JOINT MEDITERRANEAN EUWI/WFD PROCESS

Mediterranean Groundwater Report

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

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Produced by the

MEDITERRANEAN GROUNDWATER WORKING GROUP (MED-EUWI GW WG)

http://www.emwis.org/GroundWaterHome.htm

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 GW WG)

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 Groundwater WG)** 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 (Joint Med EUWI/WFD 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) approach 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.

CONTENTS

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 on the average more than double the average population density. This situation is reinforced by a seasonal, tourist and migratory flow of more than 100 million people.

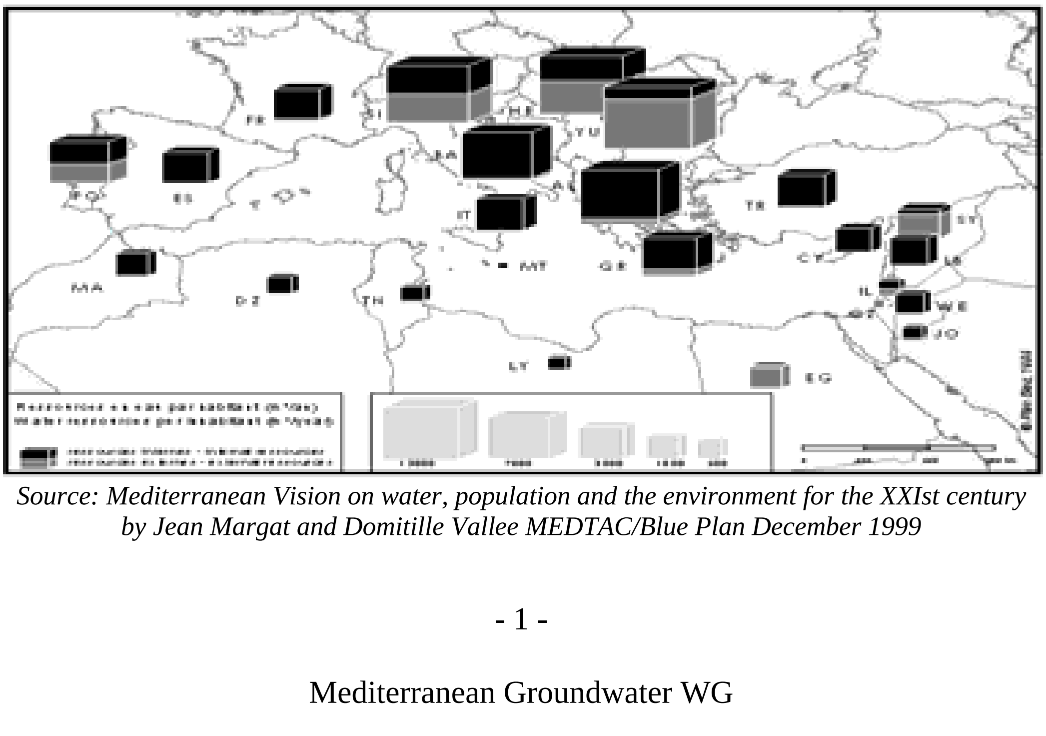
The arid and semi-arid regions of the Mediterranean combine a low rate of rainfall and a high rate of evapotranspiration and are subject to extreme recurrent droughts. The Mediterranean climate is characterized by a yearly precipitation, comprised of between more than 1000 mm for the northern countries (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.

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/yr compared to 7176 m^3/yr for the planet or 37.5% of the global average. The per capita available water *(Figure 1)* is also varying, from 4733 m^3/yr in the north Mediterranean countries to 810 m^3/yr in the south Mediterranean countries and 2585 m^3/yr in the east Mediterranean countries.

Figure 1: *Water resources per capita in Mediterranean countries*

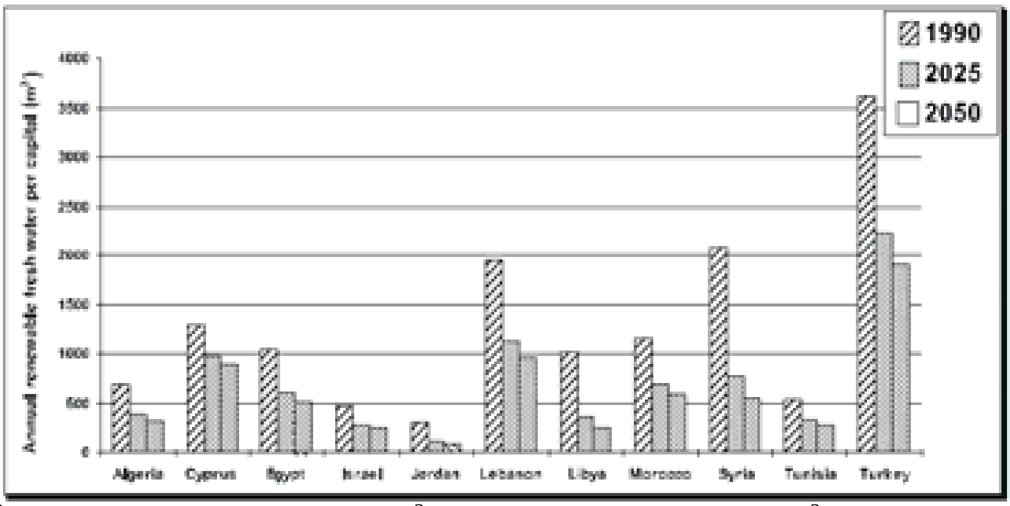


Source: Mediterranean Vision on water, population and the environment for the XXIst century by Jean Margat and Domitille Vallee MEDTAC/Blue Plan December 1999

The per capita available water ranges from overabundance in Albania and in the countries of the former Yugoslavia (over 10.000 m³/year per inhabitant) to extreme water-poverty in the Palestinian Territories-Gaza and in Malta (less than 100 m³/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 m³/year per inhabitant (annual average). Of these 160 million persons, 30 million are living below the line of absolute water-poverty of 500 m³/year per inhabitant: in the Palestinian Territories, Israel, Jordan, Libya, Malta and Tunisia.

Figure 2: *Available fresh water per capita in southern Mediterranean countries, 1990–2050*



1700 m³ = periodic water stress, 1000 m³ = chronic water stress, 500 m³ = absolute water stress

Source: UN–PD (1994)

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.

Groundwater is variously linked with surface water: they are interdependent more often than independent of each other.

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 Near 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:
  - 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.
- 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 Near 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.

  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 Near 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 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 1 000 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.

4 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 m^3 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 km^3/year) followed by drinking water supply (17.4 km^3/year) and industrial use (3.2 km^3/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.

5 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.

6 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.

Assessment and management of water bodies will be carried out on a River Basin District basis. 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 m3/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. 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.

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 Directice 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.

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

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.

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, has now been issued and is being discussed within the European Parliament and Council environment working parties. The proposal 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.

CHAPTER I: OVER-EXPLOITATION OF GW RESOURCES

I.1 CONCEPT OF OVER-EXPLOITATION AND EFFECTS

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.

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. 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 et 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 et 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.

As a matter of fact, groundwater mining is today practised in a good number of regions (Bemblidia et 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.

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 %.

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.

Some consequences of overexploitation can be summarised as follows:

- <u>Groundwater level depletion:</u> Groundwater depletion caused by deep wells can cause the drying up of shallow wells 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 in Italy, Spain and Turkey 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 et 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.

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.

Scarcity is often accompanied by poor quality, especially in the Southern Mediterranean countries, where water is often highly saline, reducing its utility. 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. Over-pumping has caused seawater intrusion into Israel's coastal aquifer, a substantial freshwater source. Some 20% of the aquifer is now 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.

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 km3/yr, which represent over 2/3 of the water resources of the region (1270 km3/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.

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.

Table 2: *Main Groundwater Bodies in Mediterranean countries (Margat et Valle, 2000 in Blue Plan)*

Country & Entities		Name	Type of reservoir	Area (km2)	Average Discharge (hm3/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
MT	Malta	Mean sea-level aquifer	Fractured carbonate aquifer	217	34

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.

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. While Albania and the former-Yugoslavian countries have over 10,000 m3/yr/inhabitant, figures for Gaza, Malta and Libya add up to less than 100.

Eight countries, with a total population of 115 million inhabitants, now lie below the desirable resource threshold of 1,000 m3/yr/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 m3/yr/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.

Groundwater resources represent more than 21% of total renewable resources in Mediterranean countries (*Table 3*), with very wide variations from one to another country (from 11% in Syria to more than 80% in Malta, Gaza Strip, Water Bank and Libya).

Table 3: *Groundwater resources in Mediterranean countries (Margat et Valle, 2000 in Blue Plan)*

Country & Entities		Date of estimation	Total renewable resources km^3/yr	Groundwater resources km^3/yr	Groundwater resources %	Natural flow groundwater resources km^3/yr
ES	Spain	1997	112.1	29.9	26.7	1.7
FR	France	1994	181	100	55.2	2
IT	Italy	1990	167.5	43	25.7	12
MT	Malta	2003	0.036	0.032	89.0	
SI	Slovenia	1990	35.5	10	28.2	
HR	Croatia	1996	71.4			
BA	Bosnia-Herzeg.		37			
YU	RF Yugoslavia		186			
MK	FYR Macedonia		12.5			
AL	Albania	1995	42.59	6.2	14.6	1
GR	Greece	1990	69	10.3	14.9	
TR	Turkey	1998	204.05	41.3	20.2	3.2
CY	Cyprus	1993	0.79	0.28	35.4	0.06
SY	Syria	1993	36.9	4.2	11.4	0.2
LB	Lebanon	1994	4.837	3.2	66.2	0.7
IL	Israel	1994	1.67	0.5	29.9	
GZ	Gaza Strip	1994	0.73	0.679	93.0	
WB	West Bank	1994	0.056	0.046	82.1	0
EG	Egypt	1993	57.7	8	13.9	0.05
LY	Libya	1995	0.8	0.65	81.3	0.1
TN	Tunisia	1995	3.84	1.51	39.3	0.7
DZ	Algeria	1989	14.33	2.3	16.1	0.7
MA	Morocco	1991	30	10	33.3	1.7
Total			1270.33	272.11	21.4	24.15

Almost 10% of groundwater resources in Mediterranean countries come from non renewable resources and 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*).

Figure 3: *Groundwater resources in Mediterranean countries (% Total renewable resources)*

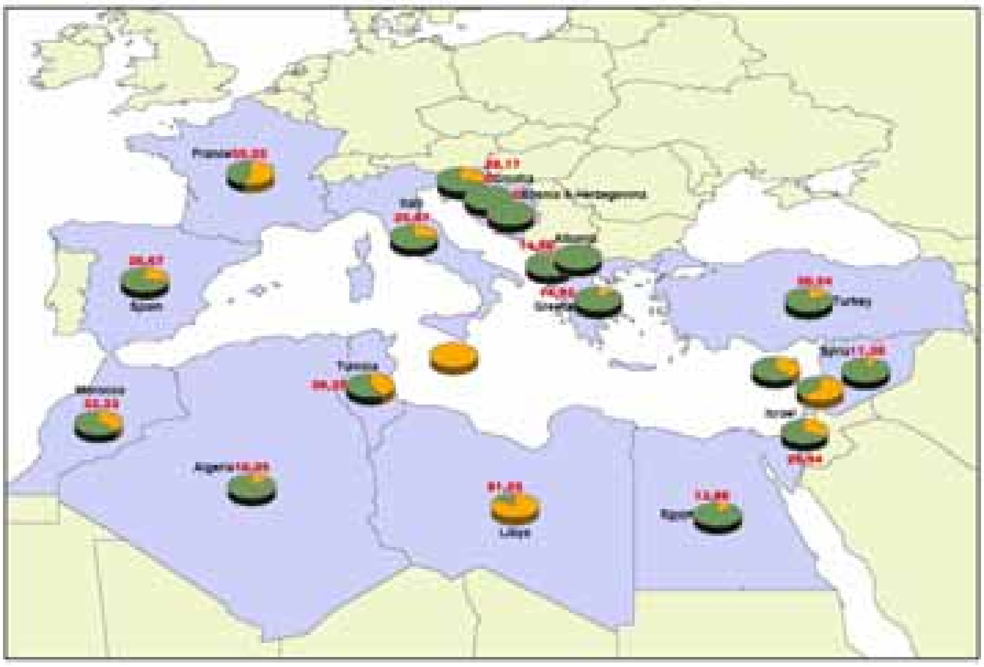


Table 4: *Groundwater abstractions in Mediterranean countries (Margat et Valle, 2000 in Blue Plan)*

Country & Entities		Total demand	Withdrawals partition to satisfy demands			
			Groundwater			
		km^3/yr	Renewable resources km^3/yr	Non renewable resources km^3/yr	Renewable resources % Total	Non renewable resources % Total
ES	Spain	35.329	4.822	0.71	13.6	2
FR	France	40.67	5.997	-	14.7	-
IT	Italy	45	13.9	-	30.9	
MT	Malta	0.059	0.032		53.0	
SI	Slovenia	0.495			0	
HR	Croatia	0.76			0	
BA	Bosnia-Herzeg.					
YU	RF Yugoslavia					
MK	FYR Macedonia					
AL	Albania	1.4	0.63	0		
GR	Greece	7.03	2	-	28.4	
TR	Turkey	35.85	6.3	-	17.6	-
CY	Cyprus	0.23	0.11	0.04	47.8	17.4
SY	Syria	14.78	2.3		15.6	0
LB	Lebanon	1.29	0.4	0	31	0.2
IL	Israel	1.76	0.68	0.32	38.6	18.2
GZ	Gaza Strip	0.2	0.18	-	90	
WB	West Bank	0.125	0.085	0.03	68	24
EG	Egypt	55.3	2.67		4.8	0
LY	Libya	3.885	0.65	2.955	16.7	76.1
TN	Tunisia	2.27	1.4	0.23	61.7	10.1
DZ	Algeria	4.7	2.85	0.41	60.6	8.7
MA	Morocco	11.8	3.79	-	32.1	-
Total		262.93	48.78	4.70		

The Blue Plan estimates that as early as 2010 – i.e. nine years from now – 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 Algeria, Tunisia, Cyprus and Syria. 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.

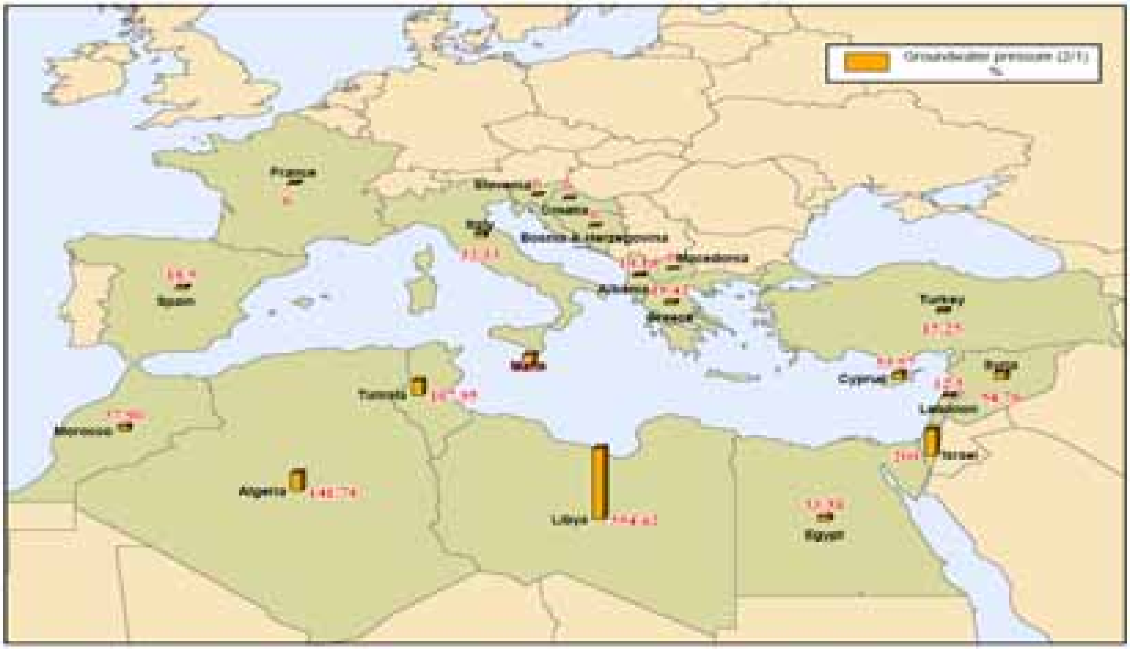
According to Margat et Valle, (1999) in Blue Plan, aquifer overexploitation is considerable in many Mediterranean countries: 13% in Cyprus, 24% in Malta (in 1990), 29% in Gaza, 32% in Israel (in 1994) and 20% in Spain. Aquifer overexploitation was registered also in Egypt, Greece, Libya, Morocco, Turkey, and Tunisia. Therefore since early 90s groundwater resources have been partially substituted with non-conventional resources (desalination of brackish and salt waters).

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

Table 5: *Groundwater pressure in Mediterranean countries (Margat et Valle, 2000 in Blue Plan)*

Country & Entities		Groundwater resources (1)	Groundwater abstractions (2)	Groundwater pressure (2/1)
		km^3/yr	km^3/yr	%
ES	Spain	29.9	5.5	19
FR	France	100	6.0	6
IT	Italy	43	13.9	32
MT	Malta	0.058	0.032	55
SI	Slovenia	10		
HR	Croatia			
BA	Bosnia-Herzeg.			
YU	RF Yugoslavia			
MK	FYR Macedonia			
AL	Albania	6.2	0.63	10
GR	Greece	10.3	2.0	19
TR	Turkey	41.3	6.3	15
CY	Cyprus	0.28	0.2	54
SY	Syria	4.2	2.3	55
LB	Lebanon	3.2	0.4	13
IL	Israel	0.5	1.0	**200**
GZ	Gaza Strip	0.679	0.2	27
WB	West Bank	0.046	0.1	**250**
EG	Egypt	8	2.7	33
LY	Libya	0.65	3.6	**555**
TN	Tunisia	1.51	1.6	**108**
DZ	Algeria	2.3	3.3	**142**
MA	Morocco	10	3.8	38
Total		272.11	53.5	

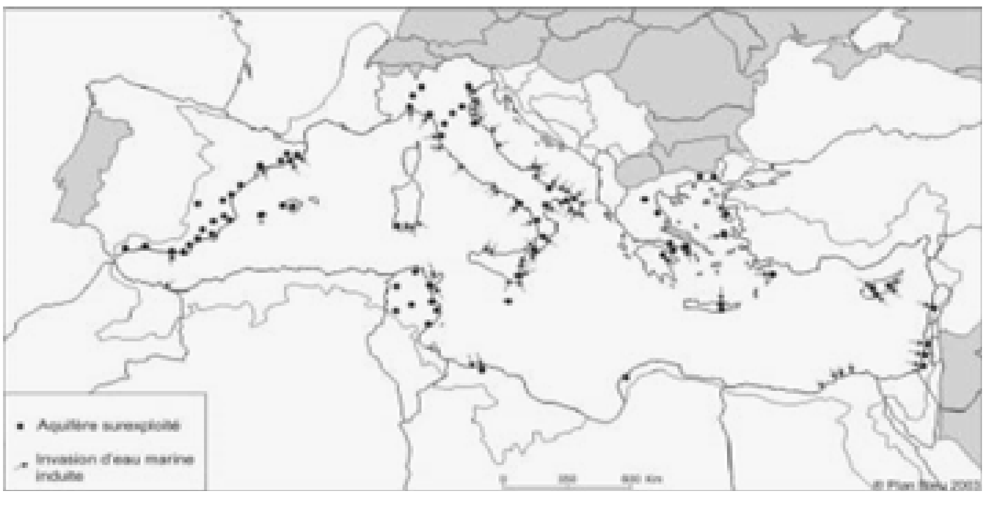
Figure 4: *Groundwater pressure in Mediterranean countries*



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 and Turkey.

Figure 5: *Areas where overexploitation of groundwater was registered in the Mediterranean region according to Blue Plan (Margat et Valle, 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 41 billion m^3/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 16% of total water demands (*Table 6*) and 34% of total groundwater withdrawals (*Table 7*).

Irrigation accounts for a major part, if not an overwhelming share, of water use – over 80% in almost all Southern countries, and up to 87% in Libya. In developed countries its contribution 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.

Table 6: *Sectorial Water Demand in Mediterranean countries (Margat et Valle, 2000 in Blue Plan)*

Country & Entities		Population (million of inhab)	Total Water Demand (km^3/yr)	Sectoral Water Demand		
				Public Supply %	Agriculture %	Self-supplied industries %
ES	Spain	39.11	35.52	13.1	67.8	4.6
FR	France	56.45	40.67	14.6	12.2	9.7
IT	Italy	57.54	40.61	17.7	45.4	16.8
MT	Malta	0.398	0.059	32.9	34.5	4.6
SI	Slovenia	2	1.27	19.4	0.3	5.5 h
HR	Croatia	4.8	0.639	46.3	ε	8.8
BA	Bosnia-Herzeg.					
YU	RF Yugoslavia					
MK	FYR Macedonia					
AL	Albania	3.39	1.4	28.6	71.4	
GR	Greece	10.05	7.03	16.3	80.5	2
TR	Turkey	53.7	35.5	15.5	73.2	11.3
CY	Cyprus	0.726	0.235	23.4	76.6	0.2
SY	Syria	12.53	14.41	3.7	0.3	1.9
LB	Lebanon	3.2	1.25	29.5	70.1	0.4
IL	Israel	5.8	2.05	29.3	63.9	6.8
GZ	Gaza Strip	1.475	0.17	38.2	59	2.9
WB	West Bank	0.932	0.131	36.6	61.8	1.5
EG	Egypt	54.8	56.1	5.6	86	8.3
LY	Libya	5.22	3.89	9.3	86.9	3.9
TN	Tunisia	8.785	2.829	12.9	85.9	1.9
DZ	Algeria	25.06	4.5	24.9	60	10.7
MA	Morocco	25.09	11.8	14.2	85.8	3.3
Total/Mean		371.056	260.063	16	75	11

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. Globally, agriculture represents the main sectorial demand with 75% of total demand (*Table 6*). Speaking in terms of groundwater contribution, agriculture withdrawals supply 29% of total demand and represent 58% of total groundwater withdrawals in the Mediterranean countries (*Table 7*).

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.

Figure 6: *Sectorial Water Demand distribution in Mediterranean countries (%)*

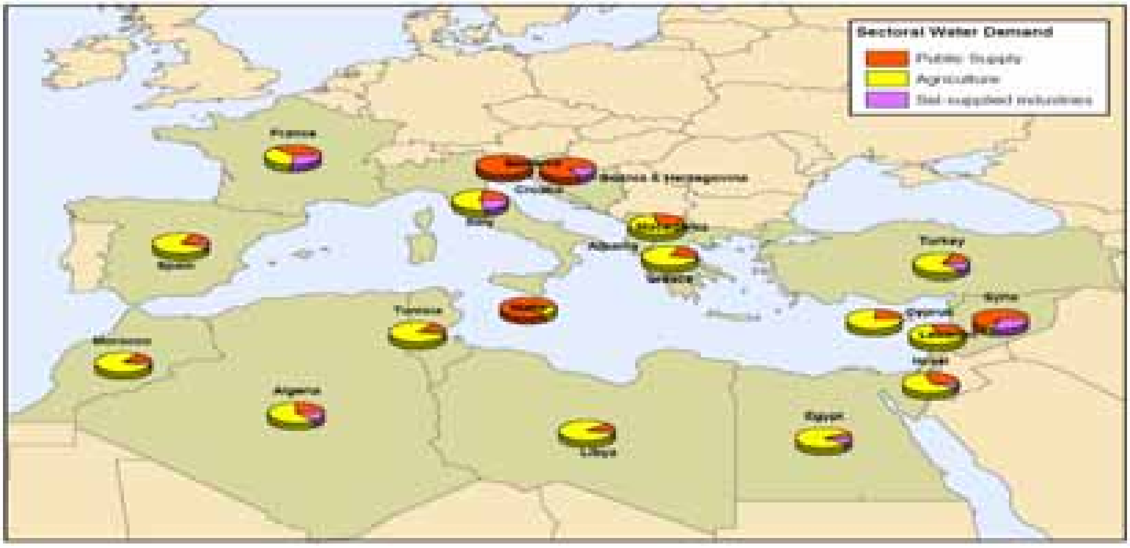


Table 7: *Sectorial Water Demand supplied with groundwater in Mediterranean countries (Margat et Valle, 2000 in Blue Plan)*

Country & Entities		Population	Total Water Demand	Groundwater Sectorial Water Demand Supply			Groundwater Sectorial Water Demand Supply			
		(million of inhab)	(km^3/yr)	Public Supply	Agriculture	Self-supplied industries	Public Supply	Agriculture	Self-supplied industries	Total
				(km^3/yr)	(km^3/yr)	(km^3/yr)	%	%	%	%
ES	Spain	39,11	35,52	0,961	4,364	0,103	3	12	0	15
FR	France	56,45	40,67	3,381	1,007	1,594	8	2	4	15
IT	Italy	57,54	40,61	5,4	8	0,5	13	20	1	34
MT	Malta	0,398	0,059	0.0082	0.0157	0.0015	14	27	3	44
SI	Slovenia	2	1,27							
HR	Croatia	4,8	0,639							
BA	Bosnia-Herzeg.									
YU	Yugosl.									
MK	Maced.									
AL	Albania	3,39	1,4	0,3	0,33	0	21	24	0	45
GR	Greece	10,05	7,03	0,74	1,16	0,1	11	17	1	28
TR	Turkey	53,7	35,5	1,95	3,8	0,55	5	11	2	18
CY	Cyprus	0,726	0,235	0,039	0,269	0,0005	17	114	0	131
SY	Syria	12,53	14,41	0,3	1,9	0,1	2	13	1	16
LB	Lebanon	3,2	1,25	0,052	0,31	0,036	4	25	3	32
IL	Israel	5,8	2,05	0,18	0,8	0,02	9	39	1	49
GZ	Gaza Strip	1,475	0,17	0,042	0,071	0,002	25	42	1	68
WB	West Bank	0,932	0,131	0,065	0,11	0,005	50	84	4	137
EG	Egypt	54,8	56,1	1,56	1,11		3	2	0	5
LY	Libya	5,22	3,89				0	0	0	0
TN	Tunisia	8,785	2,829	0,163	1,4	0,063	6	49	2	57
DZ	Algeria	25,06	4,5	1,3	1,4	0,15	29	31	3	63
MA	Morocco	25,09	11,8	0,61	3,18		5	27	0	32
Total/Mean		371,056	260,06	17	29,2164	3,22361	13	29	1	44

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.

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 represents only a small part (11%, *Table 6*) 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.

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 et 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 km3 and the maximum pumping projected is lower than 1 km3/year. Blue Plan points out the importance of non-renewable water reserves in south Mediterranean countries (*Table 8*).

Table 8: *Non-renewable Water Resources in south Mediterranean countries (Margat et Valle, 2000 in Blue Plan)*

Country & Entities		Volume of theoretical reserves or estimated volume exploitable	Potentially exploitable in the long term (capacity of annual average production)	
		(km3)	Horizon of reference	km^3/yr
EG	Egypt	6000	-	-
LY	Libya	4000	2050	2.8-4.5
TN	Tunisia	1700	-	1
DZ	Algeria	1500	-	5
MA	Morocco	3	-	-

Compared with demands, reserves represent the theoretical possibility to supply demands during 107 years in Egypt, 1028 years in Libya, 600 years in Tunisia and 333 years in Algeria. Morocco shows very scarce reserves. 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.

I.5 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.

CHAPTER II: DETERIORATION IN GW QUALITY

II.1 CHEMICAL GROUNDWATER POLLUTION

Historically, groundwater has been naturally very clean because of the filtering effect. However, increased use of chemicals in everyday life means that groundwater is now vulnerable to the same pressures as water at the surface. Since water continuously flows from one to the other *(Figure 7)*, groundwater can become polluted with nutrients or chemicals when surface water carrying these substances drains into the groundwater environment.

Figure 7*: Point and diffuse sources of GW pollution*

Pollution may occur naturally or result from human activity. In general, chemical pollution sources may be classified into the following types:

- <u>*Point sources*</u>

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.

Although Plan Bleu (2004) highlights that it is difficult to give any overview of water pollution due to the high variety of causes and processes (point or diffuse pollution, accidents or chronic pollution) as well as of the variety of temporal and spatial effects of pollution processes, it is clear that the pollution of groundwater makes it necessary to increase the treatment processes to produce drinkable water and, in some cases, makes it impossible to use water for human supply (e.g. for its high salinity).

II.1.1 Current Situation in the Mediterranean region

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.

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

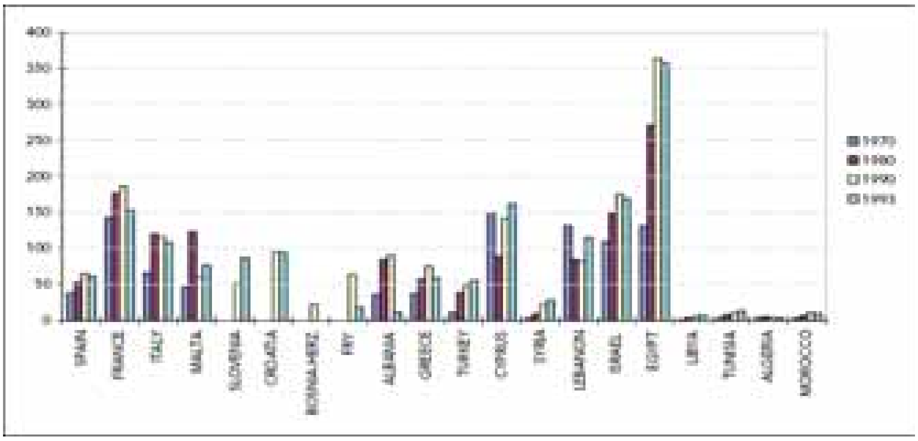
II.1.2 Groundwater uses which affect the problem

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, pesticides and release of olive-oil-mill wastes.

Figure 8: *Fertiliser consumption in the Mediterranean countries from 1970 to 1993 (kg/ha)*



Source : 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

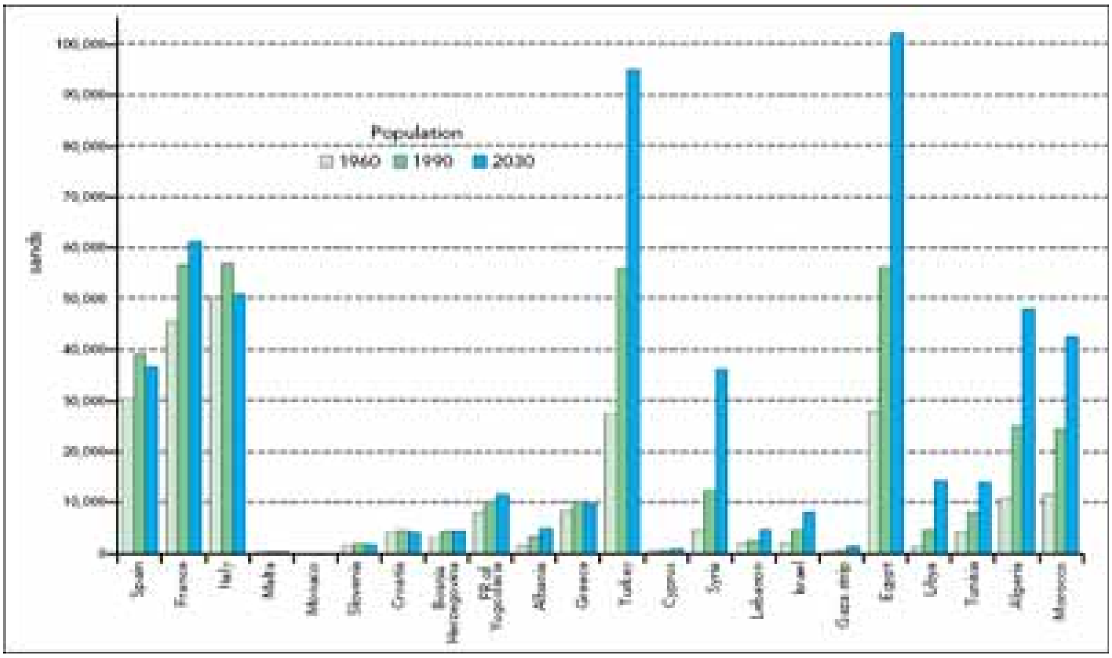
There is a large range of different industrial activities (from mining to manufactured products) scattered all around the Mediterranean basin, and a number of hot-spots are concentrated mainly in the north, generated by heavy industry complexes. Discharges of contaminants from these industries pose a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

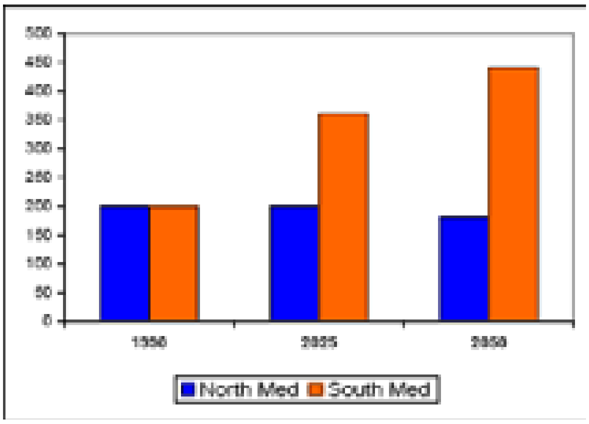
Figure 9: *Population increase in the different Mediterranean countries*



Source: 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.

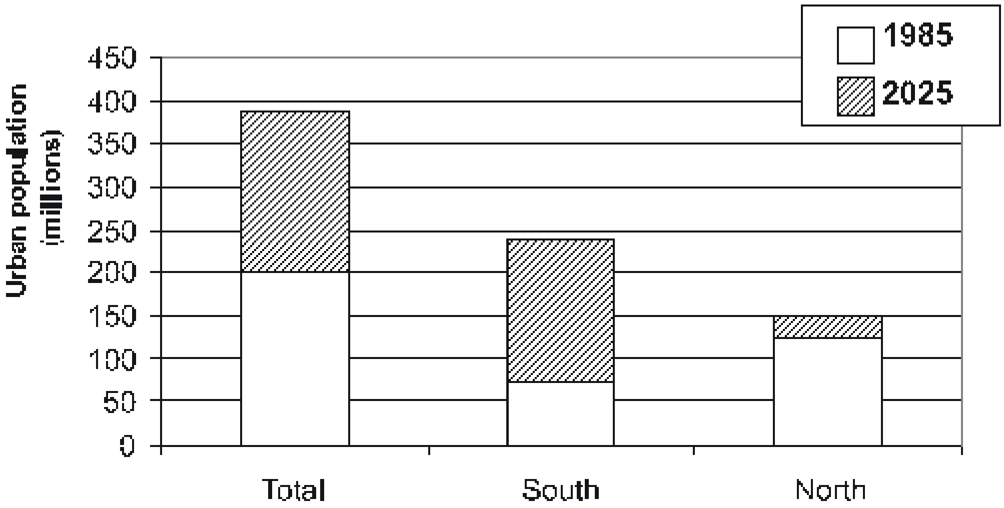
Figure 10: *Population in the Mediterranean countries – Evolution trends 1990-2050 (million inhabitants)*



Source: United Nations Population Division, 1994

Rapid population growth is always linked to fast urbanisation *(Figure 11)*. 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 11: *Urbanisation growth in the Mediterranean, 1985-2025*



Source: 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.

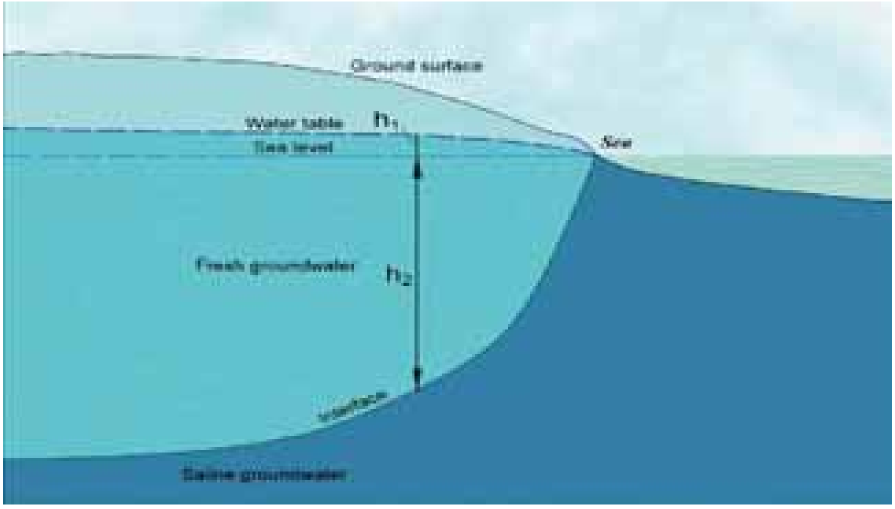
II.2 SALINE WATER INTRUSION

Groundwater over-exploitation in coastal aquifers alters the equilibrium of the interface between freshwater and sea water in the groundwater system, which provokes saline water 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.

In the countries with semi-arid and arid climate, the phenomenon of salinisation of not very deep aquifers, strongly affected by over-pumping, is also known inside the grounds. In general, the climatic deficit creates a gradient of salt concentration of the upstream towards the downstream.This concentration increases the proportion of the water mineralized in flow and the reserves.The follow-up and the comprehension of the phenomenon are more complex than in edge of sea.

Higher levels of salt in irrigation water also increases the salinity of agricultural land leading to reduced productivity and in the worst cases to the complete loss of land.

***Figure 12**: Saline water intrusion*



Most Mediterranean coastal aquifers suffer from over-exploitation due to the concentration of agriculture and tourism in coastal areas where the 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 (Plan Bleu, 1999), Turkey (EEA, 2003) and Algeria (e.g. plain of Mitidja, Annaba, etc.)

II.3 GROUNDWATER AND PROTECTED AREAS

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; and
- 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 m3 per day or serving more than 50 persons, Member States must ensure 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.4 EXAMPLES OF GROUNDWATER POLLUTION IN THE MEDITERRANEAN REGION

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.

Beqa’a plain - Lebanon

In the Beqa’a plain, a major agricultural region in Lebanon, the overuse of fertilizers and the reuse of wastewater have caused soil and groundwater pollution. These activities have resulted in elevated levels of nitrate and heavy metals, such as chromium, nickel, cadmium, lead and zinc in the Beqa’a soil profile and shallow groundwater aquifer (Darwish et al.., 2000). The aquifer is vulnerable to contamination, including by heavy metals, as its depth below the soil surface is in some locations very shallow with a minimum of only 0.5 metres. Heavy metal concentration in the soil profile decreases with depth (Darwish et al., 2000) with highest reported values of 0.28, 28.5, 93.6, 28, 72.8, 15.5 and 97.2 mg/l for cadmium, copper, chromium, cobalt, nickel, lead and zinc, respectively. In the groundwater, concentrations of 13.9, 6.4, 0.06, 115.2, 0.86 µg/l of Ni, Cr, Cd, Zn, and Pb respectively were found at a depth of 2 metres, and similar levels of 12.5, 5, 0.03, 219.5, and 0.95 µg/l at a depth of 8 metres, while in the 70-metre deep well, concentrations were significantly lower at 5, 4, 0.02, 36.8 and 0.4 µg/l, respectively, as shown in tables 6, 7 and 8. Although these values indicate elevated levels of heavy metals, all concentrations are still well below WHO drinking water quality standards. In contrast, nitrate concentration in the groundwater was sometimes above the WHO drinking water quality standard of 50 mg/l, reaching maximum values of more than 200 mg/l.

II.5 GROUNDWATER POLLUTION – HEALTH IMPACT

Contaminated drinking water is the main cause of illness and death in the world. Ingestion of, or exposure to contaminated water causes a number of diseases. Others may be caused by exposure to naturally found harmful chemicals or man-made pollutants in ground water. There are short-term and longterm health risks associated with contaminated water. These may be microbial (bacteria, viruses, parasites), chemical (metals, pesticides, disinfectants by-products, etc.) or toxin-related (toxins produced by microorganisms). Contaminants in irrigation water can also affect agricultural products and cause health problems by entering the food chain. Consequently, the absence of proper wastewater collection systems and the persistence of open channels or pools of wastewater will serve as breeding grounds for many diseases.

Illness resulting from water consumption may be caused by chemical contamination, such as radioactive material, arsenic, cadmium, lead etc. or biological contamination by viruses, parasites and bacteria.

II.6 GROUNDWATER PROTECTION FROM CONTAMINATION

The protection of groundwater resources may be based on different methodologies involving either empirical or sophisticated methods. 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.

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.

II.6.1 Groundwater remediation methods

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.

(to be further discussed)

II.6.2 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, flocculation, 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.

(to be further discussed)

II.6.3 Soil profile remediation methods

Excavation is an unsophisticated remedial option. Depending upon the depth and extent of contamination, the only requirement is earthmoving equipment and trucks. If the polluted soil is considered hazardous waste, it must be land-filled or treated, e.g. burned.

Soil washing is the physical removal of contaminants by flushing the soil with water, detergents, solvents, or nutrients. The process may occur as a by-product of bioremediation or be performed to enhance the bioremediation process. The emphasis is on the physical removal of the contamination from the soil by the action of washing liquid. Soil washing may be conducted in situ or on the surface. It is difficult to achieve in silty and clayey soils, and its effectiveness is limited when used as a remedial option by itself.

(to be further discussed)

II.6.4 Future innovative technologies

(to be discussed)

II.7 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.7 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.7.2 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.

II.8 CASE STUDIES OF GROUNDWATER PROTECTION AND REHABILITATION IN THE MEDITERRANEAN REGION

II.9 CONCLUSIONS

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

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.

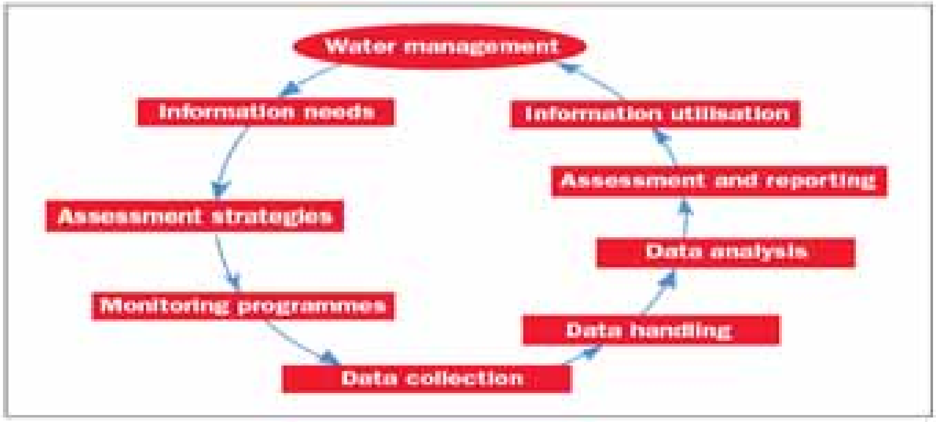
After a preliminary characterisation of the groundwater systems, further monitoring should provide information about the aquifer dynamics such as seasonal variations and changes of the groundwater flow system and about the effects of measures and other anthropogenic influences.

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 13)* 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.

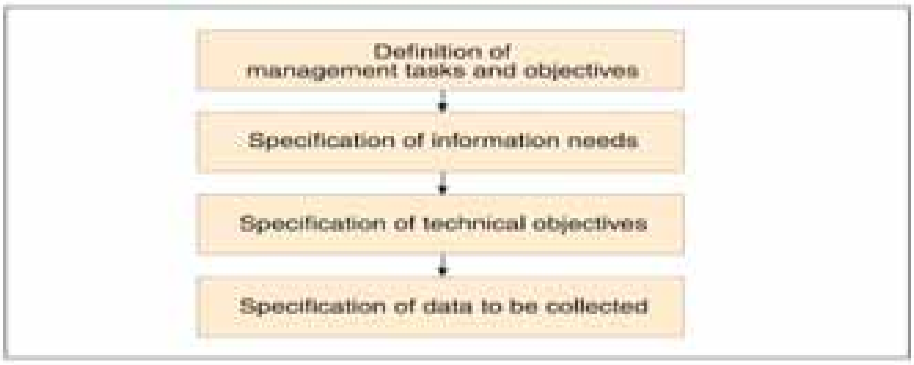
Figure 13*: Monitoring cycle*



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 14.

Figure 14*: 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.

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. Eventually, some stations may be transferred to the basic or specific network.

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.

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 and
- 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.

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.

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 GROUNDWATER MONITORING UNDER THE WATER FRAMEWORK DIRECTIVE (2000/60/EC)

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. Based on the results of the characterisation of groundwater bodies *(Table 9)* 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.

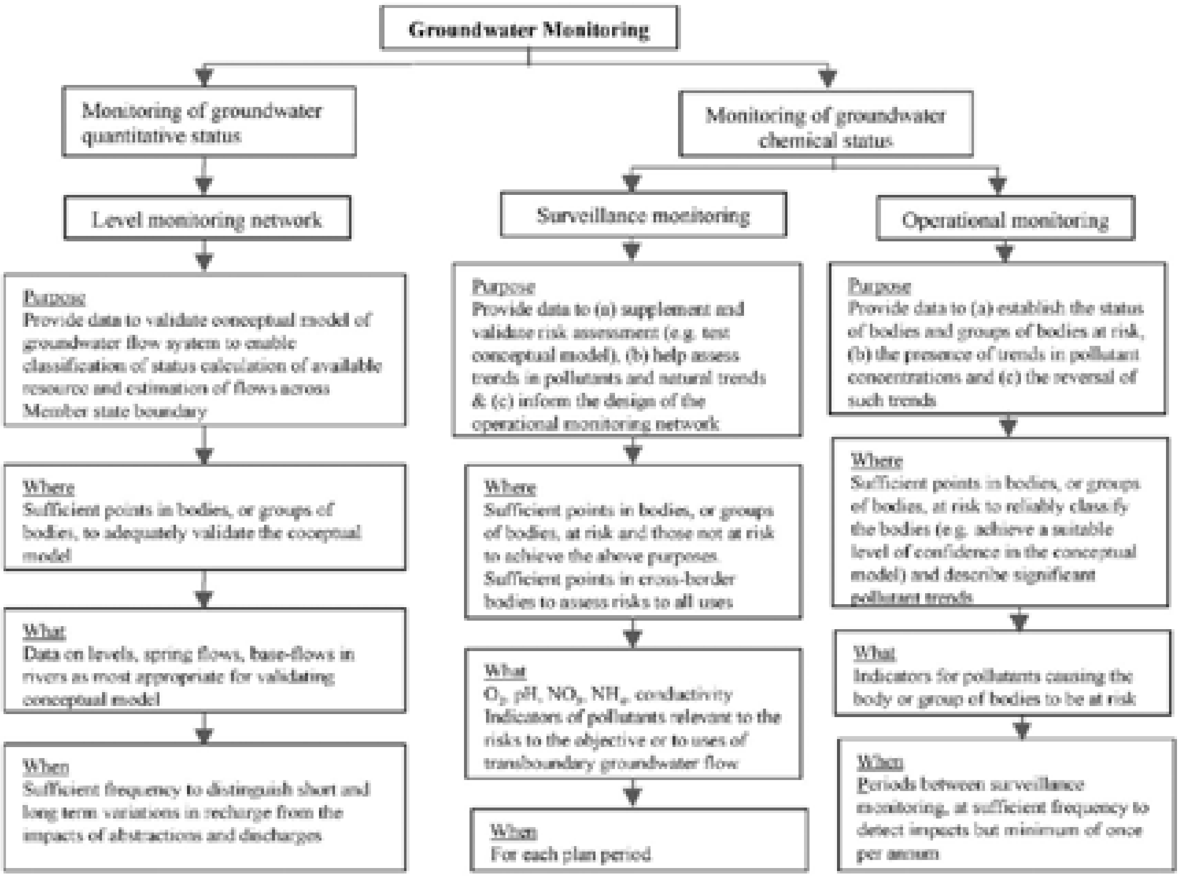
Table 9*: Groundwater characterisation requirements under the WFD*

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).

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 15 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 of the WFD.

Figure 15*: Summary of groundwater monitoring obligations under the WFD.*



III.4 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 north Mediterranean countries (EU Member States), 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.
- 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.

III.5 TRANSBOUNDARY GROUNDWATER RESOURCES

General

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.

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.

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 GROUNDWATER MONITORING APPROACHES AND PRACTICES

Groundwater monitoring in France

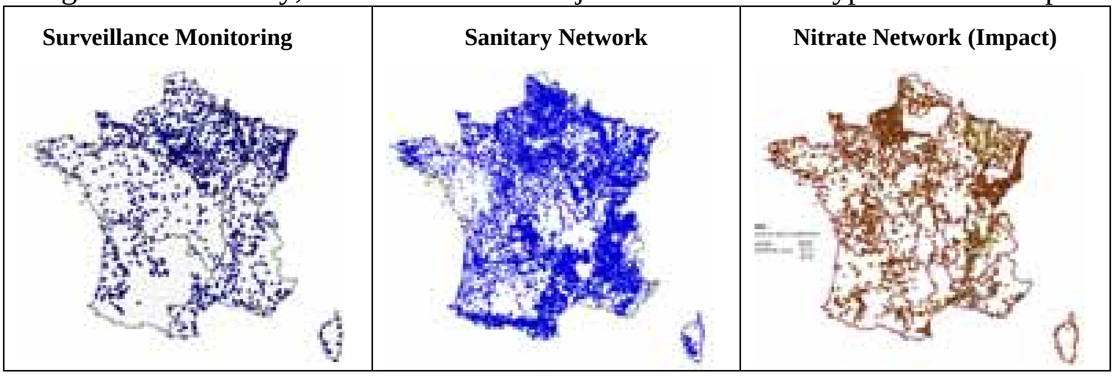
In 2003 the French Guidance document on Groundwater Monitoring was published as well as the national groundwater database was made available (ADES: http://ades.rnde.tm.fr).

➢ 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.



➢ Monitoring of groundwater quantitative status

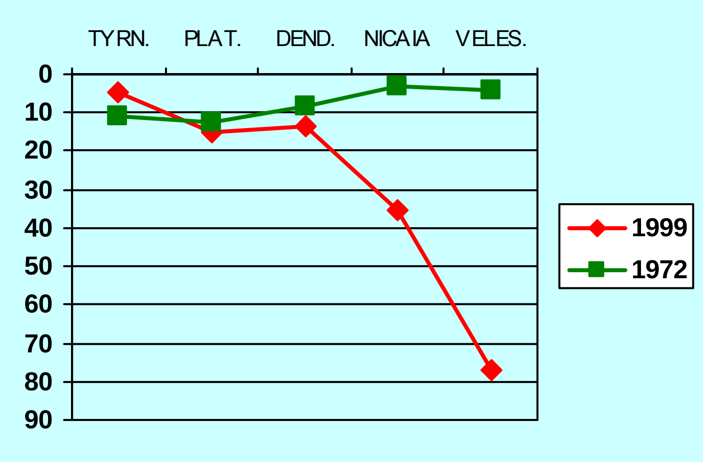
Two monitoring networks exist:

- 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



<u>Variation of water table depth</u>

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.

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.

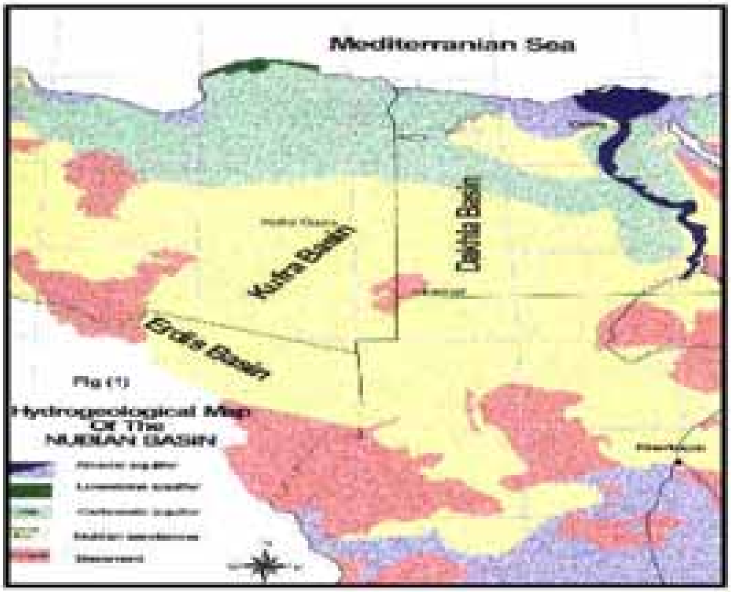
The construction of AsSamra waste stabilization ponds (AWSP) in 1985 above Wadi Dhuleil basin has raised many questions about the possibility of AWSP to pollute the aquifer system below it. The shallow unconfined aquifer at Dhuleil has shown signs of pollution after a few years of AWSP construction.

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.

III.8 TRANSBOUNDARY GROUNDWATER MONITORING APPROACHES AND PRACTICES

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.



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.

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.9 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.

The situation is better in the northern countries of the region, where the existing groundwater monitoring programs are under revision according to the requirements of the EU Water Framework Directive.

CHAPTER IV: INTERNATIONAL COOPERATION

IV.1 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 Fig. 16 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 16: *Schematic representation of hydrological and hydrogeological processes in transboundary areas (UNESCO/ISARM, 2001).*

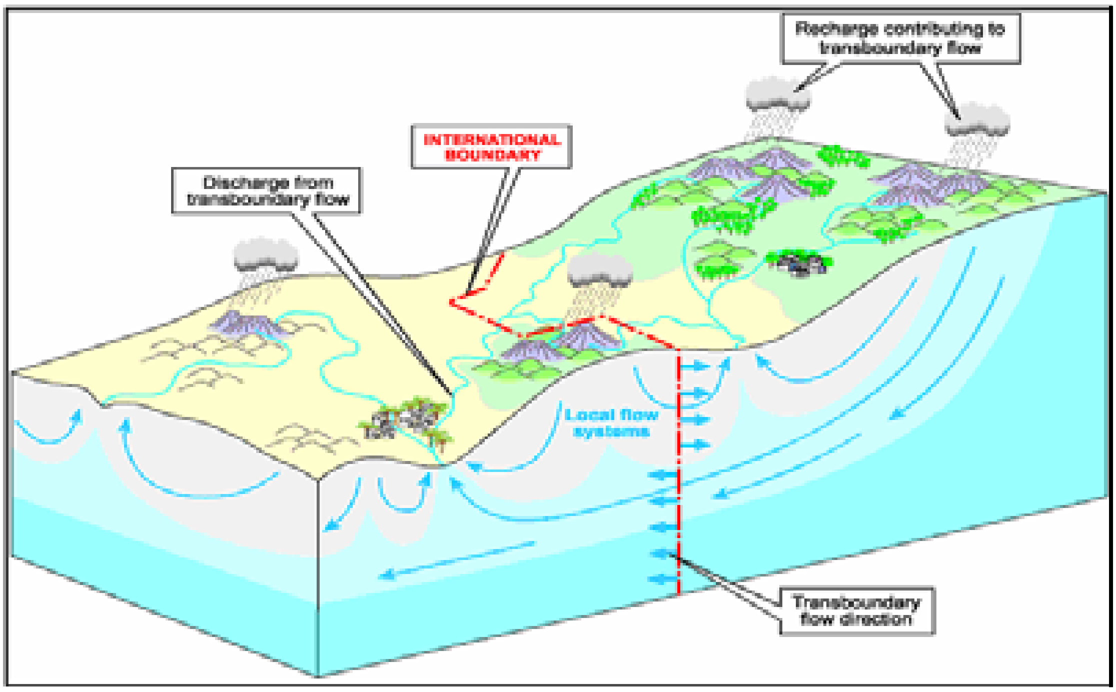
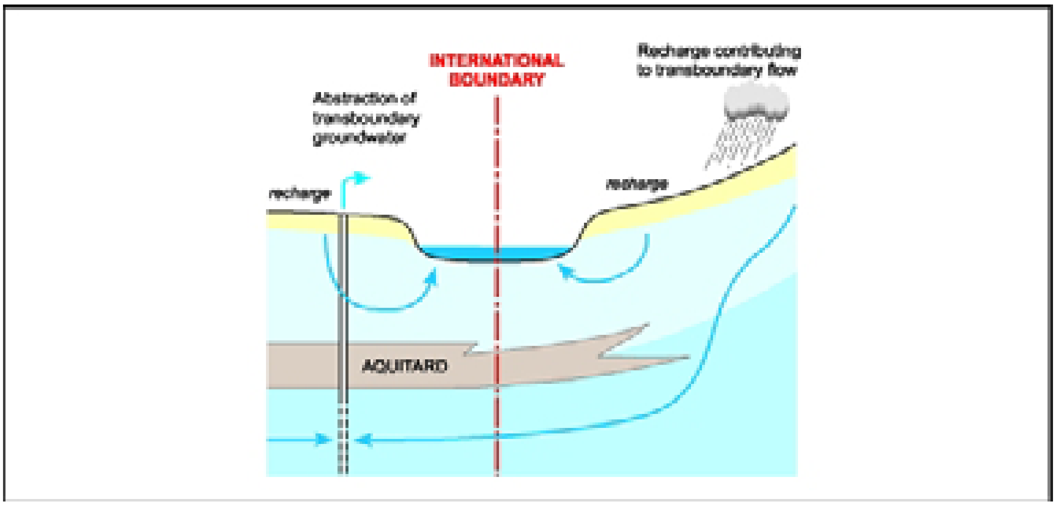


Figure 17: *Interaction between surface and groundwater flows near an interstate boundary (UNESCO/ISARM, 2001).*

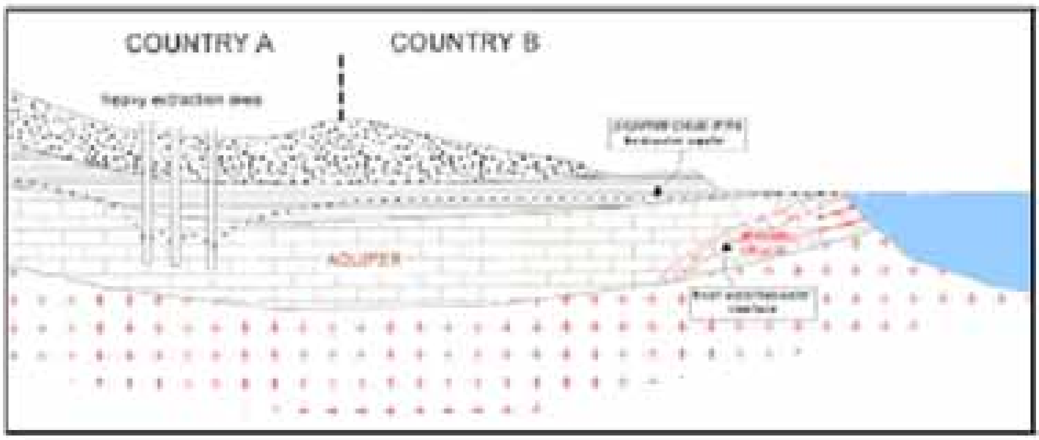


In many real situations interactions between surface and groundwaters from both sides of the international border may create international disputes. As shown in Figures 11 and 12, groundwater overpumping in one side of the boundary may lower the water level of a shared surface lake or river or accelerate 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 18: *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 (see, 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.

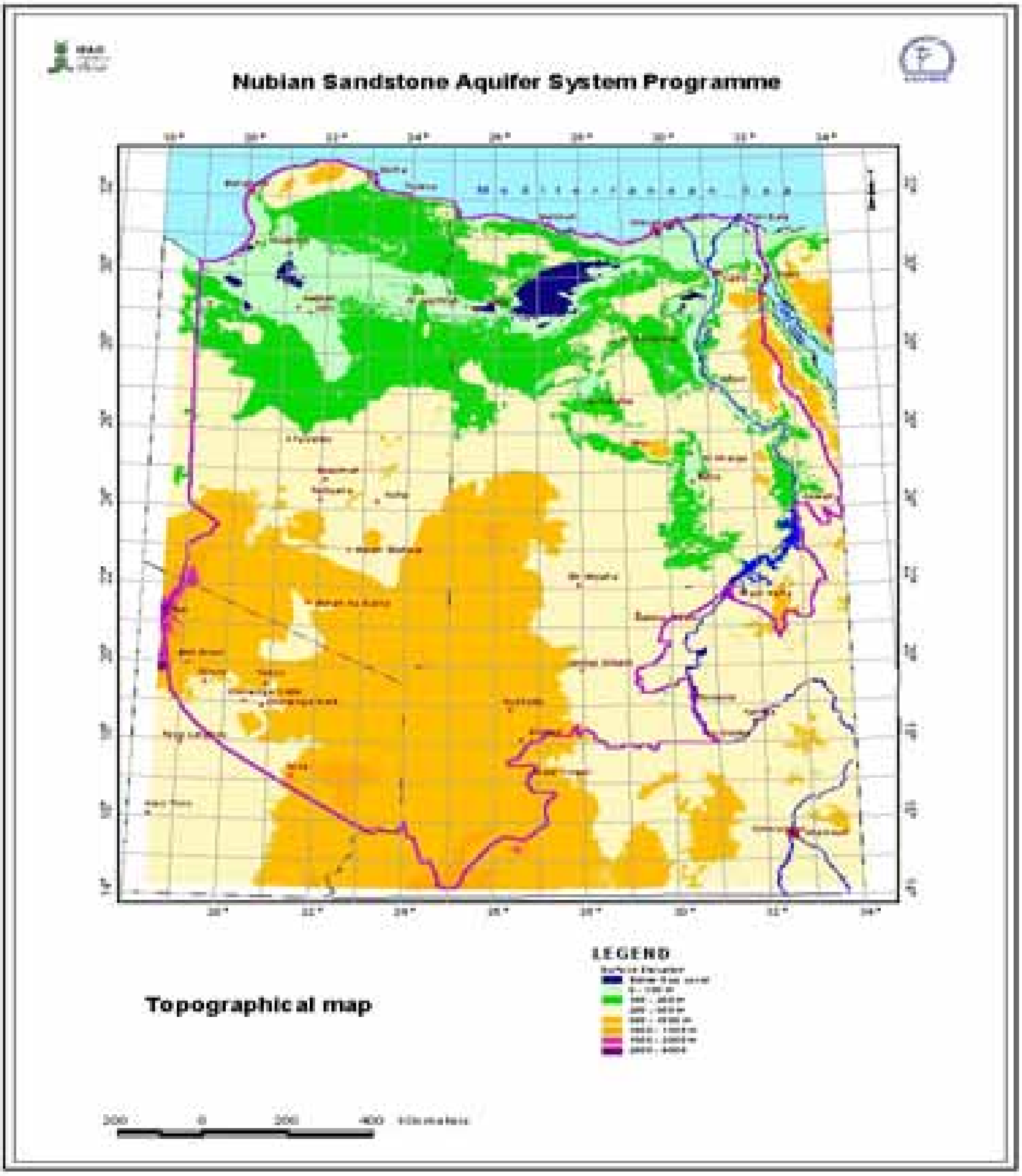
IV.2 SHARED AQUIFERS IN THE MEDITERRANEAN REGION

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.

Figure 19: *The Nubian Sandstone Aquifer System – Topographic map*



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.

Shared aquifers in the Balkans

No	Name of shared aquifers	Countries involved
1	Dragonja	Slovenia & Croatia
2	Kupa	Slovenia & Croatia
3	Kupa	Croatia & Bosnia Herzegovina
4	Una	Croatia & Bosnia Herzegovina
5	Cetina	Croatia & Bosnia Herzegovina
6	Neretva	Croatia & Bosnia Herzegovina
7,8	Sava	Croatia, Bosnia Herzegovina & Serbia Montenegro
9	Backa & Banat	Croatia, Hungary & Serbia Montenegro
10	Srem, Macva & Posavo-Tamnava	Croatia, Bosnia Herzegovina & Serbia Montenegro
11,13	West Serbia	Bosnia Herzegovina, Serbia Montenegro & Former Yugoslav Republic of Macedonia
12	SW Serbia	Bosnia Herzegovina ,Serbia Montenegro ,Albania &Former Yugoslav Republic of Macedonia
14,20	Central Serbia	Serbia Montenegro, Former Yugoslav Republic of Macedonia & Romania
15	Zemen	Serbia Montenegro & Bulgaria
16,17,18	Gower-Nesla, Zhepole, Tran	Serbia Montenegro & Bulgaria
19	East Serbia	Serbia Montenegro, Bulgaria & Romania
21	Upper Pannonian/Lower Pleistocene	Serbia Montenegro & Romania
22	Middle Sarmatian/Pontian GWB	Romania & Moldova
23,24	Sarmatian, Upper Jurassic/Lower Cretaceous GWB	Bulgaria & Romania
25	Vjosa/Pogoni	Albania & Greece
26	Mourgana	Albania & Greece
27	Prespes	Albania, Greece & Former Yugoslav Republic of Macedonia
28	Galicica	Albania & Greece
29	Pelagonija/Florina catchment	Former Yugoslav Republic of Macedonia & Greece
30	Gevgelija	Former Yugoslav Republic of Macedonia & Greece
31	Lake Dojran	Former Yugoslav Republic of Macedonia & Greece
32	Sandansky-Petrich	Bulgaria, Greece & Former Yugoslav Republic of Macedonia
33	Gotze Delchev/Agistro-Orvilos	Bulgaria & Greece
34,35	Nastan-Trigrad, Smolyan	Bulgaria & Greece
36,37	Rudozem, Erma Reka	Bulgaria & Greece
38	Svilengrad/Orestiada/Edirne Aluvion	Bulgaria, Greece & Turkey
39	Meric/Evros Aluvion	Turkey & Greece

IV.3 CONCLUSIONS

International cooperation has been proven to be essential to facilitate IWRM, and favour 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 Fora, the 6th Framework Programme of the EC, the EU Water Initiative and some important organisation are: Blue Plan, JRC, GWP-Med, IME, CEDARE, EMWIS, WWF, MENBO, IUCN, CIHEAM.

A detailed list of projects and initiatives related to Groundwater management in the Mediterranean region can be found in Appendix 1. This Appendix shows the will of Mediterranean countries to cooperate, and promote a sustainable development through integrated groundwater management.

CHAPTER V:
INSTITUTIONAL ASPECTS

V.1 GENERAL INTRODUCTION

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 functions have to be shared. The main activities to be undertaken are:

- Strategic planning, through the production of a management plans, including both surface water and groundwater should be a first objective at country level;
- Regulation, in terms of groundwater rights, emission controls, definition of protected areas, is another aspect together with enforcement.
- Economic assessment of groundwater protection
- Public participation

V.2 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 recent EU Water Framework Directive.

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. 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.3 ECONOMIC ASSESSMENT OF GROUNDWATER PROTECTION

V.3.1 The 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.3.2 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.3.3 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.

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.

V.4 CURRENT SITUATION IN THE MEDITERRANEAN

<u>Existing legal framework regarding groundwater resources management in the Mediterranean region</u>

The institutional use and property rights over groundwater often prohibit sustainable groundwater management in several parts of the Mediterranean.

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.

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.

Public participation and groundwater resources management

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.5 THE WATER FRAMEWORK DIRECTIVE APPROACH

The requirements in terms of Institutional aspects are the following:

1. **Administrative arrangements and delimitation of River Basin districts (RBD) - Art.3**

1/ Delimitation of River Basin districts
- Small RB may be combined with larger river basins or joined with neighbouring small basins
- Where **groundwaters** do not fully follow a particular river basin, they shall be identified and assigned to the nearest or most appropriate RBD.

2/ Identification of the appropriate competent authority

3/ International RBD
Coordination of all programmes of measures
Identification of a national or international body as competent authority

2. **Recovery of costs for water services – Art. 9**

3. **Production of River basin Management Plans – Art. 13**

Reference to guidance document n°11 – Planning process

4. **Public information and consultation – Art. 14**

The EU Water Framework Directive (WFD) clearly addresses public information and consultation in water resources management: It is obligatory for the Member States to involve the public in the implementation of the Directive by publishing specific information relevant to the River Basin Plans and to be open to comments made by the public about the planning process.

More specifically, in the WFD public participation is regulated by Preamble 14 and 46, article 14 and annex VII A (points 9 and 11). Preambles 14 and 46 stress the need and the importance of sound information policy and active involvement of the public. Preamble 14 underlines that the success of the WFD depends directly on a successful involvement of the public. Preamble 46 highlights the importance of timely information to ensure public participation.

The core provision for public participation in the WFD is Article 14, “Public Information and Consultation”. Three levels of participation are mentioned in this article: information, consultation and active involvement. 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. For this purpose contact points and procedures have to be included in the river basin management plan (Annex VII A.11). Annex VII A.9 of the WFD moreover requires that the management plan documents the measures taken to inform and consult the public, the results of the consultations, and the respective changes made.

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”.

Reference to guidance document n°

V.6 CONCLUSIONS / RECOMMENDATIONS

The WFD gives a framework for implementing a 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.

The best way to protect groundwaters is to have a comprehensive management toll including both surface and groundwater

CONCLUSIONS – RECOMMENDATIONS

APPENDIX 1:
LIST OF ON-GOING REGIONAL AND NATIONAL PROCESSES, INITIATIVES AND PROJECTS DEVELOPED TO RESPOND TO GROUNDWATER ISSUES IN THE REGION

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