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Groundwater in the Southern Member States of the European Union

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EASAC

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Groundwater in the Southern Member States of the European Union: an assessment of current knowledge and future prospects

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Foreword

Groundwater is a very important resource for Europe, particularly for the countries in Southern Europe, where surface water cannot by itself sustain demand from agriculture, industry and households. In these parts of Europe, groundwater plays a major role, particularly for agricultural and domestic purposes.

Yet there are many pressures on groundwater, from surface pollution seeping down into aquifers to encroachment of seawater. There are also indirect consequences associated with using this valuable resource. For example, excessive extraction can cause damage to valuable ecosystems.

Sustainable development of groundwater resources therefore requires careful management, balancing the benefits of using groundwater against the need to prevent pollution of aquifers and to guard against the unwanted effects of extraction.

The need to protect groundwater in the European Union is recognised though the Water Framework Directive and its Daughter Directive on groundwater. These measures set ambitious targets for protecting groundwater and take account of the pressures on groundwater and its value to the citizens of Europe. However, the pressures on groundwater and demand for it vary greatly across Europe and, as a single measure for Europe as a whole, the Directives do not highlight the particular circumstances of those parts of Europe where the pressures and demands are most intense.

The particular circumstances of the Southern European Union Member States (Portugal, Spain, France, Italy and Greece) are of concern to scientists, not only in these parts of Europe but in Europe as a whole. At the June 2006 meeting of its Council, EASAC, the European Academies Science Advisory Council, decided to form a Working Group under the leadership of Professor Ramon Llamas of the Spanish Royal Academy of Sciences to prepare a report on the special issues that arise in the use of groundwater in the Southern European Union Member States.

This Working Group has now reported and their conclusions are of considerable significance for the future of this valuable resource in Southern Europe. In particular, this report highlights the role groundwater will play in mitigating the adverse effects of the potential water resources scarcity, pollution and mismanagement of surface waters, and the potential increase in drought frequency in the SEUMS, owing to climate change.

One of the key messages of this report is that there are continuing and severe pressures on groundwater, and that the impacts of these on groundwater and the environment as a whole will need careful monitoring. At present there is a shortage of information, and the Southern European Union Member States will have significant challenges in meeting the requirements of the Water Framework Directive.

The Working Group has considered what needs to be done now. The report includes recommendations on the measures that are needed to ensure a sustainable future for Europe's groundwater, mainly through the implementation of the provisions of the Water Framework Directive.

On behalf of EASAC it is my great pleasure to thank Professor Llamas, the members of the Working Group and the many experts who contributed to the preparation of the report. I am also pleased to acknowledge our great debt of gratitude to the Areces Foundation of Madrid whose sponsored and supported a workshop in Madrid to develop conclusions for the report

Professor Volker ter Meulen
Chairman, EASAC

Summary

What is the importance of groundwater for Europe?

When rain or snow falls on land, some of the water runs into rivers or lakes and some is released back into the atmosphere through evaporation and transpiration (or alternatively combine as 'evapotranspiration'). Much of it, however, collects in the ground where it is taken up by cracks and pores in rocks and soils. The distinct underground areas where groundwater collects are known as aquifers; in the terminology of the Water Framework Directive (WFD), these are also known as groundwater bodies. Groundwater, drawn up from aquifers in wells or boreholes, is an important resource and is widely used in Europe for agricultural irrigation and for domestic purposes, including drinking. There is an important distinction to be made between 'blue water', stored in surface waters and groundwater bodies, flowing through rivers and aquifers, and 'green water', which is stored in the pores of the soil, taken up in plants and released back to the atmosphere through evapotranspiration.

Within the European Union (EU), it is recognised that groundwater is a valuable resource. The WFD of 2000 (200/60/EC)[1], a major piece of EU legislation, contains measures that are designed to protect it. However, there are considerable differences in the availability of groundwater and in the pattern of demand for it across the EU and these are not explicitly recognised in the Directive. The consequence of this is that, although many EU Member States have found it possible to implement measures that will ensure that the aims of the Directive for groundwater protection will be achieved, in other parts of Europe this remains a challenge and it may not be possible to achieve the aims specified.

The science academies of the Southern European Union Member States (SEUMS) have collected evidence on the importance, current status and use of groundwater within the region in order to report on the sustainability of these resources and their future development, in agreement with the goals of the WFD.

What is distinct about groundwater the SEUMS?

The evidence from the different Member States shows that there are many common factors across the Southern European region. Throughout the SEUMS, with the exception of France, the largest single use of blue water is for agriculture, amounting to up to 80% of all water consumption, compared with an EU average of 24%. Groundwater makes a major contribution to this, up to 65%, in Portugal. This compares with a European average of 23% of agricultural water sourced from groundwater. By contrast, the proportion that groundwater contributes to domestic use in the SEUMS is close to the European average of about 55% of the total (European Environment Agency 2009)[2].

There are strong geological similarities across the SEUMS. Aquifers in this region are of broadly similar kinds. Environmentally, they are subject to a similar range of pressures from the use of agricultural chemicals, urbanisation and the growth of tourism. There are also parts of the region where the industrial legacy has added to the pollution of groundwater.

There are also significant problems associated with the recent uncontrolled increase in pumping rates in the region, in particular impacts on surface ecosystems and the degradation of groundwater quality.

However, it is recognised that the use of groundwater has produced considerable advances in rural economies of the SEUMS. It is also a resource that is used with care; in many parts of the region evidence shows a considerably greater economic and hydrological efficiency in the use of groundwater than in the use of surface waters for agricultural use.

What are the main concerns about groundwater in the SEUMS?

A common concern across the region is the rapid growth in the number of users of groundwater, which has, in many parts, led to a significant unregulated community of users. In some parts of the SEUMS, these unregulated users are in number equal to the regulated sector and make a similar level of demand. This rapid growth in unlicensed pumping is considered a major issue in the accuracy of current estimates of extraction rates. It also creates a significant social and political obstacle that has to be overcome if good management of aquifers is to be achieved in the SEUMS.

In some parts of the region there are also concerns about groundwater pollution due to the (mainly) historic uncontrolled use of land, including the pollution of groundwater by nitrates. This is by far the major issue in some parts of the SEUMS, for example in Italy. Even though groundwater may be abundant, it is increasingly vulnerable and has to be considered increasingly unreliable as a source of future drinking water supplies.

1 Directive 2000/60/EC, Official Journal (OJ L 327), 22 December 2000.
2 EEA (2009). Water resources across Europe — confronting water scarcity and drought Report No 2/2009.

There are also parts of this region, notably in Greece, where increased abstraction due to demand from tourism is causing seawater intrusion into aquifers.

What is the state of knowledge about groundwater in the SEUMS?

In general there has been considerable advance in the identification and characterisation of groundwater bodies, driven by the demands of the EU WFD. However, in many parts there are insufficient data to be clear about the current and future trajectory of groundwater conditions. This will make full compliance with the obligations of the WFD a significant challenge for many of the SEUMS.

What is the future for SEUMS groundwater?

The current trends suggest a future in which there will be an increasing demand for groundwater, both for irrigation of crops and for water supply in areas of increasing urbanisation and growing tourism. The agricultural uses may be offset to some extent by advances in water management and improved methods of cultivation. However, measures to reduce per capita demand in the case of tourism have had little effect so far. However, most of the increased use in urban water supply due to tourism can be met through seawater desalination, because the growth in tourism is mainly seen in coastal areas and the cost of seawater desalination can be recovered though charges on the tourist industry. It is important, however, to keep this in perspective: the use of water for tourism and urban water supply is only a small fraction of the water used for irrigation. The use of desalinated seawater for irrigation is considered not to be generally feasible from an economic point of view, except perhaps for very special types of crops of high economic value.

According to the most recent assessment by the Intergovernmental Panel on Climate Change, climate change, in the longer term, may have powerful impacts on groundwater, particularly through its effect on hydrological cycles. One of the key predictions of current assessments is that there will be more frequent and longer periods of drought, and that this would impact heavily on natural recharge. However, there is uncertainty about the likely scale and location of these effects.

What steps are needed to secure the sustainable development of groundwater resource in the SEUMS?

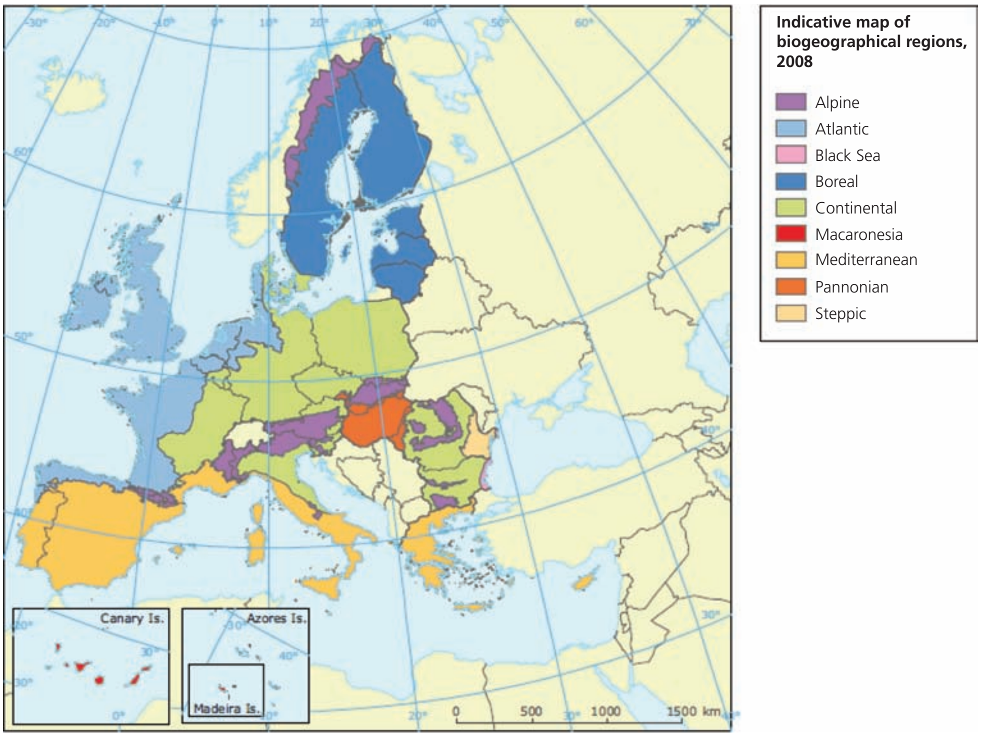
The principal step that will ensure the future of groundwater in the Southern SEUMS will be full implementation of the WFD and, in particular, the associated Groundwater Directive. However, this in itself depends on a good quality of knowledge about groundwater in the region, including its current status and the pressures on it. This report shows that knowledge about groundwater is patchy and that many of the SEUMS will struggle to meet the requirements of the Directive to the agreed timetable. Regulation of groundwater is complicated in some parts of Southern Europe by the amount of groundwater use that falls outside the regulated sector. The immediate steps that are needed, therefore, are accelerated programmes of investigation to establish the full facts about the current status of groundwater throughout the region, including current uses and their impacts. In parallel with this, programmes are needed to improve understanding of the uses that fall outside current regulation and, in consequence, are not measured.

1 Introduction

1.1 Groundwater in the SEUMS: why this is an urgent issue for the EU

Groundwater is an important resource for Europe as a whole. This is recognised by the EU in several recent measures aimed at protecting it from anthropogenic pressures and their corresponding impacts. These measures are based on a common approach for EU Member States. The use of groundwater, however, varies across the EU, and it is the aim of this report to focus specifically on the patterns of use that are emerging within the SEUMS. The SEUMS form a distinctive region of the EU in which conditions contrast with those in the Northern and Central EU Member States (Figure 1).

Figure 1 Biogeographical regions in Europe (source: European Environment Agency 2008).



During the past half century, however, it is mostly in arid and semi-arid countries that the abstraction of groundwater has dramatically increased. This is a new phenomenon and quite distinct from systems for the use of surface waters, mainly for irrigation, that have been in place over the past centuries and even millennia (Llamas & Custodio 2003)[3].

Until recently, abstraction of groundwater was generally local and of small scale compared with the use of surface water. The situation has changed owing to improvements in the technology for drilling water wells, chiefly because of the development and popularisation of the turbine pump. In most countries today, if the geology allows it, the abstraction of groundwater for irrigation is easy and cheap compared with the direct or immediate benefits obtained. Externalities such as environmental impacts are very rarely considered in analyses of water resources.

The intensive use of groundwater can be considered globally, and in arid and semi-arid regions, as a 'silent revolution', because it is the result of the actions of millions of small private farmers with little planning and control by the usual governmental water-management agencies (Llamas & Martínez-Santos 2005)[4]. In a sense, the problem is hidden from the regulatory authorities because it is the accumulation of small-scale activities, any one of which would fall below the regulated level.

There is an urgent need to obtain better data on the intensive use of groundwater to understand the real scale of groundwater development and its economic significance over recent decades. There is also a need to understand what rights different communities, individuals

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3 Llamas, MR & Custodio, E (2003). Intensive use of groundwater: a new situation which demands proactive actions. In: *Intensive Use of Groundwater: Challenges and Opportunities* (ed. MR Llamas & E Custodio), pp. 13–31. Dordrecht: Balkema.

4 Llamas, MR & Martínez-Santos, P (2005). *Intensive groundwater use: silent revolution and potential source of social conflicts*. Journal of Water Resources Planning and Management September/October, 337–341.

and institutions have over the use of groundwater, and how these are determined and enforced by different administrations.

This silent revolution has produced great benefits in supplying drinking water and food to hundreds of millions of people, mainly, but not exclusively, in India and in many developing countries. For example, California and Texas in the USA are two regions with very intensive use of groundwater. However, intensive use of groundwater without planning and control is not a panacea for all water problems, and in some cases it has caused a range of problems including water quality degradation and impact on aquatic ecosystems. In particular, it has led to the severe damage done to surface ecosystems, such as wetlands, as the abstraction of groundwater drains water from the surface water bodies. Frequently, however, the nature and scale of such problems has been distorted through lack of reliable data, with the result that it has proved difficult to develop satisfactory policies to address them.

The main goal of this report is to provide an objective and transparent overview of groundwater development in the SEUMS and of its future. This assessment will emphasise the economic, ecological, legal and institutional aspects of the 'silent revolution' in each country. One reason for this emphasis is to avoid duplication with other reports or analyses performed by other EU teams, which deal mainly with the hydrological aspects (quantitative and qualitative) of the groundwater issues in the SEUMS (or Mediterranean countries). In at least some cases, it can be expected that the main result of the assessment will be to show that there is a clear lack of awareness of the problem among high-level water decision-makers.

1.2 The current study

The current study has been commissioned by the Council of the European Academies Science Advisory Council (EASAC) as a contribution to the improvement of EU legislation on water resources. A Working Group of experts appointed by academies was established with the aim of producing a report on the following:

- the current scientific consensus about the status of groundwater in Southern Europe;
- an assessment of current pressures;
- further steps required to secure a more sustainable future for groundwater resources and their uses in the SEUMS.

The EASAC Working Group on the Groundwater Issues of the Southern EU Member States held its first meeting in London in November 2006, under the chairmanship of Professor MR Llamas of the Spanish Royal Academy of Sciences, with the participation of the academies of Spain, Portugal, Italy and Greece. The second meeting followed an international seminar, sponsored by the Areces Foundation of Spain, on 19 and 20 April 2007 in Madrid. A representative of Turkey was also invited to this meeting. A third meeting with the participation of representatives of the academies of France, Spain, Portugal and Italy and of the Northern Member States was held in the EASAC secretariat in London on 18 July 2007.

The methodology that has been adopted has been to produce Country Reports on the groundwater situation in each of the SEUMS and to use these Country Reports as the reference material for this overview report. The Country Reports are published in full on the website of EASAC (www.easac.eu). Some of them are also on the websites of the corresponding academies.

2 Policy context

2.1 Policy background

Water resources in Europe are considered a priority for EU action and Member States have agreed to a major new legislative measure to ensure their sustainable management. The WFD, which came into force in December 2000, is a major piece of legislation and a radical departure from previous environmental measures; it requires Member States to ensure that all inland, transition and coastal waters reach 'good chemical and ecological status' for surface waters and 'good status' for groundwater in terms of quality and quantity by 2015.

The Directive requires Member States to establish a river-basin district structure within which demanding environmental objectives are to be set, including ecological targets for surface water and groundwater bodies.

According to the Directive, defining and enumerating surface water and groundwater bodies is an important first step towards understanding the situation of groundwater in each Member State. It is then necessary to assess the pressures on each groundwater body and the corresponding impacts of these on its ecological status or health. Finally, where necessary, Member States have to define the measures that are required to recover good ecological status by the year 2015.

The programmes of measures should be included in the River Basin Management Plans[5], which were due to be sent to the Commission by 2009. Before then, in 2008, these programmes of measures should have been debated with the stakeholders of each groundwater body; a considerable task by itself. The available data seem to indicate that some SEUMS have difficulties in fulfilling this provision of the WFD. It seems inevitable, therefore, that they will need to ask for a certain number of groundwater bodies for an extension of 6 or 12 years of the deadline (2021 or 2027). Alternatively, they may declare that some water bodies can never achieve the WFD goals. In such cases the SEUMS will have to present the circumstances clearly and their proposals will have to be subject to consultation with stakeholders. This implies a dramatic change compared with the current situation.

Agreement on further measures to protect groundwater, in the form of a Daughter Directive of the WFD, was reached in a Conciliation Committee in October 2006 and was adopted in early 2007. It aims to clarify some of the objectives in the WFD, in particular the meaning of 'good chemical status' for groundwater, the identification and reversal of pollution trends, and the control of pollution.

The new Groundwater Directive, or Daughter Groundwater Directive[6], lists criteria pollutants and thresholds for groundwater. The specific measures required by this new Directive involve the assessment of groundwater pollutants and reporting to the Commission. In particular, Member States are required to report on the trend in pollutants and, where the trend is towards higher concentrations, to take measures to reduce them.

However, it was recognised in drafting the Daughter Groundwater Directive that a uniform approach across Europe would not be appropriate because of the very different circumstances in different parts of the EU. The 2006 Daughter Groundwater Directive has not been transposed to most Member State legislation and there is actually no experience on its implementation. Because of this, we do not deal with it in this report.

This report supports the development of a more effective approach to groundwater management in the EU based on dealing with the different issues that arise in a region (the SEUMS) where groundwater use is especially important.

In its work on the development of the Union, the current Commission has focussed strongly on the Lisbon agenda[7], emphasising competitiveness and social progress. The environmental strand of the EU Sustainable Development Strategy has become a junior strand. There is still a requirement for DG Environment to develop an environmental agenda, in particular where failure to do so may place future economic progress at risk. In the current political climate it is therefore essential to be clear about priorities. The EASAC work on groundwater issues will also support the development of priorities for this area of the DG Environment's work. In accord with this broad approach, the EASAC report gives prominence to socio-economic factors, especially important in the Southern EU where groundwater may contribute some 50% of the total economic value of irrigated agriculture. The contribution of groundwater to urban water supply (including tourism) is greater than 50% of the total water used, except in Spain.

The Mediterranean Groundwater Working Group (MED-EUWI WG on Groundwater), published its Technical Report on groundwater management in the Mediterranean and the WFD in February 2007[8]. This report analyses the status of groundwater in the 20 Mediterranean countries participating in that Working Group, compared with the six countries in this report.

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[5] http://www.eea.europa.eu/themes/water/water-management/river-basin-management-plans-and-programme-of-measures.
[6] Directive 2006/118/EC.
[7] http://www.parliament.uk/commons/lib/research/briefings/snep-03404.pdf.
[8] http://www.semide.net/media_server/files/l/f/Mediterranean_Groundwater_Report_final_150207.pdf.

However, as previously mentioned, our main emphasis is on the economic, social and institutional aspects, which are not treated comprehensively within the EUWI report. The EASAC Working Group has maintained close contact with the EUWI work while preserving its independence of any EU institution.

Agricultural policy, in particular the reform of the Common Agricultural Policy, is expected to have a significant, though currently not fully quantified, impact on the pattern of use of water resources in the EU. This will include impacts on groundwater use. Moreover, it cannot be forgotten that the future Common Agricultural Policy will be contingent on the next agreements by the World Trade Organization.

On 18 July 2007, the European Commission adopted a Communication on Water Scarcity and Drought (COM 2007 414 final)[9]. The Communication emphasises the economic cost of water scarcity in the EU. As an illustration it gives the impact of the 2003 drought to be of the order of €8.7 billion. However, the EU Council of Ministers rejected the proposal of preparing a new Directive on Water Scarcity and Droughts, although the preparation of a new Directive on Floods was approved. The Commission and the Council of EU Ministers regard the full implementation of the WFD as an urgent priority for all Member States. Ineffective water pricing policies that do not reflect the sensitivity of water resources at a local level are blamed for the extravagant use of water and the Communication notes that 'user pays' principles have hardly been implemented in sectors other than drinking water supply and wastewater treatment. Although groundwater is not explicitly mentioned in the communication, the general thrust of the Commission's policy recommendations is likely to be felt in all uses of water, in particular in the non-metropolitan uses including agricultural irrigation.

2.2 What the WFD requires

In summary, the EU WFD requires EU Member States to identify groundwater bodies, identify anthropogenic pressures on them, quantify their consequences and develop management plans for long-term sustainability. As a part of this it is necessary to assess current pollution levels and their trends (whether pollution levels are rising or falling). Member States should also, in the context of the WFD, consider where the use of groundwater has consequences for surface water bodies.

The specific requirement of the WFD is that by 2015 all water bodies (surface water and groundwater bodies) will achieve a good ecological status. The steps to achieve this are as follows.

(a) Definition and characterisation of the water bodies and their pristine state.

(b) Identification of the various pressures on the water bodies because of human activities.

(c) Evaluation of the impacts due to the pressures on the ecological health of the water bodies.

(d) Proposal of the measures to be taken to recover, if necessary, by 2015 the good ecological health.

(e) Perform cost–efficiency analyses of the different measures proposed.

(f) If the economic or social costs are excessive, propose to the Commission a delay of 6 or 12 years (2021 or 2027) to implement the goal of good ecological status.

These analyses and proposals should be completed and included in the River Basin Management Plans that were due in 2009. The River Basin Hydrological Plans should follow a comprehensive process of public and stakeholder participation, to have begun at least one year previously, namely in 2008. It seems clear that these deadlines have not been achieved in most SEUMS.

The WFD throughout emphasises the need for comprehensive and reliable data. In the following section of this report, the availability and quality of data on groundwater bodies in the SEUMS, as well as their assessment, is a major consideration.

9 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2007:0414:FIN:EN:PDF.

3 Groundwater resources in Southern Europe

The environmental context for this report is the combination of physical, economic and social factors in the SEUMS that gives rise to common concerns for the future of groundwater across the region. The Country Reports (published in full on www.easac.eu) illustrate the common features that influence groundwater conditions across the region. In general, there is a considerable degree of similarity and this marks the region out as a distinctive part of the EU in which conditions contrast with those in the Northern and Central EU Member States.

Climatically, this is a region in which conditions are frequently semi-arid, with seasonal and geographically highly differentiated rainfall. The geology in this region provides hydrological regimes that are dominated by karst (regions in which landscape is shaped by holes made by the dissolution of soluble bedrock – usually carbonate rock such as limestone – or dolomite), clastic sediments (such as sandstone) and fractured rocks.

The Country Reports also highlight those aspects of groundwater use and it impacts that differ between significant parts of the SEUMS and other parts of the EU.

The SEUMS each have considerable resources of groundwater and, following the requirements of the WFD, have taken steps to create inventories of aquifers ('groundwater bodies' in the terminology of the WFD). This section contains a summary of the data available on groundwater bodies in the SEUMS and an assessment of the quality of these data against the requirements of the WFD. Firstly, however, we provide an overview of the relative importance of groundwater in the context of the overall use of water in SEUMS.

3.1 Agricultural and other uses of groundwater

The SEUMS share broadly similar climatic conditions. There are northern parts of Portugal, Italy and France that have a humid climate similar to Central and Northern Europe. However, the SEUMS are characterised, in the main, by semi-arid conditions with highly seasonal patterns of rainfall. In particular, agriculture is increasingly dominated by production in semi-arid conditions. In the SEUMS this makes water a central concern for farmers and, in the broader sense, for the economies of the region. It is also quite clear that, as agricultural areas expand, water, particularly groundwater, is increasingly a major factor in agricultural production. In fact, the expansion of agricultural areas is, in many parts of the region, driven almost entirely by the availability of groundwater.

Table 1, summarised from the data in the Country Reports, illustrates the uses of water and the relative importance of groundwater in the SEUMS. It illustrates the finding that irrigation is a major water use in the SEUMS and that most of this demand is satisfied by groundwater. It supports the finding that the situation in the SEUMS differs from the European norm in this especially heavy reliance on water for irrigation and in the use of groundwater[10].

For many of the SEUMS, the predominant blue water use (surface water and groundwater) is agricultural (Table 1). If the use of water includes consumption of agricultural products produced by irrigation, rather than simply general or applied water use, the importance of irrigation is even greater. Nevertheless, unless specified, in this report we do not use values associated with agricultural consumption because the data on this aspect of use are in general not complete. (For reference, however, these data are available for France[12].)

Table 1 Estimation of water use and the relative importance of groundwater in the SEUMS

Data for Italy are from IRSA-CNR (1999)[11].

Country	Total water use (Mm3/year) (Percentage of total)	Domestic	Industrial and other	Irrigation
France All sources	15,000 + 19,000 for energy production	6,300 (42%)	3,800 (25%) +19,000 for energy production	4,900 (33%)
Ground-water	6,300 (100%)	3,700 (59%)	1,500 (24%)	1,100 (17%)
Greece All sources	8,243 (100%)	956.6 (12%)	268,20 (4%)	6,859.50 (84%)
Ground-water	3563 (100%)	400 (11%)	110 (3%)	3100 (86%)
Italy All sources	42,000 (100%)	7,940 (19%)	13,900 (33%)	20,140 (48%)
Ground-water	13,900 (100%)	5,400 (39%)	0,500 (4%)	8,000 (57%)
Portugal All sources	8754 (100%)	561 (6%)	1642 (19%)	6551 (75%)
Ground-water	4747 (100%)	349 (7.5%)	188 (4%)	4210 (88.5%)
Spain All sources	37,500 (100%)	5500 (15%)	7500 (20%)	24,500 (65%)
Ground-water	5,500–6,500 (100%)	1,000–1,500 (20%)	300–400 (5%)	4,000–5,000 (75%)

10 EEA (2000). Environmental Assessment Report 3 http://www.eea.europa.eu/publications/groundwater07012000.
11 IRSA-CNR (1999). Un futuro per l'acqua in Italia, Quaderni 109, Roma, 235 pp.
12 See pages 21 and 22 of the France Country Report published on www.easac.eu.

3.2 Groundwater bodies in the SEUMS

The EU WFD requires each EU Member State to characterise its surface water and groundwater bodies as a first step towards defining their ecological health. This is by itself a significant task and has been the focus of much activity in Southern Europe. The results of this work are shown in Table 2, which summarises the current state of knowledge and the situation in the SEUMS, as given in the Country Reports.

Table 2 gives an overview of the groundwater bodies identified in the different SEUMS, those that are at risk of not achieving the requirements of the WFD in 2015 and those that are in need of further characterisation. It illustrates the wide range of different circumstances among the SEUMS.

The number of individual or groundwater bodies identified in national reports, and the extent of the Country under which they lie, vary greatly. In Portugal, for example, there are 91 water bodies covering some 15% of the land area[13]; in Spain there are almost 700 covering about 70%[14]. In Portugal, however, the aquifers identified are typically large whereas in Spain there are many small ones. This raises questions about methodology and whether the differences reflect differences in geology or in the definitions of aquifer boundaries.

The processes of identification and characterisation of Italian groundwater bodies were formally initiated following the implementation of Law 152/06 (1999). However, the analyses aimed at such characterisation have mainly concentrated on quality rather than quantity. Quantitative characterisation is a fundamental prerequisite of management but is as yet fairly weak: as a result not all the aquifers have been identified. ISPRA (Istituto superiore per la protezione e la ricerca ambientale), formerly known as APAT (Agenzia per la Protezione dell' Ambiente e per I Servizi Tecinci), is the agency committed to the task of collecting and assessing the information available in a way that enables the definition of water bodies as prescribed by Law 152/06 (1999). However, this work started relatively recently (in 2006/7) and is far from complete. Consequently, the data reported in Table 2 should be treated only qualitatively.

In the view of the EASAC Working Group the data now available on numbers of aquifers and their extent within the SEUMS provide a still incomplete picture of the groundwater bodies in this region This lack of information suggests that further work is needed in some SEUMS (notably Italy and Greece) to meet the requirements of the WFD.

3.3 Groundwater reserves

Table 3 summarises the estimated annual reserves and recharge for each SEUMS.

The estimation of total groundwater storage or reserves (estimated as the amount of water contained in characterised groundwater bodies) is considered to be rather imprecise because it depends on a range of initial assumptions (useful depth of the aquifer, specific yield and others), which may vary from calculation to calculation. Estimates for Spain, for example, vary from 150,000 Mm^3 to 300,000 Mm^3 [15], but these figures do

Table 2 Characterisation of the groundwater bodies in the five SEUMS

Country	Number of water bodies	Area (km^2) (Percentage of land area)	Percentage that are fully characterised	Number not at risk	Number at risk	Under evaluation
France	553	?	100	237	216	100
Greece	236	?	100	126	110	0
Italy	500	?	60	?	?	500
Portugal	91	?	76	63	6	22
Spain	699	354,000	63	184	259	296

Table 3 Reserves (storage), precipitation and total recharge rates for groundwater bodies in the SEUMS

The data for Italy have been derived from IRSA-CNR (1999) and MED-EUWI (2007) reports.

Country	Estimated reserves (Mm^3)	Annual input from rain (Mm^3)	Annual recharge potential (Mm^3)	Groundwater use (from Table 1) as a percentage of annual recharge potential	Average residence time (years)
France	2,000,000	479,000	100,000	6.3	20
Greece	?	?	?	?	?
Italy	?	296,000	43,000	32.3	?
Portugal	?	?	12,000	39.5	?
Spain	300,000	350,000	30,000	18.3–21.7	10

13 See page 9 of the Portugal Country Report published on www.easac.eu.
14 See page 5 of the Spain Country Report published on www.easac.eu.
15 Ibid.

not include groundwater below about 200 m and are generally considered to be an underestimate of the total resource. For France, a widely used estimate is 2,000,000 Mm^3 (Margat 1986)[16].

Nevertheless, greater accuracy in estimating groundwater reserves may not be necessary. The more important aspect is the relation between the amount of groundwater stored in the aquifers and the annual recharge that they receive (mainly from the infiltration of precipitation), which in Southern Europe is generally two or three orders of magnitude higher. (In France, the ratio of reserves to recharge is estimated to have a value of 20, which is based on the average residence time in years.) This normal property of aquifers is the explanation of their resilience to dry spells. This is in contrast to the relation between water inputs and the surface water storage in conventional reservoirs, where the annual streamflow is usually smaller than the water stored in the reservoir.

The lack of quantitative characterisation of the groundwater bodies makes it impossible to provide figures for the estimated reserves or for the average residence time.

3.4 Chemical quality and trends

The chemical quality of water is clearly important for the general protection of the environment, but in particular for the protection of human health. The chemical quality of water is therefore a major concern in European legislation. It is governed by a series of EU measures, including the Nitrates Directive[17] and the WFD.

Particular threats include nitrates and other residues of application of fertilisers and pesticides to farmland, industrial pollution and deposition of air pollutants. It is expected that the effects of climate change will be to intensify these threats.

Groundwater is considered particularly vulnerable to chemical pollution because groundwater bodies are characterised by long residence times compared with surface waters. The recognition of this vulnerability was one of the key drivers for the Groundwater Directive and is a major reason for enacting the measure.

Good information about the levels of pollution in groundwater bodies is an essential prerequisite to managing groundwater, and the processes of monitoring and assessing the quality of groundwater are therefore particularly important in the long-term health of aquifers. This is also a major requirement with the WFD.

Evidence from the Country Reports suggests that there is a great variation in the extent of monitoring and assessment across the SEUMS.[18]

In Italy, where the main threats to groundwater are from agricultural chemicals, industrial pollution and deposition of air pollutants, the monitoring network for groundwater quality is variable. Some regions (like Umbria) have made effective progress whereas others remain behind the schedule. The National Protection Agency, APAT, has been delegated to address issues of fragmentation at a national level[19]. Data on the chemical status of groundwater have been collected for several years, but procedures capable of characterising the status of water bodies, starting from local measurements, have not been widely developed. However, the threshold values foreseen by the new Directive have already been defined.

Other SEUMS report less progress in this area, and we conclude that the information available provides little confidence in the ability to characterise the chemical status of groundwater with any precision. We also conclude that more needs to be done to develop monitoring and assessment systems before it is possible to understand current chemical status and, more importantly, trends.

3.5 How well do we know the groundwater resources of Southern Europe?

Information collected for this report suggests that the state of knowledge varies across the Southern EU. Data on definition and characterisation of groundwater bodies seem to be rather different from country to country. Our overall assessment is as follows.

(a) Definition and characterisation of water bodies is largely complete.

(b) Identification of pressures is mostly complete in general terms but it seems that much work still has to be done on detail. The exceptions are perhaps Portugal and France, where the groundwater bodies identified as at risk are few.

(c) Evidence from the Country Reports suggests that evaluation of impacts (current status and trajectories/trends) remains incomplete.

(d) The assessments of risks to specific bodies and development of measures have not been completed by 2009 as required and in some cases may not be completed by 2010.

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16 Margat, J (1986). Comptes des Eaux Continentales. Report INSEE.
17 EU Nitrates Directive (1991). http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31991L0676:EN:NOT.
18 See, for example, section 6.3 of the Spain Country Report, section 1.1.4 of the Italy Country Report, section 3.2 of the Portugal Country Report, section 6 of the Greece Country Report and section 7.2 of the France Country Report all published on www.easac.eu.
19 See pages 5, 6, 16 and 40 of the Italy Country Report published on www.easac.eu.

Plans are under development in the SEUMS. The major activity in progress is the quantitative characterisation of aquifers, based on collection and assessment of information.

In the case of public/stakeholder consultations, the current position reported in the Country Reports suggests that progress will be slow. Theoretically, in 2008 all EU Member States Water Authorities should have begun consultation processes. In Spain, for example, the water authorities had begun very actively to promote meetings for presenting the advances of some of the Water Plans to stakeholders. However, considering that there is little tradition of consultation and participation, it remains too early to assess the effectiveness of these meetings[20]. It appears that very little has been done in this respect in Italy so far, except that during severe droughts or hydro-emergencies some consultation occurs through the so-called 'cabine di regia', although these are not established in a systematic manner[21]. We do not have reports of active public and stakeholder activity elsewhere in the SEUMS.

The EU 2nd Water Conference of April 2009[22] provided a further platform for engagement with stakeholders across the EU as a whole and was specifically targeted at public participation.

It is not clear at this stage that the submission of Water Plans to Brussels was achieved across the region in time by the end of 2009.

Monitoring systems are being developed for groundwater in Europe. A current assessment published by the European Commission shows that there is a growing network in the SEUMS[23]. However, the coverage across the region remains incomplete; reports are not available for Greece.

The Country Reports also express concerns that the quality of data is compromised by the presence of very many unlicensed users of groundwater. As an example we reproduce the observation sent by the Italian team for their country:

In Italy, more than 3,000 points are sampled at least twice a year, and a minimum set of 14 chemical–physical parameters is compulsorily determined as well as priority substances, which can represent a critical pressure for the groundwater bodies. The hydrochemical data are classified according to a threshold approach, which takes into account the concentration of pollutants and natural substances. Owing to volcanic and tectonic activity, 28.4% of groundwater monitoring points are classified as 'peculiar' and are often exploited as thermo-mineral resources; besides, parts of the Po alluvial aquifer contain peculiar groundwater (with iron, manganese and arsenic of natural origin). Some interesting examples of the Italian approach to groundwater monitoring are the following: Umbria, managing over 100 telemetered stations at springs and wells; Venice, with the mapping of several water bodies at increasing depth; and Campania, defining the chemical status of relevant groundwater bodies at regional scale and creating an isotope laboratory[24].

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20 See section 7.3 of the Spain Country Report published on www.easac.eu.

21 See section 6.2.3 of the Italy Country Report published on www.easac.eu.

22 EU Second Water Conference (2009). Report available at: http://circa.europa.eu/Public/irc/env/wfd/library?l=/framework_directive/implementation_conventio/2009_conference/d_-_final_report/ewc2009-conf_proceedings/_EN_1.0_&a=d Summary of main findings available at: http://circa.europa.eu/Public/irc/env/wfd/library?l=/framework_directive/implementation_conventio/2009_conference/d_-_final_report/ewc2009_summary_6/_EN_1.0_&a=d.

23 EU (2009). Groundwater Monitoring Systems in Europe http://ec.europa.eu/environment/water/water-framework/facts_figures/pdf/groundwater.pdf.

24 Contribution of G Seminara to this EASAC report.

4 The economic, social and environmental value of groundwater in the SEUMS

In this section we consider what is known about the overall value of groundwater in the SEUMS, on the basis of the Country Reports (published in full on www.easac.eu).

It is certain that water has considerable economic value, although the WFD reminds us that it cannot be considered solely as an economic asset. In the case of the SEUMS, water use, in particular groundwater use, is a major factor in economic development. For some parts of the SEUMS, groundwater is the critical factor in the development of new businesses in agriculture and tourism. In Spain, for example, whole new areas have been opened for agricultural development solely because of the availability of groundwater, notably in the southern region around Almeria[25].

However, groundwater also provides several environmental services including support for surface ecosystems. These ecosystem services are important and the role they play in Europe is considered in an EASAC report on Ecosystem Services and Biodiversity (February 2009)[26]. It is noted that ecosystem services have considerable value and that, increasingly, it has proved possible to monetise this value.

In general, costs associated with groundwater use are not fully estimated at present in the SEUMS. Consequently, groundwater in general is not priced. This means that the costs of groundwater extraction, from the point of view of farmers and other users, is confined to the capital and running costs associated with boreholes, pumps and other equipment and energy supplies. The water itself has no cost to them. Regulation of extraction is therefore a matter of licensing and permitting.

However, there is an emerging and rapidly growing non-regulated sector. This has emerged in particular in Spain, where it seems that more than half of all boreholes are not licensed[27].

We conclude that groundwater has considerable value but there is no connection between this value and the price of the resource. There is therefore a risk of excessive rate of extraction in the absence of price signals.

4.1 General patterns of use

The key feature that distinguishes the pattern of groundwater use in the SEUMS is that it is predominately agricultural. This is in sharp contrast with the situation in Northern and Central Europe, where agriculture is predominately rain-fed (green water) and the principal use of groundwater is for public drinking supplies. Again, it should be noted that, in the case of water use for irrigation, most of the blue water applied is finally consumed (typically about 75–80%)[28]. By contrast, only about 10–20% of the water used in urban supply is actually consumed: the other 80–90% returns to the system, but, if it is not treated, in a polluted form. In coastal areas, the urban water waste, treated or not, is usually discharged to the sea. In this case the practical consumption is 100% of the use. However, the reuse of treated wastewater for agriculture or for other uses is increasing steadily in coastal areas of the Mediterranean.

In some parts of Southern Europe, principally in Italy and France[29], groundwater has been used in the past for industrial purposes. Although this use has declined, it has left legacy problems for these parts of the region.

4.2 General economic context: agriculture, tourism, industry/energy supply

Understanding the economic value of groundwater is not an easy task. From an ideal methodological point of view, the starting point would be to understand the value of water in general, corresponding to the willingness to pay (WTP) of each user for an extra amount of water, or alternatively by the economic damage it would suffer if left with a lesser amount of water than requested. Then, the cheapest alternative to groundwater for supplying that quantity of water should be evaluated.

However, the case of groundwater is complicated because it is readily available on short timescales over much of the SEUMS, whereas alternative sources may be available only after a costly investment is made, and even so not necessarily with the same characteristics of

[25] Hernández-Mora, N & Llamas, MR (eds) (2001). *La economía del agua subterránea y su gestión colectiva*. Madrid: Fundación Marcelino Botín y Mundi-Prensa. 550 pp.
[26] EASAC (2009). Ecoservices and Biodiversity in Europe. Report available at www.easac.eu.
[27] Llamas, MR & Custodio, E (2003). Intensive use of groundwater: a new situation which demands proactive actions. In: *Intensive Use of Groundwater: Challenges and Opportunities* (ed. MR Llamas & E Custodio), pp. 13–31. Dordrecht: Balkema.
Llamas, MR & Garrido, A (2007). Lessons from intensive groundwater use in Spain: economic and social benefits and conflicts. In: *The Agricultural Groundwater Revolution: Opportunities and Threats to Development* (ed. M Giordano & KG Villholth), pp. 266–295. Wallingford, UK: CAB International.
[28] See section 4 of the Spain Country Report published on www.easac.eu.
[29] See section 1.2.3 of the Italy Country Report and section 4.1, with Table 5, of the France Country Report, both published on www.easac.eu.

prompt availability at request. This is particularly the case for irrigation, where surface-water distribution systems normally require rotation in shifts. Water demand is highest in certain phases, especially once all expenses have already been made, and a drought might cause the destruction of a whole crop. This situation almost never occurs in groundwater irrigation and this is perhaps the main reason for the spectacular increase of groundwater irrigation during recent decades in most arid and semi-arid regions.

Another difficulty in evaluating the economics of groundwater lies in the fact that most users have little or no margin for adapting the quantity of water they use. Only in a very few cases can we imagine that users might reduce the amount of water they use; most frequently, the choice is whether to develop a water-demanding activity or not; once the activity is established, its water requirement in absolute terms is given and almost fixed. For this reason, the economic value for the same activity can vary even by some orders of magnitude, comparing an already established activity with a similar hypothetical one in a different location.

For most established uses, functions of water demand show a typical nonlinear shape: demand is very inelastic up to a threshold value, corresponding to the total economic margin generated by the activity. Above this threshold, demand suddenly drops to zero if no alternative solutions are available. Alternative supply solutions might eventually improve the raw resource productivity (that is, the ratio between how much water is finally used in the process and how much raw water is extracted from the environment). It could be possible, for example, to derive water from other sources; to change crops; to invest in more efficient irrigation techniques; to develop wastewater reuse systems and other techniques.

As long as these alternatives are available, the shape of the water demand function becomes characterised by steps, each subsequent one corresponding to the cheapest alternative to the present situation. Therefore, the value of groundwater should correspond to the difference between the total economic surplus that is generated using groundwater, less the surplus that is generated in the cheapest alternative scenario.

In practice, this kind of evaluation is uncommon. More often, what is measured, and in consequence understood, is the added value of water-intensive activities and the structure of their water demand. In the SEUMS the highest water economic productivity (that is, the total economic value of the services or goods produced by the use of water, estimated in euros per cubic metre) appears to be domestic supply (both residential and touristic), followed by industrial demand and agriculture. Within the agricultural sector, there are huge differences between water economic productivity of greenhouse products – very intensively developed, for example, in coastal Spain – of high-value crops such as fruit and irrigated continental crops of staple foods or commodities, such as cereal, maize, forage and others.

The range of values, for agriculture, can be estimated with a lower figure around €0.10–0.20 per cubic metre for commodity crops, and figures that are 10–20 times higher for other crops (Berbel Vecino & Gutierrez Martin 2004)[30].

In the case of domestic (residential) supply, the value of water can be considered as infinite, at least for basic needs.

To find out the value of groundwater, we should consider the cost of extracting it and subtract from this value the cost of the cheapest alternative source. For example, in coastal areas this might be desalination (€0.5 per cubic metre plus pumping costs) or perhaps wastewater reuse and leakage reduction in some other cases. The cost of groundwater, in turn, depends on the depth of the well (energy for pumping, drilling of the borehole) and on the composition of the soil or rock to be drilled. This varies from site to site; as a matter of comparison, according to the Italian Country Report, in many Italian projects the investment cost has been found to be in the region of €30 per hectare – almost negligible – and the variable cost in the region of €0.15 per cubic metre[31]. Large surface water systems, in turn, are characterised by very high fixed costs and low or negligible variable costs. Therefore, if a surface distribution system is available and poses no constraints, it is normally more convenient than groundwater; yet, when the infrastructure does not exist or has reached full capacity, groundwater becomes the preferable solution. The same occurs when ready and prompt availability on demand adds further value to water supply, as is normally the case in high added-value activities.

4.3 Economic value of groundwater

Across the region, as has been said, the predominant use of groundwater is agricultural. However, there are considerable differences in its relative importance in the context of water use as a whole, as Table 1 showed. The national figures, however, conceal the real economic importance of groundwater as a resource for agriculture. There are regions, notably in the arid parts of Spain, Italy and Portugal, where groundwater is the predominant source of water for agriculture. In Table 4 we have summarised the data available, recognising that it is sparse.

[30] Berbel Vecino, J & Gutierrez Martin C (eds) (2004). Sustainability of European irrigated agriculture under WFD and Agenda 2000. European Commission, DG Research.

[31] See sections 4.1.2 (page 20) and 4.2.2 (page 28) of the Italy Country Report both published on www.easac.eu.

In Spain, the economic productivity of continental agriculture (in the Spanish semi-arid interior plateau) irrigated by surface systems, is three to five times lower than that of Mediterranean agriculture (Vives 2003)[32]. Owing to the higher efficiency of water use, Mediterranean agriculture can afford the use of groundwater, which is almost entirely self-financed, whereas the full cost of large surface water systems would be totally unaffordable for continental agriculture.

The main reasons for the higher hydrological and economic productivity of groundwater irrigation, as explained in the Spanish Country Report, are the following:

(a) its resilience to dry spells;

(b) it provides water on demand for the farmer without waiting for the usual shifts in surface water irrigation systems;

(c) the farmer has to pay directly the costs of pumping energy; therefore the waste use of water is small; and

(d) groundwater irrigation is usually done by the farmers, therefore it is rarely done on land without good agricultural properties.

4.4 Services provided by groundwater

The United Nations Millennium Assessment of Biodiversity[33] drew attention to the value that humankind draws form the world's natural environment. Apart from the importance of food and products derived from plants and animals, which can be considered as economic services, there are also less obvious benefits that come from the different ecosystems that comprise the natural world. These include the regulation of climate, water and disease, and support for life including the cycling of nutrients in the environment and the formation of soils. Collectively, these benefits to humanity have become known as 'ecosystem services'. Although they appear as free goods, it is widely accepted that they have a value and there is an extensive literature on the means of quantifying their contribution to human welfare. The corresponding economic estimate of the value of France's wetlands is €345 million per year[34].

In the case of groundwater, the services include economic services through the supply of water for agriculture and other uses, and a range of regulating and supporting services. The economic services have been outlined in section 4.3. The following sections focus on the less immediate, though important, services derived from groundwater.

It is clear from previous sections that groundwater has a direct value. It increases agricultural productivity in arid and semi-arid parts of the EU and there has been a significant growth in the area of cultivation in the SEUMS as a result. However, the value of this contribution to productivity is generally not reflected in the price of groundwater. Similarly the external costs associated with groundwater use, for example impact on surface ecosystems, have never been internalised or taken into account in the cost. In many places, therefore, it is treated simply as a free good; once the necessary infrastructure costs have been met there are no additional volume-related costs.

Table 4 Economic information on groundwater use in the SEUMS

Country	Prices in domestic (range)	Charges for industrial use (range)	Estimate of value of agricultural use (range)	Charges for agricultural use	Comments/other column
France	2.5–3 €/m^3	?	0.05–0.11 €/m3	2–8% of the value	
Greece	0.4–3.14 €/m^3	0.81–0.95 €/m^3	0.1–0.3 €/m3		
Italy	0.75 (average)	—	0.015–0.1	0.006 (average)	Average, indicative values
Portugal	?	?	?	?	
Spain	0.5–2.0 €/m^3	0.5–2.0 €/m^3	0.01–15.0 €/m3	0.01–0.03 €/m3	Irrigation of Mediterranean greenhouse crops is more than 100 times as productive as irrigation of continental crops
Greece	?	?	?	?	

32 Vives, R (2003). *Economic and social profitability of water use for irrigation in Andalucía*. Water International **28**(3), 326–333.
33 Millennium Ecosystem Assessment (2000). Synthesis report available at: http://www.millenniumassessment.org/documents/document.356.aspx.pdf.
34 See section 5.6, page 29, of the France Country Report published on www.easac.eu.

The external costs, however, are not trivial. Groundwater has a value in providing ecosystem services, although these are in general less direct than those from surface water bodies and the science of quantifying them is still in its infancy.

Given, however, that groundwater has such value, European institutions need to consider what means are necessary to ensure that it is not over-exploited, including pricing mechanisms to reflect full value and externalities. Unfortunately, the authors of the Country Reports could find little evidence that this is in prospect.

5 Anthropogenic pressures and their impacts on groundwater bodies

The guidelines given by the European Commission require that the impacts produced by the different pressures on each groundwater body should be estimated. These impacts have to be compared with the ideal pristine situation of the groundwater body. Where needed, a proposal should be made for measures to recover such an ideal situation.

5.1 Pressures on groundwater arising from extraction and their impacts

In many parts of the SEUMS, the impacts of current rates of use are considered significant.

There are two main types of impact: saline intrusion into aquifers and impacts on surface systems.

5.1.1 Saline intrusion into aquifers

These are found widely in coastal regions, especially in Spain[35], Portugal[36] and Greece[37]. In some cases this degradation is due to the fact that pumping rates exceed the rate of natural recharge and seawater is drawn into the aquifer to make up the deficit; but in most cases this is caused by the lack of planning and control of the groundwater abstraction. For example, the coastal plains of Israel and southern California have been developed for more than 50 years without problems of this kind. At the last World Water Week (Stockholm, 16–23 August 2008) the Orange County of California received an award for control of seawater intrusion, achieved through a sophisticated system of artificial recharge.

5.1.2 Impacts on surface ecosystems

These are found where the pumping rate causes a decline of the phreatic surface (which normally corresponds with the water table) below the corresponding wetland. This decline can generate only a small fraction of the replenishment rate of the groundwater body related to the ecosystem. There are many recorded instances of loss of wetlands due to unplanned and/or uncontrolled pumping from aquifers. One particularly well-documented case is that of the La Mancha Biosphere Reserve in the Upper Guadiana Basin in Spain (Martínez Cortina 2001)[38].

There are also well-known cases of depletion of springs and base flows of rivers due to groundwater abstraction.

In central Italy the situation of the lakes in the volcanic area of Lazio (Albano, Bracciano and Bolsena) is of great relevance: these lakes have severe problems of water budget due to excessive groundwater withdrawal[39].

Subsidence is discussed in the Italy Country Report (published in full on www.easac.eu). In particular, for Venice, the Report notes that, 'the case of Venice Lagoon has also been thoroughly analyzed (Gatto and Carbognin, 1981)[40]: the total subsidence experienced by the city of Venice throughout the last century amounts to 14 cm, with an acceleration experienced around the 1970s when the Marghera industrial settlement was established and large volumes of water were pumped from the underlying aquifer'[41]. It can be added that, since pumping was interrupted, the ground in Venice has experienced an 'elastic rebound' amounting to about 2 cm.

5.2 Pressure on groundwater due to agriculture, industry and other human activity, and its impacts

The key pressures on groundwater from agriculture and other human activities that have emerged from this study are broadly similar across the region.

Modern industrialised farming has introduced new pressures on groundwater through the entrainment of agricultural chemicals into groundwater bodies. The degree of this pressure can be estimated from the levels of contaminants such as nitrates in groundwater. Measurements show that in many places these exceed regulatory levels, for example the levels set in the 1991 EU Nitrates Directive. Studies in Portugal show that there are many aquifers in the Algarve province where levels exceed 25 mg NO_3 per litre, and there are several where they are above 50 mg per litre[42]. In Spain some 20% of the control points, established to monitor compliance with the EU Nitrates Directive, exceeded the level of 50 mg per litre[43].

35 See section 6.2 of the Spain Country Report published on www.easac.eu.
36 See section 7.4 of Portugal Country Report published on www.easac.eu.
37 See section 6, page 19, of the Greece Country Report published on www.easac.eu.
38 Martínez Cortina, L (2001). Estimación de la recarga en grandes cuencas sedimentarios mediante modelos de flujo subterráneo. Aplicación a la cuenca alta del Guadiana. Doctoral thesis, University of Cantabria. 418 pp.
39 See section 5.2 of the Italy Country Report published on www.easac.eu.
40 Gatto P & Carbognin L (1981). *The lagoon of Venice: natural environmental trend and man-induced modifications*. Hydrological Science Bulletin **26**, 379–391.
41 See section 5.3, page 33, of the Italy Country Report published on www.easac.eu.
42 See section 6.3 of the Portugal Country Report published on www.easac.eu.
43 See section 6.2 of the Portugal Country Report published on www.easac.eu.

Agricultural pesticides are also considered a significant pressure in some parts of the region.

In some parts of the SEUMS, there are also pressures from old industrial processes, the chemical burden from which remains as a threat to the quality of groundwater. In Italy, for example, the legacy of industrial sites in close proximity to groundwater sources has led to contamination with heavy metals and other industrial wastes[44].

In addition to these chemical pressures there are also pressures from greatly increased rates of extraction of groundwater from some aquifers, particularly those in close proximity to regions of rapid agricultural development. In many parts of the SEUMS it appears that the groundwater bodies themselves are well able to sustain the levels of demand placed on them, principally because of their great volume. However, there are parts of the SEUMS where the extraction of groundwater for agriculture has impacts on surface water systems as the recharge rates greatly exceed the historic norm (see above).

In some parts of the SEUMS, notably in coastal areas and on some islands, tourism places pressures on groundwater resources through demand for water for drinking and for personal hygiene. There is evidence that in some places such pressures on aquifers are such that the aquifers begin to be recharged by seawater and become saline[45].

These pressures are, with the exception of industrial legacy, associated with activities that are projected to increase. Therefore it can be expected that they will be more significant in the effects they have on aquifers in the future. This makes it all the more important that the pressures are well understood, characterised and managed in future.

The WFD is a first attempt at doing this. However, this report suggests that the pressures in the SEUMS are such that there should be a greater emphasis on groundwater bodies in this part of the EU.

[44] See section 5.3.2 of the Italy Country Report published on www.easac.eu.
[45] See page 21 of the Greece Country Report published on www.easac.eu.

6 Current arrangements for the management of groundwater resources in SEUMS (including the extent of unmanaged exploitation)

There is a common view across the region that the current governance arrangements are not adequate to the challenge of managing groundwater resources today. In most cases, the current arrangements were set in place to cover the regulation of surface water use and are not well adapted to the specific requirements of groundwater regulation. Where there are specific measures for regulating the use of groundwater, it transpires that they have not kept pace with the rapid growth in groundwater use, in terms both of users and volumes used.

The situation is complicated by the changing shape of the communities of groundwater users. In many of the SEUMS the number of users outside the regulated community is growing rapidly. In Spain, for example, it is estimated that there are now more unlicensed users than licensed users; additionally, although it is difficult to estimate with any accuracy, unlicensed users may be using up a significant proportion of the total groundwater pumped for agricultural purposes. The situation is probably similar in Italy and Greece.

To manage groundwater resources, several tools are available, including those we list below. We have not, however, been able to form a complete picture of how they are applied in the SEUMS.

- Land-use control. In some parts of the EU, land use control is the main instrument for managing the quality of groundwater. For example, in the UK the environmental agencies have defined source protection zones for some 2,000 groundwater sources such as wells, boreholes and springs used for public drinking-water supply[46]. These zones show the risk of contamination from activities that might cause pollution in the area, including agriculture and industrial processes. It is recognised that the closer the activity is to the source, the greater the risk. Three main zones (inner, outer and total catchment) are specified, with a fourth zone of special interest, which is occasionally applied to a particular groundwater source. Controls on land use are specified, with the more stringent requirement on the closer zones.

- Controls on industrial discharges. In general in the EU, industrial discharge from large industrial plant is regulated by local pollution control legislation, with EU standards as a guide[47]. However, discharges from smaller industrial plant are in general subject to less stringent and less universal regulation.

- Controls on the use of agricultural chemicals. There are many EU measures designed to regulate the use of plant protection products, including the EU Directive on pesticide residues in food[48]. These focus mainly on action within the supply chain and there is scope for further action, for example on application rates, at local and regional level. Although it is not widely recognised as such, the problem of diffuse agricultural pollution is one of the principal ecological issues in the EU. Even after some 20 years of regulation, the chemical condition of most groundwater bodies has not improved.

- Licensing of boreholes. In many parts of the EU, including in the SEUMS, there are regimes of regulation and groundwater protection that include the licensing of boreholes[49]. However, there are considerable differences in monitoring and enforcement across the EU. Bringing more borehole owners within the licensed sector would reduce the number of uncharacterised abstraction sites as a first step towards estimating quantities drawn from groundwater bodies.

- Abstraction licensing. As a second step, attaching license conditions to the quantity of groundwater withdrawn would improve national estimates of total groundwater use.

- Artificial recharge is used in many parts of the world for improving the sustainable yield or quality of groundwater bodies by channelling excess surface water into aquifers. It has not, however, been widely applied in the SEUMS, partly because of costs but partly because it has become a matter of considerable controversy. If, however, a trend towards more arid conditions is confirmed in future, it is likely that there

[46] UK Environment Agency for England and Wales: Groundwater Protection Zones, available at http://www.environment-agency.gov.uk/homeandleisure/37833.aspx.
[47] http://europedia.moussis.eu/books/Book_2/5/16/03/02/?all=1.
[48] EU (1991). Council Directive 91/414/ECE concerning the placing of plant protection products on the market (91/414/EEC), available at : http://eur-lex.europa.eu/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=31991L0414&model=guichett.
[49] See section 1.1.3 of the Italy Country Report published on www.easac.eu.

will be greater interest in harvesting excess water and, in consequence, in artificial recharge (Miracapillo 2009)[50].

- Pricing. Where groundwater can be drawn without cost there is clearly no incentive to use it efficiently. Even modest charges associated with the construction of boreholes and abstractions can provide signals about usage that are likely to feed back into more careful use. Where costs do fall on groundwater users, in contrast with surface water users, they pay the whole direct cost of groundwater (investments, financial cost, operation and maintenance). However, they practically never pay for 'externalities', including impacts on the environment or other users. Cost signals, derived for example from a tax, might be useful in persuading users to reduce these impacts.

[50] Miracapillo, C (2009) Use of artificial groundwater recharge techniques: a task in case of aquifer exploitation or depletion. http://ec.europa.eu/research/sd/conference/2009/papers/8/cinzia_miracapillo_-_artificial_groundwater_recharge.pdf.

7 Findings

The Working Group considered the evidence from the Country Reports (published in full on www.easac.eu) and has formulated its findings as responses to several key questions.

7.1 To what extent do the SEUMS constitute a distinct region of the EU in terms of the groundwater issues they face?

- As previously mentioned, although the northern parts of Portugal, France and Italy are rather humid, SEUMS in general are defined by an arid or semi-arid geography, and there are some members of this group that cover a wider geographical range. It appears, however, that within this broad group of Member States there are particular regions characterised by the following:
    - intensive use of irrigation;
    - large number of small users, with consequent institutional challenges of regulation;
    - naturally low recharge rates.
- Climate and resource variability are similar across this region so that the groundwater issues that arise are also broadly similar. It makes sense, therefore, to treat the SEUMS, in particular the parts characterised above, as a specific region within the EU for the purposes of the WFD.
- Common pressures on groundwater, and consequent impacts, across the region include the following:
    - diffuse agricultural pollution;
    - deterioration of groundwater quality;
    - history of poor public and political awareness of groundwater (water policy has previously been driven mainly by surface water and by engineered solutions);
    - general unplanned groundwater development;
    - history of poor implementation of laws;
    - over-abstraction in some water bodies.

7.2 What are the major uses of groundwater across this region of the EU?

- Groundwater use for urban water supply generally exceeds 50%, except, for historical reasons, in Spain, where this use is less than 25%.
- The major groundwater use in the SUEMS is for agricultural irrigation (ranging up to 90%).
- It appears that over 50% of economic product from irrigated agriculture depends on groundwater, however.
- Irrigation by groundwater seems to use significantly smaller volumes than surface water irrigation for the same level of production. This is mainly because the use of groundwater, in contrast with surface water irrigation systems, has proved to be resilient to drought and easily provides water on demand.

7.3 Are there sufficient data, of suitable quality, to assess the status of SEUMS in respect of the WFD?

- It is the view of the Working Group that, given the current quality of data on groundwater resources, it will be difficult for some of the SEUMS to assess and demonstrate compliance with the WFD.
- In particular, it appears that monitoring across the region is generally inadequate to determine trends.

7.4 What are the key gaps in knowledge?

- The areas where there is a critical lack of data, are mainly related to the following:
    - total groundwater use;
    - numbers of boreholes, many of which are unregistered or illegal and which may amount to as many as half of the total;
    - detailed data on groundwater quality changes, including those related to saline intrusion (there are slightly better data in some cases, Italy for example);
    - economic data on groundwater costs and prices;
    - Interactions between surface water and groundwater.

7.5 In particular, will these countries be able to achieve implementation of the WFD?

- It is the view of the Working Group that some Member States in this group face a significant challenge in achieving full implementation of the WFD.

- In particular the following areas of groundwater status and management have been noted as problematical:
  - knowledge of the quantitative status (available reserves);
  - surface–groundwater interaction, salt intrusion;
  - improving management and region-state relationships, e.g. need for advisory boards of technical experts able to help the management and co-ordination of activities concerning the collection and management of data;
  - management of inter-regional aquifers.

7.6 What problems do the SEUMS face, institutionally and economically?

- The Working Group found a considerable difference across the region in the extent of institutional control of groundwater, with contrasting experience in the effectiveness of mechanisms designed to control use of groundwater or other pressures on it.
- In the most extreme cases, the institutional control extends to only part of the groundwater users, with a commensurate paucity of data.
- It is noted that there are many parts of the SEUMS where the value of groundwater is high in the sense that agricultural production at current levels, with the consequent economic benefits it brings, would be impossible without groundwater use. This places a high value on groundwater but, without pricing mechanisms, brings the potential danger that the common resource may become over-exploited However, the very large volumes of groundwater available in some of the concerned aquifers makes over-drafting a distant prospect in terms of its impact on the groundwater resource. The impacts of current extraction rates are more likely to be found in the damage done to surface ecosystems through induced leakage or reduced discharge to surface water. This situation demands a thorough analysis of the application sustainability criteria in the SEUMS, where economic and socio-political considerations tend to take precedence over ecological considerations.

7.7 What measures would improve the implementation status of these countries?

- It is noted that this is a complex area of regulation, in part because of the very many stakeholders affected by potential controls on groundwater abstraction.
- In the view of the Working Group, there is an urgent need for new institutions to ensure sustainable management of aquifers. Extensions of simple 'command and control' regimes are unlikely to deliver the level of compliance required for effective management.
- Because of the scale of challenge facing regulatory systems, new measures to control groundwater will require a high level of 'buy in' from stakeholders. It is likely, therefore, that such new institutions will be highly participative, in the form, for example, of self-governed aquifer management communities.

7.8 Are sufficient tools/technologies available to deal with problems where they arise or are there gaps to be filled?

- The Working Group does not view availability of technology as a barrier to implementation of the WFD.
- There are, however, developments that will support implementation and these are considered in the report.
- Research in the following areas would be particularly helpful:
  - inventory and assessment of their performance of the groundwater user associations in the SEUMS;
  - use of remote sensing to control water uses in irrigation;
  - assessment of the different hydrological and economic productivity between surface water and groundwater irrigation in the SEUMS;
  - economic studies of the value of the different water uses in order to achieve the Article 5 goal of the WFD. This is going to be done in Spain in the preparation of the Water Plans. The tool used is the water footprint tool as applied in Spain to the Guadiana Basin;
  - use of management models in a framework of uncertainty, attempting to quantify the degree of confidence to be attributed to responses obtained from the models;
  - improvement of groundwater modelling in general;
  - development of evaluation procedures for background levels.
- Training remains an important problem in the SEUMS, including that of competent technicians who are able to use software for groundwater.

8 Recommendations

- The SEUMS should be noted as a distinct region of the EU in terms of the groundwater issues they face. (It is important to note that these findings do not apply to the whole EU but mainly to the semi-arid areas where groundwater irrigation is relevant.)

- The Commission should take clear and decisive steps to enforce the requirements of the WFD within the SEUMS. The submission of the River Basin Management Plans of all the Water Districts (2009) was a crucial moment. It seems that several SEUMS have not achieved this deadline. The Commission should pursue the matter urgently.

- Arrangements for data collection and reporting should be strengthened. In principle, each significant abstraction point should be identified as a water well or group of water wells, characterized by location, estimates of the annual abstraction and data on water quality.

- The collection of socio-economic data about the use of groundwater should be strengthened, and methods should be developed that are sensitive to the many unregulated uses in some parts of the region.

- The Commission should engage with the governments of the SEUMS to develop and implement better groundwater governance in each aquifer at risk. This would require a greater consultation with, and participation of, all aquifer users.

- It is recommended that SEUMS take urgent steps to reach out to all stakeholders in the use of groundwater and achieve greater transparency about the reality of the groundwater situation in the region.

- Given the conditions in the SEUMS, and the pressures on groundwater, for example from agricultural, climate and demographic change, it is all the more important to implement the requirements of the WFD. Governments in the regions should therefore take urgent steps to address the areas of weakness in implementation highlighted by this report, including lack of data and planning for public and stakeholder consultation.

- There is a common view across the region that the current governance arrangements are not adequate to the challenge of managing groundwater resources today. In most cases, the current arrangements were set in place to cover the regulation of surface water use and are not well adapted to the specific requirements of groundwater regulation. Where there are specific measures for regulating the use of groundwater, it transpires that they have not kept pace with the rapid growth in groundwater use, in terms both of users and volumes used.

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