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Enhancing the use of Science in International
Waters projects to improve project results

SYNOPSIS REPORT

GROUNDWATER

A global Synopsis of Groundwater science
and transboundary management



GEF IW:Science Project

Synopsis Report of the Groundwater Working Group



IW: Science, or *Enhancing the Use of Science in International Waters Projects to Improve Project Results* is a medium-sized project of the Global Environment Facility (GEF) International Waters (IW) focal area, implemented by the United Nations Environment Program (UNEP) and executed by the United Nations University Institute for Water, Environment and Health (UNU-INWEH). GEF ID Number: 3343.



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Synopsis Report of the Groundwater Working Group

March 2012

This report is written as part of the IW:Science series of reports comprising a Synopsis and Analysis for each of five classes of global transboundary water system: River Basin, Lake, Groundwater, Land-based Pollution Sources, and Large Marine Ecosystems and Open Oceans. The findings and content of the Synopsis and Analysis Reports are then integrated into two IW:Science Synthesis Reports to provide a global water view with regard to *Emerging Science Issues and Research Needs for Targeted Intervention in the IW Focal Area*, and *Application of Science for Adaptive Management & Development and use of Indicators to support IW Projects*. All reports can be found on the IW:Science, UNU-INWEH, IW:LEARN and GEF websites.

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Cover photo: Rural village in southern Bolivia near the border with Argentina / A. Dansie

List of Acronyms and Abbreviations

ACRONYM	MEANING
DIKTAS	Dinaric Karst Transboundary Aquifer System
GEF	Global Environment Facility
GIWA	Global International Waters Assessment
IAS	Iullemeden Aquifer System
IGRAC	International Groundwater Resources Assessment Centre
ISARM	Internationally Shared Aquifer Resources Management
IW	International Waters
IWCAM	Integrating Watershed & Coastal Areas Management in Caribbean Small Island Developing States
NSAS	Nubian Sandstone Aquifer System
NWSAS	North Western Sahara Aquifer System
SADC	Southern African Development Community
SAP	Strategic Action Programme
SPREP	Sustainable Land Management (SLM) - Pacific Regional Environmental program
TBA	Transboundary Aquifer

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CHAPTER ONE

Introduction: background, purpose, approach and limitations of this Synopsis Report

Enhancing the Use of Science in International Waters Projects to Improve Project Results is a GEF IW:Science project launched in 2009 covering the five main areas in the GEF International Waters portfolio: surface water; lakes; groundwater; large marine ecosystems; and deep oceans. A working group was formed to address each of these areas.

The project's objective is to enhance — through knowledge integration and information-sharing tools — the use of science in the GEF IW focal area to strengthen priority setting, knowledge sharing, and results-based, adaptive management in current and future projects. The project has three components:

1. Understanding and documenting, for future analysis and reference, the scientific experience and scientific best practices from the IW project portfolio.
2. Undertaking and reporting a comparative, cross-sectoral assessment of IW:Science, identifying intended users and impacts, contemporary scientific challenges, research and science-policy gaps, emerging issues, and global-scale impacts.

3. Creating an IW scientific learning network for information sharing and mutual learning among IW projects and with the wider water science community.

The first component consists of three main activities: (i) development of a project document database (by UNU-INWEH); (ii) review of the documents of relevant projects, with particular emphasis on extracting science; and (iii) analysis of the reviewed projects on the basis of a number of predefined core questions.

This Synopsis Report is the outcome of the second activity of the first component, as carried out by the Groundwater Working Group. Its purpose is to provide a clear review of relevant transboundary aquifer projects in the GEF portfolio as a basis for further analysis, thus contributing to the objective of the IW:Science project.

Standardized templates developed by UNU-INWEH have been used to conduct the reviews in a uniform way, allowing easy integration of information, both inside the set of groundwater projects and across the five water system types. The template was slightly modified to adapt it to groundwater projects (see Appendix A). In one of the projects, the Guaraní project, an additional questionnaire was developed to encapsulate knowledge and views from professionals involved in the project (see Appendix B). Eleven project reviews are presented in Appendix C. In addition, some thematic reviews were made across the set of projects: results of these are presented in Appendix D.

The Synopsis Report relies on project documents contained in the IW:Science project documents database and additional information acquired by individual reviewers. Together, these sources form the basis of the report; however, an important limitation to note is that for most projects it proved impossible to collect a reasonably complete set of reports.



Guarani Aquifer System, a well in Uruguay / O. Tujchneider



Kibae Park – Dhaka, Bangladesh / UN Photo

CHAPTER TWO

What is ‘science’ in the context of the IW:Science project?

To decide how to interpret the word “science” in the context of the IW:Science project, we may look, on the one hand, to numerous definitions of science, and, on the other, to the nature of the GEF projects under consideration.

The following definitions and statements are typical examples of the way science is regarded.

Sheldon Gottlieb (http://www.theharbinger.org/articles/rel_sci/gottlieb.html) describes science as follows:

Science is an intellectual activity carried on by humans that is designed to discover information about the natural world in which humans live and to discover the ways in which this information can be organized into meaningful patterns. A primary aim of science is to collect facts (data). An ultimate purpose of science is to discern the order that exists between and amongst the various facts.

Karl Popper, in *The Logic of Scientific Discovery*, adds uncertainty as a typical characteristic of science:

I think that we shall have to get accustomed to the idea that we must not look upon science as a “body of knowledge”, but rather as a system of hypotheses, or as a system of guesses or anticipations that in principle cannot be justified, but with which we work as long as they stand up to tests, and of which we are never justified in saying that we know they are “true”.

Many investigators define science by describing “the scientific method”. For example, Frank Wolf defines it as follows (http://teacher.nsr1.rochester.edu/phy_labs/AppendixE/AppendixE.html):

The scientific method is the process by which scientists, collectively and over time, endeavour to construct an accurate (that is, reliable, consistent and non-arbitrary) representation of the world. Recognizing that personal and cultural beliefs influence both our perceptions and our interpretations of natural phenomena, we aim through the use of standard procedures and criteria to minimize those influences when developing a theory. As a famous scientist once said, “Smart people (like smart

lawyers) can come up with very good explanations for mistaken points of view.” In summary, the scientific method attempts to minimize the influence of bias or prejudice in the experimenter when testing an hypothesis or a theory.

The scientific method is often summarized as a four-step approach (*Journal of Theoretics*, Vol 1-3, Aug/Sept 1999, Editorial):

1. Observation and description of a phenomenon or group of phenomena.
2. Formulation of a hypothesis to explain the phenomena. In physics, the hypothesis often takes the form of a causal mechanism or a mathematical relation.
3. Use of the hypothesis to predict the existence of other phenomena, or to predict quantitatively the results of new observations.
4. Performance of experimental tests of the predictions by several independent experimenters and properly performed experiments¹.

From the above, we may conclude that for some people (theoretically oriented scientists), science focuses on hypotheses and theories, while for others (applied scientists) it is concerned with producing “useful models of reality”.

Given that GEF projects are aimed at producing tangible impacts on the environment, an inclusive rather than restrictive interpretation of the word “science” seems more appropriate, and would encompass everything related to producing “meaningful patterns in the world around us” and “useful models of reality”, including how these patterns may change in the future. Similarly, IW: Science should not focus solely on the “natural sciences”, but also take into account the social and applied sciences. This broad interpretation was incorporated in the approach of the Groundwater Working Group.

¹ This fourth step is obviously meant to validate or falsify the hypothesis.

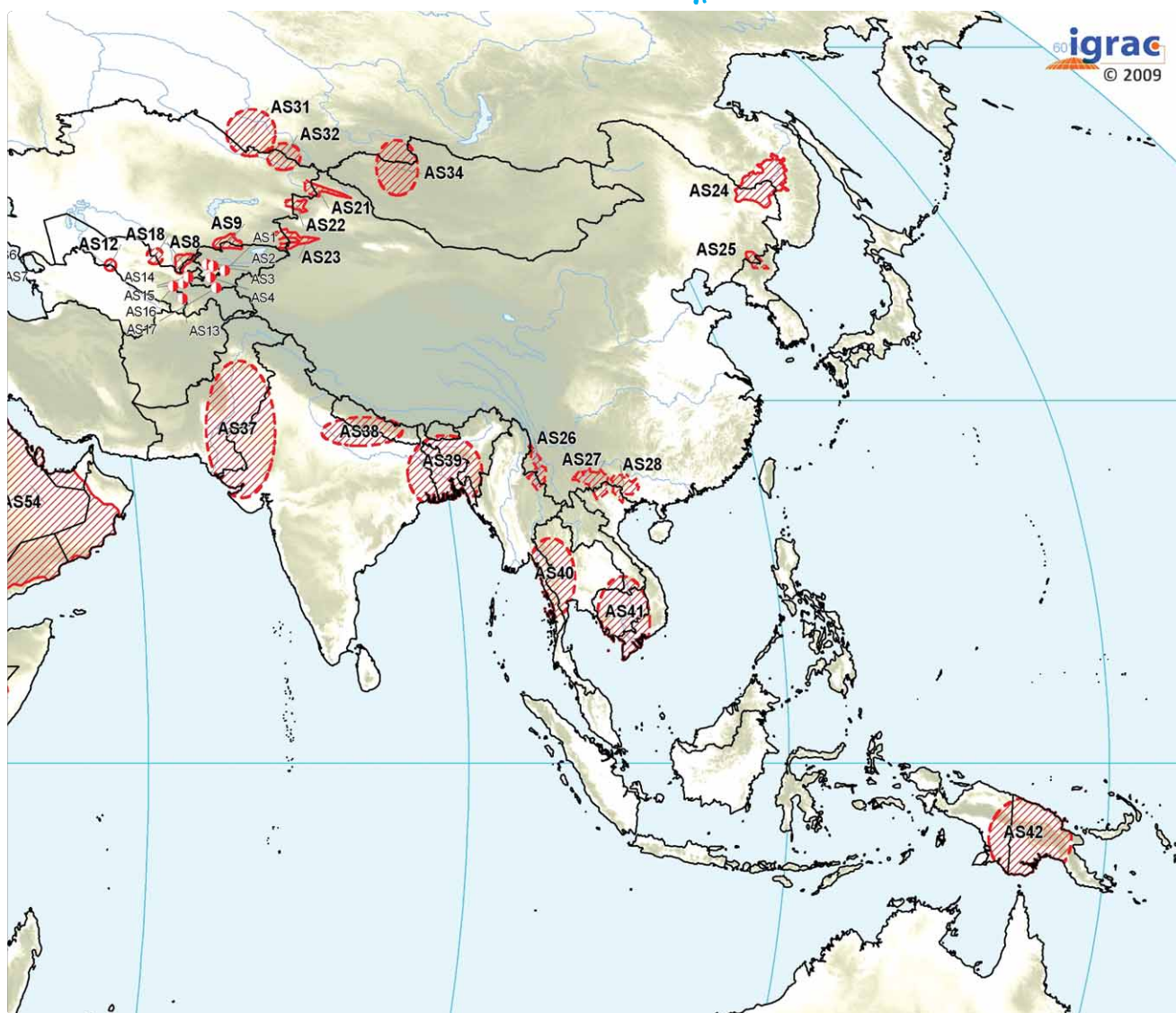


Figure 1 Transboundary Aquifers of South-East Asia Map

The figure depicts South-East Asian transboundary aquifers based on information provided by various organisations and projects dealing with transboundary aquifer assessment and /or management and compiled by IGRAC in 2009. For a comprehensive explanation of this map, please refer to the figure caption on the back inside-cover (p. 20).

CHAPTER THREE

Reviewed projects and available documentation

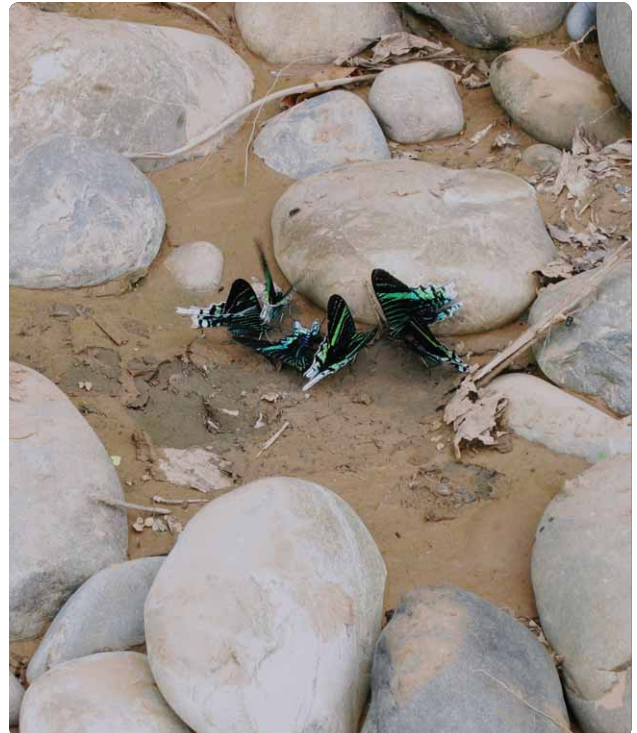
Within the GEF portfolio, the number of projects related to groundwater is relatively small; therefore, the Working Group attempted to include all of them in the review, even bringing in some non-GEF projects. Of the resulting list of 15 possible projects, four were deleted for practical reasons (see Table 1). The final set of 11 includes all six completed GEF groundwater projects and one completed project carried out as an Internationally Shared Aquifer Resources Management (ISARM) activity.

UNU-INWEH has developed a large on-line project document database on IW projects, accessible since January 2010; however, availability of reports for the selected GEF groundwater-related projects is still relatively poor. Documentation is probably complete only for the Global International Waters Assessment (GIWA) project. For most of the other projects, key reports appear to be missing: e.g., final technical reports and technical reports on some of the project components. GEF apparently has no systematic storage of project reports at its headquarters. Attempts by reviewers to trace reports from professionals involved in the projects did not produce much more information. In several cases, however, the reviewers already had a number of reports in their possession because of their own involvement in the projects, or were able to find additional documents on the internet, or acquire them from colleagues.

Impressive efforts were made to collect information on the projects under review but the lack of completeness (in some cases even key documents are missing) severely limited the content of the reviews and created some uncertainty as to the validity of judgments and overall conclusions.



Water collection, Tanzania / A. Dansie



Wildlife in Brazil, surface water and groundwater require effective hydrological understanding to identify connectivity and ensure effective management. / A. Dansie



Table 1 Shortlisted and reviewed international groundwater projects

PROJECT	GEF #	NUMBER OF DOCUMENTS AND STATUS OF DOCUMENTATION		
		IN IW: SCIENCE DATABASE	STATUS	
Completed projects:				
1	Guaraní Aquifer System	974	176 documents. Reasonably documented, but still incomplete.	Reviewed
2	Managing Hydrogeological Risk in the lullemeden Aquifer System	2041	12 documents. Administrative and final reports missing.	Reviewed
3	North Western Sahara Aquifer System (NWSAS)	1851	12 documents. Unclear how much is missing.	Reviewed
4	Groundwater and Drought Management in the SADC Area	970	6 documents. No technical reports	Reviewed
5	Eastern Desert Egypt (renewable groundwater in arid lands)	985	5 documents. No technical reports	Reviewed
6	GIWA	584	99 documents. Looks complete.	Reviewed
7	TBA in Asia: case study Amur River basin.	-	Unknown – Not a GEF project	Reviewed
Ongoing projects:				
8	Integrated Management of the Nubian Sandstone Aquifer System (NSAS)	2020	8 documents. No technical reports	Reviewed
9	Mainstreaming Groundwater in Nile River Basin Management	3321	4 documents. No technical reports	Reviewed
10	SPREP		28 documents. Unclear how many are missing.	Deleted
11	IWCAM (Caribbean region)		59 documents. Unclear how many are missing.	Deleted
12	ISARM	-	Not a GEF project	Reviewed
Recently starting:				
13	DIKTAS		5 documents. Only administrative ones.	Deleted
14	La Plata		Not clear; does the project coincide with FREPLATA (GEF Id no 613)?	Deleted
15	Management of Coastal Aquifer and Groundwater (part of Mediterranean Sea project)		9 documents, only administrative documents.	Reviewed

CHAPTER FOUR

Selected issues across the set of reviewed projects

4.1 Project aim and purpose/ role of the use of science

First of all, it is very important to observe that there is quite a diversity in objectives or aims among the eleven projects (see Appendix C), which makes comparison more difficult and complicates the analysis.

Roughly, we may distinguish the following aims among the set of projects:

- *Identification and initial characterization of transboundary aquifer systems* (TBA in Asia/Amur Basin and ISARM). This is a very important and relatively inexpensive initial step, without which it is difficult to define priorities among TBAs and to make an optimal design for more advanced projects addressing prioritized aquifer systems. The main output of this category of projects is descriptive. The role of science here is to understand what is relevant for a general characterization of transboundary aquifers and how to collect, process and interpret relevant data.
- *Prioritization for GEF funding and identifying hotspot areas for water resources management interventions* (GIWA). The role of science in this case is to develop a well-balanced methodology for prioritization and to collect reliable information at adequate scale to perform the prioritization and identification.
- *Increasing knowledge on one or several physical characteristics of a TBA* (Eastern desert project; North Western Sahara Aquifer System project (NWSAS); Nubian Sandstone project (NSAS); Nile River Basin Management project). This category of projects is characterized by use of specialized techniques: e.g., hydrochemical and isotope techniques, modelling techniques, remote sensing. Reliable results require a good scientific knowledge

of the phenomena to be investigated, scientifically collected data on the local system, and knowledge of the scientific principles behind the methods used.

- *Catalysing the process of joint water resources management* (Southern African Development Community project (SADC); Iullemeden project; Mediterranean Sea project). The role of science here is to develop and underpin policies and/or a strategic action programme, to establish a framework for co-operation, to build capacity, etc.
- *Combination of previously mentioned aims*. This applies particularly to the case of the Guaraní project, but to some extent also to the NWSAS, NSAS and Nile River Basin Management projects.

4.2 Predominant categories of science observed

Table 2 shows the different scientific disciplines used or themes addressed in each of the reviewed projects, according to the reviewers and based on a predefined set of 18 disciplines and themes. Differences in perspective among reviewers and, in many cases, a lack of appropriate documentation complicate the issue somewhat, but a certain pattern can be observed:

- The two projects that focus on identification and initial characterization of TBAs (Amur River Basin and ISARM) cover more than two-thirds of the 18 predefined themes. This is inherent to the purpose of these projects. The science included is aimed at providing an overview. Defining the transboundary systems and linking their hydrology and geology across the boundaries produces original knowledge; additional characterization is perhaps not original and in-depth, but it is broad in scope and requires processing of large quantities of data and information using good professional judgement.



- Two more projects (SADC and Guaraní) also include a wide range of aspects (more than 80 per cent of all predefined ones). This is because the projects are trying to catalyse cooperation between partners in a multidisciplinary context.
- The GIWA project also addresses more than half of the defined aspects, but with some bias towards social science and with use of scores that cannot be easily related to characteristics of individual aquifers or river basins.
- It is quite understandable that the projects that primarily aim to develop more knowledge on a single aquifer system are scientifically less broad in design, but tend to go deeper into the subject and to develop new knowledge (Eastern Desert; NSAS; NWSAS; Nile River Basin; Mediterranean; and Iullemeden). The scientific orientation of most of these projects is biased towards natural sciences, in particular hydrogeology and water quality (hydrochemistry and isotopes).
- Legal and/or institutional aspects have been identified by the reviewers in five out of 11 projects. It is thought that these aspects played a role in two other projects as well (NWSAS and Iullemeden project), but the reviewers could not confirm this, simply because they had no access to any corresponding documents.

From a scientific point of view, four different categories of products can be distinguished in these projects:

- *Balanced compilations of relevant information*, covering hydrogeology, environmental science, socio-economic aspects, governance and management. These compilations are important for providing guidance to next steps in the process, as well for exchange of knowledge and raising of public awareness.

- *Methodologies* for prioritization and for plan development (causal chain analysis, policy option analysis).
- *Answers to scientific questions related to single aquifer systems*, such as on the origin and rate of renewal of groundwater, and on the evolution of the groundwater system under future conditions (popular tools are hydrochemistry and isotope techniques, as well as numerical modelling)
- *Building blocks towards transboundary aquifer management plan development* (in particular Transboundary Diagnostic Analysis (TDA) and Strategic Action Programme (SAP), but awareness raising also).

Looking at the project content from the point of view of the DPSIR framework of analysis² we may observe that:

- The majority of the projects pay little or no attention to the drivers of change (D), such as demographic changes, climate change, changing socio-economic or political setting, etc.
- Pressures (P) are taken into account in most of the projects, in particular increase of abstraction and pollution.
- However, most of the attention is paid to the state (S) of the groundwater systems. The present state is explored and studied on the basis of field observations (especially by monitoring and by using hydrochemical and isotope techniques), whereas prediction of future states is performed mainly by modelling.
- Socio-economic and environmental impacts (I) receive attention in less than half of the projects.

² The DPSIR Framework of Analysis structures processes of change on the basis of Drivers (D), Pressures (P), State (S), Impacts (I) and Responses (R).

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Table 2 Fields of science and scientific themes covered by the reviewed projects

GEF PROJECT NO.	NAME	HYDROGEOLOGY	GEOLOGY	HYDROLOGY/WATER BALANCE	
		1	2	3	
1	-	TBAs in Asia (emphasis on China) – Amur basin	x	x	
2	985	Eastern Desert Egypt (renewable groundwater in arid lands)	x	x	x
3	584	GIWA	x		x
4	974	Guarani Aquifer System	x	x	
5	2041	Managing Hydrogeological Risk in the Iullemeden Aquifer System	x		x
6	GFL-2322-2731-4A05	Management of Coastal Aquifer and Groundwater (Mediterranean Sea area)	x		
7	3321	Mainstreaming Groundwater in Nile River Basin Management	x		x
8	2020	Integrated Management NSAS	x		x
9	1851	NWSAS	x		x
10	970	Groundwater and Drought Management SADC	x	x	x
11		ISARM	x	x	x

	HYDROCHEMISTRY/ WATER QUALITY	DEMOGRAPHICS	CLIMATOLOGY	ECONOMICS	ENVIRONMENT	GROUNDWATER ABSTRACTION	GROUNDWATER POLLUTION	WATER MONITORING	PUBLIC WATER SUPPLY	ECONOMIC WATER USE	SOCIO-ECONOMIC IMPACTS	ENVIRONMENTAL IMPACTS	PUBLIC AWARENESS & PARTICIPATION	LAW, INSTITUTIONS, GOVERNANCE	WRM
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	x		x		x	x	x	x	x	x		x	x		x
	x					x	x	x							x
	x		x	x	x					x	x	x		x	x
	x	x		x	x	x	x	x	x		x	x	x	x	x
								x						x*	
	x				x		x								
	x									x		x			x
	x						x	x						x	x
	x					x		x						x*	x
	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	x	x	x	x	x	x	x		x		x	x		x	x

Note: x* means that the subject was addressed in the project, but without the results being accessible to the project reviewers.

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Response (R) in terms of developing governance (legal instruments and institutions) and joint water resources management planning is only modestly addressed in the projects (as far as accessible documents reveal). Furthermore, this component of the DPSIR framework is often more related to preferences and enforcement (what do we want?) than to science (what do we know?). Alternatives for economic/ institutional governance responses are rarely considered and developed.

4.3 Missing or poorly covered science components

In general, some of the missing or poorly covered science components in the set of projects can be deduced already from the discussion above. This statement refers in particular to the very limited attention to “drivers of change” (extremely important if one has to prepare for the future) and only moderate attention to “impacts” of changes of state, which is key to formulating area-specific management objectives for water resources. In terms of scientific disciplines, one may argue that social sciences, including economic governance, are under-represented.

4.4 “Cutting edge” versus “conventional” science

- From a very rigorous point of view, most of the science observed in the selected set of GEF projects belongs to the category “conventional science”. This is not meant to be a disparaging comment. “Conventional science” is an extremely strong tool for gaining better and useful knowledge on the world around us; moreover, “innovative science” is not necessarily the most useful in every case. With that said, several examples of “innovative” use of science are evident in the set of projects:
- Causal chain analysis of problems in water resources management: e.g., in GIWA;
- Advanced isotope surveys as applied to hydrogeological systems (NSAS);
- Sharing data and information on-line in an unprecedented way both from a technical and a co-operative point of view: e.g., Eastern Desert, ISARM-Americas;
- Modelling very large groundwater systems (Guaraní, NWSAS).

4.5 Flaws and errors in using science

Flaws and errors have been observed at different levels and are briefly pointed out below, with some reservation due to the fact that documentation is incomplete.

At the project design level, the first case is GIWA. The geographic units chosen for GIWA were incompatible with getting clear assessment results that could be related to individual water systems, such as aquifers and river basins. Hence, the outcomes are too abstract and fail to increase knowledge. A second comment on project design is the bias toward physical aquifer systems, resulting in limited attention to institutional development, in spite of the GEF-IW focus on enabling environment and strategic aspects and plans. This bias is present even in several projects where the project title or aim is much wider in scope than physical systems (e.g., NSAS, NWSAS, Iullemeden, Nile River basin). Linking of natural and social sciences appears to be weak in many of the projects and attention to “drivers of change” is minimal.

At a more technical level, observed flaws are a lack of sufficient reliable data for modelling and analysis; lack of verification and calibration of models; insufficient attention for spatial variations; and absence of solid conceptual frameworks.

4.6 To what extent did science help achieve project objectives?

The scientifically guided descriptions in the characterization-oriented projects (e.g., Amur River Basin; ISARM) undoubtedly have helped achieve project results.

In the case of GIWA, however, the design flaws and lack of real data collection made the project outcomes in terms of priorities and “hot spot areas” not very convincing.

Science in the Guaraní project very clearly contributed to better understanding and consensus on important issues related to the Guaraní aquifer system among the four countries involved. In particular, it has helped correct the previous erroneous assumption that groundwater drawdown and contaminant transport would be large across the international borders.

In the case of the Eastern Desert project, project results ensured that groundwater was included in the policy plan of the Ministry of Water Resources and Irrigation.

The NWSAS scientific project results have contributed to awareness of the type, magnitude and location of the risks of uncontrolled groundwater abstraction. This gives direction to international co-operation on the shared groundwater system.

4.7 Scientific best practices and their possible replication

The following scientific activities are considered “best practices” and have ample scope for replication in a variety of transboundary aquifer projects.

- *Systematic data and information collection, harmonization and compilation:*
A number of the reviewed projects include a systematic review and compilation of available data and information. This is an essential component that capitalizes on previous efforts and provides building blocks for conceptual models, simulation models and other types of analysis. At the same time it shows the extent to which additional data acquisition actions are needed in order to make data availability consistent with data needs. Data compilation is very significant and strong in the ISARM programme, and also in a few other projects (Amur River Basin; Guaraní; Eastern Desert).
- *Transboundary Diagnostic Analysis:*
After a certain level of knowledge has been developed on a transboundary aquifer, its state and its functions, it is very important to define the main groundwater resources management issues to be addressed, and, in particular, to find out how and to what extent negative or positive impacts may occur in and around the transboundary aquifer. This is done in a Transboundary Diagnostic Analysis (TDA), such as applied in the Guaraní, Iullemeden and NSAS projects. The outcomes of a TDA give focus and direction to transboundary aquifer projects. It is not clear if in projects lacking a TDA some other sort of systematic analysis was done to define major management concerns.
- *Investigating key questions basic to development of joint management strategies:*
A few of the reviewed projects looked for answers to questions considered essential for understanding the groundwater system and for estimating possible changes of state and functions over time. Examples are prediction of the changing state of the aquifer under different abstraction scenarios (e.g., NWSAS, Guaraní), and assessment of groundwater renewal (Eastern Desert project) and groundwater-surface water interrelations (Nile River Basin project).
- *Capacity building of local staff for inventory, characterization, TDA and SAP:*
Several projects include a capacity-building component with the objective that staff of local institutions of the countries sharing an aquifer are trained to develop the capacity to take care of all scientific aspects of transboundary aquifer management. This entails “hard science” and “social science”, as needed for identification and characterization of transboundary aquifers, and for TDA and SAP. This capacity building component boosts the application of science at the local level.
- *Science-based tools to assist policy makers:*
Some of the projects include science-based tools to help policy makers incorporate science into decision-making. An example is GIWA with its indicators and scores, as well as its causal chain analysis. The methodology is interesting, although its application in GIWA is considered unsuccessful because of too much spatial aggregation and a general lack of data.
- *Sharing and disseminating relevant information:*
Many of the projects made very successful efforts for sharing and disseminating information on transboundary aquifers. Awareness campaigns, published papers, on-line databases (with GIS applications) and changing attitudes toward colleagues in neighbouring countries have an unprecedented impact on the state of knowledge on transboundary aquifers all over the world. It cannot be emphasized enough that this widespread communication of information is extremely important for all transboundary water projects.

CHAPTER FIVE

How are the main themes being addressed, from a scientific point of view?

5.1 Hydrogeology

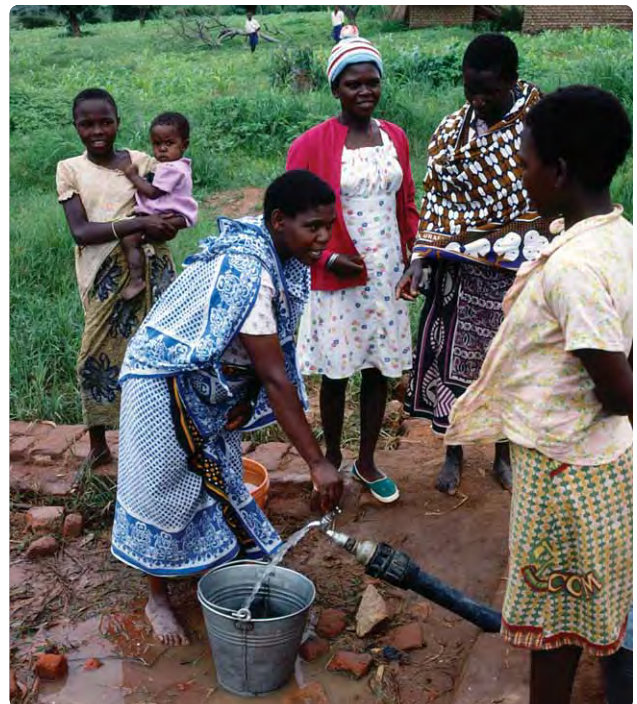
Appendix D-1 presents a brief review of the use of hydrogeology in the set of projects considered. The table in this appendix confirms that hydrogeology is a component in all projects considered and provides more detailed information on the aspects addressed and techniques used. Data compilation, modelling, water quality techniques and conceptual models are observed in the majority of the projects, followed in frequency of occurrence by database development, isotope methods and remote sensing. Groundwater-dependent ecosystems, groundwater/surface water interaction, and pollution and protection are regular themes addressed in the projects.

The hydrogeological science component is considered rather strong and dominant across the entire set of projects. Nevertheless, there are shortcomings, but these tend to be project specific. For instance, in several projects, modelling seems not sufficiently supported by data or by a good conceptual model, nor convincingly validated — at least not in the reports available to the reviewers. In other ones, too strong a reliance on isotope techniques and isotope data tends to narrow views and apparently leads to overlooking the importance of hydraulic and hydrological data for characterization and understanding of hydrogeological processes.

There is much scope for improving communication of the hydrogeological aspects of transboundary aquifer systems. Not only should professional hydrogeologists inform each other, but they should make the public aware also.

5.2 Socio-economics

A brief review of the use of socio-economic analysis in the set of projects is presented in Appendix D-2. It shows that not all GEF groundwater projects address socio-economic aspects. Very few, and notably the newcomer projects, consider macro-economic drivers, micro-economic instruments, and economic governance opportunities. There is a growing trend of expanded adoption of economic water governance in all regions. An immediate opportunity for institutional economic and economic governance sciences is to define the scope for economic management and governance interaction in the approximately 200 internationally shared aquifers identified under the ISARM program.



Tanzania / UN Photo, B. Wolff



5.3 Legal and institutional aspects

As stated in Appendix D-3, in the set of selected GEF projects only three include a legal/institutional component significant enough to be detected in project design and outputs: the Guaraní project (GAS), the NWSAS project and the Iullemeden project (IAS). Projects like SADC and NSAS allude to such a component, but this is insufficiently substantiated by the accessible documentation. In addition, the non-GEF ISARM -Americas project includes an inventory of groundwater-related legal aspects and instruments in the entire Western Hemisphere. The latter is meant to provide information on existing frameworks and instruments.

The legal/institutional components of the Guaraní, NWSAS and Iullemeden projects, on the other hand, have the objective of facilitating transition from technical co-operation to a political commitment on shared aquifers. To this end, these legal/institutional frameworks need to be carefully designed, adapted to the local conditions, and rigorously based on state-of-the-art legal/institutional methodologies and practices. Even if these conditions are fulfilled, however, there is no guarantee that the framework will be accepted and implemented by the countries concerned. No matter how rigorously conceptualized and crafted, the draft of an agreement among the four Guaraní Aquifer sharing (GAS) countries failed to be accepted by all four countries, apparently because six-plus years of cooperation at the technical level among the GAS countries were not sufficient to pave the way for firm engagement at the political level, and for a lasting legal agreement and institutional arrangement.

This experience is in contrast to the NWSAS project, which resulted in the draft of a legal instrument providing for continuity of post-project cooperation among the three countries sharing the aquifer — Algeria, Libya and Tunisia — through establishment of a tri-partite institutional arrangement. By mid-2008, the tri-partite institutional arrangement (*mécanisme de concertation*) had been inaugurated and continues to function.

The IAS project experience stands somewhat in between these two extreme in terms of success. While cooperation in data collection and modelling has made significant advances, full engagement at the political level has been held up by the opposing views of two of the three IAS countries on the seat of the proposed tri-lateral institutional arrangement for continued post-project cooperation.

There is no doubt about the importance of getting the law “right” from the start of a project, by injection of scientific rigour in the conceptualization and design of a legal framework and institutional arrangements to ensure permanent inter-state transboundary engagement, extending beyond the life of a project. However, the eventual uptake by the project countries of the legal and institutional arrangements for lasting cooperation designed by the project depends on variables that lie beyond the domain of the law, and need to be investigated with the help of other disciplines and parameters.

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5.4 Stakeholder involvement

Appendix D-4 reviews stakeholder involvement in the selected transboundary groundwater projects. Apart from making a distinction between different categories of stakeholders, it is difficult to discuss “stakeholder involvement” in a scientific context, since — as far as we know — none of the projects presents an analytical approach to this aspect or develops corresponding methodologies. Rather, the inclusion of stakeholder involvement is based on experiences showing that stakeholder involvement contributes significantly to the success of projects (by contributing information and views), and that it builds confidence and acceptance among the general public, which is crucial for implementation.

To enable effective and useful involvement of stakeholders, information on the groundwater systems concerned should be made available in a suitable format. Similarly, groundwater management objectives should be defined in such a way that stakeholders understand what is at stake and can make up their mind about acceptability of proposed developments.



Nyala region, Sudan / UN Photo, F. Noy

5.5 Ecosystem approach

According to Appendix D-5, “the ecosystem approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. Thus, the application of the ecosystem approach will help to reach a balance of the three objectives of the Convention on Biological Diversity: conservation; sustainable use; and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources”. The ecosystem approach is based on appropriate science, in a holistic and adaptive context. Humans are considered to be part of so-called “socio-ecological systems”. “Ecosystem services” is a central concept in the ecosystems approach, and important elements are (i) maintaining environmental flows, (ii) economic valuing of ecosystem services, and (iii) payment for ecosystem services.

Few of the consulted documents refer to the concept of ecosystem services of groundwater and/or aquifer (NSAS and Groundwater in SADC). In most cases, the fact that aquifer and groundwater can have provisional, regulating, cultural and supporting functions is not mentioned. Although human dependency on groundwater for consumption and production, and groundwater fluxes to rivers, lakes and other ecosystems are often mentioned, they are not explicitly defined as possible services aquifers can provide.

The Guaraní project mentions the concept of environmental costs. None of the projects tries to value the ecosystem services of the aquifers and groundwater. None of the consulted projects mentions payment of watershed services as a possible mechanism that might be put in place as part of transboundary aquifer management.



Figure 2 Transboundary Aquifers of Latin-American map

The figure depicts Latin-American transboundary aquifers based on information provided by various organisations and projects dealing with transboundary aquifer assessment and /or management and compiled by IGRAC in 2009. For a comprehensive explanation of this map, please refer to the figure caption on the back inside-cover (p. 20).

CHAPTER SIX

Conclusions

Science is a significant presence in this set of transboundary aquifer projects and is indispensable to achieving project objectives. A large degree of variation between the reviewed projects with regards to science is evident, giving rise to the question: Is this a result of tailor-made project designs, or of limited or earmarked budgets, or is it simply reflecting professional affinity or preferences of those who formulated the projects?

Hydrogeology (including water quantity and quality) dominates the science in the reviewed projects. Projects covering all relevant aspects of transboundary aquifers and their coordinated or joint management are rare; most are more limited in scope. Aspects of the ecosystem approach and related holistic approaches can be observed in several projects, but they do not yet seem to form a methodological backbone to any of the projects. A limited number of projects has or had a legal/institutional component, but some projects with names that suggest a focus on management processes are, in fact, only investigations of physical groundwater systems. Socio-economics is absent or only modestly present in several of the projects.

The projects contain useful science elements that may be replicated in new projects. No doubt the level of science may be excellent in many cases, but it was not possible to verify this during the review process, due to factors such as limited time, poor access to project documents, or lack of detailed reporting on scientific activities.

Flaws have been observed in several projects. One is numerical modelling or defining scores for prioritization in cases where it is not convincingly shown that sufficient data at the appropriate scale level are available. In such cases, the reliability of the presented results is in doubt. Another flaw is that some projects concentrate on one or a few techniques, without incorporating other types of information that could help in drawing firm conclusions.

Finally, the importance of acquisition, compilation and organization of data into readily accessible databases is perhaps not yet fully recognized by all projects.

The preceding chapter gives a general impression, while more detailed reviews can be found in the appendices to this report.



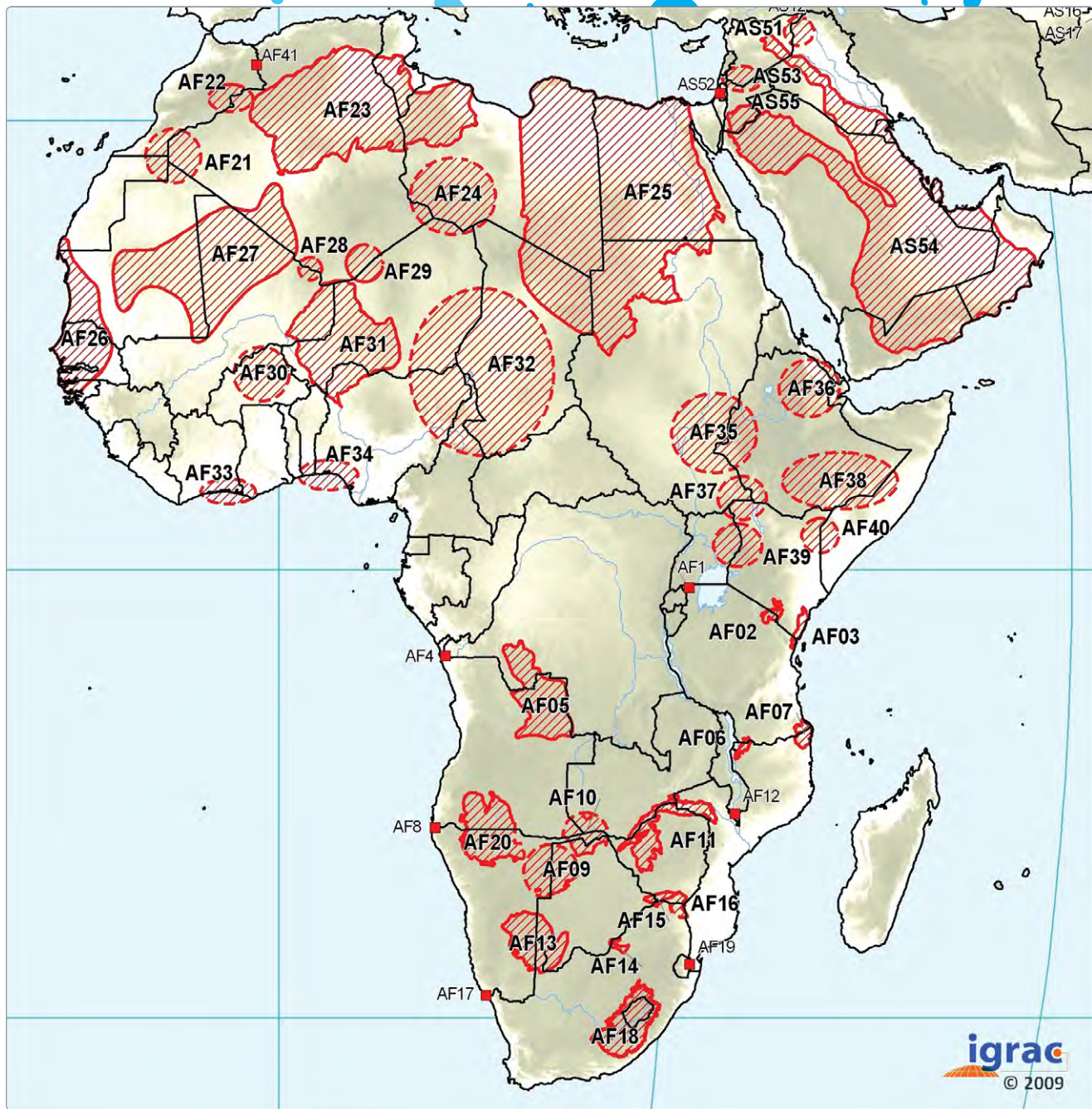


Figure 3 Transboundary Aquifers of Africa map

The figure depicts African transboundary aquifers based on information provided by various organisations and projects dealing with transboundary aquifer assessment and /or management and compiled by IGRAC in 2009. For a comprehensive explanation of this map, please refer to the figure caption on the back inside-cover (p. 20).

Synopsis Report



Transboundary Aquifer (TBA) maps provided by IGRAC: The map fragments presented in this report bring together information on transboundary aquifers as was known in 2009. The information was provided by various organisations and projects dealing with transboundary aquifer assessment and /or IGRAC compiled the available information in this TBA map based on the guiding principle to stay as close as possible to the information provided by the original sources, while presenting the information as appropriately as possible for the originally chosen scale of the map (1:50,000,000). The TBA map shows aquifer extent (if known), for aquifers with an area larger than 6,000 km². Smaller aquifers are represented with squares. If the exact aquifer boundaries are known and acknowledged by all sharing countries, they are delineated with solid red lines. If not, they are delineated with dashed red lines. Small (filled or half-filled) circles are used to depict aquifers whose extent is not known. A filled circle represents an aquifer whose occurrence is confirmed by all countries involved; if an aquifer is not recognized by all countries, it is depicted by a half-filled circle.



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