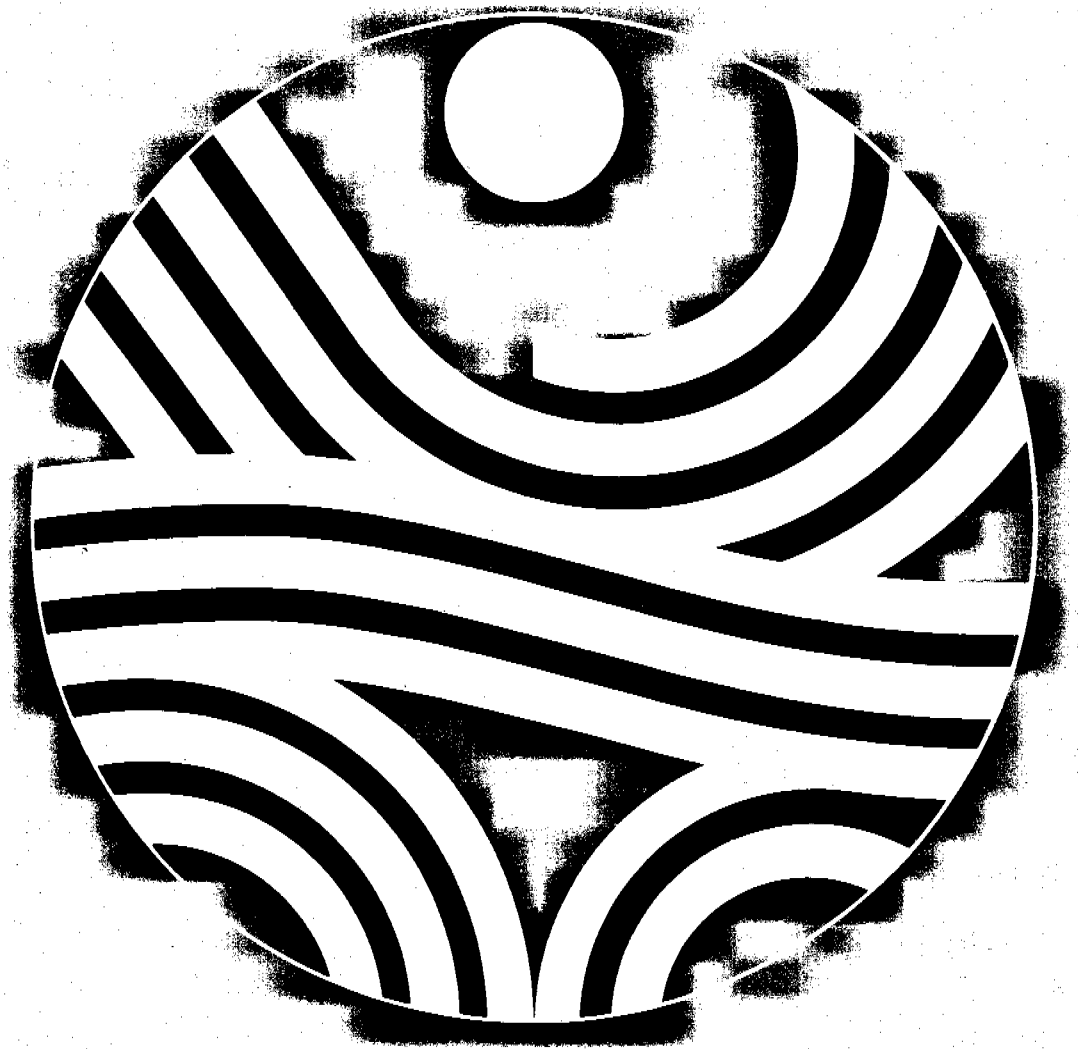


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Integrated Land-Use Planning and Groundwater Protection in Rural Areas

*A Comparative Study of Planning
and Management Methodologies*

Technical Documents in Hydrology



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Hydrological Programme
United Nations Educational,
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INTERNATIONAL HYDROLOGICAL PROGRAMME

Integrated Land-Use Planning and Groundwater Protection in Rural Areas

A Comparative Study of Planning and Management Methodologies

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PREFACE

Although the total amount of water on Earth is generally assumed to have remained virtually constant during recorded history, periods of flood and drought have challenged the intellect of man to have the capacity to control the water resources available to him. Currently, the rapid growth of population, together with the extension of irrigated agriculture and industrial development, are stressing the quantity and quality aspects of the natural system. Because of the increasing problems, man has begun to realize that he can no longer follow a "use and discard" philosophy - either with water resources or any other natural resource. As a result, the need for a consistent policy of rational management of water resources has become evident.

Rational water management, however, should be founded upon a thorough understanding of water availability and movement. Thus, as a contribution to the solution of the world's water problems, Unesco, in 1965, began the first worldwide programme of studies of the hydrological cycle - the International Hydrological Decade (IHD). The research programme was complemented by a major effort in the field of hydrological education and training. The activities undertaken during the Decade proved to be of great interest and value to Member States. By the end of that period a majority of Unesco's Member States had formed IHD National Committees to carry out the relevant national activities and to participate in regional and international cooperation within the IHD programme. The knowledge of the world's water resources as an independent professional option and facilities for the training of hydrologists had been developed.

Conscious of the need to expand upon the efforts initiated during the International Hydrological Decade, and, following the recommendations of Member States, Unesco, in 1975, launched a new long-term intergovernmental programme, the International Hydrological Programme (IHP), to follow the Decade.

Although the IHP is basically a scientific and educational programme, UNESCO has been aware from the beginning of a need to direct its activities toward the practical solutions of the world's very real water resources problems. Accordingly, and in line with the recommendations of the 1977 United Nations Water Conference, the objectives of the International Hydrological Programme have been gradually expanded in order to cover not only hydrological processes considered in interrelationship with the environment and human activities, but also the scientific aspects of multi-purpose utilization and conservation of water resources to meet the needs of economic and social development. Thus, while maintaining IHP's scientific concept, the objectives have shifted perceptibly towards a multi-disciplinary approach to the assessment, planning, and rational management of water resources.

As part of UNESCO's contribution to the objectives of the IHP, two publication series are issued: Studies and Reports in Hydrology and Technical Papers in Hydrology. In addition to these publications, and in order to expedite exchange of information, some works are issued in the form of Technical Documents.

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FOREWORD

A number of projects have been undertaken during phases I and II of the International Hydrological Programme concerning groundwater protection and pollution. Project 10.6, Integrated Land-Use Planning and Groundwater Protection Management in Rural Areas, included in IHP phase III was a follow up to the IHP II project *Impact of Agricultural Activities on Groundwater*. This monograph provides the findings of project 10.6. Both of the above projects were carried out by the Groundwater Protection Commission of the International Association of Hydrogeologists (IAH), and are a contribution by this association to the International Hydrological Programme.

The activities of project 10.6 included: organization of an international symposium, publication of its proceedings, and preparation of a comparative study on planning and management methods.

The international symposium on integrated and planned use of land and groundwater protection, was held at Karlovy Vary, Czechoslovakia, in 1986 and its proceedings were published in 1987. The symposium was organized by the IAH and sponsored by the Czechoslovak Government, UNESCO, FAO, WHO, UNEP, and several international non-governmental organizations. It was attended by 286 participants from 35 countries; 67 papers were published in the symposium proceedings.

The conclusions of the symposium form the basis of the present comparative study, which deals with the problems of integrated land-use and groundwater protection management, and related environmental, economic and social impacts. Modern scientifically based national planning and management of natural resources require a sophisticated approach and comprehensive analysis within the framework of national water policy and must satisfy both the environmental requirements and socio-economic interests of society. National groundwater protection policy and strategy should integrate both aspects. The role of hydrogeologists is to provide scientific information to enable well informed decisions to be made on protection of groundwater and the rational use of land. The main objective of this study is to contribute to sustainable land-use planning and rational management and

protection of groundwater resources, in order to meet national goals and to support economic and social development as well as environmental protection of rural areas.

Besides the listed authors, many other members of the Groundwater Protection Commission of IAH provided valuable suggestions during the preparation of this study. Stimulating ideas and recommendations concerning its content arose from discussions held during the Commission's sessions in 1987 (Budapest), 1988 (Berlin), 1989 (Skály, Czechoslovakia) and 1990 (Bilthoven, the Netherlands). Thanks are expressed to Mr. J.S. Gladwell, Project Officer, UNESCO Division of Water Sciences, who cooperated actively in the realization of the whole IHP/UNESCO project 10.6, Integrated Land-use Planning and Groundwater Protection Management in Rural Areas.

Jaroslav Vrba,
Chairman
IAH Groundwater Protection Commission

1. EXECUTIVE SUMMARY AND CONCLUSIONS

by
J. Vrba

The policy of rational planning and management of water resources, due to the impact of human activities on the aquatic system, was included in the first phase (1975 to 1980) of the International Hydrological Programme (IHP). The mounting effects of human activities on water resources aggravate many water quality problems. This is why many IHP-II projects strongly emphasised water protection, including the development of methods to prevent the pollution of aquifers. IHP-III stresses the importance of the rational management of water resources for economic and social development. Project 10.6 - Integrated Land-Use Planning and Groundwater Protection Management in Rural Areas - deals with one of the basic concepts of IHP-III. Groundwater protection must be planned and managed in an integrated manner and should take into account the relevant social, economic and environmental aspects. In this way the diverse national goals and objectives may be achieved.

This study is mainly concerned with the qualitative aspects of groundwater resources protection resulting from inadequate land-use management. Quantitative depletion of groundwater resources is also covered, with falling groundwater levels due to overdevelopment of aquifers the most common problem. The consequences for groundwater quality of poor management and uncontrolled land-use are much more complicated, long-term and may be very difficult to remedy.

1.1 BALANCING LAND-USE AND GROUNDWATER PROTECTION

The level of sophistication and integration of the planning and management of groundwater protection and land-use varies from place to place. Integrated planning incorporates and coordinates sectoral planning. It calls for a multidisciplinary approach and assessment of the requirements for land-use and groundwater protection in rural areas.

Land-use planning in relation to groundwater protection management should be seen as a dynamic process. Within it, hierarchical interests may conflict

and priorities change in terms of time (temporary, long-term, permanent) and space (local, regional, national). The social, economic and environmental impacts influence in various degrees the use and protection of land and groundwater in rural areas. These include especially the growth of rural settlements, development of local industries, the transport network, mining and processing of minerals, tourism, farming, groundwater exploitation etc. Specific circumstances based on natural conditions, cultural levels, traditional customs, and educational development of a society, as well as legislation and financial resources must be considered in order to achieve a satisfactory balance. Reconnaissance studies and assessment of land and groundwater resources should precede the planning process. Groundwater is the most important source of drinking water in most rural areas throughout the world, being the only permanent source of water in desert and arid regions. Protection and conservation of groundwater is therefore a top-priority task, particularly in such regions of limited available water resources.

Land and water planning and exploitation should be harmonized with society's interests. Their use and protection should not be seen as conflicting problems. In many parts of our planet to sacrifice water for the benefit of different uses of land and vice versa may mean the choice between thirst and hunger. It is therefore always necessary to seek the optimum consensus as far as land-use and groundwater protection are concerned.

1.2 CONSEQUENCES OF LAND-USE FOR GROUNDWATER RESOURCES

The impacts on groundwater quality resulting from poor planning and management of land-use in rural areas are manifold. The land-water system is most seriously affected by spillages of chemicals, leakages from waste disposal sites, pollution from faulty septic tank systems and various agricultural activities. Problems posed by agriculture have increased in range and intensity in many countries during the twentieth century. Examples include changes in the structure of land-use, such as the uncontrolled destruction of forests and the ploughing up of natural grasslands to grow arable crops. Certain methods of irrigation and excessive application of fertilizers are also causing serious damage to both land and water in many parts of the world. The use of pesticides and herbicides are another source of concern, as these have often been used

without consideration of their wider and long-term effects. Lowering of the groundwater level by mines and the overpumping of aquifers have led both to quantitative and qualitative impacts on groundwater resources.

The effects of diffuse pollution from farming (fertilizers and pesticides) on groundwater quality is an especially serious problem in many European countries and in some parts of the USA. They result from intensification and specialization of agricultural production, in which the traditional crop rotation has been replaced by monocultures and intensive breeding of a single species of animal. The economic interests of agriculture usually have been given unquestioned priority without concern for the environmental impacts. This is particularly the situation when the consequences for groundwater quality of an unsuitable fertilizer regime were not immediately obvious. The management and control of the agro-groundwater system is a complex task of general interest and great practical importance. It requires a specific approach and solution in each region and a comprehensive analysis of the physical and socio-economic aspects of those farming practices that affect groundwater resources. This enables the adoption of a systematic approach, and establishment of strategies and policies in the utilization and protection of land and water.

1.3 DATA REQUIREMENTS AND DATABASE MANAGEMENT

Frequently, representative data are missing for decision-making on integrated land-use in respect to groundwater protection in rural areas. There are no organisational structures in many countries responsible for the operation of monitoring networks, nor integrated databases for the different components of the environment and sources of existing and potential pollution. Information and communications systems are underdeveloped. Moreover, frequently, there is a shortage of specialists able to apply the data obtained from the monitoring activities.

A well developed and integrated monitoring system, including observations of the natural processes and human impacts that affect the use of land and groundwater, can help enhance antipollution policies and strategies. It assists planning and management of land-use and groundwater protection and enables anticipation or alleviation of threatening problems of groundwater pollution. It also permits the study of the time and spatial changes in the

physical, chemical and biological composition of a groundwater system. The benefits derived from the money spent on the design and operation of monitoring networks and analysis of monitoring data, must be weighed against the value of the information obtained. It is therefore generally accepted that a monitoring programme is only beneficial if the data it yields are applied and used for decision making.

It is particularly important to monitor the processes that take place in the unsaturated zone so as to allow preventive protection of groundwater. Unfortunately, routine monitoring of this zone has so far been performed only in exceptional cases.

The importance is stressed of sampling techniques that are used to obtain representative water samples from a pre-defined depth of the aquifer (vertical profiling). The sampling frequency, appropriate density of monitoring stations in local and regional networks, and special requirements for the design and screening of monitoring boreholes are also emphasised.

Integrated automatic pilot monitoring stations are an essential requirement for the collection of representative data on behalf of rural communities. These stations provide the necessary quantitative and qualitative data on air, water and soil. They provide valuable information both in areas of intensive human impact and areas still with natural conditions. Data acquisition and the related database management are part of the activities and responsibilities of local and regional government. They are designed to implement a comprehensive water and land-use strategy and policy that will lead to the management and control of integrated land-use and groundwater protection programmes.

1.4 LAND-USE PLANNING AND GROUNDWATER PROTECTION MANAGEMENT

Land-use planning and groundwater protection management in rural areas is not an isolated programme. Rather it is an integral part of regional and national economic and environmental policies and strategies. Specific site land-use and groundwater protection programmes should be based on scientific and technical analysis of the rural area studied, but should simultaneously respect the goals, objectives and peculiarities of each rural community. These need not be identical with the regional or national interests and

requirements. By the same token, the hierarchy of local priorities, preferences or potential conflicts may follow a different time-scale than the same aspects on a regional level. Soil and water resources in rural areas generally should not be used for the benefit of a region or country without the consent of, or compensation to, the rural community in question. However, cases will exist where regional or national interests may override the local ones (for example extraction of an economically important mineral deposit, development of groundwater and its transport to other regions etc.). What is important is that the local population be informed in time of the reasons and the plans for land-use, and that it morally - perhaps even financially - supports the implementation of such programmes and projects, or that it has a certain profit from them. The complex and integrated nature of the problems that occur in rural areas require a multidisciplinary approach based on the modelling of alternative scenarios of the current situation, predictions of the likely future state, and application of the process of analytical hierarchy.

Systematic, scientifically based planning is essential for rational integrated land-use and groundwater protection. The failure to consider an integrated approach to the use and protection of natural resources will have long lasting environmental, social and economic consequences. Remedies are technically and financially demanding, and usually time consuming. Cases are all too numerous where the deterioration or even destruction of a local or regional groundwater system is so extensive that it cannot be rectified on a human time-scale.

1.5 GROUNDWATER PROTECTION

In the past, protection of groundwater from the impacts of human activities was not included in national water management plans. Nor was it an integral part of regional hydrogeological investigations and development of groundwater resources. The main reasons for neglecting groundwater protection included:

- . groundwater is not a visible resource;
- . aquifer response to pollution usually is not immediate;
- . deterioration of groundwater quality was not identified due to the lack of groundwater quality monitoring systems and networks.

In the 1950s it began to emerge that groundwater was at risk and not a guaranteed safe source of water. Groundwater pollution and depletion observed during the past few decades, especially in developed countries, was having serious consequences in the environmental, economic and social spheres. Considerable financial resources had to be spent on the treatment of polluted groundwater used for drinking purposes, or on the transport of drinking water to regions in which aquifers had been polluted or depleted.

Groundwater protection policy and strategy should be based on the concept that prevention of pollution is always less expensive than aquifer rehabilitation - a costly, long-term and technically demanding task. Groundwater protection is not an isolated action but a long-term and multidimensional programme. It comprises research, mapping, monitoring, modelling and analysis of the changes and processes that take place in a groundwater system.

Groundwater protection strategy should also be coordinated with the protection of the remaining components of the hydrological cycle, land-use planning and abstraction of other natural resources. This enables their rational development and better allocation. Risk analysis, based on modelling and forecasting of different scenarios, enhances decision-making on the integrated use of land and natural resources which must include groundwater use and protection.

Groundwater resources vary in their quality and vulnerability, and possess different environmental and socio-economic values on regional and local scales. The criteria for defining the management of groundwater protection in relation to land-use therefore differ from one locality to another. They can only be determined on the basis of adequate knowledge of the natural conditions, taken together with a full and accurate listing of the human impacts on the groundwater system in question.

Two categories of groundwater protection management exist: general protection and comprehensive protection.

General protection covers both the exploited and the so far untapped resources. The criteria for general protection of a groundwater system are usually set in national and regional water management plans. The strategy

of general protection is based on good knowledge of the parameters of the saturated and unsaturated zones of the groundwater system and its vulnerability. It includes assessment of existing and potential pollution sources, analysis of the data obtained from groundwater quality monitoring networks and systems, and careful checking of legislative measures.

Comprehensive groundwater protection deals with public water supplies and can have a major effect on the use of land in rural areas. The delineation of protection zones - usually at two or three levels around water supply systems - is obligatory in many countries. For areas with these protection zones, changes, restriction or even prohibition of certain human activities are stipulated. Therefore the benefits and costs of land utilization and groundwater protection must always be defined simultaneously with the delineation of these zones. The residence time of diffuse pollution sources (particularly pollution of an aquatic system due to an incorrect regime of fertilization) and non-degradable persistent pollutants, must be investigated and evaluated with special care as they determine the extent of the protection zones. Delineation of these zones requires the use of up-to-date methods and techniques to minimise the degree of uncertainty in their definition.

Internationally agreed scientifically based procedures, guidelines and standards for the delineation of groundwater protection zones which adequately take into account environmental and socio-economic requirements are desirable.

1.6 LEGISLATION AND REGULATION

Legislative measures based on water and environment acts are essential for implementing comprehensive groundwater protection strategies and policies. Water acts - often covering both surface and groundwater - have already been adopted in many countries. They are necessary so that national, regional and local government may have the authority to enforce groundwater protection. Water acts should be supplemented by the relevant regulations, codes and standards that are essential for effective protection of groundwater. Legislative measures should cover not only the protection of utilised groundwater resources but also so far untapped sources. In only a few countries is the water act linked with the environmental, and

socio-economic consequences of groundwater protection. Legislation on water protection should be reviewed and updated at regular intervals (maximum ten years). The principal purpose of water legislation is to ensure continued good quality water for the benefit of the present and future generations.

Special attention should be devoted to regulations concerning the licences and permits for groundwater abstraction, to prevent depletion of groundwater resources and impacts on surface streams, soil humidity and vegetation.

The regulations on groundwater quality protection should first of all define the responsibility of polluters, determine appropriate penalties and outline satisfactory arrangements for the discharge of wastes. Within the anti-pollution programmes, various incentives should be introduced. Examples include tax relief or low interest loans, for the construction of water treatment plants and waste-free industrial facilities, or grants for the construction of recycling systems etc. Incentives to encourage alternative farming methods using less inorganic fertilizers, changing to an organic system of farming or even set aside should also be provided.

Where the polluter of groundwater is known, it should not be the general rural population which has to bear the financial burden. The responsibility for providing alternative water supplies should be that of the polluter (the polluter pays principle). However, it should be emphasized that sanctions are only a temporary tool rather than a long-term solution to the problem of groundwater quality protection and conservation. The protection of groundwater must gradually evolve into prevention, and this process must be strongly supported by legislation. In several European countries and in North America, legislation and regulations solely to protect groundwater have been appearing since the 1970s. Regular field inspection to monitor compliance with water protection legislation is essential.

Another important aspect is international responsibility and cooperation in the protection of groundwater resources from transborder pollution. This is contained in the conclusions of the Helsinki Conference (Helsinki Rules, 1966): "Each basin state is entitled within its territory, to a reasonable and equitable share in the beneficial uses of the water of an international drainage basin".

1.7 IMPLEMENTATION MEASURES

The implementation of regional or local development and environmental programmes requires the setting up of institutional and organizational arrangements. These should be operationally independent and be responsible for the planning, policy, strategy and management of integrated land-use and the protection of groundwater resources. Well planned institutions with clearly defined responsibilities play an important role in the protection of groundwater systems. A multidisciplinary and intersectoral approach is especially important. This also requires representative data obtained from monitoring networks, easily accessible databases and a smooth transfer of information. Budgeting and accounting procedures and availability of trained manpower are important when implementing such programmes. Participation of the rural community is very desirable, and public wishes and fears should be taken into account by decision makers.

The programme of integrated land-use planning and groundwater resource protection and conservation in rural areas is constrained by several factors. These are economic, socio-political and technical, and sometimes take priority over environmental considerations. Such is the case of soil and water, the key natural resources for sustaining human life. Both are non-renewable and usually highly vulnerable. The two resources often are still being exploited intensively and in an uncoordinated manner, with serious consequences for their quality (destruction of the soil organic matter, groundwater pollution). The environmental impacts of the use of soil and groundwater need therefore to be assessed in order to alleviate or mitigate the adverse effects. This is not always possible. For example, assessment of the social consequences of living in areas with an impaired environment is only rarely part of a cost/benefit analysis. The incidence of disease, death rates, psychological effects, human migration etc. are intangible factors. They do not lend themselves readily to conversion to financial equations on balance sheets.

Achieving the balance between land-use and groundwater protection puts heavy demands on technology, human energy, finances, legislation, and control and inspection systems. A properly functioning monitoring system is the final link in the process of integrated land-use and groundwater protection. It is the best guarantee that measures for pollution prevention are observed

and the environmental and socio-economic benefits for the rural community will be attained.

1.8 PUBLIC INFORMATION AND EDUCATION

Public information and education programmes concerning integrated land-use and groundwater protection should cover schools, the general public, policy and decision makers, and land-users, especially farmers. Because it is unseen, groundwater is a resource of which the general public is largely unaware, which results in little thought for its protection. Mass media - press, radio and television - are powerful tools for public environmental education. However, the educational programmes must be presented in an easily understandable form, making full use of attractive visual aids.

Good scientists may not always automatically be good communicators. They often require special training on how effectively to present information to the public.

Special efforts should be made to ensure that regional and local government decision and policy makers are kept well informed of the importance of groundwater protection.

Public education should be systematic and well organized. Environment ministries or agencies should play an important role in public environmental education for they are recognised by the population as competent authorities with skilled experts at their disposal.

The scientific and technical quality of the information must be good and relate to the level of knowledge possessed by the group of people to whom it is addressed. Delay in providing information to a rural community, on the environmental plans for their region, leads to numerous misunderstandings. This can result in serious problems arising between the population and the local/regional government. The use of maps, graphs and tables for communicating information is often helpful.

Regular exchange of information is very necessary amongst scientists at both national and international level to avoid duplication of research. International scientific journals, as well as scientists' attendance at

international conferences, symposia and workshops are all valuable ways of keeping people up-to-date with technical and administrative procedures.

Public understanding and support of the need for environmental programmes is very important. This is especially true where sizable expenditure and restrictions in land-use are involved. Such support is most likely to occur when people are confident they are being kept fully informed by the authorities. Potential conflicts and misunderstandings, within the sphere of environmental protection, are likely to be minimised by using this approach.

2. BALANCING THE REQUIREMENTS OF LAND-USE AND GROUNDWATER PROTECTION IN RURAL AREAS

by
J. Hahn

2.1 INTRODUCTION

The conflict between utilisation of land and protection of the environment has existed ever since humanity ceased to rely for its needs solely on natural ecosystems. In moving from the stage of hunter and gatherer, through selection, breeding, and intensification of production of useful plants and animals, humans have made ever increasing demands on the natural environment.

This "agricultural revolution" was the starting point for securing and raising food production and so encouraged settlement, population increase, division of labour and the formation of organised states. Simultaneously, increasingly massive inroads were made into the natural environment. Ever increasing requirements of space for ever growing settlements demand additional nutritional resources, creating special needs and more intensive use of available space.

Even early cultures record water damage amongst the first effects of intensive utilisation of land. This showed itself in the first instance, by increased salinization of soil and in the reduction of the quality of groundwater. Family and village wells became polluted by infiltration of effluents from houses and the keeping of domestic animals.

Due to the rapid increase in the Earth's population, environmental pressures accelerated worldwide. Increased demands were made on rural space by industry, traffic, tourism, exploitation of mineral resources and groundwater use, thus exasperating the competition for ever shrinking space.

The quality of groundwater, the most important and enduring foundation for the provision of drinking water for the population, thus became increasingly endangered by the effects of diverse, partially overlapping uses of the

available space.

2.2 LAND-USE AND GROUNDWATER

Groundwater is formed by percolation through the soil of precipitation and surficial water. Thus the water acquires its chemical character essentially by passing through the living soil and the unsaturated zone, from which it dissolves not only naturally present constituents, but also artificially incorporated pollutants. Depending on the amount of precipitation, aquifers frequently require many 100km² in area for replenishment, to service human requirements. Dominant influences on the quality of groundwater are those uses of large areas of land which introduce possible pollution, such as agriculture. Point sources of pollution such as waste from mineral excavations, waste disposal sites, small settlements and toxic accidents, not only may cause concern locally, but may contribute considerably to general damage to the overall quality of the groundwater.

The direct and indirect transfers, accruing to groundwater from different land-uses, are very numerous and complex, affecting both the quality and the quantity of groundwater. Table 2.1 can but indicate this multiplicity. Not least, because the various uses and incursions frequently overlap, so that the deleterious effects can cumulatively enhance each other. Similar tables could be constructed showing the consequences for soil and landscapes, as well as the dangers to the economic, cultural and healthy development of the population. These entail an uninhibited overlap of the various demands made on a region.

Unfortunately these interconnections are often not yet realised, are underestimated or in order to reduce costs are just ignored. Sometimes, it may be apparent in the initial stages of proposed projects that the short-term economic profit will cause serious damage in the long-term for the population and for the regional economy.

A study of the relevant laws of different countries, including those of the economically less developed, shows surprising care is lavished on the protection of land and groundwater. In practice however, one realises very quickly there is an enormous gap between theory and reality. This is due to the simple fact that "no judge is required, if there is no plaintiff".

Table 2.1 Land-use effects on groundwater quality and quantity

+) these are uses that change the composition of the water directly or indirectly.

++) A: quantitative effect on ground and surface water.

B: qualitative effect on ground and surface water.

CAUSES +)		CONSEQUENCES	++) Effects
<u>Construction</u>			
- industry	sealing of surface	reduction of infiltration and recharge	A
- trade	excavations	lowering of groundwater level	A
	high-rise building		
- settlements	- building on floodplains	increase in the quantity of run-off	A
	- production, use, storage and transport of potentially polluting liquids	introduction of	
	- cemeteries	- pathogenic organisms (eg salmonella)	B
	- emissions into the atmosphere	- hydrocarbons (eg oil, petrol etc)	B
	- introduction of heat from cooling facilities	organic substances of human or animal origin	B
		poisons like: As, Se, Cd, Cr, Hg etc	B
		alteration of the water temperature and therewith	B
		reduction of the self cleaning cycle	
<u>Refuse disposal</u>	- leaking disposal sites	infiltration of polluted water into ground and surface water	B
<u>Waste water disposal</u>			
	- introduction of waste water seepage	introduction of pollutants or poisons	B
	- introduction of waste heat	alteration of water temperature	B
<u>Energy production</u>			
	- need for cooling water	reduction of quantity of drainage	A
		lowering of groundwater table	
	- emissions into the atmosphere	introduction of pollutants via air into water	B
<u>Fisheries</u>			
	- siting of fishponds in regions with wells	- introduction of nutrients, interruption of ecosystem	B
	- stocking procedures	- changes in the composition of the fauna and flora	B
<u>Leisure pursuits</u>			
	- certain sports	reduction of infiltration by soil compaction	A
		aquatic sports: pollutants (eg Cl ₂)	B
	- allotments	introduction of fertilizers	B
<u>Agriculture</u>			
	- irrigation, drainage, alteration of crop growth	alteration of established run-off, increase in seepage	A
	- river regulation	rapid water removal	A
	- fertilizers, slurry disposal, use of insecticides, storage of potential water pollutants	Introduction of: pesticides, herbicides, insecticides and inorganic ions like Cl ⁻ , NO ₃ ⁻	B

continued next page).

Table 2.1 Land-use effects on groundwater quality and quantity (cont.)

+) these are uses that change the composition of the water directly or indirectly.

++) A: quantitative effect on ground and surface water.

B: qualitative effect on ground and surface water.

CAUSES +)	CONSEQUENCES	++) effects
<u>Production of raw materials</u> <ul style="list-style-type: none"> - Large-scale production of sand and gravel - mismanagement of water resources - change in flow direction of groundwater - exposure of groundwater - decrease or removal of protective cover 	<ul style="list-style-type: none"> - change in the direction of groundwater flow - lowering of groundwater table - water loss due to evaporation - increased access by pollutants to groundwater 	<p>A</p> <p>A</p> <p>A</p> <p>B</p>
<u>Supply of drinking and domestic water</u> <ul style="list-style-type: none"> - excessive demands 	<ul style="list-style-type: none"> - lowering of groundwater table - reduction in the quantity of run-off - upward trend of deepseated, salty groundwater 	<p>A</p> <p>B</p>
<u>Transport</u> <ul style="list-style-type: none"> - sealing of surface - damming or interruption of groundwater flow by underground construction (eg Metro) - salting of roads, accidents, road-cleaning 	<ul style="list-style-type: none"> - reduction of infiltration - rise in run-off - introduction of salt, petrol etc 	<p>A</p> <p>A</p> <p>B</p>
<u>Construction connected with water</u> <ul style="list-style-type: none"> - damming surface water - lowering riverbeds for the purpose of flood control - regulation of riverbeds, shortening of riverbeds - riverbed and bank consolidation, construction of regulation profiles - piping, dam construction 	<ul style="list-style-type: none"> - alteration of run-off conditions - reduction of infiltration - loss of flood plain, rise in flow velocity - more difficult hydraulic connection of groundwater with surface water - total prevention of such hydraulic connection 	<p>A</p> <p>A</p> <p>A</p> <p>A</p> <p>A</p>

Plaintiffs, who even in industrialized countries, occasionally put their faith in the efficacy of the divining rod and who credit mother nature with supernatural abilities to cleanse pollution and, who moreover cannot comprehend that clear water can in fact be highly polluted, indeed make poor prosecutors! The prerequisite for the protection of a natural resource is the acknowledgement of the existence of that resource; both its extent and composition. This requires exploration and supervision, as well as an interdisciplinary consensus on how the resource can be used safely by competing interests in one and the same region.

2.3 GROUNDWATER PROTECTION THROUGH REGIONAL PLANNING

The difficult task in accommodating the various demands for the use of available space, whilst at the same time preserving the land and protecting the groundwater, can only be achieved through an integrated effort embracing local, regional and national planning. Priorities should be assigned at the planning stage and adhered to.

In this respect the geosciences have a decisive role, since they possess or are able to obtain information, on the main relevant factors. These include the occurrence and size of economic deposits, soil types, building or construction materials and above all the availability of groundwater and the natural conditions for the latter's protection. It is therefore necessary to compile this geoscientific data in order to make it available to planners. After all planning considerations can only contend with what is actually known, quantifiable and warranted.

Hydrogeological maps are of great importance for the preservation and protection of groundwater resources. A proven example are the maps of the nature potential of Lower Saxony and Bremen, on a scale of 1:200,000. The groundwater map of this series contains indications of the area needed to recharge groundwater, the conditions for its protection, the transmissivity of aquifers, natural salinity, and the groundwater level. It also includes the location of the discharge areas of individual existing water sources, as well as potential ones. Further information can be deduced.

Other maps in the same series portray the geology, soil types, building and construction materials, near-surface raw materials, including classification

of their economic importance, and deposits at greater depths like ores, solid fuels, salt, oil and gas.

Those areas, both existing and potentially possible as recharge areas for aquifers, were specially marked on a regional plan and classified as priority groundwater regions. Future competing options in these regions are not meant to interfere with the planned priority of the provision and protection of groundwater.

These hydrogeological data are incorporated in a "Water Economy Plan" which shows the countrywide groundwater resources, as well as the possibilities regarding the quantitative and qualitative use of their measured availability.

The hydrogeological delineation and planned protection of groundwater bearing regions potentially suitable for use, is a first step towards assigning priorities in groundwater protection.

This enables the decision maker to forestall new ventures that are contrary to established utilisation options or requirements. Unfortunately the lack of clear demarcation of groundwater resources, as well as their inadequately known extent, frequently endanger the adoption of measures to prevent pollution or enable rehabilitation of degraded groundwater.

2.4 GROUNDWATER PROTECTION AREAS

More readily identifiable and less costly measures of protection are possible, if a clearly defined catchment area is considered. The location of wells and the quantity of withdrawal should be established at an early stage, which however presupposes a thorough knowledge of the groundwater occurrence, as well as the natural conditions of protection which are present.

The demarcation of such a "protection area" follows the identification of an actual or planned withdrawal of a given amount of groundwater and should contain the entire recharge area inclusive of existing aquifers. The protective measures attempt to ensure that continually pure groundwater is available in the source area. This does not require however, that the

groundwater is equally protected in all parts of the catchment area.

(For a more detailed description of groundwater protection areas see chapter 6).

2.5 GROUNDWATER PROTECTION THROUGH INVESTIGATION OF ENVIRONMENTAL COMPATIBILITY

Preventive measures for the protection of the environment, requiring an interdisciplinary assessment and planned decisions regarding utilisation of land, are contained in the EC - Directive 85/337 of 27.6.1985. This directive "on the assessment of the effects on the environment of certain public and private projects" starts with the assumption that overloading the environment should be avoided in the first instance, rather than subsequently attempting to remedy initially faulty decisions.

According to this directive permission to proceed with public or private projects that are liable to cause considerable damage to the environment should only be allowed after the possible environmental impact has been properly assessed. In the course of such an inquiry the direct and indirect effects of the project on land and water should be identified, described and examined. This legal basis of preventive measures to protect both land and groundwater introduces a novel quality in the protection of groundwater. It ensures the input of competent specialists so that questions regarding groundwater are treated seriously rather than, as was frequently the case, in a cavalier fashion.

2.6 FUTURE TRENDS

The scientific and technical state of mankind offers numerous possibilities for the simultaneous utilisation of a given region and the assessment of the diverse claims made on that region. The complex relationships require however, interdisciplinary collaboration of specialists in order to deal with the dynamic interdependence between land-use requirements and groundwater availability and protection. In this way the manner and type of potential conflict can be properly assessed. In order to achieve the goal to minimise harmful human impact on groundwater, it is essential to curtail certain user claims or to decide on a clear sequence of priorities.

The availability of groundwater of an irreproachable standard constitutes part of the very quality of human life. The difficulties and cost of treating dirty water and the impossibility, even in the medium-term, to rehabilitate polluted groundwater systems should encourage us to understand the vital need of maintaining the good quality of groundwater resources.

3. CONSEQUENCES OF LAND-USE FOR GROUNDWATER RESOURCES

by
S. Kaden

3.1 INTRODUCTION

Human activities associated with changes in society and, often combined with inadequate land management, affect adversely the recharge, storage, yield and quality of water. In many countries groundwater quality has been degraded and the quantity available reduced. Large-scale changes in land-use and widespread felling of virgin forests have led to serious erosion of soil and regional changes in water balance (LaMoreaux, 1987). The impact of such human activities have a global significance both for future socio-economic development and for the environment.

The consequences for groundwater resources of inappropriate planning and use of land are manifold, depending on natural, environmental and socio-economic conditions. This chapter summarises the major impacts and consequences and provides examples. Some of the impacts occur not only in rural areas but also in urban or industrial regions. Moreover, activities in industrial areas may affect significantly the environment and way of life of those living in rural areas. Figure 3.1 gives a schematic overview.

3.2 GROUNDWATER DEPLETION CAUSED BY OVERPUMPING

One of the main threats to groundwater is overpumping. Dense and rapidly increasing population requires both large amounts of drinking water and water for industrial and agricultural purposes. In many countries groundwater is the main source of water supply in rural areas. Widespread overpumping may produce a number of undesirable consequences, such as a reduction in the available water supply, deterioration in water quality and increased pumping costs.

Depletion of unconfined aquifers and especially of artesian aquifers in large basins, leads to increased additional costs as a result of longer and more complex pumping and more sophisticated equipment. A good example is

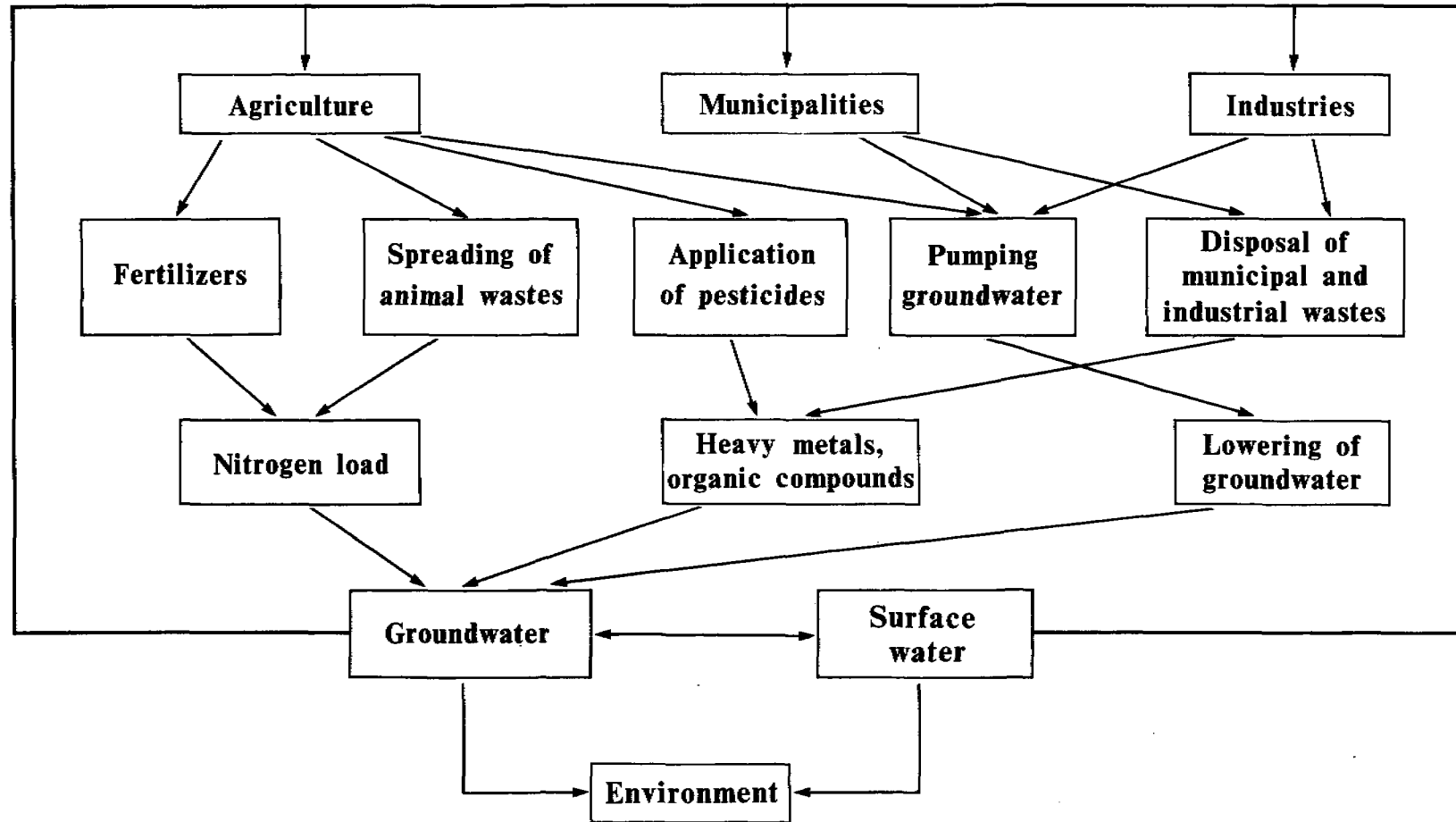


Figure 3.1 Interaction of land-use and water resources.

provided by van der Gun (1987) in his description of the situation in the Yemen Highland Plains:

"Depletion of the groundwater resources is a serious threat for all these zones: public water supply will become increasingly difficult, the viability of groundwater-irrigated agriculture will gradually decline and in extreme cases the resources may be completely exhausted".

Another consequence of overpumping of groundwater resources is saltwater encroachment in coastal zones. In this case quantity problems are accompanied by quality problems of groundwater degradation, (Custodio and Bayo, 1987).

In some regions drainage from surface mines (e.g. lignite mining) may result in the formation of large cones of depression, lowering the groundwater level over wide areas by tens of metres. Side effects include the extra cost of water supply (municipalities, agriculture and industry) in those regions (Orlovski et al, 1986).

3.3 GROUNDWATER DEGRADATION DUE TO IRRIGATION

Intensive irrigation may result in the salinization of large tracts of land as well as of groundwater. The environmental problems of irrigation can be extreme, especially in sub-tropical regions. Indeed, as much as half of the world's irrigated area may already have been damaged to some degree by water-logging or salinization. In Pakistan, out of a total of 15 million ha of irrigated land, as much as 11 million ha are already affected by salinization (Singh and Afruz, 1987).

In regions with insufficient water resources for irrigation, municipal effluents are frequently used for this purpose. In such cases the danger of salinization and groundwater pollution is even higher (Kaplin and Shandybin, 1987).

3.4 GROUNDWATER POLLUTION

Groundwater pollution is usually classified according to the type of

source; non-point (diffuse), linear and point pollution. In rural areas, non-point and point sources are the most common but linear sources can cause local pollution (leaking pipelines, transport systems etc.).

Non-point pollution, caused by the large-scale application and/or the improper use of fertilizers and pesticides, typically occurs in areas of intensive tillage in developed countries.

Excessive application of nitrogen fertilizers has drastically raised the nitrogen level in groundwater in many regions. As a result groundwater sources are frequently qualitatively affected. Mixing, treating and even abandoning existing water supply wells all are possible solutions. Provided sufficient low nitrate water is available, mixing with the high nitrate water often is the simplest and cheapest method. There are close relationships between the type of land-use, land management, hydrogeological conditions and nitrogen leaching, as explained in chapter 5.

The application of pesticides is one of the sources of raised organic compounds in groundwater. For example in 1986 in the USA, traces of 17 pesticides were detected in the groundwater in 22 States (Holden, 1986). In many parts of the world, this remains a hidden problem. The reasons are lack of awareness, shortage of sampling equipment, inadequate monitoring of groundwater quality and insufficient laboratory facilities for water analysis.

Spreading of manure and wastewater on arable land are other typical sources of pollution of groundwater resulting from agriculture.

In some regions non-point pollution from agriculture is aggravated by air pollution (acidification of the soil-water). The effects of acid rain are especially serious in regions where the natural conditions are already acid and thus lack the capacity to buffer the acid precipitation.

Typical point sources of groundwater pollution in rural areas are septic tanks, feedlots, waste disposal sites, agricultural chemical storage, and disposal of animal wastes and wastes from local industry.

Septic tanks are widely used in rural areas. They pose severe threats to

groundwater through poor siting, either in areas of permeable subsoil or very rapidly draining ground; frequently these are not properly managed, so that leakages from tanks endanger domestic wells in the vicinity. In rural areas with a high density of such tanks, they may even result in a "diffuse" pollution of groundwater by nitrogen compounds. In agricultural regions with growing animal production, animal wastes become important sources of groundwater pollution. For example, in Ireland between 1960 and 1980 the average cattle herd increased in size by 171% and between 1965 and 1979 the number of farms with more than 20 cows rose from 10% to 81% (Aldwell and Burdon, 1987).

Another typical and growing point source of groundwater pollution, in rural areas of humid regions, is silage leachate. In Ireland silage making increased in volume from 190,000 tons in 1960 to 13,478,000 tons in 1983 (Aldwell and Burdon, 1987).

The extent to which highly intensive agricultural production affects the nutrient load in groundwater is shown in Table 3.1 (Orlovsky et al, 1986).

Table 3.1 1980 Nutrient balance for Nitrogen and Phosphorous from agricultural land in the Southern Peel, the Netherlands.

	N (Kg/ha/yr)	P (Kg/ha/yr)
animal slurries	525	178
mineral fertilizers	225	18
total input	750	196
uptake by crops	320	26
excess minerals	430	170

Such excessive use of nitrogenous fertilizers results in high nitrate concentrations in groundwater and rising nutrient loads in surface water, causing eutrophication, especially in lakes. Agricultural production however, is not the only danger for groundwater in rural areas. Hazardous wastes from local industries and in particular from the chemical industry are also an increasing threat to groundwater in rural areas.

In many countries a large number of local groundwater bodies have already been polluted. Although the pollution is local, it is having increasing regional effect, extending even to rural areas. For instance in the U.S.A in 1980, there were 200,000 landfills and dumps receiving 150 million tons per year of municipal solid wastes and 240 million tons per year of industrial solid wastes. In the USA more than 2,800 public and private wells had to be closed due to agricultural and industrial activities (Feliciano, 1986). Abandoned or poorly constructed wells are another source of pollution of aquifers in rural areas. Both permit pollution of deeper aquifers by shallow poor quality water.

The problems facing water management in rural areas are both local and regional. The main causes of the problems are the attempts to increase agricultural production and how to safely dispose of the growing volume of wastes of all kinds. A solution to this problem is essential in order to protect groundwater in rural areas everywhere.

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4. DATA REQUIREMENTS AND DATABASE MANAGEMENT

by
J. Miller

4.1 INTRODUCTION

The foundation for any successful groundwater protection plan is the collection, storage and management of basic data. This chapter addresses the types of data and the procedures for obtaining and storing such basic data necessary for developing a program to protect groundwater quality within the context of land-use planning in rural areas.

4.2 DATA REQUIREMENTS

Decision-making processes require accurate, appropriate and sufficient collection, review and storage of data for later use. Groundwater protection in rural communities involves the making of land-use and water-use decisions that may appear to be in conflict at times. The likelihood of avoidance of conflict or lessening of the potential for conflict is increased by the accumulation of data regarding the local geology, land-use and water resources situation.

Data Acquisition

Much of the information needed to prepare a groundwater protection plan is probably already available but in scattered locations. Information regarding land-use, potential polluting sources, hydrogeologic conditions, well locations and amount and quality of groundwater pumped, can often be obtained from local or regional government agencies. However, certain information such as groundwater chemical analyses or potential sources of pollution may not always be available, and for some rural locations there may be no data. Under these situations an intensive, initial field and office effort to build such a database is needed.

Information and Database Management

Although a rural community will generally not have as large a database for

decision-making as a large city, such information needs to be properly collected, processed, filed and maintained in order to reflect changing local conditions. A groundwater protection plan must be flexible and responsive to change. As new information becomes available, the plan should be updated to take account of the new data.

Appropriate, standardized forms for recording data should be prepared. The completed forms are filed in an organizable and easily retrievable manner. Once filed, the data need to be maintained and updated at a central location, either in a manual or computerized form.

In many cases, rural communities may not have the economic or technical resources for maintaining the database. A number of communities could group together to share the cost and effort of records collection, filing and maintenance.

Base Maps

Well-balanced decisions regarding groundwater protection require organization of the database beyond the use of standardized forms. Decisions are difficult if the entire land-use, water-supply or scientific/technical picture can not be seen and understood with minimal effort. This is accomplished in part by plotting specific information on specially selected and prepared base maps so that it is readily viewed and comprehended. Such base maps have basic local geographic and political information on them; local land-use, water resources and scientific/technical data are plotted on this base.

4.3 UNDERSTANDING OF GROUNDWATER RESOURCE

Groundwater protection plans require an understanding of the groundwater resource and its use. First and foremost, a solid understanding of the geologic framework through which the groundwater and its potential pollutants move should be developed. Additionally, information is needed regarding the natural groundwater quality of the area; the locations and characteristics of wells, and present and future demands for potable, agricultural and industrial water supply. The following is a basic discussion of the general process for developing this information.

Hydrogeologic Framework and Aquifer Mapping

Most hydrogeologic mapping takes place in areas of greatest population concentration. In rural areas such mapping is often minimal and limited to regional geologic mapping. Therefore, one of the first efforts to pursue is the development of more detailed local hydrogeologic maps. This should include knowledge of soil and unsaturated zone properties, as well as specific aquifer parameters such as aquifer dimensions, flow patterns, recharge characteristics, transmissive and storage properties, groundwater quality/quantity distribution patterns, interaction with surface water, aquifer boundary conditions and aquifer mineralogy.

Where sufficient existing wells are available, maps of the water table or potentiometric surface should be prepared. If serious data gaps are present and funding is available, additional wells should be drilled to acquire the necessary data. Aquifer pumping tests can be performed on community supply wells and other wells in the area, particularly large-capacity agricultural or industrial wells. This provides information regarding the hydraulic parameters of the aquifer(s) supplying groundwater to the community, local industry and agriculture. It also furnishes information regarding regional or area-wide aquifer hydraulic parameters to be used in developing groundwater protection areas.

Background Groundwater Quality

The long-term base for groundwater protection is knowledge of the ambient or natural background water quality. There is a saying that "in order to know where you are going, you have to know where you have been". This is also true of groundwater quality; in order to note future changes, knowledge of present water quality is required.

Taking into account groundwater flow patterns and land-use activities, appropriate upgradient locations for installation of background monitor wells are selected. Water quality monitoring data of potable water supply wells are selected. Water quality monitoring data of potable water supply wells should be compared to these background wells and to the supply well's long-term records. These show up changes or trends in water quality that may forewarn the community of groundwater quality deterioration. Where there are known areas of existing groundwater pollution due to agricultural

or other activities, monitor wells should be installed between the outer limits of the pollution and the potable supply wells. While this does not truly protect the supply; it does provide an early warning system. In coastal areas where salt-water encroachment is a problem, monitoring wells should be located between the public supply well(s) and this source of natural water quality degradation.

Long-term observations of vulnerable shallow aquifers often show great and sudden variations in groundwater quality (Prudil, 1987). In order to establish mean values for the parameters being monitored, regular monitoring is necessary. Initially, it is also recommended that sampling of more than one background monitor well is undertaken. The variations may be caused by a number of factors, including human activities, seasonal groundwater recharge impacts on the aquifer, differences in sampling technique or equipment, or analytical error.

The National Research Council (1986) extensively discusses various approaches used by the states in the United States to establish ambient groundwater quality. Most of these approaches are based upon basic water quality parameters, but the recommendation is made that organic compounds such as pesticides, organic solvents and petroleum components be included.

Vrba and Balek (1987) discuss conceptually the design and operation of groundwater data collection and monitoring systems. They emphasize that financial expenditures for the design and operation of groundwater monitoring systems are not always reasonably utilized. Most critical is that information be presented to decision-makers in a form that is easily understood and usable.

A thorough discussion of groundwater quality monitoring under different agricultural conditions is provided by Vrba (1987). Included are procedures for delimitation of the monitored area and the design of the monitoring system, data acquisition (sampling point location, sampling procedures, frequency and techniques for both the saturated and unsaturated zones); data transmission, storage and processing, data retrieval and analysis, and data utilization for decision making.

Knowledge of local and regional natural groundwater quality permits the

development of an area-wide groundwater classification system to be used for groundwater management. The classification of groundwater quality beneath an area can be one means of placing limits on the use of the land surface. Logically, the highest quality water should have the highest classification and the greatest protection.

Water quality data needs require adequate laboratory facilities. Such laboratories must produce high-quality data for use in prevention as well as for response to emergencies and ongoing pollutant clean-up. The local community should locate a dependable (quality control oriented) facility that can supply this service on a long-term basis.

Water Supply Well Data

In order to augment the database needed for development of a groundwater protection plan, all wells within the rural area should be located and construction details obtained. Geologic or boring logs for these wells should be acquired, so that a more detailed understanding of the geologic framework may be developed. Water level and water withdrawal data should also be obtained. Well locations should be plotted on the local community base maps.

Water Demand

Knowledge of the demand for potable water by the local community is important in preparing a groundwater protection plan. Such information is used to anticipate growth and to make provision for the water-supply needs of the future.

Present Demand - Information regarding present demand is probably only generally known in a rural community. More detailed knowledge, without the use of expensive metering systems, can be obtained through the performance of water-use studies of individual homes. In this manner, a local per-capita daily demand can be established. Considering the local population and small-scale industrial activities present, a relatively accurate daily demand can be determined for the entire community. The assumption is, however, that the community is supplied by local wells with an interconnected water supply system.

Additionally, knowledge of agricultural groundwater use in the vicinity of the rural community is also needed. Such agricultural water-demand data provide information regarding the extent of competition for the resources. This competition may influence the movement of polluted groundwater.

Future Demand - If growth of the community is not taken into account, the capability of the well(s) and/or local aquifer to produce sufficient water for public supply may be gradually approached and exceeded. In order to avoid this situation, the population growth of the community and the limits of the present water supply must be monitored in order to allow for expansion or to develop new resources. Groundwater preserve lands are often set aside for this purpose, so that good quality potable water can be assured for the future population.

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5. LAND-USE PLANNING AND GROUNDWATER PROTECTION

by
J. Miller

5.1 INTRODUCTION

The combination of best-use land management and groundwater resource protection is a relatively recent approach to protecting groundwater quality when there are competing uses for land. It is particularly applicable to rural areas where the cultivation of crops, raising of animals, and other agricultural activities are often, or can be, in conflict with the basic need for a potable water supply. Rural areas, however, are not limited to sources of potential groundwater pollution specifically related to agriculture.

This chapter addresses the basic requirements for developing a program to coordinate activities in the areas of land-use and groundwater use so that both undertakings can be of benefit to society without serious impact upon each other. An excellent summary of integrated land-use planning and groundwater protection management is provided by Purnell and Thomas (1987). They emphasize the need for a multi-disciplinary approach that is site-specific and not standardized. Each area has its peculiarities that will influence its land-use plan relative to protecting groundwater quality.

5.2 LAND-USE CONSIDERATIONS

As mentioned, an understanding of local land-use patterns and plans is very important to groundwater protection. Such protection is highly dependent upon present, past and future land-use together with the natural vulnerability of the ground. With the ever-increasing number of potential sources of groundwater pollution we must anticipate potable water supply quality problems rather than wait for them to occur.

Ge Ming-hao and Zhong Ping (1987) discuss the relationships between agricultural development and groundwater pollution by applying the process of analytical hierarchy. Their work shows the intricate relationships of

various rural development activities and indicates how to proceed in evaluating and preparing for the most critical potential polluting source.

A similar discussion of hierarchical approaches is provided by Kaden (1987), who also points out that the complexity of the problem demands the development of models for the decision-making process. However, he points out that practical decision makers may not always be ready to accept such new tools.

Existing Land-Use Mapping

Existing land-use should be plotted on the base maps developed for the groundwater protection planning effort. Every use of the land has the potential for producing pollutants that impact on the underlying groundwater quality to some extent. These potential impacts, which depend in part on the natural vulnerability of the ground, must be known in order to evaluate an area for future potable water supply and to anticipate problems with the present supply. Such maps require periodic updating.

Long-Term Development Plan

Once land-uses are mapped, dominant patterns and trends of land-use will be obvious. If expansion of the community is noted to be taking place in a certain direction and at a known rate, it might be anticipated that additional sources of water supply will have to be developed in the direction of growth at a certain time in the future. Under such conditions, advance planning enables the community to set aside protected lands (preserves) for new wells.

Best Land-Use

During the course of land-use planning, it will become obvious that there is a best-use for each tract of land. Where the community is strongly oriented toward agricultural production, soil fertility will be a prime factor in determining the use of the land. However, in some cases, potable water supply for the community may be a better use for the land. The costs of bringing water through pipelines from long distances may be too great to be considered as being reasonable; such a community will require protection of

groundwater close to the population. Under certain circumstances, such as at locations where the groundwater has already deteriorated due to agricultural activities, it may be necessary to preserve and protect the groundwater resource of an area located at some distance from the community.

At the same time, there may be means of satisfying both agricultural production and groundwater quality protection. Antal, Benetin and Soltesz (1987) indicate that one method of lessening the impact of agricultural activities on groundwater quality is by developing a thorough understanding of the most appropriate periods for the application of agricultural chemicals.

Past Land-Use and Future Supplies

When addressing the subject of maintaining long-term groundwater quality, it is important to consider not only protection of the present source of potable water supply but also future supplies. Groundwater withdrawals at the present location may eventually exceed the production capability of the well and/or the aquifer. Under such conditions, the community may need to consider additional locations for wells.

In order to avoid or lessen the chance for groundwater quality problems in new wells, knowledge of past land-use at the location of the proposed new water supply facility is critical. Past land-use may have already degraded the quality of the underlying groundwater, such that it cannot be used. With this in mind, land-use maps should be employed as a means of recording past land-use as well as present and proposed land-use.

5.3 PLANNING OF THE PROGRAM

The basic steps involved in the preparation of a groundwater protection plan are shown on Figure 5.1 (Kilner and others, 1984), many of which can proceed concurrently. Some portions of this planning process have been discussed earlier in this chapter and are not further mentioned.

A critical role in the planning process has been established for local input from community councils and committees; the planning is not to be performed

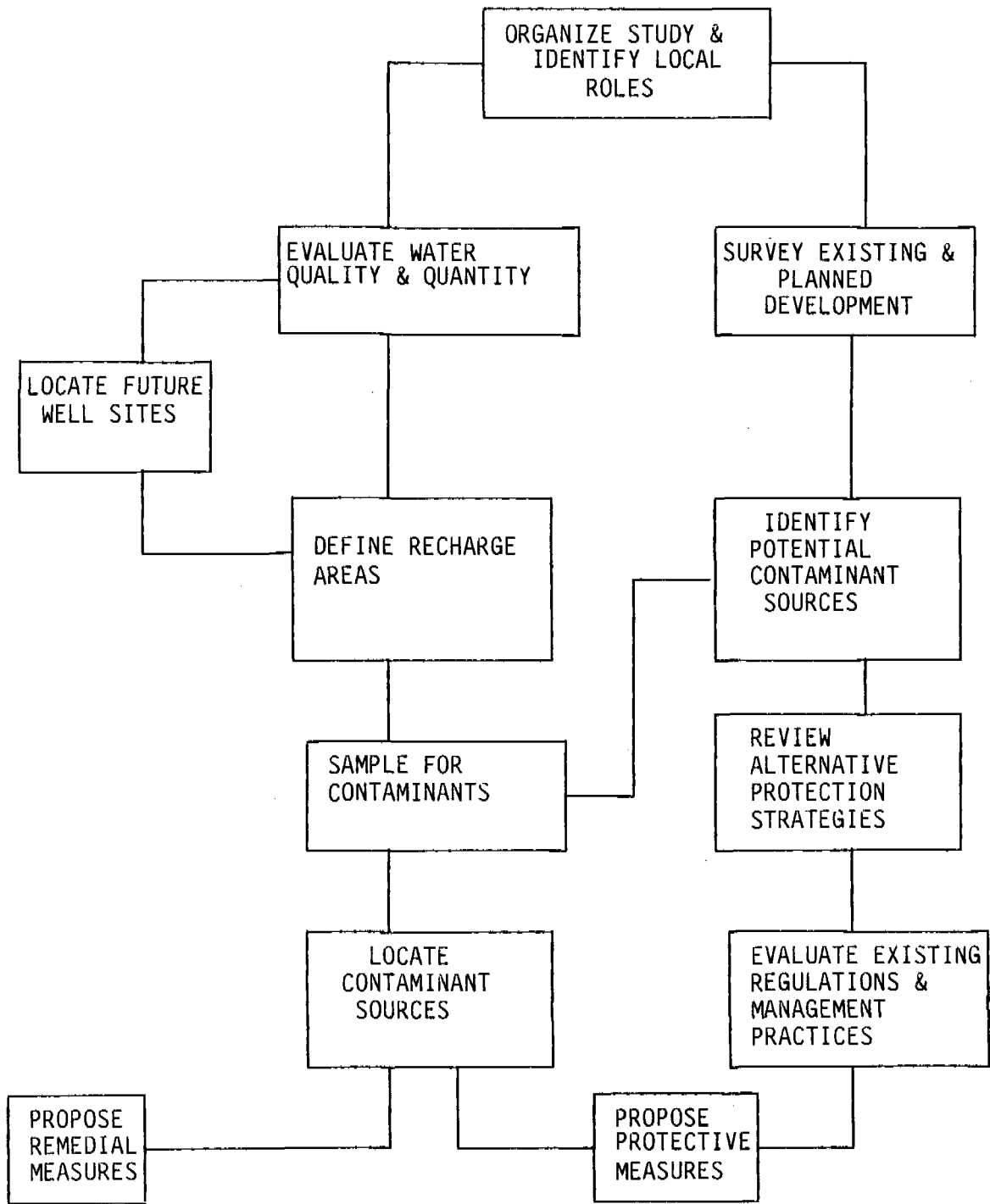


Figure 5.1 Aquifer Protection Planning Process
(Kilner, Rizzo and Shawcross, 1984)

solely by scientific/technical staff. Input is needed from a wide-ranging group of individuals whose needs must be balanced by the primary need to protect groundwater quality. Selection of the members of a citizens group to represent the various separate and often conflicting interests is necessary for acceptance of the plan by the rural community.

Zaporozec (1987) provides further discussion of the management strategies and alternatives of groundwater protection in rural areas. He places the burden for maintaining the quality of groundwater in rural communities, primarily private wells rather than water systems, on the local government. Emphasis is placed on the fact that there is no "correct" way to design a groundwater management program; community goals and objectives must be identified before specific management program techniques can be selected or carried out.

5.4 POLLUTION SOURCE PRIORITIZATION

Each rural area will have certain dominant sources of potential groundwater pollution. These should be prioritized in terms of which ones are the most likely to cause groundwater quality problems. Considering the varying sources of potential pollution, certain pollutants will be most likely. In this manner, the parameters monitored will reflect the activities taking place in the vicinity of the public supply well or wellfields. Additionally, this provides the community with a cost-saving mechanism of determining which pollutants are the most logical ones to be analysed and included in the pollution response and remedial action program.

5.5 POLLUTION RESPONSE AND REMEDIAL ACTION PROGRAMS

Finally, an essential portion of the planning process is the response to groundwater pollution. Remedial action or alternative sources of potable water supply are of critical concern.

Acute Pollution Events - The release of pollutants near a supply well requires an immediate response from the community so that the pollution can be removed from the soil or groundwater before it reaches the well. The

best procedure would have been to avoid the use of any potential pollutants within the groundwater protection area, but accidents are not foreseen. In any case, the community should have an emergency plan to protect the existing water supply. This can be as simple as turning off the pumps and using wells outside the area of the pollutant release, until clean-up can take place.

Chronic Pollution Events - In other cases, long-term water quality monitoring of public supply wells might reveal that the concentrations of certain undesirable water quality parameters are slowly rising to unacceptable levels. This gives the community a longer period to react. The result might be to eliminate the source of the long-term water quality degradation and provide treatment or to plan for a new well or wellfield in an area that can be better protected.

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6. GROUNDWATER PROTECTION

by

J. Vrba and H.G. van Waegeningh

6.1 INTRODUCTION

In earlier times, little attention was paid to the protection of groundwater quality, mainly because people were unaware of the threats to this invisible and hidden resource. However, the intensity of human impacts and polluting activities on groundwater systems were much lower in the past than nowadays. Thus, it is only a few decades ago that ideas on groundwater protection began to emerge, especially in countries with intensive industrial and agricultural development.

The consequences of groundwater pollution produce adverse economic, social and environmental effects requiring the expenditure of enormous financial resources. It may be necessary to treat polluted groundwater or transport water of good quality over long distances to the regions in which aquifers have been polluted and are unusable.

Prior to the 1960s almost all investment in groundwater projects tended to be channelled into groundwater resources development. Since the 1960s however, several countries have spent large sums of money on groundwater protection and aquifer rehabilitation. For example, countries such as Czechoslovakia and the USA show that over 50% of expenditure on groundwater projects is now being used for groundwater protection measures.

However even nowadays, one wonders if the degree of protection in many countries is really adequate. Moreover, that protection which does exist is mainly concerned with preventing the pollution of public water supplies and largely ignores soil quality, shallow vulnerable aquifers and currently unused groundwater resources.

Groundwater usually has a good natural quality, which is relatively stable and is less vulnerable to pollution than surface water. As a source of water supply, groundwater often requires at most simple treatment such as filtration and aeration. However once polluted, groundwater rehabilitation

is a long-term, costly and technically demanding process. These are the main reasons why preventive measures to protect groundwater are so necessary.

Protection measures are still at an early stage and require considerable further refinement. In many countries, there is growing awareness of the need to protect groundwater, both as an important resource and as a vulnerable and valuable component of the environment.

6.2 MAIN PROTECTIVE MEASURES FOR GROUNDWATER

Until quite recently, protective measures were concerned with microbiological and inorganic parameters only. However, during the last two decades many countries have been confronted with numerous findings of severe groundwater pollution from heavy metals and organic-chemical compounds from industrial and agricultural sources. The toxicological effects of organic-chemicals on humans and on the environment are not yet fully understood, so for safety reasons, very high standards have been set for these compounds.

Adverse effects on groundwater quality can be caused by compounds which are harmful to health (toxic, carcinogenic, mutagenic, radioactive and pathogenic): compounds which affect the taste, odour or colour of water, and compounds which reduce the level of oxygen or which make water more corrosive or raise its temperature.

6.3 GROUNDWATER PROTECTION STRATEGY

The principal objective of a groundwater protection strategy is to preserve the natural quality of groundwater, particularly for drinking purposes, for the benefit of the present and future generations. This requires the building of an organizational structure with the necessary powers and resources for the creation, coordination and implementation of a comprehensive groundwater strategy and policy. In turn, legislation is needed to regulate the management and control of groundwater protection and quality conservation programmes. Creation of a governmental office for

groundwater protection, within the ministry or agency responsible for the protection of the whole environment, is therefore strongly recommended.

The main goals of groundwater protection strategy include:

- . to define the value of groundwater resources, taking into account local, regional and national interests and needs;
- . to define the extent, degree and criteria of groundwater protection and assign their implementation to all levels of relevant government authorities (national, regional, local);
- . to establish the legal and institutional basis, regulatory statutes and standards for groundwater protection;
- . to establish a system of inspection and an effluent control system, including fines on the "polluter-pays" principle;
- . to provide methodological and technical guidelines for activities related to groundwater protection and rehabilitation;
- . to support and coordinate research programmes for the development of methods of groundwater protection and technologies for detecting and eliminating pollution in the underground;
- . to educate the general public about groundwater protection programmes.

With respect to the objectives of groundwater protection strategies, the following activities related to technical aspects are emphasised and recommended for early implementation:

- . identification and listing of past, existing and potential pollution sources, and evaluation of their nature and extent;
- . operation of efficient groundwater quality monitoring programmes and implementation of the data obtained;
- . provision of technical and scientific assistance in the solving of problems involved in groundwater protection and pollution;
- . availability of experienced and highly qualified professional personnel.

The money necessary for groundwater protection strategies, includes governmental financial support and income collected from water charges and fines for failure to observe the laws and regulations for groundwater protection. However, fines and charges do not constitute the goal of groundwater protection strategies. They are rather a temporary tool, at a time when the management and inspection needed for groundwater

is still developing and the financial means are not available for the installation of adequate waste treatment technologies. In any case, a well developed charging system, as part of an environmental fund, should yield the financial resources which, in turn can be invested in groundwater protection and aquifer rehabilitation in rural areas.

6.4 GROUNDWATER PROTECTION POLICY

It is generally accepted that not all groundwater resources must be protected, since most countries possess extensive groundwater resources within their national territories. To protect all groundwater resources at the same level would be unsustainable economically, useless in terms of hydrogeology, and unrealistic in terms of management and control.

The criteria for groundwater protection policy depend on:

- . the value of groundwater and its vulnerability;
- . the current and expected demands for groundwater use and protection in a given region;
- . implementation of effective legislation related to groundwater protection and land-use.

The classification of groundwater resources by the above listed criteria is always complicated and controversial and requires good knowledge of the hydrogeological, economic, and social aspects of the area concerned.

A good example of groundwater protection criteria is from the USA (Table 6.1) in which three classes of groundwater are defined (EPA, 1984).

**Table 6.1 Classes of Groundwater in USA
(EPA, 1984)**

Class	Basic Criteria	Level of Groundwater Protection	Remarks
I Special groundwater	Highly vulnerable, irreplaceable or ecologically vital	Extremely high	Significant water resources value
II Current and potential sources of drinking water and waters having other beneficial uses	All other groundwater use or available for drinking or other purposes	High to moderate prevention of contamination, based on technological remedies rather than through restrictions	Majority of usable groundwater in USA
III Groundwater not considered potential sources of drinking water and of limited beneficial use	Heavily saline or heavily polluted	Usually low migration to class I or II groundwater or discharge to surface water must be precluded	Limited beneficial use

Another example of groundwater protection policy comes from Czechoslovakia, where the most valuable groundwater resources occur in the Czech Cretaceous Basin. This basin covers some 15,000 square kilometres and $7\text{m}^3.\text{s}^{-1}$ of groundwater is abstracted for public water supplies. An additional $10\text{m}^3.\text{s}^{-1}$ of usable groundwater is available. The groundwater protection policy, based on a good level of knowledge of the hydrogeology and the vulnerability, is reflected in a pragmatic approach to the protection of

groundwater resources. Simplified figures (Table 6.2) show that only about 20 per cent of groundwater in this basin requires complex and comprehensive protection (land acquisition, restriction of agricultural activities, intensive monitoring etc.) The level of protection for the remaining groundwater is markedly lower, both in hydrogeological and financial terms.

Table 6.2 Czech Cretaceous Basin - Level of Groundwater Protection

Extent:	15,000 km ²
30 m ³ /s	Total volume of groundwater resources
	20% high level protection
	40% medium level protection
	20% low level protection.

Groundwater protection policy should always be interrelated with the protection of the remaining components of the hydrological cycle, soil protection, land-use planning and abstraction of other natural resources, with a view to their integrated development and better allocation.

The conflicts and restrictive measures produced by protection of groundwater must be identified and analysed from the environmental, social and economic points of view. The main task is to choose a suitable strategy to define priorities, preferences, and potential conflicts in rural community development and to find the balance between environmental protection policy and economic considerations.

6.5 GROUNDWATER PROTECTION MANAGEMENT

Groundwater protection management must be dealt with simultaneously with groundwater development, as a part of a Water Management Plan (Master Plan). Reconnaissance, investigation, pilot studies, planning and evaluation of usable groundwater resources should always precede their abstraction. Together with the steps in groundwater development, the criteria for groundwater protection should always be examined and determined.

Two categories of groundwater protection management can be considered:

- General protection of groundwater resources;
- Comprehensive protection of groundwater around public water supplies.

General Protection of Groundwater is based on the assumption that all effectively accessible groundwater resources are, or will be, tapped for drinking or other purposes, and therefore their protection is desirable. Under water management plans, national, regional or local governments and water authorities should therefore bear the responsibility for, and financially support the protection of unused groundwater resources.

Implementation of general protection of groundwater resources calls for the following activities:

- . investigation of the groundwater system and determination of its vulnerability;
- . identification, listing and assessment of the existing and potential pollution sources;
- . monitoring of the groundwater system;

Comprehensive Groundwater Protection is mostly concerned with public water supplies. The groundwater resources utilized for public drinking water supplies are protected by protection zones, referred to as wellhead protection areas in the USA, usually comprising two or three levels of protection. The main purpose of groundwater protection zone delineation is to protect drinking water supply wells or wellfields from pollution and provide the population with water which meets the standards for drinking water. In several countries, wellhead protection is an obligatory part of groundwater protection policy and strategy programmes, and is based on the relevant legislation.

Comprehensive protection of public water supply wells requires:

- . cooperation between national, regional or local water authorities, waterworks companies and land users (particularly farmers);
- . establishment of a general concept of groundwater and land management in protection zones taking into account rural community needs.
- . implementation of technical, institutional, legislative and control measures and regulations in protection zones.

The techniques and methods employed for delineating groundwater protection zones of water supply wells depend primarily on aquifer permeability (porous, fissured or karstic), complexity and vulnerability, properties and thickness of the unsaturated zone, quantities, properties and degradability of potential pollutants and their distance from the wells or wellfield.

First level groundwater protection zones, protect the well and its immediate environment from mechanical damage and direct pollution. Their extent is usually small - several tens of square metres at the maximum. They exclude all activities.

Second and third level groundwater protection zones are extensive (several hundreds of square metres to several square kilometres) and include the discharge areas, the cones of depression (zone of influence) around pumping wells, the recharge and contribution areas and other vulnerable areas of a given water supply system.

In several European countries, the second level zones cover areas having a delay or residence time of 50 to 60 days. It should be emphasized that the delay time has been determined so as to protect water supply wells from the risk of groundwater microbial contamination, but it may become inadequate for viruses and certain chemical pollutants.

The third level zone protects groundwater quality in water supply wells from persistent chemical pollutants. It is the most extensive zone, but there are less restrictive measures. Van Waegeningh (1985) recommends a 10 to 25 year residence time.

In general, the level of restrictions and prohibitions in groundwater protection zones decreases with the distance from a well or wellfield. The second and third level protection zones cover significant areas of ground, frequently including arable land. For this reason, the over-protection of water supply wells is not desirable because restrictive measures or exclusion of land from farming activities lead to economic losses. On the other hand, the under-protection of wells and wellfields may cause groundwater pollution requiring long-term and costly remedial action. Overall, a delicate cost/benefit balance is involved when determining the extent of protection areas.

Protection zones should be delineated by means of a combination of up-to-date methods and techniques to minimize the degree of uncertainty in their definition. Protection zones should be as small as possible but as large as necessary (van Waegeningh, 1985 and EPA, 1987). Expressed in financial terms, higher input costs on accurate protection zone delineation will lead to reduced operational costs for well and wellfield protection. Since the operation of water supply systems is long-term, the operational costs involved in their protection should be as low as possible. A sophisticated approach to protection zone definition therefore is preferable.

The Guidelines for Delineation of Wellhead Protection Areas (WHPA) in the USA (EPA, 1987) provide good examples of potential costs ranging from the simplest to the most complex delineation methods. Estimates of potential costs (Table 6.3) consider labour costs and the level of technical expertise required for each of the methods applied.

Table 6.3 Costs of Delineation Associated with Various WHPA Methods in the USA (after EPA, 1987)

Method	Manhours required per well	Level of Expertise*	Cost per Well	Potential Overhead Costs
Arbitrary Fixed Radii	1-5	1	\$10-50	L
Calculated Fixed Radii	1-10	2	\$13-125	L
Simplified Variable Shapes	1-10	2	\$13-125	L-M
Analytical Methods	2-20	3	\$30-300	M
Hydrogeological Mapping	4-40	3	\$60-600	M-H
Numerical Modeling	10-200+	4	\$175-3500+	H

* Hourly wages per level of expertise (based on National Water Well Association, 1985)

1. Non-Technical	\$10.00	L = Low
2. Junior Hydrogeologist/Geologist	\$12.50	M = Medium
3. Mid-Level Hydrogeologist/Modeler	\$15.00	H = High
4. Senior Hydrogeologist/Modeler	\$17.50	

However, in many cases the delineation costs must be expected to be markedly higher, especially when the criteria cannot be exactly defined and additional techniques (such as boreholes, pumping tests, field measurements, tracer tests) must be applied because of a lack of data and information on the aquifer system and potential polluting sources.

Examples of pollution of public water supplies in many countries, show that the capital and running costs for the protection of water supply wells are always lower than treatment of low-quality water resulting from inadequate protection of wells. In extreme cases polluted wells must be abandoned. Additional construction and related costs to provide alternative water supply wells are then generated. The effect of distributing lower quality groundwater on human health cannot be expressed numerically as yet, but it must be considered too, as an intangible cost. Cost/benefit studies should therefore always include the social and environmental value of groundwater resources.

In regions with the population living in both urban and rural areas and with suitable hydrogeological conditions, it is usually advisable to provide centralized water supply systems. For these systems, the total extent of protection zones with restrictive measures will be smaller than in the case of numerous public and individual wells.

It has been shown that different systems of zoning protection areas around water supplies are in use. Most simple zoning systems pay little attention to technical features; they give rough indications, for example the fixed radius method and variable shapes method (EPA,1987, van Waegeningh et al., 1978). A more sophisticated system is the German one (DVGW, 1975); it distinguishes between protection against disease causing degradable pollutants and against resistant chemical pollutants. This system is applied in many central European countries (van Waegeningh, 1985).

In the Netherlands, a system fully dependent on delay times is in force; the delay time is based on the survival time of germs and on the delay time needed to provide emergency measures to safeguard the water works, and on economic grounds (van Waegeningh, 1985).

From recent research (Duijvenbooden et al., 1981 and 1987), it appears that

diluting and decaying processes are in the first place time dependent (e.g. dying off) or distance dependent (e.g. adsorption); both criteria are interrelated according to the situation.

Overviews of zoning systems and of methods for the calculation of protection zones also are given by EPA (1987) and Lallemand-Barres et al. (1989).

It is desirable to establish and implement internationally agreed concepts and guidelines for protection zone delineation, as an important scientific, environmental, and economic task with considerable significance for the development of many rural areas.

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7. LEGISLATION AND REGULATION

by

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7.1 INTRODUCTION

Legislation to protect groundwater, as with much other legislation, often is brought into being only after problems begin to appear. In the case of groundwater the principal trigger for legislation was the recognition of the need to protect water supplies, especially sources of drinking water.

In the case of groundwater, the situation is made more complex because groundwater is hidden from view and therefore may easily be seriously damaged without it being recognised or the cause being evident.

Worldwide, the subject of a wholesome and safe water supply is of growing concern. The degree to which this concern is reflected in national legislation is determined by a variety of complex political, social, economic and natural factors. This chapter attempts to deal with the history, development and content of groundwater protection legislation and regulations as they relate to land-use planning.

7.2 EVOLUTION OF GROUNDWATER PROTECTION LEGISLATION

The Early Stages

First attempts to protect groundwater in many countries use already existing general laws. Such laws may include planning, water in general, nuisance acts, environmental protection and rights of land owners. Laws specifically to protect groundwater usually start off with concern for the protection of drinking water and public water supply sources, especially from point pollution. These groundwater laws normally require modification after a few years in the light of operational experience and as a result of improved understanding, and increased knowledge and availability of data. Examples are provided in the case histories of this report.

Factors Determining Legislation

Important factors determining the type and level of legislation countries employ to protect groundwater are:

- availability of groundwater and other water resources;
- level and types of economic activity and land-use;
- vulnerability of aquifers;
- type of legislative system;
- cultural attitudes.

Different Approaches

In some countries groundwater protection grew from a single basic law dealing with surface and groundwater, with some specific provision for groundwater. Supplementary legislation and regulations concerned with protecting groundwater came later. These often included both controls on well sinking and minimum standards for new wells. The problem of abandoned wells is also sometimes covered. Countries which followed this approach include those with many different legal backgrounds e.g. Finland, Israel, Italy, Poland, Spain, the UK and some US states.

In another group of countries, groundwater protection came about from a range of regulations dealing with single aspects such as depth of wells or limits on quantities of groundwater to be abstracted or as an aspect of environmental impact. This was the case in France, the Netherlands, Romania and Turkey for instance (FAO, 1964).

Recent Developments

As environmental aspects in general, including the question of water quality protection, received increasing attention, so environmental protection and groundwater protection legislation and regulations began to appear in many countries.

This could be seen during the 1970s and more rapidly in the 1980s as in Europe and North America. For example, the European Community in 1979 issued its directive 80/68 on the protection of groundwater against pollution caused by certain dangerous substances. Almost simultaneously

issued was directive 80/778 relating to the quality of water intended for human consumption.

Example of the Range of Legislation - the USA

The Federal legislation in the USA during the period 1970-1990 provides an example of the range of legislation now involved in the interaction between land-use and groundwater protection. US water rights and pollution control are based on six main federal laws. These empower the Federal Environmental and Protection Agency (EPA) to establish and enforce standards and regulations to protect and clean up groundwater:

1. The Clean Water Act, 1972 (amended 1987) gives the EPA authority to protect surface and groundwater.
2. The Safe Drinking Water Act, 1974 (amended 1986) sets drinking water standards, including maximum levels for 83 specific substances. It introduces the concept of "sole source aquifers" which enables the EPA to screen projects to see if they threaten to pollute a designated aquifer. Initially, the EPA can block federal money from any project they consider to be such a threat.
3. The Federal Insecticide, Fungicide and Rodenticide Act, 1974 (amended 1988) empowers the EPA to control the use of pesticides that may leach into groundwater.
4. The Toxic Substances Control Act, 1976 enables the EPA to limit the use or even ban toxic chemicals shown to pollute groundwater.
5. The Resource Conservation and Recovery Act, 1976 (amended 1984) empowers the EPA to prevent hazardous wastes from leaching into groundwater from such activities as landfills and underground tanks.
6. The Comprehensive Environmental Response Compensation and Liability Act, 1980 known also as "the Superfund Act" provides the EPA with the authority and money to clean up hazardous waste sites which threaten human health and the environment. Groundwater is one beneficiary of this act (LaMoreaux, 1990, US EPA, 1990).

7.3 PRINCIPLES BEHIND GROUNDWATER PROTECTION LEGISLATION

The Objective

The desired aim behind sound groundwater protection legislation is to ensure adequate low priced good quality water for the reasonable needs of the population.

Other Interests

Since people do not live on water alone but need food and a means to earn their living, other valid interests must receive due consideration. A variety of compromises therefore need to be carefully worked out when drawing up groundwater protection legislation.

Rationalisation and Coordination

Because of the number of different interests involved, rationalisation of many existing laws is often necessary. Likewise coordination and cooperation of regulatory agencies is of major importance.

Importance of Prevention

In many spheres of life "prevention is better than cure". In the case of groundwater this is especially true and of great practical importance.

Role of Vulnerability

The stringency of and urgency for groundwater protection legislation in a country is related, in part, to the degree of pollution risk of the main aquifers. The pollution risk in turn derives from the natural vulnerability of the aquifer combined with the pollution loading that is or will be applied to the sub-surface environment (Foster, 1987).

Priority for Major Sources and Resources

Should legislation be concerned with maintaining all groundwater at the highest quality? In many countries this latter proposal clearly is

unattainable and therefore, the legislation is aimed at protecting the important sources of drinking water supply and the main aquifers.

Protection Zones

In some geological settings, protection zones are an important feature of groundwater protection legislation. Such however, can only be effective where the travel time of pollutants is relatively slow. In many limestone terrains in particular, groundwater flow is so rapid that the whole recharge area may require regulation in order to protect it. Some countries provide a measure of compensation for the restrictions imposed on landowners within protection zones.

Licensing

In arid regions or in densely populated areas with limited resources of good quality water, regulatory licensing for abstraction is a necessary concept to attempt to assign priority and achieve equity among different water users (Safadi, 1987).

Who Pays?

"The polluter pays" is a widely accepted principle in environmental legislation. In the case of groundwater, it is not always so easy to apply, not least since the pollution may not appear for some time, may come from several sources and be hard to prove. In the case history of the Netherlands indeed, the reverse is shown to apply at least in certain situations.

7.4 CONTENTS OF GROUNDWATER PROTECTION LEGISLATION

The Objective

The long-term objective of protective legislation is to produce a local and regional balance in which the pollution loading resulting from all human activities can be coped with adequately by the natural environment. In this way both land and water remain of good quality and available for use by the present and future generations. The legislation aims to protect the land, especially the soil as well as the water. Indeed, it is not possible to

protect the one without the other.

Legislative Basis

Legislation is the essential basis for the protection of groundwater. These laws and regulations are a combination of legislation to promote good environmental management and specific measures aimed at ensuring the good quality of groundwater resources and particularly sources of drinking water supply. It is important that the various laws are carefully integrated with one another.

Requirement of Environmental Impact Assessment

Before new activities with seriously polluting potential are permitted, the local planning authorities should obtain an environmental impact study. Such a study includes the impact of the proposed activity on groundwater. One of the most useful aspects of the assessment is the preparation and careful use of vulnerability maps.

Regulation and Control of Main Polluting Activities

The following are potentially major sources of groundwater pollution in rural areas:-

- Sewage disposal, including septic tanks;
- Domestic waste disposal sites;
- Agricultural waste disposal;
- Organic wastes - oils, solvents, pesticides;
- Hazardous wastes;
- Inorganic fertilizers;
- Mining activities;
- Chemical storage areas;
- Fish farming;

Promotion of Good Practices

These can be assisted by grants and payments or the issue of licences. There may be requirements to follow certain environmentally approved

practices such as the amount, kind and timing of fertilizer application. Farmers can be paid to "set aside" land, for example as natural meadows or nature reserves.

Penalising Bad Practices

This includes fines and/or imprisonment. It can also be done by imposing a tax or surcharge on, say, fertilizers to discourage their overuse. Licences may be revoked in the case of persistent offenders.

Establishment of Drinking Water Standards

The main known pollutants are listed. Standards are set for these and usually include a maximum allowable concentration together with more stringent guideline or target levels.

Requirement of Monitoring of Groundwater Quality

This applies in the first instance to the main aquifers and to sources for human consumption.

Provision for Groundwater Protection Plans

Each water supply authority must draw up and maintain a groundwater protection plan for their area. Within the protection plan, specific protection zones or areas are set up within which potentially polluting activities are forbidden. In this regard, it is important to plan ahead and also provide protection for future supplies, strategic reserves and areas with large unused groundwater resources.

Well Construction Standards

Requirements for scientifically based siting of wells and satisfactory standards for well construction are necessary.

Provision for Rights of Inspection

Inspectors are provided with the powers to examine all activities suspected

of polluting groundwater.

Setting out of Incentive Procedures

These should follow the generally accepted legal norms of the country concerned. Particular problems may arise in the case of old industries, particularly small ones. In some countries these are provided with government grants to enable them to update their waste treatment facilities. In some legislation they are given time in which to conform, eg 5 years in the case of the UK.

7.5 PRACTICAL ASPECTS OF ENFORCEMENT OF LEGISLATION

Potential Dangers

It is one thing to pass laws which look nice on paper. Laws which are not and cannot be enforced may do more harm than good and indeed weaken respect for law and authority in general. Such laws may also produce a false and dangerous sense of security. It is also important to remember that the land itself requires protective legislation both in its own right and as the first line of defence for groundwater (see case history of the Netherlands).

Essential Database Requirements

In order that legislation can be enforced it is vital to have the necessary relevant and up to date information. This particularly applies in the field of environmental legislation where understanding and techniques are changing rapidly. The following data are of particular relevance to the practical application of legislation relating to land-use planning and groundwater protection:

- the state of groundwater quality in aquifers and public water supply sources and their vulnerability;
- the effectiveness of current groundwater protection measures;
- accurate knowledge of the location of potentially polluting sources of groundwater, past, present and proposed;

- independent monitoring of the main potentially polluting activities;
- knowledge of "no waste" or reduced waste technology in industry, agriculture and minerals extraction;
- research into environmentally friendly, yet economically feasible, methods of production in agriculture and industry.

Realistic Regulations

It is very important that the regulations intended to put into effect the protection legislation adequately take into account the actual situation on the ground. This includes the extent of the problem, the numbers of enforcement staff, and the availability of facilities and equipment needed to provide the essential data.

Provision for Regular Amendments

Since most environmental legislation is relatively new, it is necessary that it be frequently updated in the light of operational experience.

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8. METHODS OF GROUNDWATER PROTECTION IMPLEMENTATION

by
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8.1 INTRODUCTION

Increasing industrialisation and more intensive agriculture in many countries, has led to a much greater threat to groundwater than existed in former times.

Because of the interdisciplinary nature of the problems involved, much coordination and collaboration is needed. This is required at many levels, including technical, administrative, regulatory and legislative aspects.

8.2 HOW TO START

Different countries have approached the matter in a variety of ways. For instance, inter-ministerial working groups or special interdisciplinary task forces set up under individual ministries - such as water or the environment. Various professional associations, both national and international, have attempted to address the problem or aspects of it. For example, at the IAH Congress in Prague on the impact of agriculture on groundwater held in 1982, a recommendation was unanimously adopted seeking the setting up of an international multidisciplinary group to help define what now constitutes responsible and appropriate agricultural practices. Other countries such as the USA have set up special environmental protection agencies, with powers and money to ensure implementation of environmental legislation to protect groundwater by restricting harmful land-use.

Denmark is a country which has implemented an advanced level of integrated groundwater protection and land-use planning, involving considerable restrictions on land-use. The Danish experience in relation to groundwater protection and land-use is described in detail in case history II of this report. It reflects both the importance attached to groundwater in Denmark (98% of water supply) and the democratic decentralised form of local government system employed by that country. The following paragraphs outline how Denmark set about implementing the integration of groundwater

protection and land-use planning.

The Danes began with a commission or advisory group which analysed and evaluated the problems.

The members of the group comprised representatives from the various disciplines within the hydrological cycle, and the land users, including representatives of governmental, regional and local councils. The members were chosen in such a way that they represented the scientists and administrators working in hydrology, agriculture and water management. Based on the Danish model, the most important purpose of the group is to establish the existing situation in the area under consideration, to collect all available and relevant data information, analyse the problems, propose solutions and make recommendations.

This approach, involving all the relevant parties, enables a consensus to be reached on how best to prevent or correct the inadvertent pollution of groundwater by different land-uses.

The more the different land users are involved at an early stage, the more they feel responsible for helping solve the problems of land-use, together with protecting groundwater and the environment.

The process depends on the existing conditions, geology, hydrogeology, climate, culture, organisation of, and level of development of the society concerned.

The work of the water commission is illustrated in figure 8.1. All relevant basic information on water demand and conflicts in use, need to be analysed. To support this analysis and evaluation it is important to survey the usable water resources, the water quality, together with point and diffuse pollution.

The basic information enables the water commission to recommend strategy and action plans to implement integrated land-use planning and groundwater protection in rural areas.

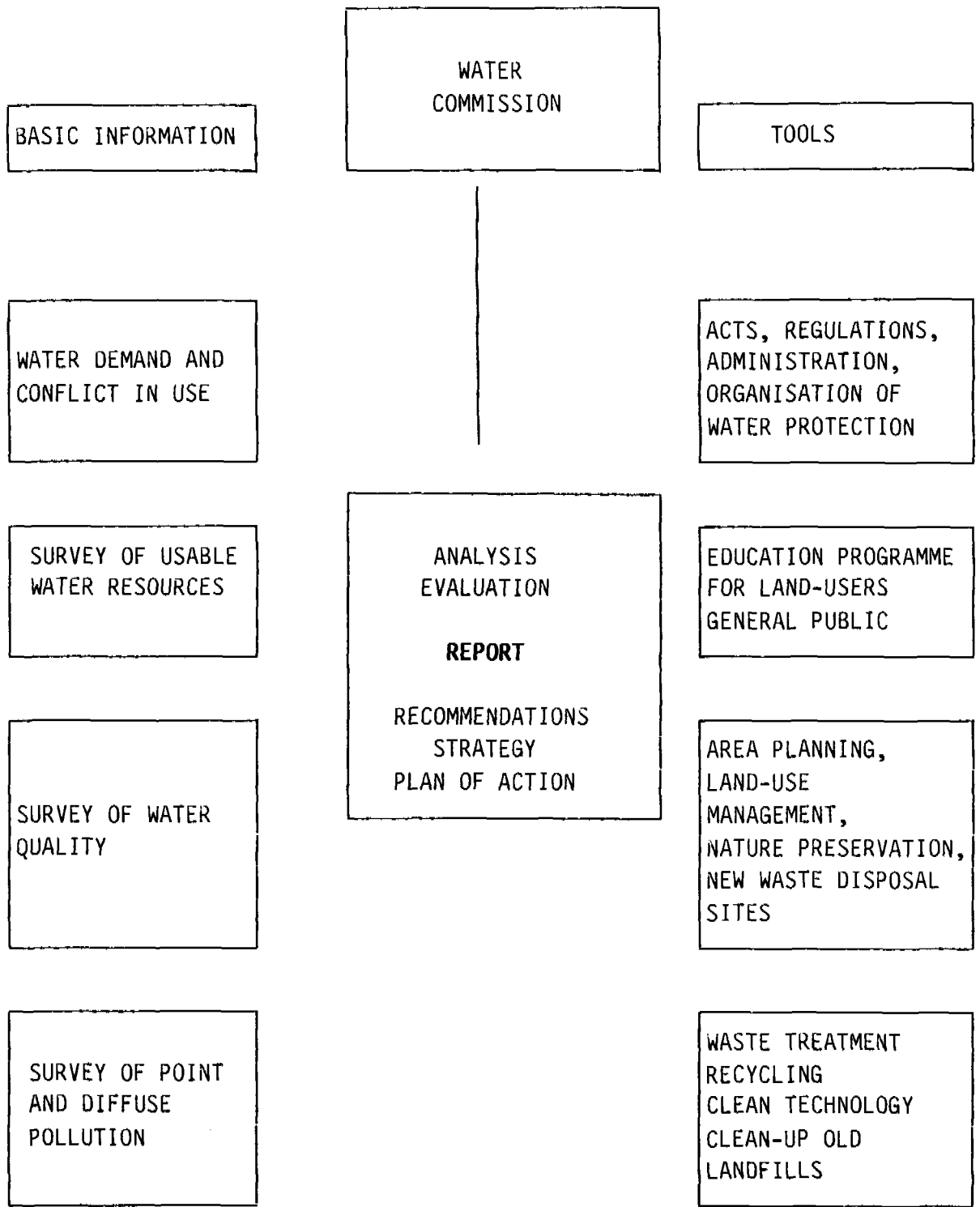


Figure 8.1 Method of implementation in Denmark

At an early stage the water commission tries to answer the following questions:

Who is doing what?

What are the present problems?

What do we fear?

Are we able to identify all water problems?

What is the present nitrogen balance?

What part of the nitrogen cycle is regulated?

What do we wish to change?

What needs to be regulated?

The implementation could be enacted with the tools shown in figure 8.1. The topics in figure 8.1 are described in chapters 1 to 5 of this report.

The work of the group should be limited in time, and their recommendations should be implemented by the authorities by legislation and regulations.

The implementation of such an approach clearly will not be possible in a single step. As the conditions, due to changing land-use affects the protection measures, in turn the land-use planning has to be altered accordingly. Therefore, the first stage of implementation must be regarded as a trial period during which the effectiveness of the different measures can be assessed.

8.3 TIMING OF PLANNING AND GROUNDWATER PROTECTION

The question of the timing of the introduction of land-use planning and groundwater protection has arisen only recently. A few countries were far-seeing enough to start very early but most others were not. Today, it is clear that planning and protection ideally should start together. Such an approach minimises problems and enables corrective action to be taken relatively cheaply. Recent changes in agriculture and industry have greatly increased the risks of polluting groundwater. The use of agrochemicals for disease prevention as well as fertilizers has increased enormously. Growing the same crop year after year also increases the risk of groundwater pollution. New industries with lots of new chemicals are an additional threat in many districts. The change from biological risks to chemical

risks may increase the total risks and the total consequences of groundwater pollution. Therefore planning land-use and protection of groundwater, in all regions where groundwater occurs in significant amounts, is essential. It should begin at the earliest stage possible.

8.4 PUTTING PROTECTION LEGISLATION INTO PRACTICE

The regional and local authorities should draw up plans for the future water supply needs and the conflicts arising from land-use, water abstraction and groundwater protection. This requires a number of surveys on water resources, water quality, as well as surveys on point and area pollution. Some of these surveys can be carried out by the regional authority, some in cooperation with the local one or provided for the region by compilation of data from local sources. The regional authorities should licence groundwater abstractions over a certain limit and make the necessary regulations for protecting the catchment area at the various levels necessary within the established protection zones.

8.5 CONTROL AND INSPECTION

The local authorities should control and inspect the licensed water abstractions and the measures to protect them i.e. sewerage and other waste water disposal. The local authorities should report on their own groundwater withdrawal and all other local water abstraction: the regional authority should supervise the local authorities and report to the central national authority by yearly reports. In connection with groundwater protection, a monitoring system for groundwater quality and quantity should be established. This should be designed by cooperation between the national, regional and local authorities. It can be run by the regional authorities. The regional authority reports the data to a central database for compilation of national reports and maps. For regional and local administration all data should be stored in national databases. The local and regional authorities supervise the quality of drinking water and report the data to the central database.

9. PUBLIC INFORMATION AND EDUCATION

by

C.R. Aldwell and D. Daly

9.1 INTRODUCTION

There are a number of obstacles to creating greater public knowledge of groundwater and the need for groundwater protection in rural areas. Firstly, for most people groundwater is "out of sight, out of mind", so that there can be a low level of awareness among many decision-makers and the general public. Secondly, country people often have a mystical view of groundwater as springing or issuing from the ground at a point, without connecting it to what is happening on the surrounding land. Thirdly, groundwater in many countries is regarded as being automatically pure and wholesome. There is little realization that groundwater may look, smell and taste pure while in fact being polluted and a serious risk to health. Lastly, water scientists may have little training in communication. They need to take account of ways of simply and clearly informing non-specialists about groundwater protection issues.

9.2 SIMPLE RULES FOR EFFECTIVE COMMUNICATION OF PUBLIC INFORMATION

Identify Target: Who is the listener or reader? Is it decision-makers such as engineers and planners, or politicians, or local communities or individual landowners?

Classify Target: Different targets will require a different message, language, approach, etc. Often it is worthwhile identifying influential people in the target group who may be sympathetic to the message and whose good example will be followed by others in their community.

Decide Message: It is crucial to consider each target's needs and to vary the form of the message depending on the target and local circumstances.

Evaluate Message Carefully:

- a) Ensure that the message is appropriate to the culture and traditions of the target; this relates both to form and content. It requires

consultation with the people involved and is particularly important where the experts are from a different region or country to that of their target groups.

- b) Ensure that the message is defensible. The facts should be accurate and up-to-date (At the same time, adequate consideration must be given to actual local conditions and care taken not to attempt to introduce unsuitable methods from other areas or countries).
- c) The message should be relevant and realistic. In this regard groundwater specialists need to have discussions with health experts, agriculturalists and engineers to ensure that what is being proposed takes into account the work and needs of other disciplines and interests.
- d) In preparing the message, try to understand and see things from the receivers' point of view. This is likely to help the expert in the formulation of acceptable and workable solutions. Changes also take time to accomplish so that patience is necessary. (The matter of incentives and penalties is a delicate one, with the right balance depending much on local tradition and custom).

Present Message Effectively:

- a) Ensure that the language used is understandable and convincing. For instance maps such as geological and groundwater vulnerability or protection maps, if aimed at planners and engineers, must use language and symbols that are immediately understandable. Accompanying reports should attempt to convince and not to patronize or command. Groundwater specialists must present simplified interpretations in the form of user-friendly, interpretive maps and reports that are readily intelligible to non-specialists.
- b) Conventional geological maps are difficult to use for environmental purposes as they are designed by geologists for use by other geologists. Thus they assume a basic understanding of the subject and a familiarity with the conventions used in the presentation. Traditional geological maps aim to communicate an understanding of the geological structure and history of an area rather than the geological implications for the environment. Simplified lithological maps with vertical sections communicate more effectively to the non-specialist.
- c) It is desirable to keep the map format as simple as possible and to use several maps or overlays rather than a single complex one. Technical

terms should be used only where essential and then only when defined in the marginal notes. The use of a brief explanatory text in the margins is recommended. The map should convey its information without the user having to read a large descriptive or explanatory volume of text.

Keep the Message Consistent: Consistency of message is important in order not to confuse the public and also projects the image of a clear thinking organisation. Changes in the message when necessary should take into account what has already been provided so as to avoid apparent contradictions. Large organisations in particular need to coordinate the activity of all their staff.

Maintain Continuity: Effective communication and public relations is an on-going planned process which takes time to achieve results. Repetition, perhaps with varied emphasis, is likely to be necessary. Periodic evaluation of the effectiveness of the approach being used is advisable.

9.3 METHODS OF PROVIDING PUBLIC INFORMATION

The method of delivery can vary enormously depending on the financial and staffing resources, level of education, the culture and traditions of the people and on the message itself. Brochures or booklets, newsletters, talks, displays, tape-slide programmes, videos and using the media - T.V. radio and newspapers - are all possible options. A few specific examples include:

Video is a powerful medium as it brings the subject to life and people in many cultures tend to be more attentive to information that is conveyed by the screen. A documentary style production can convey objectivity and credibility and can make a video more persuasive.

Visits and talks

- a) to schools and universities particularly agricultural, planning and environmental science students, can have long-term benefits;
- b) to various local community and interest groups enable contact to be made with a wide range of people, including those directly concerned.

It is often worthwhile to get a local person to give talks rather than using

specialists with a different accent or background.

If the message is likely to be controversial or unpopular, it is often better to talk to small groups rather than large meetings.

Many rural areas have annual agricultural shows or trade exhibitions. These may provide an opportunity for a display on groundwater protection or perhaps a stand staffed by groundwater personnel.

In many countries the press, especially the local provincial papers and farming publications, provide an opportunity to inform rural people about the importance of groundwater protection. A press release can be prepared written as a news story in the style of the publication. Such an approach increases the chance of the article being reproduced unaltered. Some papers may severely edit and even distort the presentation, therefore it is useful to establish personal contact with the reporter or editor concerned.

Special booklets simply worded and clearly illustrated may be provided free or at cost price by State agencies. As these already exist in a number of countries, it is worthwhile and time-saving to examine them and to adapt information from them in preparing new booklets.

Colourful eye catching posters may be produced and distributed for display in schools and public offices.

Most countries have an agricultural advisory service often with a network of advisory staff located throughout rural districts. These staff are likely to be interested in water whether for irrigation or watering of stock. Due to their normally close and good relations with farmers, they provide a valuable potential means of distributing water protection information as well as having an essential contribution to make in finding solutions to agriculturally derived pollution.

Use of prototypes The use of prototypes or demonstration models can be a very effective means of introducing any new concept to a region or country. In the case of groundwater protection this will be a basic plan which can be tried out in practice in a typical district. In the light of operating experience it can be adapted to meet local needs and used elsewhere in the

country.

The original plan may be drawn up by a government agency or educational centre and should take into account experience already obtained in other countries. Specific local problems need to be given particular attention. It is desirable to incorporate the views and experience of a range of experts, including planners, economists, agriculturalists and health workers, as well as water scientists.

Include groundwater protection in basic education It is important to introduce people to the concept of groundwater protection at a early age. For this reason efforts should be made to ensure the subject is included in primary school curricula, especially within a general introduction to protection of the environment.

Best results are usually obtained from people when they understand clearly the reasons for groundwater protection proposals and in particular how their actions can cause undesirable problems for themselves, their neighbours and the community. Time and money spent on communicating information accurately and simply is likely to be a good investment, especially in rural areas where it is not practical to have inspectors regularly checking every farm. An informed population, who understand that good water protection practices are in their own best interests, is an important means of reducing pollution.

CASE HISTORY I

**LEGAL/INSTITUTIONAL AND SOCIO-ECONOMIC ASPECTS OF
GROUNDWATER USE AS THEY HAVE AFFECTED GROUNDWATER
QUALITY AND QUANTITY IN THE NETHERLANDS**

by
J.J. van Soest

INTRODUCTION

The following outlines the experience of the Netherlands, a country where there is no need to prove the value and importance of groundwater management and that interference with the natural state of groundwater can damage the environment and human interests.

Good regulations in the fields of physical planning, water resources management and environmental protection are vital for sound groundwater management. These objectives form the basis for the directive of the Council of the European Communities on groundwater protection against pollution caused by the discharge of certain dangerous substances (1979. Dec 17 no. 80/68 EEC). It is the framework law to protect groundwater with which all European Community countries must comply.

In the Netherlands, as in many other countries, groundwater is a source of both domestic and industrial water supply. About 2/3rds of the water used is groundwater.

Moreover, groundwater influences vegetation in large areas of the country where it affects the moisture level of the upper soil layers. This is important for both agriculture and nature conservation.

In the Netherlands, the first moves to protect groundwater came from the public water supply authorities. As early as 1940, a government commission recommended general rules on groundwater abstraction and protection in a water supply act, of which a draft was prepared. World War II interrupted

further developments until the fifties.

The matter was then taken up under different headings. Protection of groundwater resources was made part of provincial physical plans, whereas rules on groundwater abstraction for public supply were enacted in 1954 by central government.

However, there were as yet many omissions that made these regulations far from satisfactory. These included the absence of general regulations on water management and environmental protection.

The 1954 Act on Groundwater Abstraction for Public Water Supply contained a licensing system for these abstractions. It gave these licensed abstractions a legal status (civil law actions were barred) but contained no rules on abstraction for other purposes (industry, agriculture) so that an equitable distribution of available groundwater resources could not be achieved. Most provinces made their own regulations on water abstraction for industrial purposes.

In the absence of adequate protection of wells for public use, some provinces made their own regulations, while in some cases the water supply companies owned the land adjoining the wells. However, the overall situation remained far from satisfactory due to differences in regulations and their application. In some cases, regulations which were not intended for the purpose had to be applied, e.g. the Nuisance Act or provincial rules on excavations.

THE PRESENT SITUATION

Since then, legislation has been completed in all these spheres in the Netherlands. The Physical Planning Act, in force since 1965, was changed in Parliament. It covers subjects which have a major impact on physical planning on a national scale, such as land, water and air traffic, electricity supply, and public water supply. These plans allow other interests to make representations. The decisions are made very carefully after official consultations and public hearings. They have to be followed by provincial and local authorities when they make their own regional and local physical plans. In the Netherlands planning legislation began in 1901

with local physical plans. Enactment of physical planning by central government only began in 1972, with a drinking water supply plan which followed 15 years of voluntary experiments.

This plan was revised in 1984 and is due to be amended for the third time in 1991. It places restrictions on ground and surface water abstractions, so as to provide for water supply needs up to the year 2010 (about 2600 million m³/year as a maximum for an estimated population of 16.4 million; in 1989 total consumption was about 1200 million m³ with a population of 14.8 million). Water management regulations underwent equally rapid development during the period 1970-1990. Starting with a surface waters sanitation act in 1969 - which came into force in 1970 - rules on ground water abstraction were enacted in 1981 and have been in force since March 1984. In 1989 a water management act, covering all remaining gaps and improving the efficiency of water management planning, was accepted by Parliament.

However, the Dutch Groundwater Act is of most importance to groundwater management. It contains regulations on groundwater abstraction and on artificial recharge in the fields of registration, planning and licensing. This Act is executed by provincial governments under the supervision of central government. Registration and licensing are obligatory for abstractions above 10m³/h. The decisions of the provincial government can be appealed to the Crown's Council. Planning must examine and assess available groundwater resources, including their quality as well as future groundwater needs and priorities.

Central government can give directives to the provincial authorities on the contents of the plans, in the national interest.

Protection of groundwater against pollution now comes under the heading of environmental management. A land protection act came into effect in 1986. In the act, groundwater is included in the definition of land because groundwater protection is impossible without protecting what lies above it. "Land" in this context includes all the layers and earth material from the surface of the ground to as far below it as human impact extends. The Act provides for national standards based on rules set by the central government.

These rules comprise a combination of effect-orientated measures (formulation of quality standards) and source oriented measures (combating pollution sources).

In addition to this general protection, specific protection must also be provided in certain areas e.g. around major groundwater supply sources, the so-called groundwater areas. The provincial authorities are obliged to draw up a groundwater protection plan and develop a set of regulations to achieve this specific protection.

As regards land, Dutch environmental policy distinguishes between local (point) pollution sources (deep well disposal, waste disposal sites, underground storage tanks, pipelines etc.) and diffuse pollution sources (use of manure, fertilizers, sewage sludge, pesticide application, acidification etc.).

Local pollution sources have to meet the so called ICM criteria i.e. Isolate, Control, Monitor in order to prevent pollution.

For diffuse pollution sources, the policy aims at preventing the entry of dangerous substances into the environment and reducing the effects of acidification and fertilizing by introducing source - orientated measures. In groundwater protection areas these measures will be more rigorous.

For example, certain pesticides which are mobile in soil, and could therefore be leached into the groundwater, may not be used on agricultural land in protection areas.

In the near future, the general use of persistent and mobile pesticides will be further restricted.

All this planning was incorporated into the 1989 National Environmental Policy Plan. This plan aims at stabilising the pollution situation by the year 2000. However, the effects of earlier pollution will continue for a long time, due to the slow movement of groundwater.

Official Planning by the Public Water Supply Industry

Many other countries have legislation on physical planning, water management and environmental protection that is equal to, or can be compared with, the Dutch system already outlined. Something new and perhaps unique are, however, regulations in the Dutch Public Water Supply Act on planning by the public water industry itself. Within the limitations contained in the government plan on water supply, the water industry has to make its own development plan for the next ten years. After consultation with the provincial governments, the plan has to be approved by central government. After this approval, it will be binding on the water industry itself. By means of this plan the water industry, consisting now of about 60 different water supply companies, is constrained to make efficient use of available water resources, while at the same time providing a guide for the licensing authorities. In most cases it is the provincial governments that have the obligation to provide the water supply in the public interest, following the guidelines of the plan of the central government on this subject.

Perhaps such a solution for "planning harmonisation", that nowadays is evolving in many countries, can only be found where the water industry itself has a strong organisation. The Dutch water supply organisation VEWIN, has indeed its own planning office and also a research institute, KIWA, at its disposal. Nonetheless, despite its high reputation for good water management and planning everywhere, the Netherlands still has problems. The legal system as a whole has still to prove its capacity to harmonise so many interests previously without planning or licensing systems. Too often, problems of environmental hygiene have a tendency to hide themselves in corners where they cannot easily be tackled. This particularly applies to the underground, till now deemed a very suitable place to dispose of wastes. When such material is covered it no longer meets the eye, but in most cases it remains a hidden and very dangerous polluting agent. Disposal of manure is just such an example in the Netherlands.

Pollution by Nitrates and Phosphates

The environmental policy on fertilizers in the Netherlands aims at reaching a level of protection sufficient to prevent percolation of phosphate to the

groundwater and reduce the amount of nitrate which leaches from the topsoil. These measures are necessary to prevent further eutrophication of surface water and to avoid additional treatment at pumping stations. This treatment is necessary in order to remove nitrate from groundwater and meet the EC drinking water limit of 50 mg/l.

Nevertheless, in some pumping stations for public water supply, the amount of nitrate in the groundwater is already so high that additional treatment is inevitable.

In 1987 a regulation was made based on the Land Protection Act, which limits the amount of manure to be spread on grassland and arable land. Furthermore, it prohibits manuring during winter especially when the soil has a snow cover or is frozen.

The proposed measures have three different phases of 4 or 5 years each. The ultimate goal, to be reached in the year 2000, is an equilibrium between the amount of phosphate added to the soil and its withdrawal from the soil by crop growth.

In the meantime, the amount of nitrate leaching from agricultural lands to the groundwater will remain too high. Therefore more stringent manuring and fertilizing regulations at a provincial level are necessary, especially in the vulnerable groundwater protection areas.

Sprinkling

Irrigation by groundwater sprinkling has become increasingly popular. Without regulating measures, groundwater abstractions for this purpose in the Netherlands are estimated for 1990 to be about 900 million m³ in a dry year (20% year) and about 1500 million m³ in a very dry year (5% year), from an average available groundwater resource of 1940 million m³. As a further 1400 million m³ is needed for domestic and industrial water supply, there is obviously a serious problem.

The main factor preventing the regulation of groundwater abstractions for sprinkling purposes is that the well and pumping units are small, widespread and numerous. Restricting the number of these units, as suggested in a

recent government report on water management, also seems difficult to implement. Perhaps other countries have encountered the same difficulties and have already tested some solutions. In the Netherlands it is intended to develop local surface water supply plans for agriculture rather than to face agriculture with water shortages that cannot be supplied by groundwater. This solution, however, will not be available everywhere. The provincial groundwater plans, for public health reasons, will have to give priority to drinking water supplies.

Financial Aspects

There is a saying that "money is the root of all evil". In this case, however, it is more or less the other way round: many good solutions could not have been reached by planning and licensing alone. The limitations and restrictions necessary were only acceptable because financial compensation was available.

Many examples can be given. Large areas in the Netherlands have a shallow water table which, if lowered, can adversely affect vegetation. Hardly any licences for groundwater abstractions could be given in such areas if there were not regulations for financial compensation, contained in the Groundwater Act. The compensation must be paid by the licensees. Groundwater protection would otherwise be impossible in the Netherlands without financial compensation for unavoidable restrictions of activities in protection zones. The Physical Planning Act and the provincial groundwater protection regulations give compensation for losses that it would not be reasonable to expect those affected to bear. Of course, compensation is paid for real losses, not for imaginary ones. Up to now, compensation payments were officially only paid by authorities that issued the restrictive measures. As they had limited funds for this expenditure, they were slow to forbid harmful activities unless the water companies promised to pay. In the past this proved to be one of the main obstacles to adequate protection of groundwater catchment areas. The act containing general rules on environmental protection now has a proviso that these costs may be charged to those who profit by the protective measures, i.e. the water companies. This could be called a "consumer pays principle".

During the last 3-4 decades, the Netherlands has developed legislation that

covers a wide range of groundwater problems, those of quantity as well as those of quality. This experience highlights that groundwater cannot be treated in isolation but all aspects of physical planning, water management and environmental protection must be taken into account. This is also the only way in which to prevent solutions becoming problems elsewhere. Harmonised planning is the vital ingredient. Financial obstacles to good groundwater management need to be identified as quickly as possible and removed. The Netherlands has gained much experience and made considerable progress but much still needs to be done in the years ahead.

CASE HISTORY II

LAND-USE PLANNING AND GROUNDWATER PROTECTION

IN DENMARK

by

L.J. Andersen & R. Thomsen

INTRODUCTION

Denmark occupies an area of some 43,000 km², with a population of 5.1 million. The country is fragmented. The peninsula of Jutland has an area of 30,000 km² and Zealand, the largest of several islands, covers 7,000 km². The highest population density is in Zealand where the Danish capital Copenhagen is situated.

Denmark is low-lying, with its highest point just 172m above sea level. Most of the country consists of Quaternary deposits overlying chalk or limestone.

The limited size of the peninsula and the islands results in only small rivers. The combination of low topography and widespread consolidated and unconsolidated aquifers ensures a plentiful and easily accessible water supply. As a consequence, groundwater provides 98 per cent of Denmark's water needs. The only surface water used for public supply is in Zealand.

Since the water quality generally is good, complex and expensive treatment is not required. Expensive lengthy pipelines, served by large central water plants, are also unnecessary. Thus, water supplies in Denmark are mainly decentralised. Altogether there are about 4,000 public supplies and some 150,000 private water sources (boreholes and dug wells).

Two-thirds of the national supply is provided by about 200 municipal waterworks and the remainder by private cooperative plants.

The natural geographical conditions in Denmark mean that strict regulations for sewage treatment are needed to protect fresh and marine waters from pollution.

The Danish Minister for the Environment recently has produced an action plan which lists the Ministry of the Environment's priorities. Top of the list is a healthy diet and pure drinking water. Next comes control of wastes, recycling and cleaner technology. This order of priorities clearly reflects the importance attached in Denmark to preserving good quality groundwater: the basis for pure drinking water that both tastes good as well as being beneficial to health.

WATER COMMISSIONS AND ADVISORY GROUPS PRIOR TO 1970

Water advisory groups have existed for many years in Denmark. Such groups were set up to provide advice on necessary changes in land-use laws. The first act which concerned water supply dates back to 1926. The geologists of the time succeeded in having an article included which required anyone sinking a water supply well to provide the details to the Geological Survey of Denmark. The result has been the creation of a most important and valuable database for planning and administrative purposes. The Water-Supply Act also introduced licences. All abstractions of groundwater, other than for domestic use, were determined by ad hoc water commissions. Other important items in the act, were the requirement for protection zones around wells and the prohibition of the release of polluting liquids to groundwater.

During the 1950s a Water Balance Committee was formed to evaluate and initiate actions to protect the environment against pollution due to change of land-use and increased groundwater abstraction.

The International Hydrological Decade, initiated by Unesco in the middle of the 1960s, resulted in the establishment of National Hydrological Committees. These were of great importance for the understanding of the water cycle, the environment and its nature, and thus the influence on the hydrological cycle by the various types of land-use.

With the increasing pollution from ever more wastes, a group named the Pollution Council was set up in the late 1960s. This group prepared reports on all aspects of wastes, and prepared recommendations regarding land-use problems. The most important outcome of this Council was to highlight the threat posed by pollution. In the early 1970s formulation began of the first Environmental Protection Act.

In 1970 the administration of regulations concerning land-use and the protection of the environment were decentralized from the central government to the new regional county districts.

ADMINISTRATION OF PLANNING SINCE 1970

Planning and public administration in Denmark is carried out at three governmental levels (Figure 1): Central government; Regional councils (14); and Local councils (275)

By a municipal reform in 1970, 23 counties and about 1200 municipalities were reduced to the present number. The principal purpose of the reform was to make public planning and administration more efficient. The aim of the amalgamation of the counties was to create a number of regional areas of reasonable size. The aim of the amalgamation of the municipalities was to create administrative units which could cope with their heavy responsibilities. The result was therefore to establish new municipalities with at least 5000 inhabitants and with a central town.

Public Planning in Denmark

Public planning in Denmark is first and foremost the physical planning of the regions and the municipalities. The principal tasks of the regions concern matters which are of interest to several municipalities. These matters include the planning of water, environment, nature preservation, open country, roads, energy, hospitals and higher level education. The planning tasks undertaken by the municipalities are primarily of a physical character, dealing with urban development and providing technical support to the municipalities.

The planning scheme is based on three main principles: framework management, decentralization and public participation.

Framework management implies that central or regional government authorities determine the framework for the actions of the subordinate authorities, but do not subsequently approve these actions.

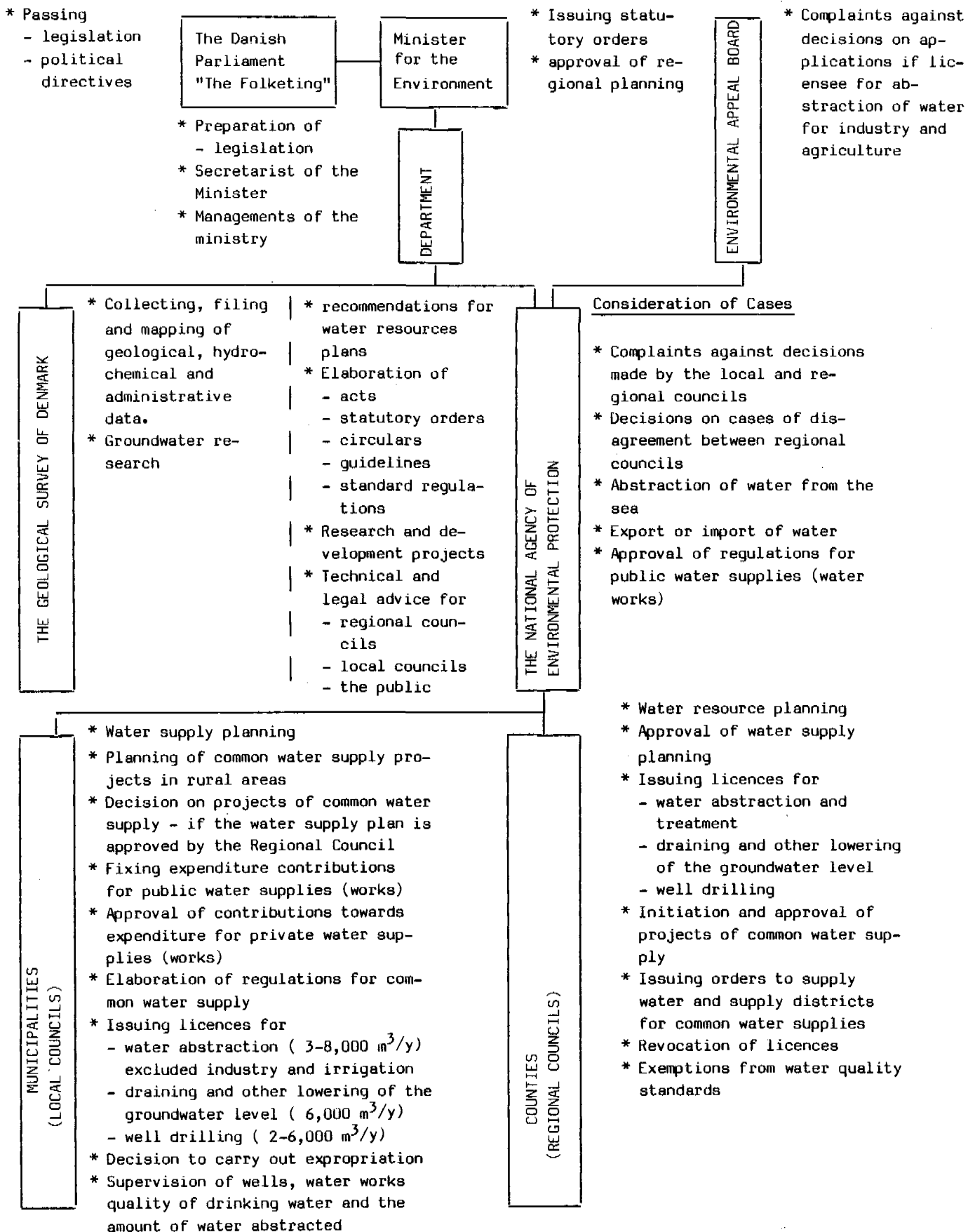


Figure 1 The Danish Water Supply Act - Water Abstraction and Water Supply - Powers of Authorities

Decentralization implies that regional and elected local authorities decide for example, on the use of water resources within a given framework.

Public participation implies that citizens should participate in the planning process prior to decision making.

Water Planning

Water planning in Denmark is carried out in conformity with the Water Supply Act of 1985 (1974).

The strategy for protecting Danish water resources is expressed in the Environmental Protection Act (1973 and subsequent amendments).

Water Supply Act

The Water Supply Act of 1985 sets rules, according to which use of groundwater and surface water may be regulated on the basis of integrated planning.

The purpose of the Water Supply Act includes ensuring that the use of water resources takes place according to integrated planning and through comprehensive evaluation of:

1. the size of the water resource;
2. the needs for a water supply that is adequate in quantity and quality for a) the general population, and b) agricultural, horticultural, fish farming and industrial purposes;
3. protection of the environment and nature, including protection of the public's interest in recreation, wildlife, and maintenance of the quality of the environment.

Environmental Protection Act

The purpose of the Environmental Protection Act of 1973 is, among other things,

1. to prevent and combat pollution of air, water and soil;
2. to establish environmental regulations based on considerations of

hygiene;

3. to provide the necessary administrative basis for the planning and implementation of pollution control.

The Environmental Protection Act is aimed particularly at safeguarding physical qualities essential to the healthy and recreational aspects of human life and to maintaining the diversity of plants and animals.

The overall strategy for protection of water resources is provided in the Water Resource Plan and the Surface Water Quality Plan. The task of the Water Resource Plan is to preserve and maintain the quality and quantity of groundwater resources, while it is the task of the Surface Water Quality Plan to preserve the quality of fresh water and coastal water areas.

In the case of both plans, possible recreational uses are taken into account.

Sector Planning

Water planning in Denmark is a part of a large system of physical and environmental planning, namely, Public Sector Planning.

The object of this planning is to ensure that the use of land and natural resources is based on an overall social assessment to provide the foundation for a sound environment, and to contribute to the prevention of pollution.

The planning scheme consists of a number of mutually balanced plans for public administration and services. The water resource plans play a vital role in the balancing of plans for the use and the protection of natural resources in the countryside.

Planning

The administration of water licences is regulated by two sets of plans:

- water resource plans, drawn up by the regional councils
- water supply plans, drawn up by the local councils.

The regional councils are responsible for the protection of water resources

from pollution and excessive use. Thus, it is the regional councils which have the authority for issuing the major part of the water abstraction licences.

The Water Resources Plan contains the guidelines for the use of water resources in a region.

The plan is based on a comprehensive evaluation of the size of the water resources, the needs of the population and industries for water supply that is adequate in volume and quality, protection of the environment, water resources and preservation of wetlands.

The local councils exercise planning, administrative and supervisory duties concerning the water works and the water supply infrastructure. They are responsible for coordination of existing water supplies, and the extension and operation of an adequate water supply both in volume and quality. The Water Supply Plan contains the guidelines for the organization of water supply.

Water Resource Plans and Other Sector Planning

As described earlier in this chapter, there is a close connection between water resources planning and other public sector planning. The most important of these interrelationships are now outlined.

- Surface water quality plan

The "surface water quality plan", prepared by the regional authorities, lays down the intended use of watercourses and lakes, and describes their required quality. Among the aims included in the surface water quality plan is the flow of water courses.

Taking into account wider plans, the local council works out an overall plan for the extension of waste water plans in its district.

The provisions of the waste water plans concerning discharge into water courses is based on the assumption that the waste water is diluted to some extent, and this again requires a certain minimum volume in the water

course.

Since any water abstraction may affect the volume of the watercourses, water abstraction may disturb the basis for both surface water quality and waste water planning.

- Landfill waste disposal

Any disposal of waste on the ground produces a risk of pollution of groundwater and surface water. Groundwater pollution may be prevented by establishing controlled waste disposal sites, where an attempt is made to prevent percolation of leachate into the ground by means of impermeable soil layers or liners.

The risk of groundwater pollution can, however, not be removed entirely. Therefore, when planning the location of waste disposal sites, areas with no groundwater abstraction sources should be selected.

- Raw material extraction

Raw material extraction may affect water abstraction possibilities and cause risk of pollution of groundwater. The regional plan for extraction of raw materials must therefore be coordinated with the resource plan.

- Preservation

There may be considerable preservation interests in connection with watercourses, lakes, wetlands and the headwaters of the watercourses. Water abstraction will affect the flow of water in watercourses and may, in connection with wetlands and springs, result in such a fall in the level of groundwater that the wetlands or the springs will dry up partially or wholly. The water resource plan and the regional plan for protection of nature must therefore be closely interrelated.

- Agricultural planning

The regional Councils shall draw up plans to safeguard particularly valuable agricultural areas with irrigation potential.

The Water Council's Plan of Action

In 1983, the Minister for the Environment appointed a Water Council. Their most important job was to assist the environmental authorities in their endeavours to preserve Danish fresh water resources by, among other things, initiating research and investigative activities in hydrology.

The Water Council, which is the Danish IHP Committee, previously worked on preparing a framework within which research and development could take place on agricultural, inorganic and organic pollution. The Council has also a research programme on purifying groundwater that has been polluted with leachate from old landfills.

Participation in these somewhat sporadic activities has convinced the Water Council that there is a need for a joint effort in the area of water pollution. In the Water Council's opinion, the content and extent of such an effort should be formulated in a plan of action to protect, re-create and preserve the quality of groundwater and surface water resources.

As a first step in developing the plan of action, the Water Council has proposed various information and research activities. The proposal outlines present knowledge in the area as well as the need for new knowledge.

The Water Council has also pointed out the need for new initiatives in the areas of planning, monitoring activities, research and information.

In order to produce the necessary basis for protecting, re-creating and preserving the quality of water resources, an ongoing collection of data (monitoring) should be implemented that can supply the necessary knowledge regarding

- the size of groundwater resources;
- the quality of groundwater resources.

The Water Council's plan of action includes

- ascertaining the existence of potential sources of pollution and intervening before damage is done and potential drinking water sources are threatened;

- preventing (or at least greatly reducing) known pollution at its source.

Research activities should be aimed at

- the necessary measures for preventing pollution;
- the need for new water treatment techniques.

The Water Council has suggested the following points as areas where steps against potential pollution should be taken

- the use of inorganic fertilizers;
- the use of pesticides;
- old rubbish and chemical waste dumps;
- oil installations and oil stores;
- slag, fly ash and flue gas desulphurisation residues;
- waste water disposal;
- deposition of airborne pollutants.

The Water Council has furthermore pointed out the need for research in reduced-waste techniques and for further development of methods of water treatment and purification.

The Water Environment Scheme of Denmark

The latest and largest Danish programme concerning changes within land-use practice, in a broad sense, is being implemented at the present time.

The so called "Water Environment Scheme" ("Vandmiljøplanen") has been developing during the 1980s. A great number of "actors" have been involved i.e.: The "Water Council", interest groups, mass media including TV, the Nature Conservancy Association, public opinion, Parliament, the Government and its Ministries for Environment and Agriculture, and expert groups. The genesis and implementation of The Water Environmental Scheme for Denmark is described and evaluated by a group established by the Academy of Technical Sciences (ATV, 1990). This description consists of about 200 pages including enclosures. Also during this complicated and multi-disciplinary process a group, the "Water Council" played an initiating and important role. Another group, the participants of a consensus conference, was an important factor in the politicians' decisions, necessary for the

implementation of the scheme.

The Danish Water Environment Scheme is a means for action to be taken against nutrient pollution of the Danish water environment. The scheme prescribes how the reduction of nitrogen and phosphorus within agriculture, numerical waste water treatment, and special industrial waste discharges should be performed. The target is to reduce the emission of nitrogen to 50% and the emission of phosphorous to 80% of previous levels. The Water Environment scheme requires changes in agricultural practices and comprehensive improvement of waste-water treatment plants, combined with a comprehensive monitoring programme within all parts of the hydrogeological cycle, including the marine environment surrounding Denmark. The total capital investment is estimated at 12 billion D.Cr (about 2 billion US \$). The government indicated that the implementation of the Water Environment Scheme in Denmark is a task of huge dimensions for Danish society and that it would require a large contribution from the individual citizen, industry and the authorities. However, the implementation of the Water Environmental Scheme was regarded as necessary to maintain pure groundwater, and living conditions in the seas surrounding Denmark, now and in the next century.

DANISH WATER PROTECTION LEGISLATION

as of 1st January 1990.

- * The Water Supply Act, Act No. 299 of 8th June 1978
 - amendments 1982, 1984, 1985, 1987, 1988, 1988.

- * The Environmental Protection Act, Act No. 85 of 8th March 1985, part 3 Protection of Groundwater and Water Supply Interests
 - amendments 1986, 1987.

- * The Waste Disposal Site Act, Act No. 420 of 13th June 1990.

- * Statutory Orders
 - No. 2 of 4th January 1980 concerning water resources and water supply planning - amendment 1983.
 - No. 3 of 4th January 1980 concerning abstraction of water and water supply - amendments.

- No. 4 of 4th January 1980 concerning well drilling for groundwater.
- No. 162 of 29th April 1980 concerning quality of surface water intended for production of drinking water.
- No. 469 of 11th July 1986 concerning imposition of contributions to distribution pipes and service pipes according to section 53 of the Water Supply Act.
- No. 470 of 11th July 1986 concerning expropriation for water supply systems.
- No. 515 of 29th August 1988 concerning water quality and supervision of water supply systems.

CASE HISTORY III

PROTECTION OF GROUNDWATER RESOURCES IN ITALY

by
M. Civita

INTRODUCTION

Italy as a whole has adequate groundwater resources which supply the main source of drinking water. However, these groundwater resources are affected by four deterioration processes which strongly influence regional schemes to exploit and protect groundwater within land-use planning: drought, overpumping, saline water intrusion and pollution.

DROUGHT

Stretching through more than 10 degrees of latitude between the Alps and Africa, the climate of Italy ranges between a semi-arid type (ppt. 450-600mm/a, ave. temp. 18°C) in southern areas, through sub-humid (500-900mm/a, 15°C) conditions in the northern perimountain region to humid conditions (800-1550+ mm/a, 13°C or less) in the Alps and the Apennines.

This wide range of climatic types, combined with unfavourable hydrogeological settings in the southern peninsula and in some regions in the north-central area, cause major problems in providing drinking water supplies.

Moreover, in the three years 1987-1989 there was a serious reduction in autumn-winter precipitation due to persistent blocking anticyclones over the Mediterranean area. This has led to severe problems, not only in the areas already mentioned but indeed in the whole country. It was possible to observe how conditions of drought may combine with overpumping and natural and/or human pollution to lower the quality of groundwater in several aquifers on the plains and along the coast.

OVERPUMPING DEPLETION AND SALINE WATER INTRUSION

This is a major problem in the Po plain, where the large yielding deep alluvial aquifers are seriously depleted in urban and industrial zones.

Great urban centres, such as Milan, Venice-Marghera, Bologna, Modena, Ravenna and their surroundings, obtain their industrial and domestic water supplies from an alluvial multi-layered aquifer whose potentiometric surface has been drawn down by hundreds of metres.

Consequences of overpumping are:

- to increase and extend pollution processes from intensively used land, where important industries and diffuse chemically based agriculture generate many sources of pollution;
- important subsidence phenomena, which severely damage monuments and ancient art centres such as Venice and Ravenna, where land subsidence has increased flooding by high tides;
- increasing saline water intrusion, as along the Adriatic coast of Romagna, in Apulia karstic aquifers, in the hinterland of Augusta-Syracuse in Sicily, in the hinterland of Iglesias, in Sardinia, etc.

GROUNDWATER POLLUTION

The most serious groundwater pollution problems are found in the Po valley and in the north of the country, as well as locally on coastal plains and along the Apennines. Groundwater pollution has steadily increased due to industrialisation, migration of population to towns from the country and the massive use of chemicals in agriculture. Several disasters involving drinking water supplies have occurred. Although available data are incomplete, best estimates suggest some 300,000 uncontrolled waste water discharges, almost 500 toxic industrial plants (60% in north Italy), average 16 Gkg/y of DSW (domestic solid waste), average production of IW (industrial waste) of about 50 Gkg/y, of which almost 10 are PNW (poisonous and/or noxious waste). Global Italian treating and dumping facilities can handle less than 15% of these wastes. Agriculture uses about 159 Mkg/y of pesticides and more than 1 Gkg/y of nitrogen fertilizers. The least accurate data concern production of livestock wastes. In some areas of north Italy (Modena, Reggio Emilia, Mantova), the density of pig farming is the highest in the world and, in some places, exceeds legal limits. The nitrogen input from breeding, in the Po Valley alone, is estimated at 400 Mkg/y.

In 1986, when Italy began to implement the EEC directive on drinking water quality (80/778/EEC), serious problems became evident in the north of the

country as is shown by the following examples.

In the Vercelli area, where land-use comprises intensive specialised chemically based agriculture (mainly rice with some maize, vegetables and fruit), systematic research took place into shallow and deep well pollution. Civita et al. (1989) reported that of 281 wells tested, 90% of shallow wells and 35% of deep wells were polluted by pesticides. In Piedmont (NW Italy), more than 220 of 1209 municipalities had to deal with pollution of groundwater sources due to pesticides. In other regions in the north, a study carried out by the National Health Institute (Funari et al., 1989) stated that over 250 municipalities had their drinking water sources highly polluted with pesticides and over 200 with nitrogen from fertilizers, livestock wastes and domestic liquid effluents. Raised levels of organic pollutants in groundwater such as chlorinated solvents (trichloroethylene, tetrachloroethylene, methylchloroform etc.) are now common in the surroundings of great industrial and urban centres of northern and central Italy, particularly Milan and Turin. In Milan and its surroundings, about 50% of groundwater is polluted by chlorinated solvents while in Turin and its surroundings, pollution runs at over 15%. Together with chlorinated solvents in these areas, chromium +6 and a new organic industrially generated pollutant, trichloroethylphosphate (generally called "Tris"), are also encountered.

Widely diffused natural substances in groundwater drinking water sources in Italy are also iron, manganese and fluoride, which sometimes greatly exceed the legal standards. High rates of manganese are detected in several zones of Piedmont, Lombardy, Emilia-Romagna, Marche, Tuscany and in volcanic aquifers near Naples where high fluoride levels also occur. These also occur in some zones of Latium and Piedmont.

LEGAL BASIS OF GROUNDWATER DRINKING RESOURCES PROTECTION IN ITALY

A number of laws and regulations include protection of groundwater quality. The most important is the 319/1976 act, "Rules of water protection against pollution", together with the "Criteria, methods and regulation for application of art. 2 of the 319/1976 law", brought into force in 1977. It was only in 1985 that a regulation on drinking water quality (DPCM 08.02.1985), based on the 80/778/EEC directive on drinking water standards,

was enforced. But the most powerful act on this specific topic is DPR 386/1988 which meets the requirements of EEC directive 80/778. This introduces as national standards guide and allowable limits and introduces water protection areas and related framework statements for control and policy.

The act also provides for full technical regulation. In late 1988 the Ministry for the Environment set up a commission of experts to undertake this task. The terms of reference cover;

- General principles;
- Protection areas for wells, springs and surface water sources;
- Hydrogeological surveys and reports;
- Land-use regulation and human activity control;
- Protection areas for drinking water sources;
- Vulnerability maps;
- Analysis and central organisation;
- Disaster plans.

The work is almost complete and soon this technical regulation will be part of Italian law.

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NOTE ON LANGUAGE USED IN THIS PUBLICATION

A conscious effort has been made to write in clear language, keeping technical jargon to a minimum. Even so, some terms are in such common use that their inclusion is considered to be justified. Problems also arise in two other areas. Some words are used with rather different meanings by individual authors and in different countries. For these words a particular meaning has been utilised in this publication as is explained in the glossary. There are also different forms of spelling of certain words, particularly between Britain and North America. British spelling has generally been used except for chapters 4 and 5 which are by an American author.

GLOSSARY

AQUIFER A body of rock which contains water sufficient to provide a water supply. In modern conditions this increasingly implies a significant source of water supply.

CONTAMINATION AND POLLUTION The action by which human activity degrades land or water. Many people treat the two words as synonymous. Others however assign distinct and separate meanings. In this publication pollution alone is used except in direct quotations or references.

EUTROPHICATION The process by which the nutrient content of natural water bodies is increased with consequent loss in dissolved oxygen. The most common causes are agricultural activities, discharge of sewage to lakes and rivers and leakage from badly designed waste disposal landfill sites. Results include aesthetic problems and limiting of the practical usefulness of the water.

HYDROGEOLOGICAL SYSTEM AND GROUNDWATER SYSTEM An interconnected body of groundwater, usually of district or regional extent, which acts as and can be studied as an unit.

GROUNDWATER PROTECTION ZONE An area of land within which activities liable to pollute groundwater are restricted or prohibited. The most stringent restrictions are close to (e.g. within 10m) a drinking water supply source. The severity of measures usually becomes less with increasing distance from the well. In the USA, the term WELLHEAD PROTECTION AREA is used.

GROUNDWATER QUALITY The chemical and biological composition of groundwater. Good quality most often refers to the suitability of a water body for drinking purposes, without the need for complex treatment.

LAND The upper layer of the Earth's crust where this is above sea level. It comprises or may comprise soil, subsoil and rock.

LANDFILL SITE An area in or on the ground in which wastes are deposited. These sites increasingly are designed and managed to reduce/avoid pollution.

POLLUTION see CONTAMINATION

POLLUTION RISK The result of the interaction between vulnerability and the pollution loading applied to a given land area.

SET ASIDE Remove land from agricultural use. This originally was introduced in some countries to reduce production when markets were oversupplied. It is also a means to reduce pollution from agriculture.

SOIL The uppermost unconsolidated layer of the Earth's crust in which plants grow.

VULNERABILITY The natural conditions of an area of land which determines the ability of the land to cope with natural and human impacts.

WELLHEAD PROTECTION AREA see GROUNDWATER PROTECTION ZONE

UNSATURATED ZONE The zone between the surface of the ground and the water table. Its composition and thickness are important factors in determining the risk of groundwater pollution. Also ZONE OF AERATION.