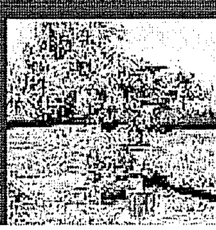
2368-00041

Natural Resource Management Standing Committee

Groundwater Quality Protection

Discussion Paper



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Groundwater Quality Protection

Discussion Paper

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[ISBN 0 9578245 4 8]

[Printed by National Capital Printing]
[Design by AFFA Public Relations]

NATURAL RESOURCE MANAGEMENT STANDING COMMITTEE

In June 2001 the Australian Commonwealth and State/Territory governments created several new Ministerial Councils from the amalgamation and redirection of the work of several existing Councils. These changes saw the winding up of the Agriculture and Resource Management Council of Australia and New Zealand, the Australian and New Zealand Environment and Conservation Council and the Ministerial Council on Forestry, Fisheries and Aquaculture, and the establishment of several new Councils among which is the Natural Resource Management Ministerial Council. The objective of this new Council is:

"to promote the conservation and sustainable use of Australia's natural resources".

The Natural Resource Management Ministerial Council, which consists of Australian Federal, State/Territory and New Zealand Ministers responsible for natural resources management policy issues has principal responsibility for, amongst other things, water issues.

The Council is supported by a permanent Standing Committee, titled the Natural Resource Management Standing Committee. Membership of the Standing Committee comprises relevant heads/CEOs of Commonwealth, State/Territory and New Zealand government agencies.

The Standing Committee agreed to release this HLSG discussion paper, *Groundwater Quality Protection*, for targetted consultation and finalisation of a Policy Position Paper for consideration by the Natural Resource Management Ministerial Council, at its second meeting in November 2001.

FURTHER INFORMATION

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1. Introduction

The 1994 COAG Water Reform Agreement required ARMCANZ to provide advice to jurisdictions on improvement in groundwater management, with particular reference to pricing of groundwater. To meet this requirement, the ARMCANZ Policy Position Paper (1996): *Allocation and Use of Groundwater: A National Framework for Improved Groundwater Management in Australia* was produced. This policy approach was confined to groundwater quantity issues. It did not consider groundwater quality protection since this had been covered in the *Guidelines for Groundwater Protection in Australia* (1995), a module in the National Water Quality Management Strategy (NWQMS).

The COAG Water Reform Agreement also required jurisdictions: "To support ARMCANZ and ANZECC in their development of the National Water Quality Management Strategy, though the adoption of a package of market-based and regulatory measures including the establishment of appropriate water quality monitoring and catchment management policies and community consultation and awareness."

Currently, the 1995 NWQMS Groundwater Protection Guidelines is the only national document specifically covering groundwater quality protection. Though it refers to a number of approaches to groundwater protection, often expressed in broad terms, the degree to which these have been taken up by States[1] is very limited and inconsistent. Moreover, the Guidelines are focussed mainly on the broad-scale protection of groundwater quality and make only limited reference to the management of groundwater near contaminated sites or to the remediation of contaminated groundwater.

There is concern among groundwater resource managers that groundwater quality protection is not being adequately addressed at the policy level. The ARMCANZ High Level Steering Group on Water has therefore prepared this paper with the aim of promoting improved protection, and where necessary enhancement, of groundwater quality.

1 In this paper the term "States" is used to denote States and Territories; "Jurisdictions" denotes States, Territories, and the Commonwealth.

2. Why we must protect groundwater quality

There is growing concern throughout the world about the contamination of groundwater as a result of human activities. Causes of groundwater contamination include use, spillage, or disposal of pesticides, fertilisers, petroleum hydrocarbons, industrial chemicals, and waste products. Contamination can also result from changes in the existing land use.

The importance of groundwater as a resource to the nation cannot be overstated. It is estimated that in the order of 30 000 000 ML/yr of groundwater is available for use. Of this, about 5 600 000 ML/yr is used. There are approximately 500 cities and towns that depend upon groundwater for drinking purposes. Almost all of inland Australia is strongly dependent upon groundwater.

In Australia, groundwater has considerable value both for its economic and social uses (i.e. drinking water, agriculture, industry, and recreation), and for its role in maintaining a range of ecosystems at the surface and below ground. The contamination of groundwater can have adverse effects on these uses, ultimately leading, as water quality deteriorates, to the groundwater being unable to support or maintain these beneficial uses. In most cases this degradation is irreversible. Remediation is very expensive and is often unsuccessful. Consequently, adequate protection of groundwater quality must be a primary aim.

Groundwater and surface water are often intimately linked, and changes to quality or quantity in one resource frequently impacts on the other. Groundwater contributes to streams, lakes and wetlands, and is particularly significant in maintaining these surface water ecosystems in dry periods. Furthermore, surface water quality can affect groundwater quality through seepage and where surface water directly enters groundwater.

Protection of surface water quality is often considered to be of paramount importance because impacts of contamination or poor water quality are readily observed. However, given the value of groundwater to the nation and the connections between surface water and groundwater, protection of the quality of groundwater should be given at least equal prominence to that of surface water. Additionally, there is a need for a greater awareness of groundwater, its key role in supporting a range of economic, social and environmental values, its significance in the hydrological cycle, and the need to protect these valuable but invisible resources.

The approach to groundwater quality protection and enhancement varies not only between States but also within them. Within some States, different agencies have differing responsibilities for groundwater quality. This gives an impression to industry and the community that groundwater quality protection in Australia is generally inconsistent and uncoordinated. It is important for groundwater management that responsibilities are clearly defined, coordinated and accepted by each agency. Furthermore, there is a "duty of care" responsibility on all agencies to act upon the information they receive.

This paper provides recommendations on key reforms required for there to be a consistent approach to improved groundwater quality protection and enhancement[2]. The scope of the paper does not cover the management of water quality changes as a consequence of salt or sea water intrusion, groundwater salinisation, or the consequences of poor bore construction.

2 "Enhancement" of groundwater quality is analogous to its "remediation"

3. Key Reforms

3.1 Fundamental Principles

A fundamental principle underlying groundwater protection is the identification and maintenance of current or potential groundwater "beneficial use" (a term analogous with "environmental values"). The benefits of groundwater use or non-use cover a range of exploitative benefits as well as a range of environmental and conservation benefits and values. These include ecosystem protection, recreation and aesthetics, raw water for drinking water supply, agricultural water, and industrial water. This is not a comprehensive list and other beneficial uses may be identified on a site specific basis (e.g. mineral water, social and cultural values).

In many cases groundwater protection is not implemented because there is no clear understanding or definition of the basis for protection, and as a consequence no identification of the beneficial use to be protected. The remediation of polluted groundwater also requires specified clean-up goals and these can be set most clearly following identification of the current and/or potential groundwater beneficial uses.

When seeking to protect a particular beneficial use, a variety of measures need to be implemented. Technically sound and appropriate interpretation of the available data should be undertaken, for example through vulnerability and risk assessment. Such an understanding is not always currently available and without it, protection measures may not be well targeted or effective. In many cases the implementation of these measures will lie with agencies responsible for land use planning.

It is essential for adequate protection of groundwater quality that the various agencies responsible for groundwater protection develop a coordinated approach as part of their duty of care responsibilities. This may require significant improvement in communication. Indeed, clear National guidelines are needed to help coordinate action between States, and to build on the collective experiences with groundwater quality protection in the various jurisdictions.

The regulatory means (e.g. prohibition of uncontrolled waste discharge, waste discharge and extraction licensing) by which the protection measures are implemented are important for promoting compliance. Economic and market measures also offer potential.

Groundwater quality protection can also be promoted by increasing public awareness. This can not only promote best practice by individuals but also encourage acceptance of, and improved compliance with, regulatory measures. Currently, public awareness of groundwater quality issues and best practices is still in its infancy.

None of these measures alone will improve groundwater quality protection. An integrated approach is required. In protecting groundwater quality, the interactions between surface water and groundwater, and between water quality and quantity must be taken into account.

Conclusion 1

Groundwater quality protection should be pursued through an approach that is:

- based on the beneficial use concept and
- implemented through an integrated approach, utilising a range of measures, including the key measures of:
    - risk and vulnerability assessment;
    - land use planning and management;
    - regulatory measures (e.g. licensing)
    - economic and market mechanisms (e.g. trading)
    - education and awareness.

The approach should also account for managing interactions between water quality and quantity and between surface and groundwater.

3.2 Impediments to Implementation

Within each State there are significant impediments to the implementation of effective groundwater protection. These include lack of technical expertise and/or number of people to identify what protection is required; poor communication between agencies responsible for groundwater protection; inadequate identification of agency responsibilities; inadequate tools for the identification and implementation of protection programs; and lack of resources or regulatory tools to adequately check compliance and enforcement of groundwater protection.

To improve groundwater quality protection it is considered a priority that States identify the impediments that hamper effective protection.

Conclusion 2

There is a need to identify impediments to implementation and enforcement of an effective groundwater quality protection program. Strategies to address the impediments and issues also need to be developed, considering the following:

- human, financial and technical resourcing
- compliance
- institutional arrangements
- availability of appropriate regulatory tools
- appropriate economic and market mechanisms
- community awareness and education.

3.3 Application of Beneficial Use

Though the Beneficial Use concept is accepted by each State, there is currently no nationally agreed approach about how it should be applied. For some States it is based almost solely on water quality criteria, in others public consultation plays an important role. In some States, classification has been straightforward, whereas in others no accepted methodology has been identified. The means by which potential beneficial uses can be identified can also be a problem since different stakeholders can have different views on how to apply the beneficial use criteria.

Risk-based approaches are increasingly being adopted for assessing the impact of point sources of potential and actual pollution on beneficial uses of groundwater, particularly within environmental protection agencies. These approaches need to be integrated within accepted groundwater quality protection policies based on the beneficial use approach so that conflicts and inconsistencies do not occur in the management of groundwater quality.

States should be accountable for the determination of Beneficial Use for all groundwater management units.

Conclusion 3

There is a need to develop a nationally consistent approach to applying the Beneficial Use. This should include integration of risk based approaches.

There is a need to develop State level programs for Beneficial Use classification for all groundwater management units.

3.4 Groundwater Management Plans

The development of groundwater management plans has been encouraged by ARMCANZ (1996) and most States are now beginning to develop such plans for important and high use groundwater resources. These plans are generally quantity focussed and are frequently dealing with over allocated systems. The 1998 NWQMS *Implementation Guidelines* propose a broad range of measures for inclusion in a groundwater quality management planning process. However, in many cases none of these activities is integrated or linked with the quantity focussed groundwater management plans currently being developed by the States.

It is considered essential that groundwater management plans also include a groundwater quality protection component. If groundwater becomes contaminated, its beneficial use may be adversely affected, and plans in relation to groundwater quantity may become redundant.

Conclusion 4

In the development of groundwater management plans, strategies to protect groundwater from contamination and maintain its Beneficial Use (including ecosystem values) should be included.

3.5 Remediation

When groundwater becomes polluted, its potential beneficial use has by definition been adversely affected. Environmental protection agencies increasingly tend to adopt a risk-based approach when assessing point source remediation goals. These do not always take account of the current or potential beneficial uses of groundwater, to the detriment of the long-term management of the resource. It is important that the risk-based approaches be integrated with groundwater quality protection policies based on the Beneficial Use concept.

Identification of existing and potential beneficial uses of a groundwater resource can be difficult, and subject to differing interpretations depending on the agency or individual viewpoint. However, it is essential that these are identified and agreed prior to setting remediation goals for locally contaminated groundwater.

It is often not technically feasible or economically viable to remediate polluted groundwater. In such circumstances, it is important to identify both the extent of the groundwater pollution, and the measures necessary to limit or restrict the long-term impact of the moving contaminant plume upon the existing beneficial uses of adjacent groundwaters and groundwater-fed surface waters. In many States, such management of polluted groundwater is not taking place.

Conclusion 5

There is a need to integrate the Beneficial Use concept and risk based approaches in the remediation of polluted groundwater.

When remediating polluted groundwater, due consideration should be given to the maintenance of existing and future beneficial uses.

State level strategies need to be developed for dealing with long term management of polluted groundwater where remediation is not effective or practical.

3.6 Diffuse Contamination

Diffuse sources of contamination are difficult to regulate since they are by their nature widespread. Unlike point sources which can be specifically targeted by regulations and licensing, the management of diffuse source contamination generally relies on a suite of large-scale planning and best practice approaches. Since the impact of diffuse sources can be widespread, specific polluters can be hard to identify, and the groundwater contamination can be difficult or impractical to clean up, the beneficial use of groundwater over wide areas can be adversely affected. It is essential for the conservation of the groundwater resource that practices are implemented which seek to minimise the impact of diffuse sources.

Conclusion 6

To address diffuse source pollution, jurisdictions need to work with industry, local government and other stakeholders to develop a suite of approaches, including land use planning and management, codes of practice, load based application approaches, economic instruments, waste minimisation, monitoring, and education.

NRMMC should co-ordinate this at the National level.

3.7 Assessment of Groundwater Quality Protection Outcomes

The effectiveness of groundwater quality management and protection relies on enforcement and a comprehensive, targeted monitoring program. Since monitoring often must be undertaken over the long term, it often suffers budget cuts or is neglected due to lack of resources. However, if baseline trends are not known, early response to potentially adverse impacts is not possible. Monitoring is a key activity to enable identification and protection of groundwater beneficial use.

There is a growing trend for companies and individuals to self-monitor groundwater where there is a potential for contamination. This places the cost on the potential polluter, but will prove ineffective if the monitoring is poorly undertaken. It is considered essential that there be improved standards and quality control placed on self-monitoring, and that there be an adequate mix of government monitoring and self-monitoring.

Also, monitoring data is frequently collected but not always analysed. Often it is not placed in an effective archive/retrieval system such that it is effectively inaccessible. For the monitoring to be of value and to serve its purpose, there should be regular reporting, review and analysis of the monitoring results. Both government agencies and the potential polluters should be subject to "duty of care" requirements. The ability for the monitoring results to be collated at State and National levels will enable auditing and assessment of the groundwater protection measures and of the quality of the groundwater resource. Public availability of the results will ensure that information of public concern is openly available, and will encourage the carrying out of duty of care responsibilities.

Conclusion 7

Groundwater quality monitoring adequate to assess the achievement of water quality objectives set for designated Beneficial Uses need to be put into place in priority areas. Regular reporting should be at the groundwater management unit scale and capable of being collated at National and State levels and be publicly available.

3.8 Tools for Groundwater Quality Protection

There are a variety of means or tools that can be used in protection of groundwater quality. The application of each tool is one element of a larger whole, which can assist in groundwater quality protection. Groundwater protection in all States would be improved if these tools were better identified and implemented.

The development of Wellhead Protection Plans around important wells, especially urban supply wells, is regarded as good practice. These plans are specifically designed to protect the groundwater from pollution, be it locally and/or regionally.

Codes of Practice are an important means by which the impact of diffuse source of pollution, in particular, can be reduced. Protection from both diffuse and point sources of pollution can be assisted through the use of land use planning control measures in combination with assessments of the vulnerability of groundwater to contamination and the risk of adverse effects. Economic instruments applied to the potential polluter, and community education and awareness are other tools that can lead to the protection of groundwater quality.

A growing practice within water resource management that can have an impact on groundwater quality is artificial recharge using potable waters or treated waste-waters. These recharge schemes are used to enhance the sustainable development of aquifers, or as part of waste-water reuse schemes. The operation of such schemes, particularly recharge using waste-waters, can be limited by environmental protection legislation on waste-water disposal, even though the impact on groundwater beneficial use may be small and transient (i.e. water is stored and then recovered). Such schemes have considerable potential benefit for water resource management and the economy generally. Since this is a practice that is becoming increasingly widespread, a national approach should be developed to ensure that artificial recharge schemes are framed within overall water quality protection strategies. These should consider the impacts on both surface water quality (which may be improved) and on groundwater quality within a single water resource management framework.

Conclusion 8

The following tools can be used to protect groundwater resources:

- wellhead protection plans
- vulnerability assessment
- codes of practice
- economic instruments
- education, community awareness and involvement
- land use planning.

In particular, there is a need for development of a National approach to the establishment and operation of artificial recharge schemes with respect to their potential impact on Beneficial Uses of groundwater.

Contribution to the

MEDITERRANEAN DOCUMENT ON GROUNDWATER 6. [for Chapter V: Institutional aspects; adding a sub-chapter on economic assessment? Or chapter II on quality?]

on

Economic assessment of groundwater protection

By

Eduard INTERWIES
Benjamin GÖERLACH
ECOLOGIC

This contribution is based on

A project financed by the European Commission

"Economic assessment of groundwater protection (ENV.A.1/2002/ 0019)

More details can be found in the following reports produced for the Commission as part of this project :

Görlach, B. and Interwies, E. (2003). Economic Assessment of Groundwater Protection: a survey of the literature. Berlin: Ecologic. (83 p.)

Rinaudo J-D. (2003) Economic Assessment of Groundwater Protection: Groundwater restoration in the potash mining fields of Alsace. Case study report N°. 1. Orléans: BRGM.

Rinaudo, J-D (2003). Economic Assessment of Groundwater Protection: Impact of diffuse pollution of the upper Rhine valley aquifer, France. Case study report N°. 2. Orléans : BRGM

Loubier, S. (2003). Economic Assessment of Groundwater Protection: a sensitivity analysis of costs-benefits results illustrated by a small aquifer protection in North Jutland region, Denmark. Case study report N°. 3. Orléans: BRGM.

Full texts of the studies available from www.agire.brgm.fr/ or www.ecologic-events.de/ecodown/

Outline

1 Economic assessment of groundwater protection

Dealing with quality, not quantity here!

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1.1 Peculiarities of Groundwater related to economic assessments

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. In this context, the presented instruments from environmental economics can then be applied in a useful manner.

1.2 The Costs of Groundwater Protection and Remediation

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1.2.1 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. Since households in most parts of Europe are 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.

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1.2.2 The cost-efficiency of different protection instruments

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. The following pages give an overview of the different instruments.

TAXES AND SUBSIDIES

In the field of groundwater protection, environmental taxes are not used widely. In principle, a tax system based on emissions represents a highly efficient instrument for groundwater protection. However, due to the associated monitoring requirements, it is difficult to implement in practice. Instead, taxes on inputs for polluting processes (e.g. fertilisers) offer themselves as a second-best alternative.

Modell-based research finds that the cost of groundwater protection taxes for diffuse agricultural pollution are generally quite low at a maximum of 4% of farm profits, even if crop yield losses and the costs of labour-intensive substitutes for fertilisation and weed eradication are included. At the same time, depending on their specifications, taxes with a comparable effectiveness impose very different costs: for example, a taxation scheme based on actual exposure values imposes costs of less than 0,25% of farm profits.

Especially in the context of diffuse agricultural pollution, there is great potential also to change incentives through a subsidy reform rather than taxation. If polluting activities are subsidised, a reduction or redirection of subsidies would have the same effect on the incentive structure as a tax would, but at a lower administrational cost. In the ongoing discussions about the reform of the EU Common Agricultural Policy, these approaches are discussed under the heading of *cross-compliance*, whereby subsidies are partly conditional on compliance with good agricultural practice standards. This instrument so far was optional only and has not been applied widely.

COOPERATIVE AGREEMENTS

Cooperative Agreements are negotiated solutions where the polluter commits himself to reducing a polluting activity, and is compensated by the beneficiary of the pollution reduction. In the case of groundwater protection, cooperative agreements are typically concluded between water supply companies and agricultural polluters. Such agreements can be very efficient, since the cost of removing nitrates or pesticides from groundwater usually far exceeds the cost of reducing applications of these substances.

Calculations for the cost of reducing nitrate concentrations through cooperative agreements in the German Bundesland Hesse found an average cost of 0.29 € per m^3 of abstracted groundwater, based on the nitrate reductions in the soil of 20 to 60 kg N/ha that were achieved through the agreement. Groundwater protection by means of cooperative agreements is thereby a cost-efficient alternative to end-of-the-pipe treatment.

A central finding from the empirical literature is that the efficiency of cooperative agreements depends on their specific design: for example, the efficiency is enhanced if compensation payments are reduced over time, as farmers successively adopt less harmful cultivation methods. At the same time, agreements need not be based on compensation payments only. An alternative compensation is training for improved fertiliser management, which brings cost savings for water suppliers as well as higher crop yields from improved fertilisation.

STANDARDS AND REGULATIONS

In most EU countries, standards and regulations have long been the backbone of groundwater protection instruments. In the case of groundwater protection, they apply a.o. to the definition of *good practice* standards, the recommendation of *best available technologies*; the *production, use, storage, transport and disposal* of dangerous substances; *bans* on the use of certain substances, and regulations concerning land use in *protected areas*.

Generally, command-and-control measures have received little attention from economists: they are regarded as fairly inefficient economically, and therefore are usually considered as a benchmark only. This is the case because standards offer little or no incentives for behavioural changes once compliance with the standard has been achieved.

However, there are some cases where command-and-control measures are clearly preferable also from an economic point of view: this is the case where pollution would lead to very large or potentially irreversible damages, and where there is large uncertainty about the effectiveness of other instruments. Standards and regulations may also be preferable if the alternative instruments are associated with high monitoring and transaction costs.

INFORMATIONAL MEASURES

Informational measures are relatively inexpensive and uncontroversial, since they neither enforce specific behaviour, nor impose direct costs on the regulated parties. They are used most effectively in *win-win*-situations, where a change in behaviour is both economically beneficial and at the same time reduces environmental pressures. In the case of agriculture, possible win-win situations arise from improved irrigation management, which saves money for the farmer, and at the same time reduces leaching of pollutants. Other win-win situations stem from more targeted fertiliser and pesticide applications. Since the environmental effects of such applications depend on the timing of the applications and on local soil conditions, targeted application of fertilisers and pesticides offers itself as a cost-effective way of reducing groundwater pollution. Therefore, informational measures represent a cheap and uncontroversial way of enhancing awareness and knowledge of different technologies.

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1.2.3 Costs of Remediation

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.

RESTORATION

Restoration measures are intended to bring a groundwater body back to its unpolluted state. They are *source-oriented*, since they aim to remove the source of contamination from the polluted aquifer or soil. In general, two broad types of restoration technologies can be distinguished: *In situ measures* that treat the contamination within the aquifer. The actual technologies used can be both biological or physical/chemical. By contrast, *ex situ measures* are measures where groundwater is treated above the ground. The most common of these are *pump-and-treat* technologies, where groundwater is pumped to the surface, treated there with biological or physical/chemical technologies, and percolates back through the soil.

In both categories, a range of technologies are available. Whether it is at all possible to restore a contaminated groundwater body, and which kind of technology is appropriate, must be assessed site-specifically. US evidence reports costs for initial investment at an average of US$1.9 million per site, with average annual operating cost of $190,000. Unit costs per 1,000 litres of treated groundwater per year amounted to annual capital costs of US$ 25 per 1,000 litres, as well as US$ 4.75 of average annual operating cost per 1,000 litres.

CONTAINMENT

Containment comprises all measures used to prevent further spread of a contamination plume by isolating, limiting and controlling the source of contamination. Consequently, containment measures are only applicable in cases of point source pollution where the pollution is limited to a relatively small area, e.g. in the case of contaminated sites. The cost and feasibility of such measures depends largely on the hydrogeological situation and the size of the contamination plume.

It should be noted that containment only prevents further spread of contamination, but does not solve the problem at its source. Experiences with the treatment of contaminated sites in the US have shown that cleaning up a site by treating the contamination is usually more cost-effective than containment: although the costs of treatment are higher initially, it is often cheaper in the long run, since containment continues to impose high running costs.

The costs for both restoration and containment options are typically variable and can amount to very large sums. A Belgian report estimates the average cost of remedial activities at €

600,000 per site, whereby 60% of all projects cost less than € 100,000. This means that the average costs for the clean-up of contaminated sites are largely determined by the few most expensive projects: the bulk of the total costs is caused by the top 3,5% of all projects, with an average cost of more than € 12 million each.

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1.3 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.

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1.3.1 Benefits estimated as Avoided Damage

A direct approach of measuring the economic value of groundwater quality is to consider the costs that users have to bear if groundwater quality deteriorates. The underlying idea is that these cost would not have to be paid if groundwater quality could be restored: therefore, the benefits of groundwater protection take the form of *avoided damage costs.* The main strands of assessing these costs are the averting behaviour approach, which measures individual expenses to avoid polluted water, and the avoided treatment cost approach, which looks at the expenses for water purification by water suppliers. A third approach, which looks at the costs of illnesses from consuming polluted water, has rarely been investigated in practice since health risks from polluted groundwater used as drinking water are normally ruled out by the quality standards and monitoring systems for drinking water.

It should be noted that all three approaches are limited to assessing the value of groundwater used as drinking water. Moreover, the value of groundwater protection is estimated only on the basis of the groundwater that is actually abstracted, and possibly also the water that will be abstracted in the future. However, the fact that a pollution reduction would also benefit the larger part of groundwater which is not used, is not considered.

Different estimates have been produced on the cost of averting behaviour, primarily on the cost of using bottled water as a substitute of tap water. Various case studies from the US and Canada report expenses in the range of 100 to 250 € per household per year.

On the cost of treatment, calculations for the whole of Austria estimate the cost at 205 to 214 million on investments for drinking water treatment, and an additional € 21,6 to 39 million in annual running costs. Of this, by far the largest part was spent on the treatment of nitrate contamination. Similar calculations for France have estimated the investment cost of installations that reduce nitrate concentrations in drinking water at up to 870,000 € per plant. The total cost, combining investment, depreciation and running costs, ranges from € 0.24 to € 0.28 per m^3 for different treatment methods, which equals € 19.20 to € 22 per person per year.

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1.3.2 Benefits estimated as Willingness to Pay

A different way of valuing unpolluted groundwater is to let individuals or households state their willingness to pay for a proposed measure that would improve groundwater quality. Such estimates are typically made through *contingent valuation* survey, whereby consumers in an area are asked to state their willingness to pay through mail survey or interviews. In order to receive more realistic answers, it is typically suggested that the interviewee would be obliged to pay the amount he or she offers to give.

A strength of this approach is that it directly addresses public concerns about groundwater pollution. These concerns need not be related to health risks only; depending on the formulation of the question and the proposed measure, it is also possible to estimate the non-use values that consumers place on clean groundwater.

A number of case studies on willingness to pay for groundwater protection have been conducted in the US. The results from the different case studies show a high variance, but usually arrive at significant results in the range between 72 and 1860 US$ per household and year, with about half of estimates ranging from 500 to 750 US$ per year. In the EU, there is much less empirical evidence on the willingness to pay for groundwater protection. The three studies we identified in this context arrived at a mean willingness to pay of 94 to 559 € per household and year. Note that, if these results are extrapolated to all affected households in the area, the potential for welfare increases from groundwater protection is substantial: one US case study argued that the implementation of a protection programme would deliver a social benefit of up to US$ 350 million.

The range of contingent valuation studies confirms that there is indeed a significant willingness to pay for improvements in groundwater quality. Hence, in the municipalities affected, stricter protection measures would enhance social welfare. Yet policy recommendations beyond the studied area are not easily derived from this: the willingness to pay has been calculated on the basis of regional surveys, taking into account highly localised demographic and geological parameters. The findings are therefore applicable only to the region where the survey was conducted - even more so if the region was chosen *because* it was affected by exposure to groundwater contamination above the national average. The transfer of results from previous case studies to other regions must be regarded with much caution. Next to methodological problems, the empirical base is considered as too small and therefore too unreliable to allow for such a benefit transfer.

Still, it can be concluded that willingness to pay is more than statistical "background noise". There are solid relations for factors that influence willingness to pay, such as income, education, and environmental awareness. People do care about their groundwater, and are willing to pay for it. In particular, there is a substantial willingness to pay for non-use values as well: groundwater protection is a concern even if there is no intention to use it.

1.3.3 Indirect and Ecosystem Values

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The concept of ecosystem benefits captures the effects that groundwater has on groundwater-dependent ecosystems. From this perspective, the benefits of groundwater protection consist in the *avoided damage* that polluted groundwater would otherwise cause to groundwater-dependent ecosystems, such as wetlands, lakes and rivers. This means that, in order to assess the ecosystem benefits, a monetary estimate is required of how the economically relevant services of the ecosystem are affected if the quality of the discharged groundwater deteriorates. In other words, the calculation of the ecosystem benefits requires two pieces of information: the value of the ecosystem itself (i.e. the sum of all ecosystem services), and the impact of groundwater contamination on these ecosystem services.

Obviously, both questions are themselves difficult tasks. On the one hand, the valuation of a groundwater-dependent wetland could be done using the same procedures that were described above for the case of groundwater. The interaction between groundwater and surface ecosystems, on the other hand, has attracted the attention of environmental economists only in recent years. Consequently, very little theoretical work has been published on the ecosystem benefits of groundwater protection (see e.g. Abdalla 1994), and even less on empirical evidence.

In the past, much empirical research has been done on the valuation of ecosystems in general. In the context of groundwater, the research on wetlands would appear to be most relevant. Unfortunately, there appears to be no empirical study so far which examines the contribution from groundwater to the value of a wetland in monetary terms, and shows how this value is affected by groundwater contamination. Therefore it is not possible to offer economic estimates of the ecosystem benefits of groundwater protection.

Different empirical estimates have assessed the monetary value of wetlands. They typically consider wetland functions such as flood control, water supply, recreation and amenity, nutrient removal and retention of toxic substances, and maintenance of biodiversity and wildlife. The reported annual value differed strongly between different studies, depending on the methods used and on the ecosystem services included in the analysis. Overall, the estimates range from US$ 1.2 to 39,777 per hectare. The European studies contained in the sample arrived at somewhat lower values, ranging from US$ 34 to 1,300 per ha and year.

1.4 Combining Costs and Benefits

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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 chose 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.

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1.4.1 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.

Past episodes of pollution also provide evidence of the evolving knowledge of the mechanisms underlying groundwater contamination, and the growing concern with its protection. By now, many decisions taken in the past would appear to be irresponsible and short-sighted. Given the limited knowledge of the dynamics of groundwater flows and the behaviour of contaminants, and the limited understanding of the interconnections between surface- and groundwater bodies, it is equally possible that decisions taken today may appear uninformed if viewed 40 years from now. Therefore, taking into account the precautionary principle, it is economically appropriate to give preference to protective measures over remediation, and to include a safety margin in setting target values.

2 Lessons learned/ implications (no Med focus yet)

- Overall, there is little experience with the application of economic approaches and tools to support policy making in the field of water protection. Even in pioneering countries such as the UK, where economic assessment of costs and benefits is mandatory for all environmental policy proposals, the experience with respect to groundwater protection is still limited. Most of the studies that have been identified were conducted by academic research teams, which tend to focus on methodological aspects only, and in particular on the development of methods to assess non-marketable environmental goods (contingent valuation, hedonic price methods, etc.).
- Empirical data concerning the costs and benefits of groundwater protection is still fragmentary and incomplete. Most existing studies focus either on the assessment of the costs or on the benefits of groundwater protection, and very few have developed a comprehensive framework to compare costs with benefits for different water protection scenarios.
- Research tends to remain very compartmentalised in terms of disciplines. Economic studies may present very sophisticated economic approaches (and models), but they rely on very simple representations of aquifers, and frequently ignore important processes. There is a definite need for *integrated research* on the economics of groundwater protection –empirical and theoretical work has focused mainly on particular aspects or instruments of groundwater protection. Concerning cost estimates, more research is needed on the efficiency of different sets of remedial measures and their integration with local hydrogeological conditions. To assess benefits, better integration with ecosystem approaches would be desirable.
- The availability of data on the benefits of groundwater protection is more unsatisfactory than concerning the costs. Benefit assessments have focussed primarily on the valuation of groundwater as a source of drinking water. More indirect benefit estimates, such as the effects of groundwater pollution on dependent ecosystems and surface water bodies, are still scarce.
- It has to be noted that economic study results are site specific. Little research has been carried out to determine under what conditions the results from site specific studies can be transferred to other contexts (meta-analyses) and most scientists are reluctant to extrapolate results. Indeed, the costs and benefits of groundwater protection are very de-

pendent on the socio-economic and hydrogeological characteristics of the study area, and by the current and future uses of an aquifer. Therefore, specific statements on the economically efficient level of groundwater protection should be assessed primarily on a site-by-site basis.

- Cost-benefit analysis often leads to an under-estimation of the benefits, in particular because of how difficult it is to estimate (in monetary terms) non-use values of groundwater. As shown by the literature review, this is especially the case for the ecological benefits of groundwater protection (e.g., for groundwater-dependent wetlands), which can be significant where groundwater bodies have extensive interconnections to dependent ecosystems. However, estimates of the contribution of groundwater to these ecosystems are rare.
- Costs and benefits of groundwater protection are very dependent on groundwater dynamics , on the fate, spread and travel time of pollutants, and on the interaction between ground- and surface water bodies. Here, the reliability of economic analysis is weakened by the uncertainty associated with our knowledge of physical and chemical processes that determine pollutant migration in the unsaturated zone
- Economics provides just one of several perspectives that can be used to assess the social desirability of various policy options. It can contribute important insights to the formulation of cost-effective groundwater protection policies. However, it should not be seen as the sole instrument for the determination of groundwater protection levels. The final decision remains a political act that has to be informed by an assessment of the impact of alternative scenarios using different and non comparable insights such as economics, ecology, human health, etc.
- It is shown show that groundwater pollution has already caused **significant direct costs** for water users. They also suggest that these costs are likely to continue increasing in the coming years because of the high inertia of groundwater systems. Therefore, a more intensive groundwater protection policy is likely to yield significant economic benefits. However, the fact that some of the benefits will be spread over a long period of time whereas costs will be immediate may reduce the political support base for the adoption of such a policy.
- **Protection measures are always cheaper than clean-up**. As illustrated by the first case study, they also avoid significant damages for current water users. From an economic point of view, this implies that a precautionary approach should be adopted in all areas characterised by a significant risk of point-source pollution. In particular, a more intensive monitoring strategy could be imposed by the GWD in zones affected by point-source pollution. The additional monitoring costs would be counter-balanced by the damages avoided (positive net anticipated benefit).
- **Areas affected by severe and historical point-source pollution should be considered separately from the water body they belong to**. As stressed above, monitoring requirements could be reinforced in such zones. The restoration targets (water quality threshold values and deadline to achieve the objective) could also be defined separately. However, the definition of less stringent objectives in these polluted areas must be justified by an economic analysis that proves that protection and restoration costs for achieving good status would be disproportionately high.