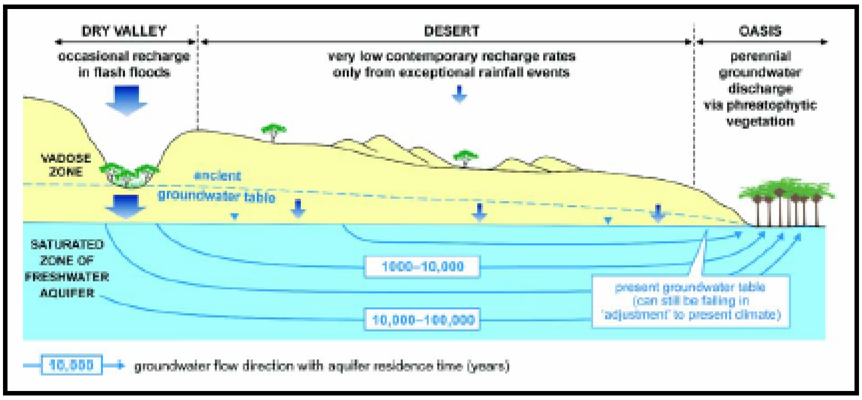


Figure 7: *Typical groundwater cycle in arid regions where underlainby major aquifers*
(GW-MATE Briefing Note 11)

In both cases, the groundwater has a regulatory function and where the aquifer reservoirs are relatively large it enhances resistance to drought. Accordingly, ground and surface water resources are strongly interdependent.

Moreover, aquifer systems relate in various ways to hydrographic structures, depending on the region:

- in some cases they are entirely comprised in highly functional hydrographic basins for which they constitute regulatory reservoirs, particularly in the North and in the Maghreb;
- in other cases, they are discordant and often more extensive than hydrographic basins with little or no functionality, either in major karstic zones such as the Dinaric region or in the arid or semi-arid zones of the South-Eastern Mediterranean; in this case, they are the most relevant frameworks for managing water resources.

- The coastal aquifers in the Mediterranean basin are of particular importance as they are very much in demand (due to increasing urbanisation of coastal areas and because of tourism) and at the same time fragile, exposed to the risk of inrushing seawater caused by overexploitation.
- The deep aquifers in several countries of the South (in particular Algeria, Egypt and Libya) and also in Jordan have substantial (though non-renewable) water reserves which require specific abstraction strategies.
- Some aquifers straddle national boundaries: mainly in the South (large Saharan aquifers shared between Algeria, Libya and Tunisia, and between Egypt and Libya) and in the Middle East (Mountain Aquifer shared between Israel and the Palestinian territory); the Disi Aquifer of Jordan which is contiguous with the Saq Aquifer of Saudi Arabia; the aquifer of the Ras-el-Aïn source of Khabour shared between Turkey and Syria) and more locally in South-Eastern Europe.

3 THE ROLE AND IMPORTANCE OF THE COASTAL KARSTIC AQUIFERS

Karstic aquifers are present in large areas along the Mediterranean coast. In most cases, these aquifers represent the unique resource of water supply for drinking, agricultural and industrial uses. Especially in the European side of Mediterranean basin, the increase of population and tourism, the concentration of agricultural and industrial practices, together with decrease of precipitation and the increase of evapotranspiration due to climatic change, determine a very high exploitation of groundwater resources.

In coastal conditions, it means that the aquifer is open toward the sea and fresh waters float on salt water of marine origin, the overexploitation of the aquifers creates a progressive salinisation of groundwater due to seawater intrusion. Coastal karstic aquifers are more sensitive to this phenomenon than porous or only fractured ones, because karstic channels, normally feeding subaerial or submarine springs, can become easy way of penetration inland of seawater, when overexploitation conditionsa of the aquifer are reached.

Such type of aquifers need a particular care in their management that can be realised only knowing exactly their functioning, especially as far as thew laws regulating the delicate equilibrium between fresh water and intruding salt water are concerned.

Spain: Spain is one of the countries where it is possible to find numerous examples of coastal karst aquifers, as more than 50% of the coastal zone is coveresd by carbonate rocks. The Mediterranean part of the Spanish coast could be devided in four sectors where the presence of karstic aquifers is significant: i) aquifers related with the materials of the Internal Zone of the Betic Cordillera (Málaga, Grenada and Almería); ii) aquigers related to the limestones of the External Zones of the Betic Cordillera (province of Alicante); iii) aquifers linked to coastal sectors of the Iberian

Mountain range and the Catalan Chain (Castellón, Tarragona and Barcelona) and iv) aquifers of the Balearic Islands (Mallorca and Menorca) also belonging to the External Zone of the Andalusian Mountain range but with strong singularity of the insularity. All of these aquifers present varied problems linked to their different status and degree of exploitation. In general, Mediterranean Spanish aquifers support high abstraction rates and in a number of occasions, some could be considered as over-exploited.

France: The Mediterranean coastal karst aquifers in France are stretching along the seashore from Languedoc to Roussillon. They consist of Jurassic and Cretaceous limestone that corresponds to the Pyrenees tectonic lineation. Three karstic aquifers can be considered representative of the French Mediterranean coast: Salses-Leucate lagoon in the Corbieres limestones, Thau lagoon in the Hérault limestones and the well-known submarine springs of Port Miou (west of Marseille) in the Cretaceous of the Côte d'Azur. All three aquifers do not present significant problems of over-exploitation, but as the demand on this tourist coast is increasing constantly, protective measures against seawater intrusion processes should be considered (some of the are sited in natural protected areas).

Italy: The coastal karst aquifers could be geographically classified in: i) the coastal karst areas of Trieste; ii) the karst of the Apulia region; iii) the aquifers of Sicily and iv) the coastal karst aquifers of Sardinia. The karst of Trieste-Kras is well known by the coastal springs of Timavo and its relation with the San Canziano caves recharge area in Slovenia. In Apulia, from Gargano to Salento, different karstification levels have been detected and linked to the Mediterranean sea level oscillations. Some of these levels seem to be related to submarine brackish springs. The carbonate aquifers of Sicily (Palermo region to the west and Iblei-Siracusa to the east) are essentially made of dolomite and limestone of Triassic-Jurassic age. The karstic aquifers of Sardinia are mainly located at the border of the island where the Paleozoic limestones are cropping out. Some of these aquifers have undergone extensive exploitation due to mining activities.

Slovenia: the aquifer of Kras – which gave the name to the international term "karst" – is the most important coastal aquifer in Slovenia and it is linked to the Timavo springs of Trieste (Italy). In this aquifer some important well fields are constructed and operate successfully apparently with no signs of saltwater intrusion. Another semi-confined aquifer that is also described as representative of the Slovenian coastal karst system is located at the coast of Izola and is not exhibiting seawater intrusion processes.

Malta: The islands of Malta and Gozo constitute two very interesting examples of coastal karst aquifers. Carbonate rocks constitute almost the totally of both islands. Outcrops belong to the carbonated tertiary Formations (Upper and Lower Limestones and Globigerine Formation) and are separated by sandstone and clay strata (Green Sandstone and Blue Clay Formation). These islands could be considered as a real research laboratory of seawater and karstification interaction.

Croatia: The karstic aquifers of Croatia follow the Dinaric structures and lineations mainly built by highly karstified limesones. In this Adratic country, some of the best examples of submarine springs in Europe exist and many of them have been exploited in order to cover water supply demands. The karstic aquifers in Croatia can be devided in two geographical groups: i) the aquifers close to the Istria peninsula (Northern Croatia) and ii) the Dubrovnik-Split coast (Southern Croatia). In addition, many of the Croatian islands could be considered as coastal karst aquifers.

Greece: Carbonate rocks cover more than 35% of Greece and many of them are cropping out at the coast. The karstic aquifers in Greece can be devided in the following groups: i) Central Greece (i.e. South Parnassos and Ghiona aquifers) with brackish water because of seawater intrusion influence, ii) Parnitha-Pateras and Hymittos aquifers with karstic conduits 150 m below sea level, iii) Eastern

Peloponnese (Tripolis and Argolis aquifers) with high discharge of water to the sea from submarine springs and iv) Crete island with the famous Almyros springs that can discharge over 50 m^3/s.

Cyprus: In Cyprus, there are two coastal aquifers which are developed in karstified reef limestones. Both are characterized by an hydraulic connection and water interchange with the sea. The most important one is the Androlykou limestone which has an average thickness of 50 to 60 m and average borehole yields 10-15 m^3/h.

Turkey: The best-known coastal karst aquifers are located in the southern part of Turkey: the sector of Gökova basin and the coastal karst of Ovacik, characterised by complicated geological and hydrogeological structure.

Karstic aquifers are also present in other coastal areas of the Mediterranean. Very important are the karstic aquifers along the Syrian-Lebanon coast.

4 UNEQUALLY EXPLOITABLE GROUNDWATER RESOURCES

The natural rain-fed and sometimes river-fed sources supplying aquifers in the countries of the Mediterranean constitute only a part of the renewable water resources that can be mobilised, taking account of the practical and economic constraints and environmental criteria, in particular the desire to conserve permanent surface drainage from low water and particular aquatic ecosystems maintained by groundwater.

The aquifer water resources differ not only in terms of the quantities they drain but also in conditions of accessibility and practicable methods of exploitation - and consequently the categories of agents who can mobilise these resources – and also in terms of the natural quality of the water which is not always flawless (frequent salinity in the South).

The most accessible groundwater resources are in the alluvial plains and valleys, which can be easily exploited through shallow wells that are often highly productive and within the reach of many individual users, in particular irrigators. The downside of this, however, is that it easily leads to overexploitation.

The karstic resources, although usually the most abundant, are unequally exploitable through deep and random borings or tunnelling, and are subject to conservation constraints.

The exploitation of deep sedimentary aquifers requires deep borings (>100 to 1000 m) which are often highly productive, with the possible advantage of tapping artesian wells (which, however, are not sustainable) more generally within the reach of public agents.

In exceptional cases, the exploitable resources of certain aquifers may exceed -sometimes considerably – their natural supply. This applies to alluvial aquifers highly oversupplied from irrigation (dependent on surface water). The best known example is the situation in the Nile valley and delta in Egypt; the aquifer of the Crau plain in France, near the Rhone delta, is another example.

Overall, groundwater resources that are genuinely exploitable in the countries of the Mediterranean amount to only about 100 billion m^3/year, in other words, on average a third of renewed natural flows, though evaluated according to various criteria pertaining to each country.

5 HIGH DEMAND FOR FAVOURED SUPPLY SOURCES

Groundwater resources play a major role in the water economy of the countries of the Mediterranean. In eight countries (Algeria, Cyprus, Croatia, Israel, Libya, Malta, Palestinian Territories, Tunisia), groundwater is the main supply source for all applications.

A total of nearly 60 billion m³ groundwater is currently abstracted each year (1990-2000) in the countries of the Mediterranean, of which 54% in Europe, 18% in the Middle East and 28% in the South, with Italy, France and Turkey as the major consumers. The main use overall is irrigation (35.5 km³/year) followed by drinking water supply (17.4 km³/year) and industrial use (3.2 km³/year)

Groundwater abstraction provides nearly half of the total production of drinking water and a fifth of water for irrigation, although the figures vary quite considerably from one country to another.

Groundwater is the safest source of drinking water. Moreover, it is generally agreed that irrigation with groundwater, in general directly abstracted by irrigators, is much more efficient than irrigation with surface water distributed by collective networks.

Over the past 20 to 30 years, groundwater abstraction has greatly increased in most Mediterranean countries, in particular in the South. Between 1970-80 and today (around 2000), abstraction has risen by 37% in France, doubled in Algeria and Turkey, and increased threefold in Tunisia, fourfold in Libya and fivefold in Egypt.

This has led to strong pressure on resources:

- On renewable resources deemed exploitable: the current rate of exploitation is close to or more than 100%, meaning that there is overexploitation in various countries in the North (Spain, Italy, Greece, Malta, Cyprus) as well as in the South (Israel, Gaza, Libya, Tunisia). The exploitation rate exceeds 50% in Turkey, Syria, Lebanon, the West Bank, Algeria and Morocco. In Egypt, the considerable oversupply of irrigation water to the groundwater reservoirs in the Nile valley and delta enables abstraction well above natural aquifer replenishment.
- On non-renewable resources: production through "mining" currently produces almost 6 km³/year, concentrated especially in Libya (over 3 km³/year) and Algeria, but also in substantial quantities in Egypt and Tunisia. Since the beginning of this exploitation (1950-1960), 50 billion m³ has been abstracted from the reserves of the two principal Saharan aquifer systems.

The water supply situation is therefore fragile in several Mediterranean countries because of the non-sustainable nature of part of current groundwater production and the overexploitation of renewable resources or mining of non-renewable resources. At present, this non-sustainable production accounts for substantial proportions of total water quantities used in a number of countries:

- 84% in Libya
- 44% in Jordan
- 34% in Algeria
- 31% in Malta
- 23% in Gaza
- 22% in Tunisia
- 12% in Cyprus

Aquifers are also beginning to contribute to regulating surface waters through artificial replenishment operations, in particular in Tunisia, which will further increase to counter the decline of surface reservoirs (silting).

Finally, groundwater plays a major role in maintaining numerous aquatic ecosystems and wetlands whose conservation imposes local constraints on exploitation.

Moreover, groundwater in the countries of the Mediterranean is vulnerable to particularly extensive pollution, especially in groundwater reservoirs of built-up and irrigated areas where urban pollution (lack of sewage and water purification facilities) or agricultural pollution (excessive use of fertilisers and pesticides) has been on the increase in many regions.

6 MANAGEMENT PROBLEMS AND GUIDELINES

The main objectives for managing groundwater resources in most Mediterranean countries are as follows:

- Controlling intensive exploitation which may have detrimental effects internally (excessive decreases aggravating production conditions or adversely affecting quality) or externally (on permanent surface waters and ecosystems or on soil stability). In particular: reducing overexploitation, especially in coastal areas where it causes inrushes of seawater.
- Reducing pollution, in particular extensive pollution and that caused by agriculture, and restoring quality; in particular, ensuring the protection of groundwater collected to supply drinking water. The weak resilience of groundwater in general causes pollution to be long-lasting and makes efforts at prevention more effective and less costly than reparative measures.
- Integrating the management of groundwater and surface water on the basis of proper recognition of the links between aquifer systems and hydrographic basins, with the participation of the various user communities, and by adopting the principle of "management per basin" promoted in Europe with regard to the diversity of the respective functions of hydrographic basins and aquifer systems in structuring water resources, and therefore the diversity of the territorial units of their management. In particular, diminishing and preventing the impact of certain overground hydraulic construction projects on the supply and control of groundwater; improving artificial replenishment.
- Preventing and settling conflicts of use:
  - between groundwater users with unequal means and/or different objectives;
  - between the various users of interdependent groundwater and surface water.
- Promoting joint management of aquifer water resources shared among several territorial entities, in particular aquifers straddling national boundaries.
- Making preparations to move away, in the medium or long term, from the non-sustainable exploitation of groundwater (overexploitation or mining) which should eventually be stopped, by mobilising other resources (including non-conventional ones) or by transforming activities and reducing water demand.

Most of these problems and management objectives are common to most Mediterranean countries. They therefore require exchanges of experience and particularly relevant and targeted cooperation.

7 SUMMARY OF GROUNDWATER ASPECTS OF THE WATER FRAMEWORK DIRECTIVE (2000/60/EC) – GROUNDWATER DAUGHTER DIRECTIVE

The EU Water Framework Directive (WFD) came into force on 22 December 2000. It was introduced in response to a consensus across Europe that water policy was fragmented. This single piece of framework legislation expands the scope of water protection to all bodies of water, surface water and groundwater, with the aim of achieving 'good status' by 2015.

The key features of the Water Framework Directive are:

- The concept of river basin management is introduced through the establishment of river basin districts as the basic management units. For international rivers these river basin districts (RBDs) will transcend national boundaries (Article 3).
- For each river basin district a river basin management plan must be developed, including a programme of measures, and these will form the basis for the achievement of water quality protection and improvement (Articles 11 and 13).
- Although its prime aims are environmental, the Directive embraces, all three principles of sustainable development. Environmental, economic and social needs must all be taken into account when river basin management plans are being developed (Article 9).
- The river basin management plans will not allow further deterioration to existing water quality. With certain defined exceptions, the aim is to achieve at least good status for all water bodies in each river basin district. Geographical factors are allowed for when good status is defined and the principle of subsidiarity allows Member States some freedom within the overall requirements of the Directive (Article 4).
- To overcome the previously piecemeal nature of water environment regulation, a number of existing directives will be replaced when new local standards are developed to meet the Directive requirements. These local standards must be at least as stringent as those being replaced. Daughter directives will be introduced to deal with groundwater quality and for priority substances (formerly known as dangerous substances) (Article 16).
- Measures to conserve water quantity are introduced as an essential component of environmental protection. Unless minimal, all abstractions must be authorised and, for groundwater, a balance struck between abstraction and the recharge of aquifers (Article 11).
- The polluter pays principle is incorporated through a review of measures for charging for water use, including full environmental cost recovery (Article 9).
- Public participation and the involvement of stakeholders is a key requirement of the river basin management planning process (Article 14).

The Water Framework Directive is, without doubt, the most comprehensive approach to water policy ever produced by the EU. It can be seen that the outline river basin planning process is essentially based on the following elementary steps.

1. Identify the water bodies that comprise the river basin district and the pressures upon them.
2. Establish the environmental objectives that signify good status for each water body.
3. Set up a monitoring programme to measure water body status.
4. Establish and implement a river basin management plan and a programme of measures to achieve and maintain good status.
5. Review and update the river basin management plan and the programme of measures to take into account any change of circumstances.

Water bodies include lakes, reaches of rivers and groundwater bodies. Groundwater bodies are defined as *distinct volumes of groundwater within an aquifer or aquifers*. The Directive sets out a series of environmental objectives to be met. Those specifically for groundwater are:

- to implement measures to prevent or limit the input of pollutants into groundwater and to prevent deterioration of groundwater;
- to protect, enhance and restore all bodies of groundwater, ensure a balance between abstraction and recharge of groundwater, with the aim of achieving 'good groundwater status' within 15 years of the Directive coming into force, except under certain special circumstances;
- to implement measures to reverse any significant and sustained upward trend in the concentration of any pollutant resulting from the impact of human activity in order to progressively reduce the pollution of groundwater; and
- to ensure compliance with the relevant standards and objectives for 'Protected Areas' within 15 years of Directive implementation (includes groundwater bodies from which abstraction for human consumption exceeds 10 m^3/d or serves greater than 50 persons).

Less stringent objectives for specific bodies of water may be set where these are so affected by human activity or their natural condition is such that it would be unfeasible or disproportionately expensive to reach good status. The 15-year target date can be extended where there are reasonable grounds.

Groundwater status consists of quantitative and chemical components (*Table 1*). Groundwater levels will be used as a measure of quantitative status. The levels in the groundwater body should be such that the available groundwater resource is not exceeded by the long-term annual average rate of abstraction. Chemical status is measured by concentrations of pollutants and changes in electrical conductivity in the groundwater body such that it:

- does not exhibit effects of saline or other intrusions;
- does not exceed the Community quality standards;
- would not result in failure to achieve the environmental objectives in associated surface waters or terrestrial ecosystems.

Ref. WFD	Good Status
Good quantitative status (Annex V.2.1.2)	The level of groundwater 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 subject to anthropogenic alteration such as would result in: (a) failure to achieve the WFD environmental objectives for associated surface waters, (b) any significant diminution in the status of such waters, and (c) any significant damage to terrestrial ecosystems which depend directly on the groundwater body. Alterations to 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.
Good chemical status (Annex V.2.3.2)	The chemical composition of the groundwater body is such that the concentration of pollutants do not exhibit the effects of saline or other intrusions (as determined by changes in conductivity) into the groundwater body, do not exceed the quality standards applicable under other relevant Community legislation in accordance with Article 17 of the WFD, and are not such as would result in failure to achieve the WFD environmental objectives for associated surface waters not any significant diminution of the ecological or chemical quality of such bodies nor in any significant damage to terrestrial ecosystems which depend directly on the groundwater body.

***Table 1**: Definitions of good quantitative and chemical status under the WFD*

The process and timetable for Member States to achieve the environmental objectives, as regards the groundwater resources, can be briefly described as follows (timings are relative to the date when the Directive came into force – 22 December 2000):

Within 4 years

- assignment of groundwater bodies to River Basin Districts and characterisation of groundwater bodies through an analysis of pressures and impacts of human activity
- identification and listing of protected areas
- review of the impact of human activity on the status of surface water and groundwater
- classification of water bodies, including those that are at risk of failing to meet environmental objectives. The latter must generally be characterised in more detail.
- economic analysis of water use

Within 6 years

- establishment of groundwater monitoring programmes

Within 9 years

- establishment of River Basin Management Plans including a Programme of Measures designed to enable objectives to be met.

Within 10 years

- appropriate water pricing policies put in place

Within 15 years

- ensure 'good status' is achieved for all water bodies except for exceptional cases.

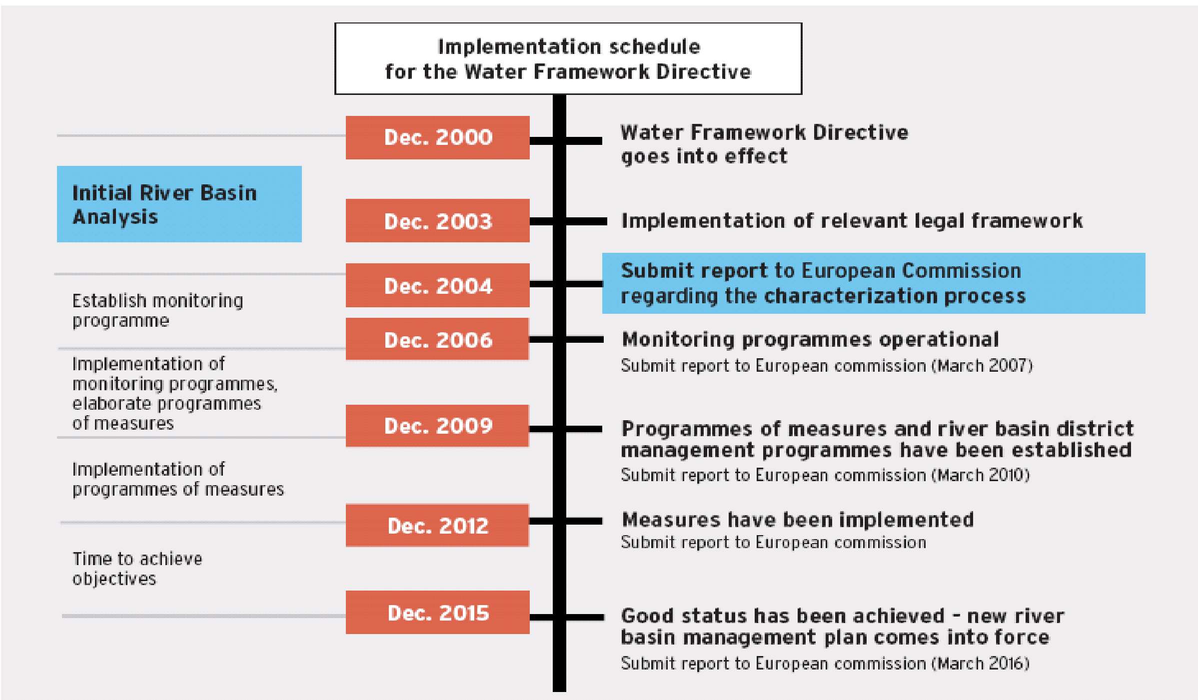


***Figure 8:** Implementation schedule for the Water Framework Directive*

Strategies to prevent and control pollution of groundwater are covered by Article 17 of the WFD, which requires the establishment of criteria for assessing good groundwater chemical status, the identification of significant and sustained upward trends and for the definition of starting points for trend reversals.

Article 17 requests the European Commission to present a proposal based on the above requirements. This new Groundwater Directive proposal, which will complement the WFD, sets up criteria for the evaluation of good groundwater chemical status (based on EU-wide quality standards, groundwater threshold values and WFD criteria), for the identification and reversal of significant and sustained upward trends in pollutant concentrations (taking account of threshold values to be developed by Member States at the national, regional or local level) and provides additional requirements concerning the prevention or limitation of indirect discharges.

The proposed Groundwater Directive will ensure that groundwater quality is monitored and evaluated across Europe in a harmonised way. The proposed approach to establishing quality criteria takes account of local characteristics and allows for further improvements. It represents a proportionate and scientifically sound response to the requirements of the Water Framework Directive related to the assessment of the chemical status of groundwater and the identification and reversal of significant and sustained upward trends in pollutant concentrations.

CHAPTER I:
OVER-EXPLOITATION OF GW RESOURCES

I.1 INTRODUCTION

Groundwater depletion is the inevitable and natural consequence of withdrawing water from an aquifer. Theis (1940) showed that pumpage is initially derived from removal of water in storage, but over time is increasingly derived from decreased discharge and/or increased recharge. When a new equilibrium is reached, no additional water is removed from storage. In cases of fossil or compacting aquifers, where recharge is either unavailable or unable to refill drained pore spaces, depletion effectively constitutes permanent groundwater mining. In renewable aquifers, depletion is indicated by persistent and substantial head declines.

The term overexploitation has been frequently used during the last three decades. Nevertheless, according to Llamas (2001), most authors agree in considering that the concept of aquifer overexploitation is one that is poorly defined and resists a useful and practical definition (Adams and MacDonald, 1995; Collin and Margat, 1993; Custodio, 1992, 2000 and 2002; Foster, 1992; Sophocleous, 1997 and 2000).

A number of terms related to overexploitation can be found in the water resources literature. Some examples are: safe yield, sustained yield, perennial yield, overdraft, groundwater mining, exploitation of fossil groundwater, optimal yield and others (Adams and MacDonald, 1995; Fetter, 1994). In general, these terms have in common the idea of avoiding ‘undesirable effects’ as a result of groundwater development. But we must clearly differentiate the terms ‘overexploitation’, which deals with renewable groundwater resources and ‘water mining’, term related to non-renewable or ‘fossil’ groundwater reserves which will be treated in chapter 1.5.

Although generally, an aquifer is considered ‘overexploited’ when the pumpage is close to or larger than the natural recharge, it must be pointed out that strictly, this is a common misconception which considers that the ‘safe yield’ or ‘sustainable yield’ is practically equal to the natural recharge and that aquifers are isolated systems, which is rarely the case. Water withdrawn artificially from an aquifer is derived from a decrease in storage in the aquifer, a reduction of the previous discharge from the aquifer, an increase in the recharge, or a combination of these changes. In many circumstances, the dynamics of the groundwater system are such, that long periods of time are needed before any kind of an equilibrium conditions can be reached. Bredehoeft and al. (1982) present some theoretical examples to show that the time needed to reach a new equilibrium or steady state between groundwater extraction and capture may take decades or even centuries. Custodio (1992) has also presented graphs to show the relationship between the size of the aquifer, its diffusivity and the time necessary to reach a new steady state after the beginning of a groundwater withdrawal and obtained similar values to Bredehoeft and al. (ibid).

When a well field is operated, even if the general input is much greater than pumping, a transient state will always occur before water levels in wells stabilise. The duration of the transient state depends mainly on aquifer characteristics such as size and hydraulic diffusivity, degree of stratification and heterogeneity. On the other hand, the natural recharge of an aquifer in semiarid and arid climates, common in Mediterranean countries, does not show a linear relationship with precipitation. In dry years, recharge might be negligible or even negative due to evapotranspiration or evaporation from the watertable. Significant recharge may only occur once every one-decade or more. Therefore the water table depletion trend during a long dry spell – when the recharge is almost inexistent and the pumpage is high – might not be representative of a long-term situation.

Therefore, deep groundwater dynamic knowledge is necessary to state overexploitation in any large and complex aquifer.

Non-renewable groundwater resources exploitation is another issue. Certain authors consider that ‘groundwater mining’ is clearly against sustainable development and that this kind of ‘ecological sin’ should be socially rejected and/or legally prohibited. Nevertheless, a good number of authors (Freeze and Cherry, 1979; Issar and Nativ, 1988; Llamas, 2001; Collin and Margat, 1993; Margat, 1994; Lloyd, 1997) indicate that, under certain circumstances, groundwater mining may be a reasonable option, or the only one available for development, taking into account that, as it happens in any mining process, is time limited. For instance, in countries with practical absence of renewable water resources, reserves can be the unique alternative for socio-economic development until technification can supply new resources.

As a matter of fact, groundwater mining is today practised in a good number of regions (Benblidia and al., 1996; Custodio, 1993; Issar and Nativ, 1988). Fossil groundwater has no intrinsic value if left in the ground except as a potential resource for future generations, but it is not clear that such future generations are going to need it more than present ones. But managers must be aware that equilibrated and sustainable exploitation of these aquifers is impossible in middle-long term.

The vulnerability of an aquifer to overexploitation depends on its characteristics, climate, hydrological conditions and its related water uses.

Groundwater development significantly increased during the second half of the last century in most semi-arid or arid countries. In some cases the lack of control on groundwater development has caused problems such as depletion of the water level in wells, decrease of well yields, degradation of water quality, land subsidence or collapse, interference with streams or surface water bodies, ecological impact on wetlands or gallery forests.

In certain regions the extent of groundwater abstraction exceeds recharge rate. In Europe, the share of groundwater needed at the country level to meet the total demand for freshwater ranges from 9 % up to 100 %. There can be found some examples of overexploitation in European Mediterranean countries (Spain, Greece) and in southern and eastern Mediterranean countries (Morocco, Tunisia, Algeria, Libya, Malta, Israel, Gaza Strip…) but this shouldn’t be considered ‘groundwater mining’.

The rapid expansion in groundwater abstraction over the past 30–40 years has supported new agricultural and socio-economic development in regions where alternative surface water resources are insufficient, uncertain or too costly. The main reported cause of groundwater overexploitation is water abstraction for irrigation, for public and industrial supply. Mining activities and dry periods can also lower groundwater tables. However, irrigation is, by far, the main cause of groundwater overexploitation in agricultural areas. An example is the Greek Argolid plain of eastern Peloponnesos, where it is common to find 400 m deep boreholes contaminated by salt-water intrusion and the Vinalopó Basin aquifers case, in Spain (South-East Júcar River Basin Authority) with severe overexploitation effects (some hundred meters water level depletion and water quality deterioration).

Adams and MacDonald (1995) noted that, in general, overexploitation is only diagnosed ‘*a posteriori*’. They consider three main indicators: a) decline in water levels, b) deterioration of water quality and c) land subsidence. Llamas (2001) and MIMAM (1998) considered two other relevant effects: d) the hydrological interference with streams and lakes and; e) the ecological impact on aquatic ecosystems fed by groundwater. Thresholds in these indicators stating overexploitation must reflect ‘undesirable effects’.

Some consequences of overexploitation can be summarised as follows:

- Groundwater level depletion: Groundwater depletion caused by deep wells can cause the drying up of shallow wells or "foggaras" (also known as "khettaras" or "khanats" - infiltration galleries) located in the area of influence of the deep wells. This may translate into social problems in regions where farmers can not afford to drill new wells or Water Authorities are not able to demand just compensation in the form of water or money to the poorer farmers. Vinalopó basin aquifer of Crevillente in Spain is a good example of water mining, which is one of the 17 hydrogeological units with provisional or definitive declaration of over-exploitation by the Ministry of Environment (MIMAM, 1998) with more than 300 m water level depletion and salt increase in groundwater.

- Groundwater quality deterioration: Continuous groundwater overexploitation can cause isolated or widespread groundwater quality problems. Over-abstraction causes a drawdown in groundwater level, which can influence the movement of water within an aquifer. Significant drawdowns can cause serious quality problems as stated in Vinalopó basin aquifers where abstractions have mobilized high time residence salty water reserves. One of these problems represents the displacement of the freshwater/saltwater interface, consequently, causing active saltwater intrusion. Saltwater intrusion is considered another negative consequence. Large areas of Mediterranean coastline have been affected by saltwater intrusion. The main cause of marine intrusion is groundwater over-abstraction for public water supply, followed by agricultural water demand and tourism-related abstractions.

- 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, Bologne and Ravenna in Italy.

- River/lakes-aquifer interactions: aquifers can exert a strong influence on river flows and lake permanence. During the summer season, many rivers depend on groundwater base flow contribution for maintaining their minimum flow. Lower groundwater levels due to overexploitation may, therefore, endanger ecological and economic functions of dependent rivers, including surface water abstractions, dilution of effluents, navigation and hydropower generation.

- Wetland alteration: Water abstraction in areas closed to wetlands can cause severe problems: groundwater pumping usually lowers groundwater table producing a new, deeper unsaturated zone. This can severely damage wetland ecosystems, which are sensitive to minor changes in water level. In the Upper Guadiana, in Spain, the degradation of some important wetlands caused by groundwater abstraction for irrigation has caused a serious conflict between farmers and conservationists. Abstractions carried out in the last twenty years in the "La Mancha Oriental" aquifer have caused a continuous drop in piezometric levels, which has led to deterioration in many of the existing wetlands, especially in the "Tablas de Daimiel National Park" (Estrela and al., 1996, MIMAM, 1998). It is important to mention, that since the implementation of the Water Framework Directive (2000/60/EC) in Member States and candidate countries water managers are taking a new approach regarding management of aquifers and their associated ecosystems. The term of "available groundwater resource" is defined in article 2, definition 27 as: *"… the long term annual average rate of overall recharge of the body of groundwater less the long term annual rate of flow required to achieve the ecological quality objectives for associated surface waters specified under Article 4, to avoid any significant diminution in the ecological status of such waters and to avoid any significant damage to associated terrestrial ecosystems."*

Finally, it can be concluded that there is overexploitation of groundwater when a significant proportion of the interannual renewable resource is withdrawn from the aquifers, causing hydrogeological functioning modifications, deriving in significant ecological, or socio-economic impacts, or major changes produced to river-aquifer associations deriving all of them in ‘undesirable effects’.

I.2 GROUNDWATER QUANTITATIVE STATUS IN THE MEDITERRANEAN

In the Mediterranean region, water is highly valued due to its scarcity, fragility, unequal distribution and wide exploitation. Hydrographic basins are commonly divided, and basins are often crossed by national borders, which make water resources common to several countries hampering their management. Furthermore, some considerable water volumes stored in large deep aquifers in Libya, Tunisia, Egypt and Algeria are non-renewable resources and their use is consequently not sustainable.

Natural and renewable water resources are unequally distributed between Mediterranean countries. The four richer countries in water resources, France, Italy, Turkey and the former-Yugoslavia, account for 902 km^3/yr, which represent over 2/3 of the water resources of the region (1270 km^3/yr). However within each country, water resources are also unequally distributed. In Spain, 81% of resources are located in the Northern half of the country; in Tunisia, the North (an area representing 30% of its national territory) provides 80% of the country’s resources; in Algeria, 75% of renewable resources are concentrated in 6% of the land, located in the Mediterranean coastal border.

In terms of population, the annual availability of water resources per capita is highly unbalanced between the relatively rich and even overabundant North, and the poor to extremely poor South and East.

Eight countries, with a total population of 115 million inhabitants, now lie below the desirable resource threshold of 1000 m^3/year/capita (UN, 1997). Naturally, tensions appear between needs and resources, particularly when irrigation is necessary. In six countries, with a population of 28 million (Israel, Jordan, Malta, Tunisia, Libya and Gaza-West Bank), water resources are below the extreme poverty threshold of 500 m^3/year/capita.

With rapid population growth and possible re-allocations between countries in the region, the availability per capita is likely to be further reduced in the region. In many countries, water withdrawals exceed the limits of natural resource renewal and deplete the stock that cannot be renewed. Thus, Libya is making massive use of its "fossil" groundwater reserves.

The following table (*Table 2*) summarizes main groundwater bodies in Mediterranean countries, which show large extensive recharge areas and hundreds to thousands millions of cubic meters of water resources. These water bodies are characterized by presenting very high memory effects and low dynamics, therefore, transitory time periods necessary to reach a new steady state after the beginning of a groundwater withdrawal, may extend through decades.

Country & Entities		Name	Type of reservoir	Area (km^2)	Average Discharge (hm^3/yr)
ES	Spain	Mancha Oriental	multi-layered sediments	3300	330
		Valencia plain	"	760	430
		Campo de Cartagena	"	1390	32
		Valle del Ebro	alluvial	1000	336
FR	France	Jura, bassins du Doubs et de La Loue	karstic	6350	4200
		Bas-Dauphiné	multi-layered sediments (mollasse)	3300	1245
		Vaucluse	karstic	1230	600
		Vercors	"	846	950
		Plan de Canjuers / Verdon	"	911	450
		Larzac	"	950	400
		Comtat / Miocène du Vaucluse	alluvial	668	165
		Crau	"	545	200
		Roussillon	multi-layered sediments	860	60
IT	Italy	Po Bassin	alluvial, multi-layered sediments	30000	15145
		Italie centrale	egroup of karstic aquifers	15000	10000
HR, SI	Croatia-Slovenia	Dinarik region	group of karstic aquifers	80000	15000
LB	Lebanon	Mont Liban	group of karstic aquifers	2085	930
IL-WE	Israel-West Bank	Mountain Aquifer	karstic	~ 5000	660
IL-GZ	Israel-Gaza Strip	Coastal plain	multi-layered sediments	2165	325
EG	Egypt	Nil Delta	alluvial, multi-layered sediments	30000	2300
		Vailée du Nil	alluvial	11000	
		Moghra Aquifer	sedimentary, carbonate	~ 200000	100 à 200
LY	Libya	Kikla Aquifer (Hamada Basin)	multi-layered sediments (c)	215000	100 à 300
		Jebal Al-Akhdar	karstic	~ 20000	~ 500
LY-TN	Libya-Tunisia	Jeffara plain	multi-layered sediments	35000	~ 400
TN	Tunisia	Nord-Ouest de Tunisie	group of karstic aquifers	8100	55

Table 2*: Main Groundwater Bodies in Mediterranean Basin of Mediterranean countries*
(Margat and Vallée, 2000 in Blue Plan)

However, large aquifers are not very representative of the Mediterranean region. On the contrary, in most cases, aquifers present small extensions and limited resources, with relatively quick dynamics, wide head variations and high sensibility to droughts.

Groundwater renewable resources represent 24% of total renewable resources in Mediterranean countries (*Table 3 & Figure 9*), with very wide variations from one to another country (from 1,4% in former Yugoslavia to more than 80% in Gaza Strip and West Bank).

Country & Entities	Country & Entities	Date of estimation	Total renewable resources	Groundwater renewable resources	Groundwater renewable resources	Exploitable groundwater renewable resources	Exploitable groundwater renewable resources
			km³/yr	km³/yr	%	km³/yr	%
ES	Spain	1997	111,5	29,9	26,8	4,5	4,0
FR	France	1994	189,5	100	52,8	30	15,8
IT	Italy	1990	191,3	43	22,5	13	6,8
MT	Malta	1995	0,06	0,027	45,0	0,015	25,0
SI	Slovenia	2002	31,87	13,5	42,4		
HR	Croatia	2002	71,4	11	15,4		
BA	Bosnia-Herzeg.	2002	37,5	6	16		
YU	Serbia-Monten.	2002	208,5	3	1,4		
MK	FYR Macedonia	2002	6,4	1	15,6		
AL	Albania	1995	41,7	6,2	14,9	2,45	5,9
GR	Greece	1990	74,25	10,3	13,9		
TR	Turkey	1998	231,7	69	29,8	12	5,2
CY	Cyprus	1998	0,78	0,41	52,6	0,2	25,6
SY	Syria	1993	26,26	5,4	20,6	3,8	14,5
LB	Lebanon	1998	4,8	3,2	66,7	0,685	14,3
IL	Israel	1994	1,67	1,075	64,4	1	59,9
GZ	Gaza Strip	1999	0,056	0,056	100,0	0,05	89,3
WB	West Bank	1999	0,75	0,68	90,7	0,54	72,0
EG	Egypt	2000	58,3	2,3	3,9		
LY	Libya	1998	0,82	0,5	61,0	0,5	61,0
TN	Tunisia	2000	4,57	1,55	33,9	1,15	25,2
DZ	Algeria	1994	14,32	1,73	12,1	1,7	11,9
MA	Morocco	1997	29	10	34,5	4	13,8
Total			1337,01	319,83	23,9	75,59	5,7

***Table 3**: Groundwater resources in Mediterranean countries*
(Margat, 2004)

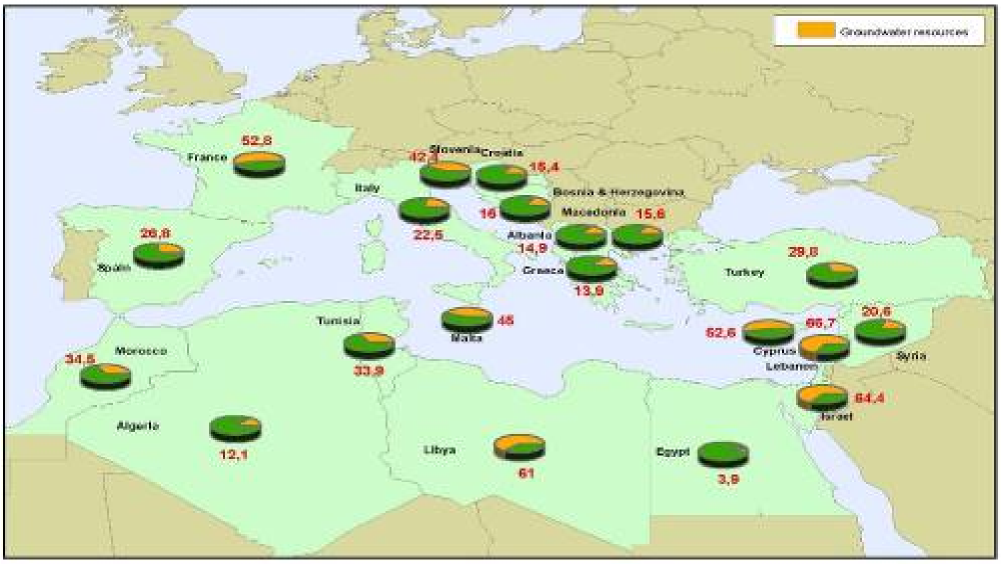


***Figure 9**: Groundwater resources in Mediterranean countries*
% Total renewable groundwater resources

The use of groundwater resources in Mediterranean countries coming from groundwater resources varies a lot. For instance, countries and entities such as Italy, Malta, Greece, Cyprus or Morocco make intensive use of groundwater, while others like Israel, Gaza, Libya, Tunisia and Algeria depend exclusively on groundwater reserves and non-conventional resources. Malta shares both, groundwater and increasing desalination resources (*Table 4*).

Country & Entities	Country & Entities	Total demand	Total groundwater witdrawals	Withdrawals partition to satisfy demands			
				Groundwater withdrawals on			
		km^3/yr	km^3/yr	Renewable resources	Non renewable resources	Renewable resources	Non renewable resources
				km^3/yr	km^3/yr	% Total	% Total
ES	Spain	35,32	5,017	4,822	0,71	13,7	2,0
FR	France	32,3	6,323	6,1		18,9	
IT	Italy	42	13,9	10,4		24,8	
MT	Malta	0,059	0,021	0,015	0,012	25,4	20,3
SI	Slovenia	1,28	0,1337	0,28		21,9	
HR	Croatia	0,718	0,42	0,42		58,5	
BA	Bosnia-Herzeg.	1	0,3	0,3		30,0	
YU	Serbia-Monten.	13	1	1		7,7	
MK	FYR Macedonia	1,845	0,014	0,2		10,8	
AL	Albania	1,4	0,6	0,63		45,0	
GR	Greece	8,7	3,563	3,56		40,9	
TR	Turkey	35,5	6,3	6		16,9	
CY	Cyprus	0,34	0,087	0,11	0,04	32,4	11,8
SY	Syria	14,71	2,3	1,8		12,2	
LB	Lebanon	1,3	0,4	0,4	0	30,8	0,0
IL	Israel	2,16	1	0,9	0,32	41,7	14,8
GZ	Gaza Strip	0,131	0,104	0,13		99,2	
WB	West Bank	0,17	0,284	0,17	0,03	100,0	17,6
EG	Egypt	73,7	5,14	5,4		7,3	
LY	Libya	4,5	4,5	0,65	3,63	14,4	80,7
TN	Tunisia	2,849	1,626	1,4	0,27	49,1	9,5
DZ	Algeria	4,8	2,85	2,2	0,41	45,8	8,5
MA	Morocco	11,48	2,7	2,63		22,9	
Total		289,26	58,58	49,52	5,42	17,1	1,9

***Table 4**: Groundwater abstractions in Mediterranean countries*

(Margat, 2004)

The Blue Plan estimates that as early as 2010 some eleven countries will be exploiting over 50% of their resources: Morocco, Algeria, Tunisia, Libya, Egypt, Israel, Palestinian Territories-Gaza, Jordan, Malta and Syria are in the forefront, followed by Cyprus. Lebanon will reach that level in 2025. Nevertheless, Malta is limiting groundwater resources abstract to 45% and increasing desalination, which in 2004 represented 55% of total water production.

According to Margat and Vallée, (1999) in Blue Plan, aquifer overexploitation is present in many Mediterranean countries: Cyprus, Malta, Gaza Strip, Israel, Spain, Egypt, Greece, Libya, Morocco, Turkey, Algeria and Tunisia. Therefore since the early 90s, groundwater resources have been partially substituted by non-conventional resources (desalination of brackish and salt waters) with an increasing rate.

The following table (*Table 5*) shows groundwater resources pressure, which is remarkable high in Israel, Gaza Strip, Egypt, Libya, Tunisia and Algeria. In Malta and Cyprus non-conventional resources have diminished groundwater pressure.

Country & Entities	Country & Entities	Groundwater renewable resources (1)	Groundwater renewable resources abstractions (2)	Groundwater pressure (2/1)
		km^3/yr	km^3/yr	%
ES	Spain	29,9	4,822	16
FR	France	100	6,1	6
IT	Italy	43	10,4	24
MT	Malta	0,027	0,015	56
SI	Slovenia	13,5	0,28	2
HR	Croatia	11	0,42	4
BA	Bosnia-Herzeg.	6	0,3	5
YU	Serbia-Monten.	3	1	33
MK	FYR Macedonia	1	0,2	20
AL	Albania	6,2	0,63	10
GR	Greece	10,3	3,56	35
TR	Turkey	69	6	9
CY	Cyprus	0,41	0,11	27
SY	Syria	5,4	1,8	33
LB	Lebanon	3,2	0,4	13
IL	Israel	1,075	0,9	84
GZ	Gaza Strip	0,056	0,056	100
WB	West Bank	0,68	0,17	25
EG	Egypt	2,3	2,3	100
LY	Libya	0,5	0,5	100
TN	Tunisia	1,55	1,4	90
DZ	Algeria	1,73	1,73	100
MA	Morocco	10	2,63	26
Total		319,83	45,72	14

***Table 5**: Groundwater pressure in Mediterranean countries*

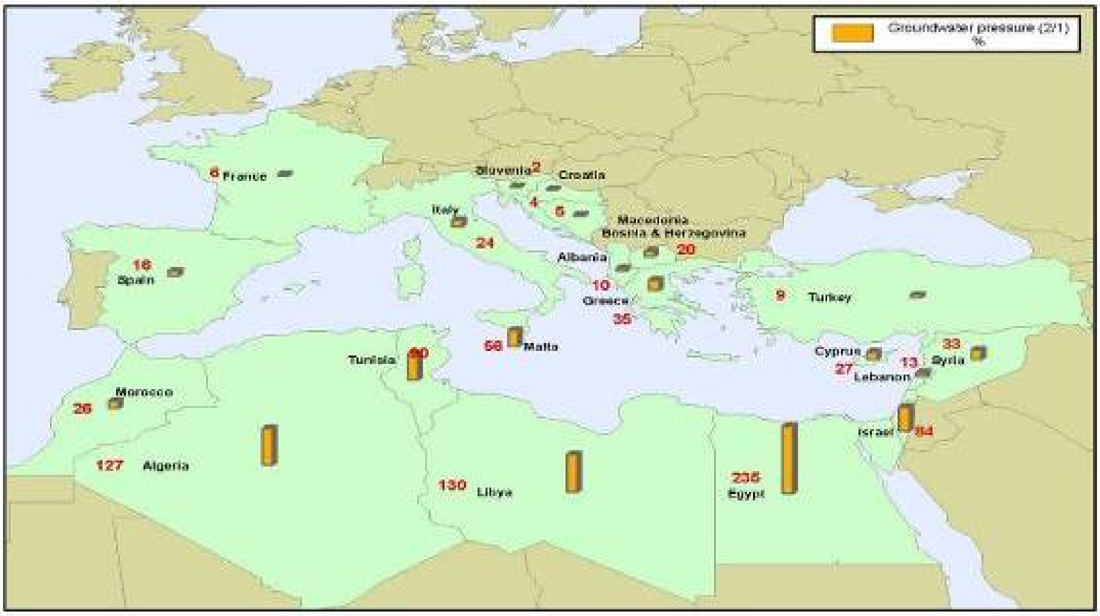


***Figure 10**: Groundwater pressure in Mediterranean countries*
(values greater than 100 reflect amount of groundwater over-exploitation)

Disordered groundwater exploitation and over-exploitation in coastal aquifers alters the equilibrium of the interface between freshwater and seawater in the groundwater system, which provokes marine intrusion. Once the salt level of groundwater has increased, drinking water quality is reduced and might require pre-use treatment or the search for alternative sources. Higher levels of salt in irrigation water also increase agricultural land salinity, leading to reduced productivity and, in worst cases, to the complete loss of agricultural land.

In agreement with afore-mentioned Blue Plan sources, most Mediterranean coastal aquifers suffer from over-exploitation due to the concentration of agriculture and tourism in coastal areas, where mild climate favours both economic activities. Coastal groundwater has been reduced to below sea level by excessive pumping in Cyprus, Greece, Israel, Italy, Libya, Spain, Algeria and Turkey.

Figure 11 shows some areas of groundwater over-exploitation around the Mediterranean region.

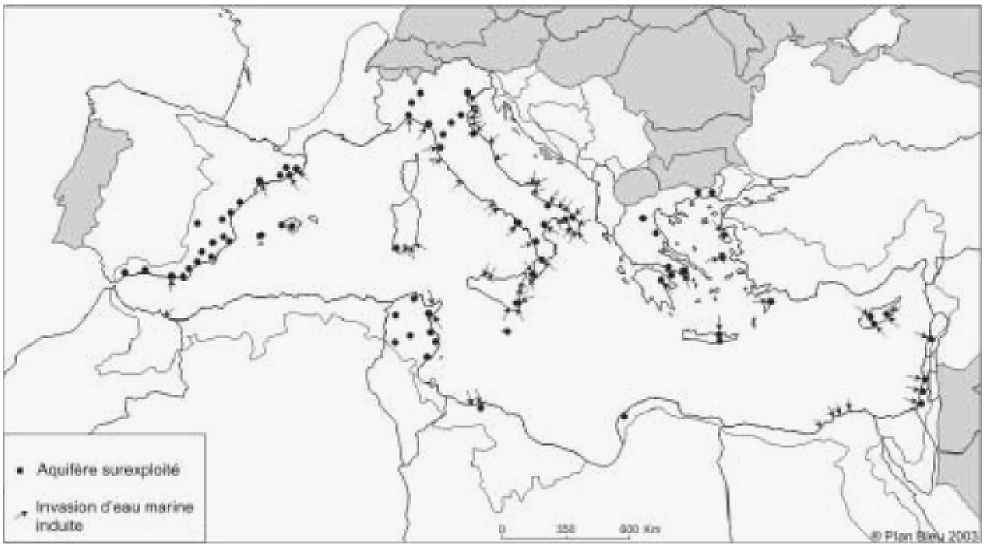


***Figure 11**: Areas where over-exploitation of groundwater was registered in the Mediterranean region according to Blue Plan*

(Margat and Vallée, 2000)

I.3 GROUNDWATER USES AND LINKS WITH OVER-EXPLOITATION

The resident population of the riparian states of the Mediterranean was 246 millions in 1960, 371 millions in 1990 and is currently about 420 millions. 'Blue Plan' estimates that depending on the development scenarios applied, this figure will rise to 520-570 million in the year 2030, is expected to reach approximately 600 million in the year 2050 and possibly as much as 700 million at the end of the 21st century. The average population growth rate in the southern countries of the Mediterranean is estimated at 3% yearly.

The distribution of population between the northern and southern countries has changed dramatically: in 1950, countries of the northern Mediterranean represented two thirds of the total population, while in 1990 it was only 50% and may be one third in the year 2025, and one fourth in 2050.

The production of drinking water to supply urban communities currently exceeds 37 billion m³/year for the whole of the Mediterranean region. It already accounts for 60% in the North and 20% respectively in the East and the South, and tends to increase in the latter regions, due to population growth and faster urbanisation. Drinking water supply represents about 13% of total water demands (*Table 6 & Figure 12*) and 31% of total groundwater withdrawals (*Table 7 & Figure 13*).

Country & Entities	Country & Entities	Population	Total Water Demand	Sectorial Water Demand		
		(million of inhab)	(km³/yr)	Public Supply	Agriculture	Sel-supplied industries
				%	%	%
ES	Spain	39,11	35,32	13,2	68,2	4,7
FR	France	56,45	32,3	18,3	9,8	11,5
IT	Italy	57,54	42	19,0	47,6	19,0
MT	Malta	0,366	0,059	69,5	11,9	0,8
SI	Slovenia	2	1,28	20,3	0,2	5,5
HR	Croatia	4,8	0,718	52,9	0,1	13,5
BA	Bosnia-Herzeg.		1	30,0	60,0	10,0
YU	Serbia-Monten.		13	6,2	7,7	40,0
MK	FYR Macedonia		1,845	11,6	73,6	14,9
AL	Albania	3,39	1,4	28,6	71,4	0,0
GR	Greece	10,05	8,7	10,0	87,4	1,3
TR	Turkey	53,7	35,5	15,5	73,2	11,3
CY	Cyprus	0,726	0,34	29,4	70,6	0,0
SY	Syria	12,53	14,71	9,4	86,7	3,9
LB	Lebanon	3,2	1,3	26,9	69,2	5,4
IL	Israel	5,8	2,16	31,5	62,5	6,0
GZ	Gaza Strip	1,475	0,131	36,6	61,8	1,5
WB	West Bank	0,932	0,17	38,2	58,8	2,9
EG	Egypt	54,8	73,7	6,2	83,5	10,2
LY	Libya	5,22	4,5	13,1	83,3	2,7
TN	Tunisia	8,785	2,849	12,8	85,3	1,9
DZ	Algeria	25,06	4,8	27,1	58,3	10,4
MA	Morocco	25,09	11,48	9,6	88,7	1,7
Total/Mean		371,024	289,26	13,1	62,6	3,2

***Table 6**: Sectorial Water Demand in Mediterranean countries*
(Margat, 2004)

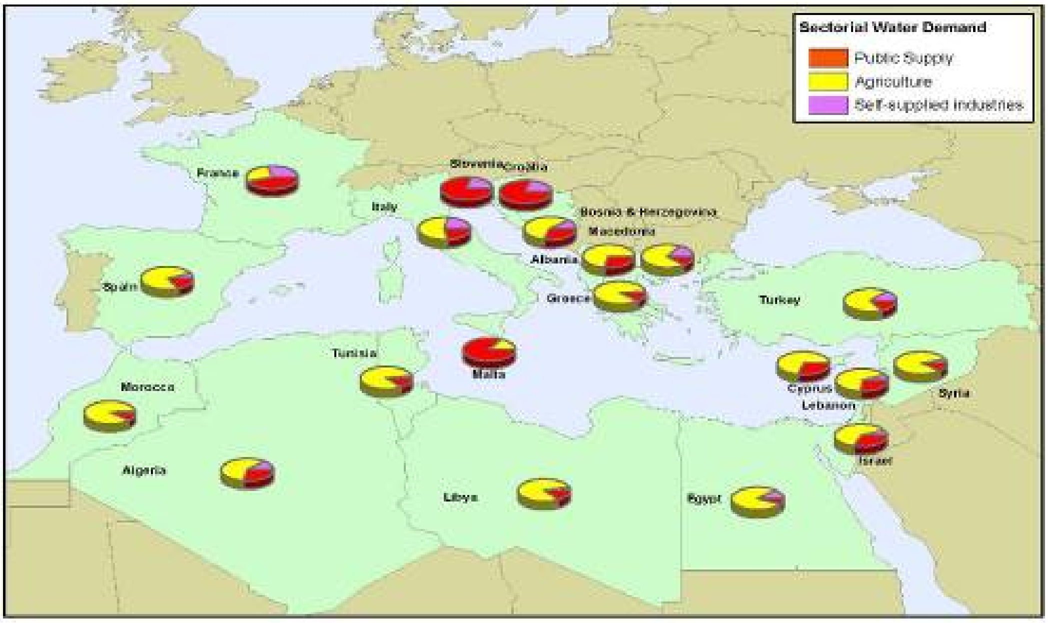


***Figure 12**: Sectorial Water Demand distribution in Mediterranean countries (%)*

Country & Entities	Country & Entities	Population	Total Water Demand	Groundwater Sectorial Water Demand Supply				Groundwater Sectorial Water Demand Supply % Total demand			
		(million of inhab)	(km^3/yr)	Total	Public Supply	Agriculture	Self-supplied industries	Public Supply	Agriculture	Self-supplied industries	Total
				(km^3/yr)	(km^3/yr)	(km^3/yr)	(km^3/yr)	%	%	%	%
ES	Spain	39,11	35,32	5,017	1,2987	3,544	0,174	4	10	0	14
FR	France	56,45	32,3	6,323	3,713	1,11	1,48	11	3	5	20
IT	Italy	57,54	42	13,9	5,4	8	0,5	13	19	1	33
MT	Malta	0,366	0,059	0,021	0,018	0,003	0,00011	31	5	0	36
SI	Slovenia	2	1,28	0,1337	0,1098	0,0003	0,0239	9	0	2	10
HR	Croatia	4,8	0,718	0,42							
BA	Bosnia-Herzeg.		1	0,3							
YU	Serbia-Monten.		13	1							
MK	FYR Macedonia		1,845	0,014							
AL	Albania	3,39	1,4	0,6	0,29	0,31	0	21	22	0	43
GR	Greece	10,05	8,7	3,563	0,445	3,1	0,1	5	36	1	42
TR	Turkey	53,7	35,5	6,3	1,95	3,8	0,55	5	11	2	18
CY	Cyprus	0,726	0,34	0,087	0,003	0,083	0,001	1	24	0	26
SY	Syria	12,53	14,71	2,3	0,3	1,9	0,1	2	13	1	16
LB	Lebanon	3,2	1,3	0,4	0,052	0,31	0,036	4	24	3	31
IL	Israel	5,8	2,16	1	0,18	0,8	0,02	8	37	1	46
GZ	Gaza Strip	1,475	0,131	0,104	0,03	0,072	0,002	23	55	2	79
WB	West Bank	0,932	0,17	0,284	0,095	0,182	0,007	56	107	4	167
EG	Egypt	54,8	73,7	5,14	1,3	3,1		2	4		6
LY	Libya	5,22	4,5	4,5	0,328	4,1	0,074	7	91	2	100
TN	Tunisia	8,785	2,849	1,626	0,163	1,4	0,063	6	49	2	57
DZ	Algeria	25,06	4,8	2,85	1,3	1,4	0,15	27	29	3	59
MA	Morocco	25,09	11,48	2,7	0,432	2,268	0	4	20	0	24
Total/Mean		371,024	289,26	58,58	17	35,4823	3,28101	6	12	1	19

***Table 7**: Sectorial Water Demand supplied with groundwater in Mediterranean countries*
(Margat, 2004)

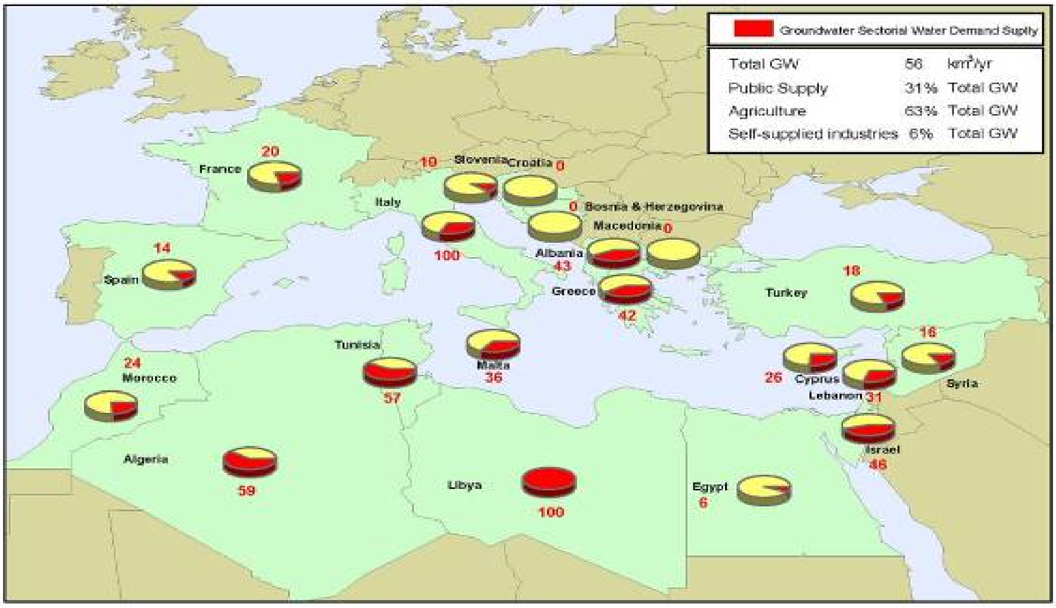


***Figure 13**: Sectorial Water Demand supplied with groundwater in Mediterranean countries*
(Margat and Vallée, 2000 in Blue Plan)

Agriculture is by far the most important groundwater use activity in the Mediterranean region, and it is also probably the least efficient sector in water use, particularly in irrigation from surface water sources. Irrigation accounts for a major part, if not an overwhelming share, of water use (over 80% in almost all Southern countries, and up to 89% in Morocco) (*Table 6 & Figure 12*).

Irrigated area in the Mediterranean has doubled in 40 years, accounting for 20.5 million ha in 2000 compared to 11 million ha in 1961. The biggest increases (*Figure 14*) in absolute terms have occurred in Turkey (3.2 million ha) and Spain (1.7 million ha). Most of the countries' water supply projects, mainly constructions of dams or ground water exploitation, are for irrigation purposes. Some countries however, show a different development. Italy for example has reduced its irrigated area over the last twenty years.

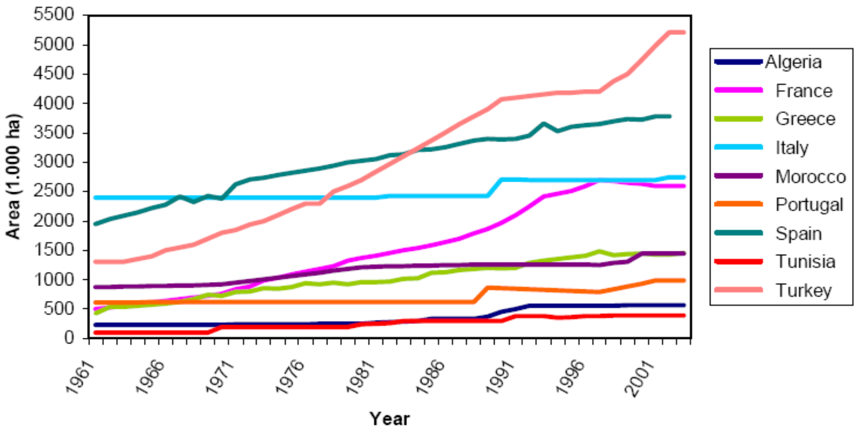


Figure 14: *Development of irrigated areas in Mediterranean countries*

("The Environmental Impacts of Irrigation in the European Union", a report to the Environment Directorate of the European Commission, Institute of European Environmental Policy (IEEP), London; INE report from June 2001)

In spite of the rapid expansion in gross irrigated areas in last half century, irrigation and drainage have undergone little technological change over this period. Most irrigation systems in the Mediterranean countries are performing far below their potential mainly as the result of inadequate technologies, management practices and policies.

Average losses of irrigation water in the Mediterranean are extremely high (55%), and they are distributed among farm distribution (15%), field application (25%), and irrigation-system losses (15%). Only about 45% of water diverted or extracted for irrigation actually reaches the crops. Losses vary widely, with those from the conveyance system varying between 5 and 50%. But this is mainly applicable to surface water irrigated land. On the opposite, irrigated agriculture using groundwater is often much more efficient. This is mainly because groundwater irrigation farmers typically assume all abstraction costs (financial, maintenance and operation) and produce high value crops because they have a greater security in their investment, as groundwater usually is minor affected by droughts than surface waters. Furthermore, losses due to transportation and drainage are avoided because water resources usually lay in the underground of crops.

In developed countries, the contribution of agriculture to GDP is very small. Therefore, this situation is giving rise to debate in many countries of the Mediterranean basin, particularly about resource allocation decisions and price establishment, since this is usually very low for surface water sources, for irrigation purposes.

It is clear at the very least that keeping up, and even more, increasing allocations to irrigation might hamper the development of other sectors of production with higher added value. Besides, competition between sectors has already begun in some regions, and it might spread, calling for more choices to be made.

There is a large range of different industrial activities scattered all around the Mediterranean basin, and a number of hot spots are concentrated mainly in the North, generated by heavy industry complexes. Although water demand for self supplied industries represents only a small part (3%, *Table 6 & Figure 12*) of total demand, discharges of contaminants from these industries pose a threat on groundwater resources, especially in the area of the hot spots.

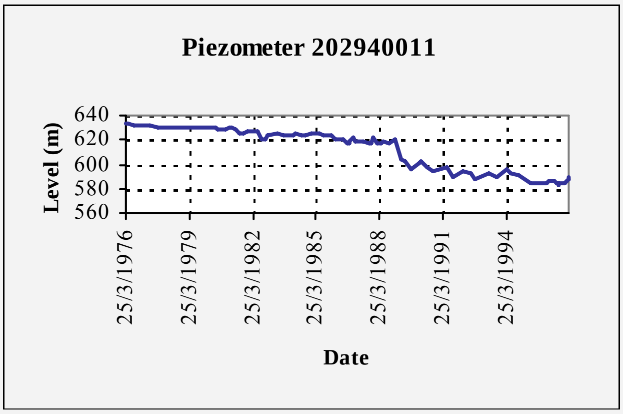
Lastly, as regards tourism, with some 250 million visitors per year, the Mediterranean basin is the premier world tourist destination. While growing demand for drinking water in the localities that receive visitors is not the only effect of tourism (500 to 800 litres per head per day are used in luxury hotels), it brings with it services and leisure activities that make extensive use of water and involves the creation of oversize distribution and purification facilities.

While there are already imbalances between demand and resources in the East and the South, in 2025 almost half the population of the Mediterranean countries will probably need more water – perhaps much more – than the natural supply can provide, and even more so compared to the resources that can actually be mobilised.

Water demand management in the Upper Guadiana Basin - Spain

The Upper Guadiana Basin includes one of the major plains in Spain. Traditionally, in the Upper Guadiana Bassin, water from the aquifers was used for agricultural needs.

Until 1960, the irrigated area was estimated at 20.000 Ha and the amount of groundwater abstracted to irrigate this area through “norias” ranged between 50 Mm^3 and 100 Mm^3. Since the seventies, irrigation increased tremendously and was accompanied by a certain socio economic expansion. Thanks to the groundwater production, the irrigated area increased from 30.000 Ha in 1974 to 125.000 Ha in 1987. The crops in this period, end of the 80s, were consuming around 600 Mm^3 of groundwater, which exceeded the capacity of renewable groundwater production in the aquifer and caused a drop of the phreatic level between 20 and 30 meters.



The piezometric level drop induced a deterioration of several wetlands areas of high interest in relation to environment.

Actions taken:

In order to compensate for these effects, some measures were taken such as:

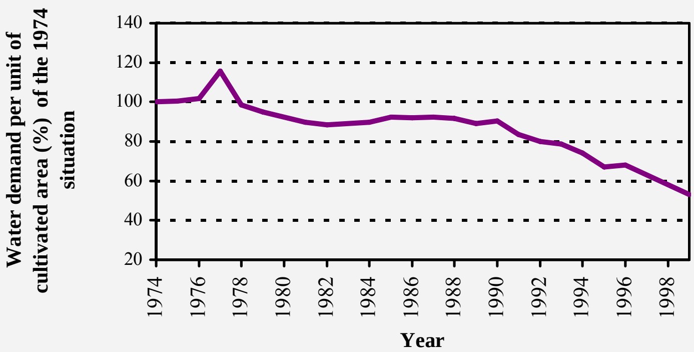
- *“Daimiel” water table hydrological regeneration plan:* a group of structural measures initiated in 1984, which included the construction of a small dam of“Puente Navarro” in 1985 in order to mobilise water in the area located in the South East of the National Park and a water transfer realisation from the“Tajo” river basin.

- *Declaration of overexploitation* of "Mancha Occidental" and "Campos de Montiel" aquifers which allowed the Basin Organisation to regulate and limit water abstraction with the elaboration of exploitation system rules, which since 1991, are applied annually.
- *Rental Agrarian Compensation Plan in the hydrological units of the "Mancha Occidental" and " Campos de Montiel" (1992),* which established a system of economical subsidies for the farmers who developed compatible measures with wetland conservation, such as irrigation water savings or introduction of less water consuming crops.

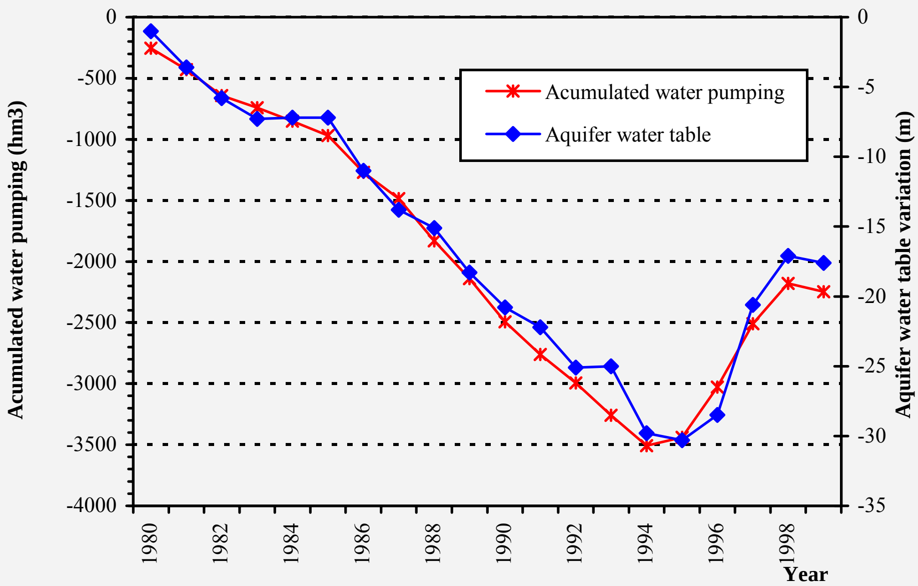
These initiatives were adopted basically under the auspices of the "Confederación Hidrográfica del Guadiana" and with the participation of irrigation associations in this area. The economical incentives for water savings were generated through the "Junta de Comunidades de Castilla la Mancha (Regional Administration) and the Ministry of Agriculture, Fishing and Food (Central Administration).

Results:

The following figure shows the water consumption evolution for one irrigated hectare. Since 1980 until 1996, this drop is quantified at 20%.



The following figure shows the evolution of the "Mancha Occidental" aquifer water table level with the accumulated water evacuation. It can be observed that between 1980 and 1995, 3500 Mm^3 were evacuated. Approximately 1500 Mm^3 of this quantity of water is recovered between 1996 and 1999. The phreatic level recovered more than 10 meters during the same period.



I.4 NON-RENEWABLE GROUNDWATER RESOURCES

Some arid regions have very small amounts of renewable water resources but huge amounts of fresh groundwater reserves, like for example the existing reserves under most of the Sahara desert. In such situations, groundwater mining may be a reasonable action if various conditions are met: 1) the amount of groundwater reserves can be estimated with acceptable accuracy; 2) the rate of reserves depletion can be guaranteed for a long period, e.g. from fifty to one hundred years; 3) the environmental impacts of such groundwater withdrawals are properly assessed and considered clearly less significant that the socio-economic benefits from groundwater mining; and 4) solutions are envisaged for the time when the groundwater is fully depleted.

In most countries it is considered that groundwater abstraction should not exceed the renewable resources. In other countries – mainly in the most arid ones – it might be considered that groundwater mining is an acceptable policy, as long as available data assure that groundwater development can be economically maintained for a long time, for example, more than fifty years and that the potential ecological costs and socio-economic benefits have been adequately evaluated (Llamas and al., 1992). Nevertheless, some authors consider this option as unsustainable development or an unethical attitude with respect to future generations (MIMAM, 1998).

Lloyd (1997) states that the frequently encountered view that water policy of arid zone countries should be developed in relation to renewable water resources is unrealistic and fallacious. Ethics of long-term water resources sustainability must be considered with ever improving technology. With careful management many arid countries will be able to use resources beyond the foreseeable future without major restructuring.

Groundwater mining, for instance, can help to transform nomadic groups into farmers. Initial high abstractions for survival crops can be dramatically reduced with time and the farmer nomads can become high-tech farmers growing cash crops, as stated in Saudi Arabia.

An example is the situation of the Nubian sandstone aquifer located below the Western desert of Egypt. According to Idriss and Nour (1990), the fresh groundwater reserves are higher than 200 km^3 and the maximum pumping projected is lower than 1 km^3/year. Blue Plan points out the importance of non-renewable water reserves in south Mediterranean countries (*Table 8*).

Country & Entities		Volume of theoretical reserves or estimated volume exploitable	Potentially exploitable in the long term (capacity of annual average production)
		(km^3)	km^3/yr
EG	Egypt	6.000	4
LY	Libya	4.000	2,8-3,9
TN	Tunisia	1.700	0,75-1
DZ	Algeria	1.500	5
MA	Morocco	3	-

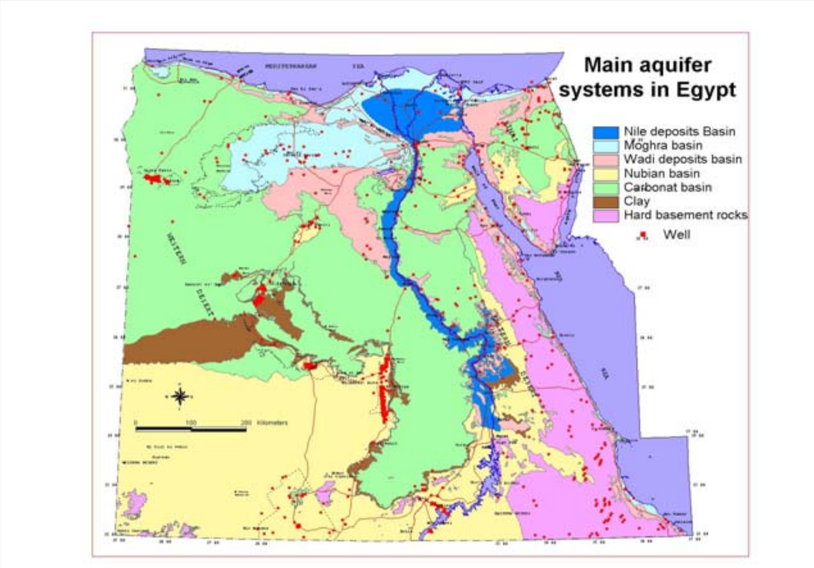
***Table 8**: Non-renewable Water Resources in south Mediterranean countries*

(Margat, 2004)

Compared with demands, estimated reserves represent a solid possibility to supply demands in the long term in Libya, in Tunisia and in Algeria. Morocco shows very scarce reserves and Egypt can access surface Nile water resources. Therefore, in countries with practical absence of renewable water resources, reserves can be the unique alternative for socio-economic development until technification can supply new resources like desalination. This opportunity must not discourage us to apply water demand management measures in order to save water resources.

Groundwater potential in Egypt

The Hydrogeological framework of Egypt comprises six main aquifer systems. They differ in general characteristics, including extension, transmissivity, renewability, etc.



Groundwater potential refers to the total rates that can be abstracted on a sustainable base; for future uses the term reserves is utilized. Sustainability, on the other hand, can be given several definitions. However, in all cases, the quality of the resource base should be maintained suitable to the originally allocated sector (i.e. no deterioration) and the environment enhanced. Three distinct examples are given below:

- In the case of renewable groundwater from external sources (e.g. the coastal aquifers and shallow wadi aquifers), the permissible development should be equal to the rate of recharge received. This may not imply that the time span be restricted to a season or a year.
- In the case of renewable groundwater from internal sources (e.g. the Nile alluvium), the permissible development should be equal to the recharge without affecting flow in surface water channels and the river. Again, this does not imply specific time spans.
- In the case of non-renewable groundwater (e.g. the Nubian sandstone, Moghra), the permissible development is made to satisfy the economy of developmental activities and to ensure that groundwater will serve several generations (up to e.g. 500 years).

Based on the previous criteria, the country groundwater potential, uses and reserves have been assessed, as summarized in Table (for the yaer 2000):

Region	Potential (million m^3/year)	Usage (million m^3/year)	Reserves (million m^3/year)
Delta	5,220	4,195	1,025
Valley	3,170	1,932	1,238
Western Desert	3,748	817	2,931
Eastern Desert	90	8	82
Sinai	210	89	121
North-West coast	80	2	78
Total country	12,518	7,043	5,475

I.5 GROUNDWATER OVER-EXPLOITATION AND WFD

The WFD gives a framework for implementing fully-integrated water resources legislation. This presents a clear interest when dealing with groundwater management. However, some parts of the Directive would need to be adapted to specific cases encountered in the Mediterranean.

Groundwater should have good quantitative and good qualitative status in 2015. Concerning quantitative status there will be serious problems with the compliance of WFD goals in 2015, in particular in the Mediterranean countries with overpumping problems and “fossil groundwater” exploitation. In connection with qualitative status, problems of WFD compliance will arise in the Mediterranean countries with saline intrusions in coast aquifers and nitrate contaminated aquifers due to excessive fertilization. As groundwater hydrodynamics is very slow compared with surface dynamics, and non-saturated zones of aquifers represent a supplementary retardation factor to contaminant transportation in groundwater flow, restoration measures require very long-term to be effective. Therefore, as low groundwater hydrodynamics is not foreseen in WFD, probably there will be a generalized demand for the application of the extensions determined in accordance with paragraph 4 of Article 4.

Under these circumstances, the deadlines established in WFD may be extended for the purposes of phased achievement of the objectives for bodies of water, provided that no further deterioration occurs in the status of the affected body of water when all of the following conditions are met:

(a) Member States determine that all necessary improvements in the status of bodies of water cannot reasonably be achieved within the timescales set out in the WFD for at least one of the following reasons:

    (i) the scale of improvements required can only be achieved in phases exceeding the timescale, for reasons of technical feasibility;

    (ii) completing the improvements within the timescale would be disproportionately expensive;

    (iii) natural conditions do not allow timely improvement in the status of the body of water.

(b) Extension of the deadline, and the reasons for it, are specifically set out and explained in the river basin management plan.

(c) Extensions shall be limited to a maximum of two further updates of the river basin management plan except in cases where the natural conditions are such that the objectives cannot be achieved within this period.

(d) A summary of the measures required under Article 11 which are envisaged as necessary to bring the bodies of water progressively to the required status by the extended deadline, the reasons for any significant delay in making these measures operational, and the expected timetable for their implementation are set out in the river basin management plan.

WFD states that River Basin Management Plans (RBMP) have to include a summary of the programmes of measures in order to achieve the environmental objectives (Art. 4) and may be supplemented by the production of more detailed programmes and management plans for issues dealing with particular aspects of water management.

In this line, RBMPs can arrange and make operational the measures proposed, considering the following recommendations:

- When developing the WFD Programmes of Measures (POM) and associated RBMPs (Art. 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 (Art. 4.1, 4.5, 4.6 and 4.7)
- Actions to manage water quantity (e.g. water over-exploitation and water scarcity) should be considered as "measures" (basic/supplementary) when developing the WFD POM and associated RBMPs (Art. 11 and 13).
- When and where needed, a specific "aquifer or groundwater body and drought management (sub) plan" should be included in the WFD RBMP (cf. Art. 13.5).
- Public participation (Art. 14) should also be organised around water over-exploitation and water scarcity management issues, as required by the WFD.

Droughts, which are more frequent in the last decades in Mediterranean countries, will make more difficult the compliance of WFD objectives and probably will aggravate over-exploitation, avoiding the compliance of no further deterioration occurrence in the status of the affected water body. Therefore, exceptions in compliance during prolonged droughts must be established.

Regarding exceptions "prolonged droughts" are introduced in the directive as force major events. But 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. RBMPs must develop contingency drought plans in order to face these issues. Drought plans must establish clear objective thresholds in order to implement the specific measures, which have to be related to an indicator system including:

- Indicators and thresholds that will establish the starting point, the ending point, 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 the prolonged drought in order to avoid further deterioration of water status.
- All practicable measures to restore the body of water to its prior status, once the event has finished and the sooner as reasonably possible
- Summary of effects and measures taken and subsequent revision and updating of the existing drought management plan.

I.6 LESSONS LEARNED AND RECOMMENDATIONS

The intensive use of groundwater, mostly but not exclusively developed in the last few decades in arid and semi-arid countries, has been a driving force to produce a large number of benefits to society. These include the affordable supply of drinking water and the development of irrigated land, which have contributed to social and economic development in Mediterranean countries.

Various factors have made possible the significant increase of groundwater development over the second half of the twentieth century, particularly in arid and semi-arid regions: 1) Technological: invention of the multistage pump, improvements in drilling methods and in the advance of the scientific knowledge on occurrence, movement and exploration of groundwater; 2) Economic: the real cost of groundwater is usually low in relation to the direct economic benefits obtained from its use. The *in situ* or social value of groundwater is rarely estimated; 3) Institutional: groundwater development can easily be carried out by individual farmers, industries or small municipalities, without financial or technical assistance from Government Water Authorities. It does not require significant financial investments or public subsidies like surface water projects typically do.

The large water storage capacity of many large aquifers allows facing interannual precipitation variability. Aquifers become an efficient solution to overcome or mitigate drought impacts.

The guarantee in supply, coupled with the low cost of extraction of groundwater facilitated by the scientific and technological advances, have led to a spectacular increase in groundwater use, especially for irrigation, in numerous arid and semiarid regions and in many coastal areas.

Groundwaters, being usually extracted close to the place of final use and users having to support directly the largest amount of the total cost, have generally led to a responsible and efficient use of this valuable resource. This has indirectly contributed to a better general use of water resources.

Nevertheless, numerous problems have arisen due to intensive use of groundwater and lack of public control. These include excessive lowering of water level in the aquifer, important aquifer water reserves depletion, land subsidence, affects on other users (e.g. drying up shallow wells, increased cost of abstraction), decrease in the flow to rivers and springs, potential mobilisation of contaminants, and impacts on aquatic ecosystems. Most of these problems can be avoided, corrected, or at least mitigated with an adequate planning and control.

The above problems are usually from a short to medium-term. Efforts to overcome them should not deviate the attention of the water policy decision makers from the most serious medium to long-term problem: groundwater contamination. However, this problem is more linked to land use planning than to the intensive use of groundwater.

Adequate information is a prerequisite to succeed in groundwater management. It has to be a continuous process in which technology and education improve solidarity and participation to the stakeholders and a more efficient use of the resource. There exists a general consensus that, in order to avoid conflicts and to move from confrontation to cooperation, water development projects require the participation of the social groups affected by the projects, the stakeholders. The participation should begin in the early stages of the project and should be, as much as possible, bottom-up and not top-down.

Good and reliable information is crucial to facilitate cooperation among aquifer stakeholders. All stakeholders should have easy access to good, reliable data on abstractions, water quality, and aquifer water levels. Current information technology allows information to be made available to an unlimited number of users easily and economically.

In summary, groundwater has provided socio-economic benefits for the region, mainly by increasing irrigated areas. Improvement of abstraction methods, low cost of resource, benefits to individual farmers and small municipalities.

Main problems deal with: lack of public control, intensive use (lowering water tables and increasing cost of abstractions), pollution (nitrates), marine intrusion in coastal areas, negative effects on streams, rivers and ecosystems.

Finally adequate planning and control is needed by: establishing/improving piezometric networks, ensuring a participative stakeholder approach and management, promoting environmental education, and having updated groundwater information available to all users.

The WFD gives a framework for implementing fully-integrated water resources legislation. This presents a clear interest when dealing with groundwater management. However, some parts of the Directive would need to be adapted to specific cases encountered in the Mediterranean.

Groundwater should have good quantitative and good qualitative status in 2015. Concerning quantitative status there will be serious problems with the compliance of WFD goals in 2015, in particular in the Mediterranean countries with overpumping problems and ‘fossil groundwater’ exploitation. In connection with qualitative status, problems of WFD compliance will arise in the Mediterranean countries with saline intrusions in coast aquifers and nitrate contaminated aquifers due to excessive fertilization. As groundwater hydrodynamics is very slow compared with surface dynamics, and non-saturated zones of aquifers represent a supplementary retardation factor to contaminant transportation in groundwater flow, restoration measures require very long-term to be effective. Therefore, as low groundwater hydrodynamics is not foreseen in WFD, probably there will be a generalized demand for the application of the extensions determined in accordance with paragraph 4 of Article 4. Under these circumstances, the deadlines established in WFD may be extended for the purposes of phased achievement of the objectives for bodies of water, provided that no further deterioration occurs in the status of the affected body of water

Droughts, which are more frequent in the last decades in Mediterranean countries, will make more difficult the compliance of WFD objectives and probably will aggravate over-exploitation, avoiding the compliance of no further deterioration occurrence in the status of the affected water body. Therefore, exceptions in compliance during prolonged droughts must be established as WFD consider droughts as ‘force major’ events accompanied of contingency drought management plans with ad-hoc measures: to identify on-set, severity and end of drought period and to mitigate drought effects.

CHAPTER II:
DETERIORATION IN GW QUALITY

II.1 GROUNDWATER CHEMICAL POLLUTION

The value of groundwater lies not only in its widespread occurrence and availability but also in its consistently good quality water. The term “quality of water” refers to the physical, chemical, and biological characteristics of the water as they relate to its intended use. Groundwater also is cleaner than most surface water because the earth materials can often act as natural filters to screen out some bacteria and impurities from the water passing through. Most groundwater contains no suspended particles and practically no bacteria or organic matter. It is usually clear and odourless. Most of the dissolved minerals are rarely harmful to health, are in low concentrations and may give the water a pleasant taste.

In view of the diverse uses of groundwater, it is essential to keep it free from any kind of pollution. While groundwater is less vulnerable to pollution than surface water, the consequences of groundwater pollution last far longer than those of surface water pollution. Pollution of groundwater is not easily noticed and in many instances it is not detected until pollutants actually appear in drinking water supplies, by which time the pollution may have affected a large area. The vulnerability of the aquifer systems to pollutants is dependent on a number of factors, including soil type, characteristics and thickness of materials in the unsaturated zone, depth to groundwater and recharge to the aquifer. Groundwater pollution is a modification of the physical, chemical, and biological properties of groundwater, restricting or preventing its use in a manner for which it had previously been suited. Substances that can pollute groundwater can be divided into substances that occur naturally and substances produced or introduced by human activities (A. Zaporozec, 2000).

Naturally occurring substances causing pollution of groundwater include iron, manganese, toxic elements, and radium (*Table 9*). Some of them are quite innocuous, causing only inconveniences, such as iron and manganese. But others may be harmful to human health, e.g. toxic elements (such as arsenic or selenium), fluoride, or radionuclides (radium, radon, and uranium). Arsenic is widely distributed in the environment and is usually found in compounds with sulphates. Arsenic is highly toxic at concentrations above 0.01 mg/l, and high doses cause rapid death.

Major constituents	*Secondary constituents*	*Selected minor and trace constituents*	
Calcium (Ca)	Potassium (K)	Aluminium (Al)	Molybdenum (Mo)
Magnesium (Mg)	Iron (Fe)	Arsenic (As)	Nickel (Ni)
Sodium (Na)	Manganese (Mn)	Barium (Ba)	Phosphate (PO_4)
Bicarbonate (HCO_3)	Strontium (Sr)	Cadmium (Cd)	Radium (Ra)
Chloride (Cl)	Boron (B)	Chromium (Cr)	Selenium (Se)
Sulfate (SO_4)	Fluoride (F)	Cobalt (Co)	Silver (Ag)
Silica (SiO_2)	Carbonate (CO_3)	Copper (Cu)	Uranium (U)
	Nitrate (NO_3)	Lead (Pb)	Zinc (Zn)
		Mercury (Hg)	Sulfide (H_2S, HS)

***Table 9**: Chemical constituents in groundwater*
(Davis and DeWiest, 1966)

Polluting substances resulting from human activities primarily include organic chemicals, pesticides, heavy metals, nitrates, bacteria, and viruses. The type of groundwater pollution of the greatest concern today — at least in the industrialized countries — is pollution from hazardous chemicals, specifically organic chemicals (*Figure 15, Table 10*). Pesticides used in agriculture and forestry are mainly synthetic organic compounds. The term pesticide includes any material (insecticide, herbicide, and fungicide) used to control, destroy, or mitigate insects and weeds. Many of the pesticide constituents are highly toxic, even in minute amounts. Nitrate is the most commonly identifiable pollutant in groundwater in rural areas. Although nitrate is relatively non-toxic, it can cause, under certain conditions, a serious blood disorder in infants. Pollution by infiltration is probably the most common groundwater pollution mechanism. A pollutant released at the surface infiltrates the soil through pore spaces in the soil matrix and moves downward through the unsaturated zone under the force of gravity until the top of the saturated zone (the water table) is reached. After the pollutant enters the saturated zone (an aquifer), it travels in the direction of groundwater flow.

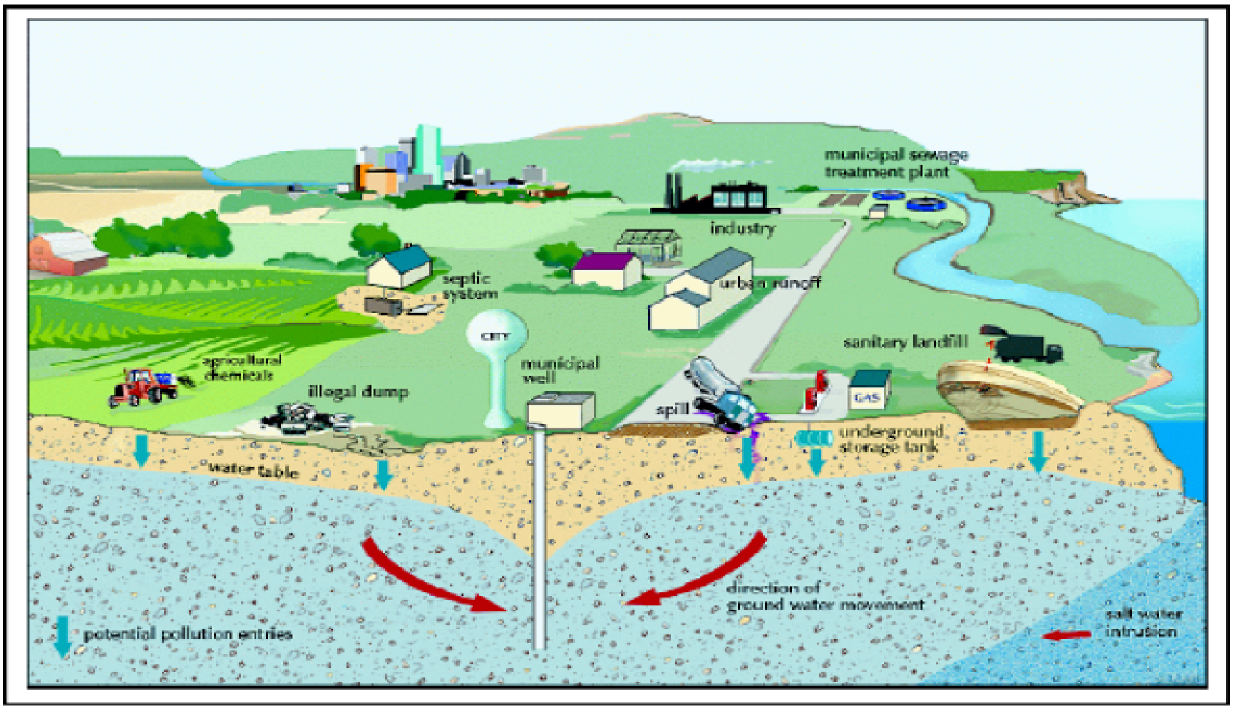


***Figure 15**: Groundwater Pollution*
(A Zaporozec, 2000)

Chemical pollution sources may be classified into the following types:

- ***Point sources***

Point sources of pollution are inputs of pollutants from individual discharge points. Typical point sources are leakage of hazardous substances from storage tanks, spills at industrial installations and farmyards, or leaching from landfills and waste disposal sites. It also includes discharges of industrial, domestic or municipal wastewater.

- ***Diffuse sources***

Diffuse sources of pollution are inputs of pollutants into the aquatic environment over a large area, especially agricultural pollution sources. Irrigation return flow can cause an on-going increase in the salinity of groundwater affecting its further use for irrigation, while residues of fertilizers and pesticides in irrigation return flow may endanger drinking water quality

Category	*Source type*	*Usual character*	*Normal location*
Natural sources	Inorganic substances Trace metals Radionuclides Organic compounds Microorganisms	Not applicable	Not applicable
Agriculture and forestry	Fertilisers	Diffuse	Surface
	Pesticides	Diffuse	Surface
	Animal waste	Diffuse/point	Surface/unsaturated zone
	Animal feedlots	Point	Surface
	Irrigation return flow	Diffuse	Surface
	Stockpiles	Point	Surface
Urbanisation	Solid waste sites	Point	Surface/unsaturated zone
	On-site sanitation	Point	Surface/unsaturated zone
	Wastewater, effluent	Point and line	Surface/unsaturated zone
	Salvage and junk yards	Point	Surface/unsaturated zone
	Leaking underground storage tanks	Point	Unsaturated zone
	Runoff, leaks, spills	Line and point	Surface
Mining/Industry	Mine tailings	Point	Surface/unsaturated zone
	Mine water	Point and line	Various
	Solid waste	Point	Surface/unsaturated zone
	Wastewater, effluent	Point and line	Surface/unsaturated zone
	Injection wells	Point	Below water table
	Spills, leaks	Point	Surface
Water mismanagement	Well-field design	Point	Below water table
	Upconing	Point	Below water table
	Seawater intrusion	Line	Below water table
	Faulty well construction	Point	Below water table
	Abandoned wells	Point	Below water table
	Irrigation practices	Diffuse	Surface
Miscellaneous	Airborne sources	Diffuse	Surface
	Surface water	Line	Below water table
	Transport sector	Point and line	Surface/unsaturated zone
	Natural disasters	Point and line	Surface/unsaturated zone
	Cemeteries	Point	Unsaturated zone

***Table 10**: Summary of groundwater contamination sources by origin*

Groundwater contamination can occur through infiltration (the downward influx of contaminants), recharge from surface water, direct migration and aquifer interface. Infiltration is the most common source of the contamination of shallow aquifers and unconfined deeper aquifers. Water penetrating downward through the soil and unsaturated zone forms leachate that may contain inorganic or organic contaminants. When it reaches the saturated zone contaminants spread horizontally in the direction of groundwater flow and vertically owing to gravity. Recharge of polluted surface water into shallow aquifers can occur in losing streams, during flooding and when the groundwater level of the aquifer adjacent to a surface stream is lowered by pumping. Leakages from contamination sources located below the groundwater level (e.g. storage tanks, pipelines, basement of waste disposal sites) migrate directly into groundwater and affect particularly shallow aquifers.

Contaminant transport in groundwater systems is a complex process and depends on rock permeability (porous, fissured, karstic), contaminant properties, groundwater chemical composition and processes controlling contaminant migration (advection, mechanical dispersion, molecular diffusion and chemical reactions). Various sources of contamination affect particularly shallow aquifers and unconfined deeper aquifers. Vulnerability of deeper confined aquifers to contamination impact is significantly lower and mostly occurs in recharge areas. However, such aquifers may be contaminated by natural constituents, like fluoride, arsenic, copper, zinc, cadmium and others. Fossil aquifers are not vulnerable to human impacts, however they are often more mineralized and of a higher temperature. Contaminants movement is generally slow, but in fissured rocks and particularly in karst rocks contaminants can move even several metres per day.

Shallow aquifer contamination problems

Several scenarios of contamination of shallow aquifers exist. Hydraulic gradients between surface water and groundwater control the possibility of bank infiltration of surface water to the adjacent aquifers and vice versa. Stream flow response to precipitation reflects short- and long-term changes in the hydraulic head of surface and groundwater bodies. During long dry periods, surface flow depends almost exclusively on groundwater (base flow conditions) and water quality of the streams reflects the quality of the underlying aquifers. Contamination occurs mostly on the ground surface of fluvial deposits and penetrates to the aquifer. Contaminated groundwater may flow in a shallow aquifer parallel to a river flow, or discharge into river or other surface water body.

However, penetration of contaminated surface water into underlying shallow aquifers may also occur far from the contamination source, where the river is a losing stream and conditions of surface water infiltration set in. Owing to the low attenuation capacity of fluvial deposits (mostly gravel and sands), which are unable to retain or remove the contaminants, shallow aquifers become contaminated longterm.

There are many shallow unconfined aquifers developed in rock weathered zones, in higher fluvial terraces or in eolian deposits that are not directly connected with surface water bodies and discharge frequently in springs. However, such aquifers are often of smaller extent only. Contamination occurs in recharge and vulnerable areas of such aquifers and may be transported along a flow path over a long distance.

Deeper aquifers contamination problems

Deeper confined aquifers may cover hundreds or even thousands of square kilometres. Groundwaters in recharge areas of deeper aquifers are unconfined and vulnerable to contamination. If contamination occurs, it can be transported laterally over a long distance along a flow path under confined aquifer conditions. The lateral movement of contaminants in the aquifer from recharge to discharge area may be accelerated by intensive aquifer exploitation.

Deeper aquifers may also be unconfined ones, which renders the transit and recharge zone vulnerable. The downward migration of the contaminants to the aquifer depends on soil properties and the thickness and lithology of the unsaturated zone. In conditions of porous permeability it can take many years before the contamination plume reaches the saturated aquifer. However, in aquifers with fissured permeability and in karst aquifers contaminants can reach the aquifer very fast (days, months). The mechanism of lateral contaminant movement in these aquifers is similar to that in the confined aquifers.

Fossil aquifers contamination problems

Fossil aquifers are well protected by the geological environment and are typically of very low vulnerability and their contamination is uncommon. Contaminants can enter fossil aquifers through vertical leakage through the sealsaround well casings when deep wells are drilled for various purposes (e.g. exploitation wells, deep disposal wells) and the drilling process is not controlled. However, many aquifers could be affected by depletion, particularly if there is mining and non-renewable groundwater storage is continuously depleted.

II.2 SALINE WATER INTRUSION

The intrusion of saline waters is a widely recognized problem in coastal and island aquifers, particularly in arid and semi-arid regions having a restrained availability of natural recharge to the aquifers. Saltwater intrusion is widely considered as type of environmental pollution arising due to human activities and further compounded by certain physical and hydrogeological factors.

Coastal aquifers constitute the main sources of drinking water and agricultural irrigation in many countries and near-coastal regions. The careful management of the status of these aquifers is therefore important since even extremely low intrusion rates produce a noticeable deterioration in the quality of groundwater; with the water becoming practically unusable at a mixing rate of around 6%.

II.2.1 Hydrological context

In an aquifer with a coastal boundary, there is direct contact between freshwater and marine saltwater. In a stable system owing mainly to the different densities of the two fluids the freshwater will float on the salt-water leading to the two water bodies being separated by a landward sloping interface. Consequently, the saline water-body adopts the form of a wedge resting on the underlying aquifer boundary.

Various different configurations exist for the balance between freshwater and saltwater at the coast, the differences resulting principally due the respective hydro-geological typologies of the aquifer formations involved. A number of such configurations are shown in Figure 16.

It should also be noted that due to physical processes such as diffusion and hydrodynamic dispersion, the interface between the freshwater and the saltwater in reality forms a wide mixing or transition zone. The thickness of this zone will depend on both the hydrodynamic characteristics of the aquifer formation and the fresh and sea water fluctuations, caused by both natural and anthropogenic activities. A sharp interface is generally assumed to occur only when the extent of the transition zone represents a few percent of the freshwater thickness.

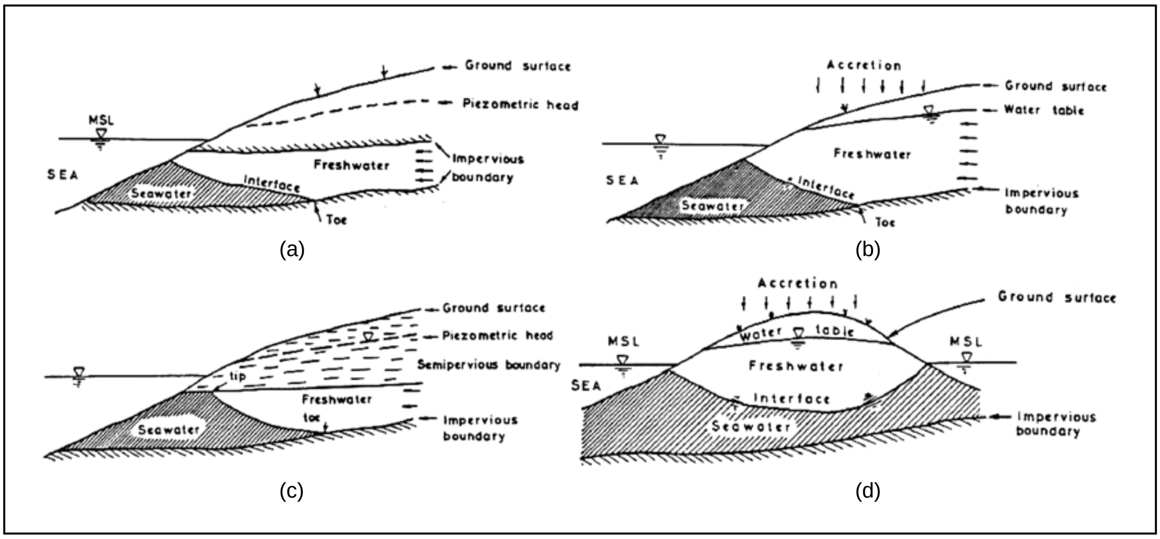


Figure 16: *Different freshwater-saltwater situations in different types of coastal aquifers. (a) confined conditions with a salt-water wedge toe; (b) water table conditions with a saltwater wedge toe; (c) semi-confined conditions with both saltwater wedge tip and toe conditions; and (d) unconfined freshwater lens conditions without 'toe'*

(Falkland, 1991)

The limits of the transition zone are generally arbitrarily defined as the surfaces of 1 percent and 95 percent seawater content, based on the total dissolved solids or chloride ion content.

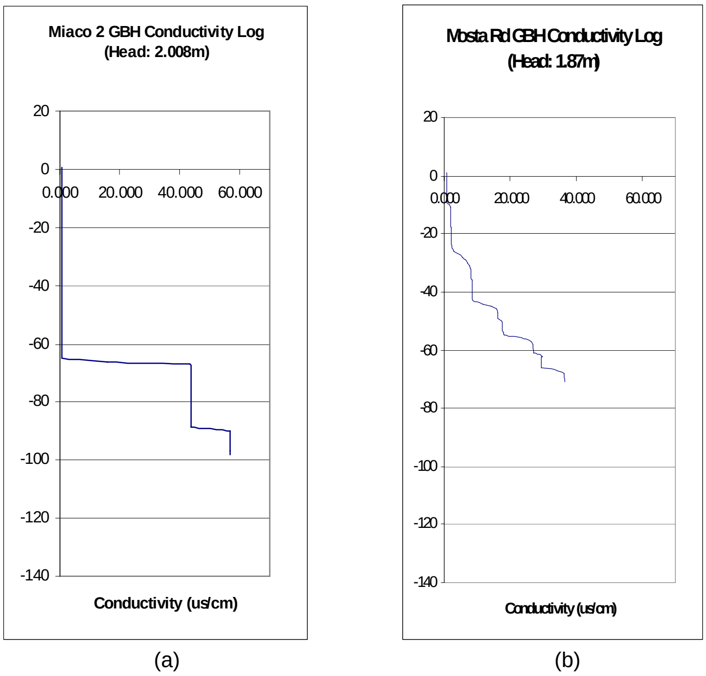


Figure 17: *Conductivity logs in the Mean Sea Level aquifer in Malta indicating (a) the presence of a sharp interface between freshwater and saltwater and (b) the development of a thick transition zone.*

II.2.2 Definition of intrusion

Saltwater intrusion is generally defined as "*the landward movement of saltwater into regions of an aquifer which were previously occupied by freshwater*".

The basic principles governing the occurrence of salt-water intrusion are relatively simple. The landward extent of the interface or transition zone in a stable system depends upon the amount of groundwater discharged at the coast. Saltwater intrusion will occur whenever there is a reduction in the rate of discharge, which reduction is generally caused by an increase in groundwater withdrawals. Reductions in the natural discharge of groundwater at the coast cannot be measured directly, but are marked by reduced ground-water levels in monitoring wells.

It should be stressed that sea water is the most important, but not the exclusive source of salinity. The presence of salinity in coastal aquifer does not only originate from present sea-water intrusion but there are other possible sources which have to be known for the correct management of the situation. A number of alternative salinity sources have been identified by Custodio (2002) and include unflushed old marine water in very slow flow aquifers, the dissolution of evaporate salts existing in geological formations and the displacement of saline groundwater contained in some deep formations (*Figure 18*).

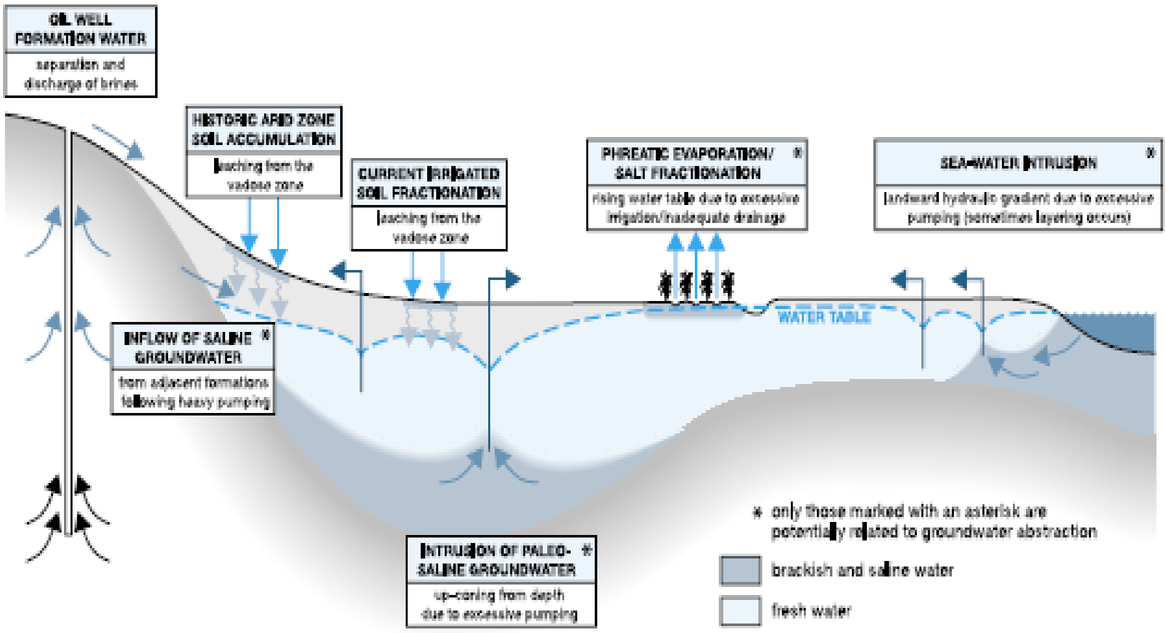


Figure 18: *The possible origins of groundwater salinity and mechanisms of aquifer salinization*
(GW-MATE Briefing Note 2)

II.2.3 Regional and localized intrusion

In practice, it is important to distinguish between local and regional salt-water intrusion. Localised salt-water intrusion at a single well or a few closely located wells results as a direct consequence of the abstraction carried out at that/those specific well or wells. This phenomenon is often referred to as 'upconing' because the interface below the well takes the shape of a cone in response to the drawdown in the piezometric surface which is created around the well.

Regional salt-water intrusion, on the other hand, is the landward movement of the interface over a large area in response to regional quantitative declines in the groundwater body. Regional intrusion is generally observable through declining water levels and/or increasing conductivity in data from properly constructed monitoring wells.

Regional intrusion as manifested by the landward movement of the saltwater wedge will however inevitably result in increasing existing localized intrusion (upconing) problems and creates new ones, potentially requiring changes in abstraction practice and/or the abandonment of affected abstraction sources.

It should also be noted that the landward movement of the saltwater body in response to increased groundwater abstraction is a very slow process, since it requires the existing volumes of freshwater to be replaced by saltwater. This replacement process will end once a new equilibrium position between freshwater and saltwater is established reflecting the new discharge characteristics. This '*transient phase*' in some instances may last several years or decades.

The 'upconing' of saltwater below abstraction wells is a much faster phenomenon than regional interface movement, although the existence of low permeability interlayerings may retard the vertical movement. Consequently, the main effects of 'upconing' disappear shortly after the abstraction action ceases. However, secondary effects, such as the expansion of the transition zone remain.

II.3 GROUNDWATER QUALITATIVE STATUS IN THE MEDITERRANEAN

Groundwater resources in the Mediterranean region are being threatened and polluted by numerous point and non-point sources of pollution generated from anthropogenic activities, such as agricultural, industrial and domestic activities.

More specifically, groundwater degradation in the Mediterranean aquifers is the result of a number of factors, the most important being:

- discharges from agro-processing plants and a high level of agrochemicals in rivers and dump sites,
- over-exploitation of groundwater, causing rapid movement of saline groundwater lenses and salt water intrusion,
- infiltration of saline agricultural drainage from large-scale irrigation into shallow aquifers,
- overuse of fertilizers and pesticides in agriculture and their migration to the shallow aquifers,
- increases in the discharge of untreated or inadequately treated domestic and industrial water in open areas and rivers.
- discharge of hazardous and toxic industrial waste in inadequate dump sites,
- unmanaged pumping leading to hydrodynamic disturbance which may cause groundwater mixing among multi-aquifer systems
- injection of brine and hydrocarbon by-products from oil production and refinery operation into aquifers,
- naturally occurring pollutants such as radium, radon and other radioactive elements.

Irrigation return flow, untreated wastewater, toxic industrial and medical waste, and accidental spills of hazardous material are the major sources of groundwater pollution in the Mediterranean region and have caused groundwater contamination in many areas, especially of shallow alluvial aquifers, but also of some deep aquifers, as a result of injection operations or fast water movement in karstified limestone formations. The degree of pollution depends on many factors, including the physical and chemical characteristics of the soil profile, the underlying aquifer and the pollutant itself, the flow dynamics and depth to the water table. The absence of enforceable regulations has encouraged the easy disposal of pollutants into surface and ground water bodies.

Furthermore, over-pumping has caused seawater intrusion into into many coastal aquifers of the region. According to Blue Plan, In Tunisia, 90% of water pumped from water tables and 80% of that from deep aquifers has a salinity of more than 1.5 g/l. In Israel, some 20% of the coastal aquifer has been contaminated by salts and nitrates from urban and agricultural pollution, and water officials foresee that a fifth of the coastal wells may need to be closed over the next few years.

Groundwater contamination is taking place in all Mediterranean countries, but limited data make it very difficult to estimate the total extent of pollution.

Groundwater quality in Jordan

Contamination of fresh groundwater by saline water is a common problem in the region. Natural sources of saline water include upward migration of highly pressurized brines in the Jordan Rift Valley and other areas; and subsurface dissolution of soluble salts originating in rocks throughout the country. East of the Jordan Rift Valley and Wadi Araba, water at depths of a few hundred meters below land surface generally is saline. Within these areas of generally high salinity, it is possible that a local source of acceptable, relatively fresh water exists. Heavy pumping in some areas has led to waterlevel declines and changes in flow directions in the aquifers. In addition to natural sources, groundwater quality can be affected by agricultural, municipal, and industrial activities in the recharge zone of the aquifer. Potential sources of contamination include recycled irrigation water, wastewater from human activities, and waste by-products from industrial activities. Nitrate is an important constituent in fertilizers and is present in relatively high concentrations in human and animal wastes.

Groundwater quality in Malta

The quality of groundwater in Malta is highly variable with contamination of groundwater by nitrates and chlorides being the main quality issues of concern.Nitrates occur naturally in the environment and are produced from the decay of vegetable material in the soil. The natural nitrate level in the main groundwater bodies in Malta is generally expected to be low. Soil cover in Malta is relatively thin and poor in organic content. Furthermore, there are no naturally occurring formations that contribute towards nitrate content in groundwater. Thus, nitrate contamination in groundwater is largely attributed to anthropogenic activities, such as agricultural practices through the application of nitrogenous fertilizers on arable land; and contamination from human and animal wastes and refuse dump runoff. The movement of these pollutants below the surface is affected by the properties of the underlying strata. Nitrate concentration varies seasonally and by location, with maximum concentrations corresponding to the rainy season (October-March) as a result of the leaching of nitrates in the unsaturated zone; this situation being particularly evident in the shallow groundwater bodies. Groundwater abstracted from the sea-level groundwater bodies has generally high levels of chloride concentrations, mainly as a result of localized sea-water intrusion (upconing) beneath the abstraction wells. This situation is further influenced by the karstic/fractured nature of the aquifers.

II.4 GROUNDWATER USES WHICH AFFECT THE PROBLEM

Agriculture

Agriculture is by far the most important groundwater use activity in the Mediterranean region, and it is also probably the least efficient sector in water use.

Agricultural activities not only threaten the availability (quantity) but also the quality of groundwater due to the extensive use of fertilisers (*Figure 19*), pesticides and release of olive-oil-mill wastes.

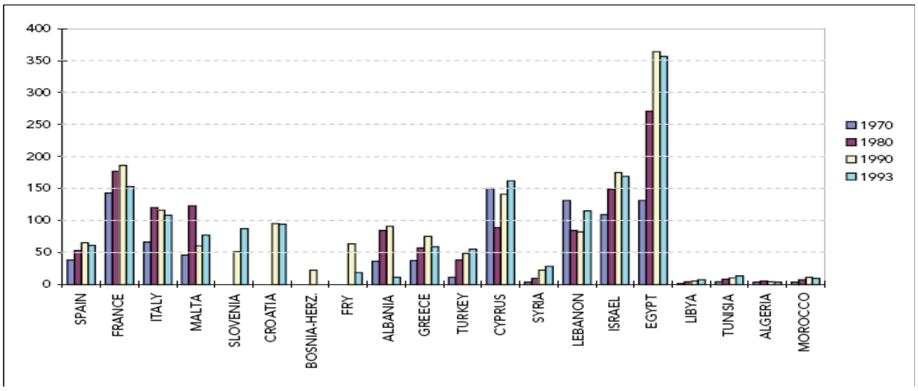


Figure 19: *Fertiliser consumption in the Mediterranean countries from 1970 to 1993 (kg/ha)*
(The World Bank, Social Indicator of Development, 1996)

In spite of the rapid expansion in gross irrigated areas, irrigation and drainage have undergone little technological change over this period. Most irrigation systems in the Mediterranean countries are performing far below their potential mainly as the result of inadequate technologies, management practices and policies.

Industry

There is a large range of different industrial activities (from mining to manufactured products) scattered all around the Mediterranean basin, and a number of hot-spots are concentrated mainly in the north, generated by heavy industry complexes. Discharges of contaminants from these industries pose a threat on groundwater resources, especially in the area of the hot-spots.

The impacts of industry on groundwater resources can be direct or indirect. Direct impacts deriving from effluents from industry, involve pollution problems at the site level that contribute to the creation of hot spots. Indirect impacts are related to the location of industries, ultimately leading to concentration of activities and urban development on the specific regions.

Urbanisation

The resident population of the riparian states of the Mediterranean was 246 millions in 1960, 380 millions in 1990 and is currently about 420 millions (*Figure 20*). 'Blue Plan' estimates that depending on the development scenarios applied, this figure will rise to 520-570 million in the year 2030, is expected to reach approximately 600 million in the year 2050 and possibly as much as 700 million at the end of the 21st century. The average population growth rate in the southern countries of the Mediterranean is estimated at 3% yearly.

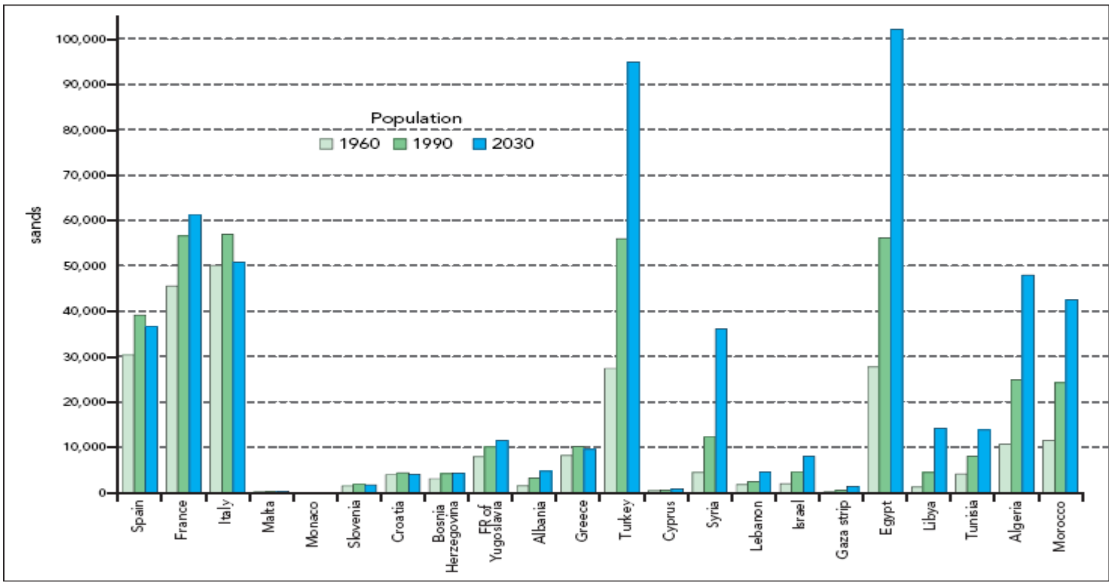


Figure 20: *Population increase in the different Mediterranean countries*
(Blue Plan databases, United Nations, World Population Prospect, The 1994 Revision)

The distribution of population between the northern and southern countries has changed dramatically: in 1950, countries of the northern Mediterranean represented two thirds of the total population, while in 1990 it was only 50% and may be one third in the year 2025, and one fourth in 2050.

Rapid population growth is always linked to fast urbanisation *(Figure 21)*. Urban growth will be explosive in the southern and eastern countries of the Mediterranean. Although the annual growth rate of urbanisation is high in the Mediterranean region in general, it is much higher in the south of the region (4.5%) than in the north (2.8%).

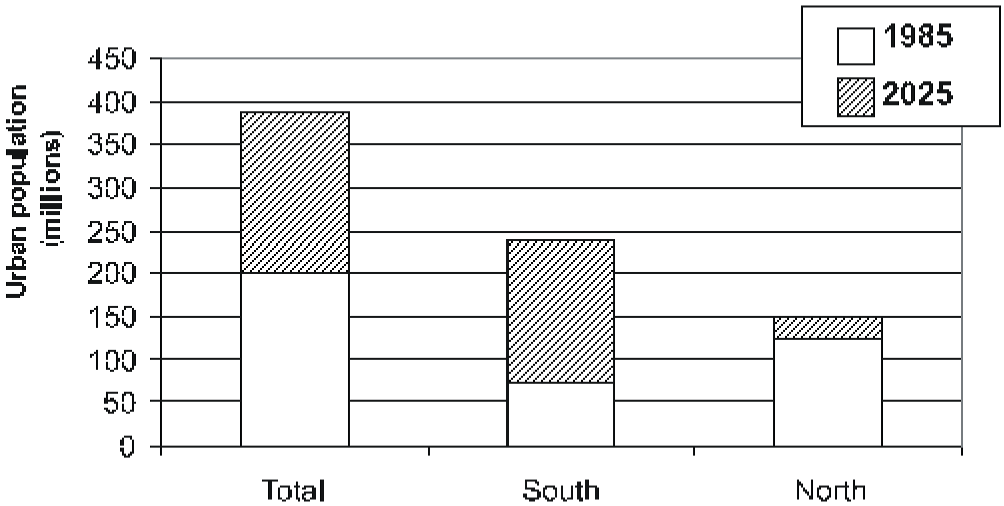


Figure 21: *Urbanisation growth in the Mediterranean, 1985-2025*
(Grenon and Batisse, 1989)

Tourism

The attractive climate and the historical and archaeological significance of the area, make the Mediterranean countries the greatest tourist destination of the world, with 176 million visits in1996 increasing at a rate of 2-3% per year, expected by the year 2010 to be 250-275 million and in the year 2025, 290-355 million. Tourism activity peaks in summer, coinciding with the time when natural water availability is at its lowest. In certain areas and at certain times of the year the population can increase two, three or even ten or more. This increase in population brings about a peak in water demand for domestic use.

While growing demand for drinking water in the localities that receive visitors is not the only effect of tourism, it brings with it services and leisure activities that make extensive use of water and involves the creation of oversize distribution and purification facilities.

II.5 GROUNDWATER PROTECTION

The protection of groundwater resources may be based on different methodologies involving preventive actions (to avoid future pollution) and remediation actions (to control the pollution threat posed by existing and past activities).

Contaminated groundwater is very difficult and expensive to clean up. Solutions can be found after groundwater has been contaminated but this isn't always easy. The best thing to do is adopt pollution prevention and conservation practices in order to protect important groundwater supplies from being contaminated or depleted in the first place.

II.5.1 Preventive actions

Various traditional strategies for groundwater protection range from the construction of groundwater vulnerability maps and the definition of protection perimeters around pumping wells, to the use of sophisticated optimisation multi-criterion decision-making techniques under risk conditions. A very characteristic example is the definition of adequate waste disposal sites in relation to the risk of groundwater contamination.

Protection can either extend across an entire aquifer or be restricted to important recharge areas, or capture zones, for specific water supply wells. The question of how much protection is needed or desired depends on the characteristics of the resource, the degree to which it is used, as well as other community social and economic goals. Alternative macro-protection land use management policies include:

No-degradation: The maintenance of the quality of groundwater at no worse than existing levels. Generally, such a policy would only be applied to vital resources, typically a resource that provides the sole source of drinking water. For practical reasons it can only be applied to groundwater resources in undeveloped areas, or areas of very low intensity development. Further land development will normally be excluded from the designated area

Limited or controlled degradation: Such a policy acknowledges that existing or proposed land uses will cause a deterioration of groundwater quality, but strives to maintain the quality above certain specified limits. This policy normally involves controlling the density and types of land development, and the prescription of specific management practices for activities that can affect groundwater quality.

Differential protection: Differential protection policies allow for combinations of nodegradation and limited degradation.

To protect aquifers against pollution it is essential to constrain land-use, effluent discharge and waste disposal practices. However, in practice it is necessary to define groundwater protection strategies that accept trade-offs between competing interests. Thus instead of applying universal controls over land use and effluent discharge, it is more cost-effective (and less prejudicial to economic development) to utilize the natural contaminant attenuation capacity of the strata overlying the aquifer, when defining the level of control required to protect groundwater quality.

Simple and robust zones (based on aquifer pollution vulnerability and source protection perimeters) need to be established, with matrices that indicate what activities are possible where at an acceptable risk to groundwater. Groundwater protection zoning also has a key role in setting priorities for groundwater quality monitoring, environmental audit of industrial premises, pollution control within the agricultural advisory system, determining priorities for the clean-up of historically-contaminated land, and in public education generally. All of these activities are essential components of a sustainable strategy for groundwater quality protection.

A sensible balance needs to be struck between the protection of groundwater resources (aquifers as a whole) and specific sources (boreholes, wells and springs). While both approaches to groundwater pollution control are complementary, the emphasis placed on one or other (in a given area) will depend on the resource development situation and on the prevailing hydrogeological conditions.

If potable use comprises only a minor part of the available groundwater resource, then it may not be cost-effective to protect all parts of an aquifer equally. Source-oriented strategies will then be appropriate, working at scales in the range 1:25.000–100.000 and:

- delineating groundwater source protection (capture) areas and flow-time perimeters
- assessing aquifer pollution vulnerability and subsurface contaminant load in the areas so defined.

Aquifer-oriented strategies are more universally applicable, since they endeavor to achieve a degree of protection for the entire groundwater resource and for all groundwater users. They involve aquifer pollution vulnerability mapping over more extensive areas (including one or more important aquifers) working at a scale of 1:100,000, or greater if the interest is limited to general information and planning purposes. Such mapping would normally be followed by an inventory of subsurface contaminant load at more detailed scale, at least in the more vulnerable areas.

II.5.2 Remediation actions

When dealing with contamination, attention must be given to both the saturated and unsaturated zones. In most cases a contaminated soil unsaturated zone acts as a secondary pollution source with regard to groundwater and therefore has to be included in remediation work. When planning remediation, it should be remembered that no single technology works every time and that more than one technology may be required.

The rate of success in restoring contaminated aquifers to drinking water quality is very low for the following reasons:

- The contaminated site is inadequately characterized before undertaking the remedial action;
- Insufficient scientific knowledge of the interaction of the contaminants with the geologic matrix;
- Gaps in the engineering knowledge required to design and complete successful actions;
- The presence of any immiscible fluid phases is not known and therefore not removed.

When a contaminant is released on or into the ground, it divides into one or more phases: vapour or gaseous phase, free phase or liquid pools of contaminants, adsorbed or residual phase on soils and dissolved phase in groundwater. Dissolved phase contamination is directly related to the other three phases, creating a persistent and complex problem in terms of remediation. Technologies for controlling groundwater contamination generally fall into one or more of three categories: 'pump and treat' systems, which pump the groundwater to the surface for treatment, plume containment through groundwater pumping, groundwater injection, and/or the use of subsurface barrier walls, and passive treatment using chemically or biologically reactive barrier walls. A precondition of the effectiveness of all remediation systems is the prior recovery of free products (DNAPLs—dense, non-aqueous phase liquids—or LNAPLs—light, non-aqueous phase liquids). In the case of volatile materials present in the unsaturated and/or saturated zone, vapour stripping by inducing air movement through the soil is recommended as an additional clean-up measure.

II.5.3 Groundwater treatment technologies

The utility of groundwater as drinking water or industrial water (process, heating and cooling water) depends on its natural physical or chemical properties, the most important of which are: approximately constant thermal consistence within a broad temperature range, natural heat and dirt transportation medium, the most universal solvent fluid, etc.

Water quality is an especially critical factor determining the usability and reliability of any particular water source. Anthropogenically uninfluenced groundwater, usually germ-free, contains various minerals which improve its quality, such as calcium or magnesium, but cause technical problems, as these substances are directly related to the hardness of the water. Traditional public health practices emphasize the need to use the best quality sources available for municipal supplies and implement source protection measures to maintain high quality raw water sources. Where raw water supplies are of less than pristine quality, greater reliance must be placed on treatment technology.

To transform lower quality raw water sources into reliable water supply options, basic water treatment technologies (chemical procedures, such as coagulation, floculation, cation and anion exchanges, acid dosage, inhibitor dosage, or physical procedures, such as filtration, reverse osmosis, magnetic field method, electrostatic method) have to be used. “Normally” mineralized groundwater can be treated without difficulty and therefore at low cost, thus meeting requirements for civil or industrial usage. In the case of polluted groundwater, remediation measures are eminently more cost-intensive (equipment costs, installation costs, operating costs, labour costs, capital costs, etc.) if the goal of obtaining usable water is to be reached.

Abstracted groundwater has to be treated before any disposal to sewer or surface water or reinfiltration into the ground. There are a number of ways of removing contaminants. The technique chosen depends on the type of contamination, the concentration of pollutants, and economics.

The different treatment technologies have advantages and disadvantages depending on which contaminants are to be removed. A combination of procedures may therefore be appropriate. While developing anthropogenically influenced groundwater is relatively cheap, costs can increase significantly if there is a need to provide complex water treatment to remove contaminants, especially in the case of longterm remediation. Long-term remediation is undertaken if less soluble contaminants are present in the form either of free product, such as floating petrol, or as residuals in the unsaturated or saturated zone of the aquifer.

II.6 ECONOMIC ASSESSMENT OF GROUNDWATER PROTECTION

In the case of groundwater, a number of factors complicate the application of economic approaches. The following problems need to be considered:

- Groundwater contamination is subject to considerable *time-lags*: contaminants may travel for decades before they reach the aquifer; this makes it particularly difficult to monitor the effectiveness of protection measures. In addition, these time lags are *variable*: they depend on a range of other factors, such as soil type, saturation, or precipitation. Once contaminants reach the groundwater body, they continue to spread, albeit at a slow pace.
- The impact that contaminant release has depends on the *hydrogeolocial conditions* of the site, such as the thickness and soil type of the topsoil layers; on the depth and volume of the aquifer; and on its connections to surface water bodies.
- The impact of groundwater contamination also depends on *groundwater uses*, such as the present and future groundwater abstractions for irrigation, drinking water or industrial uses, and on the vulnerability of groundwater-dependent ecosystems. However, many of the linkages between groundwater, surface water and dependent ecosystems are poorly understood.
- Groundwater damage makes itself felt for a long period, but is difficult or impossible to correct: in many cases, pollution can at best be contained within a certain area, but a cleanup of polluted groundwater is usually not possible. The *irreversibility* of groundwater protection increases the cost of misjudgements when determining protection levels.
- Finally, concerning the benefits of groundwater protection, some groundwater functions have hardly been researched. This applies in particular to the non-use or preservation value of groundwater, and to groundwater-dependent ecosystems: very little is known about these effects of groundwater contamination and their economic costs.

These caveats and limitations imply that any assessment of groundwater pollution and protection is largely determined by local characteristics, and will have to be done in a site-specific way.

II.6.1 Different cost categories of groundwater protection and remediation

Costs for groundwater protection arise for various actors: mainly agriculture, industry, transport, and private households.

For agriculture, costs arise from reduced *fertiliser and pesticide applications*. They comprise *diminished productivity* through less intensive farming practices; *information and learning cost* for better fertiliser or pesticide management; changing to *different crops*, or to different combinations or rotations of crops; employing alternative, more costly *weed eradication* methods; and switching to *alternative land uses*, i.e. from tillage to pasture or forestry. Other costs for agriculture emerge through better storage of pesticides, and storage and treatment of wastewater and manure from farms.

For industry, costs mainly emerge from protective measures that firms are obliged to install. These can be end-of-pipe measures to retain polluting substances, or more integrated measures, i.e. by changing production processes to reduce the use of certain substances. Opportunity costs arise if polluting activities have to be ceased altogether to comply with environmental rules. In addition, substantial clean-up costs arise after accidental spills of hazardous substances, or to make up for insufficient protection in the past. For historical contamination, these costs are frequently not borne by the polluters, but by local or regional authorities. The sectors that are most affected by this are chemical industries and mining.

In the transport sector, costs arise mainly from the installation of protective structures to prevent accidental spills of hazardous substances. Other cost factors are the substitution of methods used in the maintenance of roads and railways, such as road de-icing salts or pesticides used for weed eradication on railway tracks.

For the larger part, private households are indirectly affected by the costs of groundwater protection. In households connected to public sewerage systems, the cost for wastewater treatment is transmitted to them via water supply companies. Where there is no connection to the public wastewater system, cost arise for septic tanks etc. Apart from this, households are also affected by restrictions on pesticide use in private gardens, or by protection requirements for private underground storage tanks.

II.6.2 The cost of groundwater protection and remediation

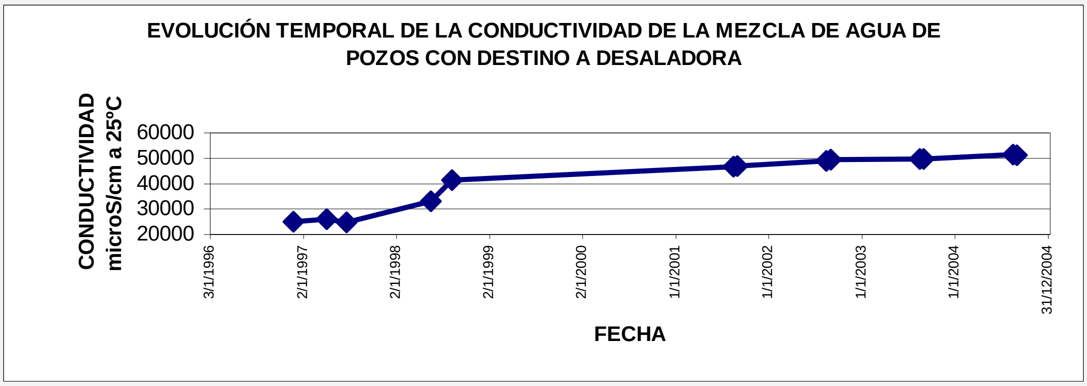
There are a number of instruments that can be used to influence the behaviour of consumers and producers towards less damaging practices, ranging from informational measures to direct regulations that ban certain behaviour. Economic instruments, which influence behaviour by changing the economic incentives that economic actors face, are gaining in relevance. However their applicability and efficiency is limited through gaps in the necessary knowledge. In addition, there are some cases where the reform of existing instruments will be helpful or necessary to improve groundwater protection.

However, in general it appears that it is not so much the type of instrument that determines the effectiveness and cost-efficiency, but rather its design. Well-designed standards that leave sufficient flexibility can be more effective than poorly designed taxes or cooperative agreements. A further general finding is that better groundwater protection is not necessarily connected to higher cost. There appears to be some potential for “no-regret solutions” whereby pressures on groundwater are reduced through better management of polluting activities. These potentials can be mobilised e.g. through information provision and cooperative agreements.

Groundwater remediation relates to all instruments for dealing with groundwater contamination. It includes *restoration* measures that reduce or eliminate pollution, and *containment* measures that control pollution by limiting its spread within an aquifer. Groundwater remediation must be approached with a double caveat: first, in many cases it may not be possible to treat or to clean up contaminated groundwater. Secondly, even where it is possible, it is likely to be much more expensive than preventing pollution before it occurs. However, since the choice for a particular restoration or containment option depends on the kind of pollution and on local hydrogeological conditions, general conclusions are difficult.

Coastal aquifer in Segura River Basin, Spain, salinised by marine intrusion

A coastal aquifer, in Segura River Basin, with declared overexploitation, is salinized by marine intrusion caused by the pumping in wells for the desalination plant. The current conductivity values in the aquifer are close to seawater values: between 35.000 and 45.000 µS/cm at 25ºC in water extracted from wells. There is a high marine intrusion induced by the pumping in wells that supply the desalination plant associated to the aquifer. Collection of sea water through wells in order to obtain water resources to provide citizens and irrigators, as an alternative to overexploitation of aquifers in the area (aquifers declared overexploited) and inexistence of alternative superficial resources.



The solution to the problem is unviable, as it would mean the ending of the sea water collection through wells, as well as the artificial recharge with fresh water, which is not available in the area as a result of the overexploitation of the aquifers in the region.

II.7 GROUNDWATER QUALITY AND WFD

Strategies to prevent and control pollution of groundwater are covered by Article 17 of the Water Framework Directive (2000/60/EC), which requires the establishment of criteria for assessing good groundwater chemical status and for the identification of significant and sustained upward trends and for the definition of starting points for trend reversals, considering:

- The characterisation of bodies of groundwater as detailed in Annex II.2 of the WFD (*Table 11*);
- Good status definitions as detailed in Table 1 of the Introduction, which is based on groundwater level regime (quantitative status) and conductivity and concentrations of pollutants (chemical status);
- Monitoring requirements to respond to the needs of obtaining a comprehensive overview of groundwater status and to detect the presence of long-term anthropogenically induced upward trends in pollutants. In this respect, surveillance monitoring is aimed at supplementing and validating the impact assessment procedure (carried out under Article 5 of the WFD) and provide information for use in the assessment of long term trends both as a result of changes in natural conditions and through anthropogenic activity, while operational monitoring should be undertaken in the periods between surveillance monitoring programmes in order to establish the chemical status of all groundwater bodies or groups of bodies determined as being at risk and to establish the presence of any long term anthropogenically induced upward trend in the concentration of any pollutant.

Monitoring results shall be used to identify long term anthropogenically induced upward trends in pollutant concentrations and to set up starting points for reversing these trends.

Annex II.2 (WFD)	Characterisation
Initial characterisation (par. 2.1)	The initial characterisation concerns all groundwater bodies, assessing their uses and the degree at which they are at risk to meet WFD environmental objectives. This analysis may use existing hydrological, geological, pedological, land use, discharge, abstraction and other data, identifying: the location and boundaries of the groundwater body or groups of bodies, the pressures to which the groundwater is subject to (diffuse and point sources of pollution, abstraction, artificial recharge), the general character of the overlying strata in the catchment area from which the groundwater body receives its recharge, and those groundwater bodies for which there are directly dependent surface water ecosystems or terrestrial ecosystems.
Further characterisation (par. 2.2)	It concerns the groundwater (or groups of) bodies which have been identified as being at risk, and aims to establish a more precise assessment of the significance of such risks and the identification of any measures top be required under the WFD Article 11. This characterisation has to include relevant information on the impact of human activity and, where relevant, on geological characteristics of the groundwater body (including the extent and type of geological units), hydrogeological characteristics (including hydraulic conductivity, porosity and confinement), characteristics of the superficial deposits and soils in the catchment from which the groundwater body receives its recharge (including the thickness, porosity, hydraulic conductivity, and adsorptive properties of the deposits and soils), stratification characteristics of the groundwater, an inventory of associated surface systems (including terrestrial ecosystems and bodies of surface water, with which the groundwater body is dynamically linked), estimates of the direction and rates of exchange of water between the groundwater body and associated water systems, sufficient data to calculate the long term annual average rate of overall recharge, and characterisation of the chemical composition of the groundwater (including specification of the contribution from human activity—Member States may use typologies for groundwater characterisation when establishing natural background levels for these bodies of groundwater).

***Table 11**: Groundwater characterisation requirements under the WFD*

In practical terms, the groundwater chemical status will have to be monitored by Member States through the River Basin Management Plan defined by the Water Framework Directive (Article 13). The evaluation will be based on quality standards and/or threshold values established for pollutants, and defined either at Community level or within each river basin district. These can be used to judge whether bodies of groundwater have poor or good chemical status. The identification of significant and sustained upward trends in pollutant concentrations and the trend reversal requirement will complement this mechanism, ensuring that the no-deterioration clause set out in the WFD can be achieved.

It is difficult to define "common indicators" that would ensure that the chemical status of groundwater is evaluated in the same way throughout Europe. This is because of the wide variety of types of groundwater – each with their own different parameters - which exist in Europe.

Given this difficulty, the first option was to require Member States to establish thresholds for pollutants (instead of fixed quality standards) in order to assess the chemical status of bodies of groundwater that are characterised as being at risk. The pollutants selected would be, on the one hand, chemical substances that might originate either from natural or anthropogenic sources (pollution from human activities), and on the other hand, synthetic pollutants that do not occur naturally in groundwater. Compliance with the rules on good chemical status would be based on these thresholds, which would take into account the risks posed by these pollutants for existing and intended uses of the groundwater, related aquatic ecosystems, and directly dependent terrestrial ecosystems.

In addition, the requirement to identify and reverse trends in pollutant concentrations would be included in this first option, with specificrequirements for point sources of pollution. These requirements are closely linked to prevention and control of the input of pollutants into groundwater, by prohibiting direct discharges and limiting indirect discharges resulting from an activity on or in the ground

The existing WFD requirements on the chemical status of groundwater (Annex V.2.3.2) are based on a definition of "good chemical status" that makes reference toquality standards applicable under other relevant Community legislation. The second option considered, therefore, was to establish a regulatory framework whereby good chemical status would be assessed against a comprehensive set of legally binding EU quality standards (maximum permissible concentrations of a range of givensubstances in groundwater), which would also represent restoration targets.

The new Groundwater Directive, requested by Article 17 of the WFD, aims to provide the necessary common criteria regarding chemical status evaluation, identification and reversal of significant and upward trends in pollutant concentrations, as well as specific clauses regarding indirect discharges to make sure that the existing protection regime will be appropriately strengthened.

The WFD aims also to ensure a balance between the abstraction and recharge of groundwater. Consequently, one of the Directive's requirements is that the chemical composition of the groundwater body does not exhibiting the effects of saline intrusion, with the aim of achieving good status by 2015.

The Directive under Annex V outlines that for achieving good quantitative status in a groundwater body "*alterations to flow direction resulting from level changes may occur temporarily or continually 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*"; thereby recognizing the importance of averting regional saltwater intrusion in the management of coastal aquifers.

Finally, Annex IV of the Water Framework Directive defines protected areas as areas designated:

- For the abstraction of water for human consumption under Article 7 of the WFD – Drinking Water Protected Areas;
- For the protection of economically significant aquatic species;
- As recreational waters, including bathing waters under Directive 91/271/EEC;
- As nutrient sensitive areas, including areas designated as vulnerable zones under Directive 91/676;
- For the protection of habitats or species where the maintenance or improvement of the status of water is an important factor in their protection, including relevant Natura 2000 sites designated under Directive 92/43/EEC and directive 79/409/EEC.

For those bodies used for abstraction of water intended for human consumption, providing more than 10 m^3 per day or serving more than 50 persons, it must ensured that 'under the water treatment regime applied' the resulting water must meet the Drinking Water Directive. Necessary protection should be in place to avoid deterioration of quality in the water bodies in order to reduce the level of purification treatment required for the production of drinking water.

II.8 RECOMMENDATIONS

Groundwater scarcity is in many cases accompanied by poor groundwater quality, especially in coastal aquifers, where water is often highly saline, reducing its utility. A general groundwater quality deterioration occurs in many parts of the Mediterranean region, due to contamination in recharge areas, mismanagement during irrigation practices, overexploitation of coastal aquifers and other reasons.

Groundwater protection should be comprehensive and not limited to water production areas. The water quality of unpolluted aquifers should be preserved. The protection strategy should also call for the development and use of techniques to alleviate existing contamination.

The planning of new activities which could pollute groundwater should include all necessary preventive measures at the pollution source and containment measures.

Clean-up priority should be given to those sites that threaten legally-protected aquifers and related ecosystems. Despite technical and economic difficulties, the necessary efforts should be made in areas with limited alternative water resources to restore aquifers rather than to abandon them or curtail their use. However, if the aquifer is extensively, severely or irreversibly polluted, it may be unreasonable to aim for a complete groundwater clean-up.

Polluters, government authorities and the public will accept to pay for the management of contaminated sites only if there is a clearly stated case-by-case assessment, taking into account the endangered receptors and uses. Consequently, instruments to assess and present results should be developed.

CHAPTER III: MONITORING AND DATA MANAGEMENT

III.1 INTRODUCTION

The groundwater resources of the Mediterranean region are either the main sources of freshwater or are vitally needed to supplement surface water sources. However, despite their importance, the groundwater resources are under stress of exploitation and contamination. Widely observed effects are decline of the water table as well as deterioration of groundwater quality and in many coastal areas of the region seawater intrusion and land subsidence.

With these problems growing, the awareness of the need for sustainable management of the groundwater resources has also increased. Moreover, it is recognised that successful management needs to be based on sufficient and reliable data regarding the groundwater resources and their environment and the stresses upon these systems.

Monitoring of water quality, water levels, and water extraction in an aquifer is, therefore, of fundamental importance as a basis for groundwater resources management. Monitoring, data collection and analysis provide the information that permits rational management decisions on all kinds of groundwater resources sustainability issues:

- understanding the flow system and assessing the current groundwater status,
- quantifying inter-relationships between surface water and groundwater,
- determining and detecting trends in groundwater levels and quality and identifying actual and emerging problems,
- assessing the magnitude and impact of pressures and the rate of use of the resource, especially where the regulatory system is deficient,
- assessing changes in status with time in response to the application of measures for improvement or prevention of deterioration and evaluating the effectiveness of management actions.

The role and importance of the transboundary aquifers of the Mediterranean region demand a careful and consistent assessment and monitoring of these resources. An integrated approach to monitoring design together with a unified and consistent information base on basic hydrological processes is a prerequisite for the sustainable management of transboundary aquifers, where the already complex interplay of geology, climate and human activities that defines a groundwater catchment is further complicated by political and legal differences of two or more neighbouring countries.

III.2 GROUNDWATER MONITORING CONSIDERATIONS

III.2.1 Preliminary characterisation of the groundwater systems

A prerequisite for designing targeted and cost-effective monitoring programmes for the assessment of groundwater resources is the preliminary characterisation of the relevant aquifer systems and the actual condition of groundwater flows.

The preliminary characterisation should allow for an identification of the extend (geometry and hydraulic characteristics) of the aquifer and the general features of the strata overlying the catchment area, a first definition of the links between surface and ground water and an assessment of pressures on water quality and quantity due to human activities: pollution, uses and abstractions.

After a preliminary characterisation of the groundwater systems, further monitoring should provide information about the aquifer dynamics such as seasonal variations and changes of the groundwater flow system and about the effects of measures and other anthropogenic influences.

III.2.2 Identification of the purposes for which monitoring information is required

The design of a monitoring network depends on the information which is required for the execution of proper groundwater resources management. In addition technical, economic and other factors determine the stage of groundwater monitoring.

The monitoring cycle (*Figure 22*) suggests that the process of monitoring and assessment should principally be seen as a sequence of related activities that starts with the definition of information needs and ends with the use of the information product.

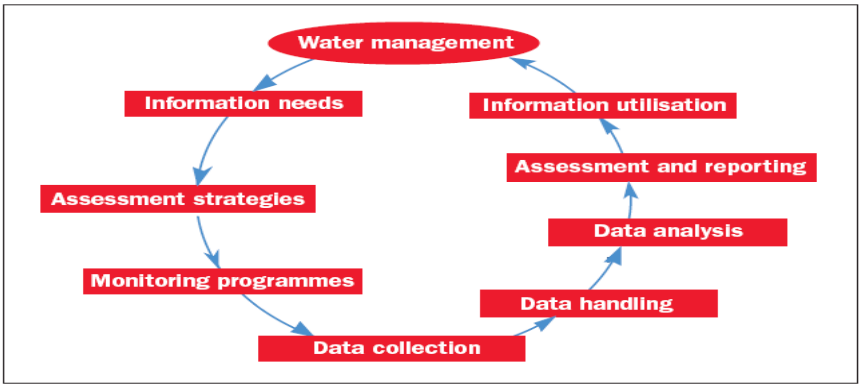


Figure 22*: Monitoring cycle*

As the UN/ECE Task Force on Monitoring and Assessment points out, successive activities in this monitoring cycle should be specified and designed based on the required information product as well as the preceding part of the chain. The evaluation of the obtained information may lead to new or redefined information needs, thus starting a new sequence of activities. In this way, the monitoring process could be improved.

The initial monitoring design stage that finally should arrive at the specification of the data to be collected contains the steps which are depicted in Figure 23.

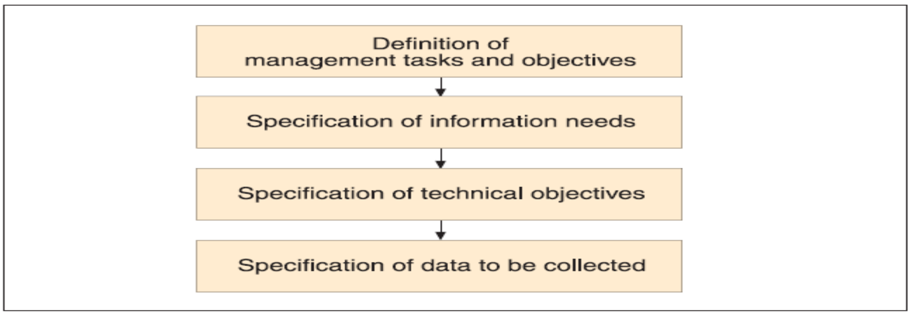


Figure 23*: The initial steps of designing a groundwater monitoring system*

Groundwater level monitoring

The principle purposes of groundwater level monitoring are to provide data about groundwater system behaviour and overall impacts on the groundwater situation caused by groundwater exploitation and other interventions.

Groundwater quality monitoring

Groundwater quality monitoring networks provide information on the chemical status of groundwater systems and the effects on groundwater quality and establish the presence of any significant upward trend in pollutant concentrations and the reversal of such trends.

Monitoring groundwater recharge and abstraction

Data on the amount of groundwater discharged from the groundwater system through different manners (springs, wells, etc.) is indispensable information for groundwater resources assessment and in particular for estimates of the potential of the system for water supply.

Monitoring seawater intrusion

Seawater intrusion occurs when natural discharge and abstraction of groundwater in a coastal zone exceed average groundwater recharge and inflow. The key to controlling this problem is to maintain the proper balance between water being pumped from the aquifer and the amount of water recharging it. Constant monitoring of the seawater interface is necessary in determining proper control measures.

III.2.3 Types of monitoring networks

The following types of monitoring networks can be distinguished:

A. Basic networks

The basic network delivers general information about the quality and quantity of the groundwater and has a permanent character. The information from this network forms the basis of the evaluation of the trends in the future and is the basis for both countrywide and local hydrogeological scientific and practical investigations.

B. Specific networks

Specific networks are constructed for monitoring selected areas or for specific kinds of pressures, for example, point sources of pollution. Therefore, they act as impact stations. The stations can form a separate network, or they can be an extension of the basic network, and thereby fulfil the need for data in areas between points on the larger basic network. The specific network can have a permanent character, or will be in operation as long as there are needs for information at that specific place.

C. Temporary networks

The temporary network stations are established to collect data in connection with particular groundwater projects, and will normally be impact stations. The network will be operational during the project period after which it is closed.

For the monitoring of groundwater quantity, an additional type of network has been identified:

D. Hydrological bench-mark or base-line network

This network should provide continuing series of consistent observations on hydrological and related climatological parameters to reflect local, regional and geographic differences.

III.2.4 Primary aspects in network design

The design of a groundwater monitoring network includes primarily the determination of:

- the parameters to be measured,
- the locations and depths for which the parameters should be representative,
- the period of time for which monitoring is required,
- the frequency of the measurements within this period of time.

The essence of a monitoring network system is the choice of parameters to be measured or analysed. Then the representativity of the measured variable, given by location and depth, is the most crucial monitoring aspect. Without knowing the representativity, the knowledge of the variable would be worthless. Next, the period of time and frequency of measurements have to be adjusted to the monitoring objectives.

III.2.5 Conceptual models/Understanding approach

Conceptual models/understandings are simplified representations, or working descriptions, of how real hydrogeological systems are believed to behave. Conceptual models/understandings are required for designing effective monitoring programmes, classifying the status of water bodies and designing suitable programmes of measures (*Figure 24*).

Designing the monitoring programmes on the basis of conceptual models ensures that they will be appropriate to the hydrogeological characteristics of the system and, where relevant, the behaviour of pollutants in the groundwater system

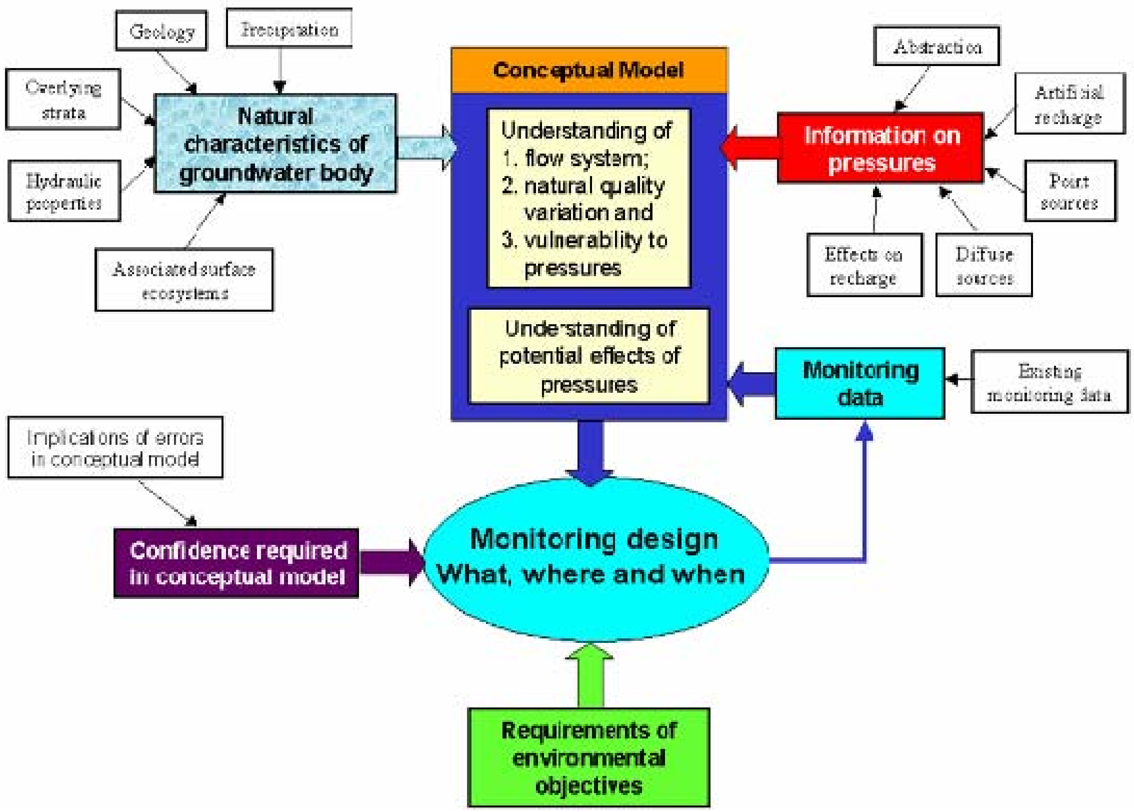


Figure 24: *conceptual model representing the understanding of the groundwater system, based on the knowledge of its natural characteristics, perceived pressures and knowledge of impacts*

III.2.6 Integrated approach

Groundwater resources management cannot be performed on its own. On the contrary, it must be a part of a comprehensive and integrated policy on the use and protection of the environment and the natural resources.

Monitoring of the aquifers cannot provide all the necessary information on the water resources for the execution of adequate groundwater resources management. Additionally, meteorological and surface water data are needed for the analysis of the information obtained from the groundwater network. The harmonisation of surface water and groundwater monitoring networks is thus very important, in order to manage and protect water resources effectively.

Furthermore, groundwater should be assessed, based on criteria that cover both water quality and quantity because of the strong relationship between groundwater flow and groundwater quality processes.

III.2.7 Data management

The flow of data, from measurement in the field up to the presentation and evaluation of the needed information, follows different stages which all need thorough attention.

Groundwater management is dependent on the existence of reliable groundwater resources information systems at national and regional levels, covering not only the collection and analysis of data but also the exchange and dissemination of these data and related information to the users, ranking from the general public to the decision makers. In addition to monitoring, institutional arrangements regarding data provision and exchange are, therefore, necessary. Improvement of data collection systems is required from time to time. Monitoring systems provide specific data, namely the data that the systems are designed to produce. Information needs may change over time. Changed information needs in turn necessitate adjustments in the data collection system.

III.3 CURRENT SITUATION ON GROUNDWATER MONITORING AND DATA MANAGEMENT IN THE MEDITERRANEAN REGION

In Mediterranean region, as well as in many regions of the world, while there have been many investments in exploiting groundwater resources for human use, not much attention has been paid to monitoring the condition of the resource and assessing its sustainability in terms of quantity and quality. Despite the obvious benefits of monitoring programs, it is common to find that they are the first functions to be cut back when resources are scarce, as they are often regarded as an optional luxury that is costly and resource-consuming.

Regarding groundwater monitoring, the actual situation in the Mediterranean region is generally not satisfactory:

- Groundwater monitoring has become a standard practice only in certain parts of the region.
- In many parts of the region, no significant and systematic groundwater monitoring going on or only project-wise or problem-driven. In these cases, data on groundwater levels or groundwater quality are monitored within the framework of local and temporal projects.
- Until recently many monitoring networks in the region were developed for the assessment only of the groundwater quantitative status (water level). The quantitative aspects were the only aspects that policy makers were interested in. Groundwater quality management became an issue only recently.

- There is a lack of standard groundwater monitoring procedures and thus datasets from different part of the region, in many cases, can not be compared.

The situation is rather different in the EU Member States in thew northern part of the Mediterranean regio, where groundwater management comes under the EU Water Framework Directive (WFD), which requires the formal implementation of long-term monitoring activities. Groundwater monitoring strategies are under revision or amendment, in order to be in line with the requirements of the WFD.

Concerning the available information on groundwater resources in the Mediterranean region, there is inadequate knowledge of both the groundwater resources and the present and forecasted demand for water. More specifically:

- There is a lack of detailed and reliable information on many aquifers (e.g., dimensions, hydraulic relations, volumes of water stored in both saturated and unsaturated zones, recharge rates, chemical composition of water, etc.).
- For many aquifers, water quantity and water use data are available but there is a significant lack of information on groundwater quality.
- Consistent and large data gaps can be identified both temporally and geographically.
- Monitoring of groundwater and surface water, of water quality and of quantity are often performed by different authorities, so the resultant information needs to be assessed in combination.
- Moreover, for many aquifers, the existing data are unsuitable, or poorly suited, for regulatory or planning use and irrelevant to the management process.

At general, existing data are not sufficient or reliable enough to plan regional actions for the sustainable use of groundwater. The lack of sufficient and reliable data causes a considerable risk of deterioration of the groundwater status, both quantity and quality, without sufficient warning.

However, in many Mediterranean countries, there is a substantial amount of data and information available on the groundwater resources, often scattered over different institutes and organisations. In these cases, there is sometimes little on no coordination between the organisations involved in the data management.

Example of specific network for specific kind of pressures (impact stations): Pollution Potential of the Shallow Aquifer in Wadi Dhuleil Basin, Jordan

Wadi Dhuleil basin is located in the Amman-Zarqa basin, one of the largest basin in Jordan used for drinking purposes.

The construction of AsSamra waste stabilization ponds (AWSP) in 1985 above Wadi Dhuleil basin has raised many questions about the possibility of AWSP to pollute the aquifer system below it. The shallow unconfined aquifer at Dhuleil has shown signs of pollution after a few years of AWSP construction. This paper addresses whether the cause of pollution of the shallow aquifer is mainly AWSP or whether other sources of pollution are responsible for such pollution. Eight wells were monitored for a period of seven years. These wells were located upstream, under direct influence of AWSP, along the watercourse where AWSP effluent is discharged, and southwest of AWSP. Wells located under the direct influence of AWSP have shown higher concentrations of pollutants in comparison with the other monitored wells. Comparison of the water quality of the wells with the AWSP influent and effluent quality has shown that AWSP is not the main source of pollution.

Groundwater monitoring in France

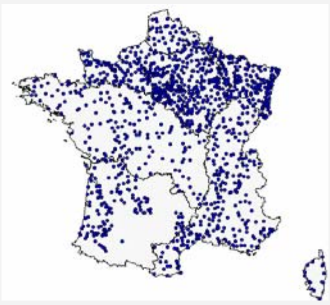
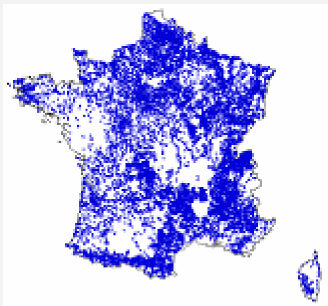
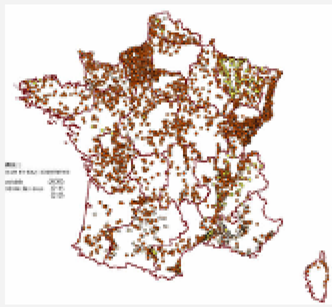
In 2003 the French Guidance document on Groundwater Monitoring was published as well as the national groundwater database was made available (ADES: http://ades.rnde.tm.fr).

➢ Monitoring of groundwater chemical status

Three types of existing networks have been streamlined.

- Patrimonial Network: covers all groundwater bodies and is intended to be used as the WFD Surveillance Monitoring Network.
- Sanitary Network: is based on the Drinking Water Directive requirements and monitors untreated water.
- Impact Networks: are intended to represent the WFD Operational Monitoring Network. They are investigating on nitrate (Nitrate Directive), on pesticides and on point sources of pollution. The aim of the Nitrate Network is the delineation of vulnerable zones.

The networks design is based on the understanding of the hydrogeological system, the geological type of the groundwater body, on environmental objectives and on the type and level of pressures.

Surveillance Monitoring	**Sanitary Network**	**Nitrate Network (Impact)**
		

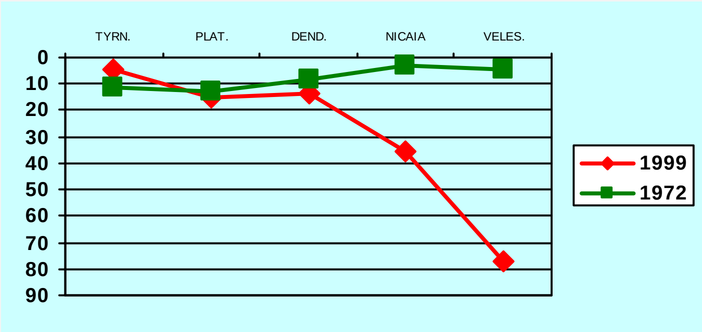
➢ Monitoring of groundwater quantitative status

Two monitoring networks exist:

- Patrimonial Network: covers all groundwater bodies and observes the general state of the water quantity.
- Impact Network: is divided into the
  - Network for Water Policy: its objective is to share information on water abstraction within different users on the local scale
  - Warning Networks: concentrates on flooding and lowest water level

Adaptation to monitoring requirements by the WFD
A working group was established for the period of 2002–2006 in order to improve the networks according to the requirements of the WFD.

Example of monitoring data analysis for specific kind of pressures in Pinios PRB – Greece



Variation of water table dept

Following the data analysis from the Groundwater monitoring network that has been established in Pinios pilot river basin (Pinios PRB) a variation of the water table depth has been observed.

The 3 first stations are located in higher altitude and the last 2 in the plain (the last one near the coastline). According to the diagram, in the last station, a lowering of the water table of more than 70m has been observed, from the year 1972 to 1999. It is obvious that this area is a high risk zone because this lowering of the water table could lead to seawater intrusion.

III.4 GROUNDWATER MONITORING UNDER THE WATER FRAMEWORK DIRECTIVE

Groundwater monitoring obligations under the Water Framework Directive (WFD) concern quantitative and chemical aspects.

Regarding the quantitative status, the monitoring programmes will have to be designed (before the end of 2006) so as to provide a reliable assessment of the quantitative status of all groundwater bodies or groups of bodies including assessment of the available groundwater resource. The network will have to consider the representativeness of monitoring points, taking into account short and long-term variations in recharge, and the frequency that should be sufficient for quantitative assessments (in particular for evaluating the impacts of abstractions and discharges on the groundwater level, and - for transboundary groundwater bodies - estimating the direction and rate of groundwater flow across the Member State boundary).

With regard to the groundwater chemical status, the monitoring networks have to be designed in order to provide a coherent and comprehensive overview of the groundwater chemical status within each river basin and to detect the presence of long-term anthropogenically induced upward trends in pollutants (*Figure 25*). Based on the results of the characterisation of groundwater bodies *(Table 11)* and the impact assessment, Member States have to establish a surveillance monitoring programme, the results of which being used to establish an operational programme in the framework of each river basin management plan. In other words, the surveillance programme will be used to supplement and validate the impact assessment procedure, and provide information to be used in the assessment of long term trends both as a result of changes in natural conditions and through anthropogenic activity.

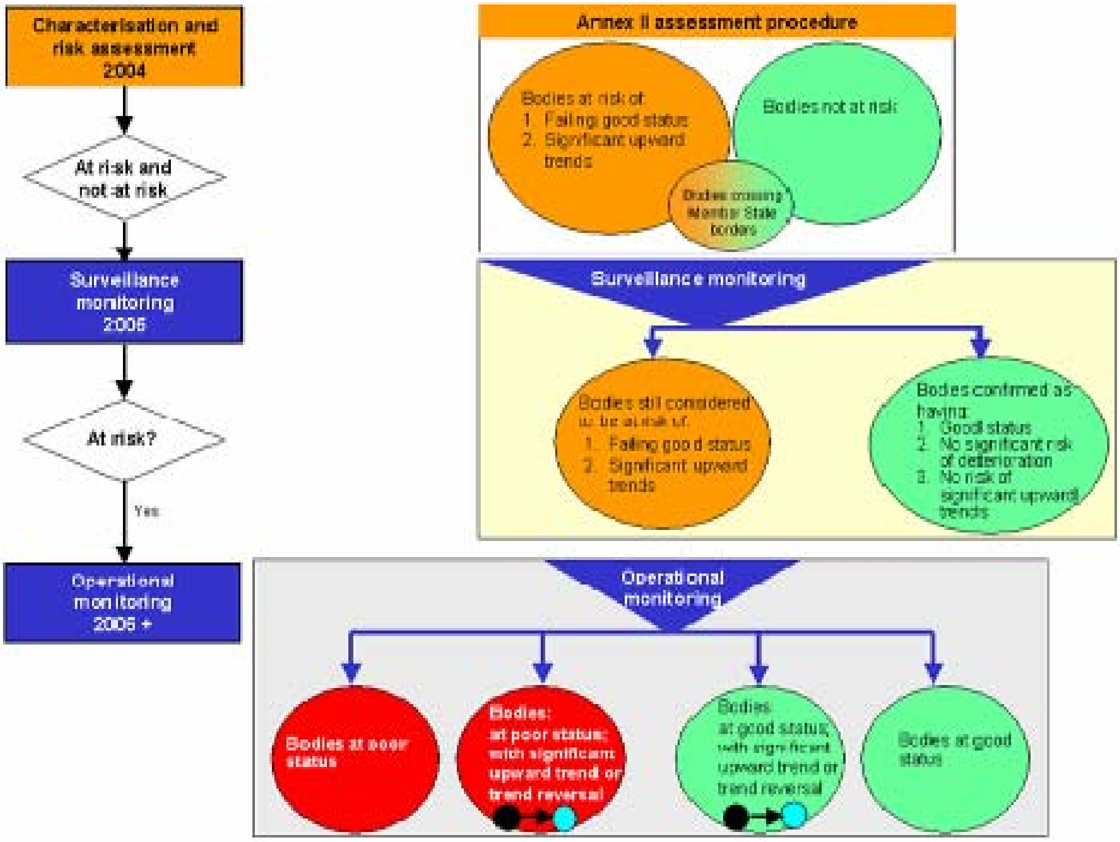


Figure 25: *Groundwater quality monitoring requirements under the WFD*

Similarly to the quantitative monitoring, aspects of representativeness and frequency will have to be carefully considered. Minimum monitoring parameters concern oxygen content, pH value, conductivity, nitrate and ammonium (for all groundwater bodies). Groundwater bodies which were found to be at risk (following the impact assessment) will also have to be monitored for those substances which are indicative of the impact of these pressures. In this respect, operational monitoring will have to be undertaken in the periods between surveillance monitoring programmes in order to establish the chemical status of all groundwater bodies determined as being at risk and the presence of any long term anthropogenically induced upward trend in the concentration of any pollutant. The frequency of surveillance monitoring is not strictly defined in the WFD, but operational monitoring will have to be performed at a minimum once per year. Regarding the identification of trends in pollutant concentrations, the monitoring programmes will have to be adapted to local situations and the trends will have to be demonstrated statistically, stating the level of confidence associated with the identification.

Figure 26 summarises groundwater monitoring obligations under the Water Framework Directive, which are described in detail in the guidance document on monitoring, developed under the Common Implementation Strategy (CIS) of the WFD.

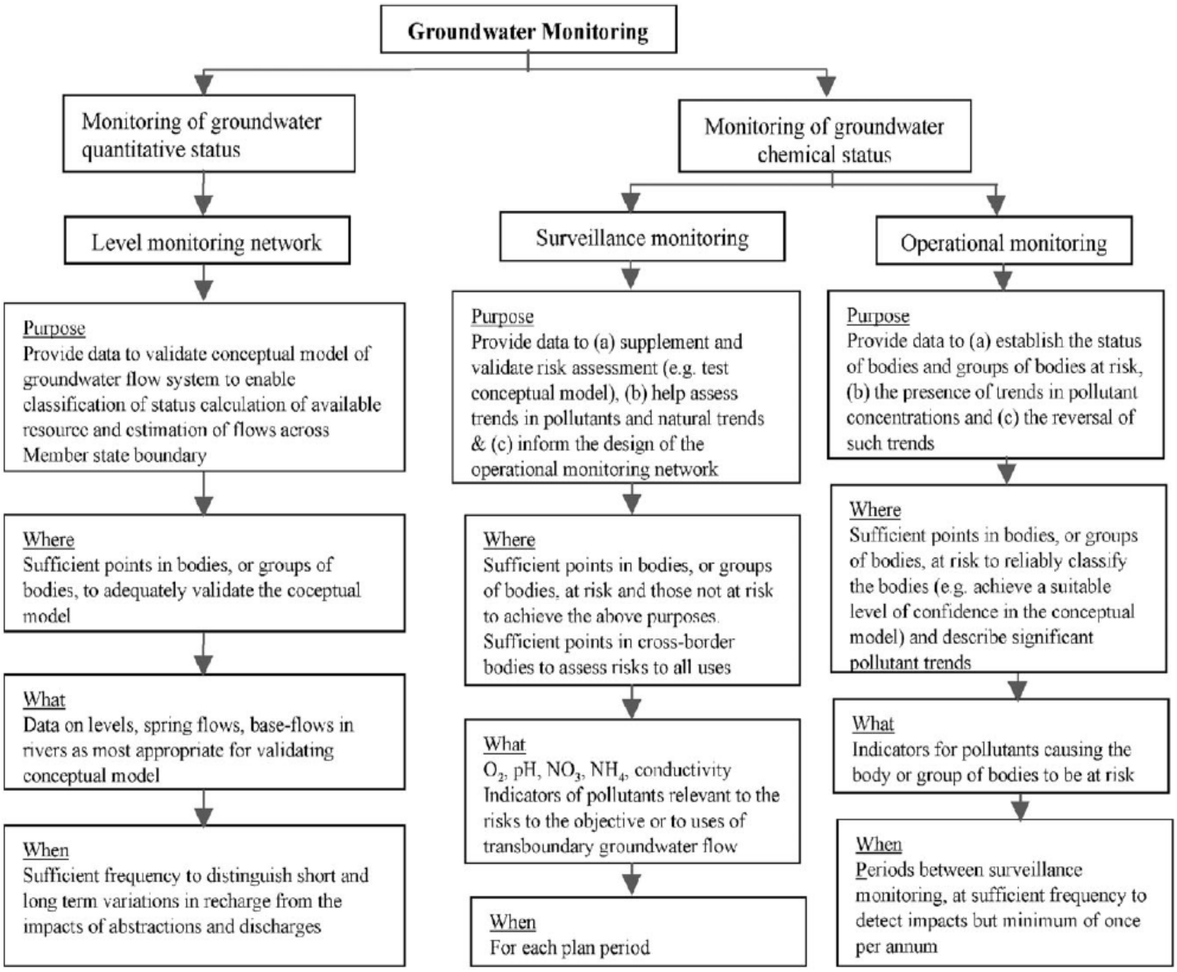


***Figure 26**: Summary of groundwater monitoring obligations under the WFD*

III.5 TRANSBOUNDARY GROUNDWATER MONITORING

Because the borders between riparian countries do not necessarily coincide with the natural boundaries of groundwater aquifers, groundwater may flow from one state to another. Moreover, abstractions or other activities on one side of the border may adversely affect groundwater functions on the other side. To be able to distinguish natural characteristics from anthropogenic effects, information are required about the aquifer and flow conditions on both sides of the border.

Moreover, on a regional basis, the shared use of groundwater resources can also cause conflict between nations, either due to groundwater over-exploitation or contamination. Such conflicts must be avoided by planning and coordinating efficient development and sustainable management of water resources both with respect to quantity and quality. This is impossible to accomplish without a reliable data base on aquifers.

The possible existing monitoring networks on each side of a national border may have been set up with different objectives, the measurement locations, times and frequencies might not match and the assessment and presentation may be different. Furthermore, it is often very difficult to obtain the required data because of logistical difficulties. Consequently, without proper establishment of cross-border groundwater monitoring and assessment, errors may occur in aquifer characterisation and in the prediction and evaluation of changes in groundwater flow and quality.

To develop and evaluate strategic policies for groundwater management it is a prerequisite that the monitoring and assessment of groundwater in the riparian countries is performed in a comparable way. This means, for example, in order to assess trends in groundwater quality, the definition of trends, the sampling procedures and chemical and numerical analysis should be comparable on both sides of the border.

III.5.1 Current situation

As far as monitoring and cooperation between countries for common management of internationally shared aquifer resources is concerned, the actual situation in the Mediterranean region is far from satisfactory.

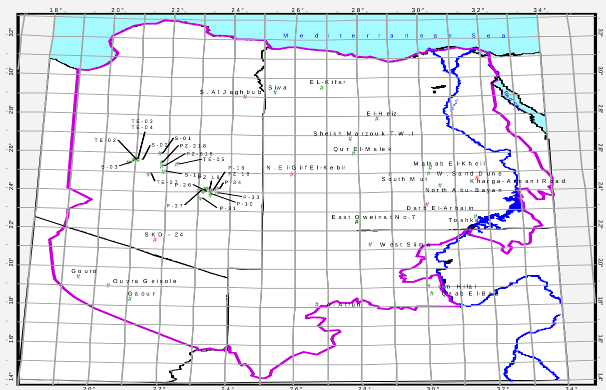
Although there are some good examples of ongoing programmes on transboundary water cooperation in the region, such activities are scarce and lack coordination. There are various reasons for this situation:

- Insufficient groundwater monitoring, lack of information and reliable data
- Weak institutional capacity and degradation of technical infrastructure
- Lack of bilateral and multilateral agreements
- Potential tensions in sharing international aquifers, especially during drought periods
- Non integrated administrative policies for environmental protection

Moreover, existing monitoring networks are mostly operated and maintained with application of national standards and quality control procedures. Harmonisation of network design, measurement frequency, standards, quality control and data storage and processing will be needed for setting up transboundary groundwater monitoring.

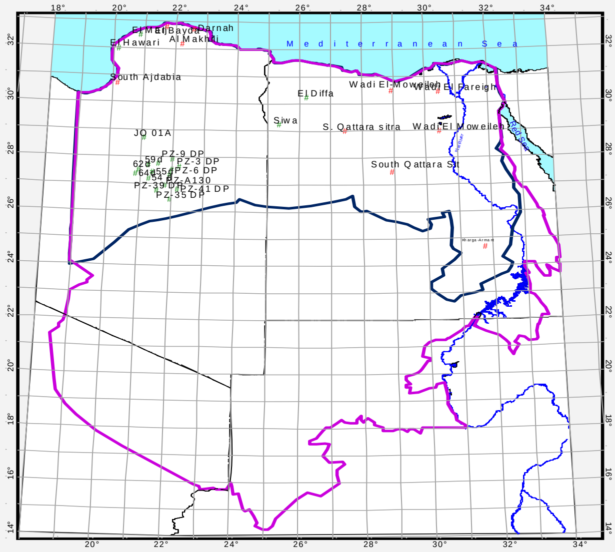
The Nubian Sandstone Aquifer System (NSAS)

The Nubian Sandstone Aquifer System (NSAS) is a huge groundwater, non-renewable, resource shared among four countries within the Eastern Sahara in North-East Africa. These countries are Chad, Egypt, Libya and Sudan. The NSAS underlies an area in excess of 2.5 million km^2. It occupies a portion of the great arid zone belt of North Africa, extending northward into the Mediterranean Steppe and merging on the southern side into the subtropical climatic zone.



Nubian Aquifer Monitoring Wells Network,
(CEDARE 2001

In order to assure the sustainable development and the continued mechanism of regional cooperation for the proper management of the Nubian Sandstone Aquifer, it was deemed imperative to share the information, monitor the aquifer regionally, and exchange updated information on the behaviour of that shared resource.



Post Nubian Monitoring Wells Network
(*CEDARE 2001)*

Therefore, the NSAS Programme had the National Coordinators of the four countries sign two agreements for the data sharing, monitoring and exchange of information.

Within the context of the first agreement the four countries will share the data that was consolidated throughout the implementation of the Programme and that was incorporated in the Regional Information System. Within the framework of the second agreement they will update the information by continuous monitoring of the aquifer and updating the Information System.

The NSAS Programme proposed a regional monitoring network, indicating representative sites that should be monitored, the parameters and the frequency of monitoring of these parameters. These included the yearly extraction in every extraction site, yearly measurement of the quality in each extraction site in addition to the water level measurements in specified locations which should be recorded twice a year. The monitoring network was designed to provide as much areal coverage as possible of the Nubian as well as the Post Nubian aquifers. The four countries sharing the resource represented by their National Coordinators adapted the regional network and agreed to continue the monitoring of the Aquifer through a mechanism specified through agreements.

The regional monitoring network included existing locations as well as proposed ones to cover the gaps of information. For the Nubian, the existing wells are 42 and the recommended new ones are 5. For the Post Nubian, the existing wells are 18 and the recommended new ones are 9.

III.6 GROUNDWATER SIMULATION MODELLING

Numerical aquifer models are essential tools for quantitative evaluation, scenario prediction and therefore, efficient management of groundwater resources, in both quantity and quality terms. Models, if properly constructed are useful to estimate the effects of future development/management schemes on the groundwater system. In addition, they can aid in understanding of the overall behaviour of a given aquifer system.

There are numerous applications of simulation models in the development and management of groundwater resources, such as:

- the response of aquifers to various patterns of groundwater abstraction,
- the definition of flow regime dynamics around individual groups of groundwater sources,
- the transport attenuation of contaminants emanating from point sources of pollution, etc.

III.7 CONCLUSIONS

Groundwater monitoring is of fundamental importance, especially in the Mediterranean region, where the groundwater resources are threatened by over-exploitation and quality deterioration. Monitoring of water quality, water levels and water extraction in an aquifer is the foundation on which groundwater management is based.

In parallel to the data collection, the processing, analysis and dissemination of reliable information and data on groundwater resources in terms of quantity and quality are vital to efforts directed towards planning to meet present and future water demands.

Moreover, many major aquifers of the region containing large reserves of, in many cases, non-renewable groundwater are transboundary. A fundamental feature of transboundary cooperation is the design and establishment of joint monitoring and assessment programmes. This process requires countries to define common information needs on the basis of their water management policies, and thereafter to design and operate monitoring programmes, agree on assessment strategies and review their water management strategies on the basis of the assessment results. Effective monitoring programmes should include exchange of harmonized data and information.

Despite the obvious benefits of groundwater monitoring, the situation in the Mediterranean region is not satisfactory. Besides that, many monitoring networks in the region were developed for the assessment only of the groundwater quantitative status and therefore there is a significant lack of information especially on groundwater quality.

Efforts must be intensified to gather fundamental groundwater data, organising them appropriately and disseminating them to those who may need them. In addition to monitoring, institutional arrangements regarding data provision and exchange are also necessary.

Among the various cooperation potentials is the establishment of Regional Groundwater Monitoring Network (RGMN). The suggested network will facilitate the regional management of shared aquifers and eventually lead to better assessment of the groundwater potential(s). The establishment and operation of RGMN needs to be studied and planned accordingly. Such network will require national commitment from various countries to monitor and report groundwater aquifer data on periodical basis.

Based on the RGMN, a Groundwater Status Report can be produced. The Groundwater Status Report will document the current conditions of the groundwater aquifers. Sustainable and non-sustainable developments will become apparent and may dictate the future policies and responsibilities of the countries to implement the appropriate mitigaton measures.

CHAPTER IV: INTERNATIONAL COOPERATION

IV.1 INTRODUCTION

International cooperation has become essential for sustainable management of shared aquifers. Among various management tools, the establishment of regional groundwater monitoring networks and publishing periodical groundwater status reports have been identify as effective tools in providing informative ground for multi-disciplinary cooperation.

Over the last few decades, various cooperation attempts have been accomplished between countries sharing groundwater aquifers. Several examples are provided in this chapter including:

- the cooperation between Chad, Egypt, Libya and Sudan on the Nubian Sandstone aquifer,
- the cooperation between Algeria, Libya and Tunisia on the North - Western Sahara Aquifer System.

Among the various programs that promote international cooperation on shared/transboundary aquifer is the Internationally Shared Aquifer Resources Management (ISARM), led by an UNESCO multi-agency effort aimed at improving the understanding of scientific, socio-economic, legal, institutional and environmental issues related to the management of transboundary aquifers.

IV.2 THE ROLE AND IMPORTANCE OF SHARED AQUIFERS

Interstate borders may cross aquifers without recognising hydrological and hydrogeological processes that may take place in different ways from each side of the border. As shown schematically in Figure 27 taken from UNESCO/ISARM Framework Document, 2001, water recharge contributing to transboundary flow may occur in one country and as a consequence deep aquifer may discharge to the neighbouring country. The groundwater flow may be to the opposite direction in local shallow groundwater aquifers near the border.

In internationally shared rivers and lakes a large progress was made on how to determine what type of water resources problems are or will likely be posed for bilateral or multilateral interstate solutions. A large number of international agreements for solving various types of interstate surface water resources problems are available for reference and act as precedents.

The situation is quite different in the case of transboundary groundwater resources. Difficulties arise in scientific and technical matters (groundwater monitoring, data interpretation, modelling), the lack of political willingness for cooperation and the weakness of the institutions involved. Major difficulties in designing groundwater development plans is that groundwater flow and groundwater quality are subject to several types of uncertainties much more important than in surface hydrology. These are related to the high variability in space and time of the hydrogeological, chemical and biological processes. The principal challenge is to set up a cooperative framework in which institutions involved from both sides could work together effectively.

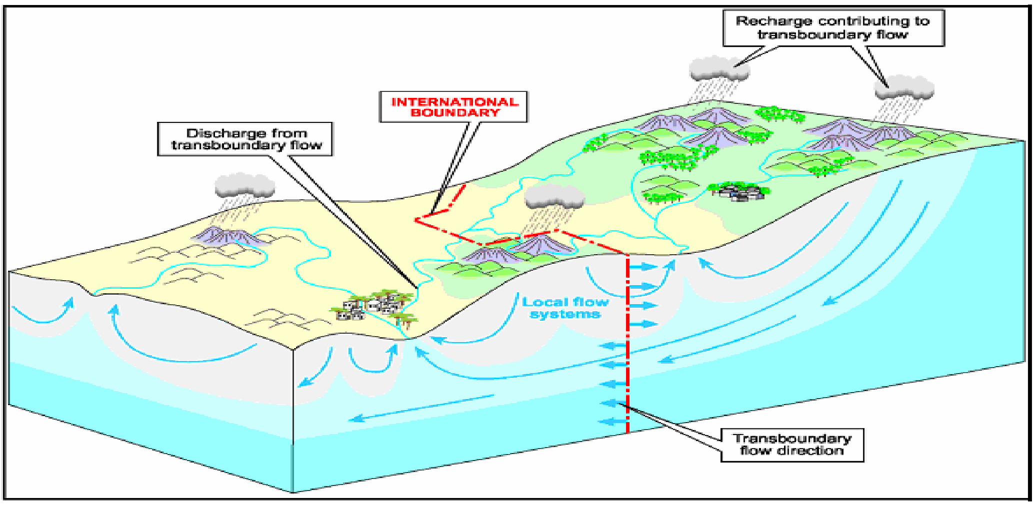


Figure 27: *Schematic representation of hydrological and hydrogeological processes in transboundary areas*
(UNESCO/ISARM, 2001)

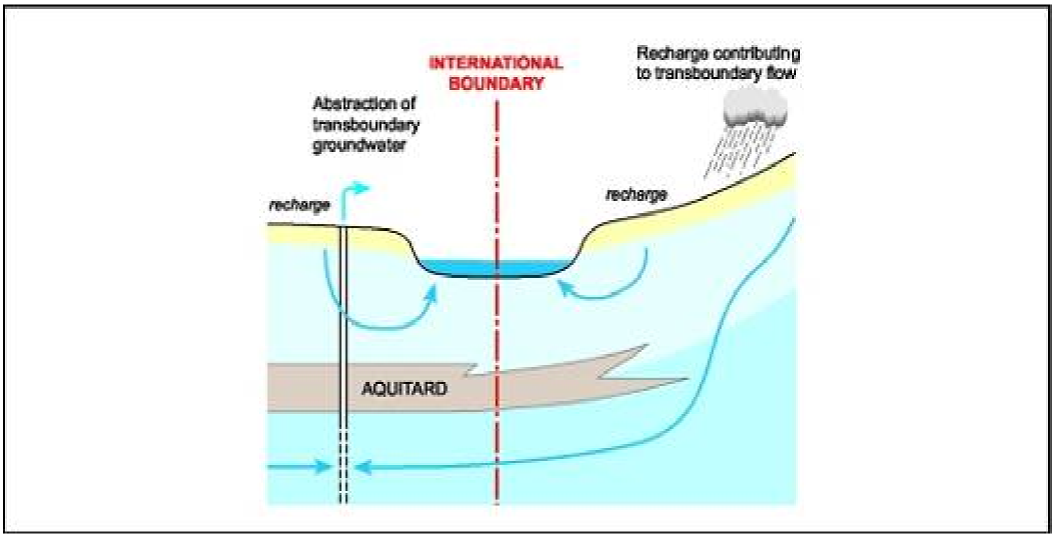


Figure 28: *Interaction between surface and groundwater flows near an interstate boundary*
(UNESCO/ISARM, 2001)

In many real situations interactions between surface and groundwaters from both sides of the international border may create international disputes. As shown in Figures 28 and 29, groundwater overpumping in one side of the boundary may lower the water level of a shared surface lake or river or accelerate the sea water intrusion in a coastal zone located in the other country.

A very characteristic case of groundwater-surface water interdependencies can be found in the South Balkans, in the region of the Dojiran lake, internationally shared between Greece and the Former Yugoslav Republic of Macedonia (FYROM). In the last decade, during a multiple years draught period, extensive pumping from the Greek side for irrigation may contribute in lowering the lake's water level substantially.

In all these situations cooperation berween countries is of primary importance in order to undersamd the problems, to agree about the underlying causes and to try to develop reliable solutions

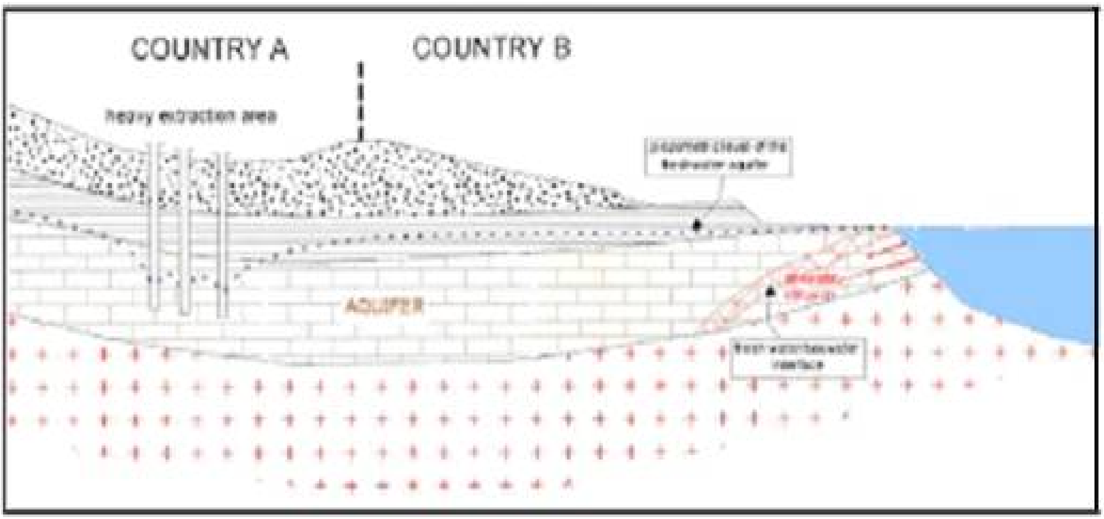


Figure 29: *Groundwater salinisation in country B due to overpumping in country A*
(UNESCO/ISARM, 2001)

Only three agreements deal with groundwater supply (the 1910 convention between Great Britain and the Sultan of Abdali, and the 1994 Jordan-Israel peace treaty and the Palestinian-Israeli accords (Oslo II)). Treaties that focus on pollution usually mention groundwater, but do not quantitatively address the issue.

The complexities of groundwater law have been described by more than a few authors (for example, Hayton 1982 and Utton 1982). Overpumping can destroy cropland through salinity problems, either by seawater intrusion or evaporation-deposition, and therefore allocating too much water (or one party's overpumping) can decimate future freshwater supplies. The Bellagio Draft Treaty, developed in 1989, attempts to provide a legal framework for groundwater negotiations. The treaty describes principles based on mutual respect, good neighborliness, and reciprocity, which requires joint management of shared aquifers (Hayton and Utton 1989). While the Draft recognizes that obtaining groundwater data can prove difficult and expensive, and its acceptance relies on cooperative and reciprocal negotiations, it does provide a useful framework for future groundwater diplomacy.

The Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Helsinki, 1992) includes important provisions on the monitoring and assessment of transboundary waters, the effectiveness of measures taken to prevent, control and reduce transboundary impact, and the exchange of information on water and effluent monitoring. Other relevant aspects deal with the harmonisation of rules for setting up and operating monitoring programmes, which includes measurement systems and devices, analytical techniques, data processing and evaluation techniques. Further needs for monitoring arise, because the Conventions aims to protect ecosystems, which may be closely connected with groundwaters and the protection of sources of drinking-water supply.

Monitoring and assessment are also part of the 1999 Protocol on Water and Health to the Convention on the Protection and Use of Transboundary Watercourses and International Lakes. This Protocol contains provisions regarding the establishment of joint or co-ordinated systems for surveillance and early-warning systems to identify outbrakes or incidents of water related diseases or significant threats of such outbrakes or incidents (including those resulting from water pollution or extreme weather). It also foresees the development of integrated information systems and databases, the exchange of information and the sharing technical and legal knowledge and experience.

IV.3 MAIN SHARED AQUIFERS IN THE MEDITERRANEAN REGION

IV.3.1 The Nubian Sandstone Aquifer System (NSAS)

The Nubian Sandstone Aquifer System (NSAS) is a huge groundwater resource shared among four countries within the Eastern Sahara in North-East Africa. These countries are Chad, Egypt, Libya and Sudan. The NSAS underlies an area in excess of 2.5 million km^2. It occupies a portion of the great arid zone belt of North Africa, extending northward into the Mediterranean Steppe and merging on the southern side into the subtropical climatic zone.

The NSAS is a non-renewable resource. Its unrestricted development and utilisation would be tantamount to depletion of the water resource in the long term. This does not imply that groundwater development cannot take place or should be limited to the present recharge. Under the scarcity conditions of water in the region, which it is an overwhelmingly important constraint to the development of the rural economies, there is considerable scope for utilising this resource provided its use is governed by principles of economic rationality and sustainable development. Within this context, the "Programme for the Development of a Regional Strategy for the Utilisation of the Nubian Sandstone Aquifer System" was initiated to build up a vision for the sustainable management of this resource for the good of the coming generations.

The area occupied by the Aquifer under study by this Programme, is 2.2 million km^2 and extends between Latitude 14º and 33º and longitude 19º and 34º to cover in Egypt 828,000 km^2, in The Western Desert, including the area known as El-Wadi El-Gedid. In Libya it covers an area of 760,000 km^2, in the eastern part of the country to include, Kufra, Tazerbo and Sarir basins all the way to the Mediterranean Sea. In Sudan, The study area covers 376,000 km^2, in Northern Darfur, and Northern Province to include the Sahara Nubian basin and part of the Nile Nubian basin. In North Chad, the Study area covers 235,000 km^2.

The regional geological framework constitutes a portion of the much wider area between Haggar massif in the west and the Red Sea massif in the east. This framework was originally established in Late Proterozoic times and was governed by the former plate tectonics affecting the area between Africa, Europe and Asia. The effect of the resulting stresses on the North African plate was the formation of basins, troughs, grabens, ridges, blocks and uplifted areas with different orientations. Volcanic eruptions followed many of the old lines and intrusion of granitic magma took place in the Lower Paleozoic. The oldest rocks exposed in the Project Area belong to the Precambrian and are referred to as the Basement rocks. These outcrop immediately to the south, east and southwest of the Project Area. Local exposures are also found at Oweinat area at the border between Egypt, Libya and Sudan. These Basement rocks are dominated by granites and granodiorites in addition to an association of metasediments, metavolcanics, etagabros and serpentines. The Basement relief, as outlined by the longterm geological and geophysical surveys is fairly well understood. Such rocks are overlain by a thick sedimentary section, refered to as the Phanerozoic.

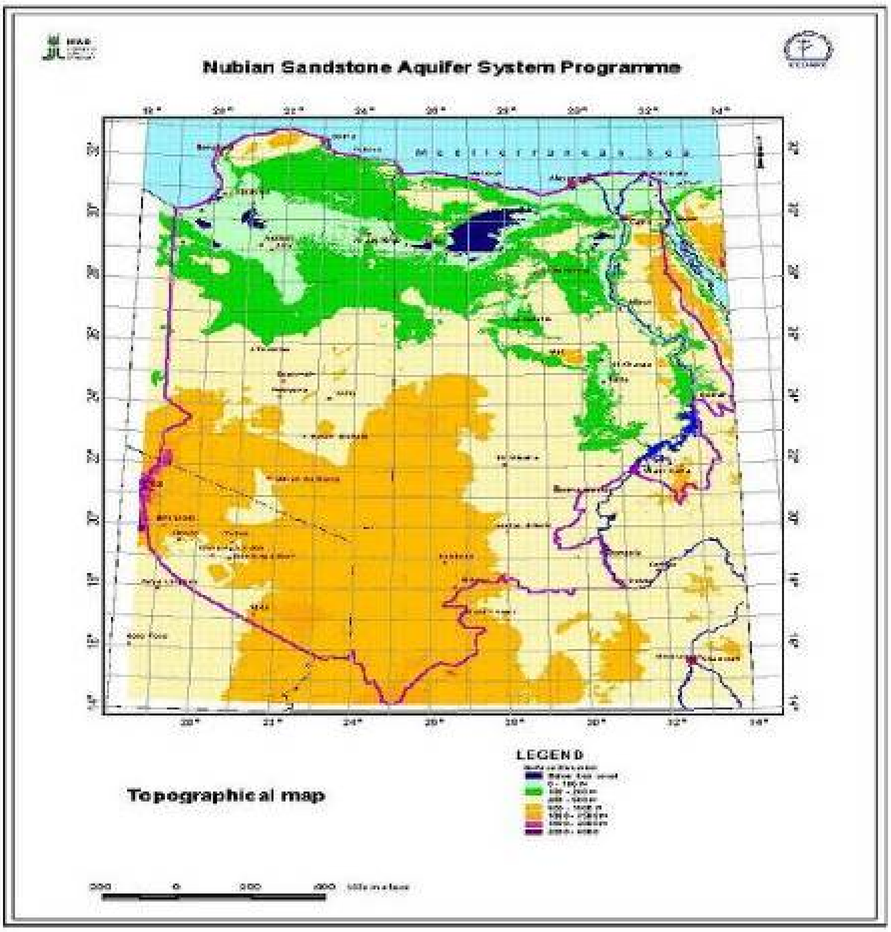


Figure 30: *The Nubian Sandstone Aquifer System – Topographic map*
(CEDARE, 2001)

Boundaries

The lateral boundaries of the aquifer as shown on the figure; determined on the eastern side by the impervious Pre-Cambrian basement complex of the mountain ranges of the Red Sea and northwards the Suez Canal. The System eastern boundary is designed as a no-flow boundary. On the southern side it is determined by the outcrops of the Basement rocks of Southern Sudan (Kordfan and Darfur blocks) and Chad (Tibesti and Ennedi), which represents also a no-flow boundary. In the southeastern side, the Nile is represented at Nasser Lake and Dongola by a fixed head boundary. On the western side there is a groundwater divide extending from Tibesti Mountains in the south and continuing northwards along the 19° Meridian. This boundary represents a no-flow boundary. The aquifer northern boundary coincides with the Mediterranean coastline, representing a fixed-head boundary.

- the base of the aquifer is taken at the surface of the Pre-Cambrian Basement complex. The Basement surface elevations fall regionally from Sea level in the southern part of the NAS to over 5000m b.s.l. along the northern boundary.
- the top of the aquifer is represented by the water table in the vast area south of Lat. 25° N., where the system is unconfined. Northwards, the aquifer is overlain by a low permeability confining bed of shales and carbonates, with its bottom forming the top of the NAS. The following figure shows the bottom of the confining bed. It also shows that the confining bed is missing north of a Lat. 30° between Marsa Matruh and Alexandria where the NAS and PNAS are in direct contact.

Aquifer Hydraulic Parameters

Data on the aquifer hydraulic parameters are only available in development project sites, leaving large areas of the aquifer with almost little or no data. Moreover, hydrogeological investigations in the study area are usually carried out very close to the surface, where most of the pump-tested wells were completed in the upper part of the aquifer (Mesozoic deposits), except for a few locations in East Oweinat in Egypt and Northern Sudan where the depth to the basement is relatively shallow and the drilled wells were fully penetrating. The system on the other hand, because of the relatively homogenous geology of the Nubian Aquifer System, where large geological units with relatively the same lithology are encountered, greater reaches can be overcome by interpolation.

The regional transmissivity varies from 100 m^2 /d in the areas adjacent to the basement exposures to over 10,000 m^2/d in the basinal area downdip where the thickness exceeds 3000m.

Aquifer Potentiometry

The data obtained from a good number of observation wells, assisted in the preparation of the initial potentiometric surface map (pre-development).

This map gives indication to:

- the groundwater divide between Kufra and Chad basins,
- the northwest flow of groundwater from Kufra to Tazerbo and Sarir (Post Nubian),
- steep northeast flow of groundwater from Kufra to Farafra,
- a northeast flow from W. Howar area to East Oweinat area and Kharga,
- a complicated flow portion in the Nile Valley area to the north of Qena Bend (faulted),
- the lack of reliable information about the flow pattern at the border area between Libya and Egypt to the south of Siwa-Jagboub area.

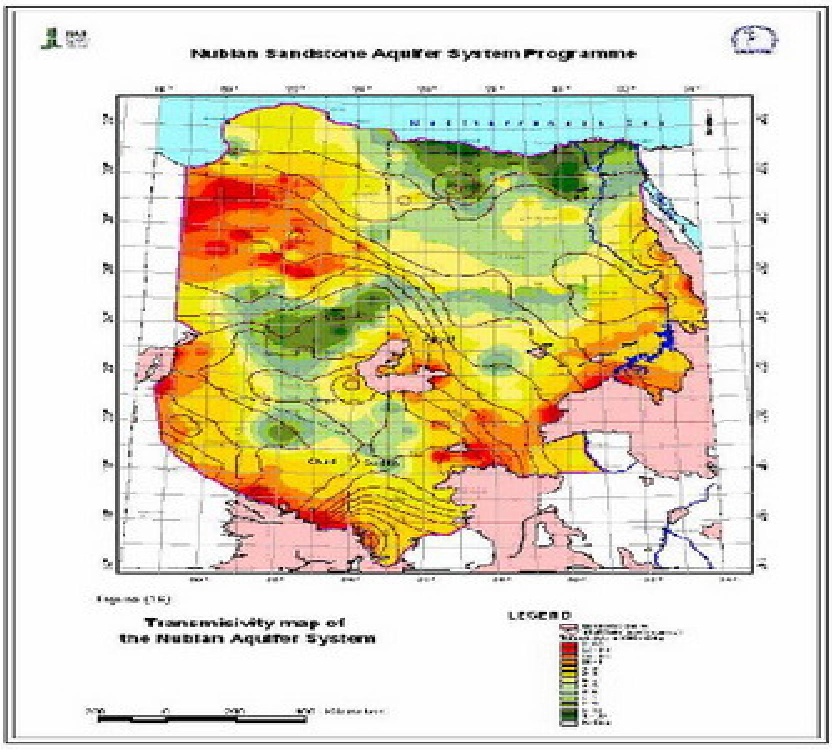


Figure 31: *The Nubian Sandstone Aquifer System – Transmisivity map*
(CEDARE, 2001)

Groundwater Extraction

Groundwater from the Nubian Aquifer System has been utilized since centuries in the Oases all over the area through springs and shallow wells. Intensive groundwater development for different purposes (Irrigation, mining, medical tourism and water supply) was initiated in 1960 in the Western Desert Oases of Kharga, Dakhla, Bahareya and Farafra while it started in 1990 in Siwa Oasis and East Oweinat areas, and lately in Darb El-Arbain area. In Libya, large-scale groundwater extraction from the Nubian Aquifer System started in 1970 in Kufra Production Project (KPP) and later in Kufra Settlement Project (KSP). No historical data regarding water extractions from the NAS was available for Sudan and Chad development areas.

The total extraction from the Nubian Aquifer System within the study area in 1998 is about 1376 mcm, of which 683 mcm in Egypt, 286 mcm in Libya and 407 mcm in Sudan. In Sudan, the figure includes extraction east of the study area i.e. east of The Nile River in Dongola area and may be even further south.

IV.3.2 The North - Western Sahara Aquifer System

The Aquifer System of North-Western Sahara (NWSAS) is shared by Algeria, Libya and Tunisia. It covers a surface of more than one million kilometers, including 700.000 km^2 in Algeria, 250.000 km^2 in Libya and 60.000 km^2 in Tunisia. It extends at a distance of 1.800 kilometers from west to east and 900 kilometers from north to south.

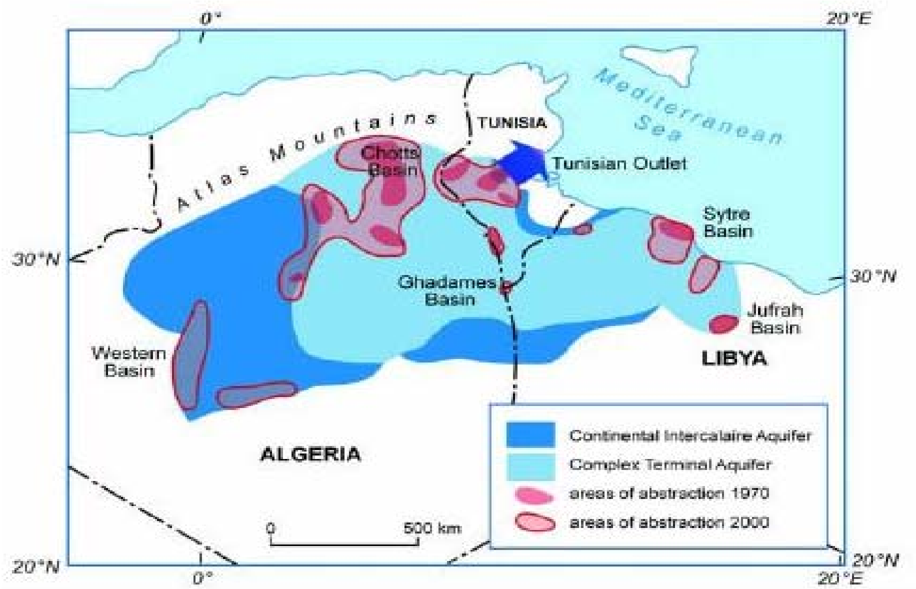


Figure 32: *The North – Western Sahara Aquifer System (NWSAS)*
(Mamou and al., 2006)

The Sahara Aquifer System consists of the superimposition of two principal deep aquifers: a) the Upper Jurassic – Lower Cretaceous sandstone, known as Continental Intercalary (CI), the deepest; and b) the Upper Cretaceous limestone, known as Complex Terminal (CT). This extremely wide aquifer system, contain considerable water reserves. The application of the isotopic and nuclear methods showed that these groundwaters correspond to those of the wet climatic periods of the Quaternary. The fossil permanent reserves are very high compared to the regulating reserves. Currently, because of the particular climatic conditions of the Sahara, their feed is very weak: 1 billion m^3 per year, on the whole, infiltrated primarily in the piedmonts of the Saharan Atlas in Algeria, as well as into the Jebel Dahar in Tunisia and and the Jebel Nafusa in Libya.

These non-renewable resources constitute layers of "mining type". The Aquifer System of North-Western Sahara (NWSAS is exploited by almost 8,800 water points, drillings, and sources: 3,500 in the Continental Intercalary and 5,300 in the Complex Terminal. These points include 6,500 in Algeria, 1,200 in Tunisia, and 1,100 in Libya (Mamou and al., 2006).

During the thirty last years, the exploitation by drillings passed from 0,6 to 2,5 billion m^2/an. This exploitation has caused many risks, namely, a continuous drawdown of piezometric level being often accompanied by an irreversible salinisation of water, a loss of the artesian flow, dryng up of outlets and conficts among countries.

The question which arises then is to know until which limit the aquiferous resources of the system can be mobilized in objectives of a durable development. For forty years, much of studies have tried to answer this question. Mathematical modelings of this aquifer system made it possible to identify the potentialities of the various areas and to define the exploitable resources in various horizons, according to several assumptions of exploitation (UNESCO 1972, UNDP 1983, OSS 2003).

IV.3.3 The Basalt Aquifer System

The basalt aquifer lies in the basalt region in the north of Jordan and the southeast of the Syrian Arab Republic in Jabal al-Arab and the surrounding areas.

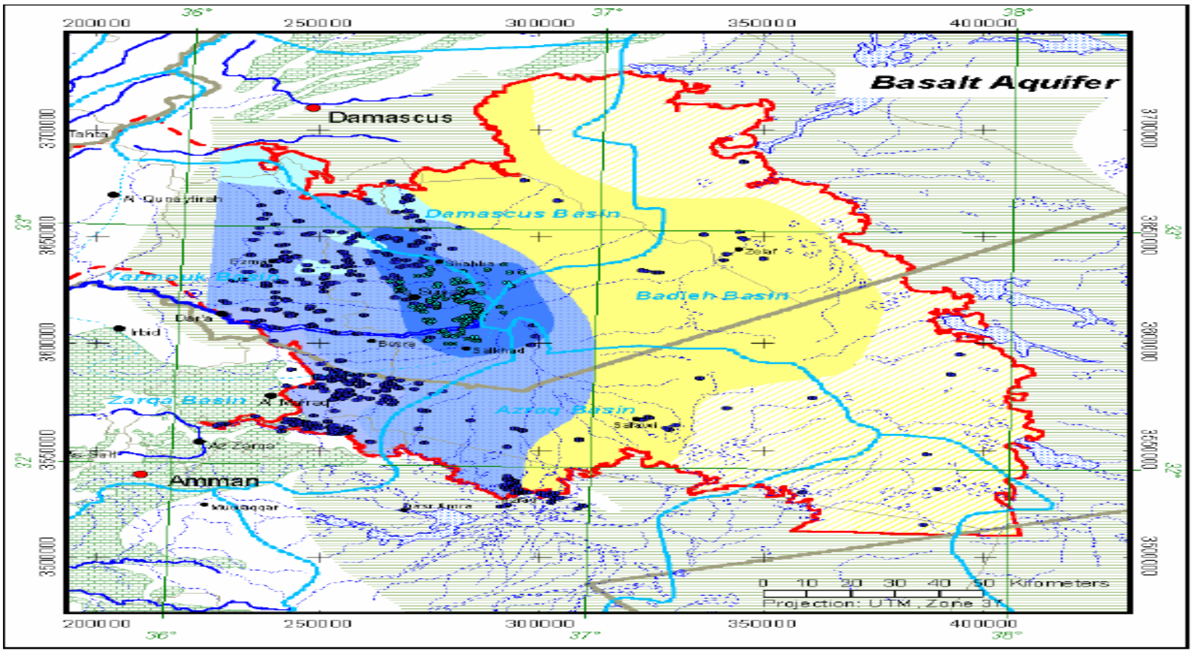


Figure 33: *The Basalt Aquifer*
(ESCWA, 1995)

Among its specific characteristics are the following:

- most of the rainfall in the basalt region takes the form of torrential downpours, estimated at 3,500 million m^3,
- the basalt aquifer is recharged from the Jabal al-Arab region and the surrounding valleys,
- the groundwater level in the aquifer varies from less than 50 m in such depressions as the Yarmouk basin and the Azraq oasis to over 400 m in the mountainous areas,

- salinity is low (between 200 and 400 mg/l total dissolved solids) in the waters of the western part of the aquifer, and high (between 1,000 and 2,200 mg/l) in a number of areas, including eastern Mafraq and the Azraq plain, as a result of the diversion of irrigation water, infiltration of agricultural drainage water and overpumping. Data recorded from a number of wells in the Douhleil area over successive periods indicate that the concentration of chloride rose from 50 mg/l in 1970 to 600 mg/l at the beginning of the 1980s, because of an increase in the concentration of nitrates.

Overpumping of the aquifer has also led to a reduction in the water level and, in some cases, failure of springs, leading to a shortfall in surface water flows and a consequent negative environmental impact, as occurred in the Azraq oasis.

IV.3.4 Shared aquifers in the Balkans

In the Balkan Peninsula, there are a number of shared aquifers. A GIS based inventory of the shared aquifers has been made by the UNESCO/ International Network of Water-Environment Centres in the Balkans and it is available in the following URL address:

http://www.inweb.gr/workshops/balkan_aquifers_map.html

Figure 34: Shared aquifers in the Balkans

IV.4 CASES OF INTERNATIONAL COOPERATION

IV.4.1 Regional Strategy for the Utilization of Nubian Sandstone Aquifer

During the past four decades, countries sharing the aquifer have made separate attempts to develop the Nubian Aquifer and the overlying arid lands. Since early seventies, they have expressed their interest in regional cooperation to share their experience and to study and develop this shared aquifer. They agreed to seek international technical assistance to establish a regional project in order to develop a regional strategy for the utilization of the aquifer. Such assistance was provided by the Centre for Environment and Development for the Arab Region and Europe (CEDARE), the International Fund for Agricultural Development (IFAD) and the Islamic Development Bank (IDB) who joined forces in 1997 to develop a shared vision for the aquifer's management through establishing a regional programme to formulate a regional strategy for the utilization of the Nubian Sandstone Aquifer.

Cooperating Coutries

The coutries that cooperated on this project were Chad, Egypt, Libya and Sudan.

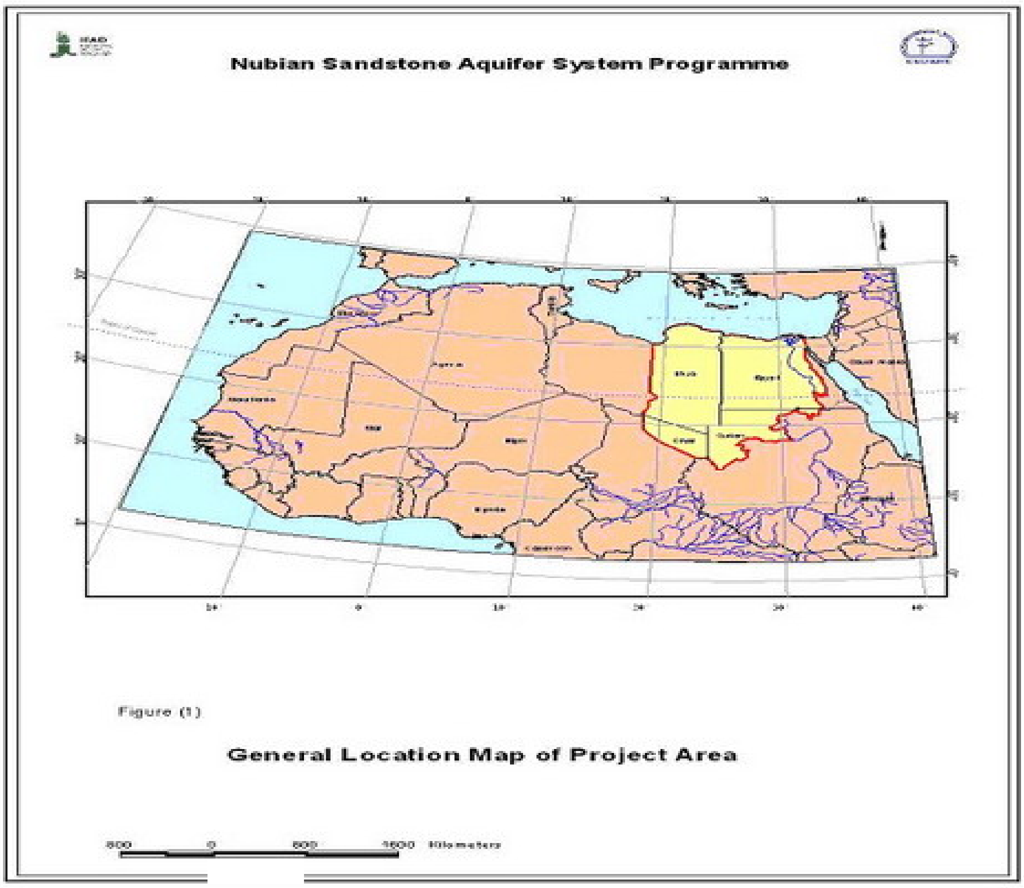


Figure 35: *The Nubian Sandstone Aquifer System – General location map*

The Programme's objective is the formulation of a regional strategy for the sustainable utilisation of the Nubian Sandstone Aquifer System.

Description of the Project

The Project Area occupies a portion of the great arid zone belt of North Africa, and extended northward into the Mediterranean Steppe and merges on the southern side into the subtropical climatic zone. The surface is essentially developed into extensive flat topped plateaux (about 500m a.s.l. and rising locally to 1000m a.s.l.). These are underlain either by light colored carbonate rocks or by dark colored sandstone rocks. The elevated plateaux alternate with low undulating plains (300m a.s.l.), which descend in places to near sea level. Locally in the south and east the surface is affected by rugged mountainous areas, which rise to more than 3000m a.s.l.. The Project Area is accessible by a good number of black roads and desert tracts, which furnish a reasonable link at the Human Settlement, scattered in that wild area. Excluding the dense populated area in the Nile Valley and the Mediterranean littoral, the number of inhabitants is much less than one million (less than one person/km^2).

The cooperation between the countries assisted in calculating the storage capacity in both confined and unconfined parts of the aquifer in the four sharing countires. Based on the calculations, the total volume of groundwater in storage in the unconfined part is about 260,000 km^3, of which 8800 km^3 is considered recoverable. The total groundwater volume stored in the confined part is about 113,500 m^3, of which 18 km^3 is considered recoverable (Abu-Zeid, 2006). Therefore, it can be concluded that the total volume of fresh groundwater stored in the NAS is about 373,000 km^3, of which 8818 km^3 is recoverable. Under the above constraints, the recovered volume from the aquifer represents 2.4% of the volume in storage.

For the Post Nubian Aquifer System, the calculated PNAS storage Capacity and Groundwater recoverable volume indicates that the total volume of Groundwater in storage is 170,000 km^3, of which 6000 km^3 is recoverable (Abu-Zeid, 2006).

The mathematical model developed by the project that was not supposed to provide a detailed prediction of the aquifer response to various water development scenarios, but it has been designed to predict the regional behaviour of the aquifer and the regional influence of water development scenarios in existing and future well fields. The results of the model – i.e. the drawdown calculated - within the well fields themselves should therefore be considered as an order of magnitude of the drawdown which will actually be observed in reality. However, the software has the capability to create a submesh in an area where more detailed information is available. This facility may be used in the future to develop sub-models in the development areas.

The cooperation between the four countries generated the following tools and documentation:

- Regional thematic maps
- Regional simulation model
- Regional information system
- Regional development scenarios
- Regional GIS
- Agreed regional monitoring network.

The Nubian Aquifer Regional Information System (NARIS)

The regional strategy for the utlization of the NSAS was presented to a regional body which is the *Joint Authority for the Study and Development of the Nubian Sandstone Aquifer System*, whose mandate is to collaborate and develop co-operative activities for the development of the Aquifer. In this respect, a Nubian Aquifer Regional Information System (NARIS) was developed to assist decision-makers and facilitate sharing of information between the riparian countries. This information system comprises information on water points characteristics, groundwater levels (historical), water quality, groundwater extractions (historical), lithology information, in addition to a bibliographic database. The system ensures harmonization, integration and standardization of information, facilitates data storage, data processing, and analysis. It also allows displaying of basic data such as water points characteristics, water levels, salinity, extractions, etc. as well as facilitating the preparation of data for models' inputs and calibrations at different scales. This Regional Information System provides a link between the concerned countries through a system ensuring the easy exchange and flow of data and information. In addition, regional thematic maps were developed for and delivered to the four countries. These maps provide a unified spatial base paving the way for easy exchange of data amongst the concerned parties. Two agreements were signed by the four countries for regular monitoring of the aquifer and the sharing and exchange of data to unveil unknowns about the aquifer beyond the borders of each country.

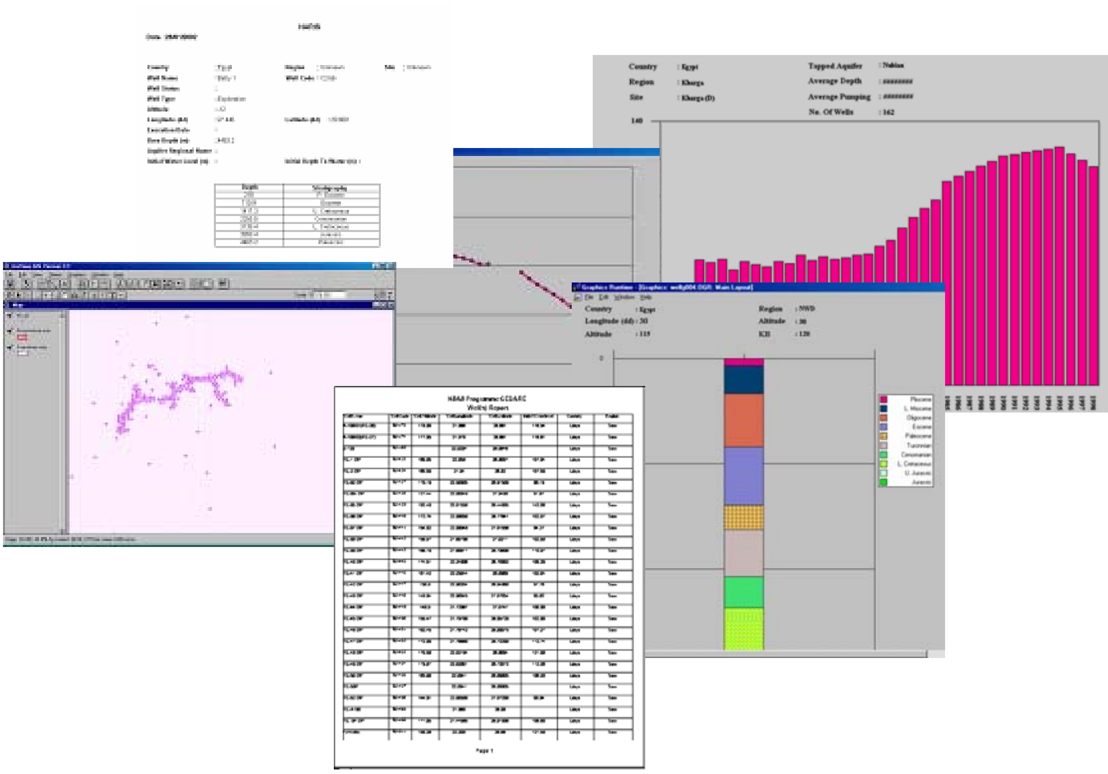


Figure 36: Output samples of the NARIS
(CEDARE 2001)

Also a bibliographic database was developed including more than 800 references about the NSAS. Also a socio-economic study was carried out and a socio-economic indicators system was developed.

IV.4.2 North-Western Sahara Aquifer System

Cooperating Countires

Algeria, Libya and Tunisia.

Description of the Project

The North-Western Sahara Aquifer System (NWSAS) project (Système Aquifère du Sahara Septentrional - SASS) started in July 1999, after an agreement with IFAD for financing the project was signed for a first three-year study that continued up until December 2002. Other donors also contributed to the finance of the project along with the three concerned countries: Algeria, Tunisia and Libya which support the operating costs of their local technical teams. The Observatory of the Sahara and the Sahel (OSS) was selected as an executing agency, and Tunis was chosen for hosting the project management team, which consists of representatives of the three countries, assisted by technical working teams in each country for data collection and transfer to the project headquarters.

NWSAS Project aims at defining the technical aspects of the basin and building of a data base and a GIS. Other objectives include the preparation of a model able to represent aquifer behaviour under the proposed development schemes and act as a management tool for the basin to meet the common interests of the countries.

During the first phase of the NWSAS project, several technical meetings were held at the level of water resources managers and technical teams. Several workshops and training courses on the different activities of the project were organized, in addition to the supply of equipment, software and vehicles that made data collection, interpretation and exchange possible.

The implementation of a shared database permits studies to be carried out simultaneously at each of the project's head offices and by each of the respective administrative authorities for water within each of the three countries. Creating this database involves multiple diverse operations at over 9,000 water points, including collecting, homogenizing the systems for classification and identification, reviewing, detecting faulty data, correcting, and validating. This management tool contains data of high quality and is now available for use. Management with full factual knowledge of the Aquifer System is facilitated by the availability of a mathematical simulation model. This model provides predictions given various management scenarios. The reference period chosen for the simulations is the historical period 1950–2000, assuming the initial situation as existed in 1950. Many alternative policies in each country have been simulated to predict their combined effects on the aquifer. A reference pattern, named scenario zero, was also defined. It consists in holding constant the withdrawals from drilled wells carried out in the year 2000, and calculating the system's corresponding evolution over 50 years (Mamou and al., 2006).

The second phase of the project was concerned with the establishment of a consultation mechanism among the basin countries. It includes a review of current water resources legislation in each country and proposing necessary amendments for better management of the shared resource. It will also improve the administrative systems and initiate a framework to realize free flow of information to meet development objectives. Cooperation between Libya, Tunisia and Algeria in the field of managing the shared aquifer system goes back to the 1970s. Periodical meetings of bilateral committees, and more recently in the framework of the Union of Arab Maghreb countries are dedicated to the exchange of information on different water issues of common interest. Nevertheless, the exploitation and the rational and durable management of the groundwater resources of the NWSAS require a permanent dialogue at the technical level as well as decisional. The goal is to insufflate a "conscience of basin" common to the three countries. To this end, the consultation mechanism is based on the following device (*Figure 37*):

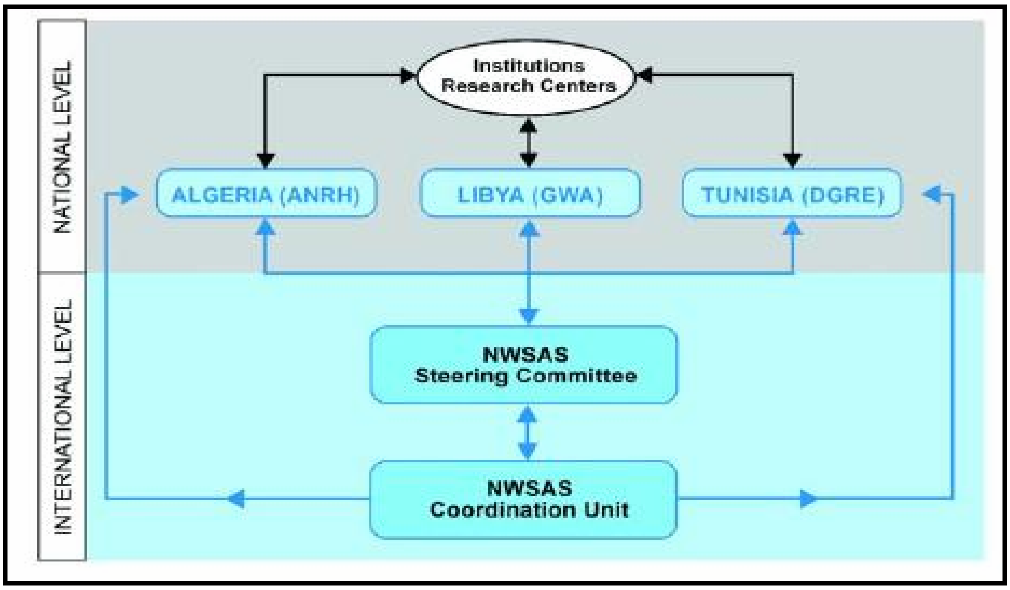


Figure 37: Institutional arrangement for the evaluation and management of the transboudary North-West Sahara Aquifer System (NWSAS/SASS)
(Mamou and al, 2006)

- **A Steering Committee** consisting of representatives of the national agencies - persons in charge for the water resources - acting as national focal points. The national partners are the Ministries of the three countries in charge of water resources management, the National Agency of the Hydraulic Resources (ANRH, Algeria), the General Directorate of the Water Resources (DGRE, Tunisia) and the General Water Authority (GWA, Libya). The Committee meets in ordinary session once per annum, and in special circumstances upon request for one of the three states. The sessions are held alternatively in each country.

- **A Coordination Unit** directed by a regional coordinator.

- **An ad hoc Scientific Committee** for scientific evaluation and orientation.

The main functions of the consulting mechanism are:

- managing and updating the tools developed by the 'NWSAS' project, including the NWSAS model,
- establishing and maintaining observation networks,
- analyzing and validating data concerning the resource,
- developing databases on the socio-economic uses of water,
- identifying and publishing indicators concerning the resource and its uses,
- promoting and performing studies and research conducted in partnership,
- developing and implementing training and improvement programmes, and
- reflecting on the mechanism's evolution.

Through improved knowledge of the hydrology of the region, together with the constitution of a shared database, the elaboration and use of a mathematical simulation model, the NWSAS project has shown that:

- the simple continuation of the present withdrawals can constitute a serious danger for the Complex Terminal's layer within the Chotts region,
- outside of the Chotts region, the Tunisian outlet and the Syrte gulf, slight increases in exploitation can still be endured without serious damage,
- simulations based upon high extraction rates (strong assumptions) lead to inacceptable situations,
- appreciable increasing of the present withdrawals is possible, however, it is at the cost of dispersing additional pumping fields to distant areas: the Western Great Erg and the confines of the Eastern Erg.

In spite of the efforts made through the project, uncertainties remain concerning knowledge of the system, as well as defining the options for development, which will require new investigations (Mamou and al, 2006).

IV.4.3 Mutual Cooperation in the management of the Basalt Aquifer System

Cooperating Countries

Jordan and Syrian Arab Republic

Description of the Project

In 1994, the Economic and Social Commission for Western Asia (ESCWA) initiated a study on the shared Basalt Aquifer System. The study was carried out in cooperation with the water authorities in the Jordanian Ministry of Water and Irrigation and the irrigation and water resources department of the Syrian Ministry of Irrigation. The study formed part of the technical cooperation project between the ESCWA member countries and the Federal Institute forGeosciences and Natural Resources, Germany (BGR).

The long-term objective of the study was to bring about effective and sustainable management of the water resources available in the basalt aquifer region through the application and implementation of laws, defining responsibilities and taking measures to reduce pollution of the aquifer, which is a principal source of water for both Jordan and the Syrian Arab Republic in many sectors, notably agriculture and drinking water.

As part of that programme, the two countries were provided with information regarding hydrology, remote sensing systems and theoretical hydrology. Digital maps of the main points were drawn up, as was a complete assessment of the water resources in the basalt aquifer.

By virtue of its use of remote sensing and geographic information systems to determine the hydrological conditions, drainage, rainwater and infiltration in the basalt aquifer region, the study was able todetermine the methods and techniques to be used in developing and managing the region's shared waterresources in the two countries. A number of recommendations were made in that regard. Among the main measures proposed were the following:

- The preparation of a programme to explore groundwater and identify promising areas
- The determination of the capacity of the Basalt Aquifer

- The rehabilitation of water quality in defined areas of the basalt aquifer, and of the watercourses that gather surface water, recharge the groundwater and harvest rainwater.

The study pointed to the need for cooperation and coordination between the two countries in the development and management of the shared Basalt Aquifer on the basis of institutional agreements. The field visits carried out by ESCWA in 2002 led to the holding of a workshop in February 2002 on international cooperation in the management of the water resources shared by Jordan and the Syrian Arab Republic.

As a result of the workshop held between the two countries, with the participation of the German side, a protocol and set of priorities for activities was established for the Joint Committee to be formed by Jordan and the Syrian Arab Republic. The Committee was intended to manage the shared basalt aquifer under the supervision of ESCWA and with support from the German cooperation project. A memorandum of understanding was drafted, which continues to be studied. It was not possible to sign and conclude it definitively because new ministerial appointments were made in both countries after the workshop was held. In October 2005 a new phase of the German cooperation project began that will lead to the revival of the cooperation project and steps to establish a joint committee to manage the basalt aquifer.

The programme involves a visit to the two countries and follow-up with the responsible officials, and the parties have been invited to a workshop with a view to forming a standing committee on the basalt aquifer and developing priorities for their requirements. The workshop will also build capacities to disseminate approaches to the exchange of information and expertise relating to the development and management of the shared Basalt Aquifer.

IV.4.4 UNESCO-ISARM

UNESCO-ISARM (Internationally Shared Aquifer Resources Management) is a multidisciplinary, international, demonstration project coordinated by UNESCO International Hydrological Programme (IHP), Paris and included in UNESCO’s 2004-2007 programme. It was launched in June 2000 at the 14th Session of the Intergovernmental Council of the UNESCO-IHP and is an intergovernmental project involving all national IHP Committees. The Council also invited the Food and Agriculture Organisation of the United Nations (FAO), the International Association of Hydrogeologists (IAH) and the United Nations Economic Commission for Europe (UNECE) to cooperate in order to create the UNESCO-FAO-IAHUNECE inter-agency ISARM initiative to promote studies concerning transboundary aquifersystems.

The UNESCO-ISARM Programme aims at improving understanding of scientific, socio-economic, legal, institutional and environmental issues related to the management of transboundary aquifers. A first phase of UNESCO-ISARM was initiated in Africa in 2002 and a second phase in the Americas in 2003. On September 24th - 25th 2003, the first UNESCO/OAS ISARM-Americas Workshop was held in Montevideo, Uruguay. A third phase was launched in the Balkans in 2003 by UNESCO-ISARM and UNESCO Chair/INWEB. INWEB organised a workshop in Thessaloniki in October 2004 to present and assess its results in close cooperation with the IAH/ Transboundary Aquifer Resource Management (TARM) Commission.

A close cooperation has also been developed with UNECE: Working Group on Monitoring & Assessment, Switzerland to follow up the European inventory made by UNECE. Close cooperation also exists with The Economic and Social Commission for West Asia (ESCWA), Lebanon, and the Observatoire du Sahara et du Sahel (OSS) Tunisia, for the Mediterranean inventory.

Among ISARM’s activities, the following map was prepared that shows the shared aquifers in North Africa.

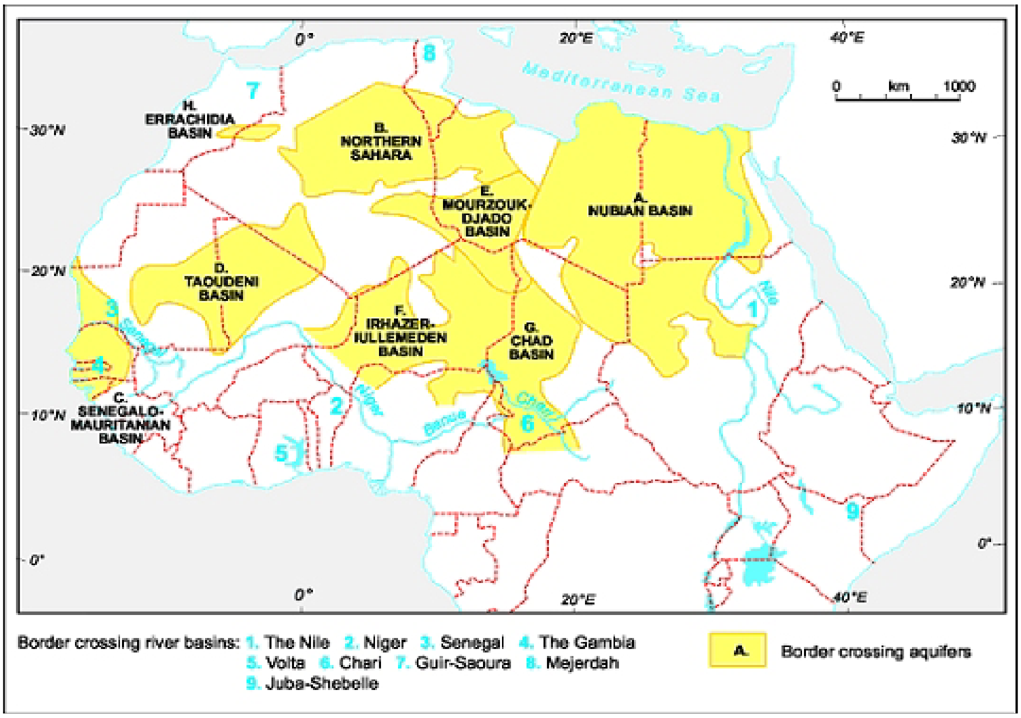


Figure 38: *Transboundary aquifers in Northern Africa*
(OSS/UNESCO, 1997; UNESCO/ISARM, 2001).

IV.5 INTERNATIONAL LAW FOR SHARED AQUIFERS

There have been several attempts to coordinate and regulate the governing regulations that control the operation of shared aquifers. In 2004, the International Law Commission at the United Nations undertook a study entitled "Shared Natural Resources". The United Nations General Assembly, in paragraph 4 of General Assembly resolution 58/77 of December 2003 entitle "Report of the International Law Commission on the work of its fifty-fifth session session", endorsed such activity by inviting Governments to provide information to the International Law Commission regarding the national legislation, bilateral and other agreements and arrangements with regard to the use and management of trnasboundary groundwaters, in particular those governing quality and quantity of such waters, relevant to the topic. A draft report has been circulated to the governments for feedback.

IV.6 CONCLUSIONS

In the case of transboundary aquifers, difficulties on integrated groundwater resources management arise in scientific and technical matters (groundwater monitoring, data interpretation, modelling, and the close groundwater-land linkages); there may also be a lack of political willingness for cooperation or the institutions involved may be weak. One of the major difficulties in designing groundwater development plans is that groundwater flow and groundwater quality are subject to several types of uncertainties and to a much greater degree than in surface hydrology. These are related to the high variability in space and time of hydrogeological, chemical and biological processes.

Enabling capacity and consultation mechanisms at decision-maker level, including harmonization of domestic groundwater law, supported by common monitoring systems and sharing information and data, is essential. The role of regional partnerships between different decision makers, scientists from different disciplines, and other water stakeholders is also important for preventing conflicts and enhancing cooperation. It is important to link and reconcile transboundary aquifer management with land management, and with regional political and social and economic regional cooperation and development policy. The principal challenge is to set up a cooperative framework so that institutions from both sides of a transboundary aqifer can effectively work together

International cooperation has been proven to be essential to facilitatethe management of shared aquifers and eventually lead to better integrated water resources management (IWRM). The cooperation also favours the exchange of information and expertise among governments. This cooperation has existed over centuries, but in past years it has been translated into practical projects, initiatives, workshops and conferences.

The creation and reinforcement of international organisations, research institutes, NGOs, information systems and networks has had a great impact on international cooperation between Mediterranean countries. Although from different backgrounds and with a diversity of objectives and goals, to some extent all organisations have played an important role in promoting exchange of information, and their initiative in many cases have proposed water management recommendations to governments and have targeted and prioritize water management actions.

Some examples of useful tools that have favour international cooperation in the field of water management include the UN through the Millennium Development Goals (MDGs), the World Summits on Sustainable Development, the World Water Forum, the 6^{th} Framework Programme of the EC, the EU Water Initiative and some important organizations are: Blue Plan, JRC, GWP-Med, IME, CEDARE, EMWIS, WWF, MENBO, IUCN, CIHEAM.

CHAPTER V: INSTITUTIONAL ASPECTS

V.1 INTRODUCTION

This chapter includes a presentation of institutional instruments available for groundwater management based on existing literature (cf. references), an analysis of the current practices in the Mediterranean, a presentation of the main requirements of the EU Water Framework Directive dealing with institutional issues and conclusions and specific recommendations on the way to adjust water management practices towards the WFD approach in the Mediterranean context.

As for surface waters, groundwater management requires combining at the same time macro-economic policy constraints and local requirements (at the level of the aquifer). From national to local authorities, key factors have to be set up to ensure sound groundwater management policies. These key elements are the following:

- Strategic planning, including the issue of institutions in charge of groundwater management;
- Regulation, in terms of groundwater rights, emission controls, definition of protected areas, together with enforcement;
- Economic aspects of groundwater management;
- Public participation.

V.2 STRATEGIC PLANNING

Groundwater is a vital resource in the Mediterranean. One of the main challenges today is to set up a global framework ensuring sustainable management of groundwater resource. That means moving from a reactive to a pro-active attitude, anticipating the demands, preparing the best ways to mobilise existing resources including groundwater and protecting them from over abstraction and pollution. Water resources at large but more specifically groundwater resources require a long-term management cycle. Prevention is a cost-effective way to manage scarce resources and to mitigate water crisis and in the Mediterranean this must be the current rule of the game.

V.2.1 Key challenges for groundwater resources management

Groundwater resources management has to deal with balancing the exploitation of a complex resource (in terms of quantity, quality and surface water interactions) with the increasing demands of water and land users (who can pose a threat to resource availability and quality). Calls for groundwater management do not usually arise until a decline in well yields and/or quality affects one of the stakeholder groups.

Key issues for groundwater supply management are the need to understand:

- aquifer systems and their specific susceptibilities to negative impacts under abstraction stress
- interactions between groundwater and surface water, such as abstraction effects (on river baseflow and some wetlands) and recharge reduction effects (due to surface-water modification).

All of these effects can be short-term and reversible or long-term and quasi-irreversible. Operational monitoring is a vital tool to develop the understanding needed for effective resource management.

On the groundwater demand management side it will be essential to bear in mind that:

- social development goals greatly influence water use, especially where agricultural irrigation and food production are concerned, thus management can only be fully effective if cross-sector coordination occurs
- regulatory interventions (such as water rights or permits) and economic tools (such as abstraction tariffs and tradable water rights) become more effective if they are not only encoded in water law but implemented with a high level of user participation
- regulatory provisions should not go beyond government capacity to enforce and user capacity to comply.

Other generic principles that emerge are that:

- both hydrogeologic and socio-economic conditions tend to be somewhat location-specific and thus no simple blueprint for integrated groundwater management can be readily provided
- the development of an effective and sustainable approach to management will always require involvement of the main stakeholders
- implementing management measures will often require capacity building, both in water-resource authorities and amongst water users.

Sound water resources management can be facilitated by a planning process. The objective is to provide a plan which is an instrument for making decisions in order to influence the future.

The planning process is a dynamic and interactive mechanism which includes several stages: (i) current and foreseen scenarios assessment, (ii) target setting and (iii) programmes of measures and actions taking. In additional, three elements have to be developed in parallel: (i) public participation, (ii) monitoring and (iii) evaluation of the process.

V.2.1 Administrative arrangements for water resources management

Institutional arrangements must provide a framework for making effective this planning process. Who is responsible for its preparation and its implementation?

To have a pro-active management of water resources including groundwater means that clear roles are defined at central level as well as local level.

This also means that a strong political will exists to outline the policy and facilitate its implementation.

At national level, central governments need to set out how basin planning can be effectively coordinated at all levels (sub basin, basin, and international basin) to ensure that the plans are coherent and consistent at each level and compatible between levels. At basin level, a competent authority has to be identified to be responsible of the development of the plan and its implementation. The detail required for management decisions means that planning needs to be carried out at a lower spatial scale, with users of the basin plan (local authorities, industries, etc.).

Since groundwaters and surface waters are linked because of the same overall hydrological cycle and conjunctive use (for irrigation and water supply mainly), they must be considered under the same planning process, except in certain cases where the groundwater flow system dominates and where it is more valid to define a groundwater resources management plan and to manage at 'aquifer level' (e.g. the Nubian Sandstone or the North and theWestern Sahara Aquifer).

There are some examples of specific management of groundwater at the aquifer level. The case of the **Astian aquifer**, in South France is one of them (source: Blue Plan)

The nappe from the Astian sands is a coastal aquifer from the Languedoc-Roussillon region. Situated between the towns of Béziers and Agde (Hérault) covering an area of 450 km², the nappe from the astian age is a water resource, which is essential for the economic development of the Hérault region. The astian nappe, which constitutes a significant resource, is the object of intensive use.

At the beginning of the eighties the risks incurred by this resource were recognised; a procedure for enforcing the decree - law 1935 - was undertaken at the State's initiative, but was unable to be implemented.

Since 1970 diverse initiatives have been undertaken, which have enabled the setting up of an assistance tool for management.

In 1990 a local management structure was created, The Combined Union for the Study and Management of the Nappe from the Astian Age. This regrouped the various parties concerned, on an environmental level:

- the 20 communities situated in the geographical region of the nappe.

- the consular chambers (Chamber of Agriculture, the Chamber of Commerce and the Chamber of Industry).

- the departmental council of the Hérault.

This Union has assured that it will :

- take responsibility for further investigations and monitor the environment and use, as well as set up awareness and information campaigns for those involved with regards the quality of the environment and its management.

- promote an institutionalised dialogue between the parties emerging, with the definition and the monitoring of the overall management policies, taking into account the needs and interests of the diverse networks of users, as well as the necessary environmental preservation.

In 1996, the union changed the statutes and its scope. Actually, when the union decided to take on the work assessment, certain communities decided to withdraw from it. Henceforth it took the title: The Combined Union for the Study and Working of the Astian.

For its vocation, it devoted itself to being a moral authority, and to guaranteeing the management goals of the aquifer: the member communities or local administrations regularly consult it over various projects (renewing camping permits, carrying out new individual drill holes).

The structure of The Combined Union for the Study and Working of the Astian (SMETA) offers the possibility of dialogue between all the water users. This dialogue prevails in the objectives of the heritage management (management for the common good) and has been outworked in a nappe contract.

This contract was unanimously approved at the union meeting of December 6th, 1996 and signed June 23rd, 1997 by; the State (Minister for the local and national Development of the Environment), the Water Agency, Rhône-Mediterranean-Corsica, the departmental council for Hérault, The Combined Union for the Study and Working of the Astian, and the member communities of the union. It covers the period 1997-2002.

During these five years its role has been to define the actions which need to be taken, identify the main parties, and guarantee the financial plans, adapted to each process.

Lessons drawn:

This contract, which sets out 5 years of actions undertaken, has taken time to get off the ground because of the fact that it is a recent structure. But this delay is also due to the difficulties encountered from an administrative, judicial and technical point of view.

The first five years of the contract have allowed the creation of a format of a perennial structure for the management of the nappe, committing to action in all the spheres of the work defined at the signing of the contract.

The development of an eventual second contract will mean that an appraisal stage can be completed and subsequent adjustment of the action plan according to the results obtained.

The results of a second nappe contract will help to establish a report of actions undergone in relation to the characteristics of the environment and fully assessing the usefulness of the structure.

V.3 GROUNDWATER LEGISLATION AND REGULATION

Different level of regulation can be considered from minimal legal control fully-integrated water resources legislation. To be effective, this legislation should set realistic requirements that take into account existing resources and institutional capacity. Modern groundwater legislation must, in general terms, be flexible, enabling and enforceable. In order to implement modern groundwater legislation, the following components have to be considered:

Groundwater Abstraction and Use Rights

Amongst other things, groundwater rights serve as the basis for abstraction charging, and in some countries may be traded.

Wastewater Discharge Licensing

The licensing of wastewater discharges (especially those to the ground), which is subject to conditions on mode of discharge and level of treatment, is designed to protect groundwater against pollution. The ‘polluter-pays-principle’ is normally embodied within this area of legislation.

Sanctions for Non-Compliance

Penalties may range from modest fines to imprisonment terms, depending upon the severity of impacts and the persistence of the offense.

Controlling Well Construction Activities

Other provisions of groundwater legislation relate to the licensing of all waterwell drilling contractors, so as to ensure better relations with (and information flow to) the water resources administration, higher standards of well construction, improved reports on the hydrogeological conditions encountered, and reduced likelihood of illegal well construction. Water legislation may also introduce controls over theimport of pumps and drilling equipment in an attempt to curb excessive groundwater abstraction.

Catchment or Aquifer Level Resource Planning

Water legislation tends to provide for water resources planning with reference to surface water basins and/or aquifer systems. Based on the inventory of water resources and of existing uses, plans provide an integrated basis for the assessment of individual applications for water rights. They normally have a legally-binding nature, and decisions on applications must be consistent with their provisions.

Conjunctive Use of Groundwater and Surface Water

Acknowledging the advantages of conjunctive water use, one permit may cover both groundwater abstraction and discharge of an effluent of acceptable quality to a surface watercourse, or surface water diversion and use coupled with recharge of an effluent of acceptable quality to the ground.

Land Surface Zoning for Groundwater Conservation and Protection

In some countries, legislation provides for the water administrators to declare 'special control areas', where exceptional measures (such as restrictions on new waterwell drilling and/or groundwater abstraction rates) become possible in the interest of avoiding further aquifer deterioration. Land surface zoning may also be targetted to serve the purpose of protecting vulnerable aquifer recharge areas and/or ground-water supply sources. In the zones so-defined restrictions can be applied in relation to potentially-polluting activities (such as certain types of urbanization, landfill solid waste disposal, hazardous chemical storage and handling facilities, mining and quarrying, etc.). For the prevention of diffuse pollution from agricultural land use, the above approach has been only locally attempted, and it is more normal to introduce bans or import control mechanisms on certain pesticides and to promote the adoption of codes of good agricultural practices.

Facilitating Water-User and Stakeholder Participation

The participation of groundwater users and other stakeholders in groundwater management is a matter of increasing concern to law-makers, who realize that implementable legal provisions are more likely to be defined when they have a say. In addition to local water-user associations, more widely-constituted 'aquifer management organizations' are needed:

- to discuss implementation of measures across user sectors and between water-user associations,
- to agree on priority actions in areas with a critical groundwater situation.
- to assist the water resource regulator generally in the administration of groundwater abstraction.

It is important to endow these organizations with formal juridical status and to integrate them into broader institutional mechanisms for groundwater resource management and protection.

The development of a stable system of water rights provides a sound foundation for the development and protection of water resources. The existence of a groundwater right cannot guarantee water supply of a given quantity and quality, and thus consideration might be given to prescribing them in terms of a 'share in aquifer production capacity (as opposed to a specified abstraction rate).

Land tenure and property rights are an important consideration when planning interventions to protect groundwater resources as they will directly influence the scope and depth of consultation and negotiation regarding land-use (Howard and al). One aspects of land tenure of particular importance is the degree to which ownership of land confers rights of ownership and use of underlying resources. For instance the Spanish Royal Decree of 1986 (N° 849) considers underground waters to be in the public domain and licenses to abstract are required.

Example of protection of water catchments designed for human consumption: the **Maghreb case** (Hassani 1999).

These last decades, the repeated droughts through the whole Maghreb countries have clearly generated the weakness of the balance between supply and demand for surface water. Surface water resources are more and more failing because of the important interannual variability of the precipitations and their strong exposure to evaporation.

In consequence of their high inertial capacity, groundwaters are less affected by the interannual fluctuations and are used to palliate the irregularity of the availability of surface water.

In many areas of the Maghreb countries, in addition to overexploitation, groundwater resources are vulnerable to diverse pollutions with as consequences, degradation of quality.

The protection against surface pollution of water catchments (well, drilling, springs…) used for human water supply consists in the setting up of protection perimeters, in which some activities can be forbidden or regulated.

The setting up of these perimeters is more and more essential in the Maghreb countries. The comparison of these countries' legislations indicates that the development of protection perimeters is included, in an exclusive or joined manner, by the water codes, the environment protection laws and, sometimes, by the public health codes.

In spite of the legislative arsenal since nearly fifteen years, the effective setting up in the field of protection perimeters is not satisfactory. It remains uncommon, limited to some areas (thermo-mineral springs, tourist areas…).

Beside deficiencies deriving from factors that go clearly beyond the water sector and the environment protection, this is mainly explained by the delay in the promulgation of the regular texts specifying these laws. The inadequacy of the juridical means, the lack of precision and the softness in the delimitation of these protection perimeters prevent each voluntary action in this domain.

Harmonisation in the several existing legislative dispositions and their good implementations will be considered only after their reinforcement by a finite, precise and renewable rule, defined according to the hydro geological contexts.

Aquifers must be legally recognised in water policies as part of water resources management and planning process.

V.4 ECONOMIC ASPECTS OF GROUNDWATER MANAGEMENT

In the case of groundwater, a number of factors complicate the application of economic approaches. The following problems need to be considered:

- Groundwater contamination is subject to considerable *time-lags*: contaminants may travel for decades before they reach the aquifer; this makes it particularly difficult to monitor the effectiveness of protection measures. In addition, these time lags are *variable*: they depend on a range of other factors, such as soil type, saturation, or precipitation. Once contaminants reach the groundwater body, they continue to spread, albeit at a slow pace.
- The impact that contaminant release has depends on the *hydrogeolocial conditions* of the site, such as the thickness and soil type of the topsoil layers; on the depth and volume of the aquifer; and on its connections to surface water bodies.

- The impact of groundwater contamination also depends on *groundwater uses*, such as the present and future groundwater abstractions for irrigation, drinking water or industrial uses, and on the vulnerability of groundwater-dependent ecosystems. However, many of the linkages between groundwater, surface water and dependent ecosystems are poorly understood.
- Groundwater damage makes itself felt for a long period, but is difficult or impossible to correct: in many cases, pollution can at best be contained within a certain area, but a cleanup of polluted groundwater is usually not possible. The *irreversibility* of groundwater protection increases the cost of misjudgements when determining protection levels.
- Finally, concerning the benefits of groundwater protection, some groundwater functions have hardly been researched. This applies in particular to the non-use or preservation value of groundwater, and to groundwater-dependent ecosystems: very little is known about these effects of groundwater contamination and their economic costs.

These caveats and limitations imply that any assessment of groundwater pollution and protection is largely determined by local characteristics, and will have to be done in a site-specific way.

V.4.1 Benefits of groundwater protection

In order to evaluate the benefits of protecting groundwater, it is necessary to consider the economic value of the services it provides. Apart from providing drinking water, clean groundwater provides manifold other services. Only few of these are traded on the market, and consequently there is no market price for most of them. Yet in order to determine the social and economic benefits of groundwater protection, a monetary value is needed to assess the different services it provides, and how they are affected by pollution. This allows to judge whether the costs of groundwater protection are warranted by the benefits.

Because of the variety of services, there is also a variety of mechanisms to assess the value of groundwater. However, one thing is common to all of them: the benefits of groundwater protection can be seen as avoided damage costs. Rather than direct economic gain, the benefits take the form of fewer damages, less risks and anxiety, or less defensive expenditures for groundwater users. Therefore, assessments of the *damage* from *increased* groundwater pollution can be seen as assessments of the *benefits* from *reduced* pollution.

The economic value of a non-marketed environmental resource can be calculated as the sum of different components: an environmental resource has a *use value* and a *non-use value*, and potentially also brings *indirect benefits*. In the case of groundwater, the use value captures the benefits that can be derived if groundwater is put to a specific use, such as irrigation or drinking water provision. However, groundwater can also be valued by someone although there is no actual intention of using it; this part of its value is consequently referred to as non-use value. It includes the value that someone places on groundwater for use by future generations (patrimonial value), as well as the value of groundwater as a resource worthy of protection in its own right (existence value). In addition, it is also necessary to consider the indirect benefits of groundwater, also referred to as *ecosystem benefits*. An important service of groundwater is to sustain surface water flows and groundwater-dependent ecosystems. These surface water bodies and ecosystems themselves have an economic value – a part of which can be attributed to groundwater, since the value of the resources would diminish if groundwater discharges declined or if their quality deteriorated. These indirect effects are not usually included in the total economic value of groundwater, not least since the interaction between different aquatic ecosystems has become better understood in recent years only.

V.4.2 Combining costs and benefits

There are different procedures to assess the economic efficiency and the social desirability of different policy alternatives. From an economic perspective, the aim is to bring together the information on the costs and benefits of different measures in a structured way. Not all of the procedures can be used to derive optimal strategies, in some cases their aim is rather to make the available information comparable and present it in a structured way.

The most extensive method for evaluating different policy options is with a ***cost-benefit-analysis*** (CBA). It estimates both the total cost of carrying out a proposed policy and the benefits that the policy brings to different stakeholders in monetary terms. If this information exists for all possible alternatives, it allows choosing the option that maximises net social benefits, and defining the socially optimal level for environmental quality standards or taxes. Unfortunately, it is difficult to arrive at reliable estimates for the benefits of groundwater protection - in opposition to the costs, where there is usually sufficient evidence. Due to these extensive information requirements and the associated costs, a full CBA should only be considered if there is substantial doubt whether the costs of a measure are in line with the expected benefits. In the context of groundwater, it appears that a CBA is therefore unsuitable for assessing policy alternatives on a national scale, but that it should rather be used to assess whether a temporary derogation from a general protection target is justifiable.

The ***cost-effectiveness analysis*** (CEA) abandons the requirement of putting a monetary value on benefits. Instead, it compares the costs of different policy options that all lead to the same, predefined target. In contrast to the CBA, the target itself is thus not determined through the analysis but has to be set ‘exogenously‘, i.e. through a political decision. Hence, if there is consensus that the benefits of a proposed measure will outweigh the costs, or if there is the quality target itself is given beforehand, a cost-effectiveness-analysis will usually be sufficient.

A ***multi-criteria analysis*** (MCA) consists of two steps: in the first step, a range of objectives in different dimensions (environmental, economic and social) are identified, and the trade-offs between these objectives are specified for different policy alternatives. In a second step, the different options are compared by attaching weights to the different objectives. These weights can be purely monetary (in which case the analysis is similar to a CBA), but they can also be based on public participation. A key feature of multi-criteria analyses is therefore that they allow for different outcomes in terms of environmental effectiveness *and* costs.

An alternative mechanism to choose optimal protection levels and the optimal allocation of funds is through **risk-based management**. The underlying idea is that the resources for groundwater protection and remediation should be allocated in such a way that overall risks for human use are minimised, rather than eliminating all pollution everywhere. Essentially, risk depends on two factors: it increases with the *severity* of the impact and with the *probability* that the impact will occur. The severity of the impact, in turn, depends on the value of the affected groundwater resource, and its vulnerability to pollution. Risk-based management, in its broadest sense, relates to policy approaches that use risk minimisation as the main criterion for the decision on a particular policy option. Consequently, risk-based management focuses groundwater protection and remediation efforts primarily on those locations where pollution would have the most severe impact, and on those areas where it is most probable that contamination will occur.

V.4.3 The role of economics in setting target values and defining policies

In principle, a full cost-benefit analysis can guide the selection of the socially optimal policy solution, where the social benefits are maximised. In practice, such a full cost-benefit analysis of groundwater protection is limited by methodological problems as well as by the limited availability of economic data.

One of the main methodological problems is that estimates of the costs and benefits of groundwater protection are always *site-specific*, reflecting the local socio-economic, hydrogeological and biophysical conditions. This means that the comparability, transferability and completeness of findings is not guaranteed. In addition, the estimates of costs and benefits are most reliable for human uses of groundwater. By contrast, the valuation of non-human uses, i.e. ecosystem benefits, so far lacks a satisfying analytical framework.

Regarding economic and social considerations in developing countries, the socio-economic status of communities is likely to influence the type of interventions that will be feasible for groundwater protection. For instance, the type of sanitation (in-situ –pit latrine and sceptic tanks- or off-sites methods), agriculture practices (irrigation, use of fertilisers and pesticides), and population growth, will impact the way to regulate groundwater protection. For example, trade-offs need to be made between protection of the groundwater resource and sanitation provision as is could be more cots-effective to treat water or use alternative source of water rather than attempt to change sanitation technology.

Concerning data limitations, the available evidence on the costs and benefits of groundwater protection is patchy and not always consistent. Bearing in mind that benefit estimation procedures are necessarily site-specific, and given the limited European evidence particularly on the benefits of groundwater protection, it is difficult to draw quantifiable general conclusions.

Moreover, due to the inherent difficulties, there is a systematic danger that the benefits of groundwater protection are underestimated. An economic assessment of the benefits of groundwater protection is necessarily more complex than assessing its costs. Because of methodological difficulties (e.g. the focus on drinking water uses and the difficulties with assessing ecosystem benefits of groundwater protection), benefits are likely to be underestimated in relation to the costs. However, the fact that the benefits of groundwater protection are more difficult to quantify empirically does not mean that they are less tangible or less material than the costs; the problem is rather that they are harder to value economically.

Notwithstanding these limitations, some general findings can be derived from the various estimates of the value of groundwater. Groundwater protection is clearly perceived as an important issue; in many cases consumers have stated their demand for better protection as well as a significant willingness to pay for it. This clearly points to a demand for more effective protection measures in the studied regions. In particular, there is a widespread perception that groundwater resources should be preserved for future uses. This can be regarded as an indication of support for the principles of non-deterioration and trend reversal, as foreseen in the Water Framework Directive and embodied in the future Groundwater Directive.

Especially in cases of point-source pollution, many pollution problems arise from disposal practices that were considered as efficient and safe at the time, but which now have clearly emerged as insufficient, leading to high costs for the clean-up of contaminated soil and groundwater. In general, the contention is therefore that groundwater protection is almost always cheaper than to incur pollution first and clean up later. Taking into account the precautionary principle, it is economically appropriate to give preference to protective measures over remediation, and to include a safety margin in setting target values.

V.5 PUBLIC PARTICIPATION

Public participation has gained wide recognition as a key water management principle. According to the Dublin Statement (second principle), “Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels” (ACC/ ISGWR, 1992). Similar statements have been made in subsequent international declarations, most recently in the Declaration of The Hague (22 March 2000). Moreover, public participation requirements have been introduced in different international conventions and national regulations, such as the EU Water Framework Directive.

When management decisions are taken unilaterally by the regulatory agency without social consensus, they often have implementation problems. Essential management activities such as monitoring, inspection and fee collection are carried out more effectively and economically. Integration and coordination of decisions relating to groundwater resources, land use and waste management is becoming easier.

Public participation can be considered as the process of ensuring that those who have an interest or stake in a decision are involved in making that decision. It can be implemented at different stages. Initially it could mean accountability, transparency and access to relevant information. It could also mean communication among the various stakeholders who carry specific interests or competences in water management sector. At a higher level, it could mean public consultation during decision making processes. More in depth, it can involve the public at a deliberative stage, by assigning them even co-decision. However, in order to be efficient and operational, public participation has to be institutionalized at legislative level and has to be modelled, with the intervention of specific expertise, and subsequently adapted to local features.

Organising effective public participation in water resources management is not easy and a number of points should get into attention. Before specific methods can be selected, the purpose and level of public participation should be determined, the different publics should be identified, and the legal and political constraints should be clarified. Moreover, a simple but effective project organisation has to be established. Furthermore, actor analysis should be conducted and a process design has to be made. Much attention should be paid to informing the public and to allowing the public to participate in policy research.

If groundwater management decisions are taken with the participation of stakeholders they should help to bring social benefits, since the equity among users tends to be promoted. Also economic benefits should be created because they tend to optimise pumping and reduce energy costs. Technical benefits are created also because the decisions usually lead to better estimates of water abstraction.

It is very important that stakeholder and community participation in groundwater management takes place at various territorial levels. In some countries, local entities have existed for a long time. They distribute groundwater from wells or springs to their members, they collect operational charges and settle water disputes. Such groups are here called water-user associations (WUAs). It is very important that WUAs have juridical personality and the authority to elect or appoint a representative for groundwater management. For higher-level user and stakeholder participation there is need of a system that is here called aquifer management organisation (AMOR). In this organisation all WUAs and other main categories should be represented. Representatives of national or local agencies should also be organised in the AMOR.

The numerous groundwater functions that can be performed by stakeholder are shown in Table 12.

Functions	WUA	AMOR	RBA
Hold groundwater rights	• 1		
Maintain groundwater supply/distribution	•		
Collect water use charges at distribution level	• 1		
Perform operational groundwater monitoring	• 2		
Make binding rules on water-use	• 1	• 1	
Undertake policing of groundwater use	• 1; 2	• 1; 2	
Participate in setting criteria/targets		• 2	•
Formulate/implement aquifer management plans		• 2	
Implement groundwater protection measures		• 1; 2	• 1; 2
Settle groundwater resource disputes		• 1; 2	• 1; 2
Review conjunctive use and water transfer schemes			• 2

Table 12: *Summary of functions commonly performed by stakeholders in participation schemes for groundwater resource administration and management*

(Garduno and al., 2003)

WUA = Water Use Association; AMOR = Aquifer Management Organisation; RBA = River Basin Authority/Committee

1: requires juridical personality to be conferred on corresponding organisation and association

2: requires formalisation of relationship with a local water resources regulatory agency

The role that government plays in participatory groundwater management is very complex. The key government function is that stakeholders have to be made aware of the importance of participation in groundwater resource management. Furthermore education programs should be developed and promoted at various levels. Government agencies can also play an important role as a mediator for conflicts amongst users.

In international river basins public participation could be organised either at the international basin level or at the national level, but internationally co-ordinated. Finally, the cultural context of public participation needs to be assessed. This is especially important in international basins and when considering the use of methods developed abroad.

V.6 CURRENT SITUATION IN THE MEDITERRANEAN

Regarding groundwater resources in particular, in the present situation, groundwater is not explicitly addressed in national water legislations. In most countries, systems of water permits were introduced in recent decades to control water use, but the over-exploitation of groundwater has defied solution. While the share of public surface waters has tended to increase, many institutional reforms (via national water laws) only affected groundwater use rights but not property arrangements. This means that, although the right to use water can only be allocated by the State via permits, property rights to groundwater remain with the owners of overlying private land.

In the southern Mediterranean countries, domestic water resources legislation is well developed in Algeria, Morocco and Tunisia. Groundwater ownership, extraction and use tend to be regulated as an integral part of water resources ownership, abstraction and use. In Turkey, groundwater is regulated in a separate, groundwater-specific law. In all these countries, groundwater ownership is vested in the State, while extraction and use are regulated through time-bound permits and concessions. However, there are exceptions to this general rule, as in the case of Morocco where a permit is required for landowners to dig a well only if this exceeds a given depth. Well-drilling is regulated through permits in Algeria, Morocco and Turkey. In addition, well-drilling in Algeria, for the exploitation of the North-Western Sahara Aquifer System, which is common to Libya and Tunisia, is regulated by separate legislation and made subject to more stringent than the average national standards. Other legislation, also in Algeria, protects groundwater from oil drilling and exploitation. The exercise of the profession of well driller is also regulated, in Algeria, Morocco and Tunisia. In Lebanon, Syria and in the territories under the Palestinian Authority, water legislation is not equally well developed.

The notion of “property” over groundwater, in combination with the lack of enforcement and control of existing regulations, encourages over-abstraction at will and even illegal use of groundwater.

Therefore, it seems that, for a long time, groundwater has been considered as a hidden, local resource, whose exploitation is in the hands of owners of overlying land. To promote sustainability in the use of groundwater resources by individuals, groundwater should also be defined as “public resource” similar to running surface waters. Property rights to groundwater should be allocated by law when this does not harm the “public use” of groundwater. To ensure coordinated groundwater policies, efforts should be made, where applicable, to concentrate overall responsibility for groundwater in a single authority.

However, Egypt and other non-EU countries are modernising the domestic groundwater management frameworks. In Egypt, groundwater has been handled by an independent groundwater sector in the Ministry of Water Resources and Irrigation and groundwater development and protection, based on improved productivity with aquifer replenishment and reuse, has become a major national policy for enhanced utilization of the national territory.

In terms of regulations at international level, international commissions have proved to be most effective institutional settings for transboundary surface water resources management. No such common institutions exist for transboundary groundwaters except for two aquifers in the Mediterranean. These two international agreements deal exclusively with groundwater resources in the African countries of the Mediterranean.

Chad, Egypt, Libya and Sudan generated the "Programme for the Development of a Regional Strategy for the Utilisation of the Nubian Sandstone Aquifer System (NSAS) – Terms of Reference for the Monitoring and Exchange of Groundwater Information of the Nubian Sandstone Aquifer System (Tripoli, 5 October 2000)" In the first agreement of this programme the production and utilisation of data is defined. The countries have to store and document the different data and have to cover all fields relevant to the Nubian Sandstone Aquifer System. In the second agreement the terms of reference for monitoring and data sharing are described.

In **Algeria, Libya and Tunisia** the "Establishment of a Consultation Mechanism for the North-western Sahara Aquifer System (SASS)" has been developed. Objective of this establishment is to coordinate, promote and facilitate the rational management of the SASS water resources. The structure of the consultation mechanism is composed of a steering committee, a coordination unit and an ad hoc scientific committee. Representatives of the national agencies on charge of water resources are building the steering committee, which meets in ordinary sessions once per year. The coordination unit is directed by a coordinator designated by the OSS (Observatory of the Sahara and the Sahel) in consultation with the steering committee. The ad hoc scientific committee is responsible for the evaluation and scientific guidance. Function of this organisation is to manage the tools developed under the SASS project (hydroegeologic data base and simulation model), to develop and follow-up a reference observation network and to process, analyse and validate data relating to the knowledge of the resource (Burchi and al. 2005).

Details on these shared aquifers are given in chapter IV.

Prices for water in the Mediterranean countries are generally low compared to the European average, especially those for agricultural use. For the EU member states, the WFD foresees cost recovery and water pricing policies that give incentives for a rational water use, to be introduced by 2010. However, the Directive leaves space for exceptions for particular situations. In May 2006, Spanish irrigators claimed to be a generic exception to the user-pays principle since a third of irrigated Spanish farmland would become uneconomic if the principle is introduced. Table 13 gives an overview over current urban waterprices in some Mediterranean countries.

Country	Water Pricing
Algeria	Industry: from € cent* 1.1/m^3 in 1985 to € cent* 4/m^3 in 1997. For irrigation there is a dual system both elements of which show increasing prices: A) from € cent* 0.13-0.18/m^3 in 1985 to € cent* 1.1-1.3/m^3 in 1995 and B) from €* 1.7-2.2/ha in 1985 to €* 2.8-4.4/ha in 1995. *converted from Algerian Dinar: 1 Euro = approx. 90 Dinars
France	€ 1.15/m^3 on the average according to the NUS Consulting Group, € 2.8/m^3 in whole France and € 2.52/m^3 for the Mediterranean region in 2001. However, the water prices differ according to the region. Agricultural water charges correspond to procurement and consumption. Irrigation is highly subsidized and is commonly priced by a two-part tariff method which consists of a combination of a volumetric (€ 0.04–0.1/m^3) and a flat rate (€ 0.07–0.12/m^3).
Greece	Water prices rose after drought in the 90s. Water fees in general depend on extraction costs. Per area charges in irrigation are common.
Italy	€ 0.78/m^3
Portugal	Since 1999, all licensed water is subject to water taxes, depending on the amount of used water and the region's relative water scarcity.
Spain	There is a huge range of urban water prices in Spain: INE reports an average of € 0.86/m^3 in 2003 (min. € 0.53 -> max. € 1.68). Prices for irrigation are also highly variable and are sometimes still fixed per area, not per volume consumed.
Turkey	All types of users have to pay for water, but the water pricing system should be revised especially for agricultural sector.

Table 13: *Water prices in some Mediterranean countries*

Regarding the participatory processes in water resources management, the actual situation in the Mediterranean region is generally not satisfactory:

- In a certain sense, public participation in the policy process has been traditionally looked at with suspicion and distrust, at least officially.
- Wide public consultation and active involvement in decision-making about water management is quite limited, as no timely and transparent.

V.7 THE WATER FRAMEWORK DIRECTIVE APPROACH

The WFD requires the achievement of good groundwater (chemical and quantitative) status by 2015 and to that end provides for the systematic monitoring of groundwater bodies as well as measures to protect and restore groundwater quality. Under this directive, the framework for groundwater imposes European Union Member States to undertake a series of steps such as delineation / characterisation of groundwater bodies and analysis of pressure and impacts (end 2004), design and establishment of a groundwater monitoring network complying with the WFD requirements (end of 2006), establishment of a river basin management plan (end of 2009) and of a programme of measures to be operational by the end of 2012. Detailed provisions for groundwater protection will be specified in a daughter directive on Groundwater.

Within this legislative framework, integration aspects play a key role for guaranteeing the success of implementation of both the WFD and the groundwater directive. In this view, 'integration' refers to consideration of (i) other environmental policies with impact on groundwater protection, (ii) interactions of groundwater with surface water and terrestrial ecosystems, (iii) scientific development and technological progress and (iv) socio-economic aspects.

In this section are presented the requirements of the WFD in line with the previous chapters (strategic planning, economic analysis, public participation) and specificities for groundwaters where appropriate.

Examples of first phases of implementation of some requirements of the WFD for groundwater can be found in a document presenting the result of the Pilot River Basin Workshop on groundwater and the WFD, Rome, May 2004 and the results of the testing of the WFD guidance documents in the Pilot River basin outcome report, EC, 2005.

Generally speaking, the planning process of the WFD includes ten main components (source: guidance document n°11):

Main Stage of the planning process	*Components according to WFD*
Current and foreseen scenarios assessment	▪ Setting the scene ▪ Assessment of the current status and analysis of preliminary gaps
Target setting	▪ Gap analysis ▪ Setting up of the environmental objectives
Alternative programmes of measures and actions taking	▪ Setting up of the programme of measures ▪ Development of river basin management plans ▪ Implementation of the programme of measures and preparation of the interim report.
Linking stages	▪ Establishment of monitoring programmes ▪ Evaluation of the first and second period ▪ Information and consultation of the public, active involvement of interested parties

1. Administrative arrangement and delimitation of river basin districts – Article 3

The directive prescribes the management activities to take place within geographic areas called River Basin Districts (RBDs).there are based largely on surface water catchments, together with the boundaries of associated groundwater and coastal water bodies.

It can happen that groundwaters do not follow a particular river basin: In this case, *groundwaters shall be identified to the assigned, to the nearest or most appropriate river basin district* (paragraph 1).

In paragraph 2 it is demanded from the Member States that they identify an appropriate competent authority that applies the rules of the Directive within each river basin district lying within their territory.

If a river basin covers more than one Member State, it shall be assigned to an international river basin district. Member States have thus to work together and have to ensure the appropriate administrative arrangements (paragraph 3).

2. Economic analysis - Article 5 and recovery of costs for water services – Article 9

The WFD integrates economics into water management and water policy decision-making. To achieve its environmental objectives and promote river basin management, the directive calls for the application of economic principles (e.g. the polluter-pays principle), economic approaches and tools (e.g. cost effectiveness analysis) and instruments (e.g. water pricing). The economic analysis of water uses aims at providing enough information for assessing the level of recovery of costs of water prices and for estimating the potential costs of measures but includes also other key functions (source: guidance document n°1):

- To carry out an economic analysis of water uses in each River Basin District;
- To assess trends in water supply, water demand and investments;
- To identify areas designated for the protection of economically significant aquatic species;
- To designate heavily modified water bodies based on the assessment of changes to such water bodies and of the impact (including economic impact) on existing uses and costs of alternatives for providing the same beneficial objective;
- To assess current levels of cost-recovery;
- To support the selection of a programme of measures for each river basin district on the basis of cost effectiveness criteria;
- To assess the potential role of pricing in these programmes of measures – implications on cost-recovery
- To estimate the need for potential (time and objective) derogation from the Directive's environmental objectives based on assessment of costs and benefits and costs of alternatives for providing the same beneficial objective;
- To assess possible derogation resulting from new activities and modifications, based on assessment of costs and benefits and costs of alternatives for providing the same beneficial objective
- To evaluate the costs of process and control measures to identify cost-effective way to control priority substances.

3. River basin management plans (RBMP)– Article 13

Member States have to produce management plans for each river basin district. This requirement is described in Article 13 and 15. The RBMP acts as the central focal point for the outcome of river basin planning. It records the current status of water bodies within the river basin district, set out, in summary, what measures are planed to meet the objectives and act as the main reporting mechanism to the European Commission and the public. The full contents of the plan are specified in Annex VII. It includes:

- General description of the characteristics of the river basin district, including a map showing the location and boundaries of surface water bodies and groundwater bodies and a map showing the different surface water bodies.
- Summary of significant pressures and impacts of human activity on the status of surface water and groundwater, including estimations of point source pollution, diffuse source pollution and pressure on the quantitative status of water including abstractions, and an analysis of other impacts of human activity on the status of water.
- Map identifying protected areas.
- Map of the monitoring network.
- Map presentation of the results of the monitoring programmes showing the ecological and chemical status of surface water, the chemical and quantitative status of groundwater and the status of protected areas.
- List of the environmental objectives established for surface waters, groundwaters and protected areas.
- Summary of the economic analysis of water use.
- Summary of the programme of measures.
- Register of any more detailed programmes and management plans.
- Summary of the public information and consultation measures taken, their results and the changes to the plan as a consequence.
- List of the competent authorities.
- Contact points and procedures for obtaining background documentation and information, including actual monitoring data.

If river basin districts are lying in different countries, Member States have to produce an international single river basin management plan. Consequently, plans can be made for individual basins where a river basin district comprises more than one river basin.

The first RBMP will be published by December 2009 and shall finalise the quality and quantity objectives to be achieved by 2015. The first RBMP will be followed by updated RBMP in the next management cycles.

But it has to be considered that the RBMP is not the outcome of the planning process. After the publication of the RBMP the programme of measures is implemented. In this phase; the role of the planning process is to guide the implementation of measures in an appropriate way so to reach the desired objectives. Furthermore the RBMP is the primary vehicle for consulting the public and stakeholders on plans for managing the water environment within the river basin district.

4. Public information and consultation – Article 14

Three forms of public participation with an increasing level of involvement are mentioned in the directive: (i) Information supply, (ii) Consultation and (iii) active involvement. The first two have to be ensured, the latter should be encouraged.

The core provision for public participation in the WFD is Article 14, “Public Information and Consultation”. In three rounds (December 2006, 2007 and 2008), the Member States have to publish the necessary documents in the river basin management planning process. In each round the public is invited to comment in writing within six months. Upon request, Member States have to provide additional background information.

The third level of participation mentioned by Article 14 is active involvement. Active involvement is a higher level of participation than consultation and "shall be encouraged" by the Member States. Active involvement implies that interested parties are invited to actively contribute to the planning process, discuss the issues and contribute to their solution. There are three levels of active involvement: 1) participation in the development and implementation of plans, 2) shared decision-making and 3) self-determination. The Member States themselves can decide on the level of active involvement.

Encouraging the first level is the minimum requirement for active involvement, while the other two levels can be considered as best practice in specific cases. In the end the appointed competent authorities are responsible for the outcome of the successful implementation and they finally decide to what extent they are going to share their power with other stakeholders. The rationale behind leaving the choice of the level of active involvement to the responsible authorities is pointed in preamble 13, which stresses that “there are diverse conditions and needs in the Community which require different specific solutions”.

Public consultation and involvement are crucial for successful planning. The potential benefits of greater stakeholder can be summarised as follows:

- RBMPs are likely to be more successful through achievement of "buy-in" to their objectives and delivery by promoting "ownership", acceptability and the cooperation of relevant stakeholders.
- Decisions making is likely to be more efficient through earlier identification and, where possible, resolution of conflicts.
- Solutions are likely to be more sustainable and equitable through the input of a wider range of knowledge and perspectives.

In the longer term, relationships between competent authorities and stakeholders are likely to be strengthened. In order to achieve best practice in the planning process, high priority must be given to establishing effective mechanisms for the public participation (consultation and active involvement) in planning and decision-making, right from the start of the international river basin management process.

V.8 CONCLUSIONS / RECOMMENDATIONS

Groundwater is a vital resource in the region and requires specific attention for its management. Its sustainable utilisation requires specific measures and specific responsibilities devoted to dedicated structures. Strategic planning, specific regulations, public participation and use of economic instruments are key elements for sustainable groundwater management.

In the Mediterranean, groundwater was utilised since the ancient times. In the ancient Greece basic concepts of hydrology were understood and included for planning and construction. But despite the fact that some countries have included some measures related to groundwater management, much remains to be done in terms of mobilisation of adequate means. Enabling capacity and consultation mechanisms at decision-maker level, including harmonization of domestic groundwater legislation, supported by common monitoring systems and sharing information and data is essential.

The WFD provides a framework for implementing fully-integrated water resources legislation. The WFD requires the achievement of good groundwater status by 2015 and the establishment of a river basin management plan by 2009 and the implementation of a programme of measures in 2012.

Apart from the timeframe of the Directive - which is not relevant for non accession countries - the planning process and the institutional mechanisms of the Directive could be of use for Mediterranean non-EU countries. But because of natural conditions and socio-economic contexts, some parts of the directive would need to be adapted to specific cases. Regarding institutional aspects, the two following elements would require specific attention when preparing convergence of partner countries' legislation towards the WFD.

- The concept of river basin district can not be applied where aquifers are not directly linked with surface water and therefore the concept of *river* basin is not relevant. This is the case for the Nubian Sandstone aquifer. There, a management structure should be set up at the level of the aquifer itself.
- The use of economic instruments, such as water pricing, can be difficult in some countries where people believe that water is a priceless (i.e. precious) public resource that should not be value-priced, but rather on operation and maintenance cost recovery charged.

Regarding the cost-recovery principle, flexibility is offered in the Directive as its states that *'Member States may in so doing have regard to the social, environmental and economic effect of the recovery as well as the geographic and climatic conditions of the region affected'* (Art. 9.1). This will have to be considered for neighbour countries where the social and economic level is lower than in the EU.

Oher aspects of the WFD analysed in this chapter - planning process leading to a basin management plan and public participation - do not seem to create specific difficulties in the region. Indeed, several countries have already prepared the ground for developing some of these aspects. But only a detailed analysis would allow identifying in details the feasibility of implementation of these requirements in neighbour countries.

CONCLUSIONS – RECOMMENDATIONS

The groundwater resources of the Mediterranean region are either the main sources of freshwater or are vitally needed to supplement surface water sources. However, they are under severe stress, in many parts of the region, because of the excessive groundwater abstraction, in the course of socio-economic development, as well as the deterioration of groundwater quality, primarily through saltwater intrusion in coastal areas. Problems such as water table drawdown, decreasing well yield, land subsidence, and salinity intrusion that have emerged as the results of overexploitation of groundwater may incur socioeconomic losses and disturb the development of the parts of the region that face the problems. These problems are either irreversible in nature or require extended periods to abate. Therefore, there is an urgent need to consider how these precious resources can be conserved, while taking full advantage of it for the development of the Mediterranean region.

A. GROUNDWATER MANAGEMENT PROBLEMS - CHALLENGES

From the point of view of the long-term perspectives of sustainable groundwater resources management, the Mediterranean region deserves special attention. This is due to a number of reasons:

a. Groundwater resources play a major role in the water economy of the countries of the Mediterranean:

- In many countries, groundwater is the main supply source for all applications.
- Groundwater abstraction provides a nearly half of the total production of drinking water and a fifth of water for irrigation.
- The demand for water is expected to increase. As a result, already existing conflicts between competing users of groundwater will inevitably worsen.
- Agriculture and -to a lesser extent- tourism are the predominant consumers of groundwater for most of the Mediterranean. Agricultural activities not only threaten the availability (quantity) but also the quality of groundwater due to the extensive use of fertilisers, pesticides and release of olive-oil-mill wastes. This will further reduce the amount of potable water. Most irrigation systems in the Mediterranean countries are performing far below their potential mainly as the result of inadequate technologies, management practices and policies.
- This has led to strong pressures on groundwater resources, both renewable and non-renewable.

b. The Mediterranean groundwater resources, abundant or rare, are unevenly distributed and unequally exploitable:

- The countries of the Mediterranean are unequally endowed with renewable groundwater. This is first of all due to the climate, but also due to the differences in geologic conditions and relief which are unequally conducive to groundwater infiltration and accumulation.
- The deep aquifers in several countries of the South (in particular Algeria, Egypt and Libya) and also in Jordan are fossil non-renewable groundwater aquifers with very limited recharge potential. Thus, by definition, groundwater management on these aquifers may become un-sustainable on the long term. It is emphasized that heavy utilization of such aquifers is highly non-recommended.

- The karstic coastal aquifers in the Mediterranean basin are of particular importance as they represent the unique resource of water supply for drinking agricultural and industrial uses. Such types of aquifers need a particular care in their management especially because of the delicate balance between fresh water and intruding salt water. Moreover, in these areas, the demand is increasing, due to increasing urbanisation of coastal areas.

c. Groundwater resources are very much in demand and at the same time fragile, exposed to the risk of pollution:

- The over-abstraction/exploitation of aquifers has in many instances led to the decline of the water table as well as to the deterioration of water quality, primarily through saltwater intrusion in coastal areas.
- Groundwater contamination, mainly through irrigation return flow, untreated wastewater, toxic industrial and medical waste, and accidental spills of hazardous material, is taking place in all Mediterranean countries, but limited data make it very difficult to estimate the total extent of pollution.
- The weak resilience of groundwater in general causes pollution to be long-lasting and makes efforts at prevention more effective and less costly than curative measures.

d. There are major difficulties in the management of groundwater:

- Some aquifers straddle national boundaries: mainly in the South and in the Near East and more locally in South-Eastern Europe. In the case of transboundary aquifers, difficulties on integrated groundwater resources management arise in scientific and technical matters (groundwater monitoring, data interpretation, modelling, and the close groundwater-land linkages); there may also be a lack of political willingness for cooperation or the institutions involved may be weak.
- The rational distribution and use of groundwater requires a resolution of conflict between the different end-users of water (e.g., the tourism industry versus agricultural activities). Such conflicting interests have contributed to unsustainable use of groundwater in the past.
- There is a lack of reliable and chronic data on groundwater conditions and trends in many parts of the Mediterranean region because there is no systematic groundwater monitoring, but only project-wise or problem-driven. Therefore, there is always a time lag between the cause of a specific problem (for example over-abstraction and pollution) and its effect (for example falling water level or quality deterioration). Furthermore, until recently many monitoring networks in the region were developed for the assessment only of the groundwater quantitative status (water level). The quantitative aspects were the only aspects that policy makers were interested in. Groundwater quality management became an issue only recently.
- Groundwater is not explicitly addressed in water legislations of many Mediterranean countries. In most countries, systems of water permits were introduced in recent decades to control water use, but the over-exploitation of groundwater has defied solution. While the share of public surface waters has tended to increase, many institutional reforms (via national water laws) only affected groundwater use rights but not property arrangements.

Most of these management problems and challenges are common to most Mediterranean countries. They therefore require exchanges of experience and particularly relevant and targeted cooperation.

B. GROUNDWATER MANAGEMENT STRATEGIES - RECOMMENDATIONS

Given the need for the protection and the sustainable utilisation of the groundwater resources, coupled with the need for satisfying the increasing water demands, the Mediterranean countries have to formulate strategic groundwater management policies and approaches, based on an integrated water resources management principle. The objective is to move away, in the medium or long term, from the non-sustainable exploitation of groundwater, by reducing water demand and therefore transforming activities and, where appropriate, mobilising other resources (including non-conventional ones).

Strategic groundwater management policies and approaches in the Mediterranean region may include the following:

1. Controlling intensive exploitation:

a. Need for adequate information

b. Stakeholders' participation

c. Water demand management, including irrigation sector

This also includes building and replacing infrastructures to mobilise and transport groundwater resources and reduce losses. More specifically:

- Loss of water to the sea either as riverine discharge or through sub-sea groundwater discharge should at least be reduced. However, in devising appropriate measures, care should be taken to avoid adverse impacts on bio-geochemical cycles and on marine ecosystems in near-coastal waters.
- Reduce losses and contamination of water in distribution networks. An improvement and/or renewal of distribution networks, even though an investment of substantial quantity should be pursued where appropriate.

d. Increase utilization of additional and non-conventional water resources

In particular, potable or irrigation water can be obtained through:

- ***Waste water recycling***: Proper treatment and reuse of wastewater for irrigation can partially offset limitations on irrigated agriculture. The amount of treated wastewater is on the increase in view of increasing population and the social and economic development of the countries of the region. As available freshwater resources grow increasingly limited, treated wastewater will play an ever more important role in the sector. Of course, the employment of wastewater on increasingly larger levels constitutes a major management challenge. The use of wastewater might become environmentally threatening if not properly treated or used.
- ***Utilization of sea or brackish water (desalinated water)***: In areas where water is insufficient to cover domestic water demand and other vital important needs, and where water transportation is not possible, the desalination of sea or brackish water would need to be considered. Brackish water can also be used after desalination or directly in irrigated agriculture where it can be mixed with freshwater to achieve specific salinity levels appropriate for certain crop types. Also, certain industries can utilise brackish water effectively. Promotion of this approach is based on the relative costs of the non-conventional methods of water supply (desalination or transport).

- ***Rainwater harvesting***: It includes different ways of collecting rainwater from rooftops, land surfaces or rock catchments for different uses. Simple collection media such as jars and pots as well as more complex means such as underground or sand dams and large size tanks and reservoirs can be used. Harvested rainwater can be used in several ways. If the water quality is controlled, it can be used as drinking water or for domestic use. Rainwater can also be used to improve (small scale) agriculture, cattle breeding and even small scale industry. It can finally be conveyed to open wells, allowing to replenish and recharge the groundwater.

2. Reducing pollution:

a. Comprehensive groundwater protection to be developed

b. Preventive measures at the pollution sources to be planned

Preventing, controlling and reducing groundwater pollution from chemical storage facilities and waste-disposal sites. When dealing with contamination, attention must be given to both the saturated and unsaturated zones. In most cases a contaminated soil unsaturated zone acts as a secondary pollution source with regard to groundwater and therefore has to be included in remediation work. For prevention and reduction strategies of groundwater chemical pollution, it must be taken into account that:

- Groundwater protection should be comprehensive and not limited to water production areas. The water quality of unpolluted aquifers should be preserved. The protection strategy should also call for the development and use of techniques to alleviate existing contamination.
- The planning of new activities which could pollute groundwater should include all necessary preventive measures at the pollution source and containment measures.
- When planning remediation, it should be remembered that no single method/technology works every time and that more than one technology may be required.
- Clean-up priority should be given to those sites that threaten legally-protected aquifers and related ecosystems. Despite technical and economic difficulties, the necessary efforts should be made in areas with limited alternative water resources to restore aquifers rather than to abandon them or curtail their use. However, if the aquifer is extensively, severely or irreversibly polluted, it may be unreasonable to aim for a complete groundwater clean-up.

Investing in wastewater treatment facilities to produce treated wastewater that is not harmful to groundwater and providing greater integration between groundwater management and the treatment and discharge of wastewater. Emphasis must be placed on the elimination of pathogens from municipal and other wastewater before it is discharged into the arid environment.

c. Clean-up priorities to be given to legally-protected aquifers

d. Cost-benefits analysis to be developed for management of contaminated sites

3. Harmonising Monitoring

a. Efforts to be intensified to gather fundamental groundwater data

Establishing and developing groundwater quantity and quality monitoring systems and data bases. Monitoring of water quality, water levels and water extraction in an aquifer is the foundation on which groundwater management is based. Integrated and reliable groundwater monitoring programs are required to assess the availability and exploitability of groundwater resources at rates that can be sustained over long periods of time. The establishment of targeted and cost-effective monitoring systems must be based on a previous characterisation of the relevant aquifer systems and the actual condition of groundwater flows.

In parallel to the data collection, the processing and analysis of reliable information and data on groundwater resources in terms of quantity and quality are vital to efforts directed towards planning to meet present and future water demands. The groundwater monitoring data can be integrated into geographic information systems in order to facilitate analysis and the use of this information in the decision-making process.

b. A regional groundwater Monitoring network to be set up

Harmonising the groundwater monitoring networks design, standards, quality control and data storage and processing in the region. To develop and evaluate strategic policies for groundwater management it is a prerequisite that the monitoring and assessment of groundwater, especially of the shared aquifers, in the countries of the region is performed in a comparable way. This means, for example, in order to assess trends in groundwater quality, the definition of trends, the sampling procedures and chemical and numerical analysis should be comparable on both sides of the border of a shared aquifer.

In this context, a Regional Groundwater Monitoring Network (RGMN) can be proposed and developed. The suggested network will facilitate the regional management of shared aquifers and eventually lead to better assessment of the groundwater potential(s). The establishment and operation of RGMN needs to be studied and planned accordingly. Such network will require national commitment from various countries to monitor and report groundwater aquifer data on periodical basis. Based on the RGMN, a Groundwater Status Report can be produced. The Groundwater Status Report will document the current conditions of the groundwater aquifers in the region. Sustainable and non-sustainable developments will become apparent and may dictate the future policies and responsibilities of the countries to implement the appropriate mitigaton measures.

4. Promoting joint management of shared aquifers

a. Cooperative framework to be set up for institutions sharing the same aquifer
b. Consultation mechanisms at decision-maker level to be enhanced
c. Enabling capacity to be streghtend
d. Common monitoring system to be created
e. domestic groundwater law to be harmonized
f. regional partnerships between decisionsmakers, scientists and stakeholders to be developed
g. transboundary aquifer management to be reconciled with land management and regional political and social and economic development policy

Promoting co-operation between countries sharing groundwater resources. Cooperation between the neighbouring countries on shared international groundwater resources is very important. The success of the cooperation will depend on political will, collaboration on sharing information, technologies, best practices and knowledge, leading to joint planning and eventual joint management of shared resources. Effective cooperation between the riparian countries can be facilitated by:

- ➢ establishing joint projects including those where there is a common data collection and analysis that can serve as basic agreed data for negotiations,
- ➢ promoting the development of shared water management agreements and treaties and supporting existing ones.

5. Developing an Integrated water resources management, including groundwater resources

Groundwater must be included in a global framework for water resources management (together with surface, coastal waters where appropriate) with a long term perspective; four essential elements are required to fulfill this objective:

a. Strategic planning to be developed

Focusing integrated management in strategic locations. Because standard management approaches tend to require substantial technical support and often involve politically or economically difficult decisions, success may depend on focusing management initiatives in areas of particular strategic importance. For example, aquifers that serve as the primary source of freshwater supply for urban areas or support critical environmental values may represent strategic locations on which to focus management efforts. In most countries, such aquifers represent a small fraction of total groundwater use. They are also likely to involve uses where it is relatively easy to generate broad consensus within society regarding the importance of management and aquifer protection. As a result, approaches that focus management on such strategic locations are more likely to be successful than efforts to manage groundwater throughout broad regions.

b. Specific regulations to be agreed at national level

Developing specific legislation and improving the enforcement of existing rules and regulations. Different level of regulation can be considered from minimal legal control fully-integrated water resources legislation. In order to implement modern groundwater legislation, the following components have to be considered:

- Groundwater abstraction and use rights have to be made clear.
- Wastewater discharge has to be licensed. It is very important that the "polluter-pays-principle" is embodied.
- Sanctions for non-compliance must be regulated. Penalties may range from modest fines to imprisonment terms.

The development of a stable system of water rights provides a sound foundation for the development and protection of water resource. Equally important are adequate and consequently executed enforcement mechanisms. This also relates to the penalties that are imposed in cases of violation and that need to be followed through consequently and coherently.

c. Public participation to be streghnted

Public participation can be considered as the process of ensuring that those who have an interest or stake in a decision are involved in making that decision. It can be implemented at different stages. Initially it could mean accountability, transparency and access to relevant information. It could also mean communication among the various stakeholders who carry specific interests or competences in water management sector. At a higher level, it could mean public consultation during decision making processes. More in depth, it can involve the public at a deliberative stage, by assigning them even co-decision. However, in order to be efficient and operational, public participation has to be institutionalized at legislative level and has to be modelled, with the intervention of specific expertise, and subsequently adapted to local features.

Implementing public education and public awareness programmes on different aspects of groundwater resources management and the value and importance of water. Public education and awareness campaigns should be continuous through the mass media, newspapers, TV, radio, leaflets, special publications, exhibitions, seminars, conferences, special discussions, forums or competitions etc. and could be done in partnership with NGOs, local authorities, etc.

Disseminating and providing access to data. Data access is probably the single most important factor determining the ability of social auditors (e.g. NGOs and other civil society actors) to press governments and society as a whole to address emerging problems and their social or environmental impacts. Therefore, there must be a continued support for the dissemination of national groundwater data, where available, to any interested party.

d. the use of economic methods and instruments for groundwater protection to be promoted

The use of economic methods for groundwater protection in the region should be strengthened, since it can provide information on cost-effective approaches to improve groundwater protection. The focus should be on protection (while the use of economic instruments can play a significant role here) than remediation, since this has proven to be cheaper in most cases. At the same time, a focus needs to be put on better understanding and eventually improving the existing economic incentives for water uses hich affect the groundwater quality and quantity (e.g. agriculture). This needs to take place within the context of sustainable development, so considering the environmental, but also economic ans social background and importance of specific water uses, in order to achieve a balanced and acceptable approach.

Economic incentives for rational groundwater use in all sectors. Incentives may be provided through:

- Introduction of conservation tariffs encouraging less groundwater use and penalising the consumers that consume more water. Groundwater abstraction by heavy groundwater users such as public water suppliers and commercial and business users should be minimized first in places facing excessive groundwater abstraction associated with negative impacts on society.
- Evaluating of the "polluter pays principle" and linking it to the principles of preventive action and rectification of damage at source, so that those who contribute to the pollution of groundwater sources become agents of its conservation and protection. However, polluters, government authorities and the public will accept to pay for the management of contaminated sites only if there is a clearly stated case-by-case assessment, taking into account the endangered receptors and uses. Consequently, instruments to assess and present results should be developed.
- Elimination/reduction of subsidies for water prices. Subsidies of various kinds have in the past contributed to either excessive water use and/or –in the case of agriculture- to cropping patterns that are economically and environmentally unsustainable
- Establishment of adequate funding mechanisms, incentives and penalties to facilitate investments in water saving.
- Supporting the development of economic activities less intensive in water use and less polluting.

Furthermore, simplifying/enhancement of the efficiency and effectiveness of groundwater administration is required. Administrative structures that are hard to comprehend and understand are prone to be ineffective. To have a pro-active management of water resources, including groundwater, means that clear roles are defined at central level as well as local level. Thus, there should be attempts to simplify and enhance the efficiency of the administrative mechanisms/structures related to water management, by:

- Improving the coordination between different organisations at policy, planning and operations level.
- Eliminating or minimising duplication/fragmentation of responsibilities.

- ➢ Promoting decentralisation, by the identification or establishment, at basin level, of a single competent authority to direct the coordination and facilitation of groundwater policymaking and implementation.
- ➢ Improving the management and operation skills of managers and technical employees in the water sector.

In addition, promoting exchange of experiences and disseminating existing good practices on groundwater management in the Mediterrenan should continue, by

- Promoting, regional projects focused on documenting existing good practice and facilitating its adoption.
- Making good use of existing regional centres and networks, experts, utilities and NGOs to facilitate exchange of information.
- Facilitating collaboration and exchange of experience among managers and Basin Authorities.

Finally, it should be emphasised that groundwater resources management should be implemented in accordance with the local hydro-geological, social, economic and cultural conditions. Successful groundwater management is a function of how optimally the different policy measures are integrated according to the local situations. It is also important that groundwater management should be regularly reviewed and updated to meet the policy needs that can change over time.

C. THE EU WATER FRAMEWORK DIRECTIVE – OPPORTUNITIES AND CHALLENGES FOR THE MEDITERRANEAN REGION

The European Water Framework Directive (WFD) constitutes the general framework for water management in Europe. This single piece of framework legislation expands the scope of water protection to all bodies of water, surface water and groundwater, with the aim of achieving ‘good status’ by 2015.

The key features of the Water Framework Directive are:

- The concept of river basin management is introduced hrough the establishment of river basin districts as the basic management units. For international rivers these river basin districts (RBDs) will transcend national boundaries (Article 3).
- For each river basin district a river basin management plan must be developed, including a programme of measures, and these will form the basis for the achievement of water quality protection and improvement (Articles 11 and 13).
- Although its prime aims are environmental, the Directive embraces, all three principles of sustainable development. Environmental, economic and social needs must all be taken into account when river basin management plans are being developed (Article 9).
- The river basin management plans will not allow further deterioration to existing water quality. With certain defined exceptions, the aim is to achieve at least good status for all water bodies in each river basin district. Geographical factors are allowed for when good status is defined and the principle of subsidiarity allows Member States some freedom within the overall requirements of the Directive (Article 4).

- To overcome the previously piecemeal nature of water environment regulation, a number of existing directives will be replaced when new local standards are developed to meet the Directive requirements. These local standards must be at least as stringent as those being replaced. Daughter directives will be introduced to deal with groundwater quality and for priority substances (formerly known as dangerous substances) (Article 16).
- Measures to conserve water quantity are introduced as an essential component of environmental protection. Unless minimal, all abstractions must be authorised and, for groundwater, a balance struck between abstraction and the recharge of aquifers (Article 11).
- The polluter pays principle is incorporated through a review of measures for charging for water use, including full environmental cost recovery (Article 9).
- Public participation and the involvement of stakeholders is a key requirement of the river basin management planning process (Article 14).

The WFD may introduce an effective avenue to address water resources management in a comprehensive and harmonized manner and provides solutions to specific problems that may arise during groundwater management, but at the same time its implementation in the Mediterranean region meets a number of **major problems and challenges**. Because of the regional natural conditions and socio-economic contexts, some parts of the Directive would need to be adapted to specific cases in non-EU countries.

Apart from the timeframes of the Directive -which are not relevant for non accession countries- specific attention is required on the way to adjust water management practices towards the WFD approach in the Mediterranean context. In this respect, the following issues have been identified:

- The concept of 'river basin district' can not be applied where aquifers are not directly linked with surface water and therefore the concept of *river* basin is not relevant. This is the case for the Nubian Sandstone aquifer. There, a management structure should be set up at the level of the aquifer itself.
- Most major groundwater aquifers in North Africa including the Nubian Sandstone aquifer and the North Sahara Aquifer are fossil non-renewable groundwater aquifers with very limited recharge potential. In these cases, a balance between abstraction and recharge is impossible to be accomplished.
- The use of economic instruments, such as water pricing, can be difficult in some countries where people believe that water is a priceless (i.e. precious) public resource that should not be value-priced, but rather on operation and maintenance cost recovery charged.
- Regarding the cost-recovery principle, the flexibility offered in the directive which states that *'Member States may in so doing have regard to the social, environmental and economic effect of the recovery as well as the geographic and climatic conditions of the region affected'* (Art. 9.1) has to be considered with attention by neighbour countries where the social and economic level is lower than in the EU.

In addition, as regards groundwater management, specificities of the Mediterranean context will have to be taken into account by Member States when implementing the Directive.

This analysis highlighted the main problems for groundwater management in the region. **Overexploitation** and **saline intrusion** are crucial problems that have to be addressed when considering the implementation of the WFD and in particular when considering the environmental objectives and the establishment of the Programme of measures. Moreover, the particular economic context of Mediterranean coastal areas has to be analysed. The impacts of tourism and irrigation on coastal aquifers need to be assessed in details.

Other aspects of the WFD do not seem to create specific difficulties in the region. Indeed, several countries have already prepared the ground for developing some of these aspects. But only a detailed analysis would allow identifying in details the feasibility of implementation of these requirements in neighbour countries.Learning how to best implement the WFD in different parts of the Mediterranean region, through a process of inter-comparisons, mutual learning and experience-sharing offers the prospects of deriving a more generic set of recommendations

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