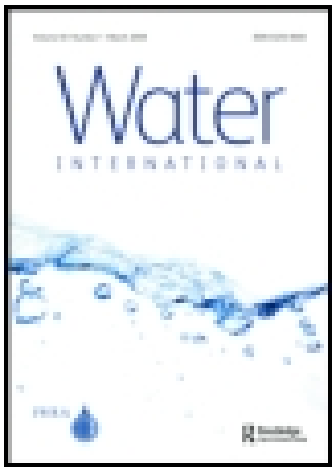

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Management of the Guarani Aquifer System
Moving Towards the Future

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Abstract: *With an extension of 1.2 million square kilometers, the Guarani Aquifer System is one of the largest transboundary groundwater systems in the world. It underlies parts of Argentina, Brazil, Paraguay, and Uruguay and was only relatively recently recognized as a transboundary resource. The four countries are now in the process of starting up a project to elaborate and implement a common institutional and technical framework for managing and preserving the Guarani Aquifer System for current and future generations. This paper briefly presents the Guarani Aquifer System Project. The preparation process is described due to its particular interest for other similar multi-country endeavors. Following the presentation of the project, the paper takes a forward-looking approach and analyzes the applicability of current international law for transboundary groundwater resources in the context of the Guarani Aquifer System. It concludes that while the basic principles espoused by international law relating to transboundary groundwater resources management are valid, they do not provide very specific guidance. The Guarani Aquifer System is unique and its complex features make it an eclectic case, which already is obliging all stakeholders to work out innovative measures – in the legal, institutional, technical, scientific, social, and economic realms – to develop appropriate activities for its sustainable management.*

Keywords: *Groundwater, transboundary, institutional, legal, Guarani Aquifer System.*

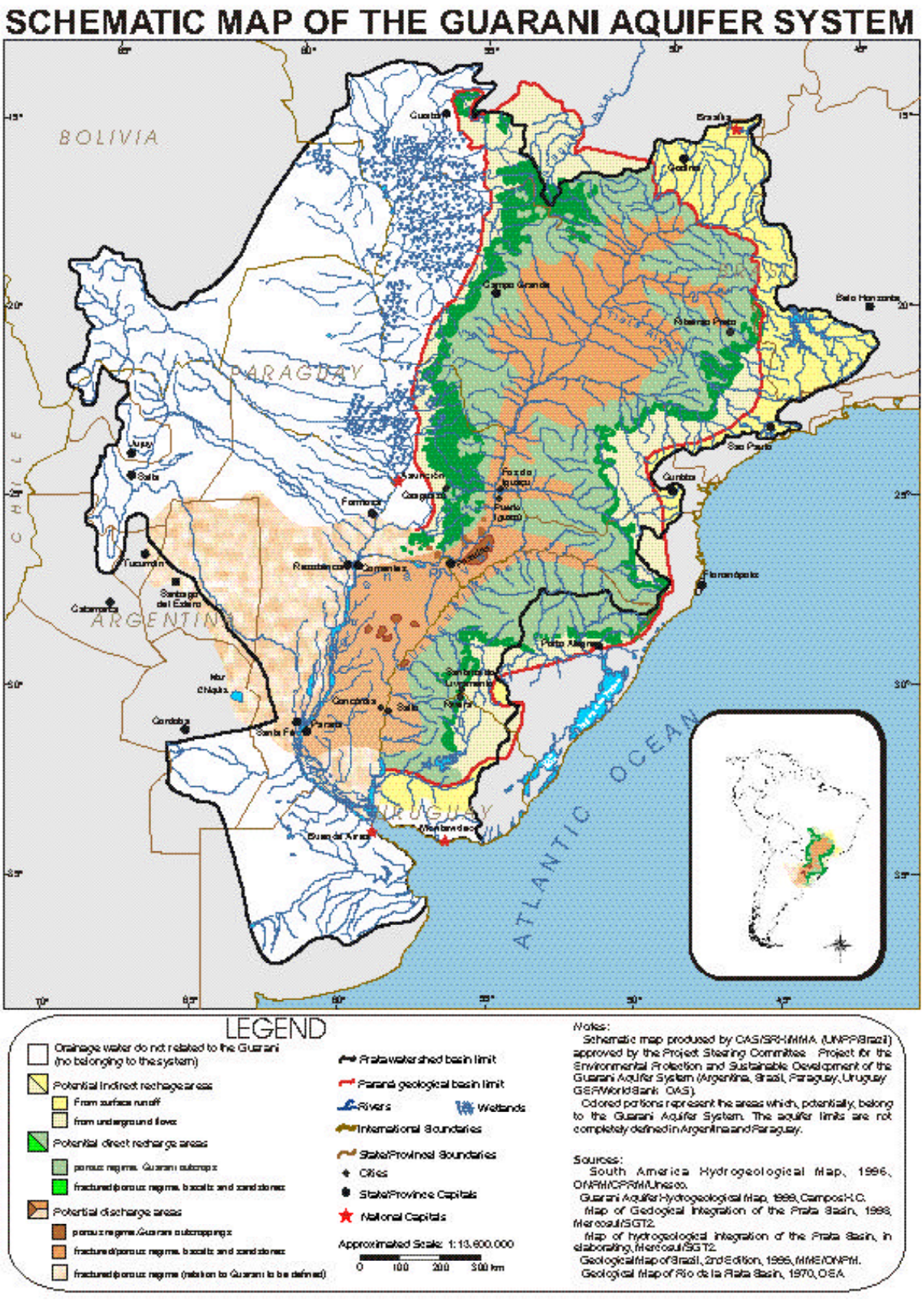
Introduction

The Guarani Aquifer System underlies the area stretching from the central-west region of Brazil into Paraguay and the southeastern and southern regions of Brazil, into northeastern Argentina and central and western Uruguay. The Guarani Aquifer System has an approximate extension of 1.2 million square kilometers, i.e. it is the size of England, France, and Spain combined (see Map). Almost 70 percent underlies Brazil. An estimated 15 million people live within the Aquifer's region. The total recharge area is 150,000 km^2. The Aquifer has an average thickness of 250 meters, with its maximum thickness exceeding 800 meters, while its depth varies from near zero in the Guarani border outcrop areas (Brazil, Paraguay, and Uruguay) to more than 1,000 meters below the surface in the central areas (Argentina, Brazil, and Uruguay.

The Guarani Aquifer System boasts an estimated average recharge of 160 km^3 per year. Furthermore, hydrogeological studies estimate that it contains some 40,000 km^3 of freshwater, and 90 percent of this volume is considered to be potable, although, in some localities salinity and fluoride may affect potability — less than 10 percent of the volume. Guarani Aquifer System water reserves are equivalent to the total water flow in the Paraná River over more than 125 years. The aquifer system could easily supply water for 360 million people — estimating 300 liters/day per inhabitant — on a sustainable basis during a 100-year period, depleting only about 10 percent of the total freshwater reserves assuming a zero recharge (World Bank, 2002). Details of the aquifer are shown in Table 1.

The Guarani Aquifer System also has a geothermal potential to be considered. In certain regions, water emerges naturally at temperatures oscillating between 33 and 75 degrees Celsius, with a weighted mean of 43°C. This potential is being exploited for water supply and tourism, and it could also become an alternative energy source, substituting for non-renewable regional energy use.

Until two decades ago, the Guarani Aquifer System had not been recognized as such and the four countries treated parts of it as national entities. In Uruguay and Argentina it was known as the Tacuarembó Aquifer, in Paraguay it was named the Misiones Aquifer, and in Brazil the Botucatu Aquifer. Only a few years ago researchers in the Region were able to turn the public's and decision makers' attention to the fact that these actually were part of the same aquifer system with a complex interrelationship yet to be completely unveiled. And eventually, to show



Map. Source of Map: www.sg-guarani.org.

Table 1. Main Characteristics of the Guarani Aquifer System

Characteristic	*Argentina*	*Brazil*	*Paraguay*	*Uruguay*
Aquifer Area (km2)	225,500	839,800	71,700	45,000
Aquifer Area (% of total country territory)	6	10	18	25
Aquifer Main Characteristics	Supply source, possible discharge.	Recharge and supply area.	Recharge and supply area.	Recharge and supply area.
Groundwater Legal Framework	**An initial National Law Framework on the subject; provincial provisions are weak or omit groundwater.**	**Federal Law that addresses groundwater; State laws incorporate groundwater in light or modest terms. Since the Guarani Aquifer Project started the National Water Resources Council has adopted some groundwater specific acts.**	**No National Law Framework; only indirect mentioning of water as such; water law projects are being assessed; informal norms are enforced but clearly need an improved formal framework.**	**A general Law Framework as such, but since the Guarani Aquifer project started, has supported local/sub-regional legal attempts by means of decrees and law enforcement actions.**
Groundwater Management Framework	**Weak at National and Provincial levels; transboundary potential issue exist with Uruguay.**	**Needs to address Federal and State attributes and to clarify groundwater licensing and protect-risk areas from over-drafting and pollution; heavy transboundary interaction with Paraguay and Uruguay needs specific framework for management.**	**Weak; informal processes help but efforts must be made to define and strengthen a groundwater management policy and framework, within new institutional arrangements and possibly a National Water Law; transboundary interaction, especially with Brazil needs to be addressed.**	**Needing to improve definition of roles among participating agencies (national-department-local), defining clear rules for water licensing, well construction and interaction with neighboring Argentinean Provinces.**
Exploitation Interests	**Low; it is gradually mounting modestly to utilize geothermal potential for tourism.**	**High; most wells exist in Brazil; the Guarani Aquifer System is a relevant potable water source and its use is increasing rapidly, even in risk areas (recharge and discharge).**	**Low to moderate; most wells are in the SAG recharge area and do not directly tap the confined aquifer because of its depth; little knowledge on geothermal potential and moderate interest to complement urban water supply needs.**	**Moderate; it is presently being used for both tourism (geothermal) and for urban water supply. Official interest in the SAG may trigger an increase in its use.**
Public Awareness	**Low; certain official official circles (Federal and Provincial) are gradually getting involved; specialized spheres (i.e. Ministries and INA - National Water Institute) are steadily increasing in interest and raising concern.**	**Moderate; certain states have increasing knowledge and concern; indigenous groups and private sector motivated to participate; government awareness at Federal level as well as in \some States is growing.**	**Low; new government institutional arrangements contribute in raising awareness; indigenous groups motivated; educational attemps are already implemented in certain areas in the eastern portions of Paraguay.**	**Moderate; awareness has raised rapidly in tourist areas with geothermal exploitation; water supply industry highly motivated as well; government awareness is considerable.**
Scientific Knowledge	**Reduced as a result of scarcely developed aquifer uses; however, important potential exists at official levels and academic sites (Universities in Buenos Aires and Santa Fe) that should be used to their full potential in**	**Moderately high and steadily growing, as a consequence of higher stakes and uses; government agencies at Federal and State levels are increasing capacities; a considerable number of universities involved in several states such as**	**Moderate; government has concentrated its capacity in two institutions closely linked to water supply for human needs; new institutional arrangements may help disseminate knowledge and raise interest; most scientific activities are**	**Moderate and steadily growing, due to increasing aquifer use and potentially competing sectors; government institutions related either to water supply or general water management, have acquired relevant knowledge and**

Table 1. Main Characteristics of the Guarani Aquifer System (Continued)

Characteristic	*Argentina*	*Brazil*	*Paraguay*	*Uruguay*
	improving baseline knowledge of the Guarani Aquifer System.	Parana, Sao Paulo, Minas Gerais, Santa Catarina, Mato Grosso do Sul, and others), have valuable information, analysis, tools, methodologiees and visions that could be shared throughout the region.	developed by Universidad Nacional de Asuncion and SENASA (National Sanitation Service, responsible for rural water supply).	are increasingly endeav oring in scientific activities (i.e. OSE - National Water Company) the Universidad de la Republica is participating with increasing strength and diversification of interests.
Exploitation Level	9 deep wells for geothermal use (mainly tourism).	Some 500 cities and townships partially or entirely supplied by the Guarani Aquifer System (70% of use); industrial uses (25%), irrigation and recreation uses (5%).	About 200 wells, mainly for domestic water supply and support to marginal agricultural activities.	135 wells for public water supply, 7 of which are for thermal use (tourism and urban water supply).
Principal Environmental Issues	1.Potentially uncontrolled drilling and extraction 2. Subject to pollution from other countries.	1. Point and nonpoint source pollution 2. Uncontrolled drilling and extraction 3. Subject to pollution from other countries.	1. Point and nonpoint source pollution 2. Uncontrolled drilling and extraction 3.Subject to pollution from other countries.	1. Point and nonpoint source pollution 2. Uncontrolled drilling and extraction. 3. Subject to pollution from other countries.
Information Level	Limited information available, especially about the western extent of the system.	Considerable information available but dispersed in different states and institutions.	Limited information available	Considerable information available

Source: Adapted from World Bank, 2002.

its unity, it was baptized as the Guarani Aquifer System in homage to the Guarani indigenous people who used to – and still do – live in the area (World Bank, 2002).

Some Timely Reasons to Develop a Guarani Aquifer System Project

Groundwater, particularly large, deep aquifers, represents a strategic reserve for water supply. Groundwater generally requires minimum treatment — normally preventive disinfection — prior to consumption. Aquifers usually boast considerable natural biogeochemical filtering processes achieving better quality than most water treatment methods applied to surface resources. Groundwater is frequently the most viable and low cost water supply alternative, especially where domestic and industrial effluents, solid waste, or contaminated agricultural runoff pollute surface water. Consequently, sustainable use, development and recharge, diligent conservation, and protecting aquifers from pollution, has become a relevant concern. As an enormous transboundary resource with geothermal features, the Guarani Aquifer System simultaneously touches upon three sectoral areas: transboundary (ground-) water management, water supply, and energy policy.

Despite considerable surface runoff yet to be used, drinking water supply in this heavily populated MERCOSUR region increasingly depends on groundwater. (The MERCOSUR is the "Common Market of the South," created by the governments of Argentina, Brazil, Paraguay, and Uruguay in 1991. The principal aim is the enlargement of their national markets through integration, in order to accelerate processes of economic development with social justice.) As in many other places worldwide, particularly in developing countries, pollution controls are weak and surface water has become increasingly contaminated. Hence the strategic role of groundwater is clear. Consequently, water supply problems and health concerns may surge should groundwater be ill managed — with regard to quantity and quality — affecting sustainable development. In many areas, as in southern Brazil, urban centers rely totally or partially on groundwater sources. Demands for groundwater are increasing, due to demographic growth, economic expansion, and increasing pollution of surface water sources.

Legal and regulatory mechanisms for groundwater

management are lacking throughout the region underlying the Guarani Aquifer System. In Argentina and Brazil, substantial pollution of shallow groundwater resources is occurring, although, due to its considerable average depth, the Guarani Aquifer System is not significantly affected. However, in areas where it is close to the land surface and in recharge areas, overdrafting may already be occurring and pollution hazards degrading water quality. A summary of the characteristics of the Guarani Aquifer System is provided in Table 1.

Undoubtedly, the Guarani Aquifer System is a strategic waterbody for the four countries. Although gradually endangered at local levels, the Guarani Aquifer System can be preserved if adequately protected and managed. Uncontrolled pollution in extraction and recharge areas and overdrafting must be successfully solved as a service for present and future generations.

Therefore, after recognizing the Guarani Aquifer System as a shared waterbody the question arose of how to sustainably and jointly manage it. As in many developing nations, groundwater resources in the region have traditionally been subject to a laissez-faire approach rather than active integrated management and the Guarani Aquifer System was no exception. Furthermore, little experience in global groundwater transboundary water management exists. On the other hand, lessons learned in many aquifers throughout the world indicate that groundwater environmental protection and sustainable development have proven difficult to achieve, even within a single country, whenever appropriate measures are not enforced in a timely manner.

Therefore, it became quite clear that a specific project to address environmental protection and sustainable development of the Guarani Aquifer System could contribute in preserving this gigantic transboundary resource for current and future generations. The Guarani Aquifer System offers a valuable opportunity to exploit the advantages of preventive activity. Such a project would ensure that, with an appropriate legal and institutional integrated transboundary groundwater management framework to be elaborated that in the face of increasing scarcity and pollution of surface water sources in the beneficiary countries this resource would subsequently be managed so as to be available as a strategic reserve for the countries when needed in the future. Crucial lessons could be learned and replicated elsewhere in the region and beyond.

The four countries, championed by the researchers and the respective water resources authorities eventually joined forces and decided to develop a project that would lead to a joint legal, technical, institutional, and environmental integrated management framework for the Guarani Aquifer System. Thus, the Guarani Aquifer System project represents an enormous effort to define and implement a coordinated shared groundwater management framework among Argentina, Brazil, Paraguay, and Uruguay to environmentally protect and sustainably develop one of the largest groundwater systems in the world. Since its preliminary stages, the project has proven to be a magnificent opportunity for the countries to harmoniously work together towards a common objective, addressing one of the greatest challenges in integrated water management.

Objectives of the Paper

The objectives of this paper are twofold. First, a brief presentation of the Guarani Aquifer System Project and, in particular, its highly complex and participatory four-country preparation process are provided. Given that the project is about to move from preparation to implementation, a specific issue to be tackled will be the explicit goal to develop a sustainable management framework for the Guarani Aquifer System. In this context the applicability of current international law for transboundary groundwater resources management is of major importance. Therefore, a second objective of the article is to describe the current status of international law and analyze it in the context of the Guarani Aquifer System with the aim of discerning implications for its future management. Conclusions are drawn as to the coming four years of project implementation, which will aim at introducing the basis for an institutional, legal, technical, and environmental Guarani Aquifer System management framework.

The Guarani Aquifer System Project

The Project for the Environmental Protection and Sustainable Development of the Guarani Aquifer System (hereafter "Guarani Aquifer System Project"), is to be financed with a grant from the Global Environment Facility, as well as funds from the four country governments, and multi- and bilateral agencies as partners. (The GEF is a financial mechanism, created in 1991, that helps developing countries fund programs that protect the global environment. GEF-funded projects are implemented through its three implementing agencies, i.e., either the World Bank, the UNDP (United Nations Development Program), or UNEP (United Nations Environmental Program). The GEF has 174 participatiang states.) The project has the long-term objective to achieve the sustainable, integrated management and use of the Guarani Aquifer System. A first step toward achieving this objective is to "support the four countries in jointly elaborating and implementing a common institutional and technical framework for managing and preserving the Guarani Aquifer System for current and future generations" (World Bank, 2002).

Seven project components are envisaged. The basis and reasons for their selection are explained as follows, together with some insight on the actual contents of these components and their relevance. As a uniquely preventive undertaking, the project will become a formidable testing ground for specific groundwater management tools and should provide answers to many demands derived from

scientists, subsectoral water users and society.

Project Background

Managing an aquifer for a single community and a single water use, even with several users, is not an easy task. International experience shows that whenever several communities participate and several water uses and users' interests are at stake, a number of factors endanger the sustainability and healthy development of a groundwater body. These includes the complexity of interactions and the aggregated effects on groundwater levels and pollution, as well as policy weakness, inadequate institutional arrangements and overall operating framework, scarce public awareness and insufficient baseline knowledge on the aquifer's features and behavior, endangering the sustainability and healthy development of a groundwater body (Kemper, Forthcoming 2003). If groundwater is naturally scarce or if its availability suffers as a result of excessive overdraft, then water stress is under way and conflicts arise as governance falters. Finally, if groundwater is of a transboundary nature, then its management becomes even more complex, especially when disputes among water users of neighboring countries have already appeared fostering claims among nations.

The Guarani Aquifer System is in many aspects a unique waterbody. Annual availability and recharge are considerable while overall water uses are rather modest in comparison. With a wide range of interested and committed stakeholders involved, present conditions are favorable to set up a solid, coordinated transboundary groundwater management framework that can anticipate and prevent future conflicts among uses and users, as well as among the countries that share this invaluable asset. While all parties agree that this framework should be as light as possible, it nevertheless cannot escape a certain complexity. Should such a framework be successful in contents, implementation and results, a clear message could be sent worldwide that attaining sustainability and integrated (ground)water management is possible in a transboundary context.

The Starting Spark

For many years different subsystems of the Guarani Aquifer System were studied, although deep overall knowledge has only been attained in specific locations as a response to water needs. While scientists addressed different parts of the Guarani Aquifer System, boreholes have been drilled in many locations. It is estimated that presently the number of operating deep wells easily exceeds 1,000, most of them located in Brazil and dedicated to domestic and urban uses. A practical knowledge base has been built up although potential mistakes could ruin portions of the aquifer if design, construction, and operation of deep-water wells are not carried out appropriately, given the geological conditions of strata that confine the water body. Hence, both scientists and practitioners developed increasing concerns and visions with regard to the need for joint management of the aquifer system (Montaño et al., 1998).

The Project Is Born

Scientists from universities in the four countries who had been working together for a number of years increased their communication, exchanged visions and knowledge, and began looking for further support to undertake a huge transboundary project to learn more about the Guarani Aquifer System. In parallel, public servants related to water management, including those directly related to water utilities as well as some other relevant water uses, became gradually aware on one hand of the aquifer's potential but on the other hand, of the potential risks unless a regulatory management framework was agreed upon by users and countries. Lobbying was used to draw the attention of international agencies, especially the GEF, World Bank, and the Organization of American States (OAS). Eventually in 1999, they succeeded in their attempts. Scientists, government officials, and international agencies joined efforts, in a participatory process, first to assess the amount of information and knowledge in order to dimension the tasks ahead, and later to orient possible activities so that a clear objective could be defined, activities designed, and stakeholder roles clarified.

The World Bank had a relevant role from the beginning facilitating trips, meetings, workshops, making experts available for specific tasks, providing visions and experience derived from other projects, helping define objectives, scope, and perspectives for a joint project, and helping obtain financial support from other agencies and, importantly, project development funding from the GEF. The OAS, with important experience in GEF transboundary water projects in Latin America and a tradition of promoting integrated water resources management initiatives in the region, was put in charge by the countries to coordinate the preparation phase of the new project. With relevant stakeholders directly participating, a work agenda was agreed and possible objectives for a future project were debated until a single objective was chosen. A project concept note was approved by consensus in 1999 and a sequence of steps to be followed towards successful project formulation was defined. (For further information about the chronology of the project, see the Guarani Aquifer System website at www.sg-guarani.org.)

Main Characteristics and Issues to be Addressed by the Project

The Guarani Aquifer System Project is not a scientific project but rather a water management framework project where environmental concerns are comprised, especially those with transboundary repercussions. During the preparation phase, the following main issues and problems were identified, and origins and potential impacts were assessed, and the results provided the basis for the formulation of the project itself:

- Main physical problems (existing or potential) were identified as local overdrafting, including border areas, and local aquifer pollution.
- Main scientific – technical issues included insufficient baseline knowledge on characteristics and behavior of the Guarani Aquifer System; little and dispersed knowledge on water uses and users; considerable information gaps due to insufficient, low quality, fragmented and dispersed data, as well as improper dissemination of information; no enforced rules for well design, construction, and operation; and weak supervision and regulatory capacity across the board.
- Main management problem include a lack of groundwater policy and development strategies as well as inadequate operating rules and decision making regarding groundwater; inadequate legal framework for groundwater management per se as well as no experience in dealing with transboundary aquifers by means of agreements, treaties, and legislation, although experience exists in dealing with surface waters on a transboundary basis; institutional gaps with regard to achieving a comprehensive and integrated groundwater management scheme at a regional level in contrast to better institutional approaches for transboundary runoff; diverging positions from national/ federal standpoints as to the essence of water authority and the required levels of involvement and responsibility, in contrast to provincial/state visions in Argentina and Brazil; the need to provide solutions to identify or define appropriate authorities to carry out groundwater management of a transboundary water body; unclear or non existing rules to allocate and license water for its users.
- Main social issues included little public awareness regarding the Guarani Aquifer System; insufficient public participation in groundwater management; a lack of incentives to foster a groundwater culture throughout the region; and weak communication channels to make information available to society at large.
- Levels of expertise and proficiency included sufficient capacity in the region to cope with most issues and challenges related to accomplishing the project's objectives. However, there is a need to utilize specific expertise from beyond the region, for various topics such as: legal framework approaches in very practical terms for (transboundary) groundwater management, institutional development, and arrangements; conflict assessment and socio-political risk assessment; facilitation, mediation, and negotiation support to prepare a joint coordinated transboundary water management framework.
- Pilot Areas were needed due to the nature of issues just mentioned, which suggested the necessity to select and implement appropriate pilot projects that address specific problems in so-called Hot Spots whose mitigation or solution could contribute to defining the overall coordinated transboundary groundwater management framework for the Guarani Aquifer System.
- Geothermal potential of the Guarani Aquifer System, which is considerable, offers development possibilities for domestic, industrial, and power generation purposes in some areas.

The four-year project that evolved based on preparation activities thus is not of a structural nature. It provides the technical knowledge and institutional basis for aquifer management. With its preventive perspective, the project is rather unique since it aims to prepare the ground for risk reduction, considering aquifer vulnerability in quantity and quality in management planning and actions.

Agreement on Institutional Arrangements and Gradual Creation of Processes

To carry on the project, under a participatory process, institutional arrangements were defined and an operative plan discussed. As the highest project body, representatives of the Ministries/Secretariats of Foreign Affairs, Water Resources and the Environment of Argentina, Brazil, Paraguay, and Uruguay integrated the Project Preparation Superior Council (PPSC) together with representatives of the World Bank, Organization of American States (OAS), and a General Secretary (The Project Preparation Secretariat was located in Montevideo, with the General Secretary and two full-time technical staff). The PPSC met either via videoconference – a medium that proved to be very productive to reduce costs and traveling and to keep discussions focused – or in special sessions taking advantage of workshops and meetings organized by the General Secretariat to maintain strong communication links and obtaining feedback. Relevant project decisions were made by the PPSC, while coordinating efforts as well as administrative and operational aspects were solved by the OAS which in turn relied on the Project Preparation Secretariat. The World Bank played an overall coordinating and facilitating role, and was responsible for project preparation results vis-à-vis the GEF. Each country created a National Project Preparation Unit (NPPU), with key representatives consisting mostly of government officials and scientists.

From the beginning, a participatory process accompanied the preparation phase. Multilateral coordination efforts among key stakeholders took place, mostly through the NPPUs to define activities, to agree on consultants for specific tasks, to accompany on-going activities, and to provide feedback during the preparation phase. Periodical meetings were held, under the auspices of the Project Secretariat as well as the NPPUs, to debate specific topics, review documents, identify issues and possible solutions, test processes and improve interaction and cooperation among stakeholders.

A wide array of stakeholders was incorporated during the preparation phase. Scientists, lawyers, water users,

school teachers, college students, indigenous groups, private sector entrepreneurs with a wide array of interests, well drilling companies, water utilities, NGOs, as well as public servants, contributed in enriching project preparation. International expertise, some of it provided by international agencies like the Food and Agriculture Organization (FAO), the UN Economic Commission for Latin American and the Caribbean (ECLAC), the International Atomic Energy Agency, Organization of American States (OAS), and the World Bank was crucial during the preparation phase, especially for groundwater specific topics, legal assessment on international agreements on several water bodies, isotope methodology to improve scientific knowledge of the Guarani Aquifer System, integrated basin management, geothermal potential, environmental protection, and institutional arrangements. Furthermore, an interesting array of possible partnerships was gradually augmented and strengthened.

Such participatory processes have yielded one of the most valuable experiences derived from the preparation phase. Individuals from different backgrounds, interests, sectors, and countries met, relevant issues were agreed, procedures were debated, and strong linkages were born and strengthened, specifically between institutions and scientists of different countries.

The Design of Project Components to Respond to Issues and Problems Detected

To respond to issues and problems detected during the preparation phase, the project comprises seven interrelated components designed to quantify the state of the aquifer system in terms of its morphology and behavior, its use and conservation, it relationships to communities, institutions, and water management instruments, and its planning and organizational needs for improving coordinated and integrated groundwater management. This knowledge is designed to provide a scientifically sound and well-documented base for establishing a framework for the coordinated and consensual management of the Guarani Aquifer System, capable of appropriately addressing environmental protection, and integrated and sustainable development of the aquifer, as key factors toward succeeding in the project's objectives. Certain project components will identify and test key management elements (including policies, mechanisms, and instruments) to facilitate the sustainable and coordinated management of the aquifer system. The resulting integrated groundwater management framework will provide the means to mitigate and/or resolve the most pressing transboundary environmental problems that threaten the aquifer, mostly derived either from pollution or local overdrafting. In addition, this framework will provide a means to address local groundwater use conflicts, especially those related to water pollution and overexploitation to provide a long-term strategy for risk mitigation, conflict prevention and solution as well as to assess its potential in providing "clean" geothermal energy to communities within the region. These components are the following:

- Expansion and consolidation of the current scientific and technical knowledge base of the Guarani Aquifer System. The objective is to synthesize, analyze, and expand the existing knowledge base related to the Guarani Aquifer System in the four countries.
- Joint development and implementation of the Guarani Aquifer System Management Framework. This component is core of the project, with other components feeding into it. Its objective is to develop a framework for the coordinated management (technical, institutional, financial, legal, and social) of the Guarani Aquifer System, considering sustainable integrated development, its problems and potential, and environmental protection concerns. It includes the development of a Strategic Action Program providing the content and directions for action after the four-year period of the present project.
- Public and stakeholder participation, education, and communication. This objective is to promote, support, and enrich public participation and involvement, and to foster environmental and water education, social communication, and the dissemination of knowledge on the project, the Guarani Aquifer System, and its management and conservation, within stakeholder communities. It includes strategies, programs, and actions, as well as support for the pilot projects in the identified Hot Spots to be conducted under Component
- Project monitoring and evaluation, and dissemination of project results. The objective of this component is to create and implement a system for recording and analyzing the progress achieved during the project period. This system will allow early detection of potential problems, and provide feedback to the participants on the experiences gained and lessons learned. This component will include the dissemination of information, results, and lessons learned for possible replication under similar conditions and circumstances elsewhere in the Guarani Aquifer System region.
- Development of management and mitigation measures within identified "Hot Spots." This component aims to to design, apply, and evaluate the costs and feasibility of good management practices at specific sites within the Guarani Aquifer System region. Appropriate management and mitigation measures to address specific threats facing the sustainable utilization of the Guarani Aquifer System will be developed for demonstration purposes. Dissemination of information on successful management and mitigation measures will help spur concrete actions in threatened areas or with existing or emerging conflicts, especially in border areas. The pilot projects will focus on preventing and mitigating specific point and nonpoint sources of pollution, as well as overdrafting in critical recharge and discharge ar-

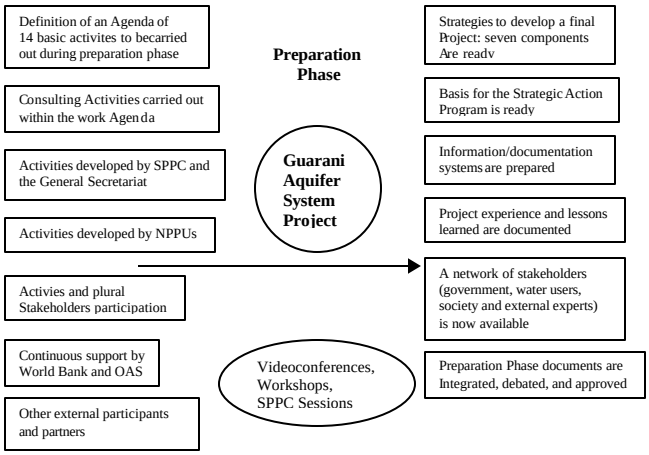


Figure 1. Project evolution during the preparation phase.

eas, or in confined areas of the aquifer with high concentration of uses and users.

- Assessment of Geothermal Energy Potential. The main task is to evaluate the Guarani Aquifer System's geothermal potential in scientific, technical, economic, financial, and environmental terms. The aquifer's thermal waters are currently being exploited on a limited basis for thermal tourism, primarily in Uruguay and, to a lesser degree, in Argentina.
- Project coordination and management. Here the objective is to provide organizational and administrative support to the project and to supply an agreed framework within which the institutional arrangements and agreements to sustainably manage the Guarani Aquifer System can be completed (World Bank, 2002).

In addition to the project's components, institutional arrangements for its implementation have been designed based on the rich participatory experience gained during the preparation phase. The aim is to support all efforts in a coordinated manner so that countries may become the steering forces for the project, a desirable and necessary goal for a sustainable process. Figure 1 summarizes the preparation experience and its outcomes up to date.

With the project having started in May 2003, the countries and other involved stakeholders are now looking forward to the next steps to be taken. One crucial issue to be tackled is the development of a joint management framework for this transboundary resource. To develop the appropriate management and institutional tools, the legal ramifications also need to be defined. The second part of the paper focuses on these by adopting a forward-looking approach and examining the international experience with transboundary aquifer management and analyzing its relevance and applicability in the context of the Guarani Aquifer System.

International Experience with Transboundary Aquifer Management and Applications for the Guarani Aquifer System Project

In the development of a shared framework for the management of the Guarani Aquifer System, it is natural to look at international experience for guidance and inspiration. As will become clear in this section, however, there is no internationally-acknowledged legal framework for transboundary groundwater management. While this may constitute an obstacle, it also is an opportunity for the four countries involved to find their own ways and for this endeavor to be a guiding experience for future projects in other regions.

One of the reasons for the absence of an international framework for transboundary groundwater is that, by its very nature, groundwater generally is invisible. Hydrogeological research on the extent of aquifers, quantity and quality of the groundwater, and recharge mechanisms is usually costly to undertake. As long as groundwater was perceived as abundant, it was thus convenient not to deal with problems like pollution or sharing of groundwater resources, either within or between countries. In many cases, the fact that the same aquifer was underlying two or more different countries was simply ignored. However, from the recent literature, it seems that this attitude has been changing over the past twenty years. While in 1981 Caponera and Alhéritière pointed out that " the special case of international groundwater resources has not received a full share of legal investigation (and) most research has been directed to surface water resources," since then transboundary groundwater resources have slowly entered the international agenda, as exemplified by the Bellagio Draft Treaty, the ECE Convention and the United Nations Convention of the Non-Navigational Uses of International Watercourses of 1997 (the "UN Watercourses Convention").

Before proceeding to a discussion of the international legal regime applicable to the management of transboundary groundwater resources, a short overview of definitions is given and the principal problems concerning quality and quantity are discussed.

Definition of Transboundary Groundwater Resources

According to FAO (1986), an "aquifer is any geological formation which in addition to absorbing water also carries out the functions of storage and transmission. All aquifers have an impermeable or semi-permeable base layers." Depending on the consistency of the base and top layer, the aquifer is confined, free, or semi-confined. Groundwater can also be found in other geological formations, called aquitards, but these usually transmit only small amounts of water and cannot be exploited.

Four main cases in which groundwater constitutes a transboundary resource can be distinguished (FAO, 1986). In each case, the implications of water use by one country

for the water use by the other country vary, as illustrated below.

- A confined aquifer is intersected by an international boundary: Any use of the aquifer's water may affect the resource of both states. (A confined aquifer is separated from other aquifers and the land surface by a confining layer, such as clay or silt-sized sediment or a tightly cemented rock. The confining layer inhibits the vertical movement of water into or out of the aquifer.)
- An aquifer is situated entirely within the territory of one state, but is hydraulically linked with an international river: If the river is effluent, i.e. the aquifer recharges the river, changes in use of the aquifer may have an impact on the river. If the river is influent, use of the water in the river may alter the hydrological regime of the aquifer.
- An aquifer lies wholly within the territory of a single state and is linked hydraulically with another aquifer in a neighboring state: Intensified withdrawals from one aquifer may decrease the water in both aquifers or can even reverse the direction of flow from one aquifer to the other.
- An aquifer is located entirely within the territory of one state, but has its recharge zone in another state: Changes in use affecting the recharge zone may have an impact on water availability and quality in the aquifer.

Transboundary aquifers can be found in all parts of the world. In addition to the Guarani Aquifer System, one of the prominent examples of transboundary groundwaters is the Northern Sahara Aquifer System stretching in an area of roughly 1 million km^2 between Algeria, Libya, and Tunisia. In Europe the aquifer of the Upper Rhine plain underlies France and Germany, with some 300,000 m^3 of freshwater. A large aquifer underlies Libya, Egypt, Chad, and Sudan. On the Arabian Pensinsula, aquifers are shared by Saudi Arabia, Bahrain, and possibly by Qatar and the United Arab Emirates. Several aquifers are shared by Mexico and the US, some of them in critical areas where water is very scarce and feasibly alternative sources are mostly absent.

The interrelationship between groundwater resources that underlie different states leads to a certain dependence in their use. The dependence may be mutual, as for example in Case 1 above where both states share the same aquifer, but it may also be one-sided as in Case 4 where the state that has the aquifer depends on the decisions and actions of the other state where the recharge zone is situated.

One could argue that the Guarani Aquifer System corresponds to both Cases 1 and 4. Due to the fact that it is a large system, and not only one homogenous body, parts of it can be designated as confined, such as its very deep areas on the border of northwestern Uruguay and Argentina. This would correspond to Case 1. At the same time, however, the Guarani Aquifer System also encompasses Case 4, i.e., the aquifer itself is found for instance in Uruguay, but recharge areas are in Paraguay and Brazil. It is estimated that 90 percent of the Guarani Aquifer System is confined and 10 percent free, mainly constituting its direct recharge area (Campos, 2000).

The following section highlights the main problems that arise from the exploitation of transboundary groundwater resources.

Pollution and Overexploitation of Groundwater Resources

The principal problems encountered regarding the management of transboundary water resources relate to pollution and overexploitation. Pollution of groundwater, for instance caused by discharges of phosphorus and nitrogenous compounds, untreated or insufficiently treated municipal sewage, chemical pollution from industries and agriculture, seepage from landfills, and atmospheric depositions has become an increasing problem, especially in industrialized and newly industrialized countries. Groundwater pollution negatively affects the usability of the resource and renders it scarce for a number, or even all, uses. In the case of transboundary aquifers, a country can significantly harm its neighbor in economic and in social terms by polluting the joint water source.

Groundwater resources in arid and semi-arid regions, where many developing countries are situated, are also subject to pollution problems, but these are compounded by the threats of quantitative overexploitation. Because of the low incidence of precipitation, a number of countries rely heavily on groundwater resources for their domestic, irrigation and industrial water use. In many cases, the aquifer's recharge rate is not known which renders it difficult to exactly determine how much water can safely be withdrawn without threatening future water availability. Therefore, some aquifers are in the process of being severely stressed, with resulting major drops in water levels towards depletion.

Increasing scarcity of groundwater resources, due to overexploitation and pollution, can lead to conflict between countries or, as pointed out by Benvenisti (2002) "as demands for freshwater and the environment intensify and diversify and supplies dwindle, interdependency becomes greater," providing the basis for more interest to develop cooperative approaches to transboundary water resources managment. (The benefits that can be derived from cooperation on international rivers are also analyzed in detail in Sadoff and Grey (2002). Although the paper focuses on rivers and not on groundwater, the general framework put forward in the paper can be equally valid with regard to groundwater resources.)

In the case of the Guarani Aquifer System, both potential overexploitation and pollution occur locally. It does occur within countries, e.g. in the state of São Paulo in

Brazil, where effects remain local and regional (one of the groundwater management pilots of the Guarani Aquifer Project is situated in this area), or on the border between countries. A potential Hot Spot for cross-border pollution are the twin towns of Rivera and Santana on the Uruguay/Brazil border. Again, it becomes clear that – due to the size of the aquifer system – measures to be developed would have to make the distinction between national-level impacts and transboundary impacts of aquifer use and management. This also implies that any institutional framework would have to take into account the principle of subsidiarity in managing the resource, i.e. to put management at the lowest appropriate level, as expressed in Agenda 21 (UNCED, 1992).

The following section will present and discuss the international legal regime that has developed with regard to the joint management of transboundary groundwater resources and conflict resolution.

The International Legal Regime of Transboundary Groundwater Resources

International Law recognizes three main sources of rules: general or specialized international conventions, international custom, and international judicial decisions and teachings of highly qualified experts. A new source gaining importance are the texts issued by international organizations, e.g. the Organization for Economic Cooperation and Development (OECD) and the International Union for the Conservation of Nature (IUCN), and conferences, such as Stockholm (1972), Mar del Plata (1977), and Rio (1992).

In the case of transboundary groundwater resources all of these sources come into play. There is no convention specifically regarding transboundary groundwater resources. However, a number of treaties, although not many, exist concerning transboundary groundwaters. The treaties and those conventions dealing with water resources in a comprehensive manner provide one foundation of the international legal regime.

The other source consists of costumary international law derived from state practice and declarations of international bodies like the UN General Assembly as well as international conferences.

Finally, highly respected professional organizations such as the International Law Association and the International Law Commission of the United Nations have made attempts to set forth principles and to codify international custom. In the following, the rules derived from these three sources are discussed.

International Custom

An important feature of international law concerning transboundary groundwater resources is that it primarily consists of customary law applicable also to other shared natural resources (Barberis, 1991). As stated by the 1977 United Nations Water Conference in Mar del Plata, "In the absence of bilateral or multilateral agreements, Member States continue to apply generally accepted principles of international law in the use, development and management of shared water resources" (Barberis, 1991). It might be expected that the Freshwater Chapter in Agenda 21, which was elaborated 15 years after the Mar del Plata Conference, was more specific about international norms for shared water resources, but instead it restricts itself to calling for activities concerning the "Development of national and international legal instruments that may be required to protect the quality of water resources, as appropriate, particularly for: (1) Monitoring and control of pollution and its effects in national and transboundary water; (2) Control of long-range atmospheric transport of pollutants; and (3) Control of accidental and/or deliberate spills in national and/or transboundary water bodies," indicating that while there is a need for more legal instruments, these have not been developed yet (UNCED, 1992). Interestingly, Agenda 21 omits reference to the quantitative aspects of shared (ground)water resources. It is limited to the rather general call for cooperation "in the assessment of transboundary water resources, subject to the prior agreement of each riparian State concerned."

This indicates that customary law as invoked in the Mar del Plata document remains the dominant source of legal norms concerning transboundary water resources, both for surface and for groundwater. As mentioned by Dellapenna (1999), however, "In contrast to the considerable state practice regarding the sharing of surface water sources, there has been remarkably little state practice regarding the sharing of underground source of water." Dellapenna proceeds to point out that this is mainly due to the fact that only after World War II vertical turbine pumps became common, facilitating the major development of groundwater sources that has been experienced worldwide in the past 50 years and contributing to transboundary disputes.

Thus, there is a need to look at customary law for transboundary water resources in general, rather than groundwater in particular. Barberis (1991) lists three principles derived from customary law: (1) obligation not to cause appreciable harm; (2) equitable and reasonable use; and (3) prior notice obligation and the duty to negotiate. These principles are derived, *inter alia*, from the recommendations of the World Water Conference in Mar del Plata in 1977, Resolution 2995 (XXVII) of the United Nations General Assembly, and the Helsinki Rules (1966).

A critical view with regard to the actual application of these norms is taken by Nollkaemper (1993), who points out that although a number of authors want to consider the above principles as customary norms, one decisive condition for their categorization as such is state *practice*. In relation to pollution of transboundary groundwater resources, actual practice of at least one of these norms, namely the principle not to cause appreciable harm, has been weak. In his opinion, the surge of a number of trea-

ties and conventions in the past decades may be due not so much to the wish to codify customary law but to fill a gap in international law. In this context, he notes that the inclusion of general obligations in treaties "implies that the lawfulness of transboundary water pollution that is covered by one of these treaties, even when no more specific obligations apply is determined by these treaty obligations, rather than by any obligations under general international law. Whereas this may appear as common sense, it stands in marked contrast to the overriding importance usually attached to general principles of law or custom as a basis for general obligations of prevention." (Nollkaemper, 1993)

Also Caponera (1987) comments the legal weakness of these principles, but points out that they "do limit other principles on sovereignty. In particular, they mark the rejection of the principle of absolute territorial sovereignty whereby a state has the exclusive and unlimited right to utilize and dispose of international waters flowing through its territory" (Caponera, 1987). The principles also provide normative guidelines for states in the elaboration of treaties and conventions.

An important aspect of the international norms concerning transboundary water resources is that they in general do not specifically mention groundwater, and in several occasions it becomes clear that they are intentionally or accidentally overlooked (Dellapenna, 1999). While in former times groundwater resources were ignored due to inadequate knowledge of the hydrological cycle (Barberis, 1991), the recognition of the interrelationship between groundwater and surface water currently leads to the incorporation of both resources into comprehensive concepts such as the drainage basin (ILA, 1966) or the watercourse (ILC, 1991; UN Convention, 1997). The Helsinki Rules define an international drainage basin as "a geographical area extending over two or more States determined by the watershed limits of the system of waters, including surface and underground waters, flowing into a common terminus." In the UN Watercourses Convention, watercourses are defined as systems of "surface waters and groundwaters constituting by virtue of their physical relationship a unitary whole and normally flowing into a common terminus." In the literature, diverging opinions exist about the appropriateness of each term. Some authors argue that the term watercourse as used by the ILC and the UN Convention evokes the image of a stream, thus de-emphasizing groundwater as compared to the more comprehensive term drainage basin. As will be discussed in the following section, a number of treaties and conventions between individual states specifically concern groundwater.

Treaties and Conventions

Other sources that help define the legal regime concerning transboundary groundwater resources originate in bilateral and multilateral treaties and conventions. Some bilateral treaties concerning shared groundwater use go back to the last century, e.g. the 1861 treaty between Italy and Switzerland, determining the joint use of the Trevigno fountain by the farmers of both States.

Well-known examples of bilateral conventions with regard to specific aquifers are those concerning the groundwater between Mexico and the United States, as well as the Genevois water table between France and Switzerland. Both conventions contain stipulations concerning water use and protection and are designed to avoid creating harmful effects to the neighboring state (Barberis, 1991). In the first case, sustainability of aquifers underlying arid and semiarid zones is a growing concern.

A more recent development is the United Nations Economic Commission for Europe (ECE) *Convention on the Protection and Use of Transboundary Watercourses and International Lakes*. As mentioned above, the term watercourse includes groundwater resources. The convention was adopted in Helsinki on March 17, 1992 and entered into force on October 6, 1996. In Europe, where the deterioration of transboundary water resources has reached dramatic proportions, more than 100 conventions, treaties, and other arrangements have been concluded over the past two decades to prevent the deterioration of water quality and to ensure reasonable and equitable use and joint conservation of transboundary waters. The *Convention on the Protection and Use of Transboundary Water Courses and International Lakes* is the outcome of this long process of concluding more limited agreements. The Convention explicitly aims to strengthen national and international measures for the protection and ecologically sound management of both transboundary groundwaters and surface water. To this end, the parties to the convention will have to introduce national measures, e.g. concerning emission limits for discharges from point sources and adoption of water quality criteria. Those "parties bordering the same transboundary waters will have to enter into bilateral or multilateral agreements, or adapt existing ones, in order to define their mutual relations and conduct regarding the prevention, control and reduction of transboundary impacts" (Secretariat of the United Nations Commission for Europe, 1994). As of December 2002, the Convention had been ratified by 31 ECE countries (Albania, Austria, Azerbaidjan, Belgium, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Italy, Kazakhstan, Latvia, Liechtenstein, Lithuania, Luxemburg, The Netherlands, Norway, Poland, Portugal, Moldova, Romania, Russian Federation, Slovakia, Spain, Sweden, Switzerland, and Ukraine), and by the European Union. Due to the large number of parties to the convention, it constitutes a significant step forward in the creation of binding international legal norms for the management of transboundary groundwater resources.

Another recent international agreement regarding transboundary water resources is the previously mentioned United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses, which was adopted in 1997, with an interesting potential but has not

been ratified by a sufficient number of countries to go into effect. The convention explicitly includes transboundary groundwater resources – except those in confined aquifers. As stated by McCaffrey (1999), therefore "the principles of equitable utilization, prevention of significant harm, prior notification concerning planned measures, and protection of aquatic ecosystems, in addition to the other provisions of the UN Watercourses Convention, all apply to ground- and surface waters alike. Their application to aquifers may in some respects be more difficult as a practical matter, given that the influences of human activity on groundwater are generally more subtle and may take more time to manifest themselves than is true of surface water. But difficulty of practical implementation in no way affects the applicability of the principles and rules of the UN Convention as a matter of law."

Thus, with regard to the Guarani Aquifer System, the interesting situation arises that in one sense it would be covered by the principles of the UN Convention, but in the sense that parts of it can be described as confined, it would neither be covered by the UN Convention nor other international framework agreements. This characterizes the Guarani Aquifer System as a unique case, which needs – even more so than other cases of transboundary groundwaters – to draw from a wide variety of resources in order to define a legal and institutional framework considered appropriate by the four countries. One such further source could be the Resolution of the International Law Commission that dealt with confined groundwater.

Respected Professional Organizations and Recognized Experts

As pointed out previously, a source of international norms are the works and teachings of respected professional organizations and experts in the respective field. Most important in the present context are the Helsinki Rules, adopted by the International Law Association (ILA) in 1966, and the International Law Commission's Draft Principles on the Law of the Non-Navigational Uses of International Watercourses from 1991, which strongly informed the UN Convention of 1997. Given, however, that the UN Convention did not deal with the case of confined aquifers, the ILC issued a separate "Resolution on Confined Transboundary Groundwater," which recommends States to be guided by the UN Convention's guiding principles (McCaffrey, 1999).

For the Guarani Aquifer System this would thus imply that the closest decision makers could come to receiving guidance from the international legal frameworks would be from the UN Water Courses Convention as well as from the ILC's Resolution.

An important source of legal knowledge often cited is also the Bellagio Draft Treaty. It was developed by a multidisciplinary group of specialists and was based on the draft treaty elaborated by the U.S-Mexico Transboundary Resources Study Group, the so-called Ixtapa Draft (Rodgers and Utton, 1987). Given the weakness of existing legal and institutional arrangements for managing transboundary groundwater resources, the goal of the Bellagio draft treaty, elaborated in Bellagio, Italy, is to provide countries facing the need to conclude bilateral or multilateral agreements with a model treaty to be adapted to their specific needs. The draft treaty's objective "is to achieve joint, optimum utilization of the available waters, facilitated by procedures for avoidance or resolution of differences over shared groundwaters in the face of the ever increasing pressures on this priceless resource" (Hayton and Utton, 1989). An interesting feature of the Bellagio draft treaty, apart from its deliberate limitation to groundwater resources, is the emphasis on quantitative management. It reflects the authors' consciousness of possible water crises due to overdraft and depletion of aquifers in the arid regions of the world. While this may only address one issue with relation to the Guarani Aquifer System, given that it is by far more complex, presenting challenges of local overdraft in the face of overall abundance, rather than a general picture of scarcity, the Bellagio Draft Treaty presents two perhaps more interesting concepts in the Guarani context. As pointed out by DuMars (unpublished), these concepts consist of: (1) focusing administration on critical zones due to overdraft or pollution, rather than to regulation of the entire aquifer (system); (2) leaving the actual implementation of any measure to those responsible for internal adminstration in each country while control would be carried out by (the) multilateral staff; and (3) any joint agency would have only limited discretion, but a commission would take most of the initiatives.

The first two concepts in particular should provide food for thought, given the size of the Guarani Aquifer System, which makes it virtually impossible to contemplate its full-scale administration, especially if it was to be carried out by staff in a joint Secretariat/Agency. The design of the Guarani Aquifer System Project already does take into account the necessity to decentralize in the design of monitoring responsibilities, participation, and in focusing on Hot Spots where current problems are found.

The Process towards a Shared Framework for Guarani Aquifer Management

The previous sections have clearly highlighted the patchy international legal framework for transboundary groundwater resources. Or, as stated by McCaffrey (1999) "On the basis of the available evidence of state practice as well as recent codification and the 1997 UN Convention, it may be concluded that the law in this field has only progressed to the point that the general principles and rules governing the non-navigational uses of internationally shared surface water are applied to internationally shared groundwater resources as well, regardless of their form. As such, the law of international groundwater may only be said to be, at best, in the embryonic stages of develop-

ment." Since the relationship between surface and groundwater resources is finally recognized, and has become essential whenever integrated water resources management is addressed, it remains to be seen if a development towards a specific international legal regime for groundwater will prosper or if groundwater will continue to be integrated in legal norms concerning water resources in general. The polemic will surely continue for some time, however the Helsinki rules, the UN Watercourse Convention, and the ECE Convention from 1992 indicate a trend towards the latter.

What Does This Mean for the Guarani Aquifer System?

As has become clear from the above, the Guarani Aquifer System is unique in its size and hydrogeological, socio-economic, and institutional complexity. It combines issues of quantity and quality that need to be addressed together with environmental protection. Due to aquifer anisotropies and the slowly-moving nature of groundwater, it also poses challenges in terms of transboundary management in border areas as well as national management within countries. It is furthermore important to note that – like most aquifers it is both confined and unconfined. This leads us to question the usefulness and necessity of the distinction made in the legal realm between confined and unconfined aquifers with regard to their treatment by the evolving legal norms. The rationale presented here clearly indicates that the guiding principles derived from international customary law include the obligation not to cause appreciable harm, the duty of equitable and reasonable use, the obligation to provide prior notice, and the duty to negotiate. No specific multilateral conventions about groundwater resources exist nor has the multilateral UN Watercourses Convention entered into effect. Instead, the legal norms that can be applied for management and conflict resolution are derived from general customary law and other conventions applicable to shared natural resources or to water resources in general.

Experience has shown that treaties and conventions by force of their words alone do not lead to better management, and in some cases may contribute to worsen the conditions they were intended to solve. For this reason the explicit aim of the efforts undertaken by the four countries involved in the Guarani Aquifer System Project is to develop a *light* straightforward management framework, which will work in a decentralized manner. This is a formidable challenge, and innovative mechanisms will have to be sought to achieve this goal.

Conclusion

The Guarani Aquifer System is a unique case and undertaking, which will need to develop its own way and will provide a very different experience. Hence, it will serve both the aquifer system itself as well as nourish other possible groundwater management schemes in pertinent cases throughout the world.

Worldwide, most attempts to control or at least mitigate acute groundwater issues have been related to heavily overdrafted aquifers. Furthermore, re-establishing a healthy water balance per se has been concentrated on river basins and aquifers with considerable scarcity – either natural or anthropic – and with already existing severe conflicts, including dangerous pollution levels. Therefore little attention has been drawn to less developed water bodies.

The novelty of the Guarani Aquifer System project rests on the fact that it is starting towards a rather new direction, where prevention is the key word, and social, economic, financial, political, and environmental costs are anticipated with ample time to be avoided, while fostering awareness, plural participation, and mature joint management frameworks. Just like it happens in the Guarani Aquifer System region, there are indeed several basins and aquifers throughout the world that still have moderate or insignificant water use and pollution. Many of them occur in developing countries. The degree of human intervention in those regions is still controllable and offers an excellent opportunity to foresee water and its related natural resources as strategic reserves as well as potential economic means for countries and subregions to help their socio-economic development processes jump to a higher gear.

The Guarani Aquifer System project outcomes may very well trigger a number of actions in those areas in the world where prevention seems timely. With such a new breed of projects, humanity may save considerable effort, conflict, and cost, while protecting the environment and promoting integrated water resources management in emerging economies.

As was shown in this paper, first steps towards this objective have been undertaken by developing a process based on dialogue and communication during project preparation. The preparation process itself has led to improved knowledge of the Guarani Aquifer System, but the project itself will render more of the necessary knowledge and explicitly includes information dissemination and awareness raising. The inclusion of stakeholders, their participation, and their involvement will be a contribution to education and culture on natural resources protection and sustainable management and the proposed pilot projects will constitute test grounds for participatory groundwater management schemes under different scenarios encountered in the Aquifer area, ranging from overdrafting, pollution, and intense use to sustainably tapping potentials.

The complexity of the Guarani Aquifer System also requires careful analysis in terms of the costs and benefits of developing legal and institutional frameworks. Given the size and the preventive nature of the required measures to be developed, the cost of imposing a heavy detailed, and centralized legal framework would almost certainly outweigh the benefits. The coming four years

therefore need to strongly focus on the feasibility of any recommended measures and their expected results. This must include a close look at what measures need to be implemented with regard to the transboundary areas between the four countries as compared to those areas which by hydrogeological standards would not be expected to have transboundary linkages in spite of belonging to the aquifer system.

"The findings, interpretations and conclusions expressed here are those of the author and do not necessarily reflect the views of the World Bank."

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