



United Nations  
Educational, Scientific and  
Cultural Organization



International  
Hydrological Programme

UNESCO-IHP

# ISARM Programme

# ATLAS OF TRANSBOUNDARY AQUIFERS

Global maps, regional cooperation and local inventories



International Hydrological Programme  
Division of Water Sciences



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Educational, Scientific and  
Cultural Organization



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**ISARM Programme**

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# FOREWORD

In recent years, water security for humanity and the natural environment has taken centre stage in much of the dialogue on international policy. Governments have reaffirmed the need for coordinated actions to protect vulnerable populations, and the natural environment that they rely on, including the sustainable use of water in aquifers.

International agencies working with national and regional organizations have highlighted the fact that many natural resources occur in transboundary contexts and that for the sound management of these resources, cooperation between countries is paramount. Governments have participated in the UNESCO led initiative on International Shared (transboundary) Aquifer Resources Management (ISARM), forming part of the International Hydrological Programme (IHP). The ISARM initiative, which has been operational since 2003, also benefits from close cooperation with the International Association of Hydrogeologists (IAH), with the Organization of American States (OAS), with other regional and international institutions, as well as with UN organizations such as the Food and Agriculture Organization (FAO) and the UN Economic Commission for Europe (UNECE), to name but a few.

One of the objectives of the ISARM Programme from the outset was to conduct a global inventory of transboundary aquifers. It is with pleasure that I am able to report that this objective has been substantially achieved and that the compilation included in this volume is the state of knowledge in 2009. Since the scientific surveys of national hydrogeologies, and associated with it the continued work on water resources assessment, are still progressing in many of the Member States, this Atlas will serve to give impetus and encourage continuation of the work of the global inventory, within the scope of IHP's Seventh phase, ending in 2013. The Atlas also provides a factual backdrop to the recent Resolution of the UN General Assembly on the Law of Transboundary Aquifers and I have pleasure in commending this volume to the Member States.



András Szöllösi-Nagy  
The Deputy Assistant Director General  
for Natural Sciences  
Secretary of the International  
Hydrological Programme  
UNESCO

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1



# Groundwater resources and global maps

# THE AQUIFERS OF THE WORLD

## The science of aquifers: hydrogeology

The understanding of hydrogeology has ancient beginnings with the construction of qanats, which are slightly inclined tunnels dug into a hillside, to tap the groundwater contained in an aquifer, for use by settled populations in many parts of the Asian continent. The Greek and the Indian civilisations thrived on water drawn from wells, which are a specialised form of qanats in the sense that a well is a vertical shaft dug into an aquifer for the withdrawal of a reliable supply of water. The transition from this form of traditional and indigenous knowledge to quantitative hydrogeology is marked by the work of the French Engineer, Henry Darcy (1803–1858) who determined the mathematical law that governs the movement of groundwater through an aquifer. In less than a decade following Darcy's statement the ability to predict the volume and rate of production of water from a well was widely understood among the earliest professional hydrogeologists.

Today the formal science of hydrogeology is well established within academia and it has widespread practical application in the sound management of the natural and built environments, wherever aquifers are significant. This atlas has been compiled to provide a user-friendly reference source for water policy makers, policy advisors, researchers and educationalists who may not be specialists in the field of hydrogeology, but nevertheless need to understand its implications.

Most people know about the occurrence of fresh water in an aquifer even if they do not recognise the term. People know about aquifers from wells – this is an excavation in the earth, either dug by hand or drilled by a machine, from which fresh water can be drawn out for drinking or irrigation. The *rock* into which the well has been dug *and the water* that is contained in that rock is called an *aquifer*. Most people will also have seen a 'dry' aquifer – the best place to see one will be in a road cutting that passes through sandstone rocks, or in a rock quarry (Photo 1). The rock in layers is a manifestation of its lithology of the different grades of sands, gravels and pebbles, that appear as layers; in a road cutting the aquifer would generally be dry, since the water in the rock will have drained to the foot of the road cutting; in a rock quarry there may well be water at the bottom.

The understanding of hydrogeology also requires a sound grasp of a number of other disciplines, such as geology, chemistry, hydrology and mathematics. These disciplines coupled with modern day technology such as digital processing, satellite image analysis and geophysical instrumentation enable the professional to provide a sound assessment of aquifer resources and their management. Today the management of aquifer

resources also requires interaction with professionals in sociology, legislation and institutional development.



Photo 1. The granular rocks that can contain water.  
(Guatemala rock quarry in the Ostua Metapan transboundary aquifer). *Photo: S.Puri.*

## Aquifers and river basins: unity of the hydrological cycle

Freshwater in the terrestrial environment is visible in rivers, lakes and frozen ice caps. Such waters are visually dynamic and flow in rivers, which have their origins in mountains, and their discharges in seas and oceans. Each terrestrial river also has its 'catchment', an area over which all the rain that falls eventually discharges to the beds of rivers. Some of the rain infiltrates into underlying rocks and replenishes the sub-surface aquifers. The essential concept that needs to be understood is that a river catchment and an aquifer do not always coincide geographically. Hydrologists and hydrogeologists can easily determine the coincidence or non coincidence of river catchments and aquifers given some basic data that defines the elements of the hydrological cycle. Putting together all these elements and adding in the related depending ecosystems, permits the full identification of 'an aquifer system'. Correctly identifying the elements of the hydrological cycle in an aquifer system is a basic prerequisite to sustainable management of water resources that will permit ecosystems to continue to function, and will support the needs of humanity.

Water resource managers and users of freshwater are increasingly recognising the importance of correctly determining the coincidences or non coincidences of river catchments and aquifer systems, so that when resources are limited they might be equitably utilised for the needs of natural and human ecosystems.

The maps that follow demonstrate a series of global overviews relative to aquifers of the world. While each map is a two dimensional image of the terrestrial setting of the planet, a third dimension is expressed through the ornamentation marked on each map. Brief explanations of each of the maps and the information portrayed follow.

## **The water resources in aquifers: their use and management**

Long standing hydrological research and investigation of the global water cycle has demonstrated that 99% of all accessible fresh water on the planet is found in aquifers. Almost 2 billion people on the planet entirely rely on a nearby aquifer for all of their daily water needs and it is stated that groundwater is one of the most extracted Earth resource.

The World's aquifer resources are an important component in sustainable development. Aquifers and the groundwater in them, form one component of the broad context of the hydrological cycle system and thus an inseparable part of the environment, operating in a complex interrelationship. In nature, groundwater is a key element in many geological and hydrogeochemical processes, and is a geotechnical factor, conditioning soil and rock behaviour. Groundwater, discharging from an aquifer, also has an ecological function, as it sustains spring discharges, river base-flow and lakes and wetlands and the aquatic habitats found in them.

As with any naturally occurring resource, its excess use, over and above its natural replenishment rate, will result in impacts of a harmful nature, a phenomenon easily observed in the case of natural forests or easily appreciated in the case of marine fisheries. Just as excess fishing from rivers will harm aquatic habitats, so also excess withdrawal from aquifers will harm ecosystems that depend on the water in aquifers. Exactly as the science underlying the sound management of forests and fisheries is well understood, so also is the science of aquifer resource management. The difficulty in the application of sound science to the sound management of aquifers is in the fact that they are found below ground and are thus a phenomenon that suffers from being 'out of sight' and thus 'out of mind' of the policy makers. Hydrogeologists have made tremendous strides in helping to visualise the hidden resources in aquifers through maps and three dimensional models, using much of the available modern day technologies. Nevertheless there remains a knowledge gap linking science and sound policy.

In the past three to five decades withdrawal of water from aquifers has exponentially increased, reflecting humanity's increasing needs for food and industrial production, for which a basic raw material is the freely available ground water in aquifers, generally treated as a common good, being poorly subject to regulation. Global groundwater resources withdrawals are estimated to average from 600 to 800 km<sup>3</sup>/year. Agriculture and particularly irrigation systems in many parts of the world depend on



groundwater resources. Groundwater is also the main drinking water source for more than a third of world's population.

Aquifers receive replenishment from rainfall and they are thus mostly renewable. Depending on the size and the climatic location of aquifers, the renewal period ranges from days and weeks (in karstic rocks), to years or thousand of years in large sedimentary basins. However, in regions where present day replenishment is very limited (such as in arid and hyperarid regions) the groundwater resource can be considered to be 'non-renewable'. Replenishment from ancient rainfall in the Pleistocene geological periods, and lying in storage since that time, has been called 'fossil water' (Foster and Loucks, 2006) for convenience, though this is an incorrect term, as it implies a change of state (i.e fossils are the petrification of organic materials).

The increasing recognition by the international community that fresh water resources are threatened because of the insufficient adoption of science based policy tools has given an impetus to the detailed analysis of water resources in aquifers and the adoption of a range of tools for their better management. Among the range of tools that have been developed is the improved 'visualisation' of aquifers and the resources contained in them.

This atlas is a first collation of global, regional and national inventories of the 'hidden' resources that summarises all available data collected by UNESCO-IHP.

# GLOBAL VIEWS OF AQUIFERS

**G**LOBAL OVERVIEWS OF AQUIFER SYSTEMS and the factors that affect them are useful in helping to formulate sound global policies that the international community is now adopting both formally (through Ministerial declarations and commitments) and informally through the work of bodies of committed scientists, practitioners and community organisations. The global overview maps presented in the following pages of this atlas should serve these concerned people to fully appreciate the role of aquifers and the water resources that are contained in. Aquifers, if adequately managed, can contribute to the global water security and sustainable development in the forthcoming decades.

## ***The map on 'Groundwater resources of the world' (UNESCO-BGR WHYMAP Project)***

Only selected features have been represented on the Groundwater Resources of the World map (pp. 19–20), published by UNESCO and BGR in 2008 at the scale of 1:25 000 000, and these include the nature of the aquifer regimes and whether or not they are replenished.

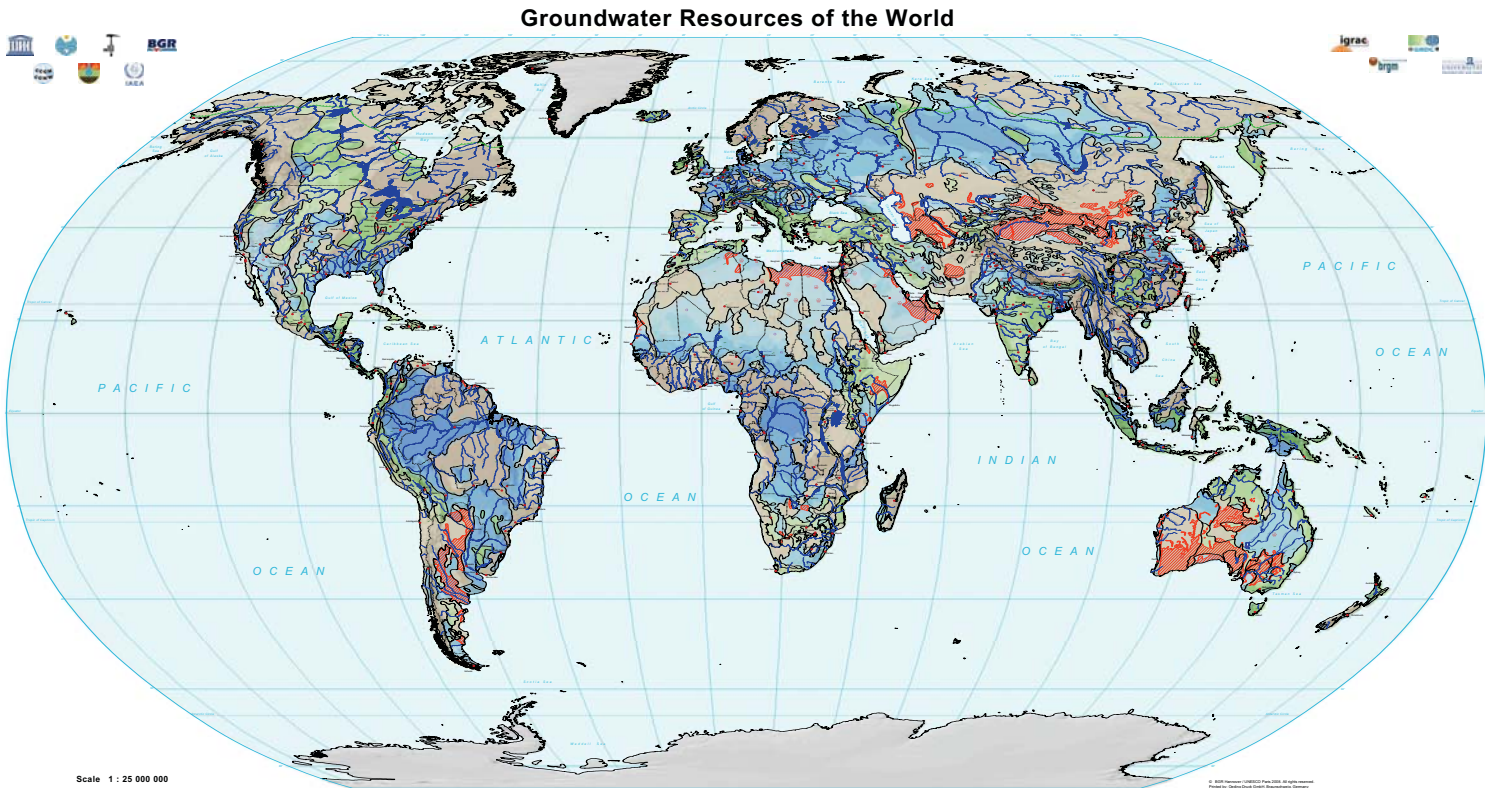
The most important aquifer systems have been shown in blue colour, and the intensity of blue colour decreases from dark blue in high recharge areas (generally more than 150 mm per year) to medium blue (generally between 150 and 15 mm per year) and to light blue symbolising aquifer systems receiving very little recharge (generally less than 15 mm per year). The exploitation of the aquifers in this latter category can generate what is called 'groundwater mining'.

The Green colour symbolises hydrogeological environments of complex structures. In these areas remote sensing techniques as well as detailed ground surveys coupled with spring and stream flow analysis may help identify zones of high yielding aquifers.

The Brown colour outlines areas with local and shallow aquifers in which relatively dense bedrock is exposed to the surface. In these areas aquifers are comprised of the alteration zone of the bedrock and overlying shallow layers of weathered bedrock.

Orange hatching has been applied in areas where the salinity of the groundwater in the aquifers regionally exceeds 5 g/l. In these places the aquifer resources are generally not suitable for human consumption, but some livestock may find it drinkable.

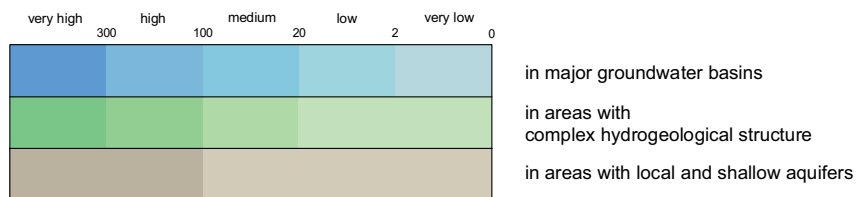
This map can be downloaded from <<http://www.whymap.org>>. Full details of the WHYMAP Project are shown later in this chapter.








## Groundwater Resources of the World 1 : 25 000 000 (WHYMAP, 2008) Legend of the previous map

### Legend





#### Groundwater resources and recharge (mm/year)







#### Special groundwater features

-  area of saline groundwater (> 5 g/l total dissolved solids (TDS))
-  natural groundwater discharge area in arid regions
-  area of heavy groundwater abstraction with over-exploitation
-  area of groundwater mining
-  selected wetland, mostly groundwater related

#### Surface water

-  major river
-  large freshwater lake
-  large saltwater lake
-  continuous ice sheet

#### Geography and Climate

-  selected city
-  selected city, partly dependent on groundwater
-  country boundary
-  boundary of continuous permafrost

### ***The map on 'Aquifers provinces of the world' (IGRAC global overview)***

The International Groundwater Assessment Centre (IGRAC) prepared a map that shows the world divided into 36 Global Groundwater Regions and gives an idea of their predominant hydrogeological setting by classifying them into four categories: Basement, Sedimentary Basin, High-Relief Folded Mountain and Volcanic regions. Shallow aquifer systems with near-surface water tables are present in most regions. Unlike deep groundwater, shallow groundwater is strongly linked to surface waters in a hydraulic sense. Variations of mean groundwater renewal rates between regions are reflected in the map by variation of colour intensities, with low colour intensity in regions with predominantly arid climates or with permafrost. In some arid zone areas, limited groundwater renewals contrast with large groundwater reserves created mainly during past pluvial periods of the Pleistocene.

This map (p. 22–23), can be downloaded from <<http://www.igrac.net>>. Full details of the IGRAC supported project and other maps are shown later in this chapter.

-----

The following global maps of this section are extracted from *Les eaux souterraines dans le monde*, published by UNESCO-IHP and BRGM in 2008 (Margat, 2008) as a contribution to the International Year of Planet Earth. Information on this publication is shown later in this chapter.

### ***The map on 'Large aquifers of the world'***

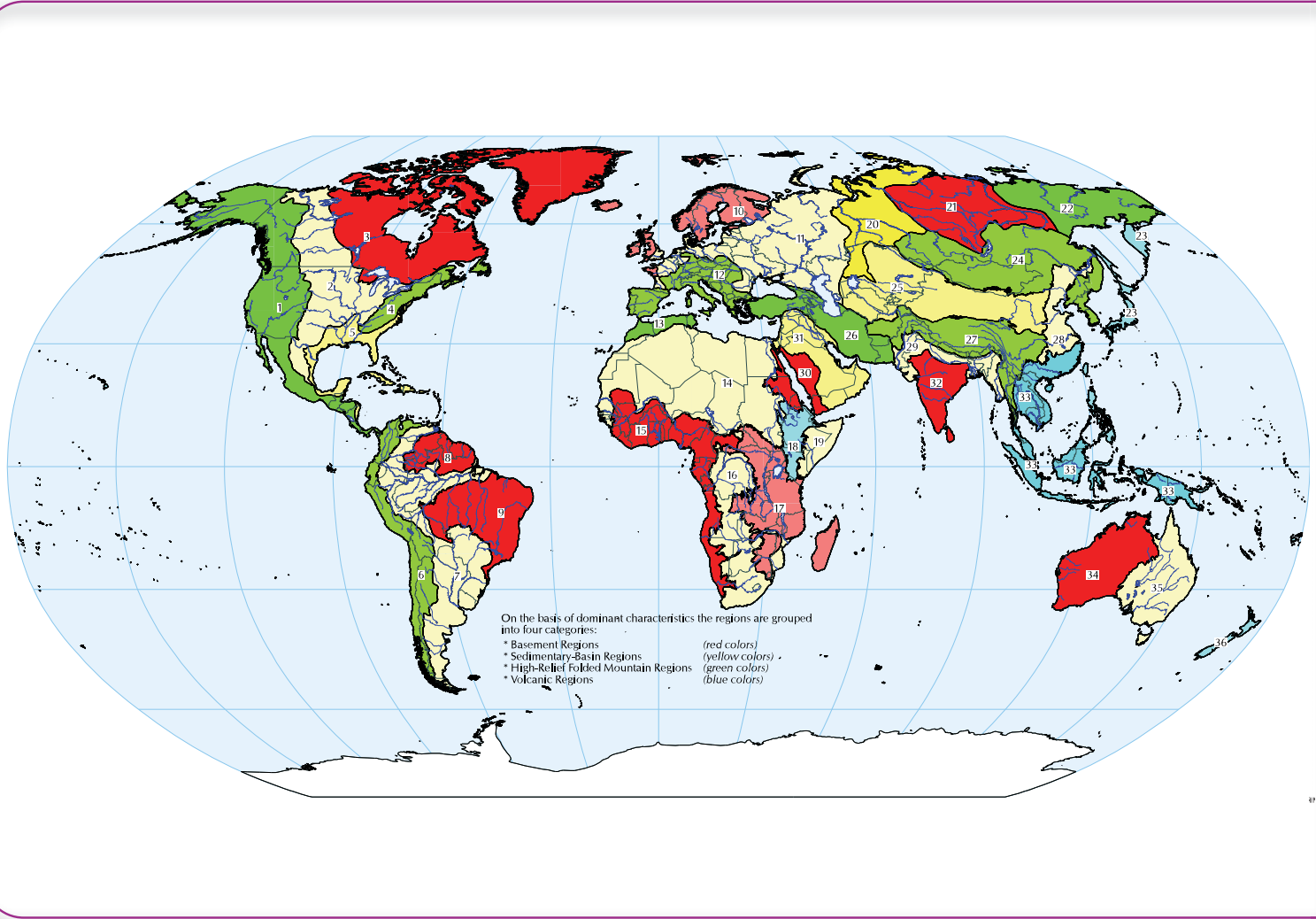
Jean Margat identifies, in the map entitled 'Large aquifers of the world' (pp. 24–25), those aquifer systems that are truly large and are comparable in size to similarly large river basins such as the Amazon, the Nile and others. The configuration of these aquifer systems is derived from the underlying hydrogeological evaluations namely, the combination of the geology and the hydrology. The presentations on this map help to visualise those areas of the world where potentially resources may be available and also area where the resources have been over exploited. By combining the information in some of the subsequent maps it may be possible to formulate the regional policies aimed at improving water security.

### ***The map on 'Groundwater recharge'***

It may be noted from the foregoing that aquifer systems are replenished by a proportion of the amount of rainfall. This map demonstrates the potential recharge distribution on each of the continents (p. 26). The arid and hyper arid regions (e.g. the Sahara region) are note worthy as those receiving practically no recharge in the current climatic conditions. Although not shown on this map, the global rainfall patters have changed over the last 10,000 years. The presently hyper arid regions did receive significant rainfall and that provided paleo recharge to many of the large aquifers shown in the Northern African region in the previous maps.



Map of groundwater regions: IGRRAC, Global Overview



## Map of groundwater regions *(Legend of the map beside)*

### NORTH AND CENTRAL AMERICA

1. Western mountain belt of North and Central America
2. Central plains of North and Central America
3. Canadian shield
4. Appalachian highlands
5. Caribbean islands and coastal plains of North and Central America

### SOUTH AMERICA

7. Lowlands of South America
8. Guyana shield
9. Brazilian shield and associated basins

### EUROPE

10. Baltic shield and Caledonides
11. Lowlands of Europe
12. Mountains of Southern Europe

### AFRICA

13. Atlas
14. North African basins

15. West African basement

16. Sub-Saharan basins

17. East African basement

18. East Africa rift and associated basins

### ASIA

19. West Siberian platform

20. Central Siberian plateau

21. East Siberian highlands

22. Northwestern Pacific margin

23. Mountain belt of Central and Eastern Asia

24. Basins of West and Central Asia

25. Mountain belt of West Asia

26. Himalayas and associated highlands

27. Plains of Eastern China

28. Indo-Gangetic-Brahmaputra Plain

29. Arabian shield

30. Levant and Arabian platform

31. Peninsular India and Sri Lanka

32. Peninsulas and Islands of South-East Asia

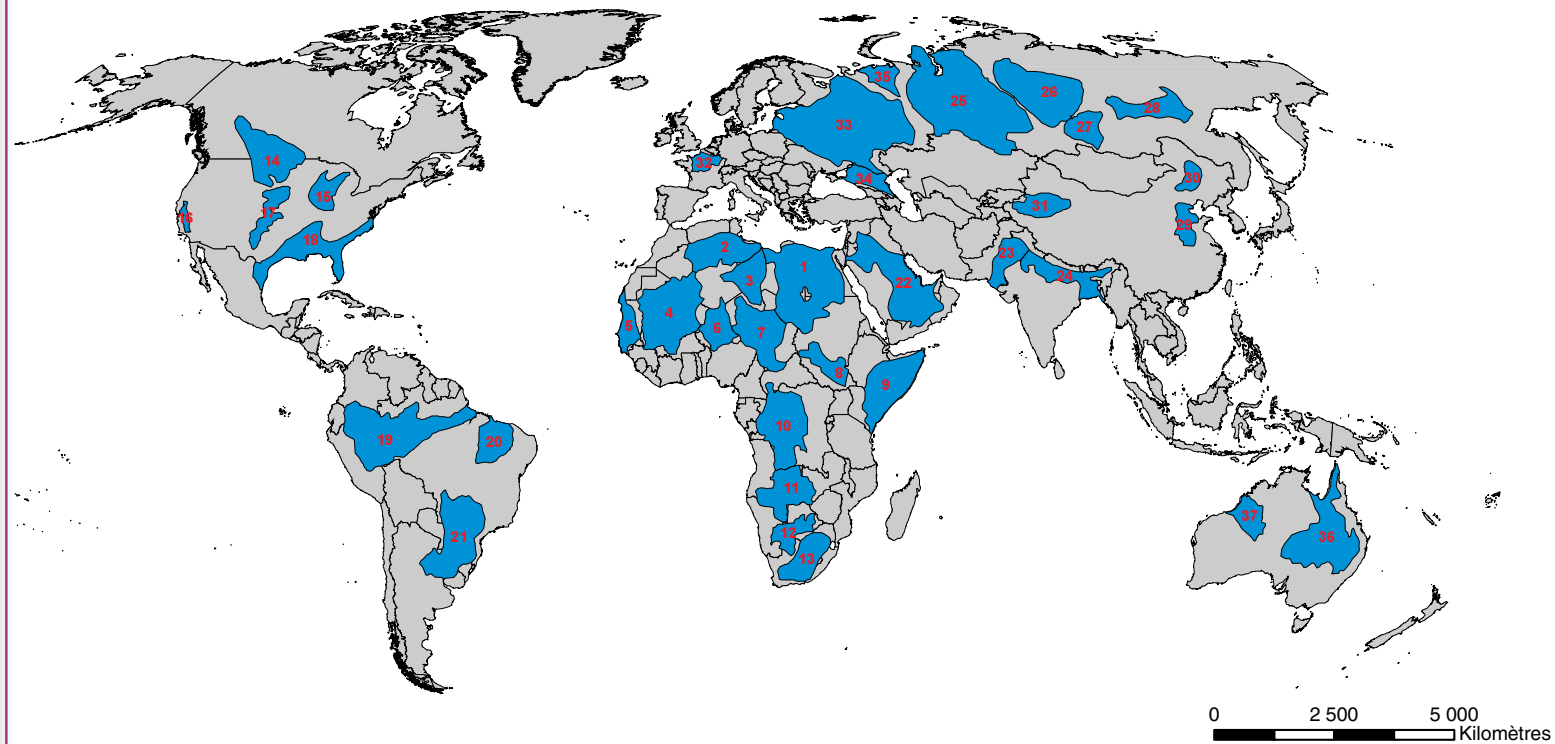
### AUSTRALIA AND OCEANIA

33. West Australia

34. East Australia

35. Islands of the Pacific

## Large aquifers in the world



Large aquifers of the world

## Large aquifers of the world *(Legend of the map beside)*

### AFRICA

1. Nubian Aquifer System  
(Nubian Sandstone and Post Nubian)
2. North-Western Sahara Aquifer System (NWSAS)
3. Murzuk – Djado Basin
4. Taoudeni – Tanezrouft Basin
5. Senegalo-Mauritanian Basin
6. Iullemeden – Irhazer Aquifer System
7. Lac Chad Basin
8. Sudd Basin (Umm Ruwaba Aquifer)
9. Ogaden-Juba Basin
10. Congo Basin
11. High Kalahari Cuvelai and High Zambezi Basin
12. Low Kalahari – Stampriet Basin
13. Karoo Basin

### NORTH AMERICA

14. Northern High Plains Aquifer System
15. Cambrio-Ordovician Aquifer System
16. Central California Valley Aquifer System
17. Ogallala Aquifer (High Plains)
18. Atlantic Ocean and Gulf coastal plains Aquifer

### SOUTH AMERICA

19. Amazonas Basin
20. Maranhão Basin
21. Guarani (or Mercosul) Aquifer System

### ASIA

22. Arab Aquifer System
23. Indus Basin
24. Indus-Gange-Brahmaputra Basin
25. Western Siberia Basin
26. Tunguss Basin
27. Angara-Lena Basin
28. Yakut Basin
29. Northern China (Huang Huai Hai Plain) Aquifer System
30. Song-Liao Plain
31. Tarim Basin

### EUROPE

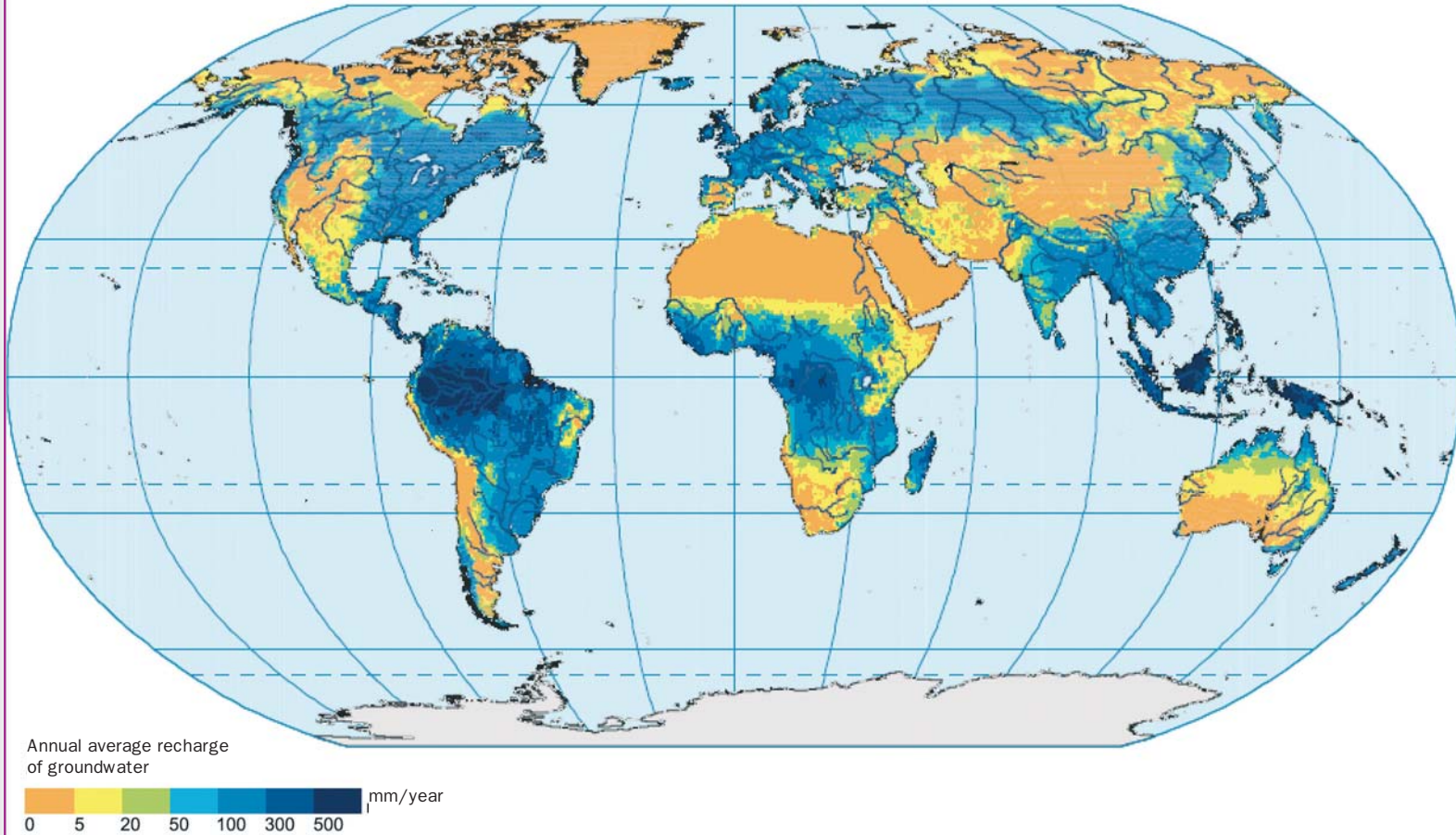
32. Paris Basin
33. Russian Platform
34. Northern Caucasus Basin
35. Pechora Basin

### AUSTRALIA

36. Artesian Grand Basin
37. Canning Basin

## World distribution of mean annual recharge of groundwater(1961-1990) calculated by 0.5 square degree grid

[1 mm/year = 1,000 m<sup>3</sup>/year by km<sup>2</sup>]



Source: P. Döll et al., 2003.



### ***The map on ‘Annual average internal flow of groundwater’***

This map (see p. 28) shows the classification of countries accordingly to the flow of groundwater produced internally by surface unit in m/year by km<sup>2</sup>. Groundwater contained in aquifers is a state of flux.

### ***The map on ‘Groundwater national extraction’***

This map (see p. 29) shows, in every country of the world, how much groundwater is extracted to satisfy human needs.

### ***The map on ‘Morphed view of extraction of groundwater’***

Cartographic morphing has been used to help in the visualisation of the extraction of groundwater in countries of the world (see p. 30). While not a quantitative technique it nevertheless allows policy and decision makers to get an impression of the amount of water obtained from aquifers in comparison to others. The map shows the intense use of aquifer resources in the Asian and the Middle East North Africa regions.

-----

### ***The maps on***

***‘Populations relying on aquifers: per capita withdrawals’***

***‘Non-renewable groundwater mining exploitation in the world’***

***‘Aquifers in the national economy of countries’***

***‘Proportion of municipal groundwater withdrawal from aquifers’***

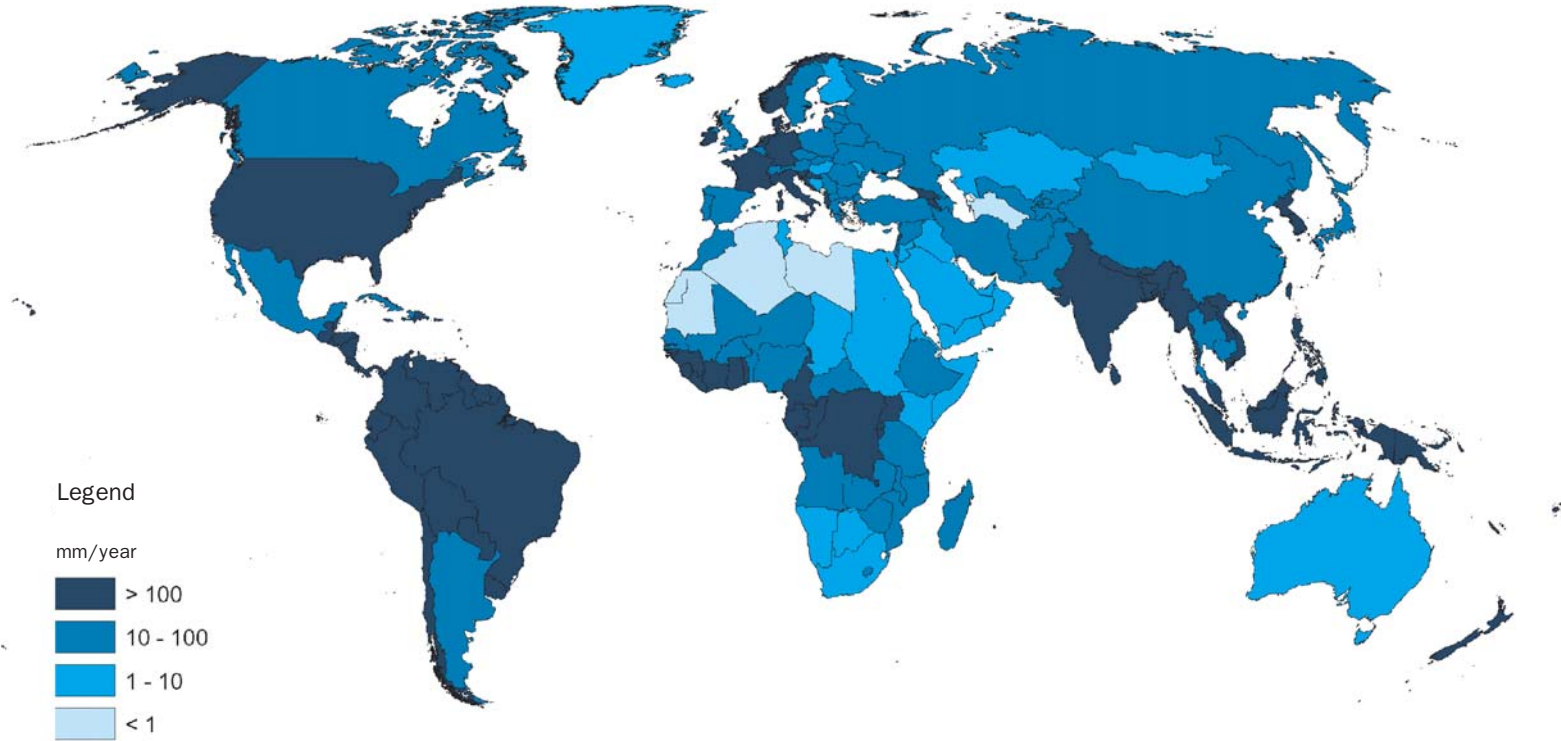
***‘Major cities of the world relying on aquifers’***

***‘Areas irrigated by groundwater’***

These six global maps listed above and presented below (see pp. 31–36) are self explanatory and illustrate the role that aquifers play in providing water security to populations and in the development of national economies. Apart from municipal requirements, which generally include industrial use, aquifer resources are mainly extracted to support food production by irrigation. An interesting feature of final map in this series is the dependency on aquifers in major cities of the world.

Countries classified according to their groundwater produced internally by surface unit, in mm/year by km<sup>2</sup>

[1 mm/year = 1 000 m<sup>3</sup>/year by km<sup>2</sup>]

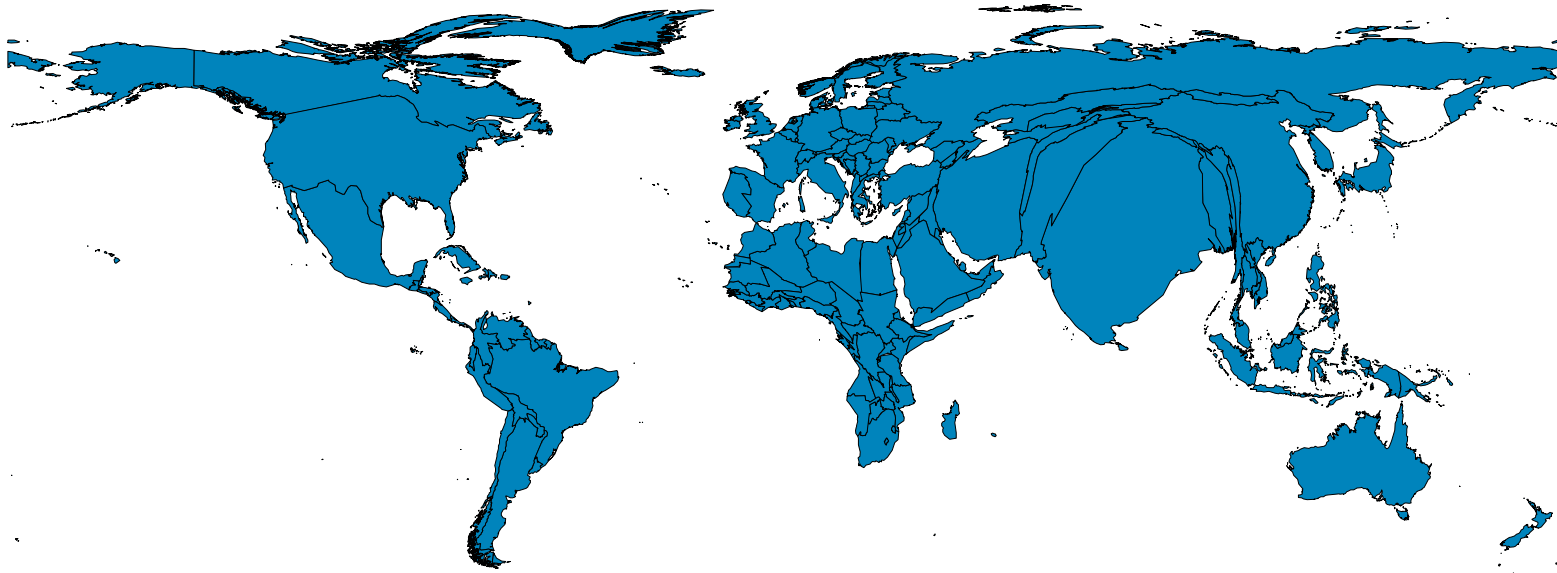


Source: FAO, AQUASTAT Database (2005), *Groundwater produced internally*.

Annual average internal flow of groundwater

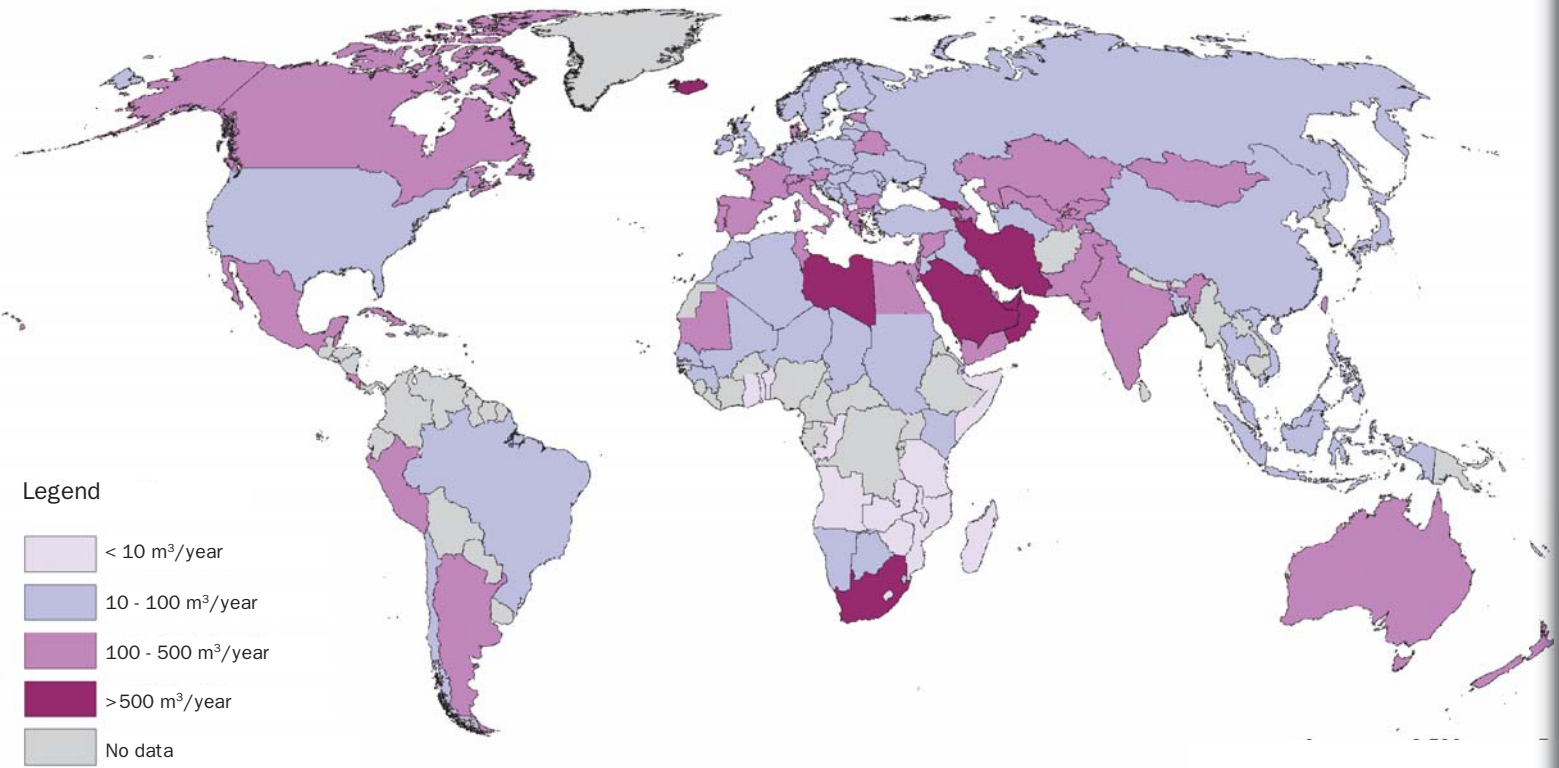


An attempt of cartographic anamorphosis, showing the groundwater extractions in each country



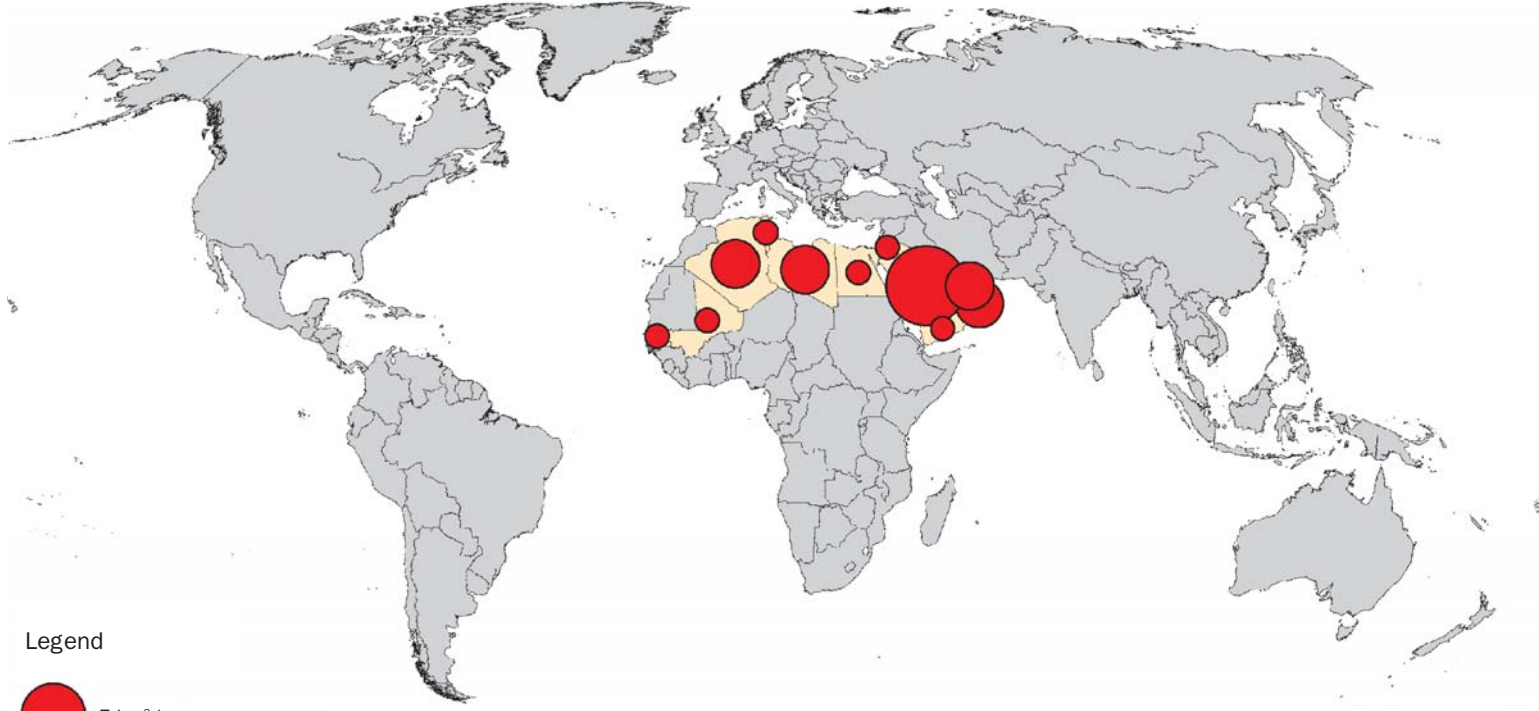
Morphed view of extraction of groundwater

Countries classified according to current groundwater extractions per inhabitant





## Non-renewable groundwater mining exploitation in the world

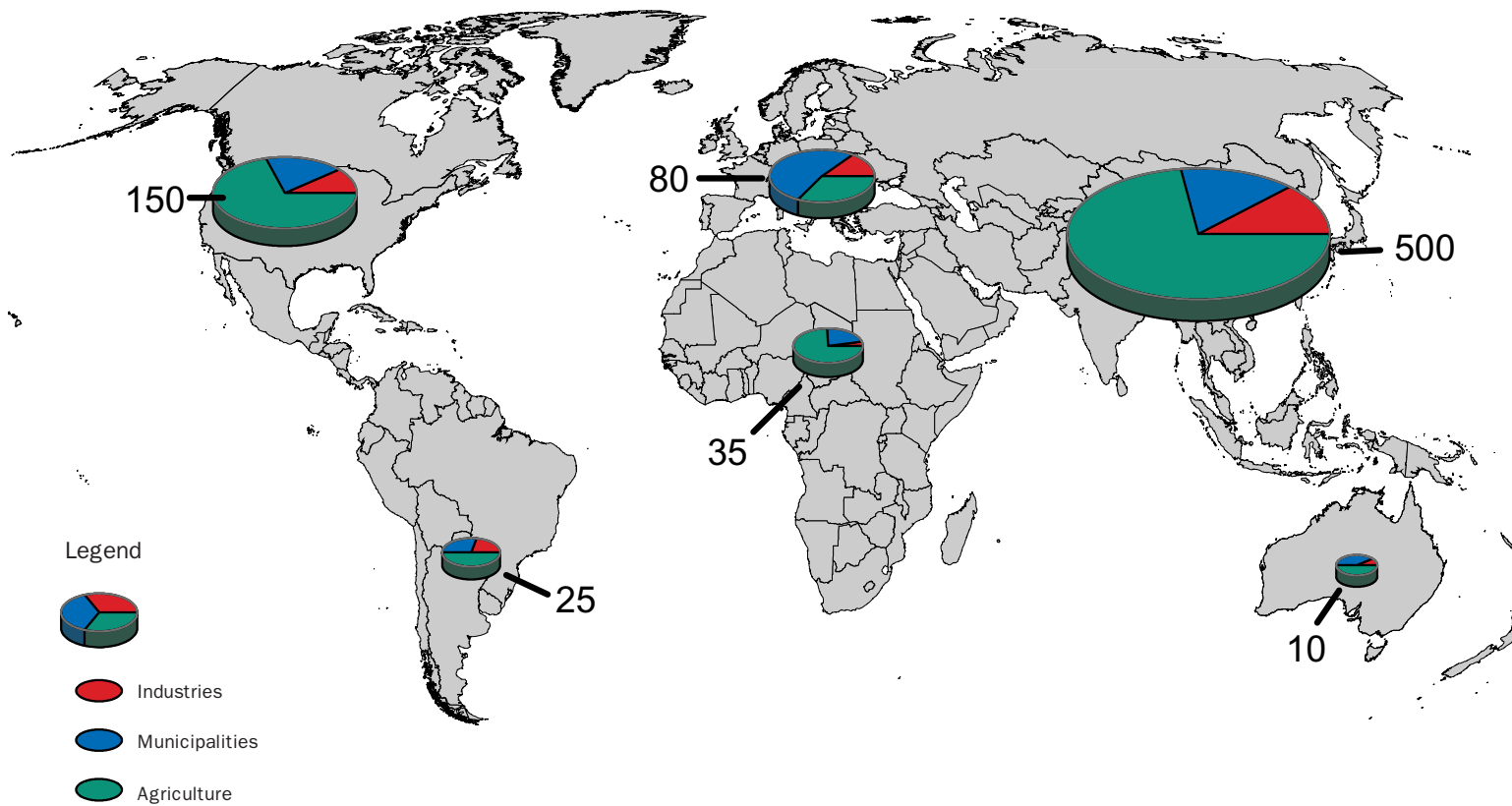


Legend

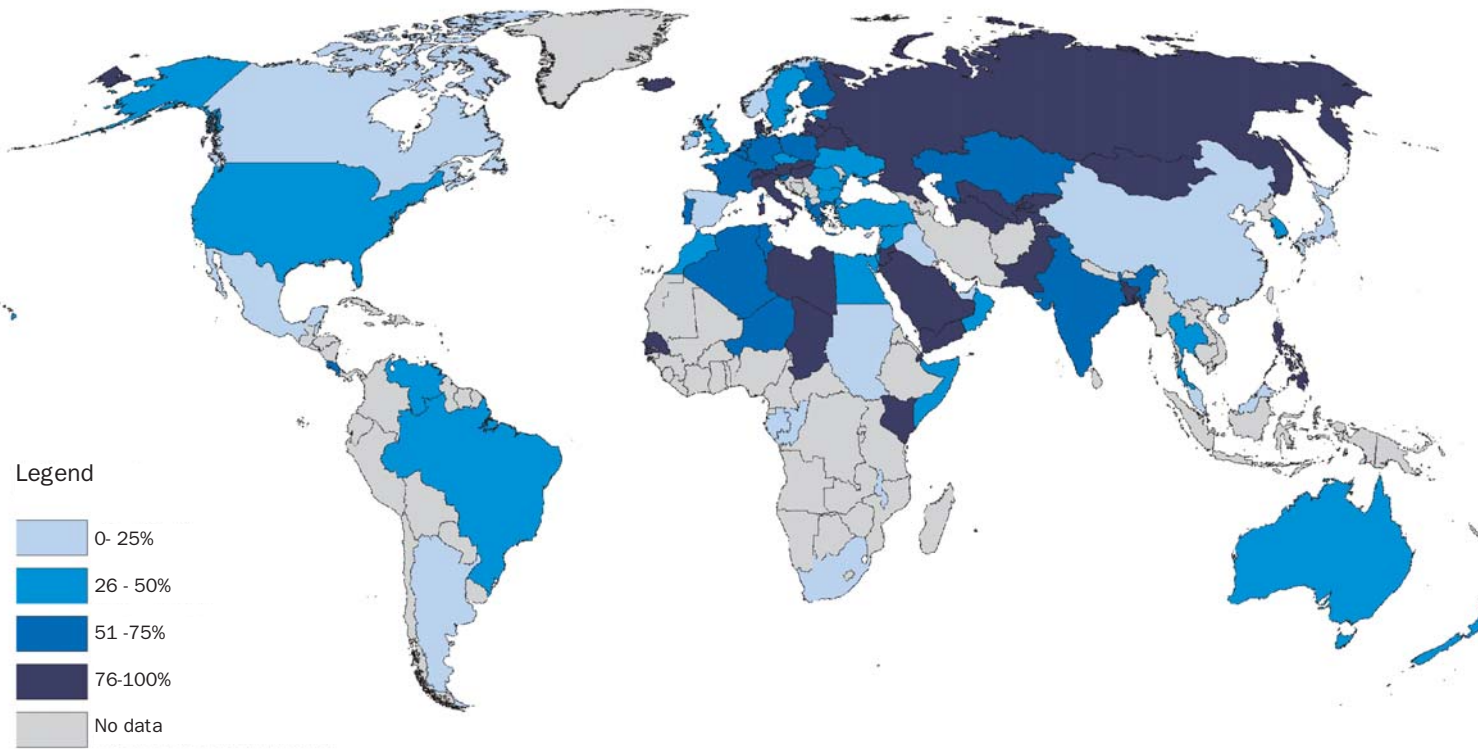
7 km³/year

Non-renewable groundwater mining exploitation in the world

Current extraction of groundwater shown by utilization sector in each major region of the world  
(totals in km<sup>3</sup>/year)

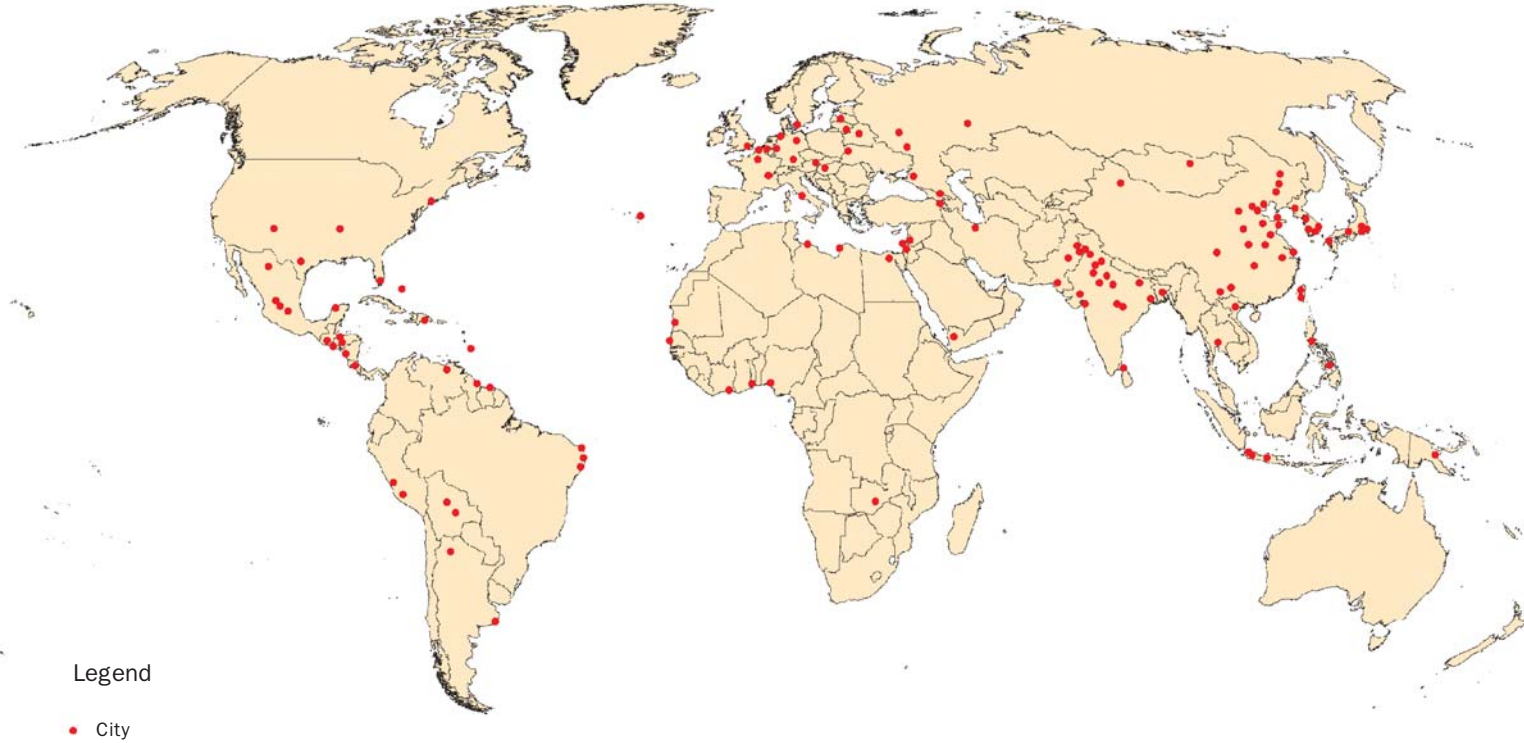


The proportion of groundwater extraction – within the total water extraction – for community potable water supply in each country



Proportion of municipal groundwater withdrawal

Main large cities of the world supplied exclusively or predominantly by groundwater  
Sources: Howard 1997; World Bank 1998; H.Zaisheng/WHYMAP , 2006; Zekster et al. 2004).







# THE PRINCIPLE CONTRIBUTORS TO GLOBAL VIEWS

## GROUNDWATER AND AQUIFERS: THE UNESCO INTERNATIONAL HYDROLOGICAL PROGRAMME (UNESCO-IHP)

The International Hydrological Programme (IHP) is the only intergovernmental scientific programme of the United Nations (UN) system devoted to hydrology, water resources management, and education and capacity building. The IHP Secretariat is located at UNESCO Headquarters in Paris, France, and it works closely with over 167 National Committees and focal points assigned by their governments that contribute to the programme implementation.

Regional cooperation is an important aspect of this programme and the UNESCO regional cluster offices and national offices coordinate regional and local activities. IHP takes a proactive role in UN system-wide initiatives such as UNWATER, the United Nations Development Assistance Framework (UNDAF), and the UN Country Programme Action Plan.

IHP operates as a global network of networks, that includes connections with the UNESCO Water-related Institutes and Centres, the UNESCO-IHE Institute for Water Education, the UNESCO water-related chairs. The UNESCO Water Portal serves as a viable tool in enhancing dissemination of information and knowledge (<http://www.unesco.org/water>). Most of the IHP publications can be freely downloaded from the IHP website.

Focusing on the demands arising from global changes, creating partnerships and initiatives for greater synergies, the IHP maintains its comparative advantage in promoting and leading international hydrological research, for enhanced water management towards meeting the UN Millennium Development Goals on Environmental Sustainability, Water Supply, Sanitation, Food Security and Poverty Alleviation. It adds value to localized research and experience by providing a policy-relevant context and harvesting the knowledge of researchers, educators, practitioners, and policy-makers so as to maximize the value of scientific outcomes and engender confidence in innovation and reform. It provides a solid scientific underpinning for the UN Decade of Water for Life and the UNESCO led UN Decade on Education for Sustainable Development.

Since its inception IHP has provided a particular attention to studies on groundwater resources and aquifers characteristics. In finding solution to water scarcity

IHP pays due attention to the role that aquifers if properly managed can play in supporting adaptation measures for coping with impacts from climate variability and changes, global changes, hydrological extremes and natural disasters.

The IHP Intergovernmental Council has launched the ISARM Project in the year 2000, with the aim of establishing common principles for development, protection and management of trans-boundary aquifers. The management of shared aquifer resources is still a high priority of IHP.

## HYDROGEOLOGICAL MAPPING AND ASSESSMENT: THE WHYMAP PROJECT

During the past decades, the interest in groundwater has increased considerably due to water shortage problems at a local, regional and even global level. The use of groundwater is considered an appropriate way out of regional water crises caused by population growth, economic growth and the associated water shortage problems. But information on these hidden resources is still weak in many places. The World-wide Hydrogeological Mapping and Assessment (WHYMAP) project is lead by UNESCO and BGR and it was launched in 1999 by UNESCO as part of the IHP Programme to contribute to the world-wide efforts to better understand, manage and protect aquifer resources.

The programme aims at collecting, collating and visualising hydrogeological information at a global scale in a geographic information system (GIS). Maps are convenient tools to convey groundwater related information in an appropriate way to groundwater experts as well as to non-experts and politicians, e.g. they are used for international publications like the World Water Assessment Programme (WWAP) issued by the United Nations. WHYMAP thus brings together the huge hydrogeological mapping efforts at regional, national and continental levels. Close cooperation with the International Groundwater Resources Assessment Centre (IGRAC) in Utrecht is assured through UNESCO to clarify the role of groundwater in the discussion on Millennium Development Goals declared by the international community.

### The WHYMAP structure

WHYMAP is the joint programme of a consortium consisting of the UNESCO,

the Commission for the Geological Map of the World (CGMW), the International Association of Hydrogeologists (IAH), the International Atomic Energy Agency (IAEA) and the German Federal Institute for Geosciences and Natural Resources (BGR). The consortium is responsible for the general thematic outline and management of the programme. BGR as the executing unit provides important resources in terms of manpower, mapping capabilities and data. In 2002, a committee of eminent international experts was established under the supervision of the consortium. This WHYMAP-Steering-Committee is supported by the continental Vice Presidents of the IAH and CGMW, the UNESCO regional offices and the National Committees of UNESCO's International Hydrological Programme IHP.

The WHYMAP Programme has already produced a number of maps presenting the Groundwater Resources of the World. As a first step of the realisation, continental drafts at the working scale of 1 : 10 000 000 were compiled based on existing hydrogeological maps of continents, regions and countries. Because the available maps were very inhomogeneous, specialised interpretation and translation was necessary to make this information compatible with the designated legend of the global map.



Coping with the different, often unknown projections of these maps was also a special challenge.

The continental drafts are revised and completed by the members of the WHYMAP-Steering-Committee as well as other hydrogeological mapping experts from all parts of the world, making use of their regional knowledge. Finally, a new consistent global groundwater map is compiled by adjusting and merging the continental drafts.

Step by step, different thematic layers are prepared for the global groundwater map. In some cases, a single organisation or a group of institutions is taking care of the compilation of one specific thematic layer, e.g. the information

on groundwater recharge is developed under the auspices of IAEA, while the layer on transboundary aquifer systems is mainly realised by IGRAC and the International Shared Aquifer Resources Management (ISARM) project led by UNESCO. Different IAH commissions are working on global maps of karst aquifers, groundwater vulnerability, coastal aquifers and the hydrogeology of hard rocks.

The main focus of the WHYMAP Programme is the establishment of a modern digital Geo-Information System (GIS) in which all global data relevant to groundwater is stored together with its geographic reference. Hydrogeological information published in national and regional maps is converted into a digital version, and is available in a GIS compatible format. Scanned maps are integrated as graphics, and metadata is collected for each map.

These activities led to a world-wide information system on hydrogeological maps. From the WHYMAP-GIS database, a variety of high quality thematic map products at different scales and complexity can be derived. In addition, the information is visualised via an internet-based map server application, which is available at <<http://www.whymap.org>>.

## First results and products

A first overview at a scale of 1 : 100 000 000 was compiled as a contribution to the 3rd World Water Forum in Kyoto in March 2003 and published in the first World Water Development Report (WWDR) of the United Nations.

In August 2004, a first special edition of the global groundwater resources map at a scale of 1 : 50 000 000 was released at the International Geological Congress in Florence. A second special edition at the same scale focussing on the transboundary aquifer systems of the world was compiled for the Fourth World Water Forum in Mexico City in March 2006. The corresponding explanatory text on the back of each map gives background information on the project and a description of the map itself. On the one hand, this is intended to inform the scientific community about the WHYMAP Programme and asks for contributions. On the other hand, WHYMAP aims at raising awareness amongst politicians and the general public of groundwater as an important natural resource. Several thousand copies of the map have been sold and distributed at important conferences and symposia. Single copies are available on request.

## Recent products

- *Global groundwater maps*: A global groundwater wall map 'Groundwater Resources Map of the World 1 : 25 000 000 (edition 2008)'.
- *Continental groundwater maps*: Africa/Asia/South East Asia, Australia and New Zealand/Europe/North America/South America.
- *Additional global maps* for publications and presentations, in particular:
  - River Basins and Transboundary Aquifer Systems,
  - River Basins and Mean Annual River Discharge,
  - Mean Annual Precipitation,
  - Groundwater Recharge (1961–1990) per Capita.
- *Geographic information system (GIS)* with supra-national, continent-wide, groundwater related data.
- *WHYMAP Web Mapping Application*

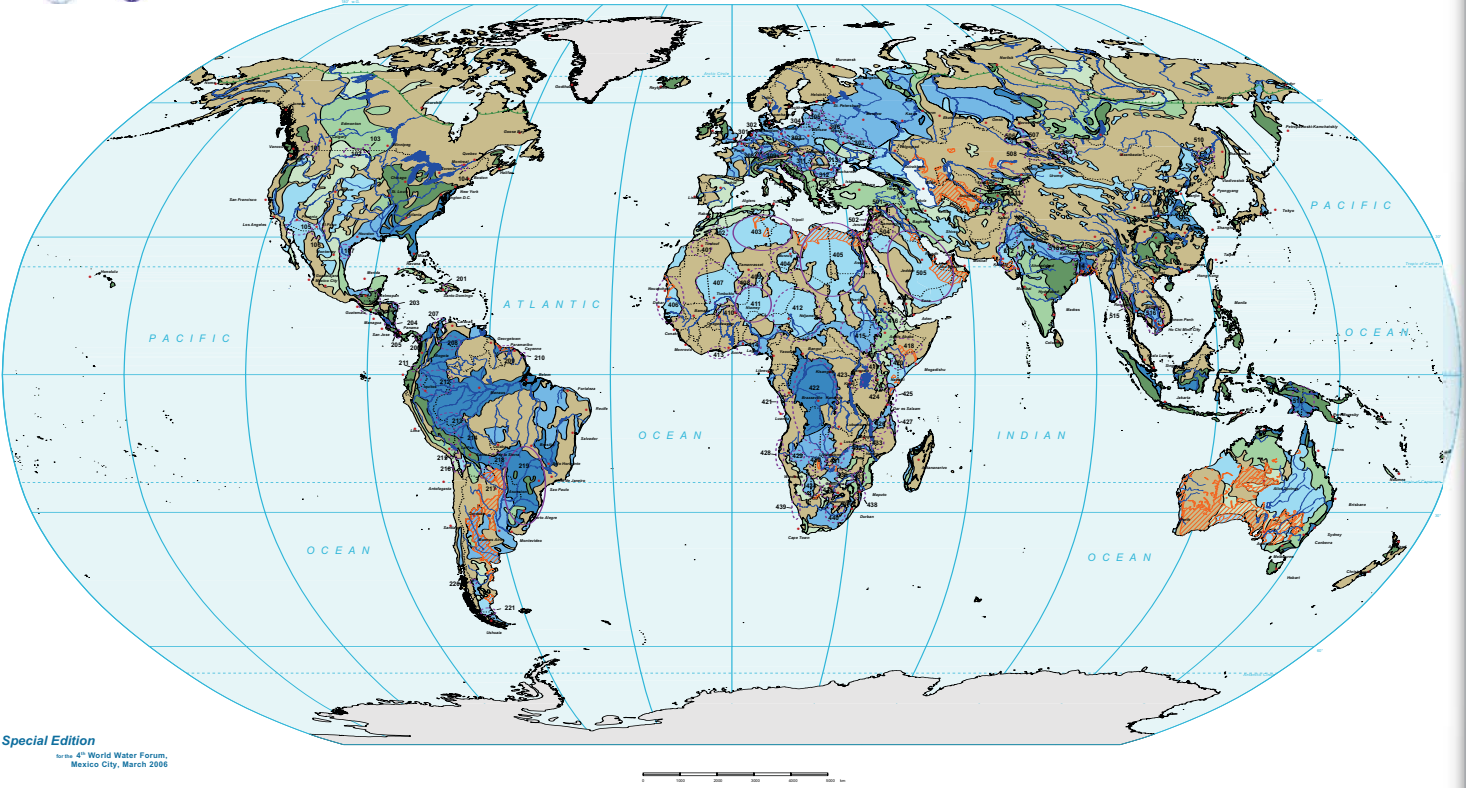
The Web Mapping Application, with embedded World-wide Hydrogeological Map Information System (WHYMIS), aims at visualizing hydrogeological information collected within the WHYMAP project at a global scale. For more regional or country level interest additional information on available hydrogeological maps is provided.

The **Transboundary Aquifer Systems** global map is showed on next page; this and other maps can be downloaded from <<http://www.whymap.org>>.





## Groundwater Resources of the World - Transboundary Aquifer Systems -



Special Edition  
for the 4<sup>th</sup> World Water Forum,  
Mexico City, March 2006



**Groundwater Resources of the World -  
Transboundary Aquifer Resources 1 : 50 000 000 (WHYMAP, 2006)  
Special edition map for the 4th World Water Forum, Mexico, March 2006**

## Groundwater Resources of the World - Transboundary Aquifer Systems 1 : 50 000 000 (WHYMAP, 2006)











(Legend of map beside)

### Legend





#### Transboundary Aquifer Systems

-  coherent modelling in progress
-  additional investigation required
- 401 number of aquifer system (see table 2)




#### Groundwater

-  major groundwater basin
-  high groundwater recharge (> 150 mm/a)
-  medium groundwater recharge (15 - 150 mm/a)
-  low groundwater recharge (< 15 mm/a)
-  area with complex hydrogeological structure
-  high groundwater recharge (> 150 mm/a)
-  medium groundwater recharge (15 - 150 mm/a)
-  low groundwater recharge (< 15 mm/a)
-  area with local and shallow aquifers
-  area of saline groundwater (> 5 g/l TDS)

#### Surface water

-  major river
-  large freshwater lake
-  large saltwater lake
-  continuous ice sheet

#### Geography

-  selected city
-  country boundary
-  boundary of continuous permafrost

# AQUIFERS OF THE WORLD: THE INTERNATIONAL GROUNDWATER RESOURCES ASSESSMENT CENTRE (IGRAC)

Lack of data at national, regional, and global scale reduce the capacity of making full benefit from the available groundwater resources and controlling effectively the groundwater-related problems. Sharing groundwater data and experience on a world-wide scale would be of great help in this respect.

IGRAC operates under the auspices of WMO and UNESCO and it is dedicated to the collection of groundwater information and knowledge in the widest sense, on a world-wide scale and on a non-commercial basis.

## Global Groundwater Information System (GGIS)

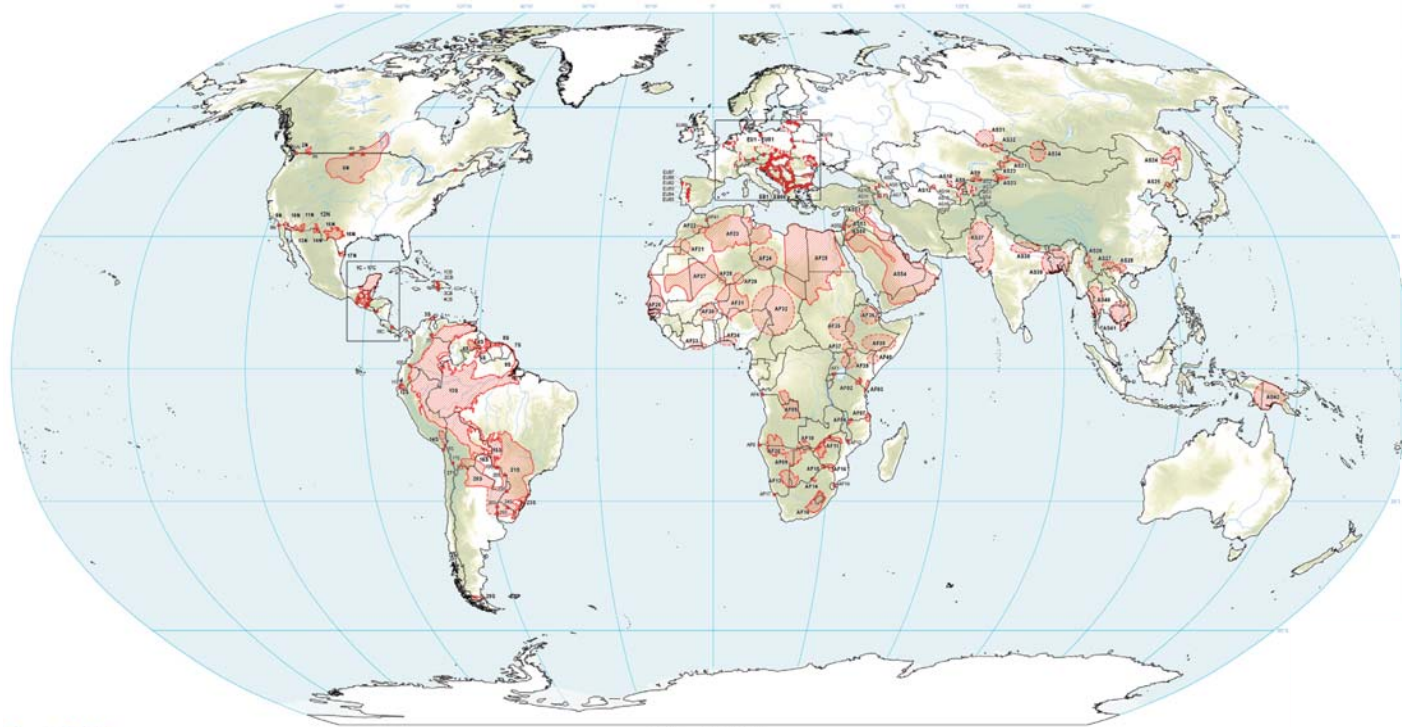
The UNESCO-WMO center IGRAC has established a GGIS interactive portal to groundwater-related information and knowledge. It leads the user from aggregated, global information (Global Overview) via related information sources (Meta-Information Module) towards a direct information exchange (Collaborative Environment). The IGRAC purpose is to monitor global changes impacts on groundwater resources.

Presently IGRAC's Global Groundwater Information System focuses on a global overview of selected groundwater attributes and the meta-information on information/knowledge sources. However, IGRAC aims to collect, systematize and make available more detailed and/or specialized information on important groundwater topics, including among others Transboundary Groundwaters, Artificial Recharge, Arsenic Worldwide, Fluoride Worldwide, NAMIS and Tsunami Impact.

The **Transboundary Aquifers of the World (update 2009)** global map is presented beside.

IGRAC has developed and maintains the UNESCO-IHP ISARM project website <<http://www.isarm.net>>, completely dedicated to the issue of internationally shared aquifers.

### Transboundary Aquifers of the World - Update 2009 -



**Special Edition**  
for the 5<sup>th</sup> World Water Forum,  
Istanbul, March 2009

Scale 1 : 50 000 000






Transboundary aquifers of the world, IGRAC,  
Global Overview, update 2009  
(presented at Fifth World Water Forum, Istanbul)

## Transboundary aquifers of the world, IGRAC, Global Overview, update 2009 *(Legend of the previous map)*



### Legend

#### Transboundary Aquifers




##### Aquifer occurrence and extent

-  AF21 aquifer extent
-  confirmed boundary
-  approximate boundary
-  7N small aquifer(s) with confirmed boundary
-  5N superimposed aquifers

##### Aquifer occurrence

-  EU9 aquifer confirmed by all countries involved
-  EU11 aquifer confirmed by at least one country

#### Geographic elements

-  political borders
-  lakes
-  rivers

##### Elevation

-  ~ 8 km
-  ~ 0 km (sea level)

# GROUNDWATER IN THE WORLD

## [LES EAUX SOUTERRAINES DANS LE MONDE]

To optimize the uses of water resources, in particular of groundwater, and to preserve them, people have to be conscious of the challenges involved and especially of the fragile nature of this treasure and of the extent of the potential consequences of the impacts of human activities.

The preservation of water resources is the concern of everybody. A change is needed both in people's mentality and behaviour, individually and collectively. Such is the condition to be met for a sustainable development of these resources.

To contribute to this goal, the UNESCO International Hydrological Programme (IHP) and BRGM (French Bureau of Geology and Mining Resources), to provide a useful source of information and data on groundwater resources, have published a book to provide useful information on the groundwater resources of the world.

Almost all the maps presented in the previous section have been extracted from this book written by Jean Margat . The book contributes to the world-wide efforts to better understand, manage and protect aquifer resources and it has received the label 'International Year of the Planet Earth'.


The maps included in *Les eaux souterraines dans le monde* and presented in this Atlas have been selected because they provide a global overview on the groundwater resources.





2





# Transboundary aquifers management and ISARM Programme

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## THE ISARM PROJECT

**T**HE INTERNATIONAL SHARED AQUIFER RESOURCE MANAGEMENT (ISARM) PROGRAMME was launched by the International Hydrological Programme of UNESCO in June 2000. Until then, no global estimation for transboundary aquifers was available. The Intergovernmental Council of UNESCO's International Hydrological Programme (IHP) responded to this knowledge gap at its fourteenth session (23–25 June 2000) and adopted a resolution to launch a worldwide inventory and assessment of transboundary aquifers (Resolution XIV-12, Appendix II).

ISARM is a UNESCO led multi-agency effort aiming at improving cooperation between countries sharing aquifers and aquifer systems. It has developed a multi-disciplinary approach including five focal areas. It intends to contribute to the understanding of a) scientific, b) socio-economic, c) legal, d) institutional and e) environmental issues related to the management of transboundary aquifers.

It is coordinated and sponsored by UNESCO International Hydrological Programme (UNESCO-IHP). IHP cooperates with a wide number of organizations, including the International Association of Hydrogeologists (IAH), UN Food and Agriculture Organisation (FAO), UN Economic Commission for Europe (UNECE), Organisation of American States (OAS), International Network of Water-Environment Centres for the Balkans (INWEB), International Groundwater Resources Assessment Centre (IGRAC), World-wide Hydrogeological Mapping and Assessment Programme (WHYMAP), (Federal Institute for Geosciences and Natural Resources) BGR, Bureau de recherches géologiques et minières (BRGM), the Sahara and Sahel Observatory (OSS), UN Economic and Social Commission for West Asia (UNESCWA) and GEF (Global Environment Facility).



This program has launched a global inventory and a number of global and regional initiatives. These are designed to delineate and analyze transboundary aquifers and aquifer systems and to encourage riparian states to work cooperatively toward mutually beneficial and sustainable shared groundwater resources management.

## SPECIFIC OBJECTIVES

- To establish a network of experts from different disciplines for identification and definition of shared aquifers resources.
- To promote scientific, legal, socio-economic, institutional and environmental assessment of shared aquifer resources.
- To identify several Case Studies of shared aquifers and support multidisciplinary experts teams to conduct detailed investigations.
- To learn, from Case Studies, the issues relevant to good management of shared aquifers resources.
- To raise the awareness of policy and decision makers of the significant and importance of transboundary aquifer resources, forming a critical component of the world freshwater resources.
- To promote co-operation among experts from the different countries that share transboundary aquifers, through making available scientific tools, water resource management options and methodologies that apply to such aquifers.

## SCOPE OF ACTIVITIES

- Carrying out and publication of the inventories of shared aquifers.
- Preparation and wide distribution of material promoting the concept of co-operation for optimal and sustainable management.
- Dissemination of existing information on shared aquifers.
- Setting up of databases.
- Preparation of training course material and organisation of the courses.

## PARTNERS

ISARM is sponsored by UNESCO International Hydrological Programme (UNESCO-IHP) and is operating in coordination with UNESCO-IHP National Committees, Member States and different intergovernmental, governmental and international associations. It operates through a joint effort of a number of organizations, including among others:

- International Groundwater Resources Assessment Centre (IGRAC)
- International Association of Hydrogeologists (IAH)
- UN Food and Agriculture Organisation (FAO)
- UN Economic Commission for Europe (UNECE)
- Organisation of American States (OAS)
- International Network of Water-Environment Centres for the Balkans (INWEB)
- The Sahara and Sahel Observatory (OSS)
- UN Economic and Social Commission for West Asia (UNESCWA)
- Bureau de recherches géologiques et minières (BRGM)
- The German Federal Institute for Geosciences and Natural Resources (BGR)
- Global Environment Facility International Waters (GEF IW)
- United Nations International Law Commission (UNILC).

### ***PCCP UN WWAP/UNESCO Programme***

ISARM is linked to the UN World Water Assessment Programme (WWAP)/ UNESCO Programme 'From Potential Conflict to Co-operation Potential (PCCP)', which addresses the challenge of water sharing to train decision-makers and politicians on negotiations and conflict prevention.

PCCP's is currently in its third phase and the programme activities include developing capacity building/enhancement tools.

Case studies reflecting the status of cooperation between ISARM and PCCP have been produced in the Mono River and the Ostua-Metapan aquifer, each co-authored by experts representing their respective riparian countries. The process leading to the writing of the case studies have involved major players in the selected basins and constitute an opportunity for the development of long term visions for the joint use of the resources in question.

Other joint ISARM and PCCP research activities will be undertaken and used as a platform to promote dialogue and cooperation between major stakeholders involved in the management of shared water resources.

More information about the PCCP Programme can be found at <<http://www.unesco.org/water/wwap/pccp>>.





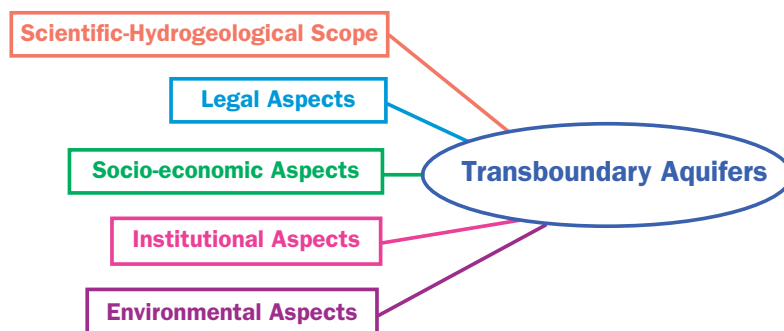
## ISARM FIVE FOCAL AREAS: ISSUES FOR MULTIDISCIPLINARY MANAGEMENT

**T**HE SUSTAINABLE AND EQUITABLE USE OF THE GROUNDWATER RESOURCES contained into transboundary aquifers requires a full understanding of the aquifers characteristics (geology and hydrogeology) as well as the clear definition of aspects related to legal, socio-economic, institutional and environmental aspects.

At global scale transboundary aquifers sustainable development seems to be hampered by weak social and institutional capacity, and poor legal and policy frameworks. This is even further amplified because of contrasting levels of knowledge, capacities and institutional frameworks on either side of many international boundaries.

Whereas there are good examples of how such issues have been dealt with in managing international rivers, there is no equivalent body of knowledge for the management of shared aquifers, the majority of which have only recently been inventoried.

The ISARM Programme has identified five key focus areas that require attention for sound development of transboundary aquifers. The ISARM Framework Document published by UNESCO in 2001 gave a preliminary overview of each focus area (this document can be downloaded at <http://isarm.net>).



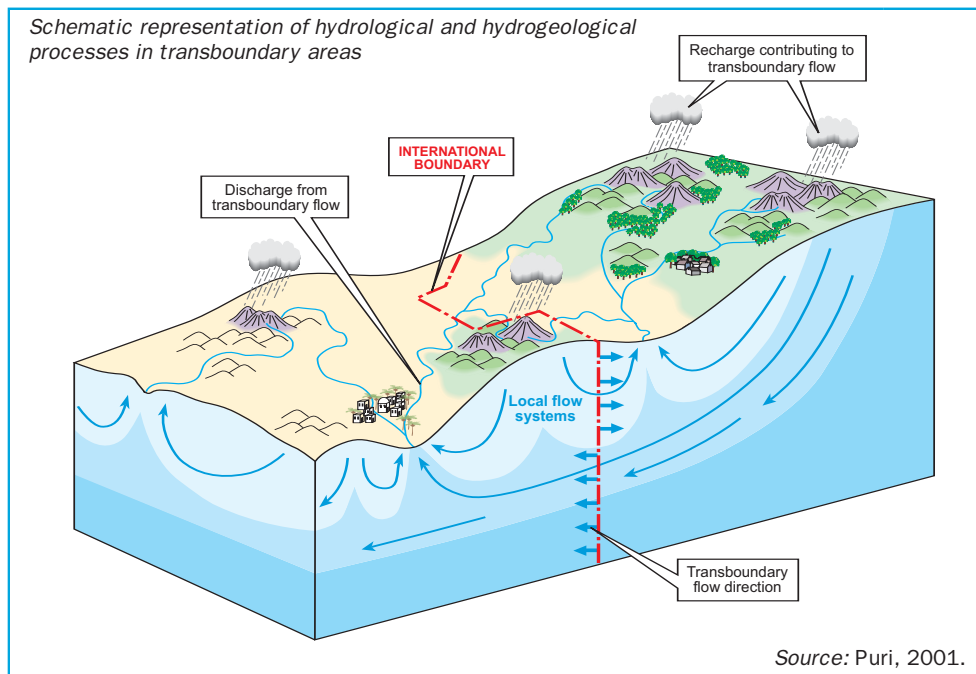
## Scientific-hydrogeological scope

There are striking contrasts in the approach to the the management of transboundary river basins and of transboundary aquifers, despite the fact that the actual utilisation of the resource, i.e. water, is for identical purposes, namely drinking, industrial use and irrigation.

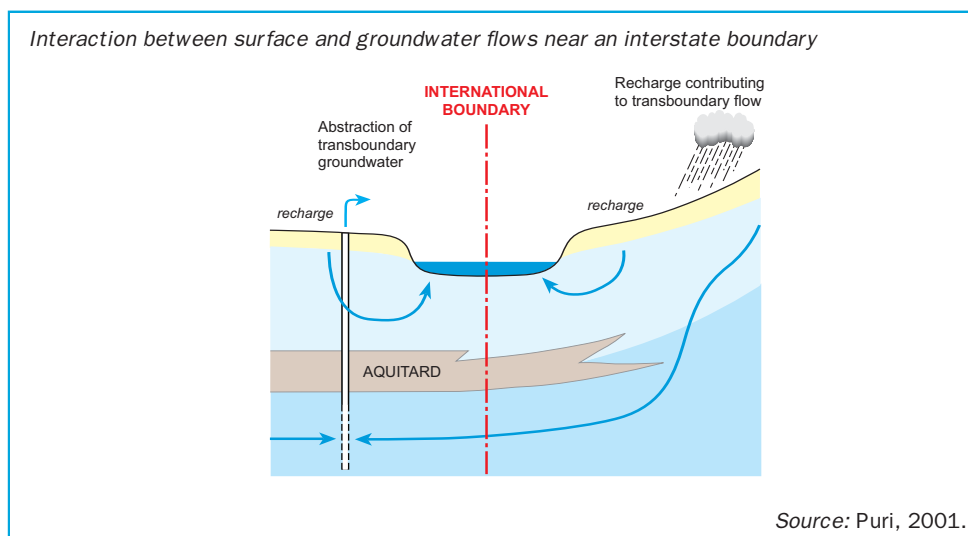
The water resources in aquifers are contained into a 3-dimensional system; resources may be extracted from, and used extensively over outcrop and subcrop, the replenishment may take place from any, or all of the 3-dimensions.

The key features of transboundary aquifers include a natural subsurface path of groundwater flow, intersected by an international boundary, such that water transfers from one side of the boundary to the other (see figure below). The aquifer might receive the majority of its recharge on one side, and the majority of its discharge would occur in the other side. Moreover, the subsurface flow system can include regional, as well as a local movement of water.

Then, management strategies can not be easily considered on an upstream versus downstream approach as for international rivers.



Even where international boundaries may follow such features as rivers, the aquifers underlying them may not reflect the true transfer of groundwater flows from one side to another (see figure below).



Very few international political boundaries follow natural aquifer physical features, and water resources can cross them unhindered. In hydrogeological terms, these crossing resources can only be estimated through good observations and *in situ* measurements of selected hydraulic parameters.

The recognition of transboundary aquifers should lead to mutual international acceptance of an effective cooperation for the equitable management of shared groundwater resources. A new approach towards sharing benefits should be considered. Nevertheless, it is essential to study the characteristics of the entire aquifer or aquifer system that can include all aquifers that are hydraulically interconnected, directly by lateral or indirectly through vertical contact or through fractures and low permeability formations (aquitards).

Good and reliable information is crucial to facilitate co-operation among aquifer stakeholders. All stakeholders should have easy access to good, reliable data on abstractions, water quality, aquifer water levels.

With such an approach it should be possible to establish mutually accepted rules, adopted by all parties, based on a holistic definition of the aquifer system and principles of equivalence of impacts of abstraction.

## Legal aspects

Many countries do not have legal instruments to regulate and monitor the use of national groundwater resources and very few bilateral agreements exist to regulate management of transboundary groundwater. Until

recently, at the global and international level, there was no legal instrument to deal comprehensively with transboundary aquifers and addressing their specific characteristics. To overcome this gap the UN International Law Commission (UNILC) in charge of the codification and progressive development of international law has included in 2002 in its program of work the topic of Shared Natural Resources and decided to start its work with the topic of 'transboundary groundwaters'. Then since the year 2003 UNESCO- IHP and UNILC have cooperated for the preparation of an international legal instrument for the management and use of transboundary aquifers that resulted in a complete set of articles on The Law of Transboundary Aquifers (UNILC report, July 2008) that was presented in October 2008 at the UN General Assembly. The UN General Assembly (UNGA) has then adopted the 11 December 2008 a Resolution (A/RES/63/124, see Appendix III) annexing these articles. This allows to expect an increased consideration of transboundary aquifers by Member States and improved attention at regional and international level. The articles represent a milestone in the international recognition of the crucial function of transboundary aquifers for human and environment. They can be used as example for bilateral and regional agreements.

The articles provide clear guidance and a reference to member states and national regional and international organizations on the use and management of shared aquifer resources. The articles define a transboundary aquifer or aquifer system as 'an aquifer or aquifer system, parts of which are situated in different States' (article 2). The articles recommend the setting up of a conceptual model of the transboundary aquifer or aquifer system (article 13§2 of the UNGA Resolution) in view of identifying key parameters to monitor, such as the evaluation of the quality and quantity of the waters and the assessment of the vulnerability.

## Socio-economic use-based management approaches

As presented above, transboundary aquifer governance has been recognized at the global level in The UN General Assembly Resolution, 63/124, 11 December 2008 on the draft Articles on the Law of Transboundary Aquifers. The draft articles provide guidance for the utilization, protection and management of shared aquifer systems based on equitable utilization, no-harm and State cooperation to meet common social and economic needs. The transboundary effects of aquifer utilization should be taken into account, with alternatives and consideration of the costs of related measures. A few countries have recently established cooperative mechanisms on shared aquifers and initiated bi- and multilateral dialogues with development of soft law cooperative arrangements for management of shared aquifers. With the transboundary aquifers being increasingly recognized as a critical strategic natural and socio-economic resource for regional and national development, regional economic development and environmental organizations (e.g. AMCOW/AWF, SADC, OAS, etc.) are assuming an important role in this process. The efficient management of transboundary groundwater water use in an aquifer is an economic, social and political issue encompassing the sectors and international borders. The effective transboundary management involves trade-offs between the

sectoral uses striking a balance between additional economic growth and water resource depletion, degradation and related environmental concerns. It targets the adoption of a common policy framework combined with decentralized institutions, management and environmental protection and active participation by the stakeholders. With the high rates of change in urbanization and agricultural intensification, the current supply-oriented technical and administrative approach for managing transboundary groundwater resources is increasingly inadequate to address competing international demands, without mobilizing the socio-economic levers for different uses and services (FAO, 2003) at the national level. As a result, and with the priority of national economic development and the cooperation between aquifer States, socio-economic drivers and economic policy instruments are increasingly considered in transboundary aquifer management. Effective transboundary management involves trade-offs between sectoral uses with a balance between additional economic growth and water resource depletion, degradation and related environmental concerns. With a general gap in the institutional arrangements for enforcement of transboundary aquifer management measures at local level, one institutional opportunity, at low transaction cost is common resource based management under the legal public trust doctrine.

The current resource- and supply-oriented technical and administrative management approaches are insufficient to address actual and future sectoral and international water use conflict and allocation to rapidly growing demands from transboundary aquifers for urban supplies and agricultural intensification.

## **Institutional aspects**

A comprehensive institutional response to acknowledged transboundary aquifer management problems has not yet emerged. There are no institutions that can equate to such bodies as the Rhine Commission or the Chad Basin Commission. Multilateral finance agencies have barely started to include ground water in basin wide projects. Shared groundwater tends to be flagged as part of a river basin commission mandate – however, groundwater cannot be subject to the same type of input-output controls that govern flows in shared watercourses.

Domestic management arrangements for implementation of international agreements may be severely handicapped for managing shared aquifers. Closely related to the valuation and competition issues, the distribution of groundwater resources and its use creates major challenges for management and the institutional arrangements for implementation. Transboundary aquifers can extend across multiple geographic, administrative and political regions. In this situation, local agencies generally have little hope of influencing regional groundwater conditions through isolated actions under their direct control. The institutional mechanisms that will deal with transboundary aquifers issues therefore need to differentiate between the domestic management regime and that required for international management.

Institutional, cultural and ethical dimensions are likely to be as important as technical and macroeconomic dimensions in the evolution of approaches to address existing and emerging transboundary groundwater problems. Sharing basic data and information on transboundary shared aquifer systems and the projected demands are clearly important, but so too is the joint promotion of effective management.

An important institutional issue for management of transboundary shared aquifer systems is therefore the scope of regional co-operative frameworks, broadly scoped social and economic communities, versus basin and aquifer commissions. Regional economic bodies could be mandated and have capacity to:

- act from the authority of political economy;
- set policy and guidelines for water management in the region;
- integrate water and economic issues into the regional economy;
- mitigate and compensate for externalities and negative impacts of regional policy on individual member states as well as the environment;
- monitor effectiveness and compliance with water management and environmental standards at regional and national level and
- identify benefits sharing possibilities.

Individual governments and the economies in a region do not form single entities but are collective in nature, and decisions represent balanced negotiated outcomes acceptable to sectors and executive, legislative and judicial powers. These facts call for introduction of alternative approaches to economic analysis in international water management, to maximise the positions of individual states and then use the agglomerated result for well-informed negotiations.

## Environmental issues

The environmental issues that affect transboundary aquifers are wide ranging and can be viewed both from a local and a global perspective.

Within the framework of the World Water Assessment Programme (WWAP) of the United Nations system, UNESCO-IHP has undertaken the task to develop groundwater resources indicators for environmental sustainability. A first presentation of the elaboration of the indicators was contained in the World Water Development Report (WWDR) that was presented at the Third World Water Forum in Kyoto in March 2003.

Most aquifer systems have ecosystems, landscape elements, or pre-existing water users that are dependent on current discharge or recharge patterns. Further development may require trading off these dependencies in favour of new plans or policy. If dependencies are not well understood or considered, management changes may have major unanticipated impacts.



There is often no inherent conflict between preservation of these ecosystems and withdrawals from transboundary aquifers for socio-economic development when the functioning of the aquifers is well studied and all possible impacts considered.

Since an aquifer system is essentially below ground, biodiversity issues generally relate to the regions where aquifers discharge as for example through rivers, lakes or swamps and coastal zones. Frequently this generate the specific characteristics of the dependent special ecosystems, related to the physical and hydrochemical features of the aquifer (Gilbert et al., 1997).

In many regions, but especially arid regions, discharging groundwater fed water bodies can be absolutely critical to the maintenance of biodiversity. Even in temperate climates, the discharge region of a transboundary aquifer can provide specific conditions of quality, temperature and nutrients that rare species will be reliant upon.

Discharge of transboundary groundwater into lakes and inland seas supports important migratory bird conditions and discharge in coastal zones supports specific marine ecosystems. Aquifer over abstraction and excessive fertiliser application in the irrigation areas can have negative impacts on the quality of groundwater flowing to surface water bodies, wetlands, oasis, and the coastal areas.

The impact of climate change on transboundary aquifers of the world is yet to be fully evaluated. The consequences of either of these impacts on abstraction, maintenance of wetlands, discharge to water bodies could be very serious, especially where well developed infrastructure has been established. Global sea level changes, may impact marine saline intrusion – the hydraulic reference point change could mean that many aquifers may extend inland intrusions, thus affecting groundwater quality.

Aquifer response to stimuli such as climate change will be even more gradual than those resulting from human intervention. The detection of these impacts will require a very careful analysis of data. For transboundary aquifers, the need for consistent data and a comprehensive conceptual understanding is essential.

## ISARM CONTRIBUTION TO TRANSBOUNDARY AQUIFERS MANAGEMENT

### **Global inventory of transboundary aquifer resources**

Since the publication by UNESCO-IHP of the ISARM Framework document, in 2001, close cooperation with international and regional partners and

the aquifer countries has been established to undertake inventories and case studies of transboundary aquifer systems in the regions, including Africa, Americas, Europe and South-Eastern Europe and Central Asia, the Mediterranean, and Western, Southern and Eastern Asia. The regional inventories include existing regional treaties and legal and institutional arrangements in the aquifer countries. The aquifer and hydrogeological data have further been compiled into global and regional datasheets and maps, including the WHYMAP with the Special Edition on Transboundary Aquifer Systems in 2006 and IGRAC in 2009. With the data bases initiatives and individual transboundary aquifer projects, the basis network with regional institutions and national focal points for scientific and governance cooperation has progressed. The number of the identified transboundary, aquifers, currently about 275, is expected to grow.

## Why shared aquifers are important?

Considering that the number of transboundary aquifers that have been inventoried since the launch of the ISARM project is comparable to the one of international river basins, and that these aquifers contain huge quantity of freshwater, it is necessary to recognise that these systems have a crucial role in providing drinking water supply, water for irrigation, water for terrestrial and coastal ecosystems, and water for the socio-economic development of many regions of the world. It is then urgent to increase awareness about these systems and set up rules of good governance.

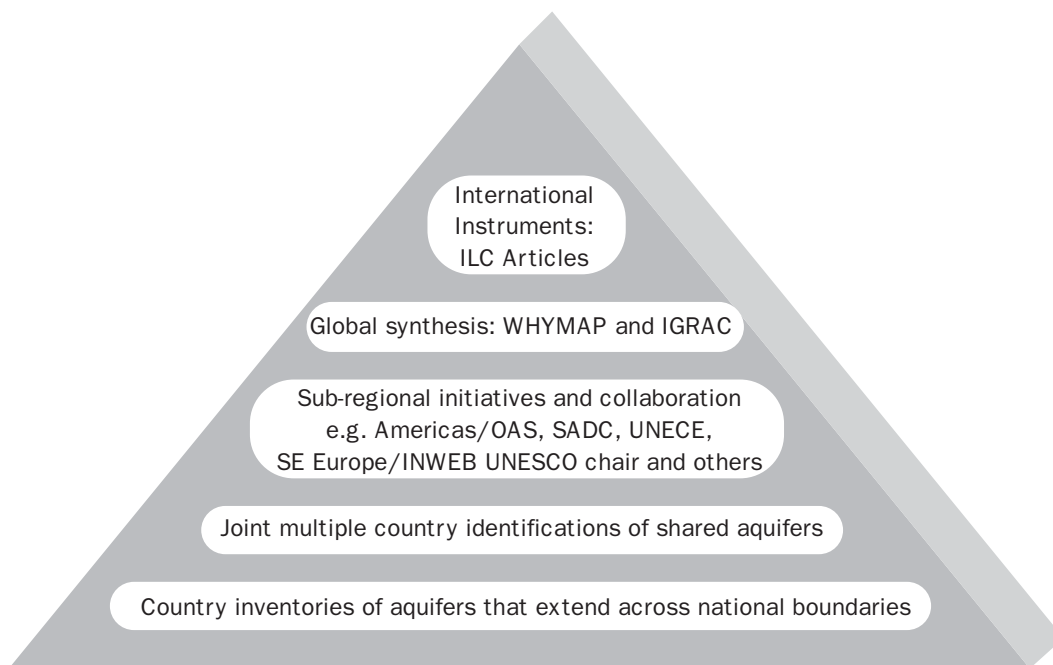
At present 68 transboundary aquifers were identified in the Americas, (29 in South America, 18 in Central America, 17 in North America and 4 in the Caribbean), 65 in South East Europe, about 10 in Western Asia and 40 in Africa. The ISARM Asia inventory is currently in its initial phase and only 12 transboundary aquifers were identified. In Europe the UNESCO's IHP works together with the United Nations Economic Commission for Europe (UNECE) in undertaking assessment of groundwater resources and transboundary aquifers in Eastern European countries and South-Eastern Europe and Central Asia.

## Building on the knowledge pyramid: The UNESCO-IHP ISARM Programme 2000-2008

Since the year 2000, ISARM has built up a significant pyramid of knowledge. At its 'base' the pyramid includes inventories and case studies of transboundary aquifer systems shared by neighboring countries; the body of the knowledge pyramid is made of Continent wide assessments of Africa, the Americas, Europe and South-Eastern Europe and Central Asia, the Mediterranean, and Western, Southern and Eastern Asia. Higher up in the body of the pyramid, there are regional inventories that include existing regional treaties and legal and institutional arrangements in the aquifer countries.

The individual country analyses of aquifers and hydrogeological data have further been compiled into global and regional datasheets and maps.

Thanks to the ISARM Programme, effective cooperation amongst countries has progressed. The ISARM knowledge pyramid has created the opportunity of data base development initiatives, a series of joint country transboundary aquifer management projects and the establishment of science networks among regional institutions supported by national focal points. This has resulted in global recognition and awareness of the importance and distribution of transboundary aquifer systems.



*ISARM knowledge pyramid*

One of the key concerns among the collaborators and the stakeholders of the ISARM Programme has been the need for quality assurance and ensuring the validity of the work. This has been achieved by a process of data collection and its synthesis – firstly, the ‘bottom up’ approach; country level data has been collated and provided by national scientists and the good offices of the IHP’s National Committees and thus represent the national view; secondly the country level data has been shared by experts in their neighbouring countries checking that cross border extensions of aquifer systems have been correctly identified and that nomenclature difference have been harmonised. Thirdly the regional data have been compiled into regional or continent wide data bases as well as in regional maps.

More transboundary aquifer systems shared among countries will come to light. ISARM is entering in a new phase. This will be driven by the continuing detailed assessments, adoption of common terminologies, and identification of aquifer ‘management units’ based on hydrogeological definitions, such as scale, governance structures, knowledge of the values and costs of aquifer utilization for socio-economic and ecological needs.

The ISARM Programme Second Phase will continue in the Framework of the Seventh Phase of the UNESCO-IHP Programme (2008–2013).

# ADDING VALUES TO INITIATIVES: ISARM REGIONAL ACTIVITIES

Since the launching of ISARM, UNESCO-IHP and its partners have carried out a number of regional activities related to transboundary aquifers: meetings, workshops and conferences. The next pages show a synthesis of regional outputs and activities in the framework of ISARM Programme. Around 275 transboundary aquifers have been inventoried since 2002. This number is comparable to the one of international water basins (Wolf, 2002) although it will increase in the future years due to more detailed investigations that will be conducted (IHP-VII ISARM 2008–2013) in particular in Asia and Africa.

More details and useful links can be found in ISARM website, hosted by IGRAC, <<http://www.isarm.net>>.

Inventories were conducted in the following regions:



**Americas**



**Western Europe**



**Asia**



**Middle East**

**Africa**



**South-Eastern Europe**



**Caucasus and Central Asia**



An overview of the regional inventories will be given in the following pages.

Western and Eastern Europe transboundary aquifers have been inventoried in cooperation with the 'Convention on the Protection and Use of Transboundary Watercourses and International Lakes' (Helsinki 1992), whose secretariat is established at the UNECE.



## ISARM-AMERICAS

The UNESCO/OAS ISARM-Americas Programme is the regional initiative for the American hemisphere and is jointly coordinated by the UNESCO International Hydrological Programme (IHP) and the Department of Sustainable Development of the Organization of American States (DSD/OAS). It is a successful example which methodology and modus operandi should be repeated in other region.

The Programme operates through a joint coordination committee of experts from UNESCO-IHP and OAS and is implemented at a country level by National Focal Points designated both by the IHP National Committees and the Integrated Water Resources National (IWRN) Focal Points.

From the start of the activities in 2003, the Programme has established a network of National Coordinators, which represent 24 countries of the American hemisphere.

The Programme encompasses three main region-wide activities, corresponding to the three phases.

The ISARM of the Americas project has in its first phase collected data regarding the hydrogeological characteristics of main transboundary aquifers and their use. A total of 68 transboundary aquifers were jointly identified by the National Coordinators of the countries concerned: 29 are located in South America, 18 in Central America, 17 in North America and 4 in the Caribbean. Evaluations showed that some of the most important aquifers in South America are transboundary systems. Results have been published jointly by UNESCO and OAS in 2007.

The second phase assessed and analyzed the institutional and legal frameworks of transboundary aquifers in the region; the results were published in April 2008.

The third phase focuses on the sustainable socio-economic and environmental aspects of transboundary aquifers for which results should be published in 2009. The close cooperation between country representatives has allowed for the preparation of the first comprehensive continental assessment of transboundary aquifers with the result of providing valuable tools to decision-makers of the region for the improvement of the understanding and management of these resources. In fact, the cooperative and participative process undertaken under the ISARM Americas project was critical to its success.

In addition, it includes a number of cases studies of selected transboundary aquifers in the region.

## Activities

### Preparatory Meetings

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- A kick off **seminar** was organised by the National Committee of Argentina for the UNESCO-IHP and the University of **Santa Fe, Argentina, 29–31 August 2001**, on the transboundary aquifer systems in Latin America.
- **XXII Brazilian Congress on Groundwater**  
held in **Florianópolis, Brazil, 10–13 September, 2002**.
- **International Symposium on Transboundary Water Management**  
held in **Monterrey, Mexico, 18–22 November, 2002**.

### Transboundary Aquifers Meetings

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From 2003 onwards, annual Regional Coordination Workshops were conducted to exchange information and views, to interpret and discuss the aggregated data on transboundary aquifers, and to develop detailed activity programmes or new initiatives.

- **First UNESCO/OAS ISARM-Americas Workshop**  
**Montevideo, Uruguay, 24–25 September 2003**

Twenty countries were represented including Haiti and the Dominican Republic. During the Montevideo Workshop the countries proposed nine transboundary aquifers as possible case studies for project implementation with the ISARM approach. This workshop provided an ideal forum for Member States to plan actions in the framework of the UNESCO/OAS ISARM Americas Programme.

- **Workshop on Transboundary Aquifers in the Central Region of Hispaniola Island - Dominican Republic and Haiti**  
**Santo Domingo, Dominican Republic, 20–24 August 2004**

The objective of the Workshop was to put together specialist of both Caribbean States (Dominican Republic and Haiti) in order to develop a common study project on Hispaniola Island shared aquifers (Artibonito and Masacre Aquifers) to be presented to the Global Environment Facility (GEF) for financing.



■ **Second UNESCO/OAS ISARM Americas Workshop**  
**El Paso, United States of America, 10–12 November 2004**

Over 30 participants from the Americas were present at the meeting. The International Boundary and Water Commission USA-Mexico (IBWC) were the co-sponsors of this event. Emphasis during this workshop was on presentation of case studies and transboundary aquifers identified by the national coordinators.

■ **Third Coordination Workshop on the UNESCO/OAS ISARM Americas Programme**  
**Sao Paulo, Brazil, 30 November–2 December 2005**

This workshop marked the conclusion of Phase I, 'Inventory of Transboundary Aquifers of the Americas'. National coordinators of seventeen countries were present. This workshop defined a structure for a three-volume report series on transboundary aquifers of the Americas and gave a strong impulse to harmonizing and consolidating the inventory of the region's transboundary aquifers.

■ **Fourth Coordination Workshop on the UNESCO/OAS ISARM Americas Programme,**  
**San Salvador, El Salvador, 20–22 November 2006**

The legal and institutional water framework from each country was presented and analyzed, and an agreement was reached on the content of the template per country for the second volume of the ISARM Americas Series 'Legal and Institutional Framework in the Management of the Transboundary Aquifers Systems of the Americas'.

■ **Fifth Coordination Workshop on the UNESCO/OAS ISARM Americas Programme**  
**Montreal, Canada, 17–21 September 2006**

During this event the advanced copy of first book of the series UNESCO/OAS ISARM Americas 'Preliminary Assessment: Transboundary Aquifer Systems in the Americas' was provided to the ISARM Focal Points. The final outline of the Second volume of the ISARM Americas series was agreed upon.

■ **Sixth Coordination Workshop on the UNESCO/OAS ISARM Americas Programme**  
**Santo Domingo, Dominican Republic, 3–5 December 2008**

During this workshop the National Coordinators and the ISARM Steering Committee approved the structure of the Third book 'Socio-economical and environmental aspects in transboundary aquifers', reviewing and giving their approval. This third publication is expected to be published in 2009.



## ISARM-AFRICA

In Africa groundwater represents a main water resource and a strategic source of freshwater: some regions in the continent depend to a major extent or entirely on groundwater. The aquifer resources in Africa are to a large extent transboundary and shared between two or more countries, but there is a scarcity of regional hydrogeological information and gaps in the understanding of the role of groundwater. Collecting scientific data and creating networks of experts is leading to better management of shared water resources of the region and then national sustainable developments.

### ISARM in Southern Africa

Southern Africa is one of the focal regions receiving support from ISARM. In Southern Africa, groundwater is likely to be the key resource to improve the water supply coverage of many areas. This is important for the industrial, agricultural and societal development of the region. Groundwater is also an important conditioning factor in regional environmental processes.

### ISARM in Western Africa

Collection of data has started by local experts.

### ISARM in Eastern Africa

Activities are starting in order to create an expert network.

## Activities

### Preparatory Meetings

- **International Conference on 'Regional Aquifer Systems in Arid Zones – Managing Non-Renewable Resources'**  
**Tripoli, 20–24 November 1999**

More than 600 participants from more than 20 countries and regional and international organizations and associations attended the workshop. It marked a milestone in the discussion of the emerging concept of regional aquifers. It provided a general understanding of non-renewable groundwater resources and was also instrumental in shaping the background of the ISARM programme.

- UNESCO-IAH. A **workshop** was organised in cooperation with IAH in **Cape Town, South Africa, from 20 November–1 December, 2000**, with the aim of setting up a network in the South African Development Community (SADC) countries for enhancing the study and assessment of Southern African regional aquifers.

### Transboundary Aquifers Meetings

- **International Workshop, 'Managing Shared Aquifer Resources in Africa (Tripoli Workshop) 2–4 June, 2002, Tripoli, Libya**

The International Workshop was hosted and supported by the General Water Authority of the Libyan Arab Jamahiriya and jointly convened with the Division of Water Sciences of UNESCO under the ISARM initiative. The meeting was co-sponsored by FAO, IAEA, IAH, UNECE and by SADC, OSS and OACT. The aim was the improvement of existing knowledge on African shared aquifer systems and the preparation of an inventory of case studies. More than 200 experts of different disciplines from 30 countries and from regional and international organisations and associations attended the workshop. As a result the first inventory of about 40 principal African transboundary aquifer systems was produced.

- An **ISARM SADC 1 Initiative** supported by UNESCO commenced in **March 2007** in **Pretoria, South Africa**. The initiative intended to provide a mechanism for coordination, establish a network and provide a transboundary aquifer inventory.
- **ISARM SADC 2 meeting** took place in **July 2007, in Windhoek, Namibia** between Botswana, Namibia and South Africa.

- **ISARM SADC 3** four-day **follow-up meeting** was held in **Namibia**, with the assistance of UNESCO, within the project area during **April 2008** and was attended by the three basin States and other stakeholders.

The purposes were to consolidate the knowledge of the Stampriet Kalahari/Karoo Basin within the three countries. This joint project is intended to establish the information necessary for transboundary groundwater security that will furthermore promote better long-term management to the benefit of all three countries. This initiative should serve as a pilot approach for other transboundary aquifers areas considered within the SADC.

- **Workshop on 'Inventory of transboundary aquifers in the Western African Region and evaluation of the status of the information available'**  
**Cotonou, Benin, 30 May–1 June 2007**

The Workshop was organised by UNESCO-IHP and IAH in cooperation with IGRAC. The main objective of this workshop was to review the data and information on groundwater available in the region for ISARM Inventory of the Transboundary Aquifers of the Western African Region. This data will be used to establish an appropriate data base at the UNESCO-IGRAC Center, and to develop a GIS-based inventory of transboundary aquifers in the region, as an input to the Continent wide inventory. This inventory may serve as a basis for formulating specific local projects for cooperative actions.

In the Western African region, countries are already signatories to a series of cooperative mechanisms e.g. the ECOWAS Regional Action Plan for water resources management and the set up of the ECOWAS Water Resources Unit in Ouagadougou. Drawing on these mechanisms the countries sharing transboundary aquifers, would work towards deepening cooperation on water use, environmental protection and economic development.

- **Third International Conference 'Managing Shared Aquifer Resources in Africa', (Tripoli Conference)**  
**Tripoli, 25–27 May 2008**

This International Conference, co-organized by UNESCO-IHP, the General Water Authority of the Libyan Arab Jamahiriya and Sahel and Sahara Observatory with support from IAH and IAHS, focusing once again on the needs of Africa, provided support for the sub regional ISARM expert networks which have been developing actions in the SADC and West Africa, drawing on suggestions made in the ISARM Framework Document. The conference has then achieved formulation of inputs and recommendations for a Regional Centre for the Shared Groundwater Resources in order to develop a plan of action supporting both the current as well as the new African Expert Groups. The scope of the Conference has also included the establishment of a Plan of Action for shared aquifer systems resources management in Africa as a whole.



## ISARM-SOUTH EASTERN EUROPE

The ISARM activities in South East Europe started in March 2004 by consultations among UNECE, UNESCO-IHP, UNESCO Chair/INWEB and the Global Water Partnership Mediterranean (GWP-MED) Secretariat in Athens, aimed at coordinating two separate ongoing activities concerning internationally shared surface and groundwaters. One of the advantages of the coordinating action was that both studies would be prepared by the same team of national experts, most of whom are members of UNESCO Chair/INWEB. Accordingly, two workshops were held in Thessaloniki consecutively in October 2004.

### ISARM-South East Europe Project

This project is a recent initiative in the South East Europe (SEE) region, sponsored by UNESCO, and carried out by the UNESCO Chair and Network/International Network of Water-Environment Centres for the Balkans (INWEB), Aristotle University of Thessaloniki (AUTH), Thessaloniki, Greece.

ISARM-SEE covers Greece, Albania, Bulgaria, FYR of Macedonia, Romania, Slovenia, Croatia, Serbia, Bosnia and Herzegovina and Turkey.

## Activities

### Transboundary Aquifers Meetings

- **UNESCO/ISARM Workshop on Key Issues for Sustainable Management of Transboundary Aquifers in the Mediterranean and in South-Eastern Europe (SEE)**

In close cooperation with the IAH/Transboundary Aquifer Resource Management Com-

mission (TARM), INWEB coordinated a workshop to present and assess its compilation and validation of data for an updated inventory of transboundary aquifers in SEE.

■ **Workshop on Transboundary Groundwaters in South East Europe  
Thessaloniki, 23–24 April 2007**

In the workshop, hydrogeologists from the SEE countries were working on delineation of the transboundary aquifers in the region. The workshop was organized by UNESCO-IHP, UNECE and UNESCO Chair/INWEB. The results of the workshop were used to prepare the section 'Transboundary Groundwaters in South-Eastern Europe' of the report *Our water: Joining Hands across Borders, First Assessment of Transboundary Rivers, Lakes and Groundwaters* published by UNECE in 2008.

■ **Workshop on Developing Regional Cooperation for Shared Karst Aquifer  
Management in SEE  
Thessaloniki, 26–27 June 2008**

This workshop formed part of the GOTRANSKARSTBA project. National experts, as well as experts from UNESCO were invited to Thessaloniki to attend the two-day workshop. A draft assessment of shared karst aquifers was sent to workshop participants prior to the meeting, and gaps in information were highlighted. Participants were requested to provide additional information for the national governance and monitoring activities of aquifers shared by their countries and to confirm information on general aquifer characteristics, use and functions, management problems and responses described in the draft assessment.

■ **UNESCO Pilot course on Transboundary Groundwater Management  
Thessaloniki, 13–14 October 2008 2008**

The objectives of the pilot course were to teach hydrogeologists, lawyers and policy-makers how to work together as a team, provide them with a common knowledge, develop a common language and make them more familiar with the methods of reasoning of their partners in order to facilitate dialogue and exchanges of ideas.

■ **IV International Symposium on Transboundary Waters Management  
Thessaloniki, 15–18 October 2008**

The aim of the IV International Symposium on Transboundary Waters Management was threefold: a) to assess the state of the art and the progress recently made in the sustainable management of transboundary waters by different disciplines such



as law, socio-economics and water science; b) to review current major international programmes concerned with the assessment and management of transboundary water resources, and c) to promote interdisciplinary approaches for integrated transboundary water resources management.

Presentations to the workshop and final version of Thessaloniki Statement, agreed by participants of 42 countries and international and regional organisations, are available at <<http://www.inweb.gr/twm4>>.



## WESTERN EUROPE

About 75% of the inhabitants of the European Union member states depend on groundwater aquifers for their water supply. Many of these aquifers are internationally shared.

ISARM has established a close cooperation with UNECE's Groundwater Group concerning the European aquifers. UNECE is in charge of the follow-up of the Water Convention and it has produced an important inventory of transboundary aquifers in Europe (Almássy and Buzás, 1999), as well as Guidelines on Monitoring and Assessment of Transboundary Groundwaters (UNESCO, 2000).

From October 2002 till September 2003 several meetings on the management of transboundary groundwaters were organised. In all the conferences/workshops presentations were given on the UNECE groundwater programme (UNECE groundwater guidelines and the European case studies).

## MEDITERRANEAN REGION

### **‘Capacity building for sustainable utilization, management and protection of internationally shared groundwater in the Mediterranean region’**

This inter-regional project aims at strengthening the capacity of water management institutions in the Mediterranean region to implement sustainable forms of utilization, management and protection of internationally shared groundwater resources. The project will contribute to water sustainability and the availability of water for drinking and food production. This supports the millennium development goals that address access to safe drinking water supplies and poverty eradication.

The project is implemented by ESCWA in collaboration with ECA, ECE, UNESCO, the United Nations Department of Economic and Social Affairs (DESA) and non-United Nations entities. The project builds upon substantial regional experience on developing tools for monitoring, assessing and managing internationally shared groundwater, as well as the UNESCO-IHP project on internationally shared aquifer resources management (ISARM). Special effort is made to draw upon the experience of the ECE in this area and to encourage knowledge transfer between regions so as to strengthen the capacity of countries to engage in inter-State cooperation in the Mediterranean region on the management of internationally shared aquifers. Targeted beneficiaries are representatives of water management institutions in selected MEDA countries of the Euro-Mediterranean Partnership and Member States in the region.

The project is expected to:

- Increase awareness and application by Euro-Mediterranean Partnership (MEDA) countries of the international norms in the sustainable management of shared aquifers,
- Transfer and exchange know-how on various shared aquifer management issues and the management of data on shared resources,
- Strengthen capability of MEDA countries to engage in inter-State cooperation regarding shared aquifers and to plan and manage their groundwater resources by using the tools and mechanisms developed in this project.

## Activities

The project 'Capacity building for sustainable utilization, management and protection of internationally shared groundwater in the Mediterranean region' supported detailed inventories and assessment of the instruments for shared aquifer management in and beyond the MEDA including socio-economic aspects and drivers of water use, food security and international trade. The project included the following regional Workshops with participation of the MEDA countries.

### Transboundary Aquifers Meetings

- **Workshop on Instruments for managing shared Groundwater resources in the MEDA region**  
**Beirut, 12–13 December 2005**
- **Workshop on formulation of a policy framework to support the establishment of mechanisms for inter-state cooperation on shared groundwater Aquifers in the Mediterranean region**  
**Beirut, 24–25 April 2006**
- **Workshop on 'Evaluation and Adaptation of Existing Water Visions and Forecasts of Shared Aquifer Management in the Euro-Mediterranean Partnership Region (MEDA)',**  
**Cairo, 30–31 July 2007**

A comprehensive study on the issue of water visions and forecasts for shared aquifers management in the region was prepared for discussion. The proposed vision title was 'A MEDA region where all shared aquifers are jointly managed to satisfy local/ national/regional water requirements to attain sustainable development, without harming neighboring countries'.

- **Workshop on 'Shared Aquifer Database in the MEDA Region: Contents, use and maintenance'**  
**Thessaloniki, 26–27 November 2007**

The workshop, organised by INWEB, aimed at discussing the findings of the survey and the progress made in developing regional databases.

Roundtable discussions were focused on the existing monitoring systems and data for shared aquifer management in the MEDA region. Participants also contributed to discussions on step by step measures for improving, using and maintaining the draft database presented by INWEB.

- **Workshop on the ‘Initial Implementation of Joint Management in the Nubian Sandstones Aquifer System (NSAS): Case Study in the Western Portion of the Mediterranean’**

**Cairo, 14–15 January 2008**

and

- **Workshop on the ‘Raising Awareness and Capacity Building on Joint Planning and Management in the Nahr El Kabir Junoubi Basin (NKJB): Case Study in the Eastern Portion of the Mediterranean’**

**Cairo, 16–17 January 2008**

Both consultative workshops were aimed at supporting the preparation of a draft joint management plan aimed specifically at hydrological monitoring network in the NSAS and the NKJB. The main focus of the workshops were the draft reports of the case studies, which were used as basis for the aquifers’ pilot projects conducted by ESCWA (UN Economic and Social Commission for Western Asia) and other partners. Whereas the case study of the NSAS, a shared non-renewable aquifer, was shown as an early phase of implementation, the NKJB, a shared renewable aquifer, was presented from the perspective of being at a stage of confidence building and joint management. The NKJB case study showed how to create awareness and build confidence on data exchange and knowledge transfer between the two riparian countries for the overall purpose of strengthening their capacity for inter-state cooperation in managing this basin. The NSAS case study demonstrated how regional monitoring and reporting on inter-regional, regional, national and shared aquifer management can be implemented to strengthen the capacity of the four riparian countries for inter-state cooperation in managing this shared aquifer.



## ISARM-ASIA

The Asian continent covers 44 million square kilometers with a population of 3.5 billion. It is the largest continent both in area and population in the world. There are 48 countries and regions in Asia with several countries with a population of more than 100 million such as China, India, Indonesia, Japan, Bangladesh and Pakistan. The combination of large populations and rapid growth mean increasing demands for water resources.

There are several transboundary aquifers in Asia involving two or more countries and UNESCO-IHP in cooperation with the Chinese Geological Survey has already identified in a preliminary study 12 significant transboundary aquifers, primarily porous or fissured/fractured aquifer systems. The successful management of these shared aquifers will contribute to peaceful relations between sharing countries.

The development of groundwater in Asia has greatly increased over the past 30 years. In some arid regions of Asian countries, where sufficient renewable groundwater resources are not available, non-renewable groundwater is being exploited to support development, such as the coastal area of the north China plains. Since the 1970s, groundwater extraction has increased greatly in China, India, the Republic of Korea and other countries in South Asia. Groundwater problems have increased rapidly over the last 20 years with higher salt content in arid and semi-arid zones, high levels of arsenic and fluoride, the encroachment of seawater in coastal areas and land subsidence due to overexploitation.

China's situation regarding groundwater and transboundary aquifer systems is a particular situation that highlights the pressure of rapidly increasing demand and extraction. China's large territory contains 26 hydrogeological units, 15 of which are inter-provincial as well as major transboundary international aquifers with Russia (middle Heilongjiang-Amur river basin), the Yili River and the Ertix valley plains with Kazakhstan, and transboundary aquifers with Mongolia, Korea, Vietnam and Burma. UNESCO and the China Geological Survey have produced a special report on 'Transboundary aquifers of Asia with a special emphasis on China'. The IHP preliminary report published in 2007 focuses on a case study of the Heilongjiang-Amur River between China and Russia and represents the first step towards addressing transboundary aquifers and management across Asia.

## Activities

- UNESCO organized a **Joint Special Session on 'Transboundary Aquifers in Asia'**, WHYMAP-Asia and 'IGCP Project 523: GROWNET' during the 34th Congress of International Association of Hydrogeologists on **13 October 2006**, at **Beijing, China** to deliberate and exchange knowledge and experiences on the technical and policy issues on transboundary aquifers, Hydrogeology Map of Asia and sharing of best practices in groundwater management.

UNESCO in collaboration with China Geological Survey carried out a pilot case study on 'Transboundary Aquifers in Asia -With Special Emphasis to China' and results of the project published as a case study document to initiate the process of ISARM-Asia and publication was officially launched during this session. This report focuses on a case study of the Heilongjiang-Amur River between China and Russia and represents the first step towards addressing transboundary aquifers and management across Asia.

More than 60 experts took part in this special session which includes IAH Council members, UNESCO, Ministry of Land and Resources of China, China Geological Survey and other institutes, Delegates from India, Russia, and other countries.





## CAUCASUS AND CENTRAL ASIA

The first assessment of transboundary groundwaters in Caucasus and Central was prepared under the UNECE Water Convention. It has been included in the Assessment of the status of transboundary waters in the UNECE region (UNECE, 2007) which was presented at the sixth Ministerial Conference 'Environment for Europe' in October 2007. The assessment was also a contribution to ISARM.

The assessment has also been a contribution to ISARM. The preliminary results of the assessment show that the aquifers under consideration in Caucasus and Central Asia are mainly used as source of drinking water and for irrigation purposes.

In many aquifers, salty water mixes with fresh water, reducing water quality. Pollution from agricultural sources ranged from moderate to serious in some cases. In others, aquifers are affected by heavy metals and hydrocarbons contamination.

Most alarmingly, the severe reduction of well water levels, due to over-exploitation, shows that without a change in water management practices, water will become even scarcer in the Region.

## Activities

### Transboundary Aquifers Meetings

#### ■ **First workshop UNESCO-UNECE-OSCE ISARM Caucasus and Central Asia**

**Almaty, 31 May–1 June 2007**

The workshop had two main objectives, a) to finalize the assessment of transboundary groundwaters in the region, and b) to identify possible follow-up activities in the region on transboundary groundwaters to be carried out by the three organizations.

#### ■ **Second Workshop UNESCO-UNECE-OSCE ISARM Caucasus and Central Asia**

**Almaty, 27–28 May 2009**

During the Second Workshop 30 experts from Central Asia and Caucasus have reviewed the state of knowledge on the basis of the information provided by experts from each country..

The first inventory was reviewed and two additional aquifers to those identified in 2007 were mentioned.

Participants were expected to agree about provision of groundwater data for a UNESCO-led inventory from the countries and identify possible follow-up activities on transboundary groundwaters that could be initiated in the region, possibly in cooperation with development partners. At the workshop, The compilation of the regional inventory was carried out within the framework ISARM initiative, to be included in UNESCO's world inventory of transboundary groundwaters. This collection of groundwater information was also a part of the organizers' contribution to UNECE's Second Assessment of the status of transboundary waters in the UNECE region, to be presented at the Seventh Ministerial Conference tentatively scheduled for 2011 in Kazakhstan.





3



# Regional and local inventories

# INVENTORIES AND CASE STUDIES

## Standardising the approach for enhanced comparison

One of the essential steps in the preparation of the inventories was the need for some degree of standardisation to enable comparisons and contrasts to be made across regions. While not prescriptive, such standardisation is often difficult to achieve given the diversity of aquifer types, the multiple uses of that water, the differing needs of society and the requirements for maintaining aquatic habitats. Consequently the inventorisation process was based on the following suggested structures, recognising that information required be collated over several iterations, as has been illustrated through the experience gained in the ISARM-Americas.

### **Standard form for the ISARM-Americas Inventory**

The structure of the Standard Form for the ISARM inventory was established at the outset of the ISARM Programme when commencing in the Americas, and discussed at the El Paso Meetings of November 2004.

#### **Overview**

- Name (scientific, international, local), definition and general features of the aquifer system and its sub-systems, (location map).
- Countries and sub-regions and populations sharing the aquifer system.
- Regional, sub-regional and national importance of the aquifer system(s) – based on national volume of groundwater use, for municipal/irrigation uses.
- Cross-border issues and risks for multidisciplinary management (identify the u/s and d/s riparians, flow directions).

#### **Scientific-hydrogeological issues**

- Hydrogeological identification and recognition of the transboundary aquifer systems (simplified hydrogeological map, key cross section along the main transboundary flowline).
- Spatial delimitation, distribution of parameters.
- Groundwater hydraulics, actual and potential international implications:  
Groundwater flow patterns (more details than that in the introduction);
  - Piezometric surface;
  - Water quality: pollution, salinity and land and water salinization; (tabulated trend in water level trends, water quality);



- Other implications;
- Summary of transboundary aquifer management issues (historic and future changes in flows/quality, etc).
- Actual and planned uses. Modern in- and outflows, recharge and captive zones,
- Limited contemporary recharge and fossil reserves – impact of climate change, if known.
- General and specific management needs and opportunities (i.e. is there licensing, control on production – levels, etc.

#### **Legal aspects**

- The need for legal agreements
- Existing rules of governance - groundwater in water law in each riparian, compare and contrast
- Rules and principles that apply
- Identified gaps in existing legal regime for transboundary aquifers
- Initiatives and opportunities for international cooperation

#### **Socio-economic aspects**

- Population served by the aquifer system – poverty profile – contribution of aquifer water to livelihoods – water quality-health issues – IWRM-poverty.
- The state of groundwater development.
- Driving forces.
- Nature of competition.
- Governance issues.
- Contribution of groundwater to local economy – what proportion of income is based on groundwater use.

#### **Institutional issues**

- Domestic and international management.
- Institutional analysis – national-regional-local; what agencies are involved, how do they inter act?
- Political and legal aspects and dimensions.



**Environmental issues**

- Sustainable development of transboundary aquifer resources – estimate of ‘life of resource’ on current and future production rates.
- Biodiversity.
- Climate change – tie into the previous section on ‘recharge’
- Poverty alleviation, water and health – based on info provided in the Socio-econ section
- Conflict prevention
- Ethical development of transboundary aquifers
- Non-traditional or specific uses: CO<sub>2</sub> sequestration, disposal of waste, thermal ASR

**Guidance for sustainable management of the transboundary aquifer**

- Joint aquifer resource monitoring strategy
- Joint (parallel) development-management institutions
- Joint water user associations

**Compiling the quantitative information**

In view of the multiple aspects of the management of transboundary aquifers, as illustrated from the inventory format above, the compilation of the quantitative data is very human resource intensive. Consequently the data is compiled in a series of iterations. In the first iteration the data on the hydrogeology of the transboundary aquifers systems is compiled from the national reports that are coordinated with the reports from neighbouring countries. The textual data and the numerical data should ideally be consolidated into a GIS, however, this has been found to be impractical and therefore simpler databases using such tools as excel spreadsheets and access databases have been used. The major effort has been consumed by the production of maps. These compilations have proved to be very complex, as data formats vary significantly across national boundaries and geological-hydrogeological extensions are often inconsistent, requiring checking with the experts in the regions. The final product of the consistent map is the first visual representation of the transboundary aquifers system. Once this has been fixed, the remaining systematic parameters describing the flow, the chemistry and the interactions with superficial features can be harmonised.

## Harmonising the spatial information

Harmonisation of the spatial information about transboundary aquifers is an essential step in their management and awareness raising. For this purpose firstly national maps, followed by multi national maps and finally regional or sub regional maps have been compiled. These three scales, progressively covering larger geographical areas, allow for correcting any of the inconsistencies that may arise in the correct formulation of the concepts of transboundary aquifers systems. The next stage of this approach to harmonisation is the incorporation into the system concept, the current or the potential users of the resources and also the spatial distribution of ecosystems that are dependent on the aquifers. Given these sequential information build up, countries sharing the transboundary aquifers may move on to sound and sustainable use of the shared resources.

## Compiling the regulatory frameworks for comparisons

Currently experience is being gained in compiling national legal frameworks that regulate aquifers. National legislation concerning aquifer management is frequently embedded in other water resource or environmental management regulations in most countries. An assessment of the legal framework of all the countries that form the ISARM Americas has shown that there is a significant paucity in available legislation on transboundary aquifers. There are many national regulations available such as the extent to which boreholes may be drilled, the quantity of water that may be extracted for given uses, the licensing at the national or local scale and reporting of the abstracted water in terms of quantity and its quality. The need therefore arises of approaches to harmonise these specific regulations in the case of transboundary aquifers, where across a border differing regulations may apply. Drawing on the suggested scope of the International Law Commissions draft articles, it will be possible in the near future to harmonise or at least compare cross border regulations.

## Assessing the social factors for equitable use

A similar situation, as for legal frameworks, has been noted as regards the social and economic data that affect transboundary aquifers. Information linking the populations served by an aquifer and the resources available in that aquifer is often not available. Further, frequently water quality characteristics

of an aquifer and the consuming population health are not analysed to assess health impacts thus not allowing locally relevant policies. Experience is still being gained in compiling quantitative data on the linkage between transboundary aquifers and social conditions.

## Defining the scope of case studies

In the ISARM programme has been phased over several stages. While the scope of work of each stage has been based on discussion and agreement, some generalised approaches were set out, as follows:

**Stage I: *Inventory and preliminary documentation.*** A good start was made with the circulation of the questionnaires. These were completed as far as possible during stage I of the programme. Further elements of this included development of criteria that define the degree of significance of the aquifer system. The methodology proposed is based on a system of weighted scores, with the weightings applied in the context of each country participating in the programme. Some possible criteria, listed in no particular order of importance, include:

- Available water resources vs. population served, including industrial, agricultural and other demands,
- Contribution from the aquifer discharge to base flows and support to aquatic or other bio diversity,
- Contribution of aquifer water resource to poverty alleviation,
- Cost benefit of development in terms of contribution to economic development.

Sub criteria based on the above could be developed as considered appropriate.

**Stage II: *Detailed Analysis and Development.*** Once the transboundary aquifers are prioritised in some manner, as suggested above a more detailed evaluation can be conducted. The Stage II of the ISARM programme suggests a multi disciplinary approach for the detailed analysis of transboundary aquifers. The hydrogeological analysis that is needed for the management of transboundary aquifers would be ideally run in parallel and in close relationship with the socio-economic, legal and institutional analyses. One of the objectives is to evaluate the extent to which inter regional harmonisation can be required. Substantial variation in the legal and institutional regimes exists between countries sharing the same aquifer. Work will be required, in the further stages of ISARM, to ensure that these different

regimes have common base lines for moving towards compatibility. Stage II seeks to encourage synergies and equivalences.

**Stage III:** *Implementation, Operation and management and monitoring.* The sequence of activities in this Stage should be considered in the longer term. There are many reasons for this, not least that seeking finances and stakeholder support is generally a process that must not be hurried. Apart from this, a fundamental reason for this Stage to extend to the long term is that aquifers respond much more slowly than surface water systems. Consequently the management of transboundary aquifers and monitoring are closely linked and have to be viewed in that perspective.

### The need for case study based approach

The immense diversity of aquifer 'types' and their configurations suggest that no one uniform approach is likely to apply to all transboundary aquifers. It was clear therefore that Case Studies under different conditions will be needed. Case studies in different parts of the world have been proposed and are expected to be conducted. In the case of ISARM-Americas case studies selected should contribute to the overall understanding of the management of transboundary aquifers.

# REGIONAL AND LOCAL INVENTORIES

## IN THE FRAMEWORK OF THE UNESCO ISARM PROGRAMME

This section shows a compilation of continental, regional or local inventories, established in the framework of the UNESCO ISARM programme.

A first overview is presented for each continent or region, followed by information for each individual aquifer. Data are non-exhaustive, and the degree of detail of the data can vary, depending on the information available.

If there are inter-state instruments or institutions and/or international agreements related to an aquifer, special mention is made on its page.

Brief information about regional case studies, pilot projects and proposals is given at the end of each region.

### Americas

The information presented were compiled by UNESCO and OAS in cooperation with 24 countries from North America, Central America, Caribbean and South America. It has been taken from the publication produced in 2007 on the framework of ISARM-Americas Programme, *Transboundary aquifers systems in the Americas. Preliminary Assessment (Sistemas acuíferos transfronterizos en las Américas. Evaluación Preliminar. UNESCO 2007a)*.

The approximate location of identified transboundary aquifers in the Americas is indicated in the general map. This spatial distribution has been obtained considering in particular the geologic transboundary formation. Individual maps show the approximate area extent (that can largely vary from an aquifer to another), topography and hydrographic network for each transboundary aquifer. Limits are still provisional.

Names used for each aquifers are the names under which they are known locally as reported by National Coordinators of Member States.

The general map and maps for individual aquifers have been initially prepared by institutions in charge of groundwater in each of the Member States and then adapted by IGRAC. A special section develops relevant information for seven pilot studies and one project concerning American transboundary aquifers.

### Western Europe

The Western Europe Transboundary aquifers inventory was initiated in the framework of the Convention on Protection and Use of Transboundary Water Courses and Inland Lakes signed in 1992 and entered in force in October 1996.

The United Nations Economic Commission for Europe (UNECE), as part of its ground water program, conducted a survey on transboundary aquifers in Europe. The survey produced 25 responses from 37 countries and identified 89 transboundary aquifers (Almássy and Buzás, 1999).

The UNECE ground water program also drafted guidelines for monitoring and assessment of transboundary ground water. These guidelines are not legally binding but have been adopted by 25 countries and are being implemented through a number of pilot projects.

Since the year 2002 UNECE and UNESCO-IHP cooperates to complete the inventory. UNESCO-IHP has translated the UNECE Guidelines in Spanish in order to use them in the ISARM of the Americas project.

## South Eastern Europe

The results of the workshop on Transboundary Groundwaters in South Eastern Europe (SEE) held in April 2007, in Thessaloniki, organized by UNESCO-IHP, UNECE and UNESCO Chair/INWEB were instrumental in the preparation of the section 'Transboundary Groundwaters in South-Eastern Europe' of the report First Assessment of Transboundary Rivers, Lakes and Groundwaters in the UNECE, published by UNECE in 2008.

These data are available at the UNESCO's INWEB website in the section 'Water Database/Transboundary aquifers', where an interactive map, an aquifers database and descriptive information can be found for all the transboundary aquifers of the region.

Transboundary groundwater resources play a significant role in SEE. The physical environment of the region – the geology, topography and major catchments – is such as to promote the occurrence of productive aquifers. These aquifers are mainly of two distinctive main types: karstic and alluvial.

In the 'Overview' map of the region, the geographical distinction between the two main aquifer types is clear, and it can be seen that several countries of the region have many of their national borders traversed by transboundary groundwaters. Joint assessment, monitoring and management of these groundwaters are, therefore, an important issue for these countries.

A special section develops relevant information about the studies undertaken for the preparation of a GEF project on the 'Protection and Sustainable Use of the Dinaric Karst Aquifer System'.



## Africa

The first inventory of African Transboundary Aquifers was produced during the Tripoli workshop in 2002. Some of the identified aquifers were studied in detail under coordination of regional bodies. For example, investigation in the North Western Sahara Aquifer System and the Iullemeden Aquifer System were carried out in the framework of OSS (Sahara and Sahel Observatory). For the majority of identified aquifers, only an approximate location is known and no details on aquifer's characteristics are available.

An adaptation of the 2006 version of WHYMAP 'Groundwater Resources of the World - Transboundary Aquifer Systems' has been used in this publication to show the 'Overview' for Africa.

Later steps aiming to improve this inventory used sub-regional approaches. In 2005, IGRAC refined the delineation of 20 transboundary aquifers in the SADC region. In 2007, two UNESCO ISARM workshops were organized in Pretoria, South Africa (in collaboration with SADC) and in Cotonou, Benin in collaboration with ECOWAS. During these meetings 18 aquifers in the SADC countries were studied and 9 aquifers in West Africa.

Maps showing the 2005 IGRAC inventory and the approximate positions of aquifers along the boundaries of six SADC sharing countries are presented after the chapter describing the detail of African transboundary aquifers.

A special section develops relevant information about four case studies or projects concerning African transboundary aquifers.

## Asia and China

Asia is the world's largest continent both in area and population. It has a large variation of topography, climate and precipitation and as a result also groundwater resources vary across Asia.

In the context of ISARM Central and Eastern Asia a number of activities have been undertaken aimed at assessing where transboundary aquifers occur. UNESCO in collaboration with the Chinese Geological Survey carried out a pilot study on 'Transboundary Aquifers in Asia with Special Emphasis to China' and the results of the study was published in 2007. The book also presents a case study of the Heilongjiang-Amur River between China and Russia and represents the first step towards addressing transboundary aquifers management across Asia.

## Caucasus and Central Asia

The results of the first inventory, jointly prepared by UNESCO-IHP and UNECE, were published by UNECE in the First Assessment on Transboundary Rivers, Lakes and groundwater (UNECE, 2007).

The groundwater information collected in the UNESCO-UNESCE-OSCE workshop in 2007 held in Almaty and subsequently published in UNECE first assessment of transboundary water are under revision as part of the UNESCO-IHP ISARM Programme (2008–2013).

## Middle East

With limited surface water and rainwater resources the dependence on groundwater is high in the Western Asia countries. This region has a precarious water balance with a major gap to water resource sustainability for regional and national development and the regional water deficit is growing.

The shared aquifer resource systems in Western Asia are characterized by large groundwater reserves that discharge into shared rivers and major springs.

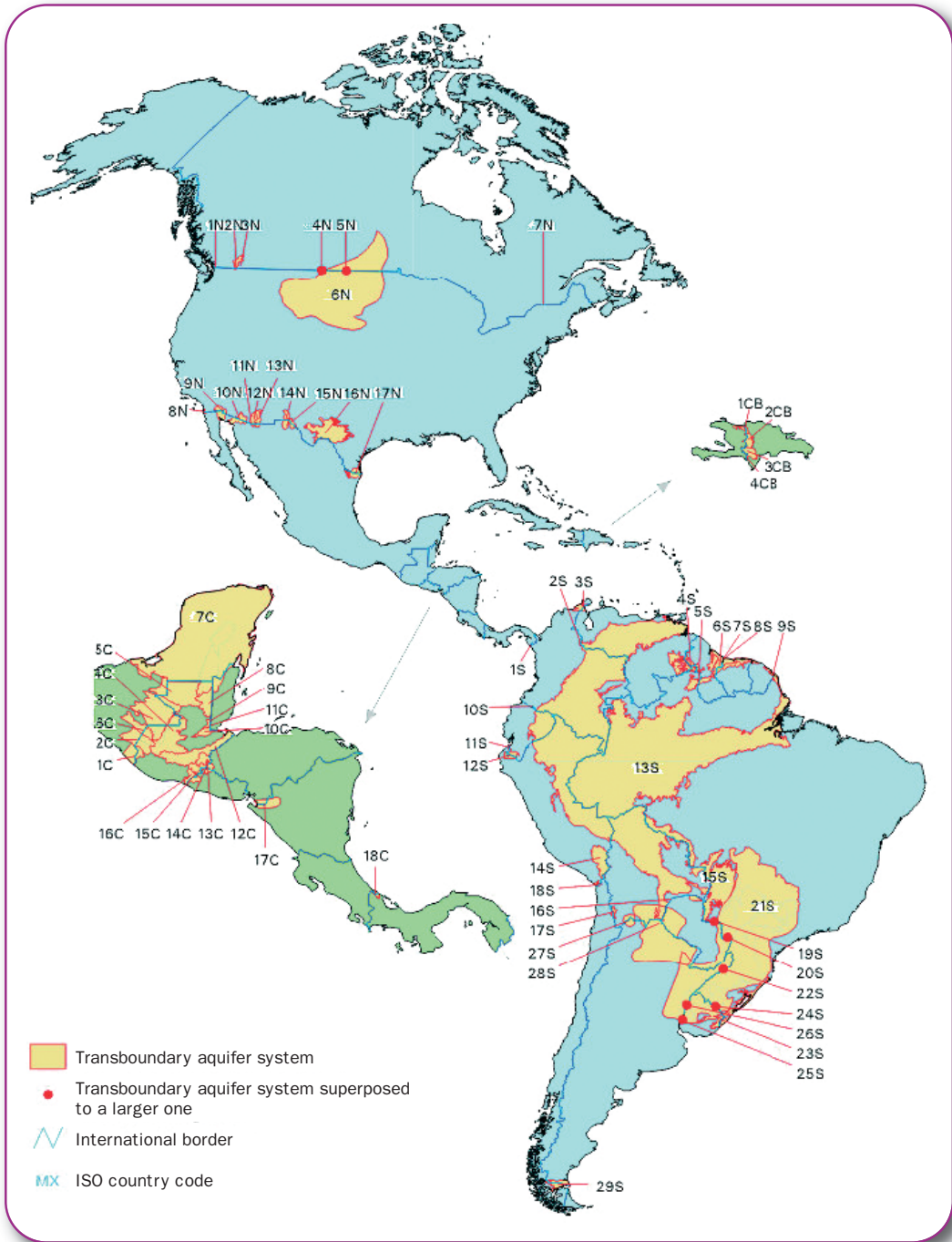
A close cooperation has been established between UNESCO and UNESCWA to better address the challenge posed by the sustainable management of transboundary aquifers in the region.

In addition, INWEB has established and maintains a database with interactive maps on East MEDA countries, on the basis of information supplied by countries experts. More information can be found at INWEB website.

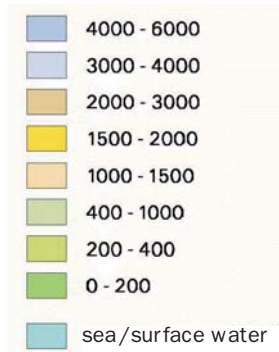
# AMERICAS

## TRANSBOUNDARY AQUIFERS INVENTORY

### OVERVIEW



Elevation (in metres above mean sea level)  
(for aquifer location maps and aquifer maps)



Type of boundary  
(for individual aquifer maps)

Class	Description	Degree of reliability of the boundary		
		Reliable	Approximate	Inferred
1	Boundary of a 'true aquifer' (subsurface body with rather good capacity for storing and transmitting groundwater).			
2	Boundary of a hydrological basin that includes aquifer zones.			
3	Boundary of a geological formation (or its outcrops) in which aquifer zones are found.			
4	Unclassified transboundary subsurface unit, possibly belonging to one of the previous classes.			

Source: UNESCO/OAS, 2007.

# AMERICAS

## TRANSBOUNDARY AQUIFERS INVENTORY

### OVERVIEW

North America		
1N	Abbotsford-Sumas	Canada-USA
2N	Okanagan-Osoyoos	
3N	Grand Forks	
4N	Poplar	
5N	Estevan	
6N	Northern Great Plains	
7N	Châteauguay	
8N	San Diego-Tijuana	Mexico-USA
9N	Cuenca Baja del Río Colorado	
10N	Sonoyta-Pápagos	
11N	Nogales	
12N	Santa Cruz	
13N	San Pedro	
14N	Conejos Médanos-Bolsón de la Mesilla	
15N	Bolsón del Hueco-Valle de Juárez	
16N	Edwards -Trinity-El Burro	
17N	Cuenca Baja del Río Bravo/Grande	

Central America		
1C	Soconusco-Suchiate/Coatán	Guatemala-Mexico
2C	Chicomuselo-Cuilco/Selegua	
3C	Ocosingo-Usumacinta-Pocóm-Ixcán	
4C	Márquez de Comillas-Chixoy/Xaclbal	
5C	Boca del Cerro-San Pedro	
6C	Trinitaria-Nentón	Guatemala-Mexico-Belize
7C	Península de Yucatán-Candelaria-Hondo	
8C	Mopán-Belice	Guatemala-Belize
9C	Pusila-Moho	
10C	Sarstún	
11C	Temash	
12C	Motagua	Guatemala-Honduras
13C	Chiquimula-Copán Ruinas	
14C	Esquipulas-Ocotepeque-Citalá	Guatemala-Honduras-El Salvador
15C	Ostúa-Metapán	El Salvador-Guatemala
16C	Río Paz	
17C	Estero Real-Río Negro	Honduras-Nicaragua
18C	Sixaola	Costa Rica-Panama
28S	Yrendá-Toba -Tarijeño	Argentina-Bolivia-Paraguay
29S	El Cóndor-Cañadón del Cóndor	Argentina-Chile

### Caribbean

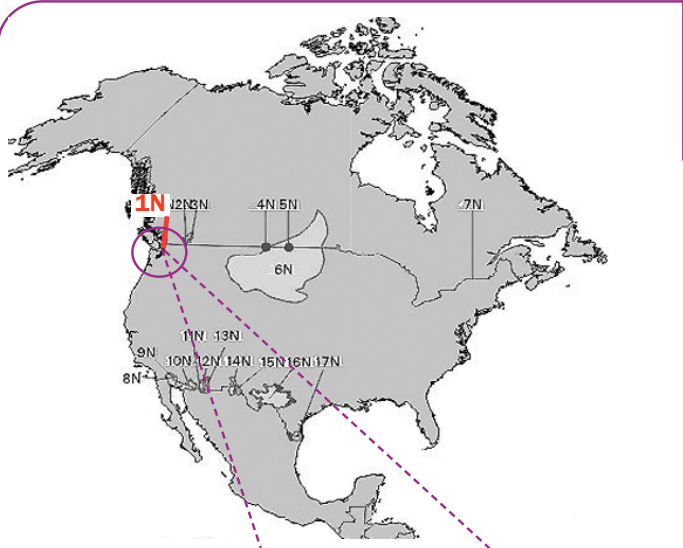
1CB	Masacre	Haití-Rep. Dominicana
2CB	Artibonito	
3CB	Los Lagos	
4CB	Pedernales	

### South America

1S	Choco-Darién	Colombia-Panama
2S	Táchira-Pamplonita	Colombia-Venezuela
3S	La Guajira	
4S	Grupo Roraima	Brazil-Guyana-Venezuela
5S	Boa Vista-Serra do Tucano-North Savanna	Brazil-Guyana
6S	Zanderij	Guyana-Suriname
7S	Coesewijne	
8S	A-Sand/B-Sand	
9S	Costeiro	Brazil-Guayana Francesa
10S	Tulcán-Ipiales	Colombia-Ecuador
11S	Zarumilla	Ecuador-Peru
12S	Puyango-Tumbes-Catamayo - Chira	
13S	Amazonas	Bolivia-Brazil-Colombia-Ecuador-Peru-Venezuela
14S	Titicaca	Bolivia-Peru
15S	Pantanal	Bolivia-Brazil-Paraguay
16S	Agua Dulce	Bolivia-Paraguay
17S	Ollagüe-Pastos Grandes	Bolivia-Chile
18S	Concordia/Escritos-Caplina	Chile-Peru
19S	Aquidauana-Aquidabán	Brazil-Paraguay
20S	Caiuá/Bauru-Acaray	
21S	Guaraní	Argentina-Brazil-Paraguay-Uruguay
22S	Serra Geral	
23S	Litoráneo-Chuy	Brazil-Uruguay
24S	Permo-Carbonífero	
25S	Litoral Cretácico	Argentina-Uruguay
26S	Salto-Salto Chico	
27S	Puneños	Argentina-Bolivia
28S	Yrendá-Toba -Tarijeño	Argentina-Bolivia-Paraguay
29S	El Cóndor-Cañadón del Cóndor	Argentina-Chile



## NORTH AMERICA : Aquifers details



### Abbotsford-Sumas

#### Canada-United States of America

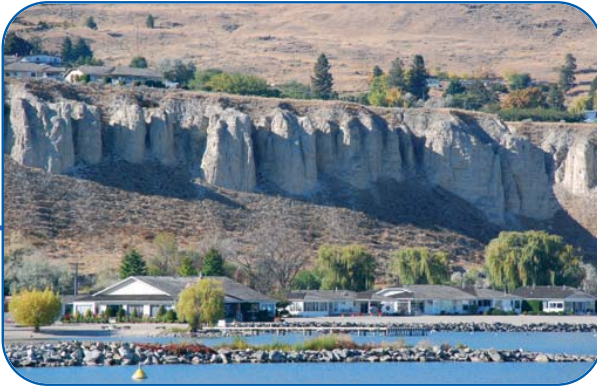
- Extent: 100 km<sup>2</sup>.
- Non confined. Sand and gravel.
- Volume: ~ 3.7 km<sup>3</sup>.
- Provides water supply to 10,000 people in USA and 100,000 in Canada.
- Locally intensively and/or overexploited.
- Vulnerable to contamination.

#### Inter-state instruments

■ **Inter-state cooperation:**  
An international team cooperates in the management of the aquifer, through regular exchange of information and common decision-making.



Lake Kananaski, Canada  
© Morguefile

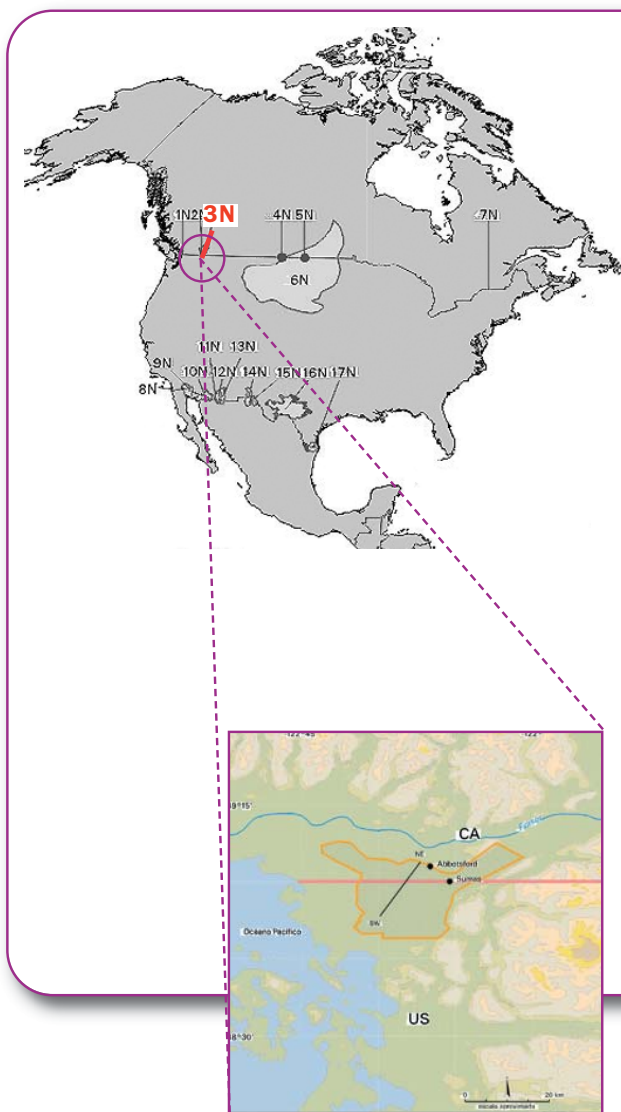


Lake Okanagan, Canada  
© Morguefile

## Okanagan-Osoyoos

**Canada-United States of America**

- Extent: 25 km<sup>2</sup>.
- Depth: 100–500 m.
- Multilayered.
- Non consolidated sediments.
- More important use in Canada all year.
- Increase in population due to development of vineyards .



## Grand Forks

### Canada- United States of America

- Extent: 34 km<sup>2</sup>.
- Depth: 50–100 m.
- Alluvial aquifer.
- Non consolidated sediments.
- Voume: 1.7 km<sup>3</sup>.
- Excellent database available.

Lake Okanagan, Canada  
© Morguefile

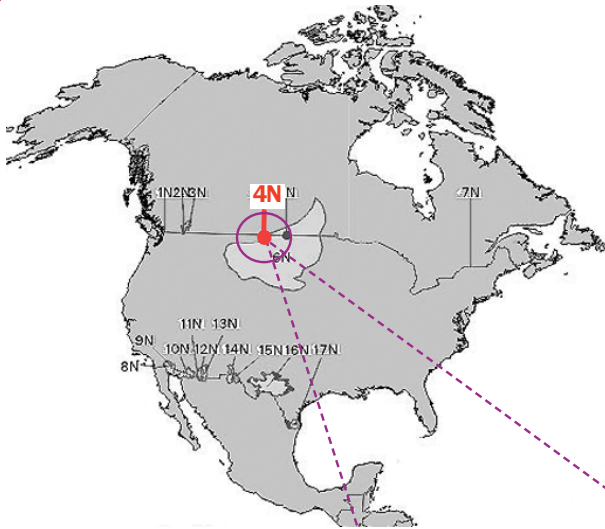




Lake Waterton, Canada  
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## Poplar

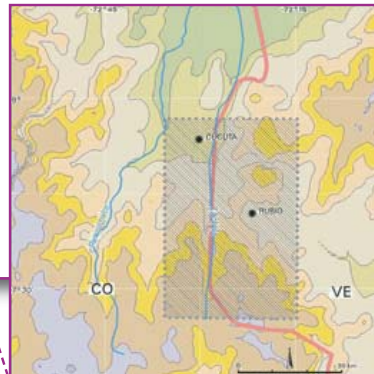
### Canada-United States of America



- Limited information available.
- Extent: more than 10,000 km<sup>2</sup>.

#### Inter-state instruments

- **Inter-state cooperation:**  
A bilateral committee has been established to exchange information on monitoring.

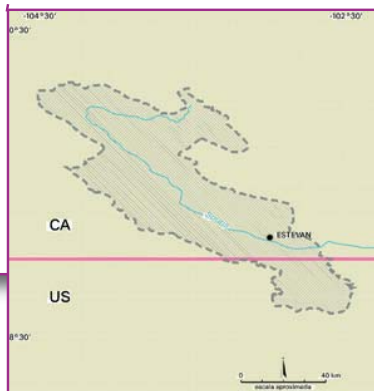
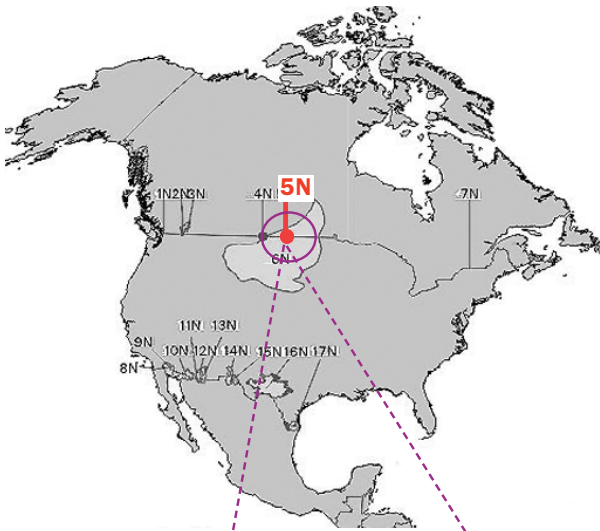




## Estevan

### Canada- United States of America

- Extent: 280 km<sup>2</sup>.
- Length: 70 km, width: 4 km.
- Confined, included in less permeable bedrock. Covered by an aquitard of 80 m approx., thickness mainly composed of moraines.
- Exploitation on Canadian side: 37.5 mm<sup>3</sup>/year.

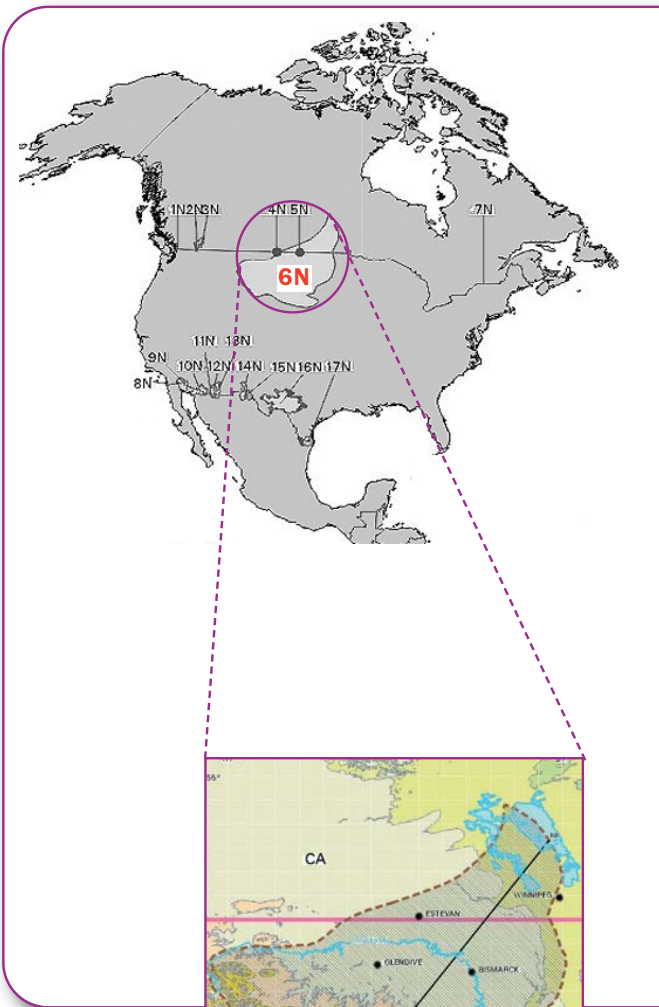


Fort Edmonton Park,  
North Saskatchewan River, Canada  
© SXC/Jeremy Bohn





Glacier National Park, Montana, USA  
© Morguefile



## Northern Great Plains

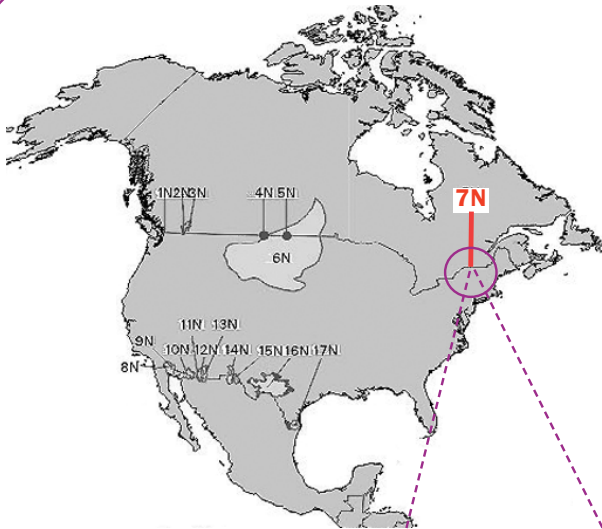
### Canada-United States of America

- Large, confined aquifer system: more than 500,000 km<sup>2</sup>, 75% in USA.
- System transmissivity: 100 m<sup>2</sup>/d.
- Combined recharge: regional scale in USA, local scale in Canada.





## Châteauguay



### Canada- United States of America

- Extent: 2,500 km<sup>2</sup>.
- Groundwater use: 15 mm<sup>3</sup>/a, on Canadian side only.
- Average thickness: 500 m.
- Important use in Canada with 55% of total area and high demand for all uses.

#### Inter-state instruments

- **Inter-state cooperation:** Bilateral cooperation.

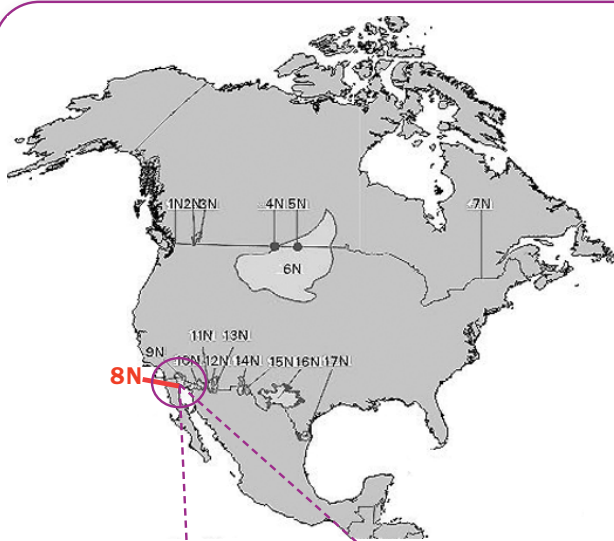


Tremblant, Quebec, Canada  
© SXC





Highway to Tijuana, Mexico  
© SXC

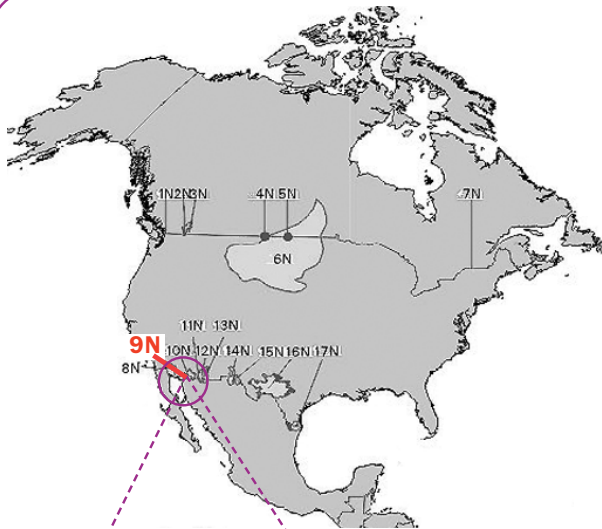


## San Diego-Tijuana

### Mexico-United States of America

- Small extent.
- High water demand in both countries, high exploitation in Mexico.
- Problems: contamination and seawater intrusion.
- Semi-arid climate.





## Cuenca Baja del Río Colorado

### Mexico-United States of America

- Semi-arid climate.
- More important use on Mexican side.
- Problems of spreading contamination due to agricultural practices.
- Aquifer studied in both countries: database and model simulation available.

#### Inter-state instruments

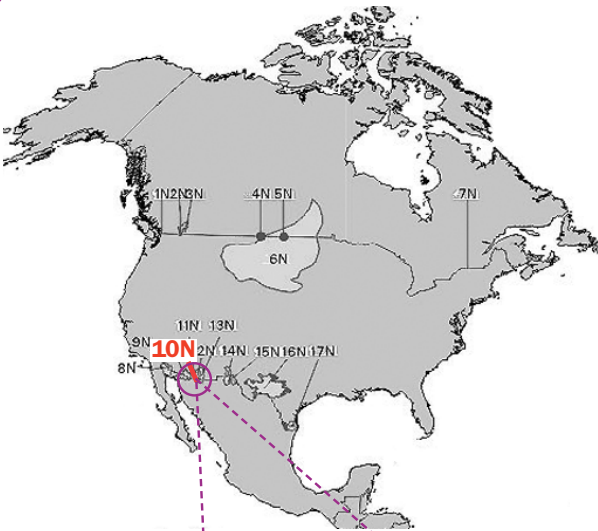
- Negotiations within **International Commission of International Boundaries and Water Commission - Comisión Internacional de Límites y Aguas (IBWC-CILA)**.

Lake Mead, Colorado River, USA  
© SXC/Shauette Babb





San Jose Mountains, Sonora, Mexico  
© Morguefile



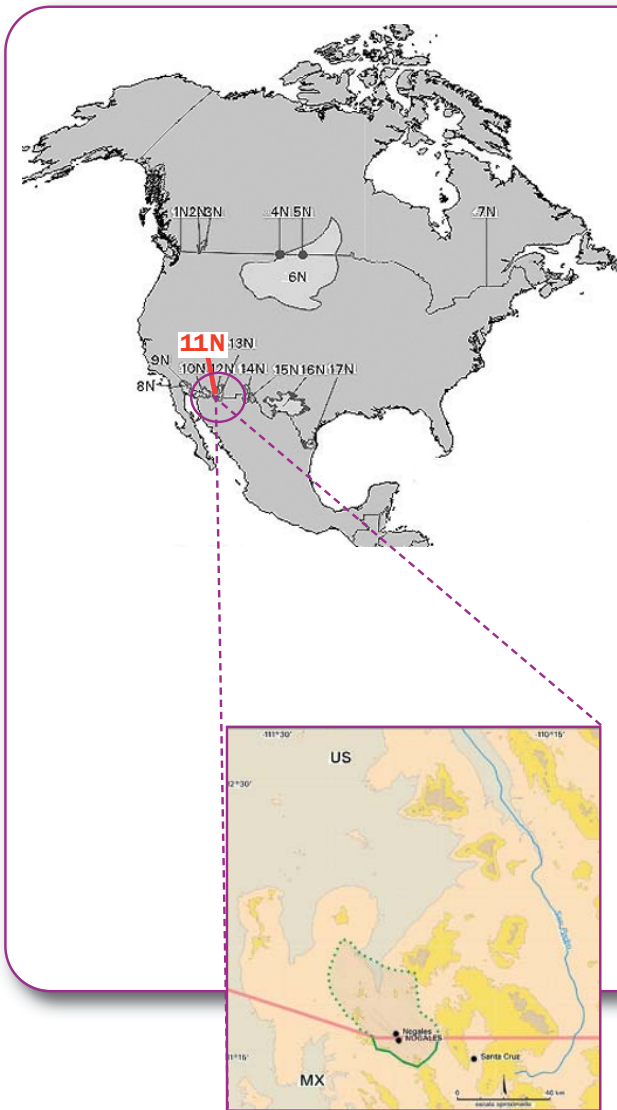
## Sonoyta-Pápagos

### Mexico-United States of America

- Alluvial aquifer.
- Depth: 20 to 200 m.
- Low population density.
- Main use: agriculture in Mexico.
- Brackish water locally.
- Semi-arid climate.







## Nogales

### Mexico-United States of America

- Alluvial materials and fissured rocks.
- Small extent, shallow depth, medium permeability.
- Semi-arid climate.
- Urban and industrial use in both countries.
- Contamination problems.

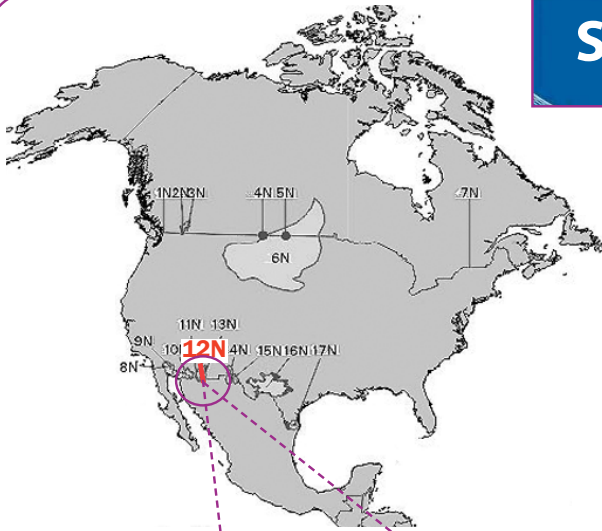
Sierra Vista, Arizona, USA  
© Morguefile





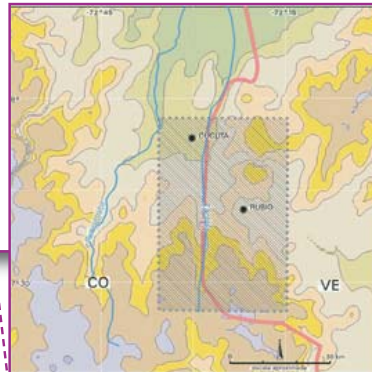
Arizona, USA  
© Morguefile

## Santa Cruz



### Mexico-United States of America

- More important use in USA, for agriculture.
- Alluvial materials, conglomerates, fissured volcanic rocks.
- Semi-arid climate.
- Several studies have been carried out.

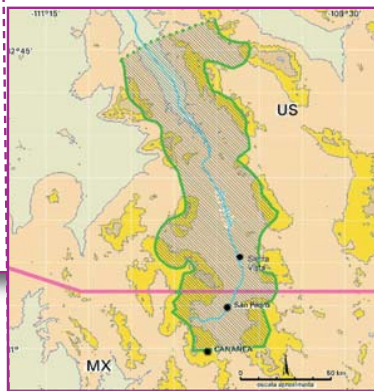
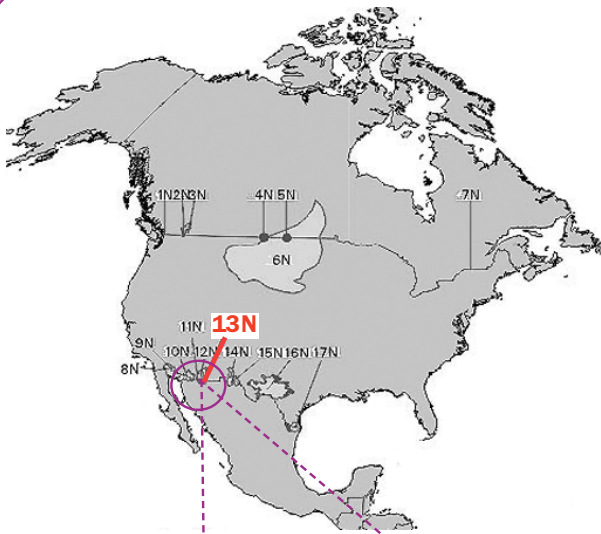




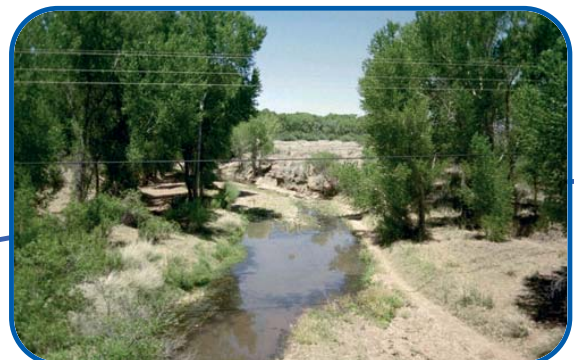
## San Pedro

### Mexico-United States of America

- Semi-arid climate.
- Alluvial materials in valleys and conglomerates in adjacent hills.
- Important for agricultural development of both countries.



San Pedro River, Arizona, USA  
© Morguefile



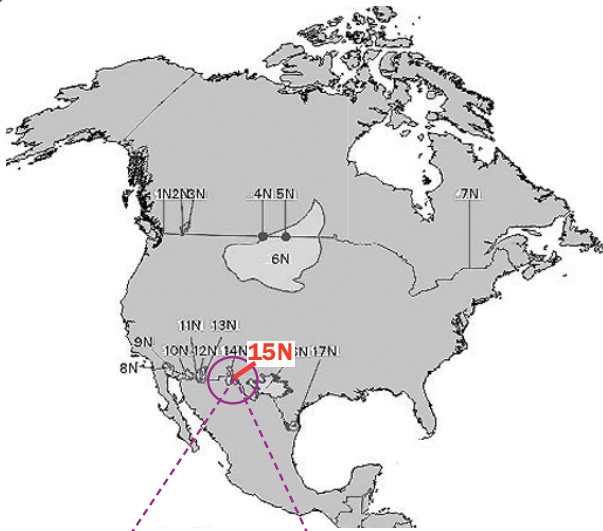


Urique River at the base of Urique Canyon, Chihuahua, Mexico  
© SXC/Rosy Figueroa

## Conejos Médanos-Bolsón de la Mesilla

### Mexico-United States of America

- Extent: 10,000 km<sup>2</sup>.
- Non confined.
- Very arid region.
- Project of artificial recharge in Mexican part of the aquifer.



## Bolsón del Hueco-Valle de Juárez-Colorado

### Mexico- United States of America

- Extent: 8,000 km<sup>2</sup>.
- Non confined.
- Semi-arid climate.
- Gradual decline in the quality of water.



#### Inter-state instruments

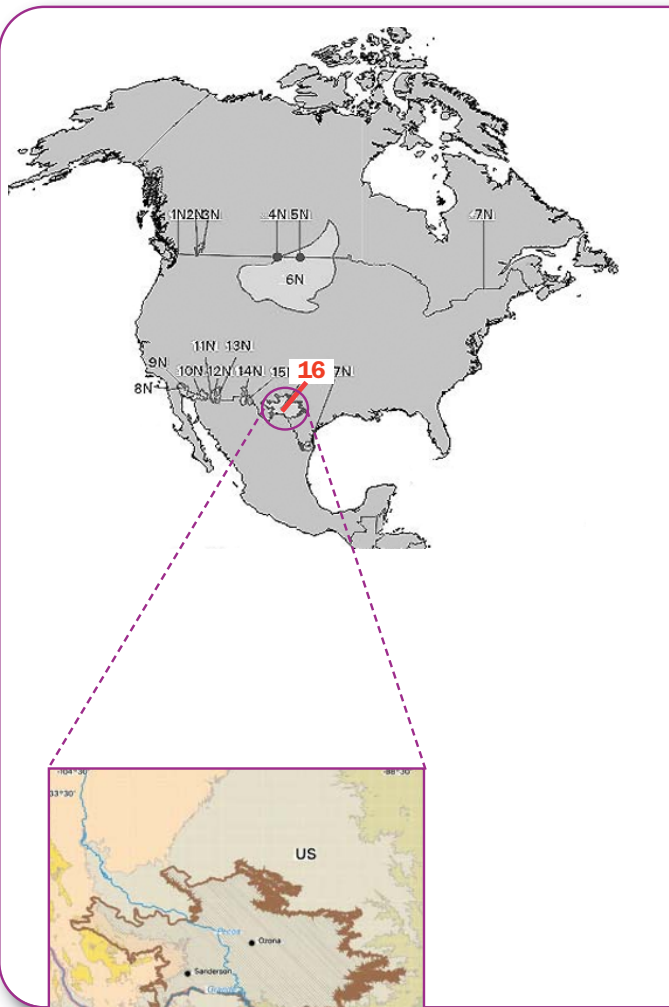
- **Inter-state cooperation:**
  - Exchange of information.
  - Bi-national study aimed at a common formulation of management strategies.

Colorado River, Texas, USA  
© SXC





New Mexico, USA  
© SXC

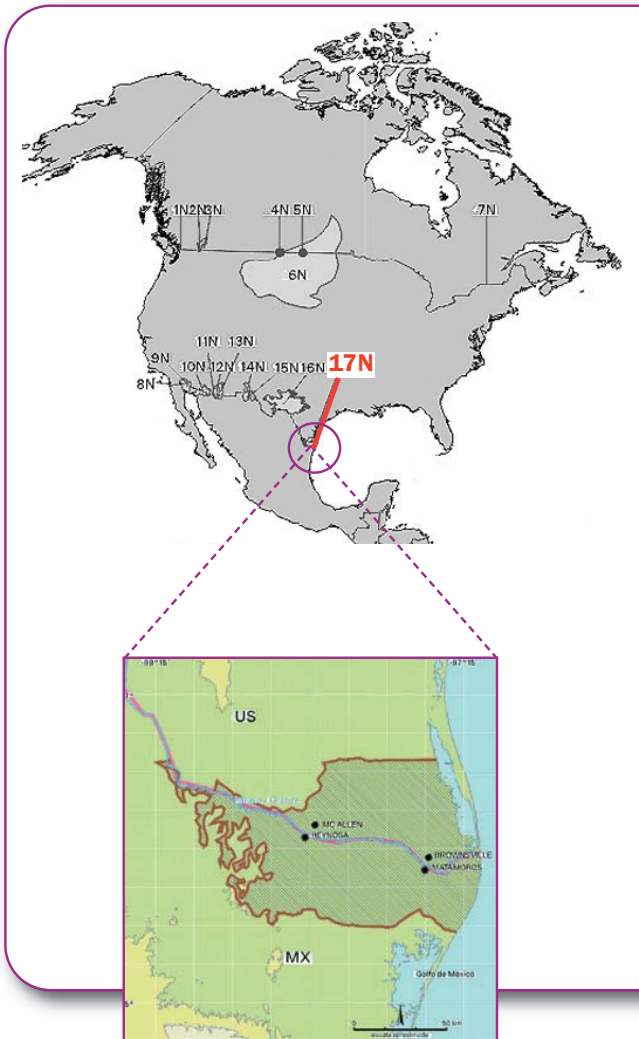


## Sonoyta-Edwards-Trinity-El Burro

### Mexico-United States of America

- Arid region.
- Extent in USA: 70,000 km<sup>2</sup> (more than 90% of its area).
- Limestone of high secondary permeability.
- Increasing population and industrial development.





## Cuenca Baja del Río Bravo/ Grande

### Mexico-United States of America

- Multilayered aquifer.
- Recharge depends on river water volume flow.
- Salinity problems.
- Semi-arid climate.

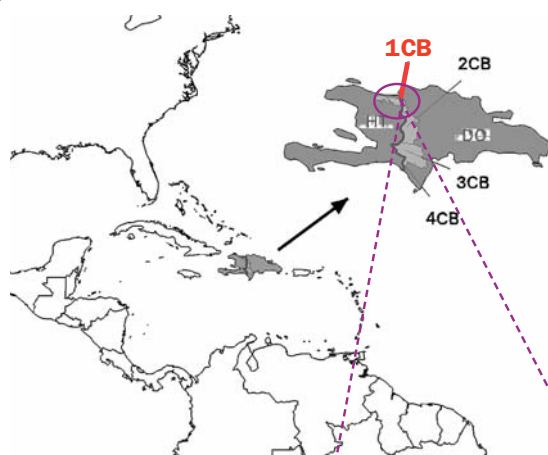
Guadalupe River, Texas  
© Morguefile



## CARIBBEAN: Aquifers details



Saut Mathurine, Haiti  
© SXC



### Inter-state instruments

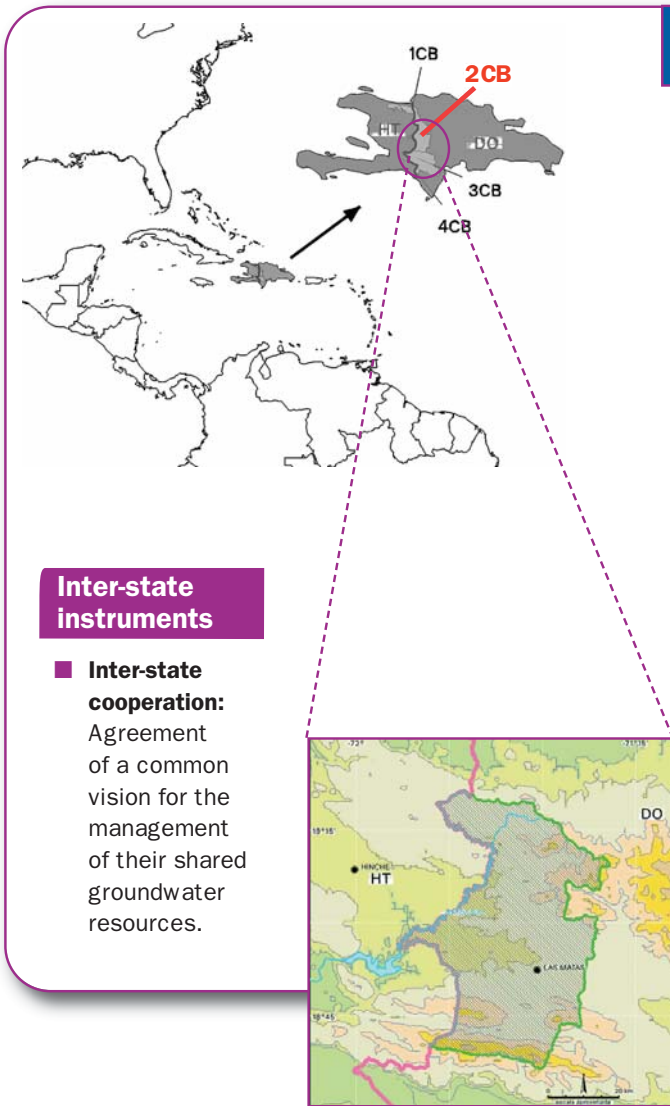
- **Inter-state cooperation:** Agreement of a common vision for the management of their shared groundwater resources.

## Masacre

### Haiti-Dominican Republic

- Extent: 1,200 km<sup>2</sup> on Dominican side and 1,080 km<sup>2</sup> on Haitian side.
- Coastal aquifer. Problems of seawater intrusion.
- Main uses: domestic and agriculture.
- Is the subject of a GEF/UNEP/OAS/UNESCO project focused on its protection and sustainable use.





### Inter-state instruments

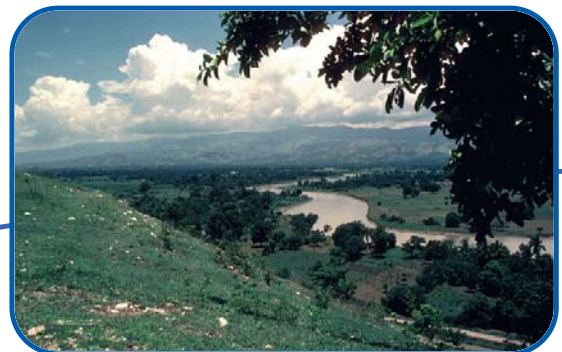
- **Inter-state cooperation:** Agreement of a common vision for the management of their shared groundwater resources.

## Artibonito

### Haiti-Dominican Republic

- Extent: 3,000 km<sup>2</sup> in Dominican Rep. and 6,780 km<sup>2</sup> in Haiti.
- As Masacre aquifer, concerned by the GEF/UNEP/OAS/UNESCO project as an example of intermountain transboundary aquifer for which the objective is to halt desertification and land degradation and alleviate poverty .

Artibonito Valley  
© UNESCO/Michel Claude



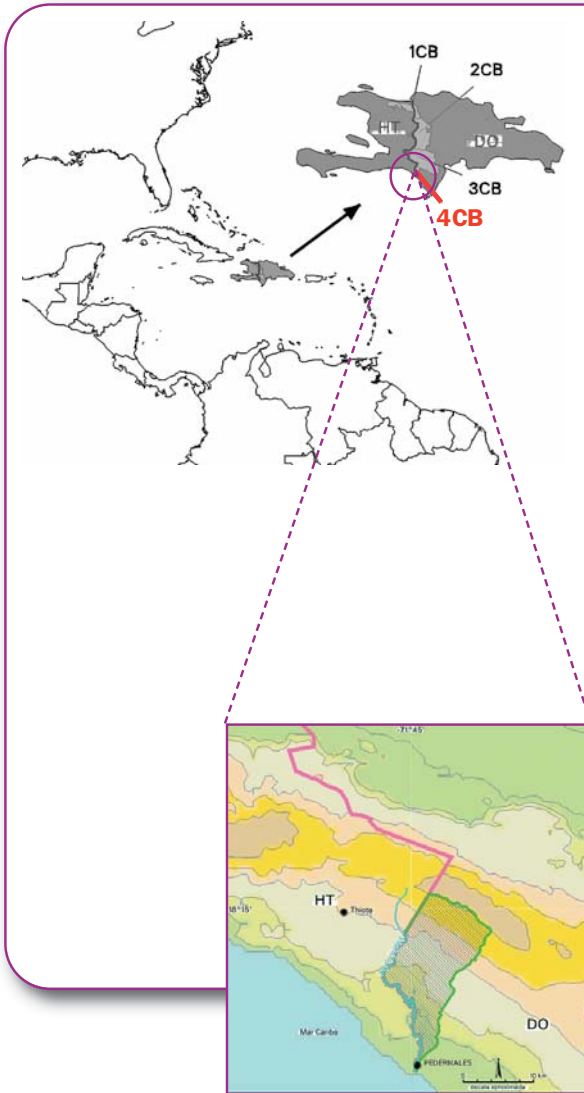


Artibonito Valley  
© UNESCO/Michel Claude

## Los Lagos

### Haiti-Dominican Republic

- Extent: 2,300 km<sup>2</sup> on Dominican side.
- Current use in both countries: domestic, agriculture, and potentially in industry.
- Recharge zone: ~900 km<sup>2</sup> on Dominican side, and ~150 km<sup>2</sup> on Haitian side.



## Pedernales

### Haiti-Dominican Republic

- Extent: 2,300 km<sup>2</sup> on the Dominican side.
- Use: agriculture and potentially for tourism on the Dominican side, domestic and agricultural use on Haiti.
- Hydrogeological characteristics are known in detail.

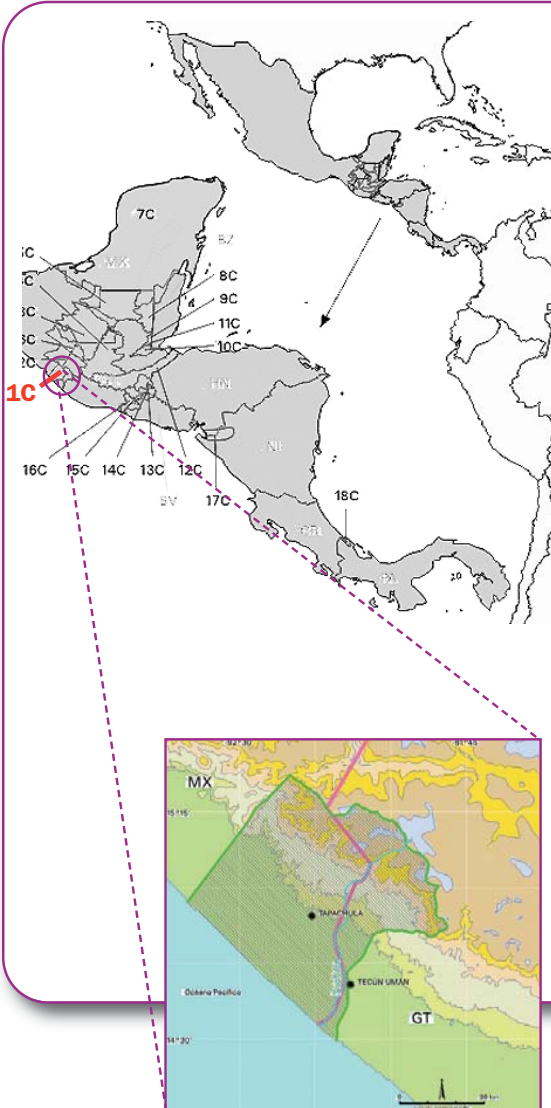
*Artibonito Valley*  
© UNESCO/Michel Claude



CENTRAL AMERICA: Aquifers details



Guatemala Highlands  
© SXC

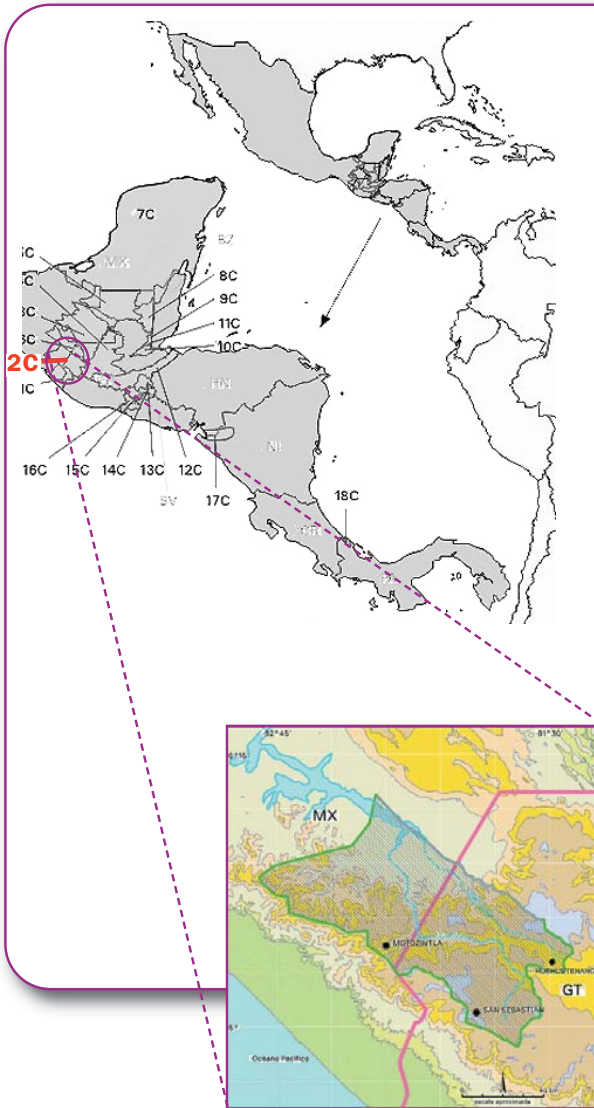


**Soconusco-  
Suchiate/  
Coatán**

**Guatemala-  
Mexico**

- Domestic use concerns 1,500,000 people.
- Used for agriculture to a lesser extent.
- Non confined aquifer.
- Local problems of salinization due to human activities.



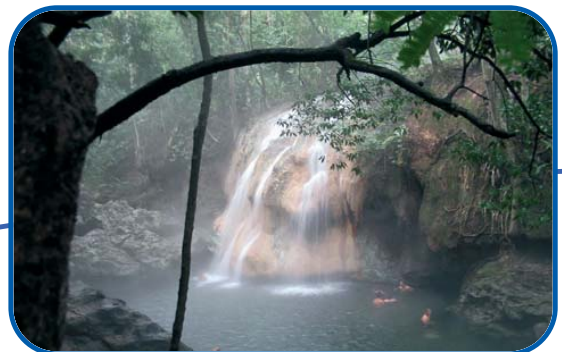


## Chicomuselo-Cuilco/Selegua

### Guatemala-Mexico

- Dry climate and mountain topography.
- Non confined aquifer with important karst development.
- Hydrogeological information available in both countries.
- Main source of supply for agriculture and domestic uses.
- Contamination due to human activities.

Izabal, Guatemala  
© SXC





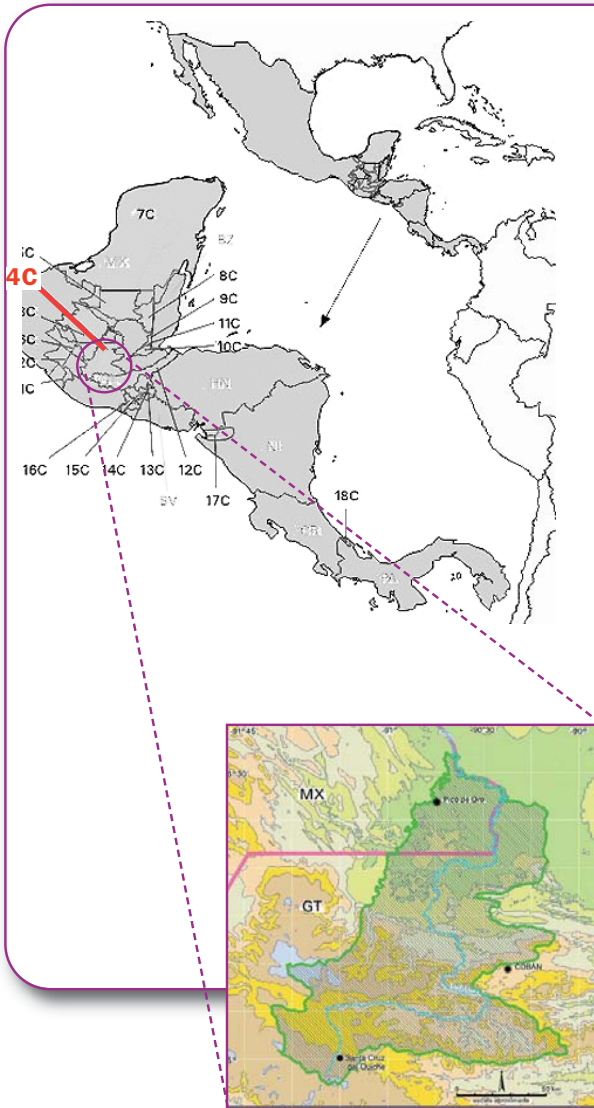
Volcano at Lake Atitlan, Guatemala  
© SXC

## Ocosingo-Usumacinta-Pocóm-Ixcán

### Guatemala-Mexico

- Karst aquifer with deep levels combined with complex flow systems.
- Locally, water is not fit for human consumption due to high concentrations of sulfates and carbonates.
- The aquifer supplies water for domestic and agricultural uses to rural population.



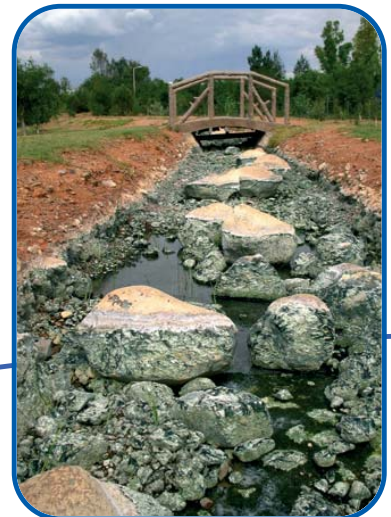


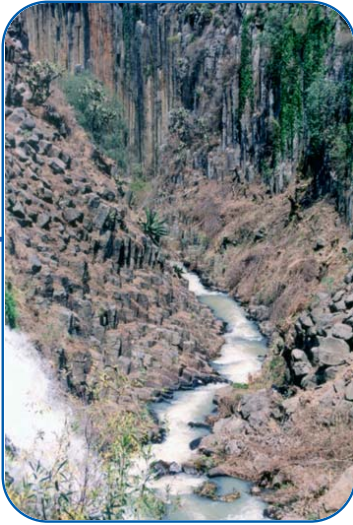
## Márquez de Comillas-Chixoy/Xaclbal

### Guatemala-Mexico

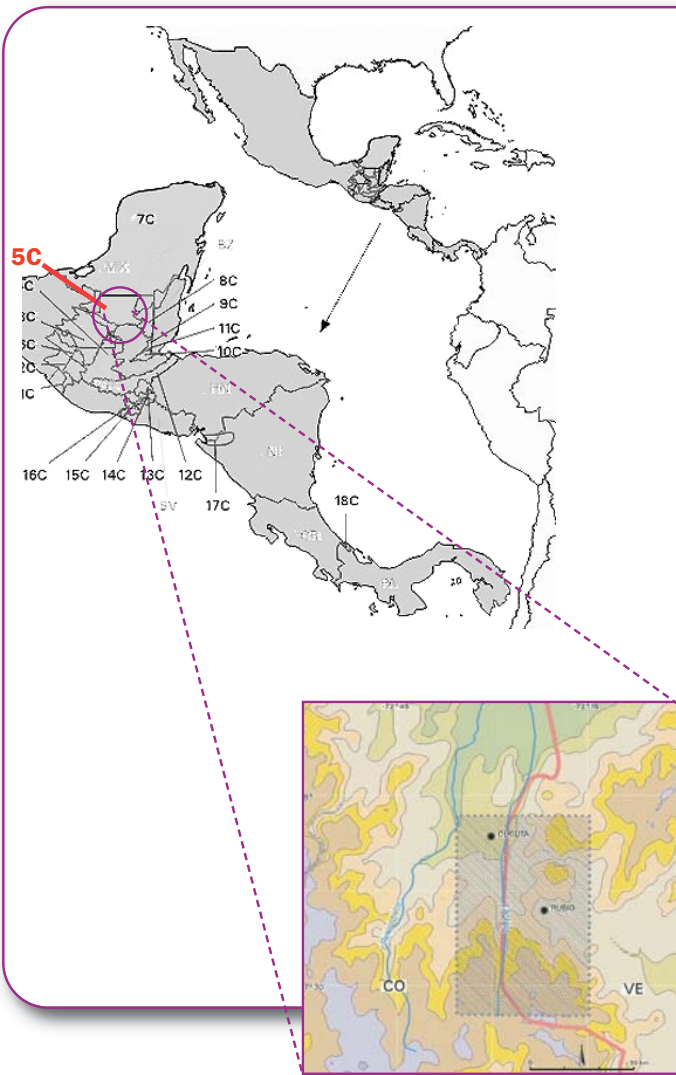
- Supplies water to urban and rural population and, to a lesser extent, for irrigation of small areas.
- Karst aquifer with deep circulation.
- Water flow from Guatemala to Mexico.

River, Mexico  
© SXC





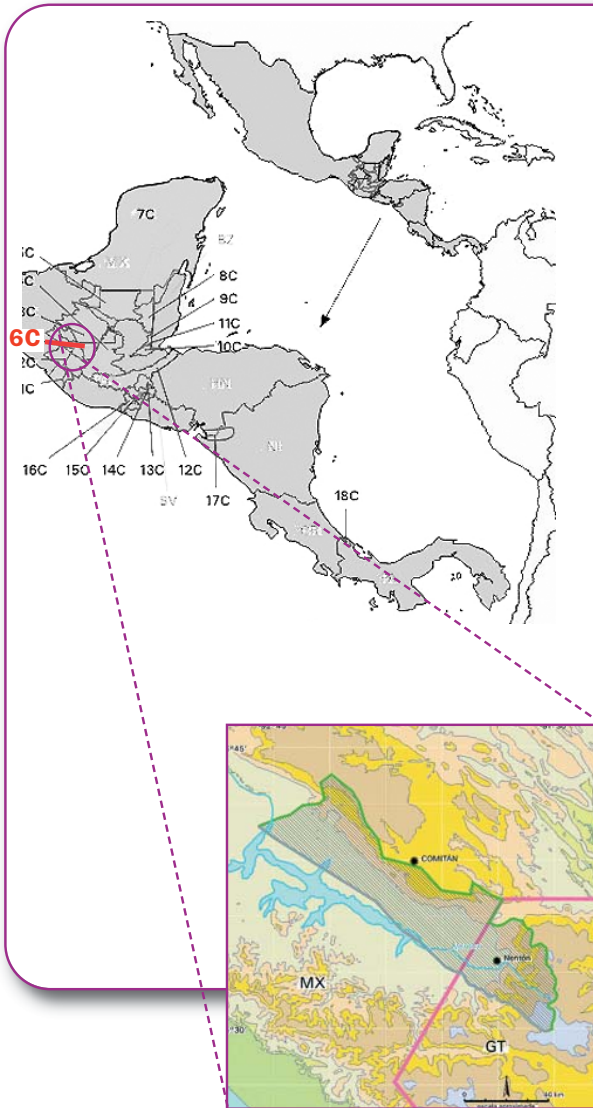
Basalt Prism Canyon, Hidalgo, Mexico  
© Morguefile



## Boca del Cerro-San Pedro

### Guatemala-Mexico

- Karst aquifer with deep circulation.
- Limited exploitation due to high content of sulphates and carbonates.
- The aquifer is being investigated by both countries.



## Trinitaria-Nentón

### Guatemala-Mexico

- Main source of supply for rural population.
- Locally contaminated due to waste water discharge.
- Non confined aquifer.
- Water flow from Guatemala to México.
- Studies are on a preliminary phase.

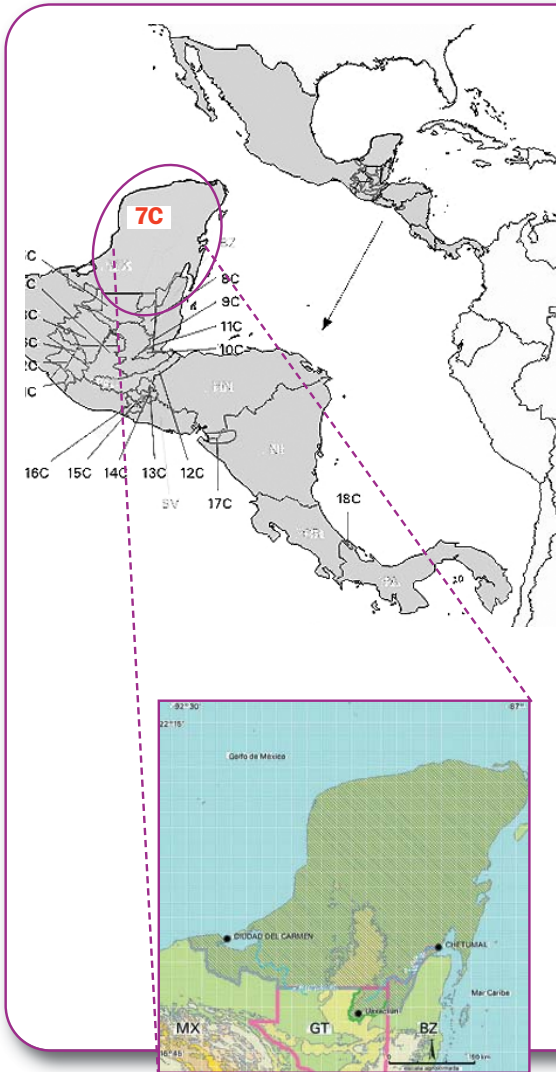
Cusarare Waterfall, Mexico  
© Morguefile







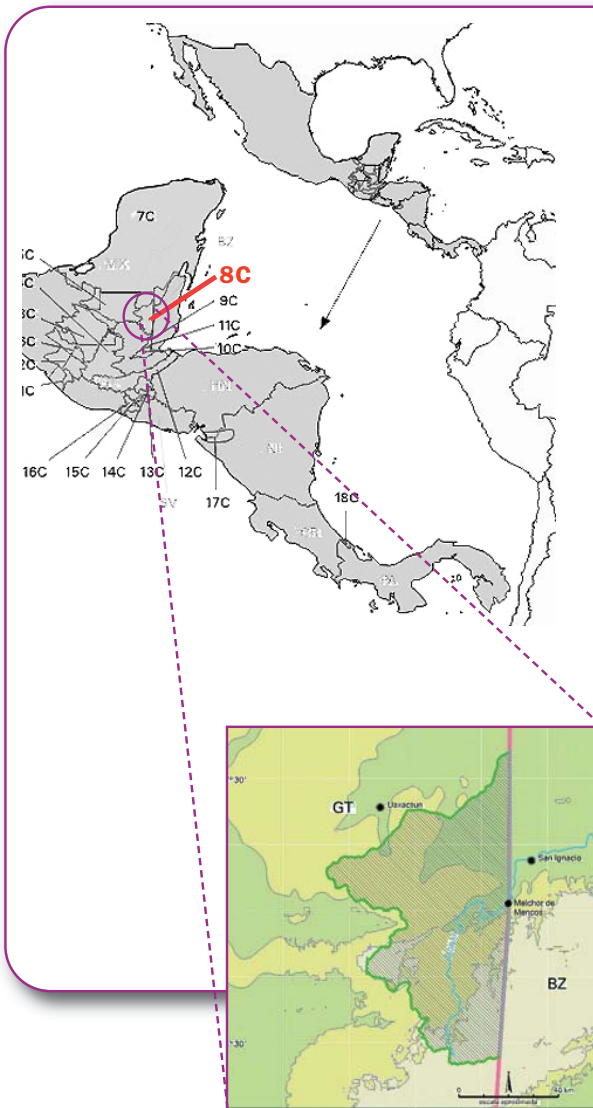
Malinalco landscape, Mexico  
© Morguefile



## Península de Yucatán-Candelaria-Hondo

### Guatemala-Mexico Belize

- Plain region with high infiltration capacity.
- Karst aquifer with high permeability and high vulnerability to anthropogenic contamination.
- Limited hydrogeologic knowledge due to low local development.
- Main source of supply for rural population.



## Mopán-Belize

### Guatemala-Belize

- Principle studies carried out on Guatemala part of aquifer, where it covers almost 5,000 km<sup>2</sup> and where discharge occurs.
- Humid climate.
- High deforestation.
- Vulnerable to anthropogenic contamination.

San Cristobal Verapaz, Guatemala  
© UNESCO/Inguat-Samajoa





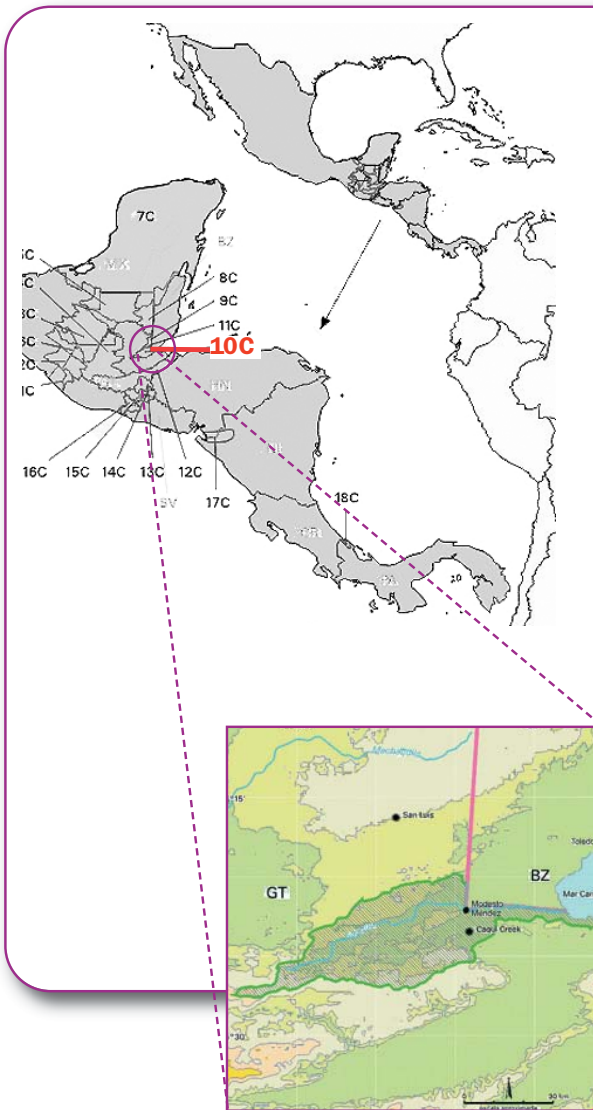
View from the top of Mayan ruins in Lamanai, Belize  
© SXC

## Pusila-Moho

### Guatemala-Belize

- Extent in Guatemala: 644 km<sup>2</sup>.
- Humid tropical climate.
- Multilayered aquifer.
- Vulnerable to anthropogenic contamination and floods.





## Sarstún

### Guatemala-Belize

- Extent: 2,109 km<sup>2</sup> in Guatemala.
- Highly deforested zone, but some remaining forest areas.
- Insufficient water supply for human and livestock consumption.

Chixoy Dam, Guatemala  
© UNESCO/Inguat-Samajoa



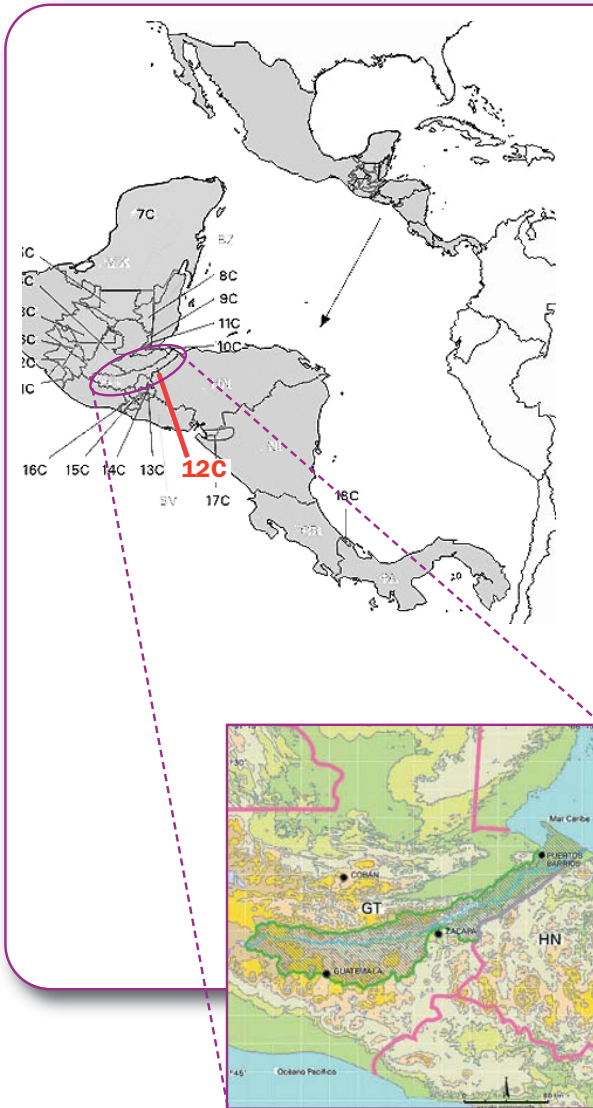


Guatemalan forestland  
© UNESCO/Inguat-Samajoa

## Temash

### Guatemala-Belize

- Extent: 69 km<sup>2</sup> in Guatemala.
- Humid tropical climate.
- Highly deforested zone, but remaining forest areas.
- Vulnerable to anthropogenic contamination and floods.



## Motagua

### Guatemala-Honduras

- Extent: ~2,300 km<sup>2</sup>, flow to the Caribbean Sea.
- Rain: 600–3,000 mm/year.
- Shallow depth.
- Variable transmissivity.

Rio Platano, Honduras  
© UNESCO/Fubomichi Kudo





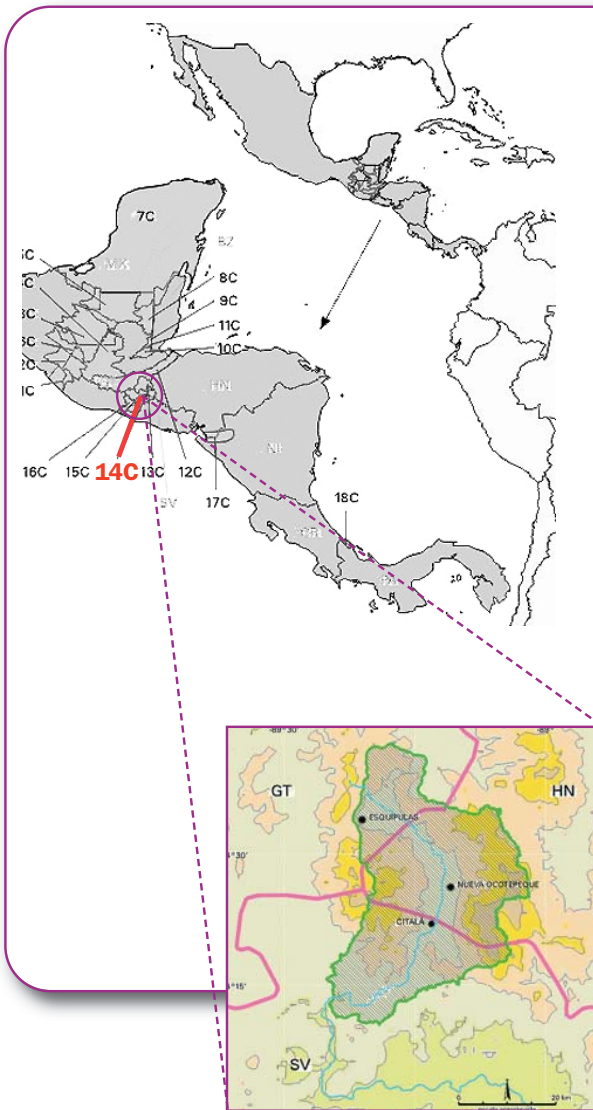
Copan ruins, Honduras  
 © UNESCO/Guillermo Cobos Hernandez

## Chiquimula-Copán Ruinas

### Guatemala-Honduras

- Region including dry sub-tropical and semi-arid zones.
- Flow from Honduras to Guatemala
- Underpopulated area.
- Subsistence agriculture.
- Water shortage.





## Esquipulas- Ocotepeque- Citalá

### Guatemala- Honduras- El Salvador

- Aquifer extent: 600 km<sup>2</sup> approx.
- Population of the area: 100,000 inhabitants.
- Humid climate.
- Multilayered and complex aquifer system.
- Problems: contamination, over-exploitation, loss of recharge areas.

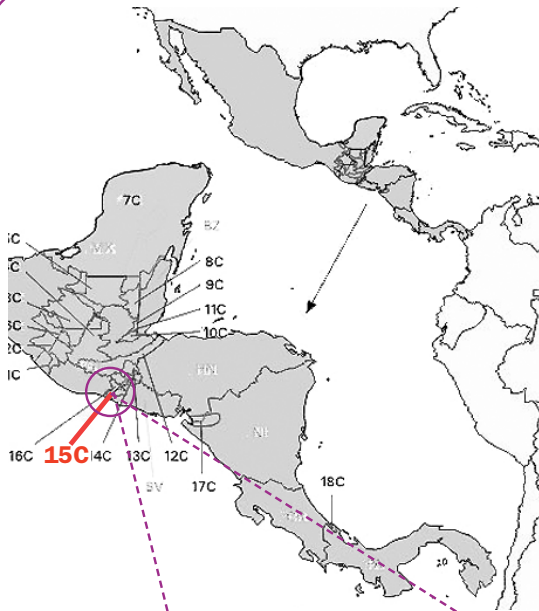
Flores, Guatemala  
© SXC





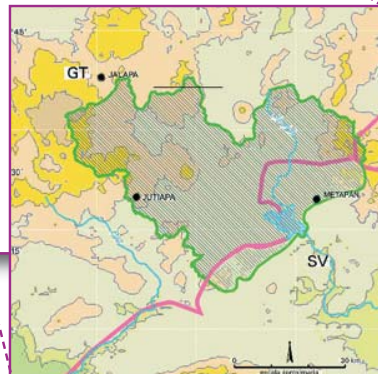
Lake Coatepeque, El Salvador  
© SXC

## Ostúa-Metapán



### El Salvador-Guatemala

- Semi-arid zone with about 500,000 inhabitants.
- Extent: 800 km<sup>2</sup>.
- Multilayered aquifer.
- Problems: contamination, over-exploitation,







## Río Paz

### El Salvador-Guatemala

- Geothermal exploitation of deeper aquifer (1,000–1,200 m) .
- Main uses: irrigation and human consumption.
- Shallow aquifers highly exploited.
- Problems: contamination, loss of recharge areas, deforestation.

San José Lake, Guatemala  
© SXC



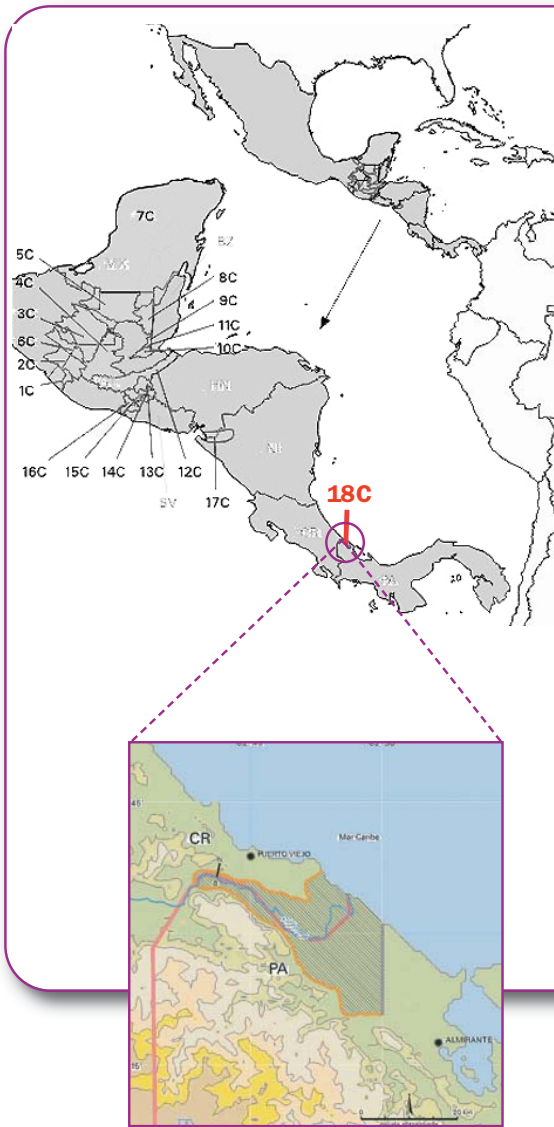


Copan ruins, Honduras  
© SXC

## Estero Real- Río Negro

### Honduras- Nicaragua

- Non confined, depth 5–60 m.
- Vital for human consumption in rural communities.
- Problems: contamination.
- Both countries are implementing integrated management procedures.

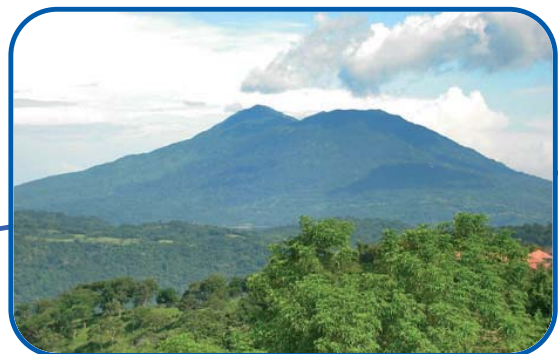


## Sixaola

### Costa Rica- Panama

- Main use: agro-industry.
- Future possible uses for human consumption and tourism.
- A strategy concerning the sustainable use of Río Sixaola exists, and both countries are considering projects for an integrated management of the aquifer.

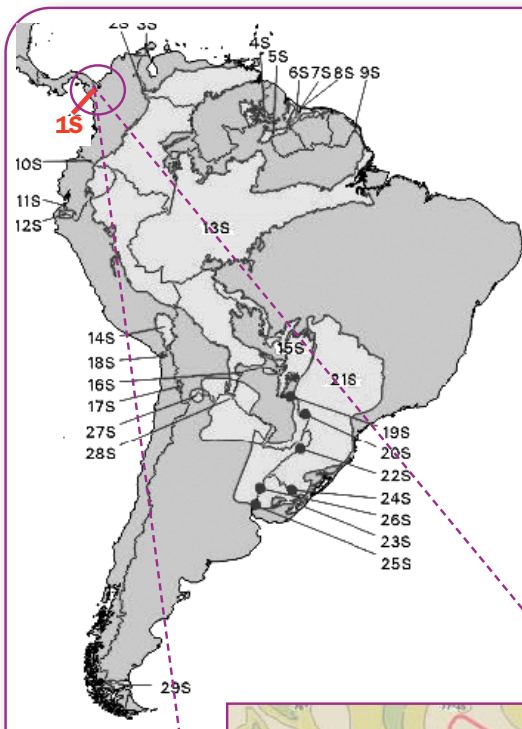
Volcano, Nicaragua  
© SXC/Charle Noe



## SOUTH AMERICA: Aquifers details



Darien National Park, Panama  
© UNESCO/Kudo Fubomichi



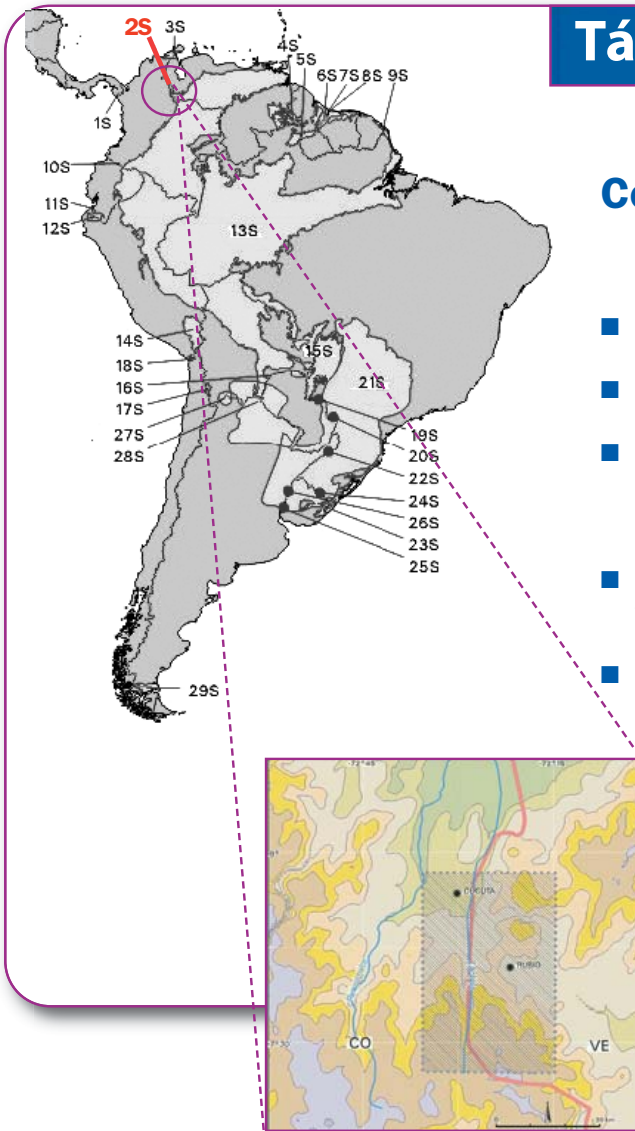
### Choco-Darién

#### Colombia-Panama

- Humid climate.
- Mean annual rainfall: 3,500 mm.
- Rainforest area with low impact of human activities (fishery, subsistence agriculture).







## Táchira-Pamplonita

### Colombia-Venezuela

- Extent: ~ 80 km<sup>2</sup>.
- Mean annual rainfall: 740 mm.
- Two superposed aquifers aged between Cretaceous and Quaternary period.
- Dynamic region between the two countries.
- Exploitation without sustainability strategy.

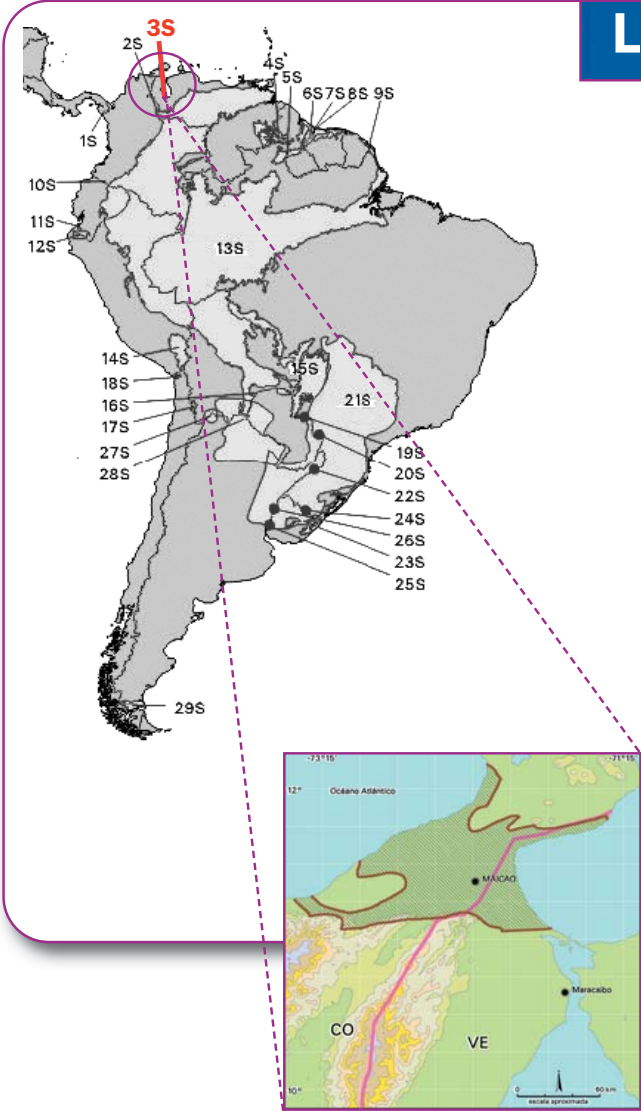
Canaima National Park, Venezuela  
© UNESCO







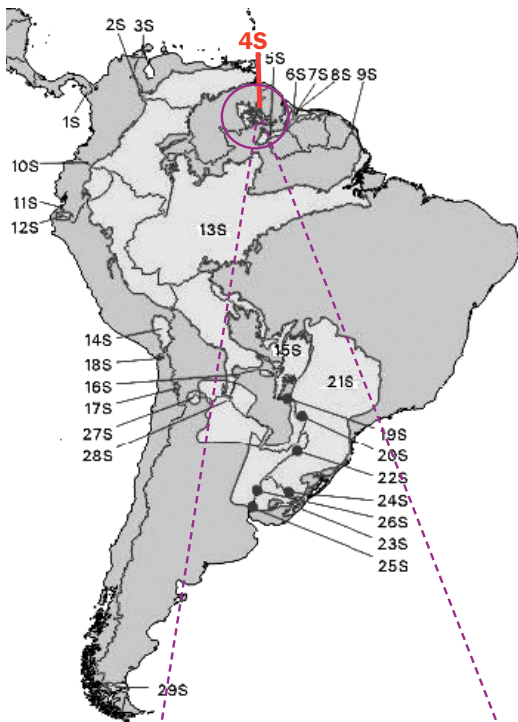
Los Tiatos National Park, Colombia  
© UNESCO/J.C. Segura



## La Guajira

### Colombia-Venezuela

- Coastal plain, elevations from 0 to 20 m.a.s.l., arid climate, mean temperature above 28° C.
- Annual rainfall below 500 mm.
- Aquifer system including shallow and deep aquifers.
- Non confined, intensively used aquifer.
- Salinization problems.



## Grupo Roraima

### Brazil-Guyana-Venezuela

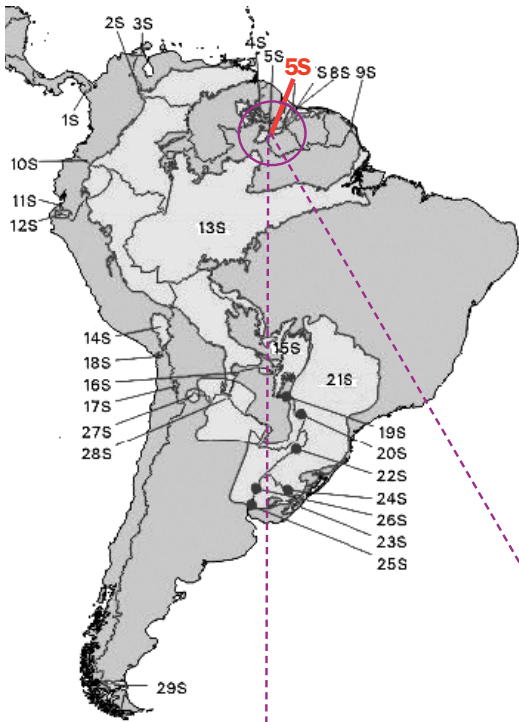
- Extent: ~ 70,000 km<sup>2</sup>.
- Altitude higher than 1,000 m.
- Mean annual rainfall: 1,200–2,400 mm.
- Tropical rainy climate.
- Larger part of aquifer system in Brazil.

Guyana Jungle, Amazonia.  
© SXC





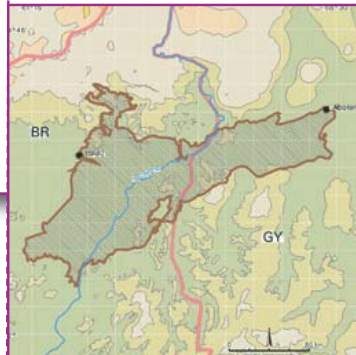
Venezuela, Guyana, Surinam and Trinidad as seen from Gemini 10  
© NASA

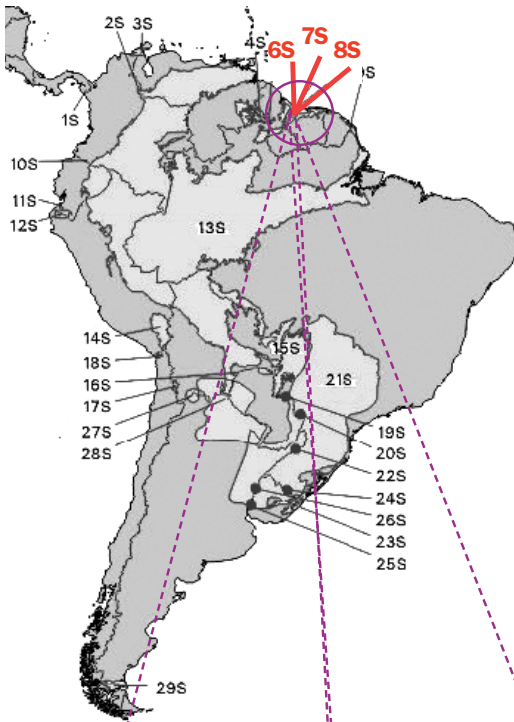


## Boa Vista-Serra do Tucano-North Savanna

### Brazil-Guyana

- Extent: ~24,000 km<sup>2</sup>, 60% in Brazil and 40% in Guyana.
- Semi-humid climate.
- Uses: public supply and agriculture.
- Aquifer predominantly non confined.
- Vulnerable to contamination by toxic products used in local agriculture.





## Zanderij Coesewijne A-Sand/B-Sand

### Suriname- Guyana

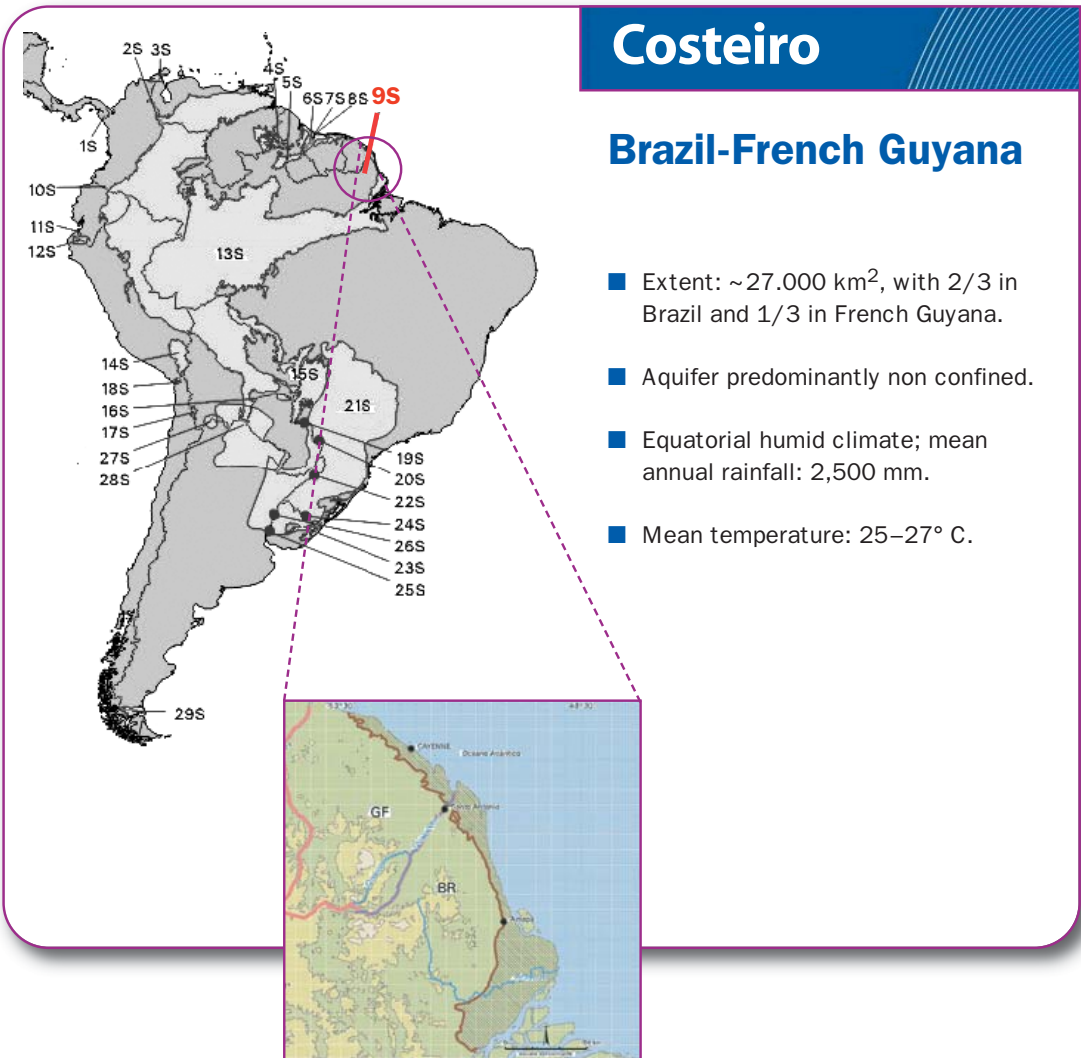
- The three aquifers are mainly located along the coastal strip of both countries. Total extent: ~200,000 km<sup>2</sup>.
- Tropical climate, mean annual rainfall: 2,000 mm.
- Main uses: domestic and public supply, main source of drinking water.
- Hydrogeology of the three aquifers is well known. A-Sand aquifer has supplied water to Paramaribo for more than 50 years. Hydrogeological investigations with international support continue in both countries.



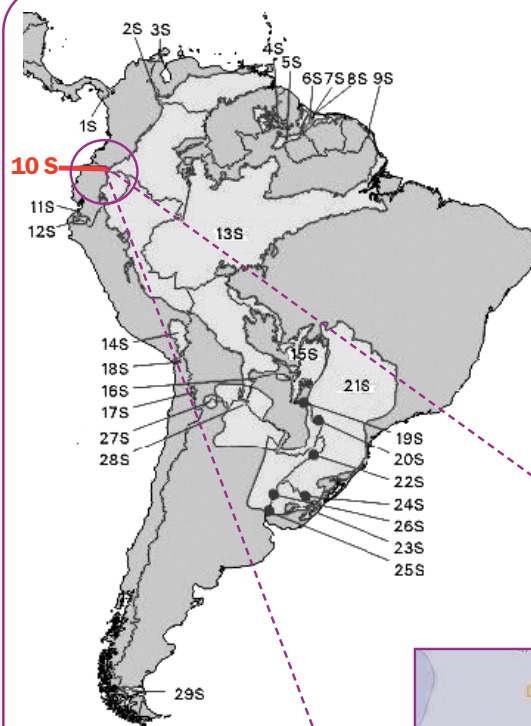




River at Maués, Amazonia, Brazil  
© UNESCO/Luis Alberto



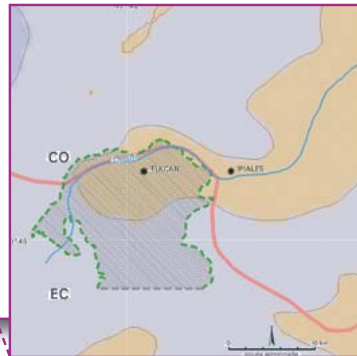




## Tulcán-Ipiales

### Colombia-Ecuador

- Important source for different uses. Good quality water.
- Thermo-mineral in some areas.
- Lack of hydrogeologic information, studies in both countries are planned.

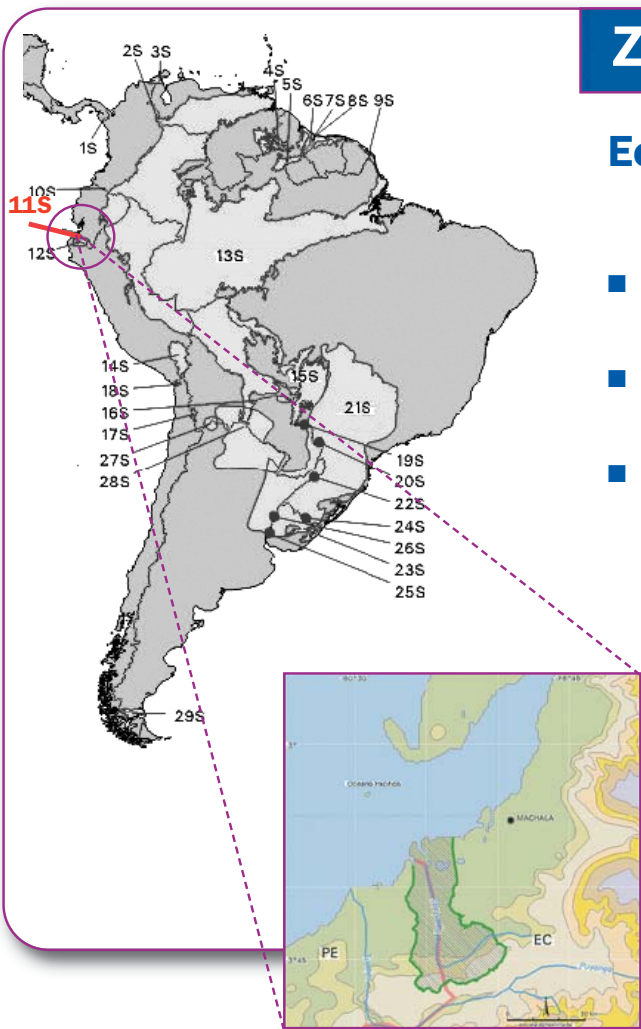


*The Napo in the Amazonian Forest, Ecuador*  
© UNESCO/Andes - CZAP - ASA





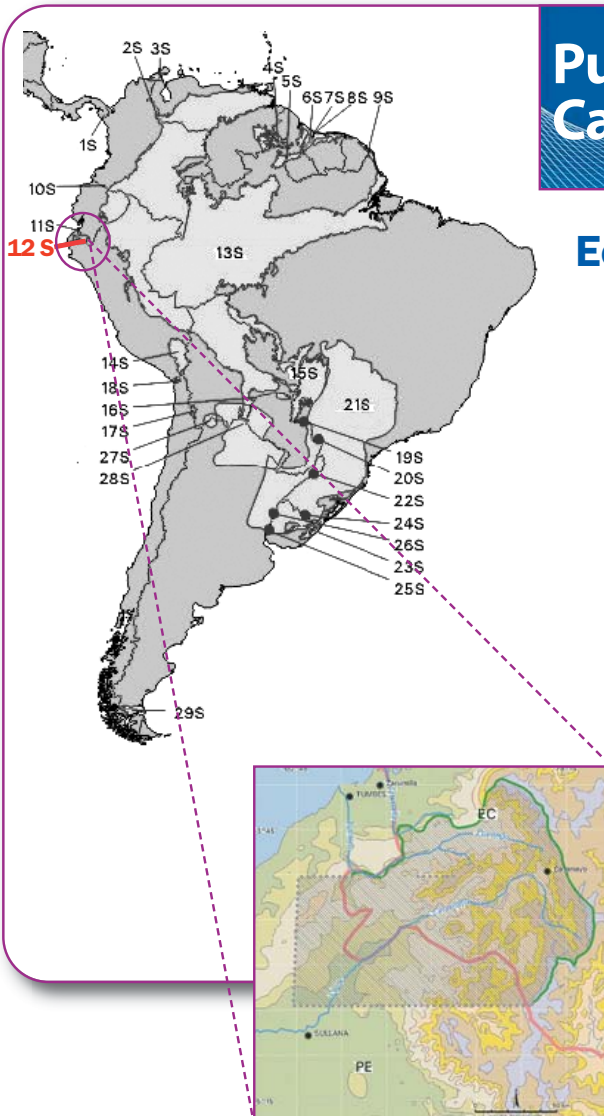
Cuenca: remains at Pumapungo of an ancient water system from the Inca city of Tumipamba, Ecuador © UNESCO/Alison Clayson



# Zarumilla

## Ecuador-Peru

- Extent: ~920 km<sup>2</sup>, population: 70,000 inhabitants.
- Arid zone. High salinity in several zones.
- Detailed studies have been executed by both countries with the cooperation of the International Agency for Atomic Energy.



## Puyango-Tumbes-Catamayo-Chira

### Ecuador-Peru

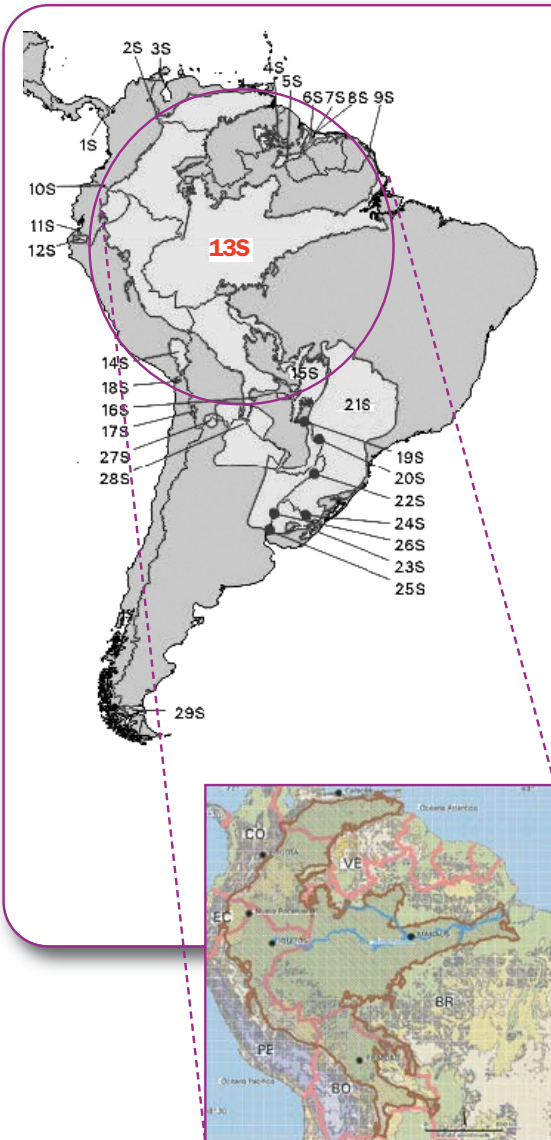
- Main local activities: agriculture and stockbreeding.
- Lack of information on its hydrogeology.
- Groundwater could be used because current water supply is not sufficient.
- Peru is currently executing detailed studies in Tumbes Valley. In other valleys both countries are planning geologic and hydrogeologic studies.

*Ancient water management technology,  
Machu Picchu, Peru*  
© UNESCO/Karen Stoltz





Amazonia, Brazil  
© SXC

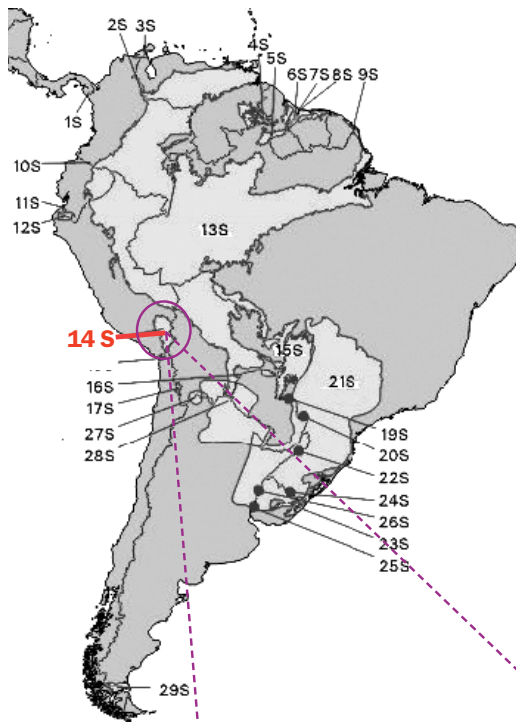


## Amazonas

### Bolivia - Brazil - Colombia - Ecuador, Peru - Venezuela

- Extent: ~3,950,000 km<sup>2</sup>
- Climate: Humid, up to 3 dry months, mean temperature above 18° C.
- Good yield and good water quality.
- Lack of studies because most of the aquifer is located in zones with few inhabitants and where access is difficult.
- Important for several communities living beside rivers because the aquifer is the only alternative to contaminated surface waters.

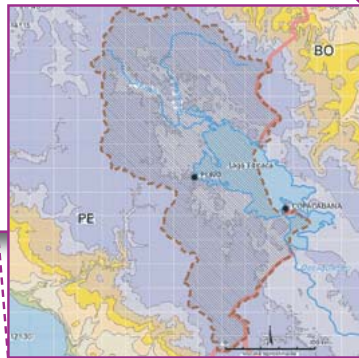




## Titicaca

### Bolivia-Peru

- Located above 4,000 m.a.s.l., located in a fragile ecosystem.
- Extent: 120,000 km<sup>2</sup>.
- Geology: Quaternary sediments.
- Aquifers confined and non confined.
- Cold and dry climate.
- Scattered population: ~1,000,000 inhabitants.
- Used for drinking water supply, livestock breeding and agriculture.



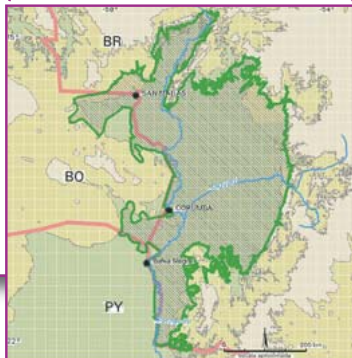
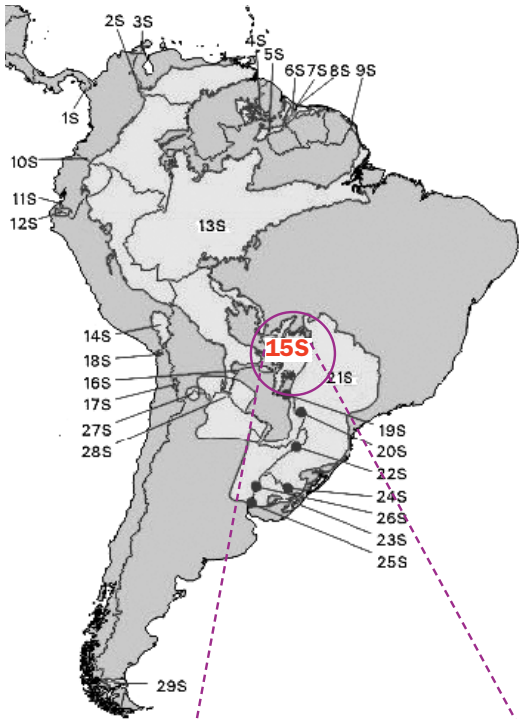
Fishermen and reed boats on Lake Titicaca, Bolivia  
© UNESCO/P. Kruthof







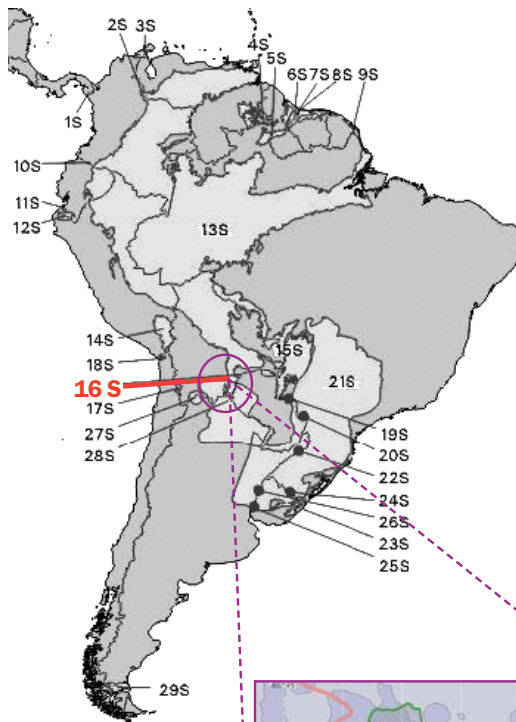
Pantanal salt bay, Brazil  
© SXC



## Pantanal

### Bolivia-Brazil-Paraguay

- Extent: above 130,000 km<sup>2</sup>, 80% located in Brazil, on the Pantanal Plain.
- Multilayered system, phreatic, composed of tertio-quaternary sediments, consolidated and non consolidated, predominantly sandy.
- Mean rainfall: 1,000–1,500 mm.
- Highly vulnerable to contamination.
- The three countries have recognized the important role of the aquifer for the ecosystem of the Pantanal wetland.
- A GEF/UNEP/OAS/UNESCO pilot project will focus on the protection of the aquifer and its dependent ecosystem.



## Agua Dulce

### Bolivia-Paraguay

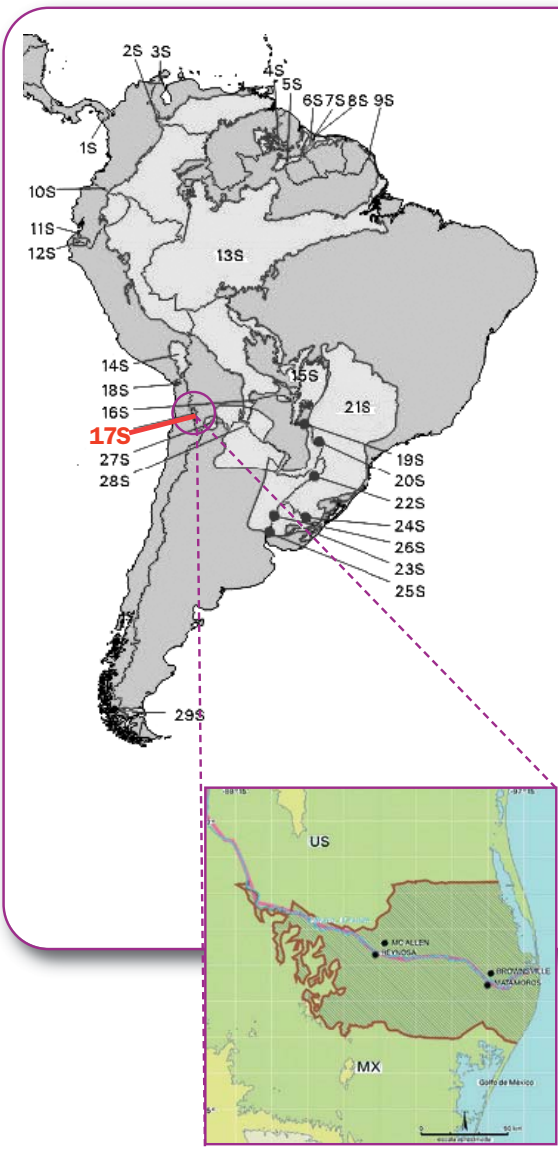
- Located in the Chaco plain, extent: ~30,000 km<sup>2</sup>.
- Aquifer system with Carboniferous and Cretaceous aquifers. Mineralized and thermal Paleozoic confined units.
- Humid tropical climate.
- Mean annual rainfall: 1,450 mm.
- Scattered population.

*Agriculture on the Chaco Plain, Paraguay*  
© NASA





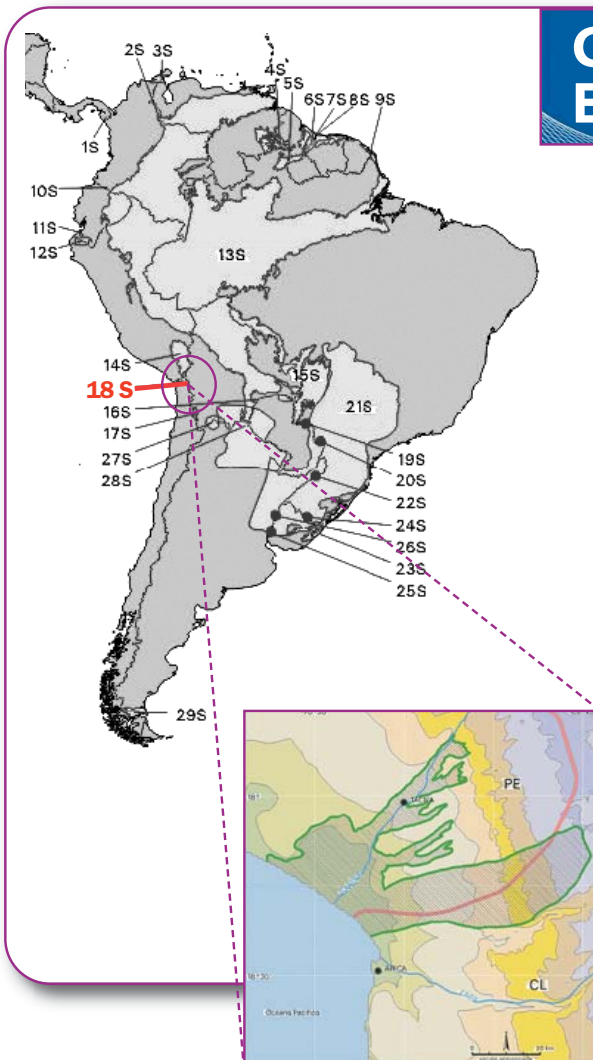
Landscape of a lagoon  
between Chile and Bolivia  
© SXC



# Ollagüe-Pastos Grandes

## Bolivia-Chile

- Located in the Cordillera Occidental de los Andes.
- Extent: ~4,350 km<sup>2</sup>.
- High mountain arid and cold climate.
- Aquifers non confined to confined, tertiary fractured rocks and quaternary sediments.
- Scattered population.
- Located in a fragile ecosystem.



## Concordia / Escritos-Caplina

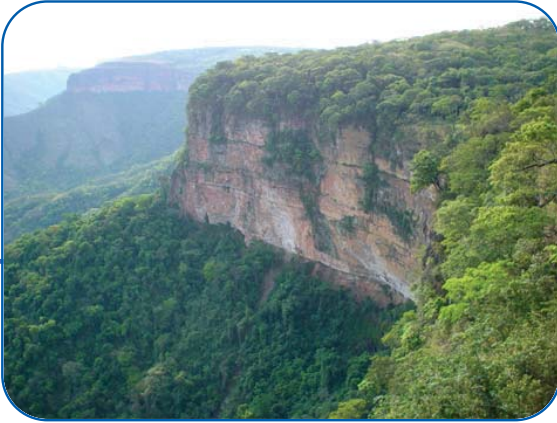
### Chile-Peru

- Arid and dry zone.
- Hydrogeological information available.
- Intensive use from both countries due to shortage of surface water.
- On the Peruvian side, overexploitation is causing contamination (marine intrusion and mineralization).
- Peru carried out detailed studies of the Caplina Aquifer.

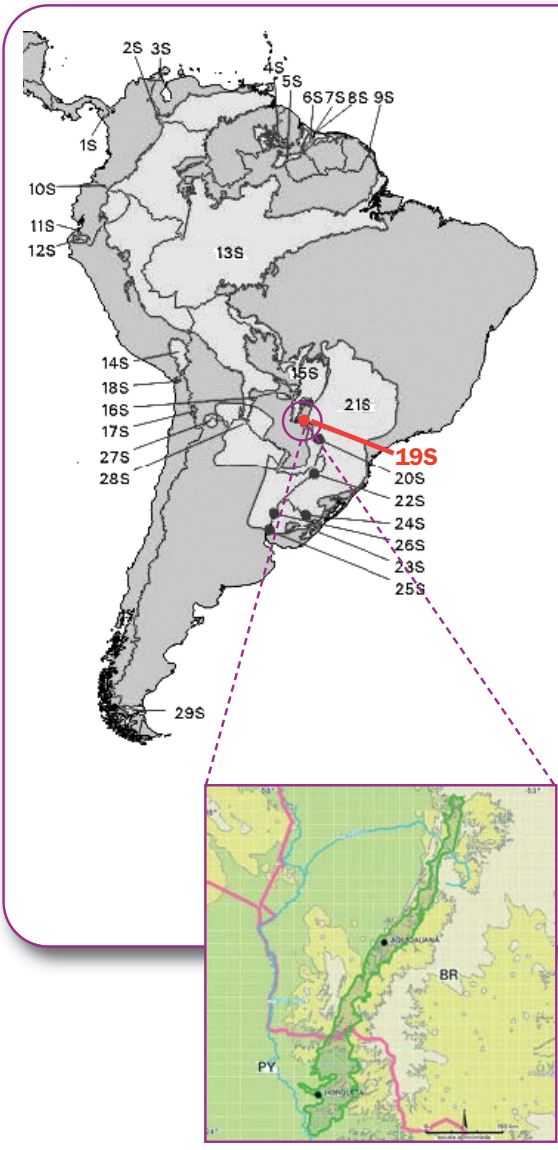
*Fauna in Chilean countryside*  
© UNESCO/Thierry Jolly







Matogrosso, Brazil  
© Morguefile

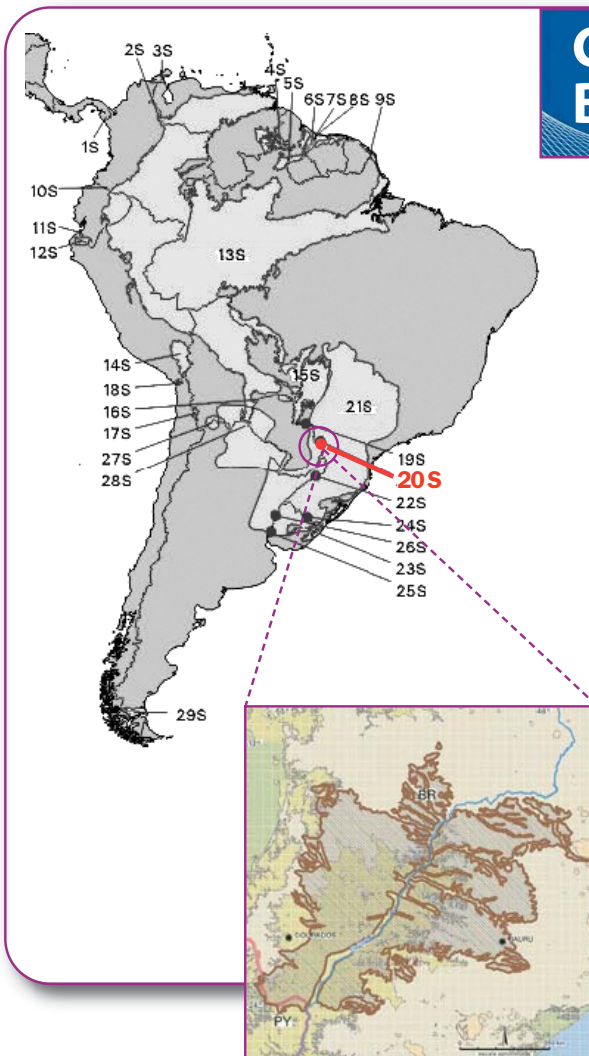


## Aquidauana-Aquidabán

### Brazil-Paraguay

- Extent: 27,000 km<sup>2</sup>.
- Rainfall: 1,000–1,500 mm/year, mostly in summer.
- Semi-confined aquifer.
- Lack of hydrogeologic information but important for development of agriculture and stockbreeding in the region.
- Uses: human and livestock supply.





## Caiuá/ Bauru-Acaray

### Bolivia-Paraguay

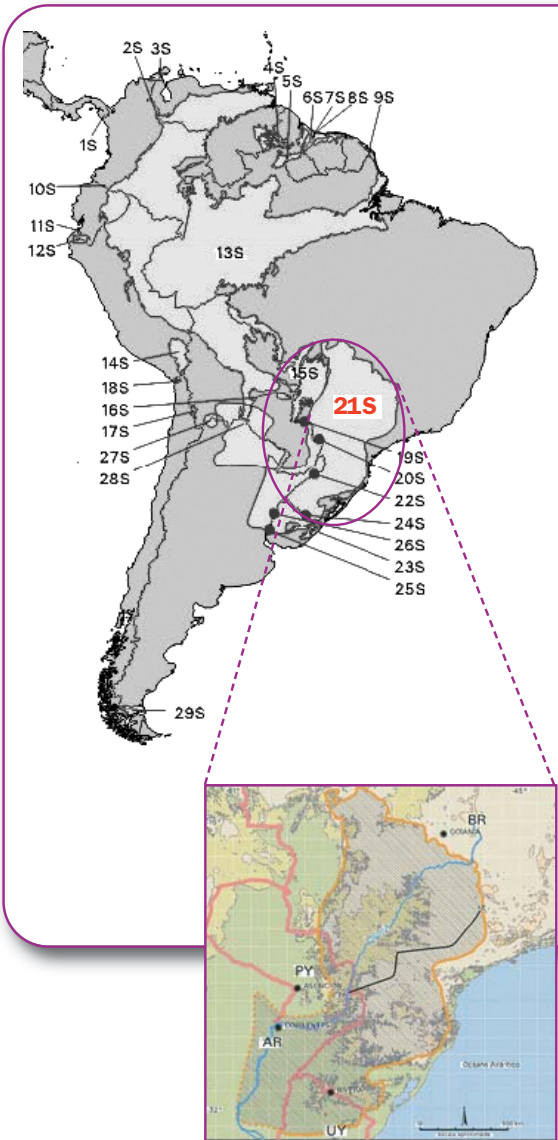
- Extent: ~300,000 km<sup>2</sup>.
- Non confined aquifer, mean thickness: 200 m, highly permeable.
- High potential for exploitation, water volume: 40–60 m<sup>3</sup>/h.
- Hydrogeological regional importance due to good quality of water and high productivity of wells.

Uyuni, Bolivia  
© SXC





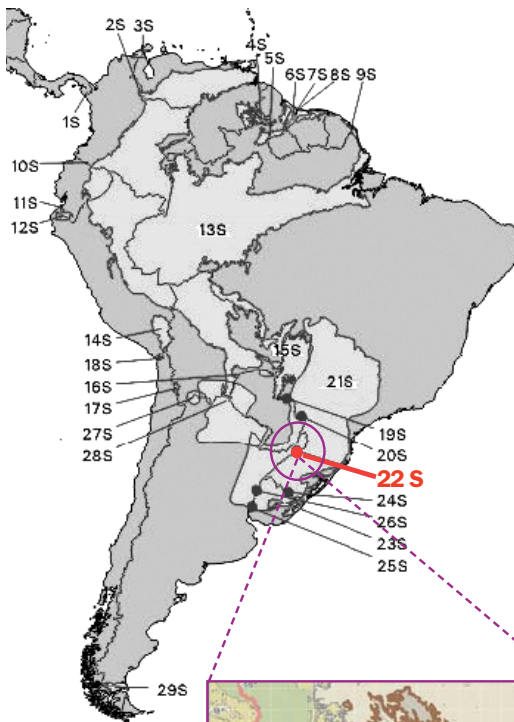
Concepcion del Uruguay, Argentina  
© SXC



## Guaraní (SAG)

### Argentina-Brazil-Paraguay-Uruguay

- Extent: above 1,200,000 km<sup>2</sup>.
- Population: 20 million inhabitants.
- Humid and sub-humid climate.
- Domestic and industrial supply, tourism developments (thermal zones).
- Sandy layers aged between 200 and 132 million years.
- Since 2002, the four countries have convened common work and carried out a project on the sustainable management and protection of SAG, with support of GEF/World Bank/OAS and participation of IAEA and BGR.



## Serra Geral

### Argentina-Brazil-Paraguay-Uruguay

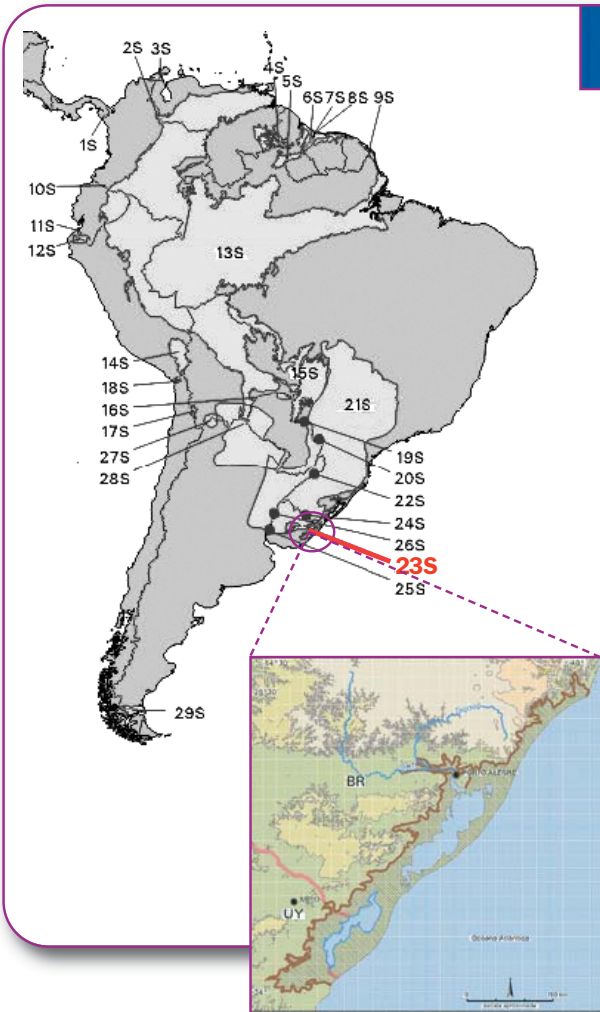
- Extent: 540,000 km<sup>2</sup>; covers, with its volcanic rocks, part of the Guarani aquifer system.
- Located in the Rio de la Plata Basin.
- Main uses: domestic, industry, irrigation.
- Largely explored, but recharge mechanism unknown.
- Intensively used across the region.
- Intensively exploited via deep wells (depth varying 80–100 m).

Parana River, Argentina  
© SXC





Laguna Negra, Rocha, Uruguay  
© UNESCO/Cornelia Holdereger



## Litoráneo-Chuy

### Brazil-Uruguay

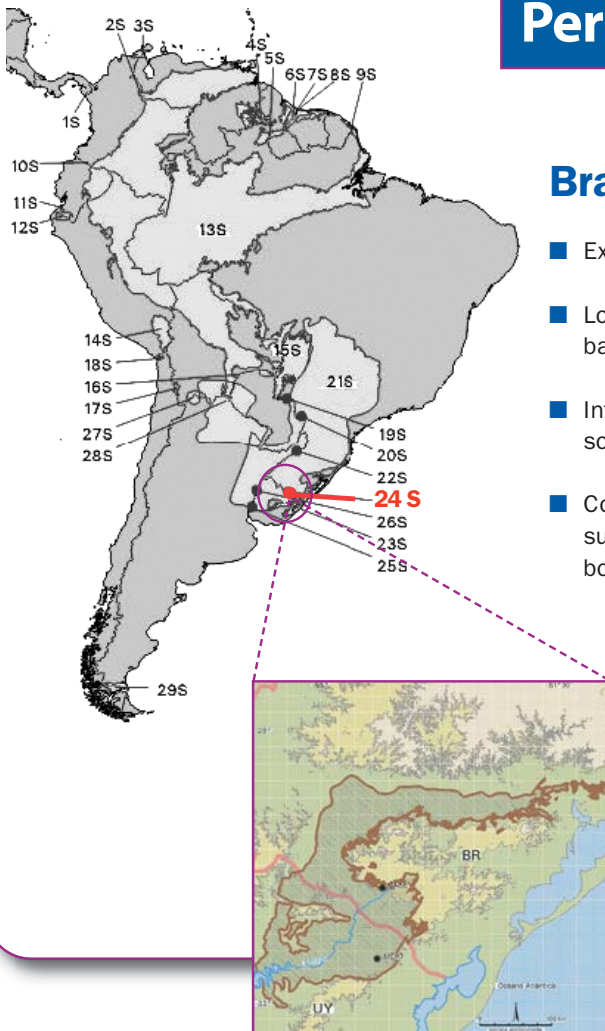
- Extent: ~41,000 km<sup>2</sup>, 80% in Brazil.
- Temperate humid climate.
- Shallow, non confined, porous, intergranular, non consolidated.
- Important source of supply for local population.
- Includes a series of lakes important to the ecosystem balance.



## Permo-Carbonífero

### Brazil-Uruguay

- Extent: 41,000 km<sup>2</sup>.
- Located in the hydrographic basin of the Uruguay River.
- Intergranular, porous, non consolidated and consolidated.
- Could be important for domestic supply on both sides of the border.



Near Uruguay-Brazil border  
© SXC







Uruguay River, from the Argentine Bank  
© SXC

## Litoral Cretácico

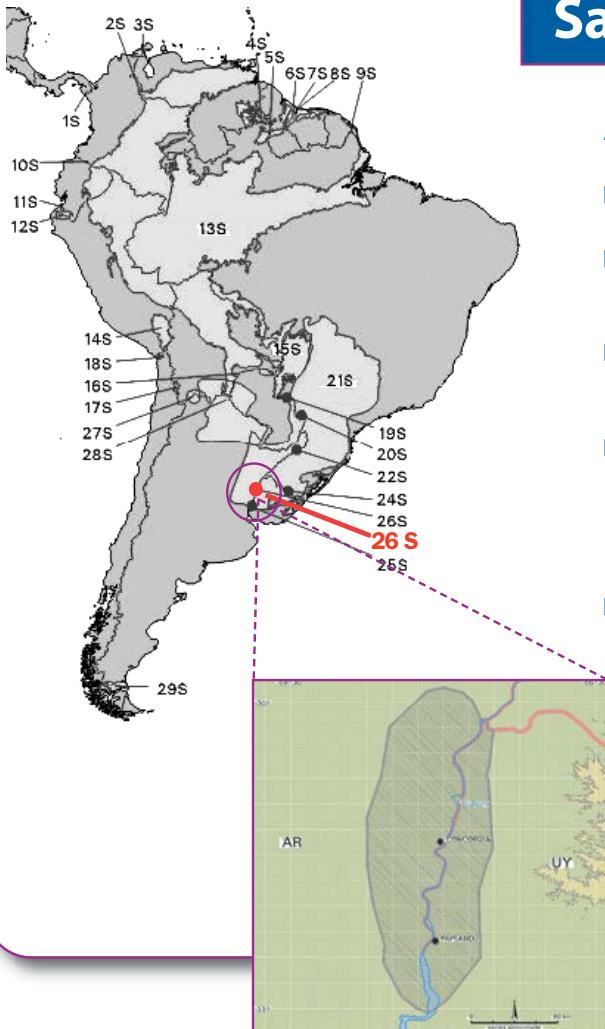
### Argentina-Uruguay

- Plain region, mean annual rainfall: 1,200 mm.
- Extent: 40,000 km<sup>2</sup>, 60% in Uruguay.
- Population: 500,000 inhabitants.
- Main uses: domestic, stock-breeding, irrigation.
- Importance of this resource: growing demand related to economic development.

## Salto-Salto Chico

### Argentina-Uruguay

- Extent: 32,000 km<sup>2</sup>.
- Humid climate; mean annual rainfall: 1,200 mm.
- Population: 500,000 inhabitants.
- Growing demand in particular for rice irrigation in Argentina and citrus irrigation in Uruguay.
- Good quality water.



Arapey River, Uruguay



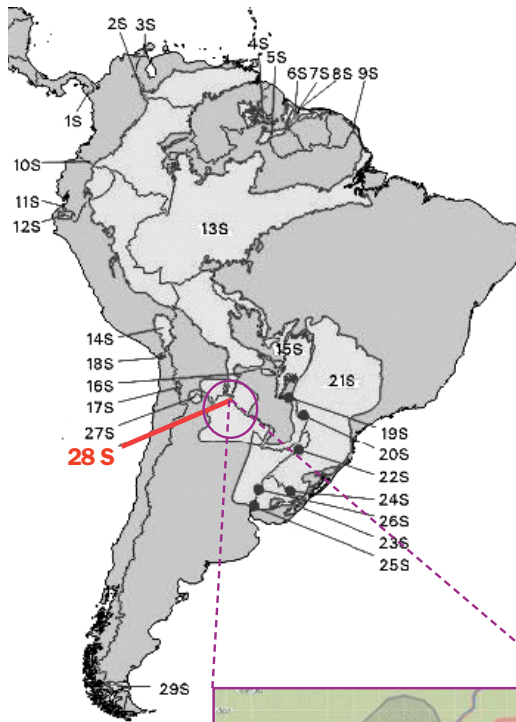


Llamas in Bolivia  
© SXC

## Puneños

### Argentina-Bolivia

- Extent: 16,000 km<sup>2</sup>, located at a high altitude (3,000–4,500 m.a.s.l.) in Andean *altiplano*.
- Rainfall: below 100 mm/year.
- Vital source of supply for several communities in one of the most arid zones of the world.

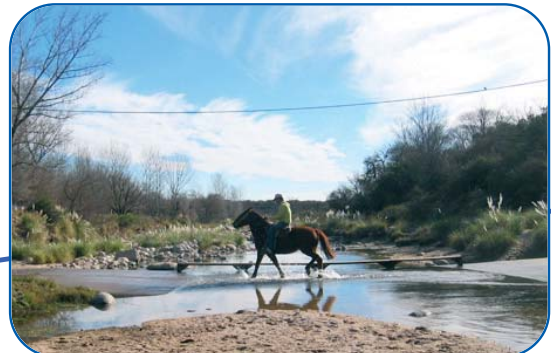


## Yrendá-Toba – Tarijeño

### Argentina - Bolivia - Paraguay

- Extent: 600,000 to 1,000,000 km<sup>2</sup>.
- Multi-layered system.
- Semi-arid climate; population: 400,000 inhabitants.
- GEF/UNEP/OAS/UNESCO pilot project to be developed in the framework of the *Programa Marco de la Cuenca del Plata* focusing on integrated water resources management, leading to adaptation to climate changes and avoidance of desertification.

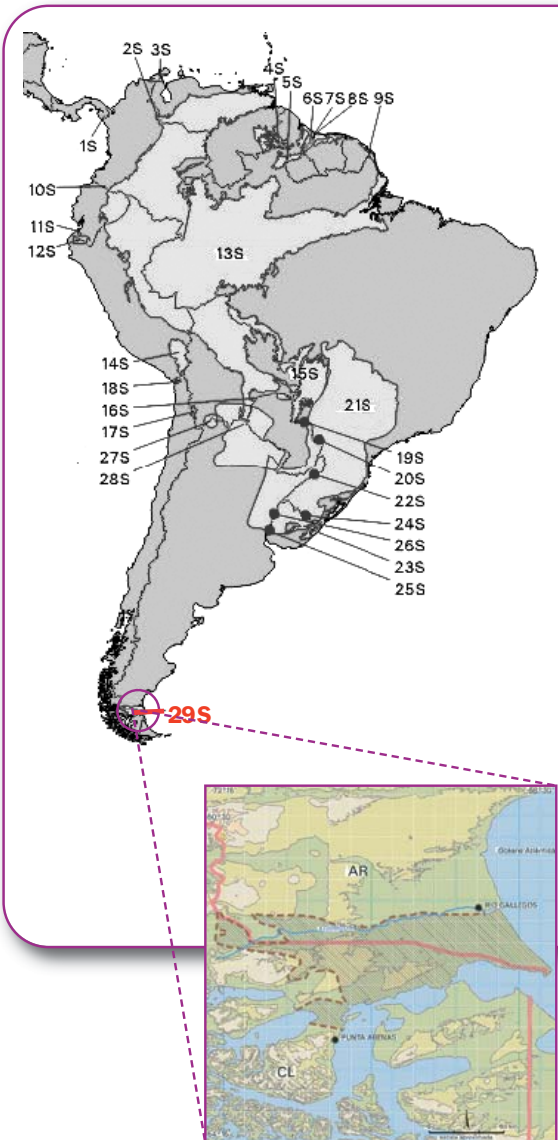
Cordoba, Argentina  
© SXC







Dalcahue Town, Chiloé Big Island, Chile  
© UNESCO/Gilles Cavaletto



## El Cóndor-Cañadón del Cóndor

### Argentina-Chile

- Extent: ~5,500 km<sup>2</sup>, located at southern end of South America.
- Two aquifers included in the system are fed by glaciers.
- Oil industry and local communities use for stockbreeding and domestic use.
- More detailed studies needed.



# AMERICAS

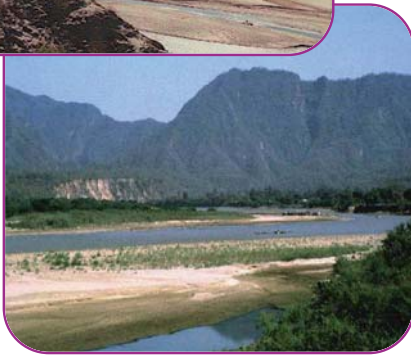
## Case studies

Out of nine possible transboundary aquifers case studies proposed by the countries during the Montevideo Workshop (2003), three initially started and three more were added in the 2006 workshop in San Salvador:

1. **Yrenda-Toba-Tarijeño aquifer (Paraguay-Argentina-Bolivia)**, representative for semi-arid areas of South America,
2. **Artibonito and Massacre aquifers (Haiti-Dominican Republic)**, representative for intra-mountainous and coastal zones,
3. **Pantanal aquifer (Bolivia-Brazil-Paraguay)**, representative for wetlands,
4. **Hueco del Bolsón (Mexico-USA)**, representative for urban zones,
5. **Ostua-Metapan aquifer (El Salvador-Guatemala)**,
6. **Estero Real-Rio Negro aquifer (Honduras-Nicaragua)**,
7. **Zarumilla Aquifer (Peru-Ecuador)**.

In addition to these pilot studies, a project was added since 2003: 'Protection of the environment and sustainable development of the Guaraní Aquifer', co-financed by the FMAM (*Fondo para el Medio Ambiente Mundial*). The project concerns the large Guaraní aquifer, which is shared by Argentina, Brazil, Paraguay and Uruguay.

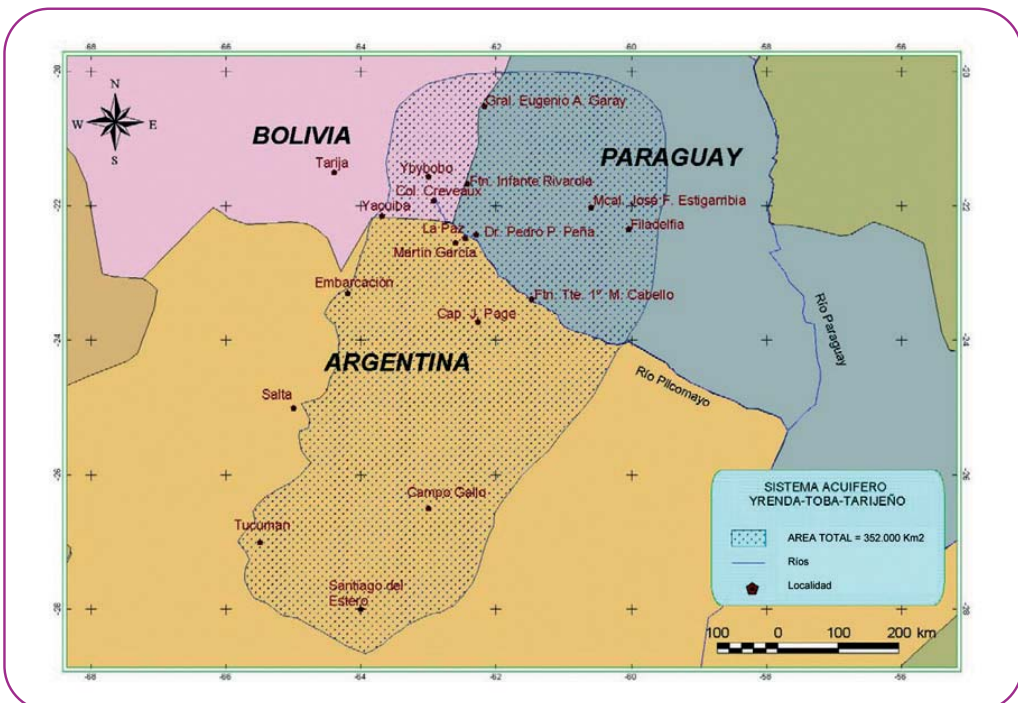
## Yrenda-Toba-Tarijeño Acuífer (Paraguay-Argentina-Bolivia)



The Yrenda-Toba-Tarijeño aquifer system occupies about 250,000 km<sup>2</sup>, located mostly in the Gran Chaco Americano region. Its recharge zone, located in Argentina and Bolivia, determines groundwater flow towards the east and crosses national boundaries, emerging in low-lying lands and draining into a series of streams that discharge into the Paraguayan-Argentine Chaco and eventually into the Parana River in Paraguay.

The livelihood of the 1 million indigenous people in the region is closely linked to the aquifer's surface area. Increasing pressure on scarce water resources, poor land quality and soil degradation is causing alarm. The natural water quality transition (fresh in Bolivia, to brackish and saline in Paraguay and Argentina) may be

changing. There are many pressures on the land in the region, which have arisen from the expansion of poorly planned mechanized agriculture, which has in turn led to land degradation, the decline of wetlands and the deterioration of water quality.



Increased rain intensity from anticipated climate change could trigger erosion, and resedimentation in recharge zones could inhibit aquifer infiltration from stream beds. Due to poor awareness and divergent regulations, current aquifer management by institutions in the sharing countries is inadequate. Therefore, coordination for the long-term management and protection of the recharge zones, as well as the discharge zones, is lacking.

***At present there is limited management of the aquifers by the sharing countries because of differing water laws and regulations. Many of the decisions on the use of the water in the aquifers are taken at municipality level and thus there is limited coordination in the long term management and protection of the recharge zones as well as the recharge zones.***



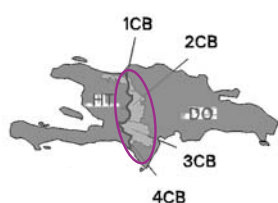
The case study's activities focus on raising awareness of the aquifer system, as well as ensuring the sustainability of its resources, the

lifeline of the local population and the aquifer-dependent environment. The project will help further develop engaged and strengthened institutions that practise sound aquifer management and offer educational and technical support to the community.

### HIGHLIGHTS

- The Case Study commenced under the ISARM Programme has several objectives – it will be conducted in close coordination with the Plata Basin Agency and will coordinate with the GEF funded Programme.
- The activities will include a diagnosis of the key issues for the improved management of the aquifer system, and its role in support of human needs and in providing continued environmental sustainability.
- The outcome of the Case Study will include tools to strengthen the institutions concerned with groundwater management, provide training and educate the community. The end outcome should be an integrated water management programme.

## The Artibonito and Masacre Transboundary Aquifers (Dominican Republic-Haiti)



These transboundary aquifers are respectively located in the intermountainous central region and in the northern coast of the Hispaniola Island, along the border between the two countries. Extensive deforestation in the upper reaches of the Artibonito basin has transformed the natural landscape, heavily impacting the health of ecosystems and introducing elements of high vulnerability to climatic fluctuations. Along the northern coast, sea-water intrudes into shallow aquifers polluting groundwater with its high saline content. Masacre coastal transboundary aquifer

represents a valuable freshwater resource for both the countries and it is being affected by saline intrusion due to overexploitation.

Under the auspices of the UNESCO/OAS ISARM Americas Programme, the Dominican Republic and Haiti officially agreed to undertake a cooperative work 'To sustainably manage the aquifers in the intermountain and coastal regions of Hispaniola with a view to reduce land degradation, excess erosion-sedimentation, and poverty', through a pilot-project which is being submitted for funding to the Global Environment Facility (GEF), and executed with the support of the OAS, the United Nations Environment Programme (UNEP) and the UNESCO-IHP.

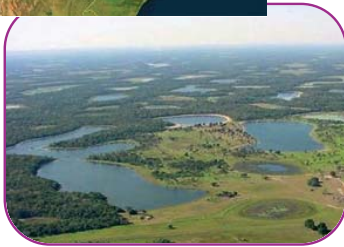
***In the Central Region of Hispaniola, along the border zone between Haiti and the Dominican Republic, accelerated erosion and runoff in the upper reaches of the Artibonito Basin are causing loss of lives, and environmental collapse.***

### OBJECTIVES

- Enhance recharge and reduce solid transport and runoff
- Expand resource base (deeper aquifers)

The joint sustainable management of the Hispaniola shared groundwater resources will help to mitigate the devastating rate of land degradation and of the ecosystems associated to groundwater. The project will identify the technical, legal, scientific and governance gaps, and strengthen the institutions responsible for water resource management. It will also focus on testing schemes for managed groundwater recharge in identified adequate locations and aquifers, as a mean to mitigate the high vulnerability of these two countries to extreme climatic conditions, such as destructive hurricanes, high rainfall periods that alternate with extended droughts, which cause innumerable deaths, economic losses and further degradation.

## Pantanal Aquifer: the Pantanal/Upper Paraguay Project (Bolivia-Brazil-Paraguay)



The Upper Paraguay River Basin is part of the Paraguay River Basin. It covers an area of approximately 600,000 km<sup>2</sup> and concerns the borders of Bolivia, Brazil and Paraguay. It has a high importance in the strategic context of hydrological resources administration because it includes the Pantanal area, one of the largest wetland areas on the planet (147,574 km<sup>2</sup>), declared Brazilian Natural Heritage Area and designed Ramsar protected Area and Biosphere Reserve.

The importance of the Pantanal Transboundary Aquifer System lies on its role in the preservation of Pantanal wetland ecosystem, the natural regulation of rainfall pattern and the supply of local communities and indigenous populations.

The three riparian countries have jointly identified the need for a sustainable management of the transboundary aquifer system, based on the understanding of hydraulic interactions between wetland and aquifer, and on the recognition of dependence of wetland as an ecosystem dependent on groundwater.

***Groundwater of the Pantanal Aquifer interacts with surface water creating the conditions for the existence and survival of the Pantanal Wetland. Its high vulnerability to contamination, excess siltation and over-exploitation had led to joint actions by the countries sharing the aquifer.***

The 'Integrated watershed Management Practices for the Pantanal and Upper Paraguay River Basin Project' was developed from 1998 to 2006 with resources from the GEF and the participation, among others, of UNEP, OAS and ANA (National Water Agency of Brazil). Next phase of the Project consists in the execution of the Strategic Action Plan.

### PROJECT COMPONENTS AND RESULTS

- I. Water Quality and Environment Protection: Sound Scientific and Technical Basis for the basin management
- II. Conservation of the Pantanal: Preserving the natural habitat through Conservation Units and Sustainable Tourism
- III. Land Degradation: Rehabilitating Critical Areas
- IV. Stakeholder Involvement and Sustainable Development: Including People, Municipalities, and the Private Sector in Developing Solutions
- V. Organizational Structure: Improving Institutional and Staffing Capabilities for Integrated Water Management
- VI. Strategic Action Program for the Integrated Management of the Upper Paraguay River Basin



## Hueco del Bolsón Aquifer (Mexico-USA)



The Bolsón del Hueco-Valle de Juárez Transboundary Aquifer System is shared by Mexico (State of Chihuahua) and the USA (State of Texas). It is located in an arid region with annual rain fall less than 200 mm/a and a potential evaporation over 2,000 mm/a.

The aquifer consists of alluvial and basin deposits, several hundred meters thick in Mexico and over 1,000 m in the territory of the USA. Its horizontal extent is about 8,000 km<sup>2</sup>, with 80% of it in the USA. It is unconfined, with medium to low permeability and high storage capacity . At shallow depths it contains fresh water (TDS < 1,000 ppm), particularly in the riverine belt

of the Rio Bravo/Grande. At intermediate depths and in its lower part it contains brackish and saline groundwater, respectively.

The aquifer system is of great importance, since it is located in an arid region with high water demands. In Mexico it is the primary source of water supply to Ciudad Suarez and the Valle de Juárez irrigation district, with the Río Bravo/Grande as a supplementary source. The latter river is in the USA the main source of water supply to El Paso city and the Bolsón del Hueco irrigation zone, while the aquifer serves as a complementary source. The population of the zone covered by this aquifer system was almost 2 million in 2005, but it is growing rapidly and expected to rise to 3.5 million by 2010.

Groundwater abstraction is presently around 310 million m<sup>3</sup>/a, most of which is abstracted in the USA. The high concentration of wells in the neighbouring urban zones of Ciudad Juárez and El Paso has caused considerable decline of the groundwater levels in the southwestern portion of the Bolsón. There, groundwater levels have declined several tens of metres during the last 30 years. There are also numerous wells in the irrigation district of the Valle de Juárez, where a large volume of groundwater is pumped for agricultural purposes.

The decline of groundwater levels not only depletes groundwater storage, but also induces a gradual migration of saline or brackish water into the shallower fresh portions of the aquifer, resulting in a gradual deterioration of groundwater quality. In Mexico, the urban population growth concentrated in Ciudad Juárez has prompted a gradual transfer of water from agriculture to the urban sector. In the USA, groundwater pumping from Bolsón del Hueco aquifer peaked in 1989, but ten years earlier it was already concluded that groundwater abstraction at that rate was not sustainable. Increased conservation efforts and doubling the city's annual amount of treated surface water reduced groundwater pumping rates to half by 2002. In the new treatment-recharge-reuse system, municipal wastewater of the city of El Paso is taken to a tertiary level treatment plant; subsequently it receives a natural treatment underground after passing through injection wells, and then it is recovered at some distance in down-flow direction to serve again the city.

Given the importance of this aquifer and the observed sustainability problems, information exchange between the two countries is taking place already since the 1960s, through the International Border Water Commission (Comisión Internacional de Límites y Aguas). Cooperation between water related institutions in USA and Mexico has resulted at the end of the 1990s in a binational report on the shared groundwater resources of this aquifer system. In the same context, groundwater flow models were developed for better understanding of the aquifer and to serve institutions at both sides of the boundary in their endeavours to manage groundwater properly.

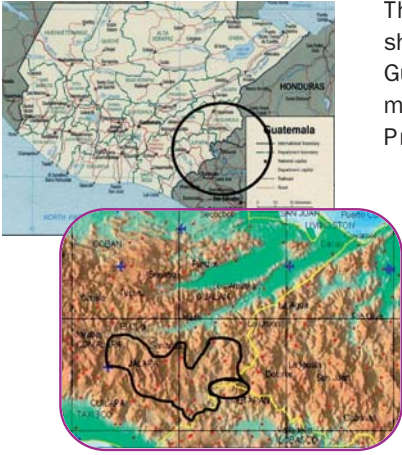
At both sides of the international border, projects for formulating an integrated water resources management plan are underway. One of the current concerns is how to ensure compatibility between these plans.

In the context of ISARM Americas, this case study was chosen as an example of highly urbanised areas.

#### **Views and cooperation between USA and Mexico in relation to the Hueco del Bolsón-Valle de Juárez transboundary aquifer system**

- Groundwater of this aquifer system is of paramount importance for the region, but storage depletion and salinization are threatening its sustainable use. Population growth and climate change may aggravate these problems.
- Both Mexico and USA are actively seeking alternative water sources, encouraging per capita water use reduction and applying or planning technical methods such as artificial recharge, waste water treatment and desalination.
- Transboundary co-operation – with emphasis on exchange of information is taking place already since the 1960s, long before ISARM came into being.
- An important institution to facilitate this cooperation is the International Border Water Commission (IBWC) or Comisión Internacional de Límites y Aguas (CILA).
- Attention is paid not only to hydrogeological aspects, but also to legal, institutional, socio-economic, environmental and management issues.
- A major challenge for the near future is to harmonize water resources management plans and their implementation across the international border.

## Ostua-Metapan Aquifer (El Salvador-Guatemala)



The Transboundary Aquifer System Ostua-Metapán is shared by El Salvador (municipality of Metapán) and Guatemala (departments of Jutiapa, Jalapa and Chiquimula). It is located in the Upper Río Lempa basin. Predominant physiographic features are the Tertiary volcanic chain, with elevations up to 2,700 metres above mean sea level. The prevailing climate is semi-arid, with annual rainfall of 800 to 1,100 mm concentrated in the period May to October, and with average annual temperature of 24 to 26°C. The zone corresponding to the shared aquifer has approximately 600,000 inhabitants, of which the majority (500,000) lives in Guatemala. Around 28% of the total population is urban.

The aquifer system covers an area of 800 km<sup>2</sup>. It is an unconfined to confined multi-layer aquifer system (unconfined being the predominant condition), with a maximum depth of 20 m for the shallow aquifer beds and 100 to 200 m for the deeper ones. There is hydraulic connection between rivers, lakes and aquifers. The general flow direction is from northwest to southeast, i.e. from Guatemala to El Salvador. The aquifer system is partly porous and partly fissured, and consists of sediments in the Quaternary alluvial valleys, basaltic lavas and metamorphosed limestones. The annual abstraction is approximately 200 million m<sup>3</sup>. By the mid-1990s, an annual volume of approximately 60 million m<sup>3</sup>/year was abstracted from the aquifer system for domestic water supply only.

Demand for water in the area is for human consumption, irrigation, animal consumption, tourism and ecotourism industry. In recent years these demands have increased significantly and therefore cannot be met completely any more.

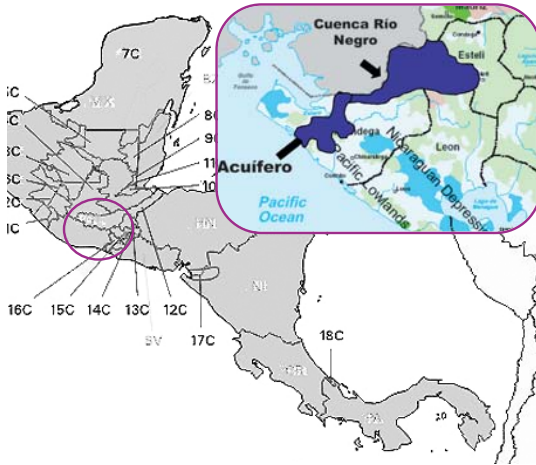
The aquifer is highly vulnerable and exposed to pollution by household and industrial activities, in particular near the border. Furthermore, it is threatened by overexploitation and reduction of recharge zones caused by urban development and deforestation.

To ensure continuous and sustainable use of groundwater in the border region of Guatemala and El Salvador, there is a need for coordinated regional and local aquifer management between the two countries, in order to exploit the resource in a more rational way, to protect it and to mitigate current and future negative impacts of groundwater development. This has motivated the countries to agree in 2006 on the execution of a case study in the framework of ISARM-Americas activities. It is complemented by a UNESCO-PCCP project building on the existing political will for co-operation between countries, for peace building and for the development of a shared vision on joint water resources management.

### Ostua-Metapán transboundary aquifer system

- *It forms part of the Upper Río Lempa basin.*
- *It provides water for agriculture and domestic use.*
- *It is highly vulnerable to contamination and is exposed to pollution sources.*
- *It is threatened by over-exploitation and anthropogenic pollution sources.*

## Estero Real-Río Negro Aquifer (Honduras-Nicaragua)



The Transboundary Aquifer System Estero Real-Río Negro is located in Central America, in south-eastern Honduras and north-eastern Nicaragua. The climate is tropical, with average annual temperatures between 27°C and 32°C.

The aquifer Estero Real-Río Negro is unconfined, with depth to groundwater level varying between 5 and 60 metres. The aquifer consists of volcanic rocks, alluvial and fluvio-colluvial deposits and is recharged by precipitation and inflows from the Río Negro. The greatest potential for groundwater

abstraction is located in the sedimentary zones. Groundwater flows from south-east to north-east. Aquifer thickness is in the order of 100 to 150 m.

Groundwater of this aquifer is characterized by good quality and has a very good potential for sustainable resource development to supply the population, agriculture and livestock. However, human activity has caused pollution by agrochemicals used in producing grains and cotton since the 1970s, in addition to nitrate pollution generated by livestock ranching and by the lack of adequate basic sanitation.

The aquifer is of vital importance in Honduras and Nicaragua to meet water demands for human consumption in rural communities where no piped water services are present. In addition, water is needed for agriculture as well as for industry and livestock. Protection of the aquifer is necessary, given the increasing pollution problems and the high vulnerability of the aquifer inherent to its hydrogeological characteristics. Immediate action is required for protection and preservation in view of contamination threats in the area.

Both countries are implementing measures for the integrated management of surface water of the Río Negro basin. The focus should be amplified by including groundwater as a component of integrated water resources management. The ISARM case study agreed upon by the countries in 2006 may be highly supportive to achieve this goal.

### Estero Real - Río Negro transboundary aquifer system

- *It is the only source of safe drinking water in this border zone.*
- *It also sustains livelihoods and coastal ecosystems*
- *It threatened by agricultural and domestic pollution sources.*

## Zarumilla Aquifer (Peru-Ecuador)

The Transboundary Zarumilla Aquifer System can be associated with the Zarumilla river basin, shared by Peru and Ecuador and covers an area of some 920 km<sup>2</sup>. The climate is arid in the flat parts of the basin and tropical- monsoonal in the mountainous zone. The average annual temperature varies from 25°C in the plains to 22°C in the mountainous zone.

The Zarumilla aquifer consists of permeable alluvial, coluvial and other deposits of Quaternary age and non-deformed Neogene sediments, intercalated by silt and clay layers. The sediments are underlain and surrounded by strongly folded and metamorphosed rocks. The general groundwater flow direction is from southeast to northwest, nearly parallel to the international boundary. Groundwater characterized by high salinity is not rare.

The population of the Zarumilla aquifer region includes approximately 70,000 people, mostly in urban centres. Approximately two-thirds of them live in Ecuador. The area is economically very weak, hence there is a need to raise the standard of living of the population and to provide elementary services. Water supply and joint sustainable water resources management are expected to contribute to achieving these goals.



### Zarumilla transboundary aquifer system

- *It is the main source of water in this region during the dry season.*
- *Hydrogeological aspects are relatively well known*
- *Groundwater salinity is a problem.*
- *Groundwater management as well as protective measures are lacking.*

Before 1988, only very limited efforts were spent on investigating water resources in the border zone between Ecuador and Peru. In that year, however, an important Agreement between both countries was signed (Acuerdo Amplio Ecuatoriano Peruano de Integración Fronteriza), which paved the way for bi-national cooperation on their shared water resources. One of the projects, embarked upon with support of international partners such as OAS and IAEA, is a study to characterize the transboundary Zarumilla aquifer.

The rationale behind the project is the need to define and implement sustainable solutions for current water shortage problems in the zone. Surface water is only available during a few months a year, because the area has a semi-arid climate with rainfall usually from December to May. Domestic water supply therefore is fully based on groundwater, but



apparently there are serious doubts on the efficiency and sustainability of groundwater resources exploitation. The Zarumilla Aquifer study pays particular attention to the use of isotopes in support of aquifer management and to the development of capacity in both countries for successfully using this technology.

The Zarumilla aquifer has recently been added to ISARM-Americas' list of case studies.

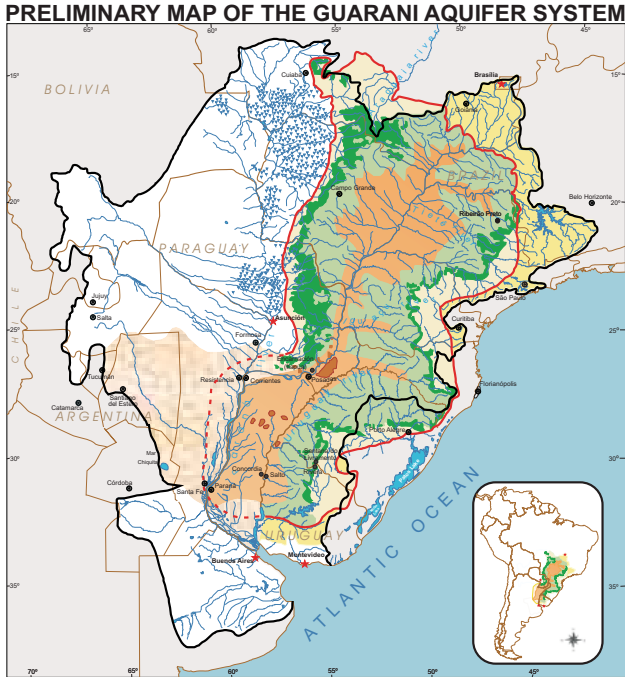
**GENERAL OBJECTIVES  
OF THE ZARUMILLA TRANSBOUNDARY AQUIFER STUDY**

- Efficient groundwater use, supported by isotope techniques.
- Strengthening national institutions in the use of isotope techniques in water resources management.
- Stimulating cooperation between countries in the region.

**SPECIFIC OBJECTIVES  
OF THE ZARUMILLA TRANSBOUNDARY AQUIFER STUDY**

- Characterization of the Zarumilla aquifer to enable its sustainable use.
- Determining the aquifer's properties, state and ongoing processes.
- Developing a mathematical model to support rational and sustainable groundwater exploitation in the boundary zone.
- Improving the quality of life of the local population.

## Guaraní Aquifer (Argentina-Brazil-Paraguay-Uruguay)



The Guarani Aquifer System is an underground water reservoir. It is a group of sandy rocks below the soils' level with water in its pores and fissures. These rocks were deposited there between 245 and 144 million years ago.

It is said to be a transboundary aquifer because it underlies four South American countries. The total surface estimation is of 1,200,000 km<sup>2</sup>, corresponding 225,500 km<sup>2</sup> to Argentina, 840,000 km<sup>2</sup> to Brazil, 71,700 km<sup>2</sup> to Paraguay and 58,500 km<sup>2</sup> to Uruguay. It is located in south east South America between 12° and 35° south latitude and 47° and 65° west longitude.

It is named Guarani because its extension is approximately the same as the Great Guarani Nation, native population that inhabited the region. The access is accomplished by perforating machines. Generally, when the excavation is done, a vertical pipe is driven into the layers until the ones that contain water are penetrated. In this level, a filter is installed allowing the access of water to the perforation and its extraction.

The perforating characteristics vary according to the deepness where the water is found. The final perforation diameter vary generally among 15 and 20 cm and its deepness may go from some meters (50 for example) to 1,800 meters in some cases. Due to the increasing water temperature when the deepness of extraction is bigger, the extracted water may have temperatures between 50 °C and 65°C.

***The Environmental Protection and Sustainable Development of the Guarani Aquifer System Project will increase the knowledge of the resource and will allow to propose a technical, legal and institutional framework for the coordinated management among Argentina, Brazil, Paraguay and Uruguay, seeking its preservation.***

Part of the rainwater that falls in the region gets directly into the aquifer infiltrating in the soil or by rivers, streams and lakes that by their beds allow the water to pass to deeper layers. The water that gets in is called 'recharge' and it is quantified in an annual volume. For the GAS, the recharge is estimated in 166 km<sup>3</sup>/year. The permanent GAS water reserves – the water deposited in rocks pores and fissures – are approximately 45,000 km<sup>3</sup>.

The water extraction in an aquifer must be done in a sustainable way to assure its preservation, that means that the quantity and quality of the resource must be maintained for the



current and future generations. In this sense, the water volume that can be extracted should be smaller than the recharge and should consider the maintenance of systems that depend on groundwater, for example, rivers and wetlands.

In reference to the quality preservation, adequate protection measures must be taken in order to control the effects of potentially contaminating activities (solid waste dumping, agrochemical excess, among others).

### PROJECT SUMMARY

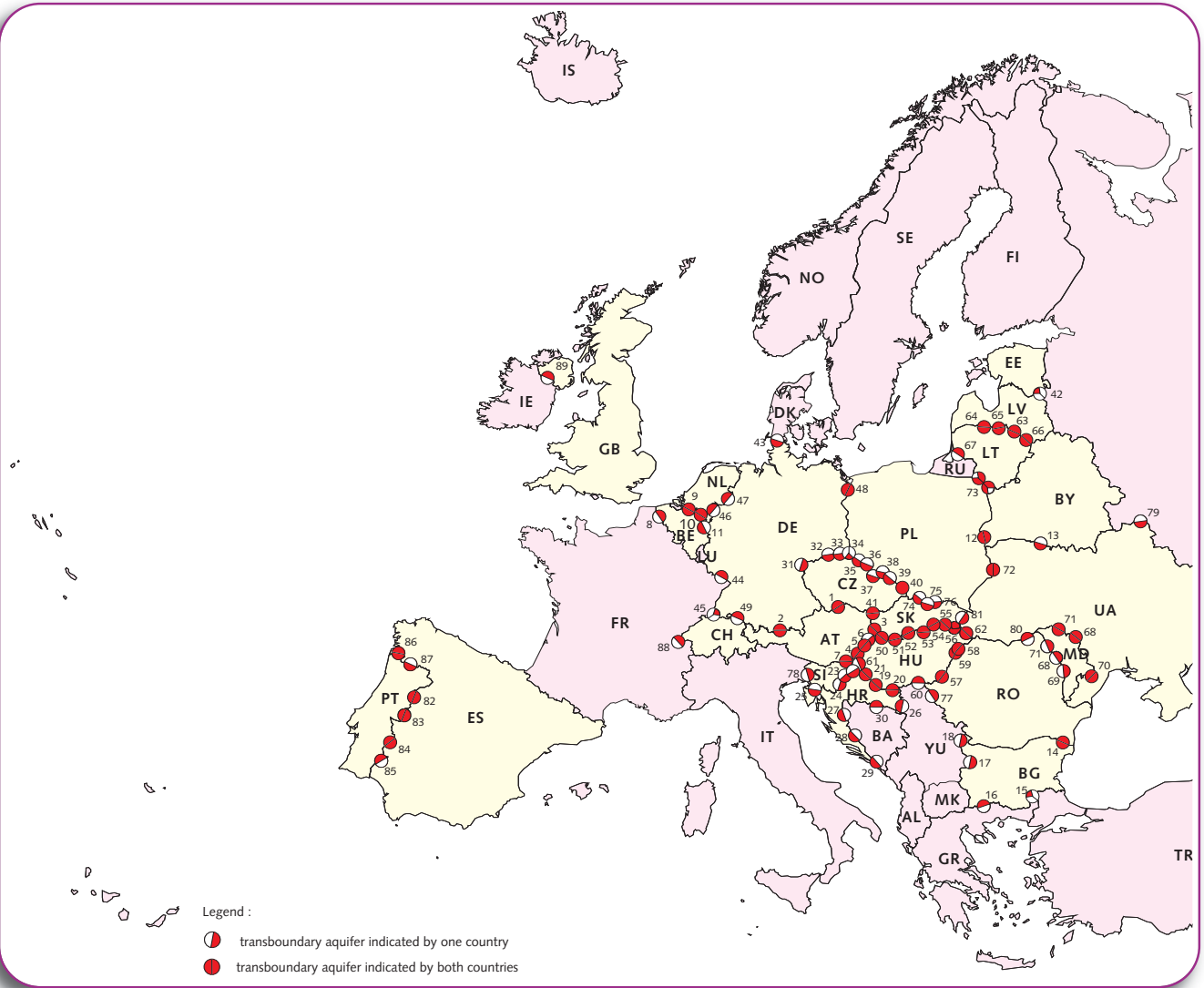
The long-term objective of the process that started with the Project is to achieve the management and sustainable use of the Guarani Aquifer System (GAS). The GAS is located in the eastern and south-central portions of South America, and underlies parts of Argentina, Brazil, Paraguay and Uruguay. This project is a first step towards achieving the long term objective. Its purpose is to support the four countries in the joint elaboration and implementation of a common institutional, legal and technical framework for the management and preservation of the GAS for current and future generations.

The Project is structured in seven components:

- Expansion and consolidation of the current scientific and technical knowledge base regarding the Guarani Aquifer System;
- Joint development and implementation of a Guarani Aquifer System Management Framework, based upon an agreed Strategic Program of Action;
- Enhancement of public and stakeholder participation, social communication and environmental education;
- Evaluation and monitoring of the project and dissemination of project results;
- Development of regionally-appropriate groundwater management and mitigation measures in identified critical areas ('hot spots');
- Consideration of the potential to use the Guarani Aquifer System's 'clean' geothermal energy;
- Project coordination and management.

The project has been executed between March 2003 and January 2009.

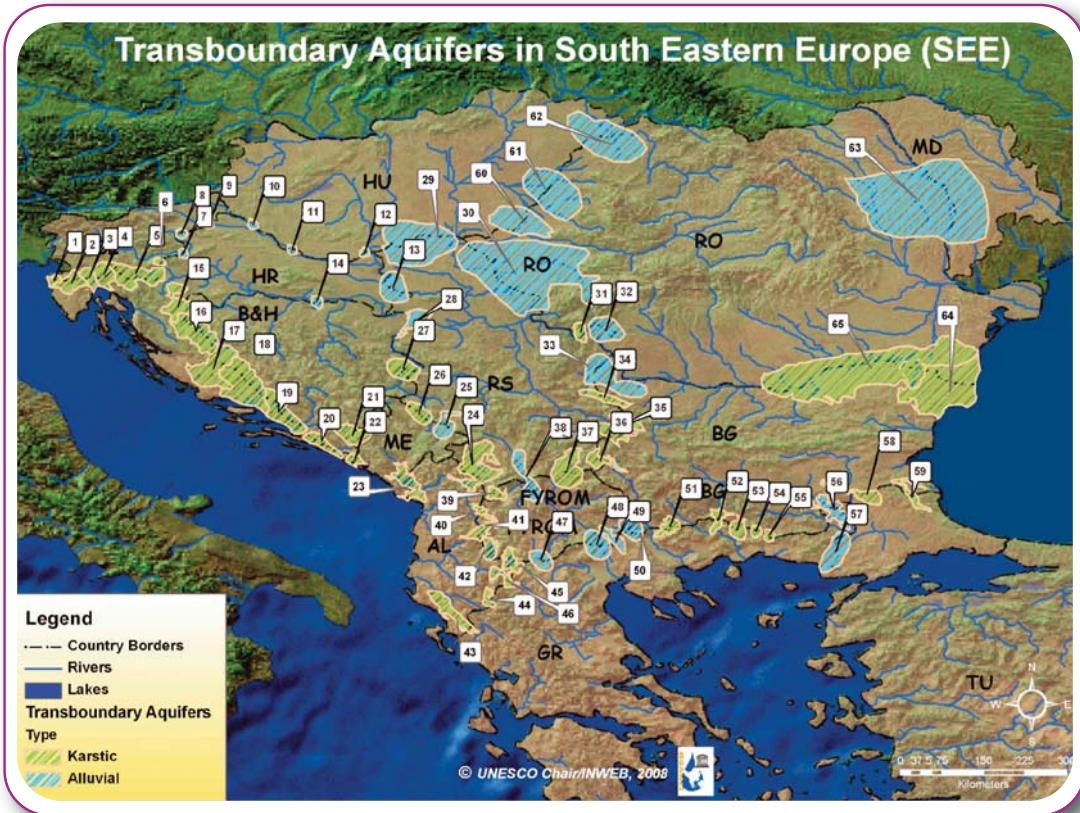
# WESTERN EUROPE TRANSBOUNDARY AQUIFERS INVENTORY



Source: Almássy and Buzás, 1999.







Source: Ganoulis, 2008.

# SOUTH-EAST EUROPE

## TRANSBOUNDARY AQUIFERS INVENTORY

### OVERVIEW

South East Europe		
1	Dragonja	Slovenia-Croatia
2	Mirna-Istra	
3	Opatija	
4	Rijeka	
5	Kupa	
6	Zumberak	
7	Sava	
8	Sutla	
9	Drava	
10	Mura	Croatia-Hungary
11	Drava	
12	Baranja	
13	West Serbia	Croatia-Serbia
14	Sava	Croatia-Bosnia and Herzegovina
15	Kupa	
16	Una	
17	Krka	
18	Cetina	
19	Neretva	
20	Dubrovnik	
21	Karst-Montenegro	Bosnia and Herzegovina-Montenegro
22	Dinaric karst West coast	Montenegro-Croatia
23	Dinaric karst East coast/Skadar Lake	Montenegro-Albania
24	Beli Drim	Albania-Serbia
25	Metohija	Montenegro-Serbia
26	Lim	
27	Tara massif	Serbia-Bosnia and Herzegovina
28	Macva-Semberija	
29	Backa	Serbia-Hungary
30	Banat	Serbia-Romania
31	Miroc and Golubac	
32	Dacian basin	

### South East Europe (cont'd.)

33	Timok Alluvium/Bregovo Novo	Serbia-Bulgaria
34	Stara Planina/Salasha Montana	
35	Nishava and Tran Karst	
36	Zemen	
37	The former Yugoslav Rep. of Macedonia-SW Serbia	Serbia-The former Yugoslav Rep. of Macedonia
38	The former Yugoslav Rep. of Macedonia-Central Serbia	
39	Tetovo-Gostivar	
40	Bistra-Stogovo	Albania-The former Yugoslav Rep. of Macedonia
41	Jablanica	
42	Ohrid Lake	
43	Vjosa/Pogoni	Albania-Greece
44	Mourgana	
45	Prespes Lakes	Albania-Greece-The former Yugoslav Rep. of Macedonia
46	Galicica	Greece-The former Yugoslav Rep. of Macedonia
47	Pelagonija/Florina	
48	Gevgelija/Axios-Vardar	
49	Dojran Lake	
50	Sandansky-Petrich	Bulgaria-Greece-The former Yugoslav Rep. of Macedonia
51	Gotze/Agistro	Greece-Bulgaria
52	Nastan-Trigrad	
53	Smolyan	
54	Rudozem	
55	Erma Reka	
56	Svilegrad/Orestiada	Bulgaria-Greece-Turkey
57	Evros/Meric	Greece-Turkey
58	Topolovgrad karst waterbearing massif	Bulgaria-Turkey
59	Malko Tarnovo kasrt waterbearing massif	
60	Upper Pleistocenesomes alluvial fan	Romania-Hungary
61	Lower Pleistocene Mures alluvial fan	
62	Lower Pleistocene some alluvial fan	
63	Middle Sarmatian Pontian	Romania-Moldova
64	Sarmatian	Romania-Bulgaria
65	Upper Jurassic-Lower Cretaceous	

## SOUTH-EAST EUROPE: Aquifers details

Note: Figures or texts not placed under one country name means that they are shared by countries.

Source: <http://www.inweb.gr>



### Secovlje-Dragonja/ Dragonja

■ Type: Karst

#### Slovenia

#### Croatia

■ Shared boundary length (km)		16
■ Altitude range (m)		6–450
■ Population resident in this area		6,200
■ Area (km <sup>2</sup> )	20	99
■ Pressure factors	Tourism and transport	Communities

#### Agreements: formal agreement ratified

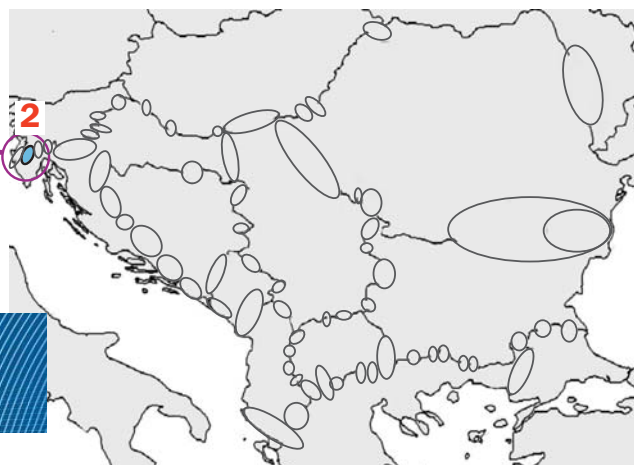
- Water management issues have already been negotiated and developed through the Slovene-Croatian Bilateral Board.
- Bilateral Slovenian-Croatian Commission of Marine and Karstic Area is responsible for transboundary issues: initiation of actions, supervision, negotiations, contracts, etc...

Lake Bohinj, Slovenia  
© SXC





Biskupije, Croatia  
© SXC



## Mirna-Istra

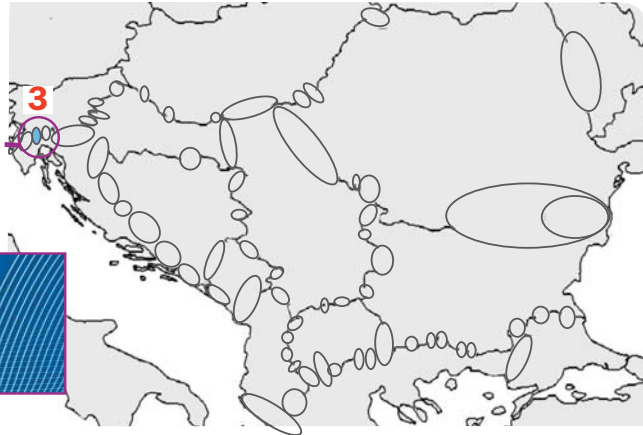
■ Type: Karst

### Croatia

### Slovenia

■ Shared boundary length (km)		26
■ Area (km <sup>2</sup> )		214
■ Water use description	Drinking water supply	Drinking water supply
■ Pressure factors	None	None, sparsely populated
■ Management measures	Existing protection zones	





## Opatija

■ Type: Karst

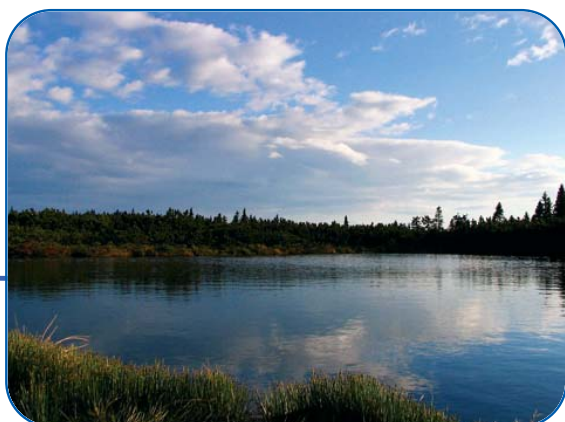
### Croatia

### Slovenia

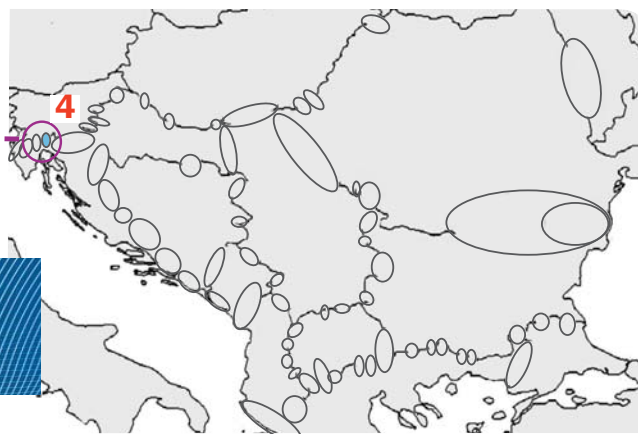
■ Shared boundary length (km)	21	
■ Area (km <sup>2</sup> )	302	
■ Water use description	Drinking water supply	Drinking water
■ Quality problems	Local problems with salinity	
■ Management measures	Existing protection zones	Protection zones of karst source Rizana
■ Pressure factors	None	Main highway from Trieste to Rijeka

Lake Bled and Castle, Slovenia  
© SXC





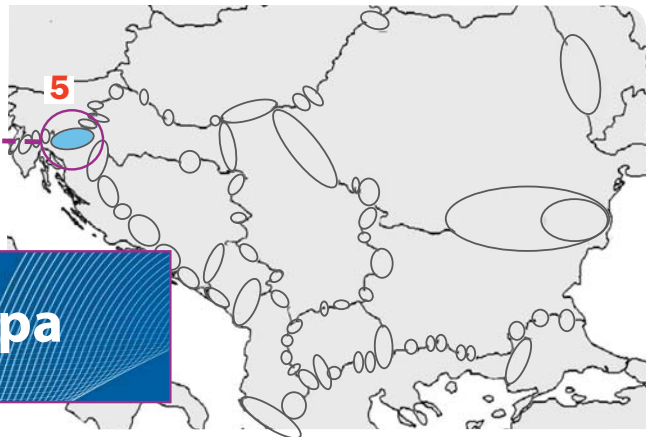
Slovenia  
© SXC



## Rijeka

■ Type: Karst

	Croatia	Slovenia
■ Shared boundary length (km)		36
■ Area (km <sup>2</sup> )		460
■ Water use description	Drinking water supply	Local drinking water supply
■ Pressure factors	None, very scattered population	Main road from Ljubljana to Rijeka
■ Quality Problems	Occasional bacteriological pollution	



## Cerknica/Kupa

- Type: Karst

### Croatia

### Slovenia

■ Shared boundary length (km)		32	
■ Population resident in the area		286,000	
■ Area (km <sup>2</sup> )	137		238
■ Altitude range (m)		115–700	
■ Mean annual rainfall (mm)		1,375	
■ Annual groundwater resources (Mm <sup>3</sup> /y)		280	
■ Annual groundwater abstraction (Mm <sup>3</sup> /y)		101	

### Agreements: informal agreements/conventions

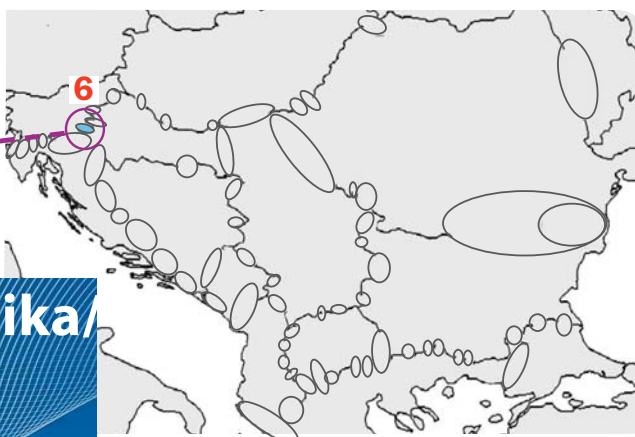
- Regional Environmental Center (REC) project: Sustainable future for the Kolpa Valley.

Korana River, Croatia  
© SXC





Novo Mesto, Slovenia  
© SXC/Andrej Jakobic



## Radovic-Metlika/ Zumberak

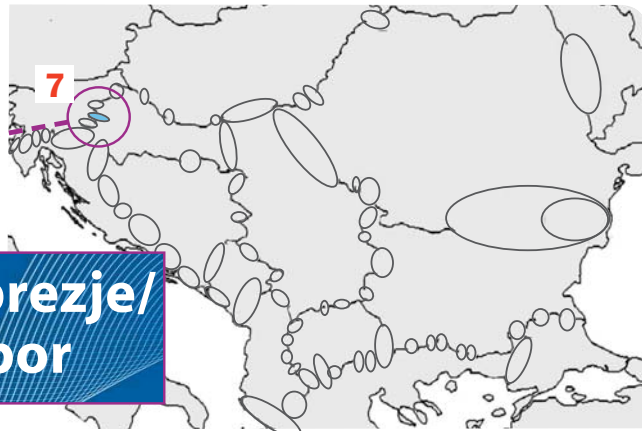
- Type: Karst

### Slovenia

### Croatia

■ Shared boundary length (km)		12
■ Area (km <sup>2</sup> )	27	158
■ Water use description	Drinking water supply	Drinking water supply
■ Pressure factors	Agricultural activities	None
■ Quality problems	Excessive pesticide content	





## Bregana-Obrezje/ Sava-Samobor

■ Type: Alluvial

**Croatia**

**Slovenia**

■ Shared boundary length (km)		7	
■ Area (km <sup>2</sup> )	54		4
■ Altitude range (m)		79–130	
■ Mean annual rainfall (mm)		825	

### Agreements: formal agreements ratified

- Framework Agreement on the Sava River basin signed by Bosnia and Herzegovina, Croatia, Slovenia and The former Federal Republic of Yugoslavia (2002).
- Agreement between the Government of the Republic of Croatia and the Government of the Republic of Slovenia on Water Management Issues (1997).
- Agreement between the Governments of the Republic of Croatia and Bosnia-Herzegovina on Water Management Issues. This was signed by the federation administration.

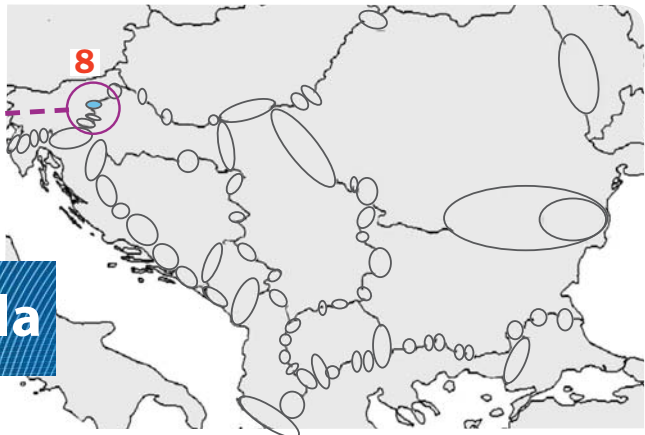


Plitvice Waterfalls, Croatia  
© SXC





Lake Bled, Slovenia  
© SXC



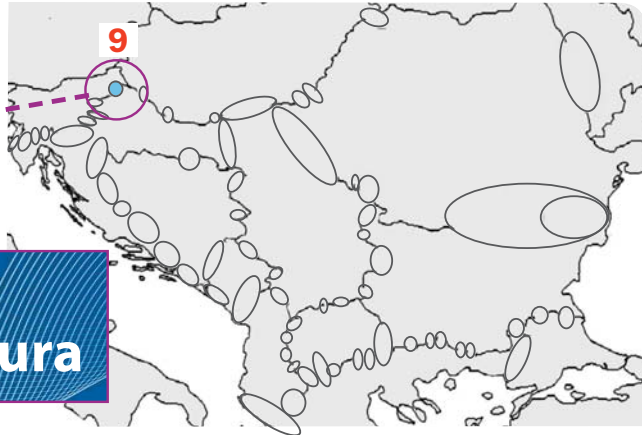
## Bizeljsko/Sutla

■ Type: Alluvial

### Slovenia

### Croatia

■ Shared boundary length (km)		4
■ Area (km <sup>2</sup> )	180	12
■ Water use description	Drinking water supply	Local drinking water supply
■ Quantity problems	None	Local lowering of groundwater levels detected



## Dolinsko-Ravensko/ Mura

■ Type: Alluvial

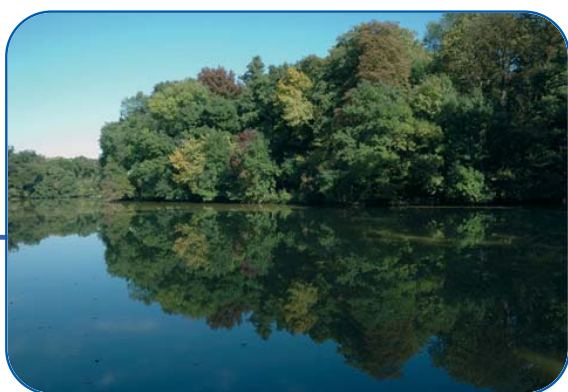
### Croatia

### Slovenia

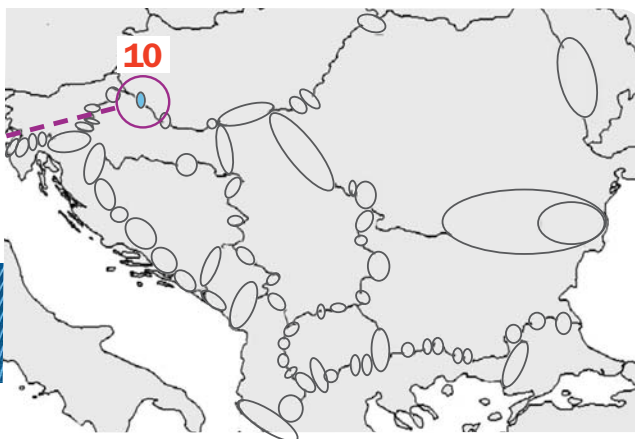
	Croatia	Slovenia
■ Area (km <sup>2</sup> )	0	449
■ Water use description		Drinking water supply in Murska Sobota, local water supply systems
■ Pressure factors		Intensive agriculture, pan-European transport corridor
■ Quantity problems		Degradation of the Mura River due to river regulation and hydropower schemes
■ Quality problems		Nitrate, pesticides

Mozirje Park, Slovenia  
© SXC





Hungarian landscape  
© SXC



## Mura

■ Type: Alluvial

### Croatia

### Hungary

■ Shared boundary length (km)

52

■ Area (km<sup>2</sup>)

300

■ Quantity problems

Local and moderate (at settlements) increased pumping lifts, reduced yields and baseflow, degradation of ecosystems;

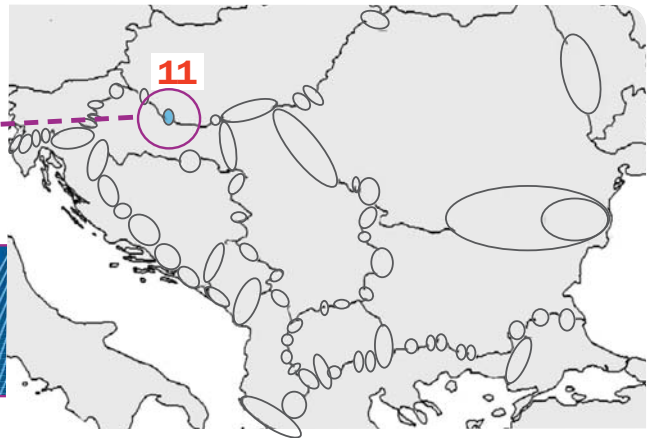
■ Quality problems

Local but severe nitrate from agriculture, sewers and septic tanks at up to 200 mg/l, pesticides at up to 0.1 mg/l.



## Drava/ Drava West

■ Type: Alluvial



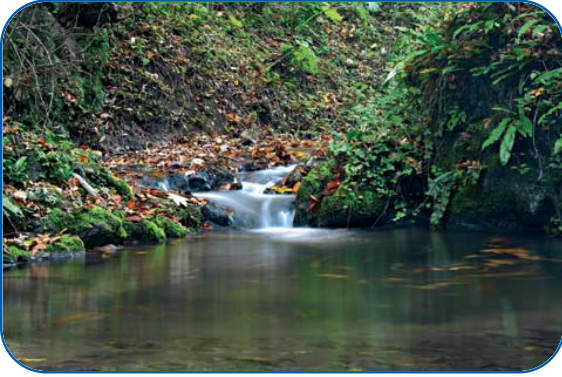
### Hungary

### Croatia

■ Shared boundary length (km)		31
■ Area (km <sup>2</sup> )	262	97
■ Water use description	>75% drinking water, <25% each for irrigation, industry and livestock	Local drinking water supply
■ Pressure factors	Agriculture (fertilisers and pesticides), sewage from industry and livestock settlements, traffic, gravel extraction under water in open pits	Extraction of sand and gravel under water in pits

*Boats on the Drava River, Croatia*  
© SXC

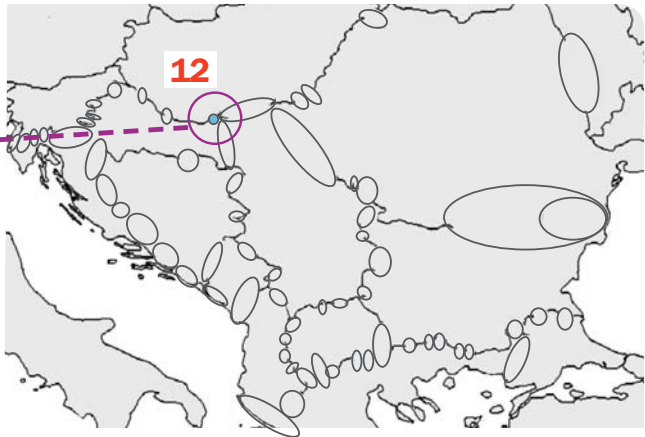




Mecsek Mount, Baranya, Hungary  
© SXC



## Baranja/ Drava East



■ Type: Alluvial

### Croatia

### Hungary

■ Shared boundary length (km)

67

■ Area (km<sup>2</sup>)

955

607

■ Water use description

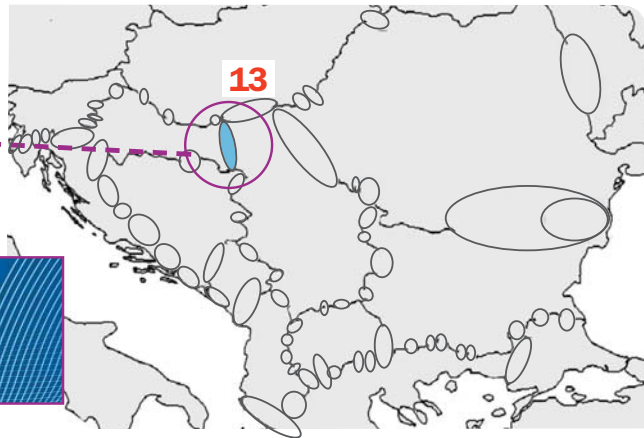
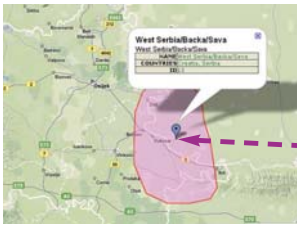
25-50% drinking water,  
25-50% drinking water,  
<25% thermal spa

>75% drinking water,  
>25% each for irrigation  
industry and livestock,  
maintaining baseflow  
and spring flow

■ Pressure factors

Agriculture (fertilisers and  
pesticides), sewers and  
septic tanks, traffic





## West Serbia/ Backa/Sava

■ Type: Alluvial

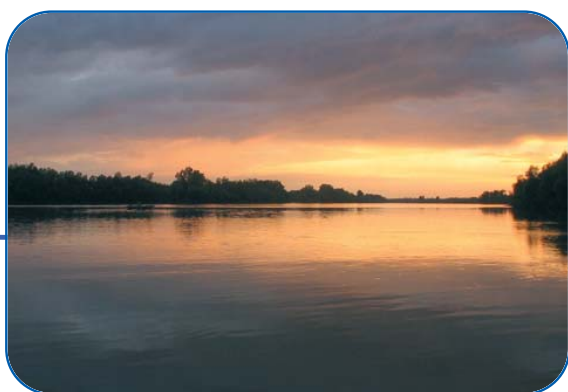
	Serbia	Croatia
■ Area (km <sup>2</sup> )	2	
■ Mean annual rainfall (mm)	850	825
■ Water use description	50-75% drinking water, <25% each for irrigation, industry and livestock	Dominantly drinking water
■ Pressure factors	Abstraction	
■ Quantity problems	Local increase in pumping lifts and reduction in borehole yields	

### Agreements: formal agreement ratified

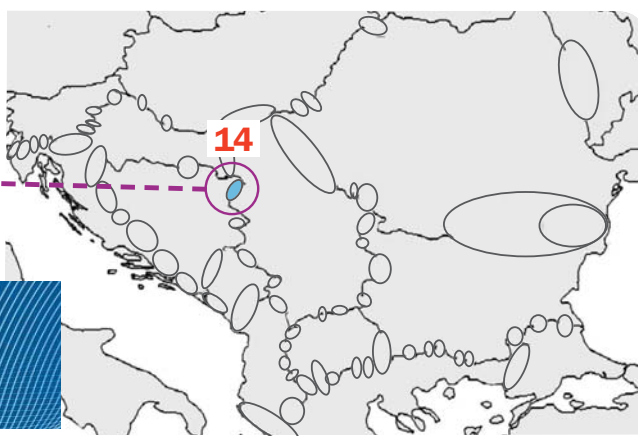
- Danube River Protection Convention implemented by International Commission for the Protection of the Danube River (ICPDR).

Sava River  
© SXC





Sava River  
© SXC



## Sava/ Posavina I

- Type: Alluvial

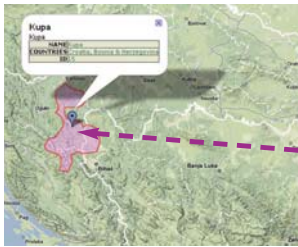
### Bosnia and Herzegovina

### Croatia

■ Shared boundary length (km)		85
■ Area (km <sup>2</sup> )	250	396
■ Altitude range (m)		79–130
■ Mean annual rainfall (mm)		1,375
■ Pressure factors	Wastewater, industry and agriculture	Agriculture

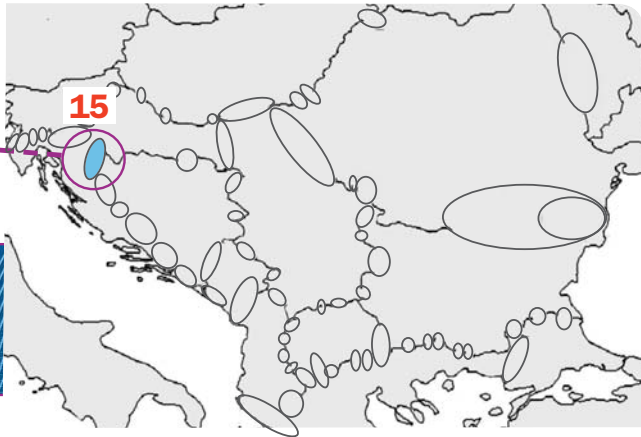
### Agreements: formal agreements ratified

- Framework Agreement on the Sava River basin signed by Bosnia and Herzegovina, Croatia, Slovenia and The former Federal Republic of Yugoslavia (2002).
- Agreement between the Government of the Republic of Croatia and the Government of the Republic of Slovenia on Water Management Issues (1997).
- Agreement between the Governments of the Republic of Croatia and Bosnia-Herzegovina on Water Management Issues. This was signed by the federation administration.



## Kupa

■ Type: Karst



### Croatia

### Bosnia and Herzegovina

■ Shared boundary length (km)	130
■ Area (km <sup>2</sup> )	452
■ Area population (inh)	286,000
■ Altitude range (m)	115–700
■ Mean annual rainfall (mm)	1,050

### Agreements: informal agreements/conventions

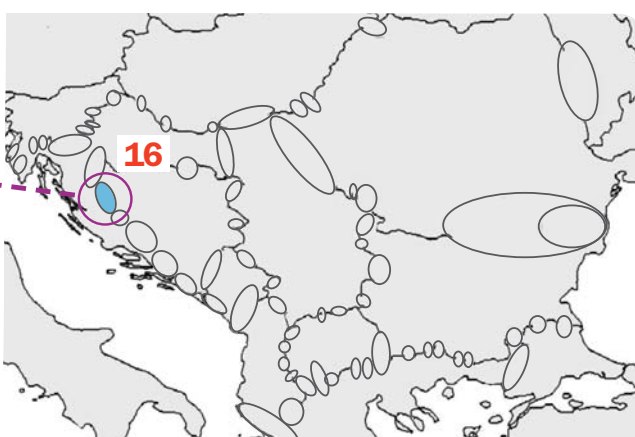
- Regional Environmental Center (REC) project: Sustainable future for the Kolpa Valley.

*Kupa River, Croatia*  
© SXC





## Una/ Plesevice



- Type: Karst

### Bosnia and Herzegovina

### Croatia

■ Shared boundary length (km)	130	
■ Area (km <sup>2</sup> )	110	
■ Altitude range (m)	94–150	
■ Water use description	>75% to support ecosystems and fishing, 25-50% of abstraction used for drinking water supply	Predominantly drinking water supply
■ Pressure factors	Solid waste disposal	Sewage from communities

### Agreements: formal agreements ratified

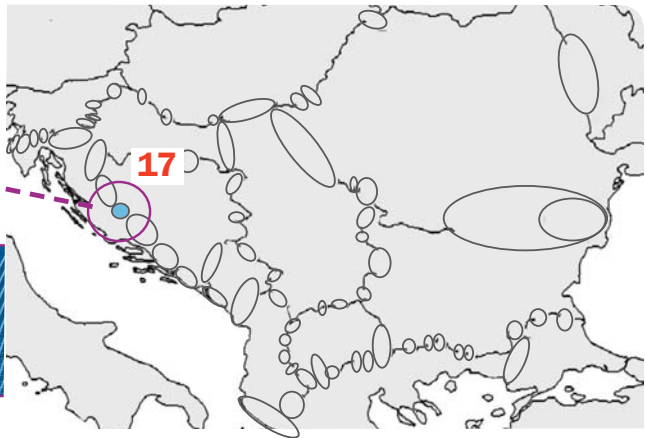
- A bilateral agreement on transboundary waters is in force with Croatia. The agreement implicitly covers groundwaters.

### Agreements: informal agreements/conventions

- Bosnia and Herzegovina is an observer to the Helsinki Convention on transboundary water.



■ Type: Karst



**Croatia**

**Bosnia and Herzegovina**

■ Shared boundary length (km)		42
■ Area (km <sup>2</sup> )	414	85
■ Mean annual Rainfall (mm)	1,100	700
■ Pressure factors	Population in communities and industry	Solid waste disposal
■ Quantity problems	None	Reduced springflow and ecosystem degradation
■ Quality problems	Occasionally, local and moderate pathogens	Polluted water locally drawn into the aquifer

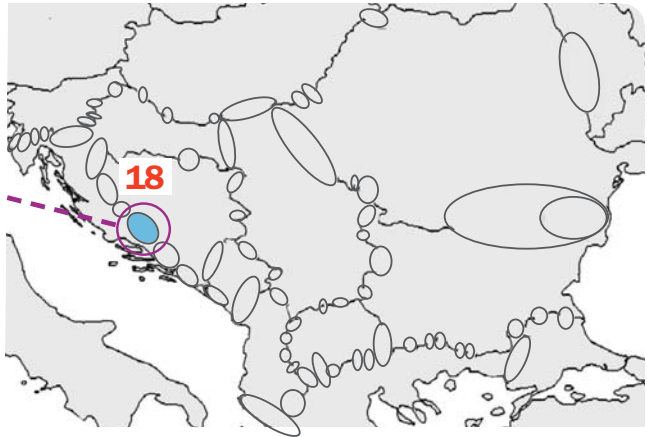
Waterfall, Krka River, Croatia  
© SXC







Lake at Pécs, Hungary  
© SXC



# Cetina

■ Type: Karst

## Bosnia and Herzegovina

## Croatia

■ Shared boundary length (km)		70
■ Area (km <sup>2</sup> )		587
■ Mean annual rainfall (mm/y)	Total annual rainfall 1,000–1,200	1,400 with spring and winter maxima

### Agreements: formal agreements ratified

- Bilateral agreement on transboundary waters is in force with Croatia. The agreement implicitly covers groundwaters.
- Agreement on water use for hydroelectric power plant Orlovac.

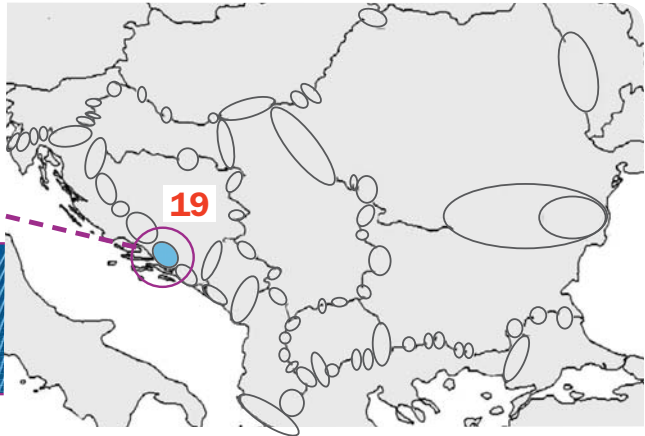
### Agreements: informal agreements/conventions

- Bosnia and Herzegovina is an observer to the Helsinki Convention on transboundary water.



## Neretva right

■ Type: Alluvial



### Bosnia and Herzegovina

### Croatia

■ Area (km<sup>2</sup>)

>1,600

862

■ Water use description

Dominantly drinking water supply and HEP, some irrigation

Groundwater: 100% of total water use  
Drinking water < 25%  
Irrigation <25%  
Support of ecosystems

#### Agreements: formal agreements ratified

- Bilateral agreement on transboundary waters is in force with Croatia. The agreement implicitly covers groundwaters.

#### Agreements: informal agreements/conventions

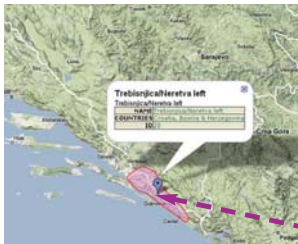
- Bosnia and Herzegovina is an observer to the Helsinki Convention on transboundary water. Croatia Regional Environmental Center organised two workshops to train local NGOs from Bosnia and Herzegovina and Croatia to prepare project proposals.

Neretva River Delta, Herzegovina  
© SXC

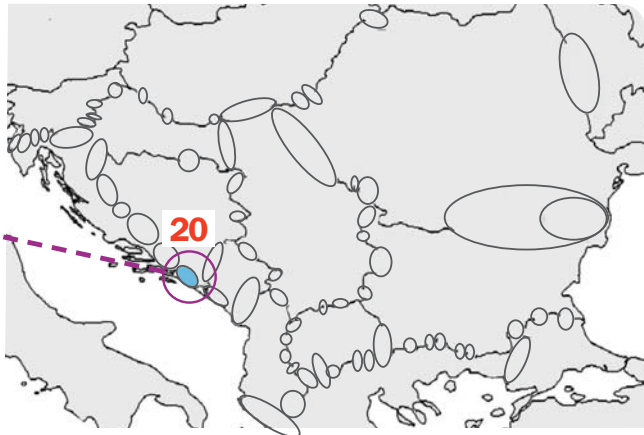




Kravice Waterfall, Bosnia and Herzegovina  
© SXC

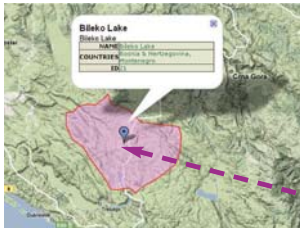


## Trebisnjica/ Neretva left



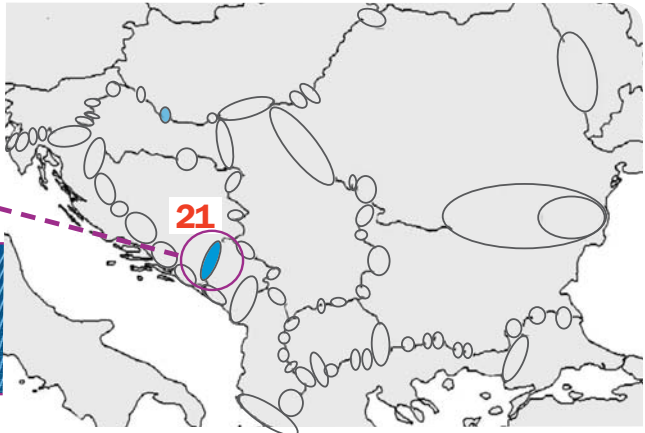
■ Type: Karst

	Croatia	Bosnia and Herzegovina
■ Shared boundary length (km)	124	
■ Area (km <sup>2</sup> )	242	> 2,000
■ Quality problems	Natural saline intrusion and occasional microbiologic pollution	Nitrogen and pathogens, widely but moderate
■ Transboundary impact	Improved connection with sink points in Bosnia and Herzegovina and wells and springs in Croatia	Decline of groundwater levels and increased groundwater pollution



# Bileko Lake

■ Type: Karst



**Bosnia and Herzegovina**

**Montenegro**

■ Shared boundary length (km)	90
■ Area (km <sup>2</sup> )	> 1,000
■ Quantity problems	Local, moderate degradation of ecosystems Local, severe deficit (because of use for energy production)

Durmitor Mountain  
© SXC



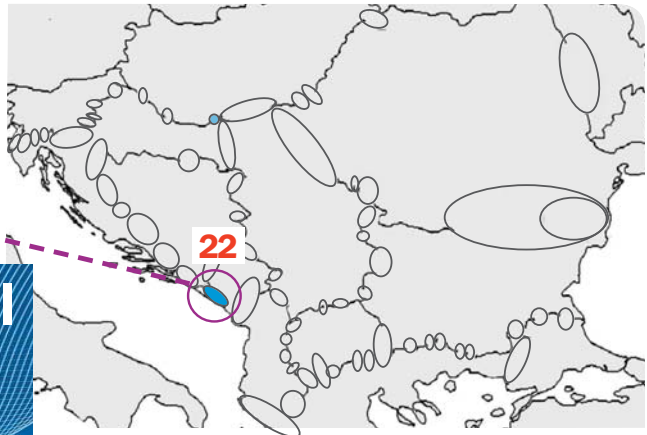




Kotor, Montenegro  
© SXC



## Dinaric litoral west coast



■ Type: Karst

■ Area (km<sup>2</sup>)

■ Water use description

■ Pressure factors

■ Quantity problems

### Montenegro

### Croatia

200

25-50% each for drinking water supply and industry, <25% each for irrigation and livestock

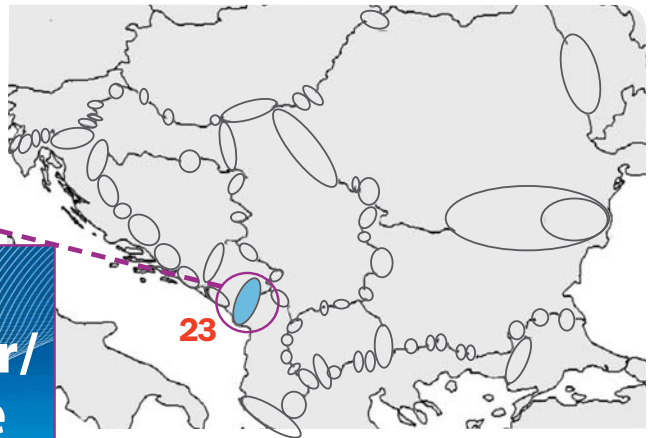
Abstraction of groundwater

Widespread and severe saline intrusion on the coast





## Dinaric east coast/ Skadar/ Shkodra lake



■ Type: Karst

### Albania

### Montenegro

■ Shared boundary length (km)

35

■ Area (km<sup>2</sup>)

450

200

■ Pressure factors

Industry, waste disposal, sanitation and sewer leakage

Groundwater abstraction

■ Quality problems

Local and moderate pathogens from waste disposal, sanitation and sewer leakage

Widespread and severe increased salinity

■ Water use

Urban, irrigation, industry

Skadar, Montenegro  
© UNESCO/Karl-Heinz Gaudry

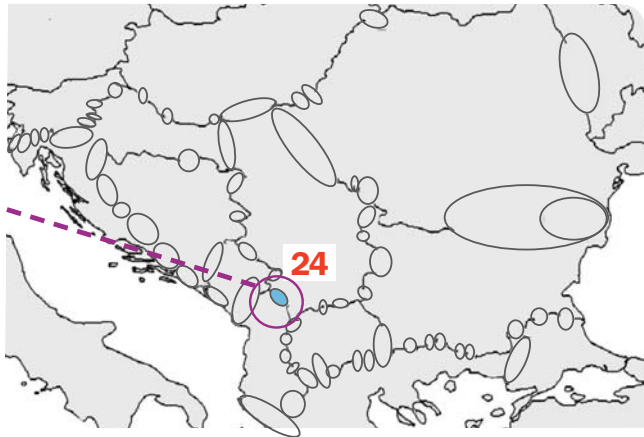




Albanian landscape  
© Morguefile

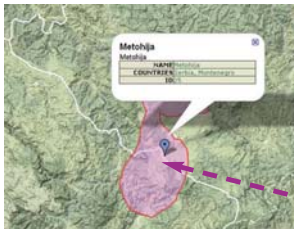


## Beli Drim/ Drini Bardhe



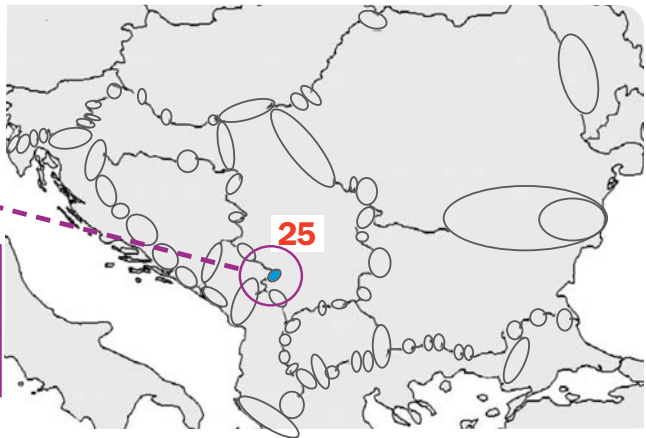
■ Type: Karst

	Serbia	Albania
■ Shared boundary length (km)		30
■ Area (km <sup>2</sup> )	1	170
■ Pressure factors	Abstraction of groundwater	Waste disposal, sanitation, sewer leakage
■ Quality problems	Nitrogen, pesticides and pathogens	Local and moderate pathogens
■ Water use	Urban, irrigation, industry	



# Metohija

■ Type: Alluvial



## Serbia

## Montenegro

■ Area (km<sup>2</sup>)

4

■ Pressure factors

Agriculture and local small industries

■ Quality problems

Pesticides and industrial organic compounds

■ Water use

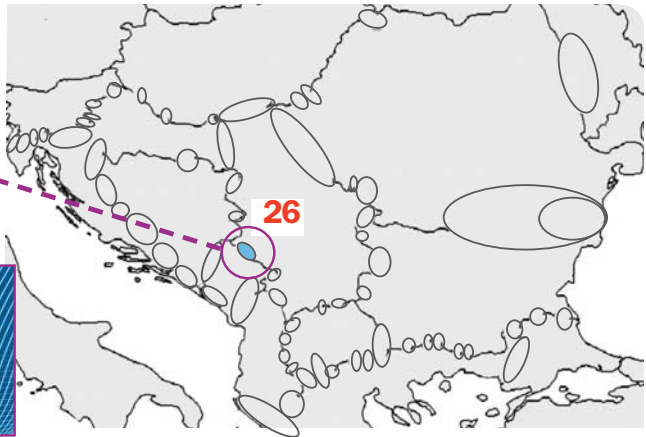
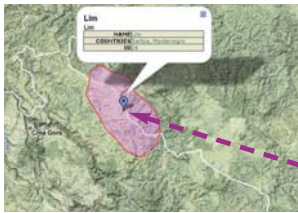
Urban, irrigation, industry

Tara River, Montenegro  
© SXC





Serbian landscape  
© SXC



# Lim

- Type: Karst

- Area (km<sup>2</sup>)

700

- Pressure factors

Waste disposal,  
mining and industry

- Quality problems

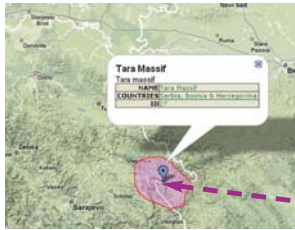
Local but severe nitrogen,  
heavy metals, pathogens,  
industrial organics and hydrocarbons

- Water use

Urban, irrigation, industry

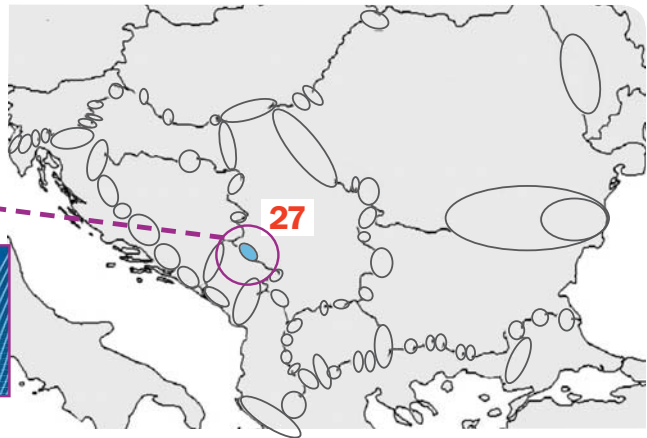
**Serbia**

**Montenegro**



## Tara Massif

- Type: Karst



### Serbia

### Bosnia and Herzegovina

■ Shared boundary length (km)	117
■ Area (km <sup>2</sup> )	211
■ Mean annual rainfall (mm)	650
■ Annual groundwater resources / abstractions (Mm <sup>3</sup> /y)	247/207

### Agreements: formal agreement ratified

- Danube River Protection Convention implemented by International Commission for the Protection of the Danube River (ICPDR).

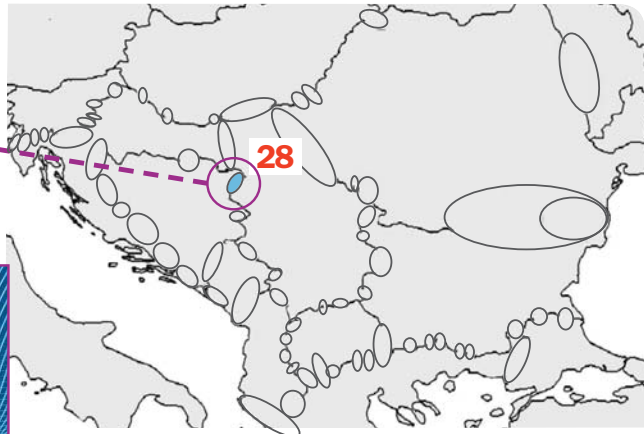
Visegrad,  
Bosnia and Herzegovina  
© SXC







Maljen Mountain, Divcibare, Serbia  
© SXC



## Macva-Semberija

■ Type: Alluvial

- Area (km<sup>2</sup>)
- Altitude range (m)
- Pressure factors
- Quantity problems
- Water use

### Serbia

967  
100/750  
Agriculture and sanitation,  
some industry

### Bosnia and Herzegovina

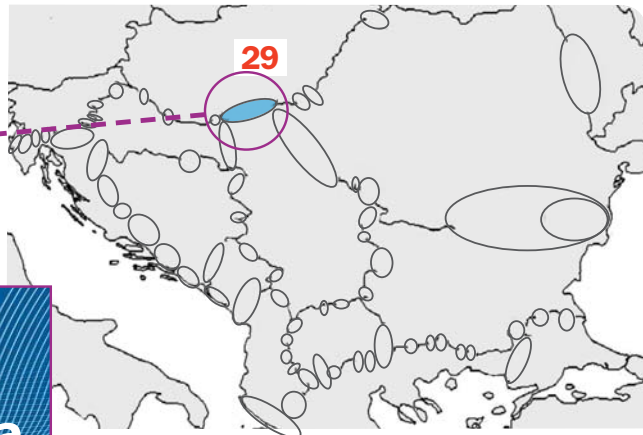
>250  
Agriculture  
and sanitation

Local and moderate increase  
in pumping lifts

Urban, irrigation, industry

### Agreements: formal agreement ratified

- Danube River Protection Convention implemented by International Commission for the Protection of the Danube River (ICPDR).



## Northeast Backa/ Danube-Tisza Interfluve

■ Type: Alluvial

**Serbia**

**Hungary**

■ Shared boundary length (km)

169

■ Area (km<sup>2</sup>)

4

9

■ Mean annual rainfall (mm)

650

550

■ Annual groundwater resources (Mm<sup>3</sup>/y)

172

122

■ Annual groundwater abstractions (Mm<sup>3</sup>/y)

1,184

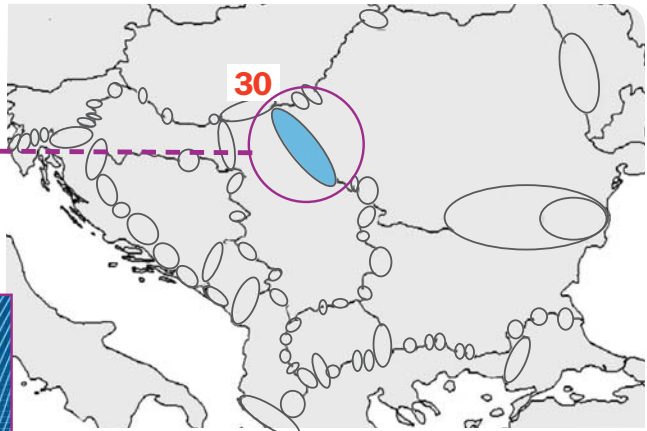
21

Tisza lake Lake, Hungary  
© SXC/Gabor Palla





Lake Grza, Serbia  
© SXC



## Banat, Region of

- Type: Alluvial

### Serbia

### Romania

- Shared boundary length (km)

225

- Area (km<sup>2</sup>)

4

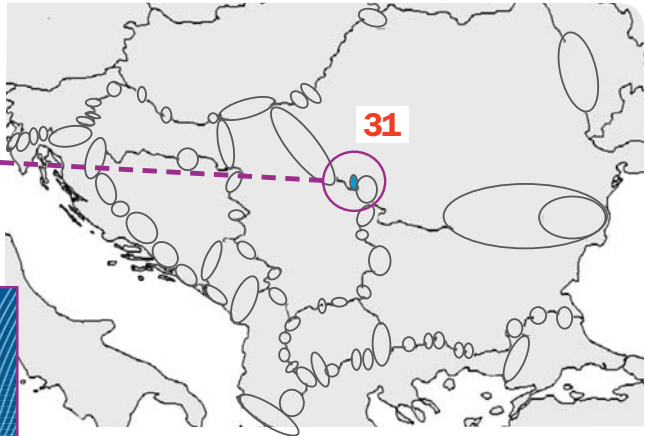
11

- Pressure Factors

Sanitation,  
irrigated agriculture,  
waste disposal,  
industry, oilfields

- Water use

Drinking water 50%  
Irrigation 20%  
Industry 30%



# Miroc and Golubac

■ Type: Karst

■ Area (km<sup>2</sup>)

■ Pressure factors

■ Quality problems

■ Water use

## Serbia

300

Waste disposal and industry

Local but severe heavy metals from industry

Drinking water

## Romania

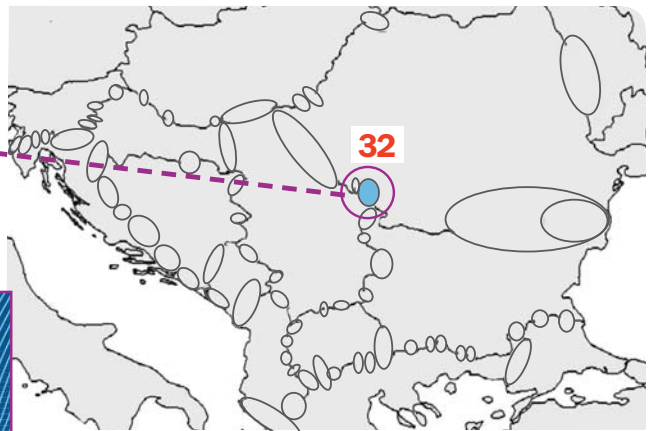
25% of total water use comes from groundwater: drinking water < 25%, irrigation < 25%, industry < 25%

Lake Bucura,  
Retezat Mountains, Romania  
© SXC





Cerna River, Herculane, Romania  
© SXC



## Dacian Basin

- Type: Alluvial

- Pressure factors

- Water use

### Serbia

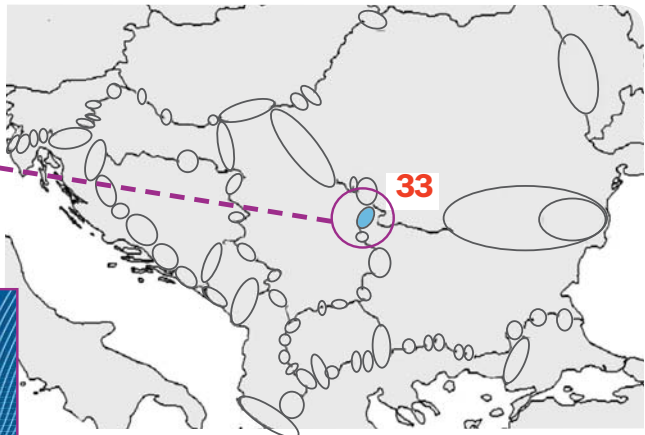
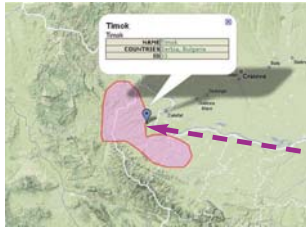
Waste disposal

< 25% each for drinking water, irrigation and industry

### Romania

15% of total water use comes from groundwater  
Drinking water < 25%  
Irrigation < 25%





# Timok

■ Type: Alluvial

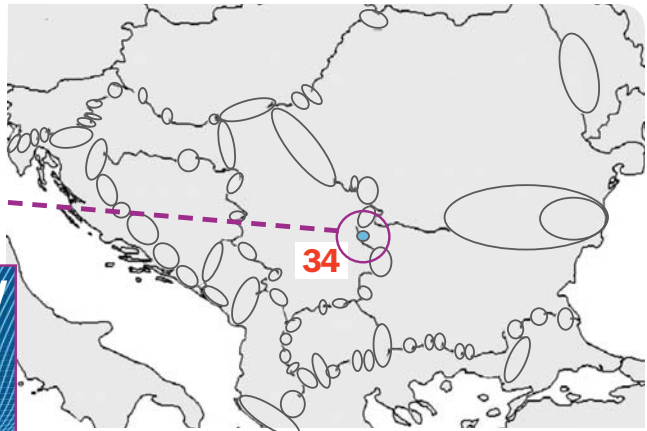
	Serbia	Bulgaria
■ Shared boundary length (km)	234	234
■ Area (km <sup>2</sup> )	200	137
■ Pressure factors	Mining and waste disposal	
■ Quality problems	Widespread and severe heavy metal, sand industrial organic compounds, local pathogens and organics	
■ Water use	Drinking, irrigation and agriculture	50% of total water use comes from groundwater Drinking water: 25-50%; Irrigation, industry, thermal spa, livestock: < 25% each



Gabrovacka River, Serbia  
© SXC



National Park 'Central Balkan', Bulgaria  
© SXC/Evgeni Dinev



## Stara Planina/ Salasha Montana

- Type: Karst
- Area (km<sup>2</sup>)
- Pressure factors
- Quality problems
- Water use

### Serbia

500

Waste disposal  
and industry

Local and moderate nitrogen  
and pathogens from waste disposal,  
more severe heavy metals  
from industry and organic  
pollutants from waste disposal

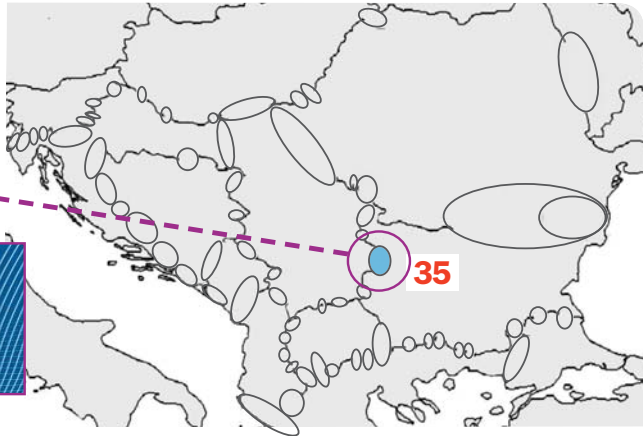
25-50% drinking water,  
< 25% each for irrigation, industry,  
thermal spa and livestock

### Bulgaria



## Nishava and Tran/Vidlic

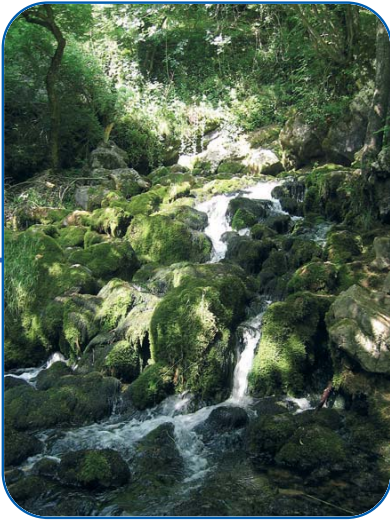
■ Type: Karst



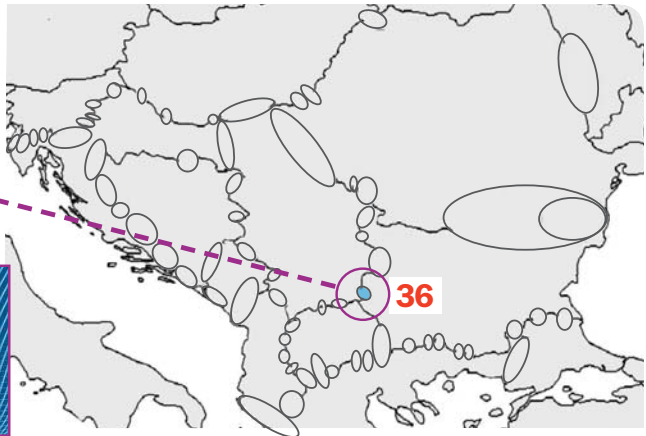
	Serbia	Bulgaria
■ Area (km <sup>2</sup> )	285	180
■ Pressure factors	Agriculture	
■ Quality problems	Local but severe pathogens from farming	
■ Water use	50-75% drinking water, < 25% each for industry and livestock, and support of ecosystems	Drinking water and irrigation

Nishava River, Serbia  
© SXC





Grza, Serbia  
© SXC



# Zemen

- Type: Karst

- Area (km<sup>2</sup>)
- Pressure factors
- Quality problems
- Water use description

## Bulgaria

>200

## Serbia

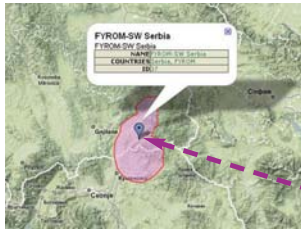
180

Shortage of water

Local and moderate nitrogen and pathogens from waste disposal

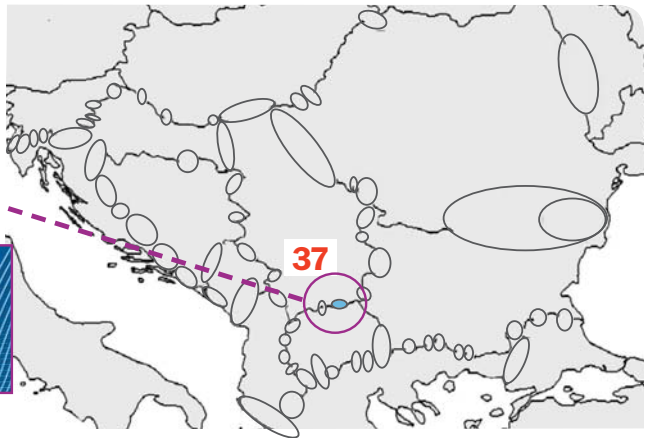
Only surface water from the confluence of the Strymen river





## FYROM-SW Serbia

■ Type: Karst



### The FYR of Macedonia

### Serbia

■ Area (km <sup>2</sup> )		300
■ Pressure factors	Local leakage of groundwater from wells and groundwater from springs	Agriculture
■ Quality problems	Local from agriculture	Local
■ Quantity problems	Local reduction of boreholes yields and spring discharges	
■ Water use description	Water for drinking, little irrigation and mining	50% for drinking water supply, 50% for agriculture

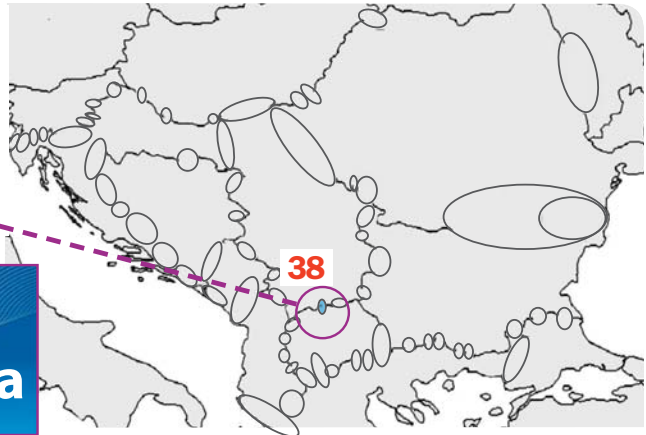
Serbian landscape  
© SXC







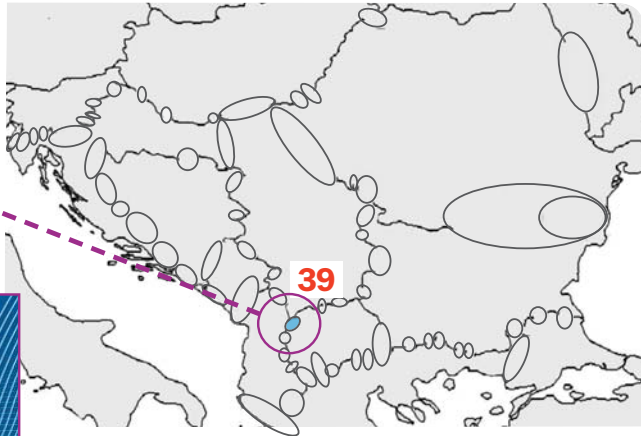
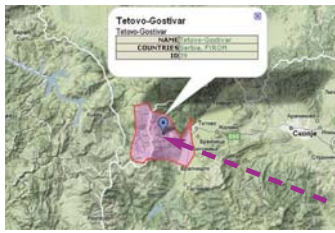
Peja countryside, Albania  
© Morguefile



## FYROM-Central Serbia

■ Type: Alluvial

	The FYR of Macedonia	Serbia
■ Shared boundary length (km)	50	
■ Area (km <sup>2</sup> )		100
■ Water use description	Water for drinking, some irrigation and mining	More than 50% surface water
■ Pressure factors	Local leakage of groundwater from wells and groundwater from springs	Waste disposal and industry
■ Quality problems	Local from agriculture	Moderate pollution drawn into the aquifer system



## Tetovo-Gostivar

- Type: Karst

### The FYR of Macedonia

### Serbia

■ Shared boundary length (km)		15
■ Area (km <sup>2</sup> )		50
■ Water use description	Drinking water, irrigation, mining and industry	50% drinking water, 50% support of ecosystems
■ Pressure factors	Local leakage of groundwater from wells and groundwater from springs	Agriculture
■ Quality problems		Local only from farming

*Radika River, Dolno Kosovrasti,  
The former Yugoslavian  
Republic of Macedonia*

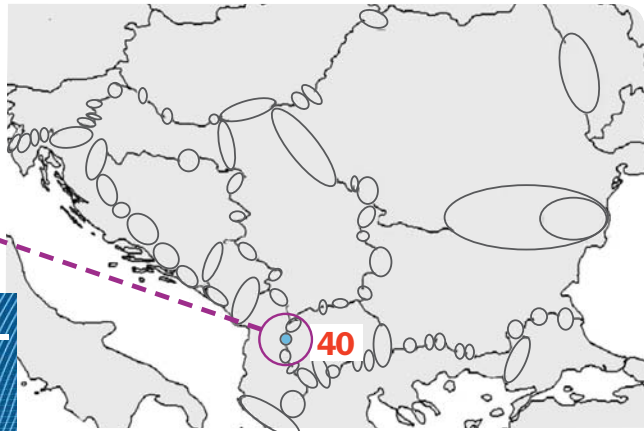




Peshkopi, Albania

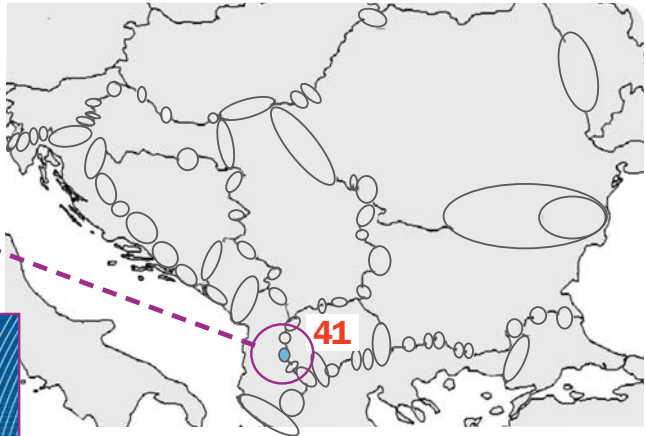


## Korab/Bistra - Stogovo



■ Type: Karst

	The FYR of Macedonia	Albania
■ Shared boundary length (km)	25	
■ Area (km <sup>2</sup> )		140
■ Water use description	Drinking water, irrigation, mining	25-50 % for thermal spa, < 25 % each for drinking, irrigation and livestock
■ Pressure factors	Groundwater abstraction, agriculture	Waste disposal, sanitation and sewer leakage
■ Quantity problems	Local reduction of discharge from springs	



# Jablanica/ Golobordo

■ Type: Karst

## The FYR of Macedonia

## Albania

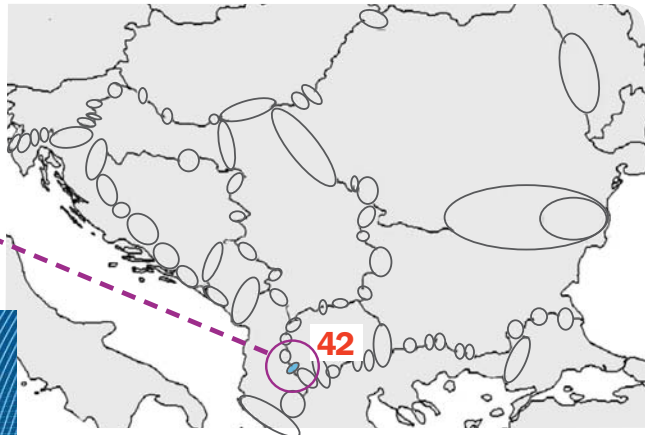
■ Shared boundary length (km)		50
■ Area (km <sup>2</sup> )		250
■ Water use description	Drinking water supply, thermal water and industry, hydroelectrical power	25-50% for irrigation, < 25% each for drinking water and industry
■ Pressure factors	Sanitation and sewer leakage	Modest pressures from waste disposal, sanitation and sewer leakage
■ Quality problems	Pesticides and industrial organic compounds	

*Jablanica Lake, The former Yugoslavian Republic of Macedonia*





SV. Kilent Church, Ohrid Lake,  
The FYR of Macedonia  
© UNESCO/Astrid Postl



# Ohrid Lake

■ Type: Karst

## The FYR of Macedonia

## Albania

- Mean annual rainfall (mm)
- Discharge flow (m<sup>3</sup>/s)
- Annual groundwater resources (Mm<sup>3</sup>/y)
- Water use description

2

1

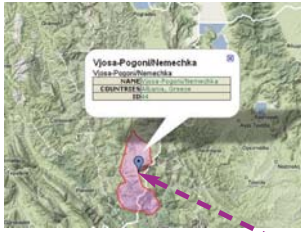
1,500

2

85

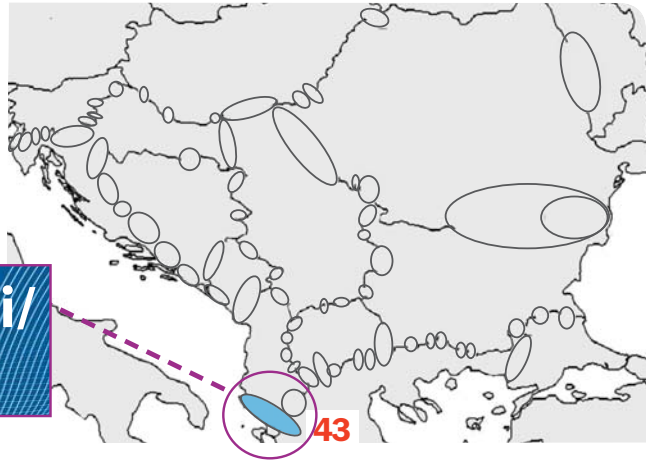
The water is used for drinking, irrigation and hydropower for the town of Bistrica





## Vjosa-Pogoni/ Nemechka

- Type: Karst



### Albania

### Greece

■ Shared boundary length (km)	37	
■ Area (km <sup>2</sup> )	550	350
■ Altitude range (m)	150/1,589	400/2,550
■ Water use description	25-50% irrigation, < 25% each for drinking water, livestock and industry, maintaining baseflow and springs and supporting ecosystems	Water supply with minor irrigation and fish farming, support of ecosystems

Himar, Albania  
© SXC

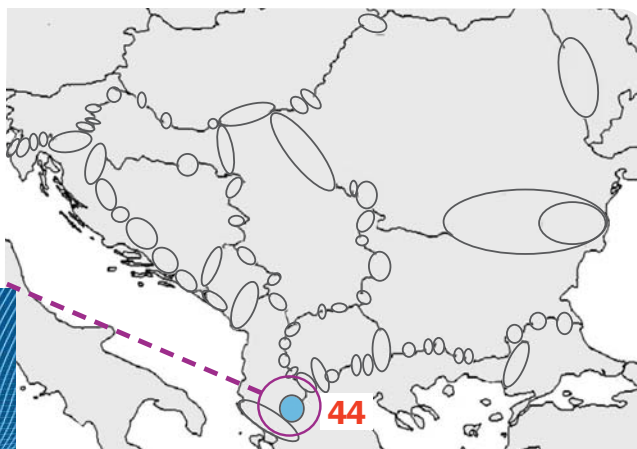




Kastoria lake, Greece  
© SXC/Markellos Plakitsis

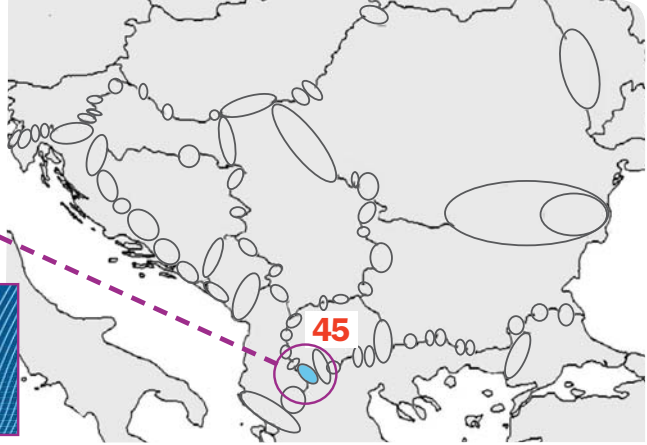
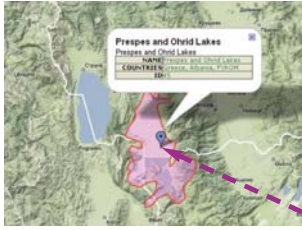


## Mourgana Mountain/ Mali Gjere



■ Type: Karst

	Albania	Greece
■ Shared boundary length (km)	20	440
■ Area (km <sup>2</sup> )	200	440
■ Altitude range (m)	300–1,800	
■ Quality problems	Pesticides and industrial organic compounds	
■ Water use description	No major water uses due to small population, some local livestock, minor irrigation and fish farming from springs	Provides 100% of drinking water supply and spa use, and >75% for irrigation, industry and livestock



# Prespes and Ohrid Lakes

■ Type: Karst

## Greece Albania The FYR of Macedonia

■ Boundaries length (km)	40	41	52
■ Area (km <sup>2</sup> )	413	750	
■ Mean annual rainfall (mm)		720	
■ Future trends	Increasing groundwater use by the growing population and intensive development of tourism. Increasing collaboration of all three countries to protect groundwater and surface water resources in a basin-wide way		

### Agreements: formal agreement ratified

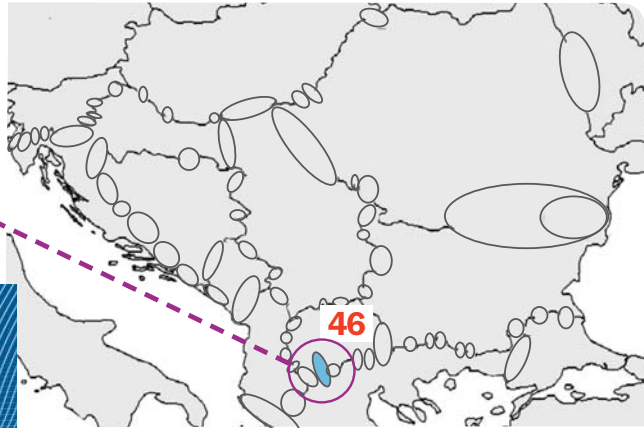
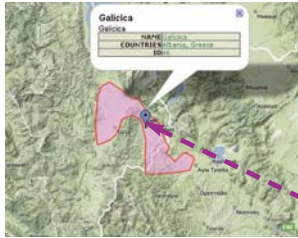
- Ramsar Convention.
- International Park and Special Protection Area-79/409/EEC.

Prespa Lake, The FYR of Macedonia  
© SXC





Lake Ohrid, The FYR of Macedonia  
© SXC



# Galicica

■ Type: Karst

	Albania	Greece
■ Mean annual rainfall (mm)	600	645
■ Annual groundwater abstractions (Mm <sup>3</sup> /y)	4	
■ Water use description		Bottling of naturally sparkling mineral water, local water supply, agriculture

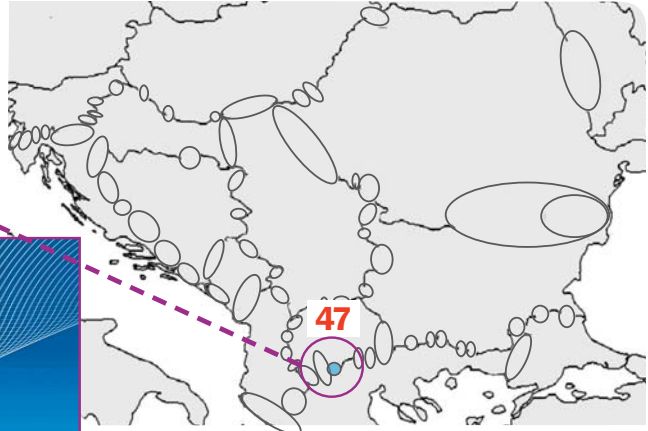
## Agreements: formal agreement ratified

■ Prespa Park Programme for sustainable development of the wider Prespa region ratified by Albania, the FYR of Macedonia and Greece.





## Pelagonia/ Florina/ Bitolsko



■ Type: Alluvial

- Area (km<sup>2</sup>)
- Altitude range (m)
- Water use description

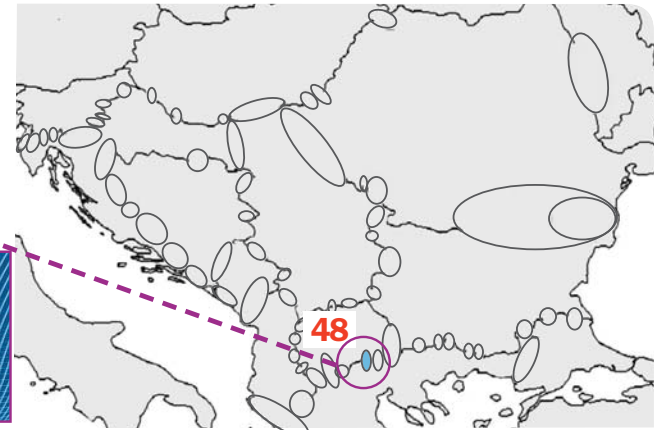
### The FYR of Macedonia

### Greece

	607	607
	800–2,500	800–2,500
Drinking water supply, support of ecosystems, agriculture and maintenance of baseflow and springs		Water supply and irrigation



## Gevgelija



■ Type: Alluvial

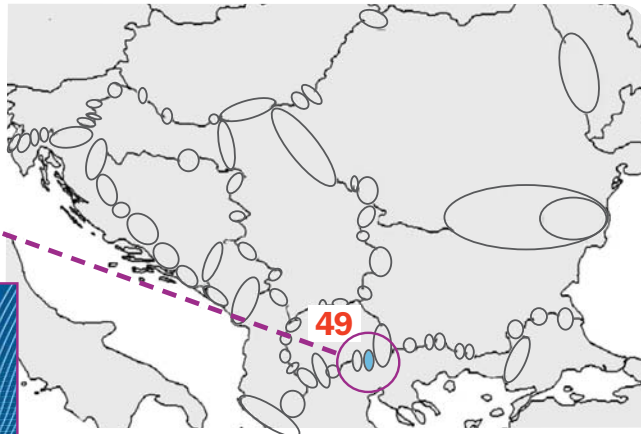
- Mean annual rainfall (mm)
- Water use description

630	616
Maintenance of baseflow and springs and support of ecosystem	Agriculture, local water hypo-thermal water





Edessa Waterfall, Greece  
© SXC



## Dojran Lake

■ Type: Alluvial

■ Area (km<sup>2</sup>)

■ Altitude range (m)

■ Water use description

■ Quantity problems

■ Pressure factors

### The FYR of Macedonia

92

Irrigation and water supply

Declining groundwater levels, reduction of water from the lake, degradation of associated ecosystems

### Greece

190

138–1,874

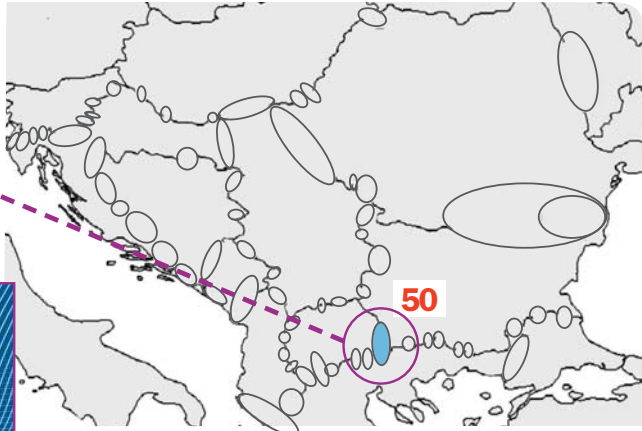
Maintenance of baseflow and springs and support of ecosystems and agriculture

Widespread but moderate reduction in borehole yields, baseflow and degradation of ecosystems; the volume and area of the lake have declined drastically

Groundwater abstraction for irrigation



# Sandansky-Petrich

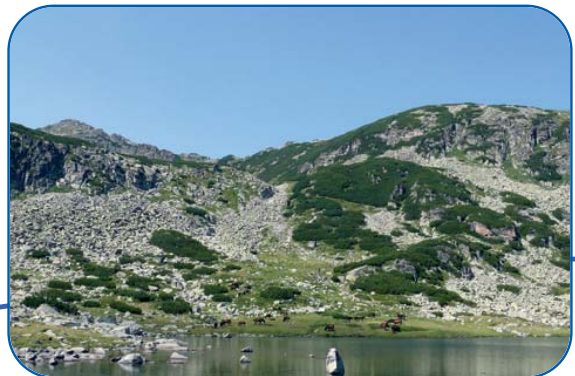


■ Type: Alluvial

	<b>Bulgaria</b>	<b>Greece</b>	<b>The FYR of Macedonia</b>
--	-----------------	---------------	-----------------------------

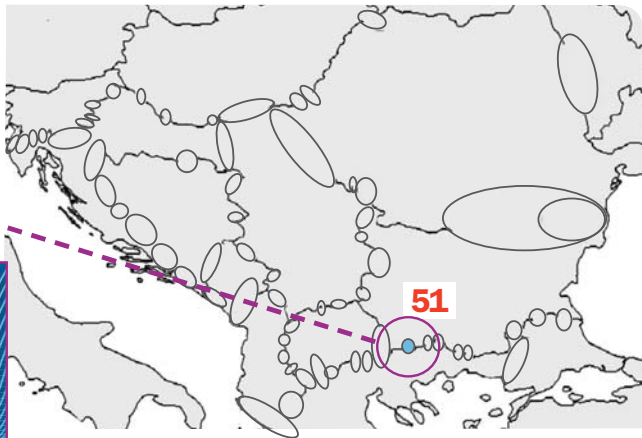
■ Shared boundary length (km)	18	18	5
■ Area (km <sup>2</sup> )	764		
■ Water use description			Drinking water, irrigation and industry, thermal springs, agriculture

Rila Mountain, Bulgaria  
© SXC





# Goltze Delchev / Orvilos-Agistros

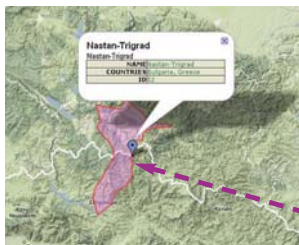


■ Type: Karst

**Bulgaria**

**Greece**

■ Shared boundary length (km)		22
■ Area (km <sup>2</sup> )	156	200
■ Altitude range (m)		350–2,200



# Nastan-Trigrad

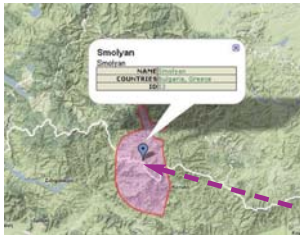


■ Type: Karst

**Bulgaria**

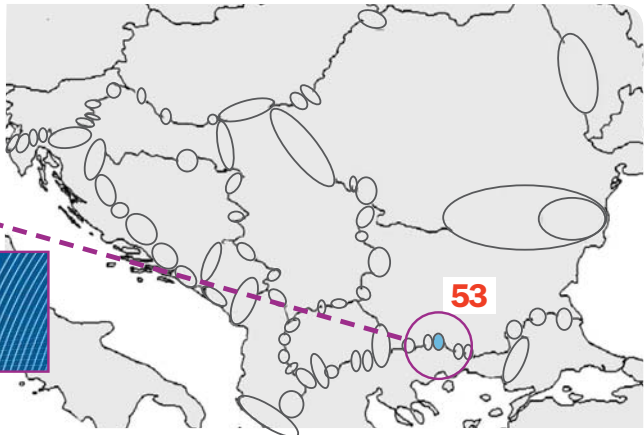
**Greece**

■ Shared boundary length (km)		6
■ Area (km <sup>2</sup> )	203	



# Smolyan

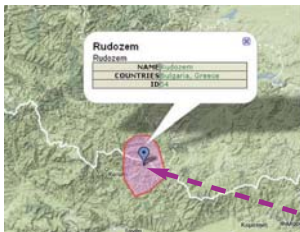
■ Type: Karst



**Bulgaria**

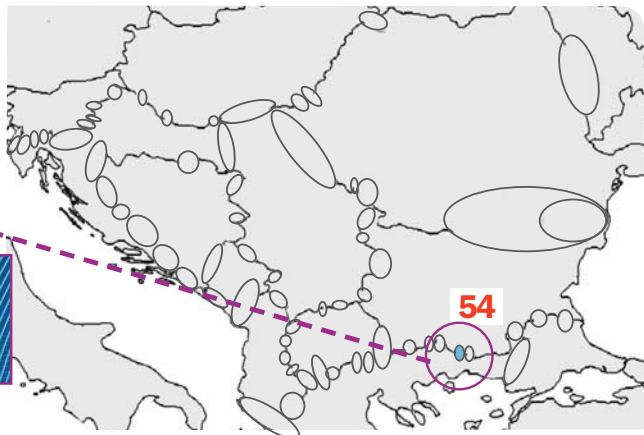
**Greece**

■ Shared boundary length (km)		4
■ Area (km <sup>2</sup> )	94	



# Rudozem

■ Type: Karst



**Bulgaria**

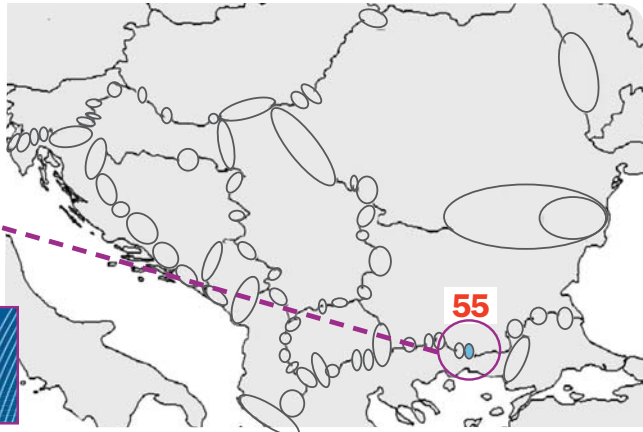
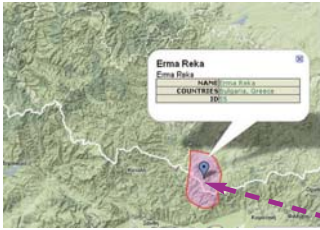
**Greece**

■ Shared boundary length (km)		34
■ Area (km <sup>2</sup> )	80	





Trigrad Gorge, Bulgaria  
© Morguefile



# Erma Reka

■ Type: Karst

- Area (km<sup>2</sup>)
- Mean annual rainfall (mm)
- Annual groundwater resources (Mm<sup>3</sup>/y)
- Annual groundwater abstractions (Mm<sup>3</sup>/y)
- Water use description

## Bulgaria

40

## Greece

641

10

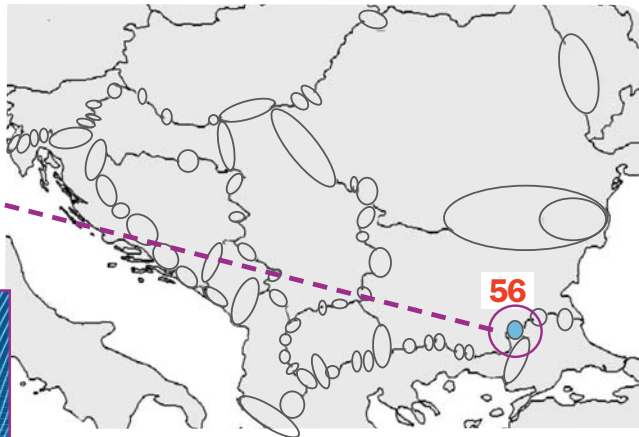
45

Many tube and shaft wells are available for drinking water supply, irrigation and industrial supply





## Svilengrad Stambolo/ Orestiada



■ Type: Alluvial

	Bulgaria	Greece	Turkey
■ Area (km <sup>2</sup> )	672	600	150
■ Altitude range (m)			25–200
■ Annual groundwater abstractions (Mm <sup>3</sup> /y)		27	
■ Water use description	More than 90% of abstractions are used for irrigation and the rest for water supply	90% for irrigation and 10% for drinking water supply, maintenance of baseflow and springs and support of ecosystems	Public-urban, industrial and agricultural

Middleage bridge, Harmanli, Bulgaria  
© SXC





Evros Delta, Greece  
© SXC/Makis Mourelatos



## Evros/Meric

■ Type: Alluvial



Turkey Greece

■ Shared boundary length (km) 105

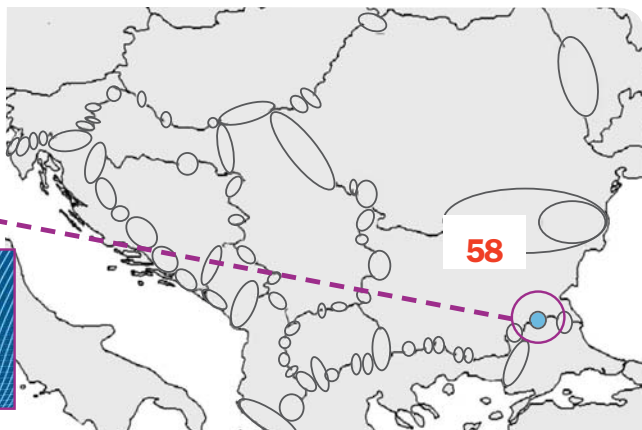


## Topolovgrad Massif

■ Type: Karst

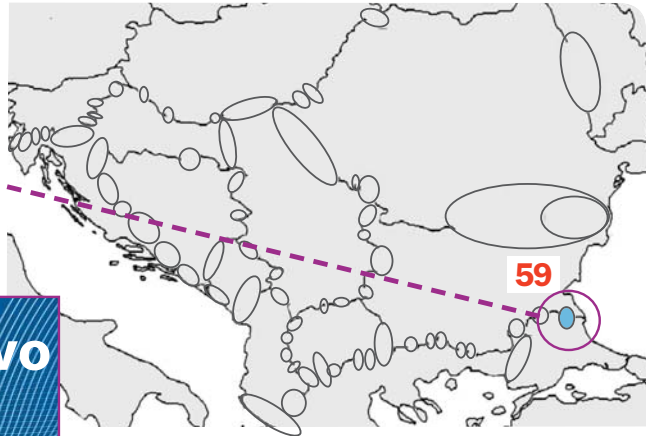
■ Water use

■ Quality problems



Bulgaria Turkey

Urban, irrigation  
Nitrate in NE area



## Malko Tarnovo Massif

■ Type: Karst

**Romania**

**Bulgaria**

■ Shared boundary length (km)

90

■ Topography

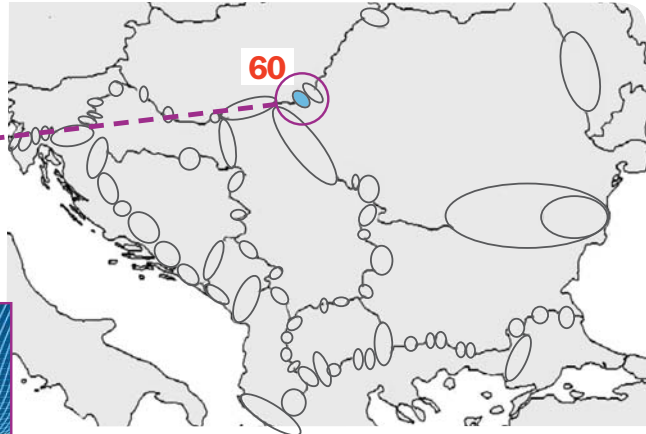
Plateau, 75 m.a.s.l.

■ Water use description

Drinking water: 45%  
Irrigation: 35%  
Industry: 20%

Danube River, Svishtov  
© SXC





## Pleistocene Someş/Szamos alluvial fan

■ Type: Alluvial

■ Shared boundary length (km)

64

■ Water use description

Upper region, 40% industry, 30% each irrigation and drinking water; lower region, 75% drinking water supply and 25% industry, minor agricultural use

>75% drinking water supply, less than 10% each for irrigation, industry and livestock, maintaining baseflow and support of ecosystems

■ Pressure factors

Agriculture, sewers and septic tanks

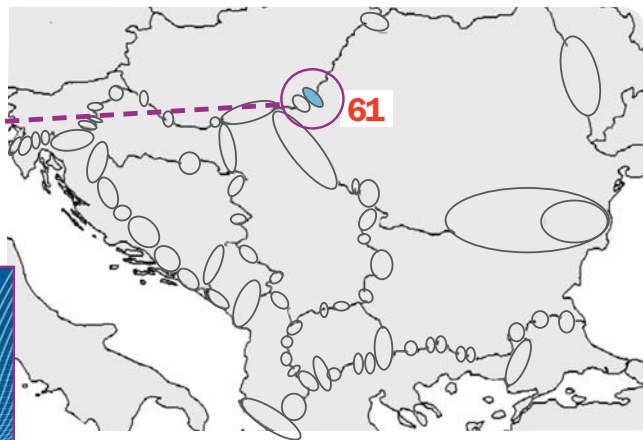
■ Quantity problems

Local and moderate increased pumping lifts and small drawdowns only around two major catchments

Local and moderate increases in pumping lifts, reduction in borehole yield, reduced spring flow and degradation of ecosystems

### Romania

### Hungary



## Pleistocene Mureș/ Maros alluvial fan

■ Type: Alluvial

■ Area (km<sup>2</sup>)

■ Water use description

■ Pressure factors

### Romania

2

75% for drinking water supply, 15% for industry and 10% for irrigation (shallow), 45%, 35% and 20% respectively for the confined aquifer

Groundwater abstraction

### Hungary

4

>75% drinking water, < 25% each for irrigation, industry and livestock, support of agriculture and ecosystems

Groundwater abstraction, agriculture, septic tanks

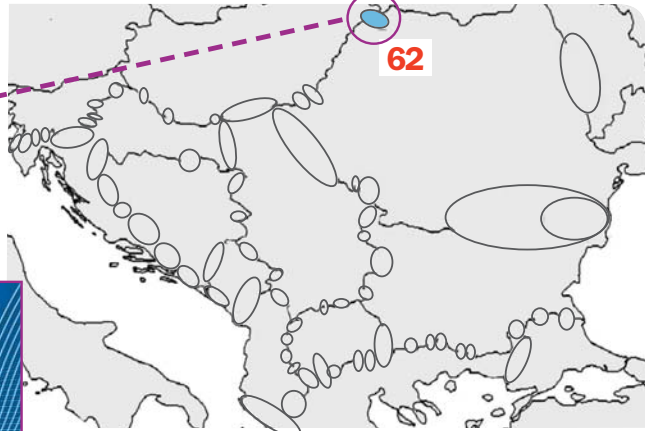
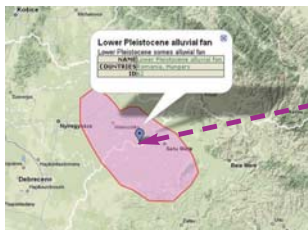
*Bucium Poieni, a small village in the Apuseni Mountains, Romania*  
© SXC







Lake Biczaz, Romania  
© SXC



## Lower Pleistocene Some alluvial fan

■ Type: Alluvial

■ Mean annual rainfall (mm)

■ Annual groundwater resources (Mm<sup>3</sup>/y)

■ Water use description

### Romania

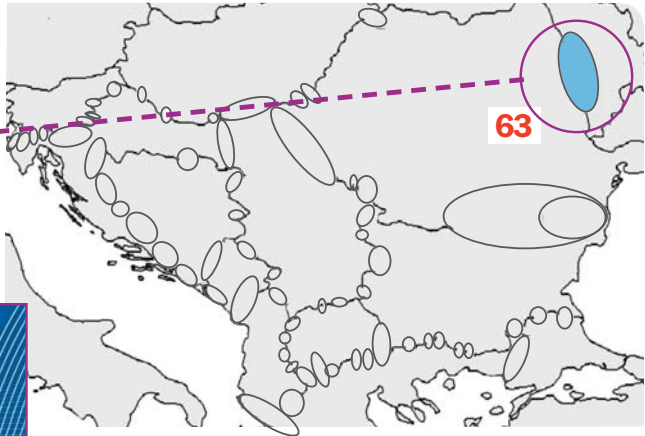
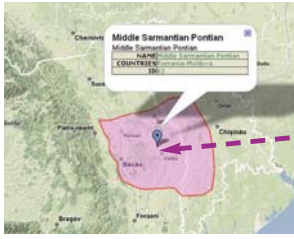
500–600

148

Drinking water 75%  
Industry 25%

### Hungary

Drinking water 75%  
Irrigation 10%  
Industry 15%

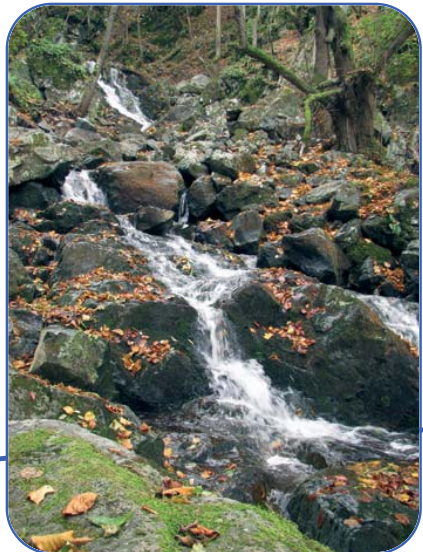


# Middle Sarmatian Pontian

■ Type: Alluvial

**Romania    Rep. of Moldova**

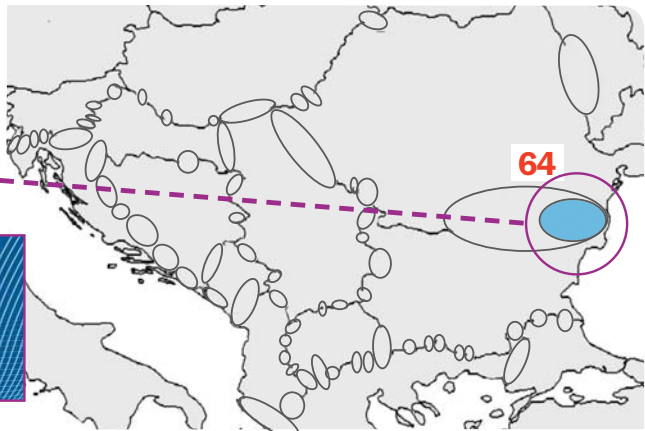
■ Area (km <sup>2</sup> )	12	
■ Altitude range (m)	220–525	
■ Mean annual rainfall (mm)		400–500
■ Annual groundwater resources/abstractions (Mm <sup>3</sup> /y)		155/45
■ Water use description	50% drinking water supply, 25% industry and 15% irrigation, minor spa	



*Boyana River in Vitosha Mountains, Bulgaria*  
© SXC



## Neogene-Sarmatian



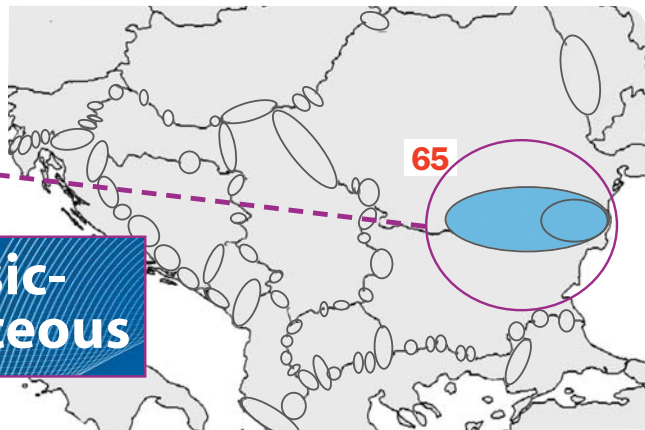
**Bulgaria**

**Romania**

■ Type: Karst		
■ Shared boundary length (km)	90	
■ Area (km <sup>2</sup> )	4	2
■ Altitude range (m)	0–150	
■ Mean annual rainfall (mm)	400–600	
■ Pressure factors	Agriculture	
■ Water use description	Groundwater provides about 30% of total water use	50% drinking water supply, 30% irrigation and 20% for industry



## Upper Jurassic-Lower Cretaceous



**Romania**

**Bulgaria**

■ Type: Karst		
■ Shared boundary length (km)	290	
■ Area (km <sup>2</sup> )	15	11
■ Altitude range (m)	17–250	
■ Pressure factors		Agriculture
■ Quantity problems	Local and moderate increased pumping lifts	Local but severe increased pumping lifts

# SOUTH-EASTERN EUROPE

## Case study

### Protection and Sustainable Use of the Dinaric Karst Aquifer System Project

GEF International Waters (IW), UNDP-GEF and UNESCO-IHP have started the preparation of a project together with the following countries: Albania, Bosnia and Herzegovina, Croatia, Montenegro, based on the UNESCO IHP ISARM inventories.

The preparation of the project is the result of several initiatives, such as Athens Declaration, Petersburg Process and the ISARM workshops held by INWEB in Thessaloniki. The project preparatory phase is currently being carried out. In November 2008 an inception workshop was held in Podgorica, Montenegro.

The significant issues that affect the Dinaric Karst Transboundary Aquifer System (DiKTAS) can be summarised as the over-exploitation of shared groundwater resources, coupled with deterioration of the environmental quality (water quality and ecosystems biodiversity). The overall goal of the proposed project is therefore the establishment of a sound management of the aquifer system in such a way as to ensure a reduction of environmental stress and a preservation of the unique Dinaric Karst habitats.



*Karst sinkholes at Biokovo, Croatia  
© SXC*

The Dinaric Karst Aquifer System, shared by several countries is one of the world's largest. It has been identified as an ideal opportunity for applying new and integrated management approaches to these unique freshwater resources and ecosystems. At the regional level the project's objectives are to:

- facilitate the equitable and sustainable utilization of the transboundary water resources of the Dinaric Karst Aquifer System, and
- protect the unique groundwater dependent ecosystems that characterize the Dinaric Karst region of the Balkan peninsula.

*At a global level  
the project aims to increase awareness  
within the international community  
of the vast but vulnerable quantity  
of water resources  
contained in karst aquifers,  
which are widespread globally,  
but poorly understood.*

#### DIKTAS ACTIVITIES

Objectives are expected to be achieved through a concerted **international** effort involving:

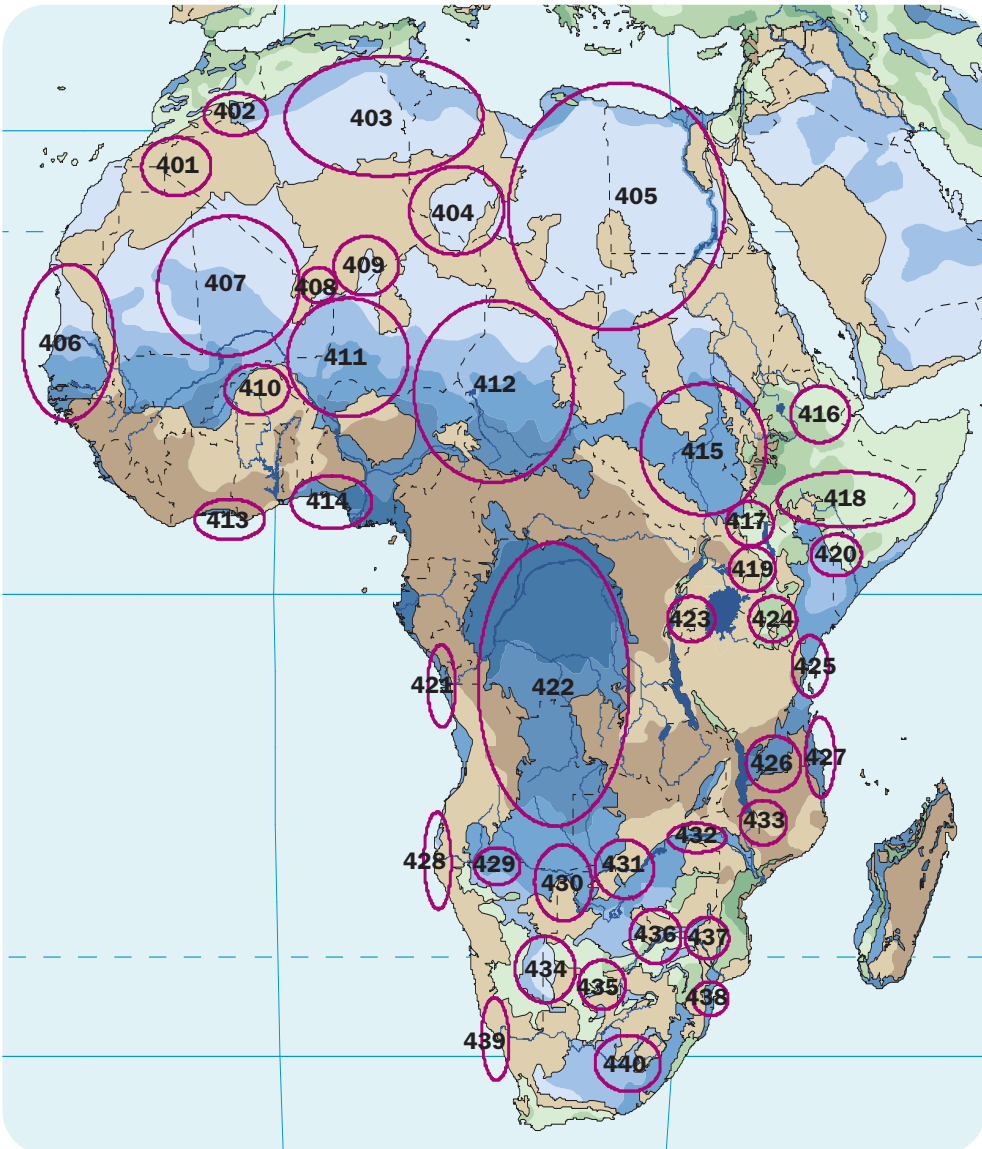
- improvement in **understanding** of the Resource and its environmental status
- building of **political consensus** and facilitation of **harmonisation** around key reforms and new policies,
- enhanced and sustainable **coordination** among countries, donors, projects and agencies



# AFRICA

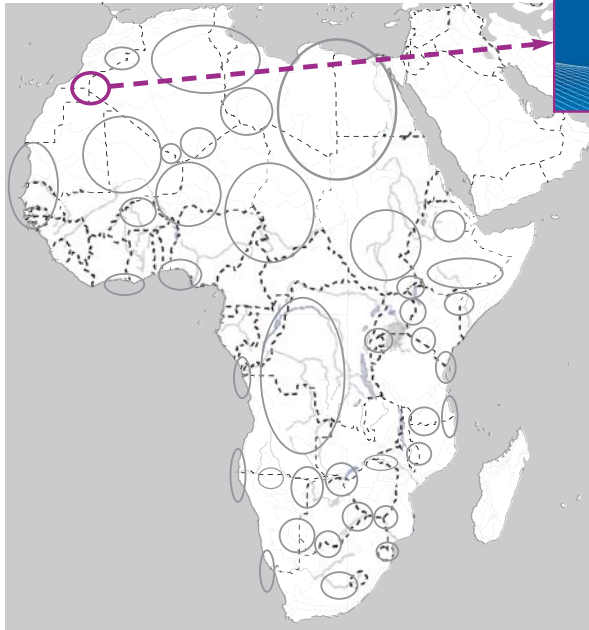
## TRANSBOUNDARY AQUIFERS INVENTORY

### OVERVIEW



Source: Adapted from WHYMAP 2006, <<http://www.whymap.org>>.

WHYMAP Number	Name	Countries
401	Tindouf Aquifer	Algeria-Morocco
402	Errachidia Basin	Algeria-Morocco
403	Northwest Sahara Aquifer System	Algeria-Libya-Tunisia
404	Mourzouk-Djado Basin	Chad-Libya-Niger
405	Nubian Sandstone Aquifer System	Chad-Egypt-Libya-Sudan
406	Senegalo-Mauritanian Basin	Gambia-Guinea-Bissau-Mauritania-Senegal
407	Taoudeni Basin	Algeria-Mali-Mauritania
408	I'Air Cristalline Aquifer	Algeria-Mali-Niger
409	Tin-Seririne Basin	Algeria-Niger
410	Liptako-Gourma Aquifer	Burkina Faso-Niger
411	Iullemeden Aquifer System	Mali-Niger-Nigeria
412	Chad Basin	Central African Rep.-Chad-Cameroon-Niger-Nigeria
413	Coastal Sedimentary Aquifer	Ghana-Côte d'Ivoire
414	Coastal Sedimentary Aquifer	Benin-Nigeria-Togo
415	Upper Nile Basin	Ethiopia-Sudan
416	Awash Valley Aquifer	Djibouti-Ethiopia
417	Rift Aquifers	Kenya-Tanzania-Uganda
418	Ogaden-Juba Aquifer	Ethiopia-Kenya-Somalia
419	Mount Elgon Aquifer	Kenya-Uganda
420	Merti Aquifer	Kenya-Somalia
421	Coastal Sedimentary Basin	Dem. Rep. of Congo-Angola
422	Congo Intra-cratonic Basin	Dem. Rep. of Congo-Angola
423	Kagera Aquifer	Tanzania-Uganda
424	Kilimanjaro Aquifer	Kenya-Tanzania
425	Coastal Sedimentary Basin	Kenya-Tanzania
426	Karoo Sandstone Aquifer	Mozambique-Tanzania
427	Coastal Sedimentary Basin	Mozambique-Tanzania
428	Coastal Sedimentary Basin	Angola-Namibia
429	Cuvelai Basin	Namibia-Angola
430	Northern Kalahari/Karoo Basin	Angola-Botswana-Namibia-Zambia
431	Nata Karoo Sub-basin	Botswana-Namibia-Zimbabwe
432	Medium Zambezi Aquifer	Zambia-Zimbabwe-Mozambique
433	Shire Valley Aquifer	Malawi-Mozambique
434	SE Kalahari/Karoo Basin	Botswana-Namibia-South Africa
435	Ramotswa Dolomite Basin	Botswana-South Africa
436	Tuli Karoo Sub-basin	Botswana-South Africa-Zimbabwe
437	Limpopo Basin	Mozambique-South Africa-Zimbabwe
438	Incomati/Maputo Basin	Mozambique-Swaziland-South Africa
439	Coastal Sedimentary Basin	Namibia-South Africa
440	Karoo Sedimentary Aquifer	Lesotho-South Africa



## Tindouf Aquifer

### Algeria- Morocco

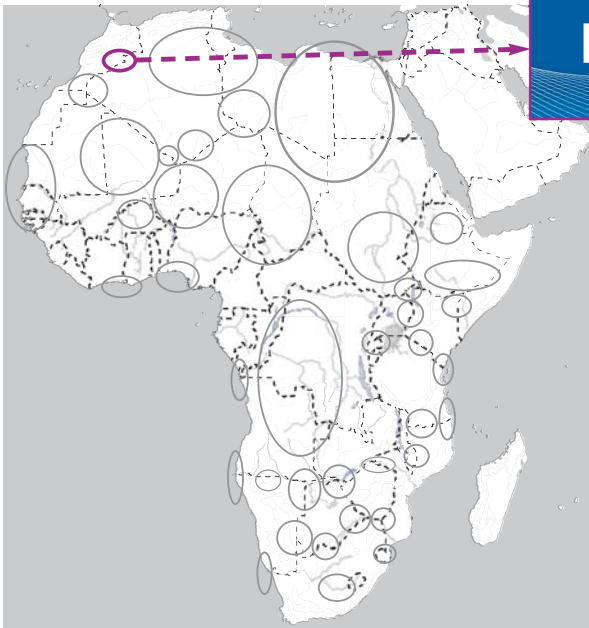
- Extent: 210,000 km<sup>2</sup>.
- Tindouf Basin is mainly shared between Algeria and Morocco and to a lesser extent, with Mauritania.
- Multilayered (Cambro-Ordovician + Devonian).
- Low demographic density.
- Extreme climatic conditions.

Algeria  
© UNESCO/F. Dal Chel





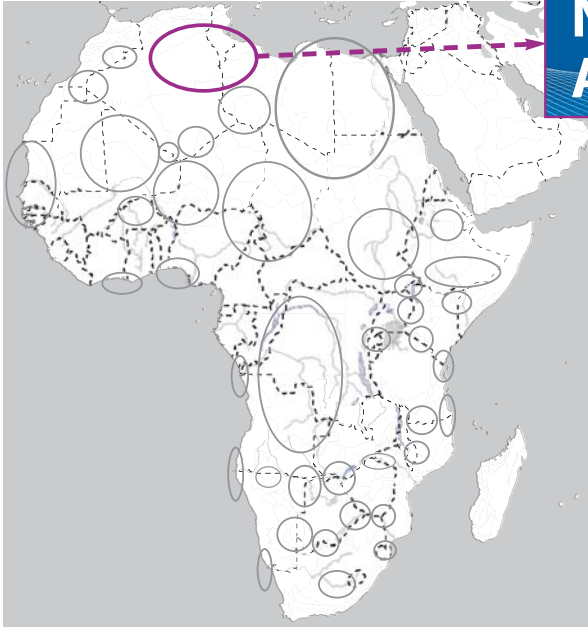
Riverbed in Atlas Mountains, Morocco  
© Morguefile



## Errachidia Basin

### Algeria- Morocco

- Extent (km<sup>2</sup>): 60,000.
- Sandstone, calcareous, dolomite.
- The area is semi-arid to arid. Rainfall is irregular and ranges from 200 mm (upstream) to 80 mm (downstream).
- Quantity problems: Abstraction of groundwater.
- Quality problems: Decrease of recharge.



## Northwest Sahara Aquifer System

### Algeria-Libya-Tunisia

- Extent (km<sup>2</sup>): 1,019,000.
- Consists of the superimposition of two principal deep aquifers: a) the Continental Intercalary (CI), the deepest; and b) the Complex Terminal (CT).
- Contains considerable reserves of non-renewable water.
- NWSAS project has developed a database, operational and accessible to the three countries.
- Continued exploitation: associated with many risks, including salinisation, loss of artesian flow, drying up of outlets and conflicts among countries.

#### Inter-state instruments

- **Inter-state cooperation:**  
Exchange of information
- **Inter-state institutions:**  
Technical Consultation Structure (2002)  
Consultation Mechanism (2008)

#### Agreements: formal agreements ratified

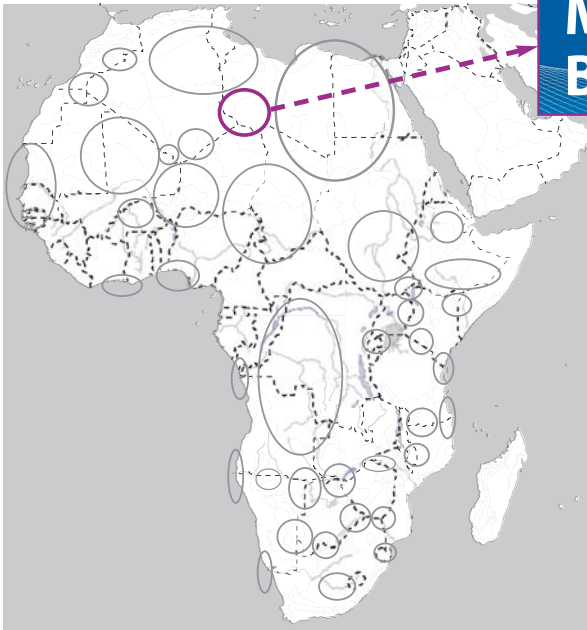
- **Establishment of a Consultation Mechanism for the Northwestern Sahara Aquifer System (SASS) [2002]**

The objective of the Consultation Mechanism is to coordinate, promote and facilitate the rational management of the NWSAS water resources. Its structure includes a steering committee, a coordination unit and an ad hoc scientific committee.





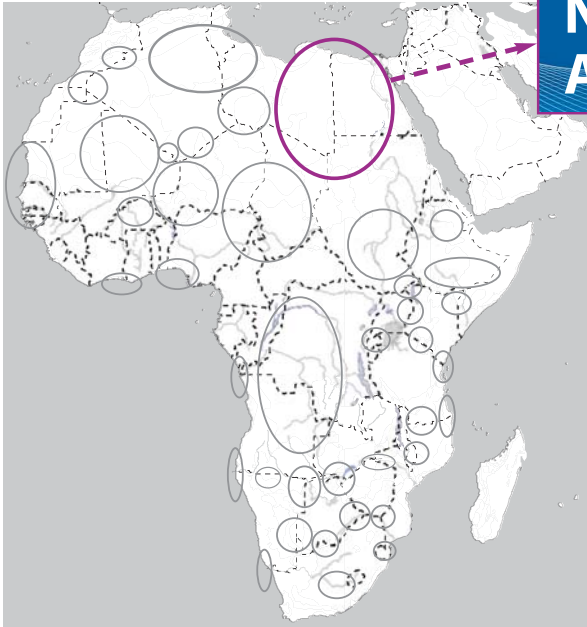
Near Gaberoun, Libya  
© SXC



## Mourzouk-Djado Basin

### Chad-Libya-Niger

- Extent (km<sup>2</sup>): 450,000.
- One of the larger sedimentary endorheic basins of Northern Africa.
- Larger extent in Libya but outcrops of ancient layers in Chad, Niger and Algeria.
- Desert zone, extreme arid climate (from above 50°C to below 0°C), very low rainfall levels.



## Nubian Sandstone Aquifer System

### Chad-Egypt-Libya-Sudan

- Extent (km<sup>2</sup>): 2,199,000.
- Pressure on groundwater due to economic growth and increase food demand for population.
- Divided into two major reservoirs: the oldest and the most extended reservoir, the Nubian Aquifer System (NAS), largely unconfined, and the other reservoir referred to as the Post Nubian Aquifer System (PNAS).
- The water quality changes from excellent in the southern part of the system to hyper saline in the northern part.

#### Inter-state instruments

- **Inter-state cooperation:**  
Exchange of information
- **Inter-state institutions:**  
Bilateral Commissions /  
Cooperation Mechanism (2001)

#### Agreements: formal agreements ratified

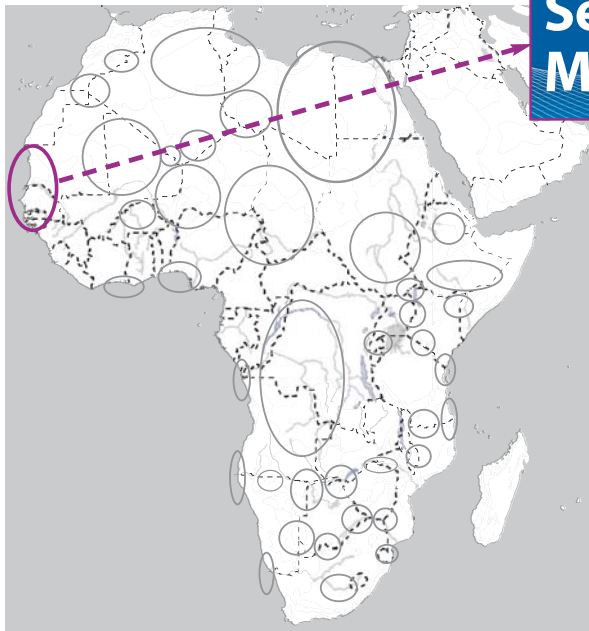
- **Programme for the Development of a Regional Strategy for the Utilisation of the Nubian Sandstone Aquifer System (NSAS), Tripoli, 5 October 2000.**

**Agreement No. 1** – Terms of Reference for the Monitoring and Exchange of Groundwater Information of the Nubian Sandstone Aquifer System

**Agreement No. 2** – Terms of Reference for Monitoring and Data Sharing



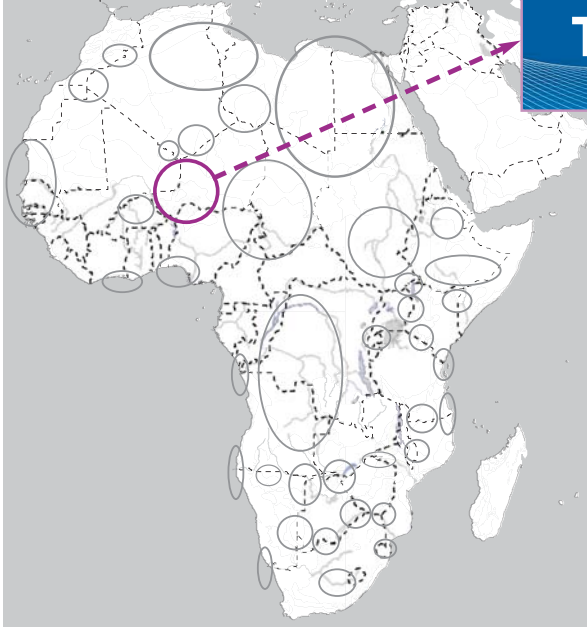
*Sine Saloum Mangrove, Senegal*  
© SXC



## Senegalo- Mauritanian Basin

### Gambia - Guinea-Bissau - Mauritania - Senegal

- Extent (km<sup>2</sup>): 300,000  
160,000 in Senegal,  
110,000 in Mauritania;  
10,000 in Gambia  
and the remaining  
in Guinea-Bissau.
- Type: Multilayered.
- Several aquiferous systems  
from the Cretaceous Superior  
to the Quaternary.



## Taoudeni Basin

### Argelia-Mali-Mauritania

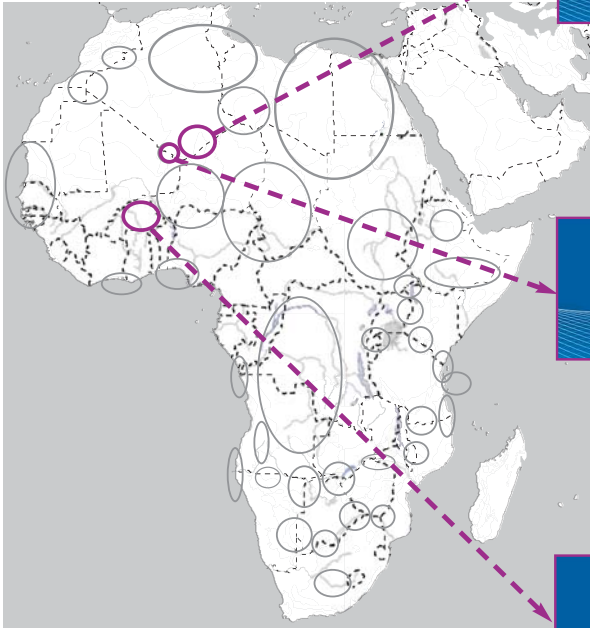
- Extent (km<sup>2</sup>): 2,000,000 (Algeria 360,000, Mauritania 500,000, Mali 1,140,000).
- Type: Multilayered (Infracambrian, Cambro-Ordovician, Devonian-Carboniferous).
- Rainfall: 1,000 mm/year in sudano-sahelian southern zone, <100 mm/year in desert northern zone.
- Exploitation: by drilling and wells.
- Uses: freshwater human consumption and livestock supply, industrial to a lesser extent.
- Overexploitation in several zones.

*Ksour of Tichitt Site, Mauritania*  
© UNESCO





Burkina Faso  
© UNESCO/Dominique Roger



**Tin-Seririne Basin**

**Algeria- Niger**

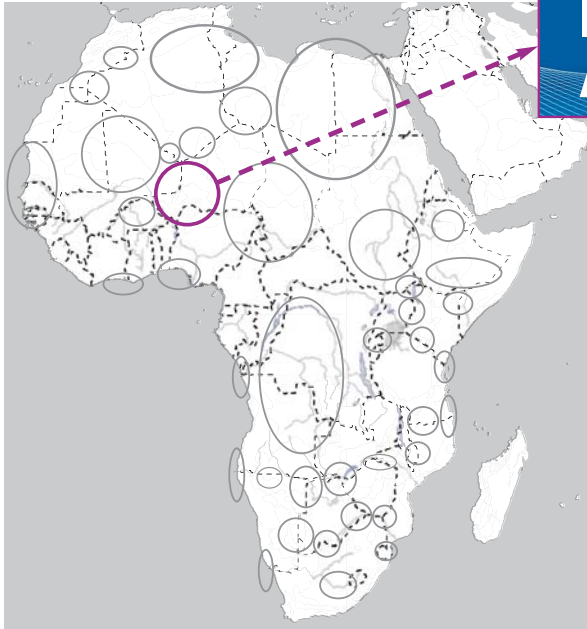
**Air Cristalline Aquifer**

**Algeria- Mali- Niger**

**Liptako-Gourma Aquifer**

**Burkina Faso- Niger**





## Iullemeden Aquifer System

### Mali-Niger- Nigeria

- Extent (km<sup>2</sup>): 525,000.
- Group of sedimentary deposits containing two main aquifers, Intercalary Continental (IC) and Terminal Continental (TC).
- Type: Multilayered.
- Population: ~15,000,000 inhabitants.
- Annual rainfall mean values (less than 100 mm to 800 mm) change from North to South .

#### Inter-state instruments

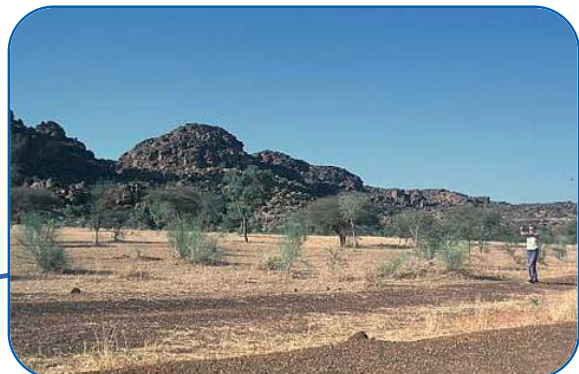
■ **Inter-state cooperation:**

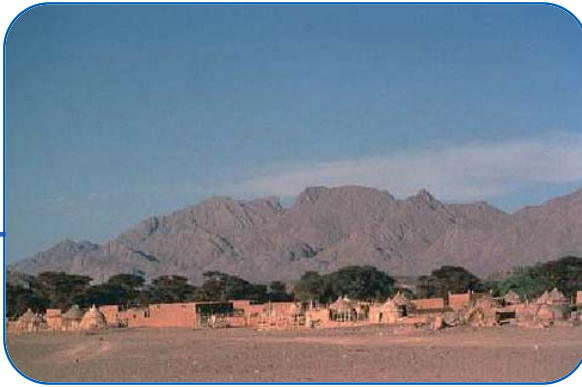
Cooperation framework (2004)  
Consultative mechanism (2006)

■ **Inter-state institutions:**

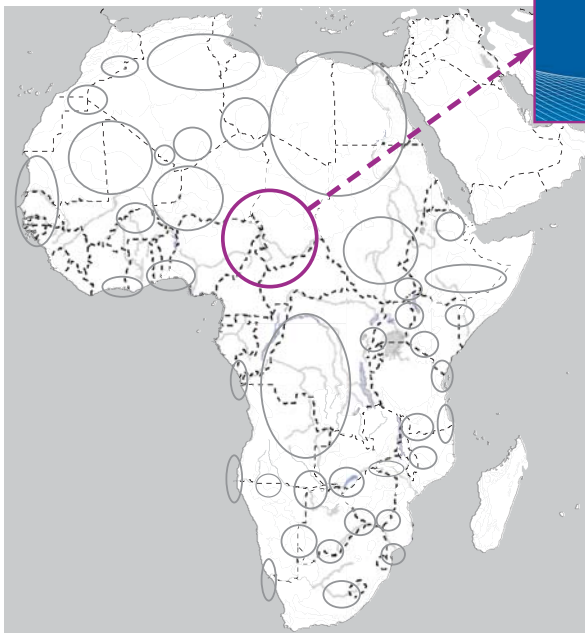
*Commission du fleuve du Niger* (1963)  
*Autorité du Bassin du Niger* (1980)

Gao, Mali  
© UNESCO/Teresa Murtagh





Tenere, Niger  
© UNESCO/IUCN



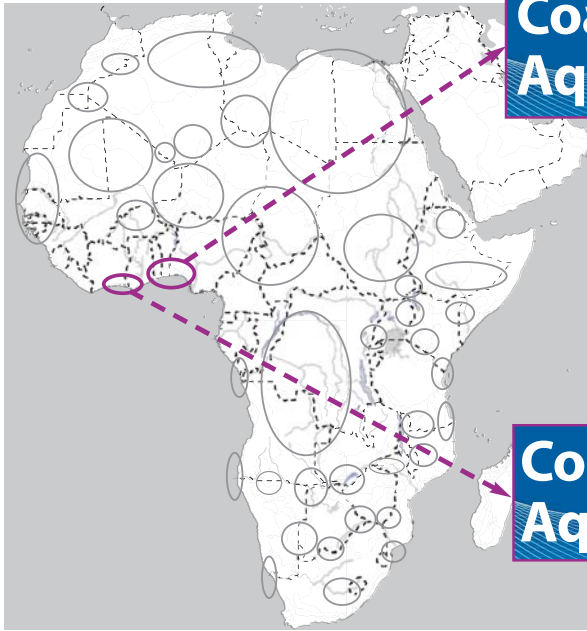
## Chad Basin

### Central African Rep.- Chad - Cameroon- Niger - Nigeria

- Extent (km<sup>2</sup>): 1,917,000.
- One of the largest sedimentary groundwater basins in Africa.
- Composed of three main aquifers: the Upper Quaternary, the Lower Pliocene and the 'Continental Terminal' (Oligocene – Miocene).
- Since the main source of aquifer recharge is from surface water, the aquifer system is also highly sensitive to climatic changes.

#### Inter-state instruments

- **Inter-state cooperation:**  
Cooperation framework (2004)
- **Inter-state institutions:**  
*Commission du Bassin du Lake Tchad* (1977)



**Coastal Sedimentary Aquifer**

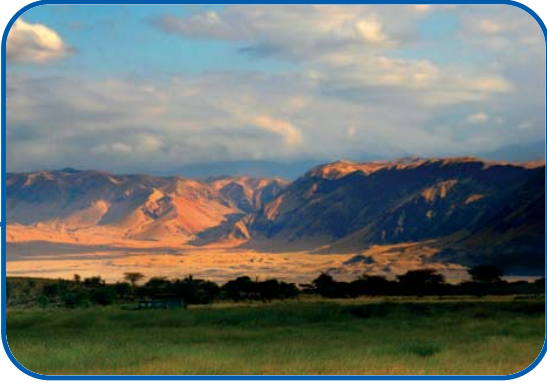
**Benin-  
Nigeria-Togo**

**Coastal Sedimentary Aquifer**

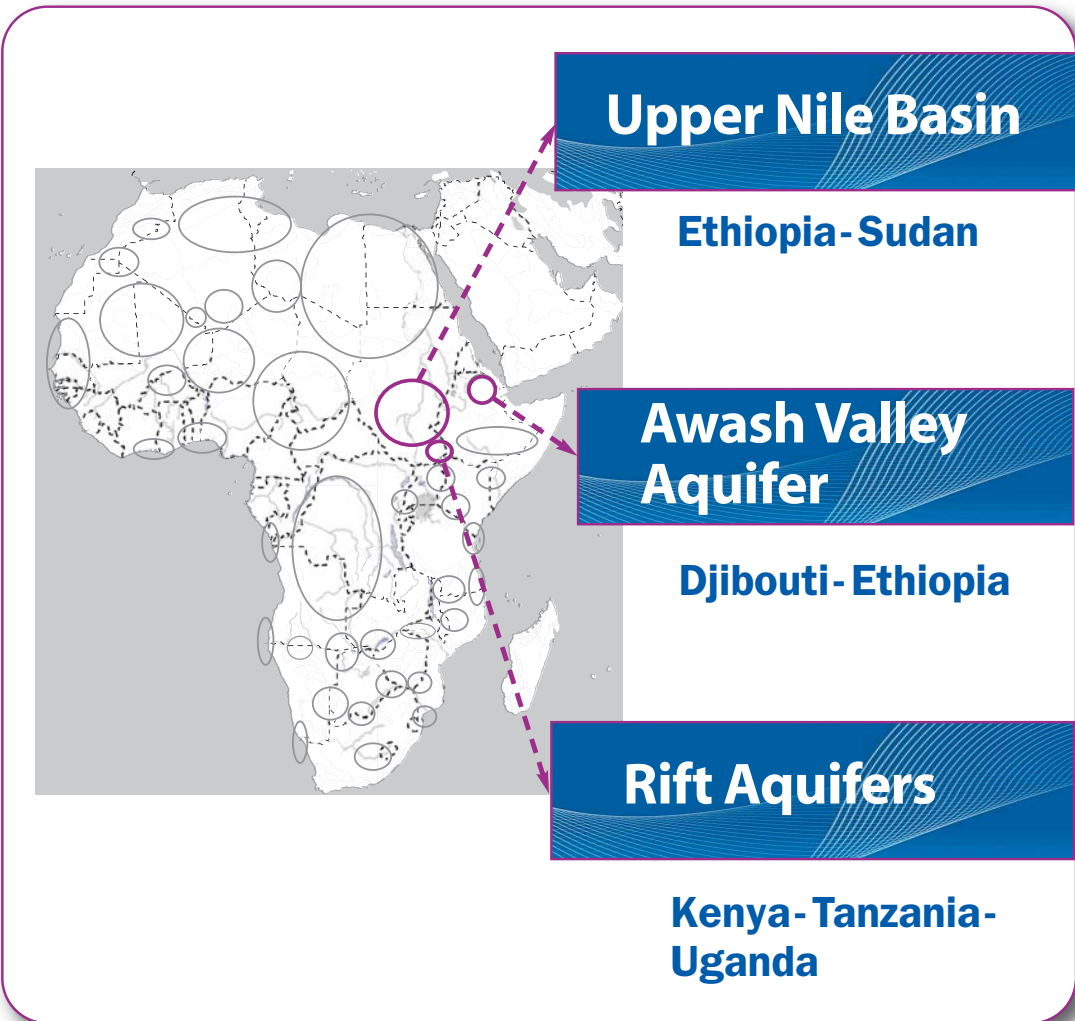
**Ghana-  
Côte d'Ivoire**

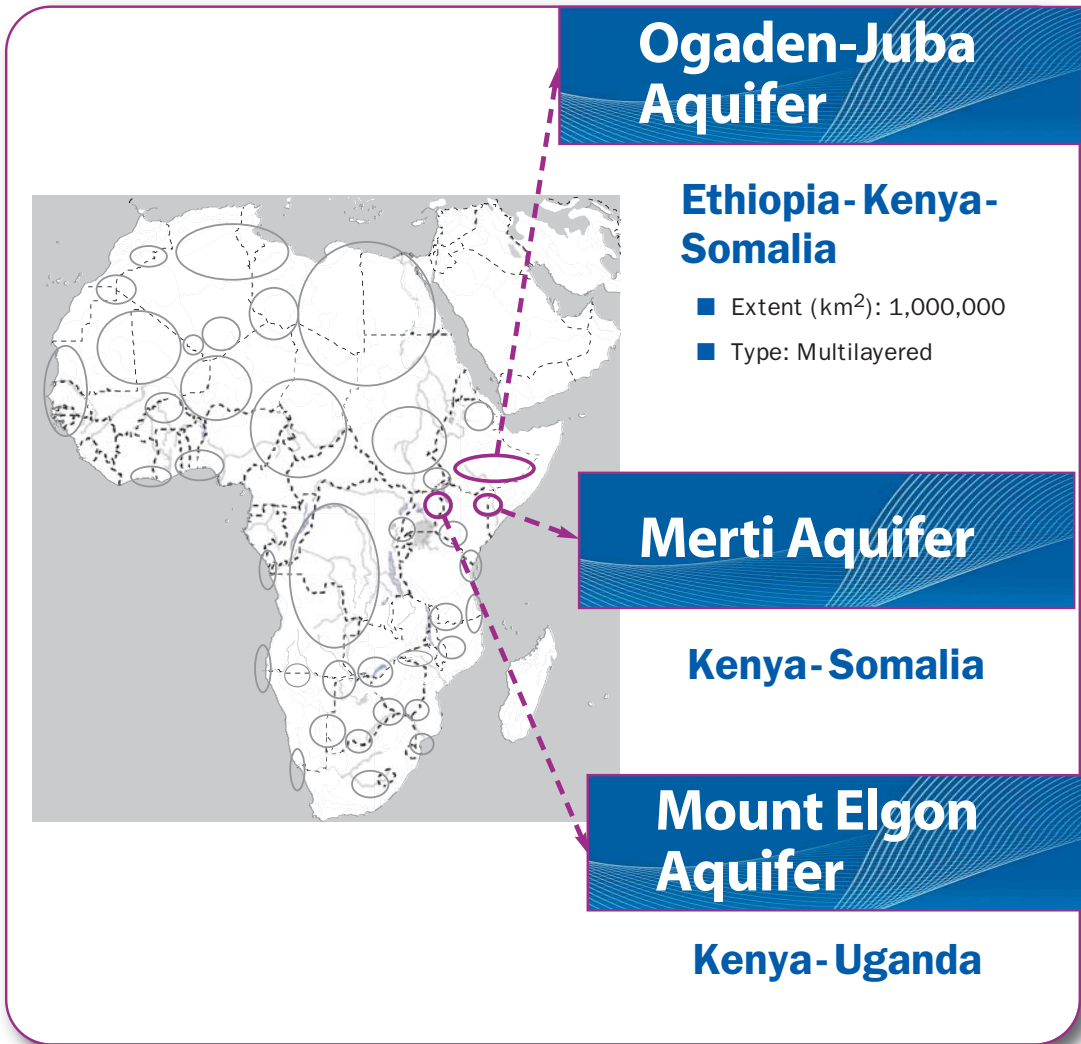


*Ganvié, Benin*  
© UNESCO/Jean O'Sullivan



Northern Rift Valley, Tanzania  
© SCX/Barbara Schneider





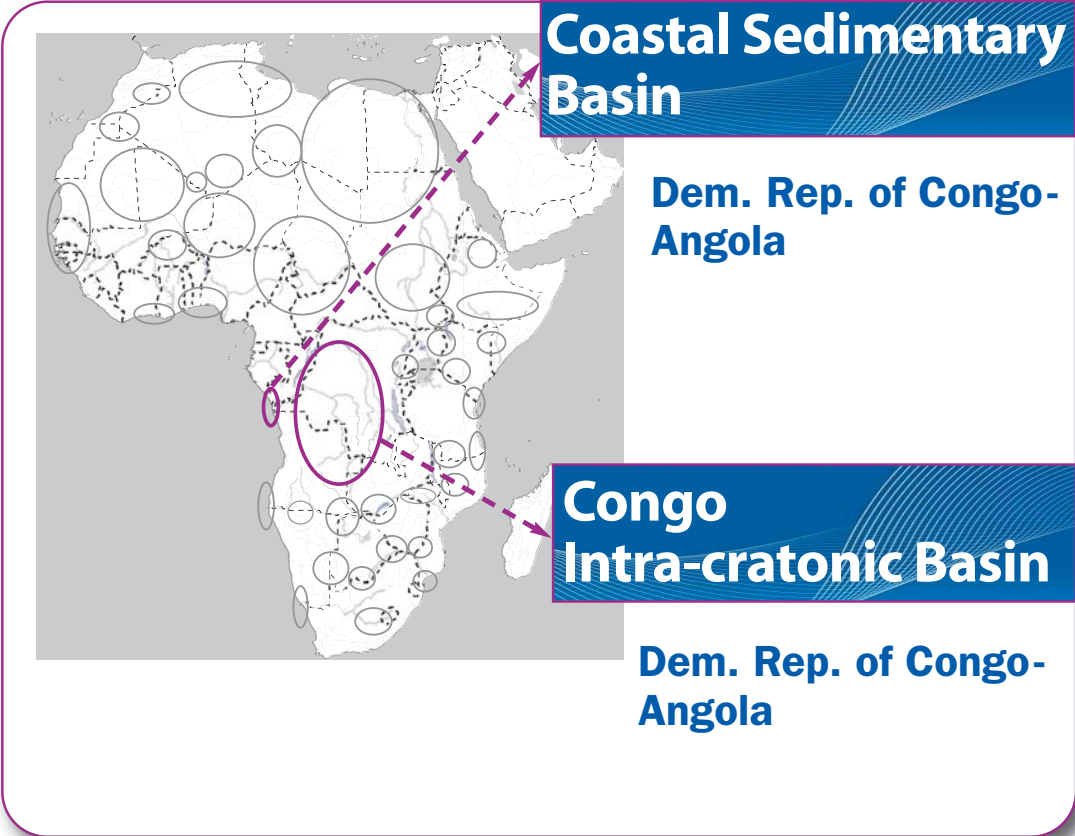
Lake Chamo, Southern Ethiopia  
© SCX/Niall Crotty







Congo River  
© SXC

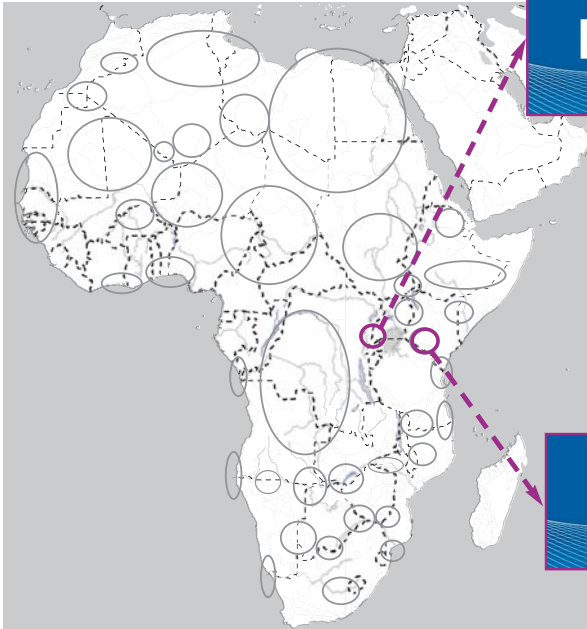


**Coastal Sedimentary Basin**

**Dem. Rep. of Congo-Angola**

**Congo Intra-cratonic Basin**

**Dem. Rep. of Congo-Angola**



### Kagera Aquifer

Tanzania - Uganda

### Kilimanjaro Aquifer

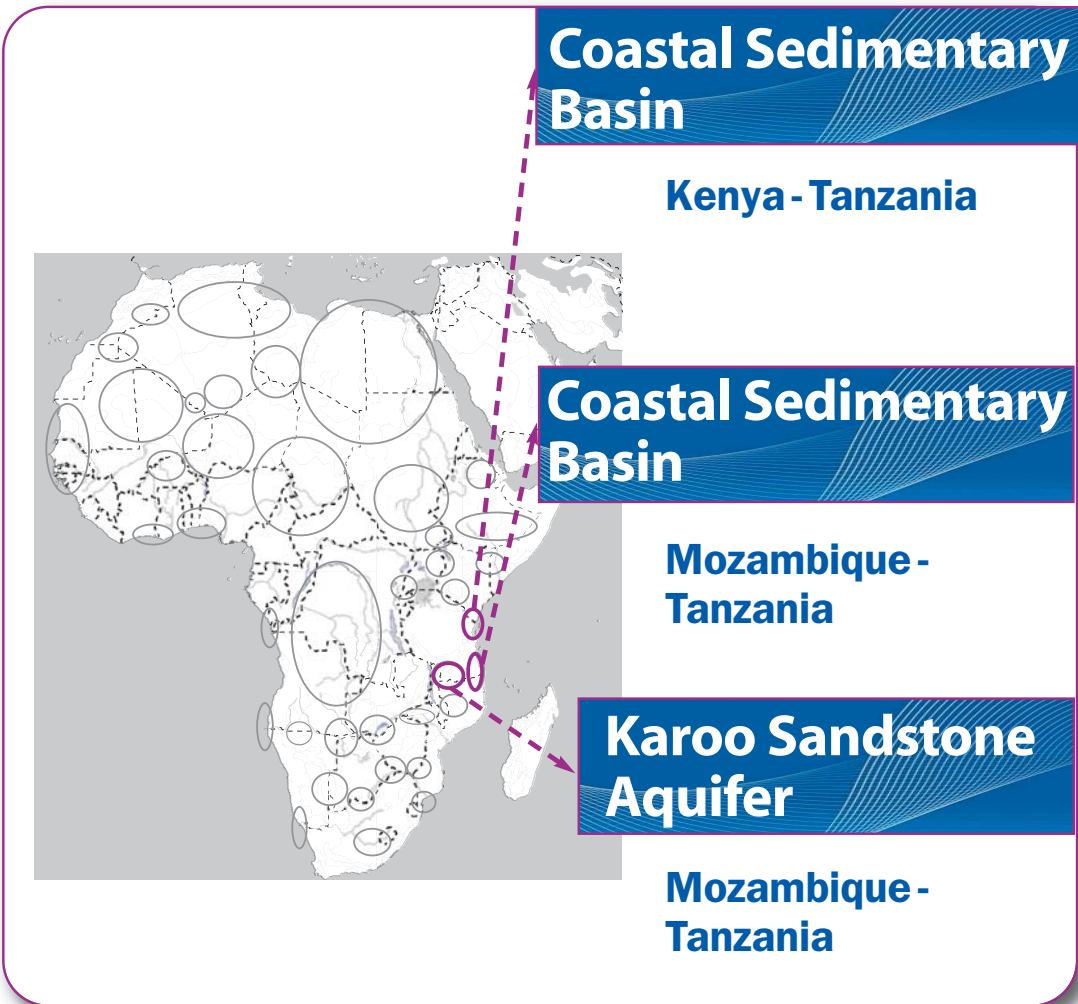
Kenya - Tanzania

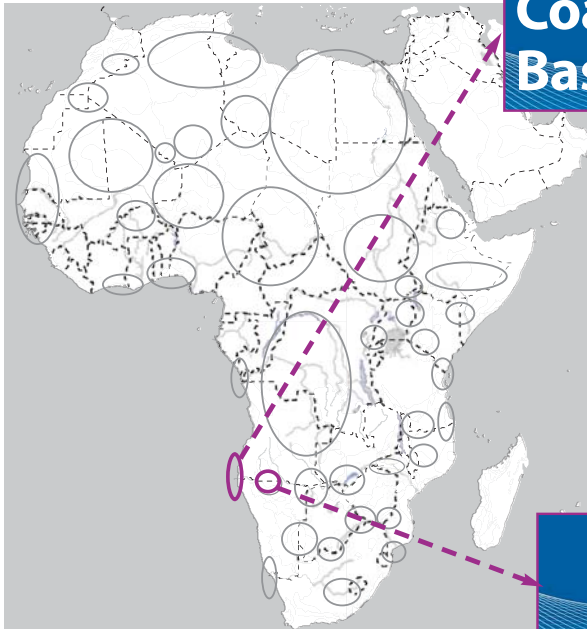
Kilimanjaro, Tanzania  
© SXC





Tanzania  
© SXC





## Coastal Sedimentary Basin

Angola - Namibia

## Cuvelai Basin

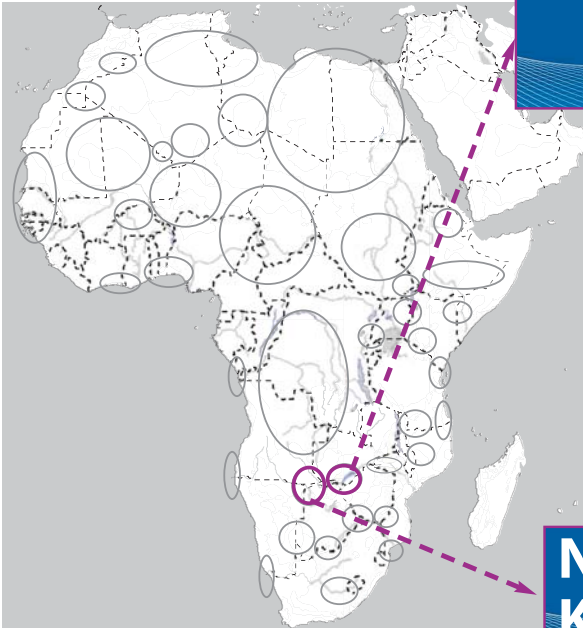
Namibia - Angola

Etosha National Park, Namibia  
© SXC





*Chobe National Park, Botswana*  
© UNESCO/Jasmina Sopova



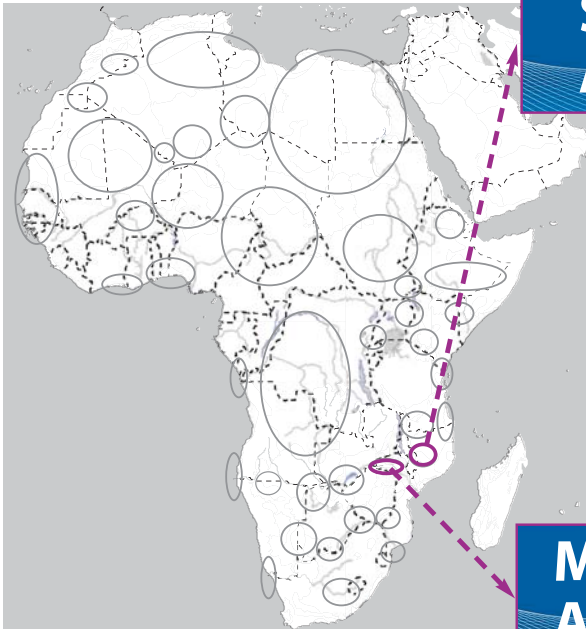
**Nata Karoo  
Sub-basin**

**Botswana - Namibia -  
Zimbabwe**

**Northern Kalahari/  
Karoo Basin**

**Angola - Botswana -  
Namibia - Zambia**





**Shire Valley  
Alluvial Aquifer**

**Malawi -  
Mozambique**

**Medium Zambezi  
Aquifer**

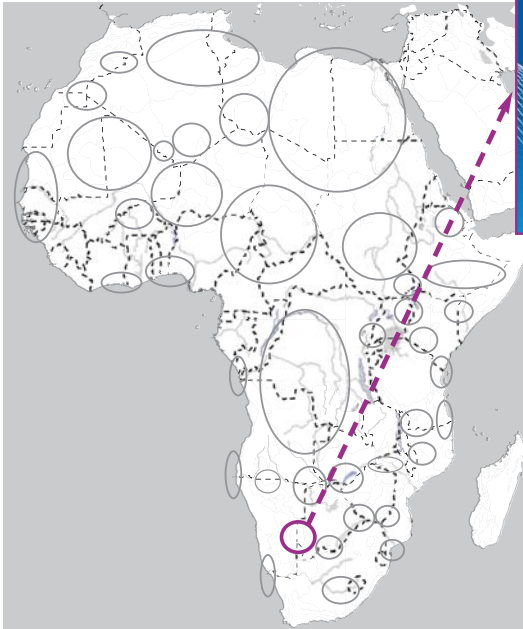
**Zambia -  
Zimbabwe -  
Mozambique**

*Okavango Delta, Botswana*  
© SXC





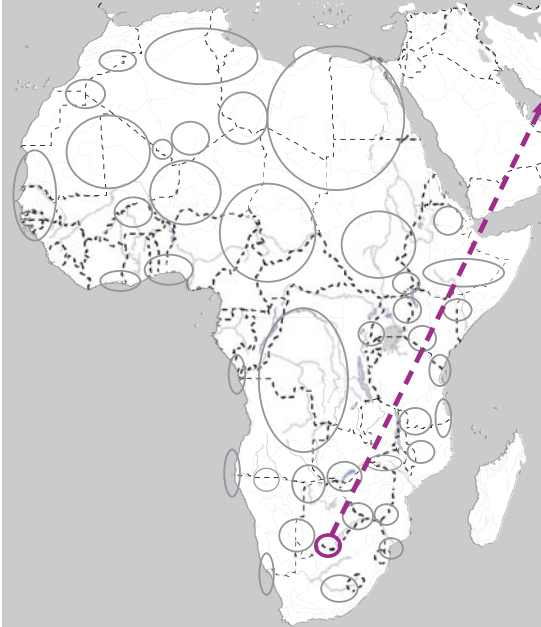
*Kalahari Desert, South Africa*  
© SXC/Pieter Roos



## SE Kalahari/ Karoo Basin (or Stampriet or Orange river)

### Botswana - Namibia - South Africa

- Shared international boundary length (km): 1,000 km.
- Areal extent (km<sup>2</sup>): Combined aquifer systems (Kalahari Group Aquifers + Karoo Super Group Aquifers) cover an area of approximately 100,000 km<sup>2</sup>.
- Main uses:
  - Domestic (isolated cases in river drainages);
  - Livestock (±95% of water use);
  - No irrigation.



## Ramotswa Dolomite Basin (or Ramatlabana/Molopo)

### Botswana - South Africa

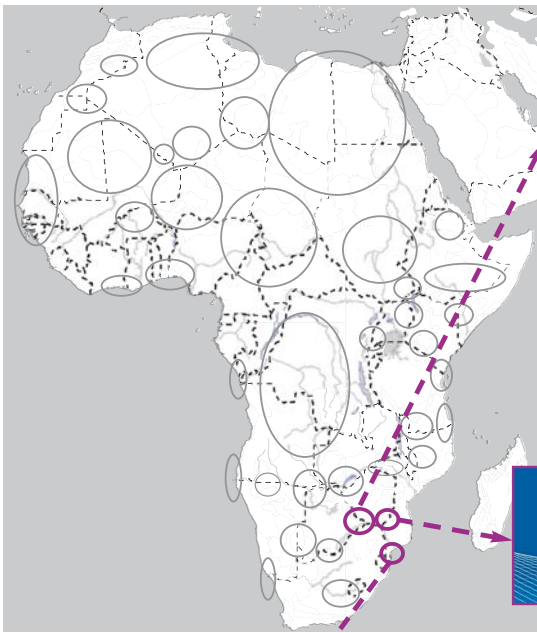
- Shared international boundary length (km): approximately 120 km.
- Karstic aquifer consisting of dolomite/chert poor and dolomite/chert rich sub-groups. Highly compartmentalized due to diabase dyke intrusions.
- Main uses:
  - Bulk (municipal, domestic) supplies,
  - Local (community, domestic and livestock watering) supplies and
  - Agriculture (livestock watering and irrigation).

*Bokaa Dam, Botswana*  
© SXC





River Incomati, Mozambique  
© UNESCO/Sergio Santimano



**Tuli Karoo  
Sub-basin  
(or Gaborone  
to Shashe River)**

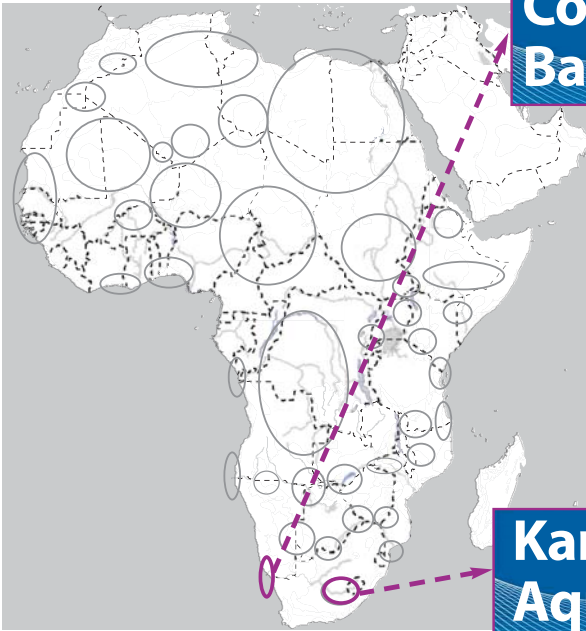
**Botswana -  
South Africa -  
Zimbabwe**

**Limpopo Basin**

**Mozambique -  
South Africa -  
Zimbabwe**

**Incomati/Maputo  
Basin**

**Mozambique - Swaziland -  
South Africa**



**Coastal Sedimentary Basin**

**Namibia - South Africa**

**Karoo Sedimentary Aquifer**

**Lesotho - South Africa**

*Mountain Kingdom, Lesotho*  
© SXC





## AFRICA: Regional transboundary aquifers inventories

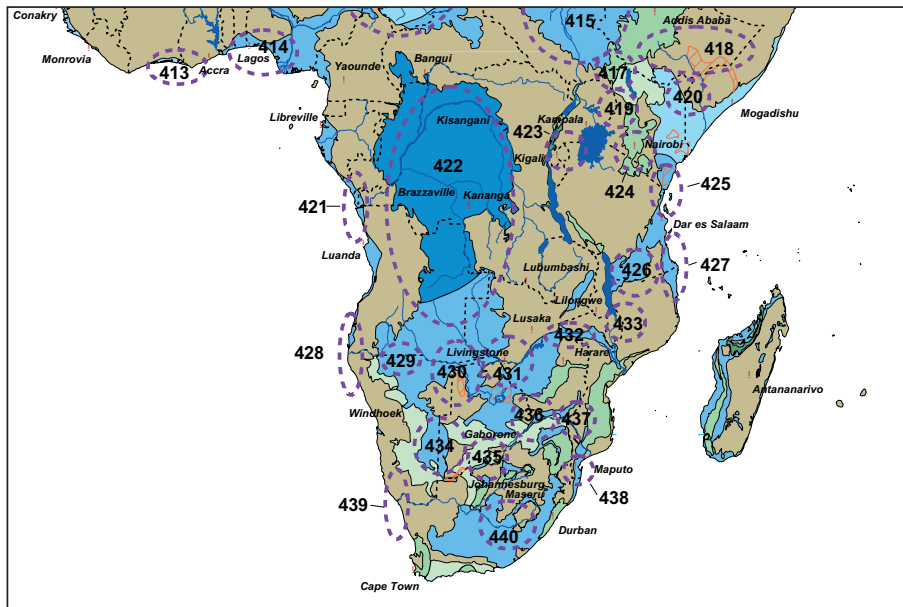
### ISARM-SADC (SOUTHERN AFRICA DEVELOPMENT COMMUNITY)

Before 2007, three information sources were available for inventories on transboundary aquifers in SADC region.

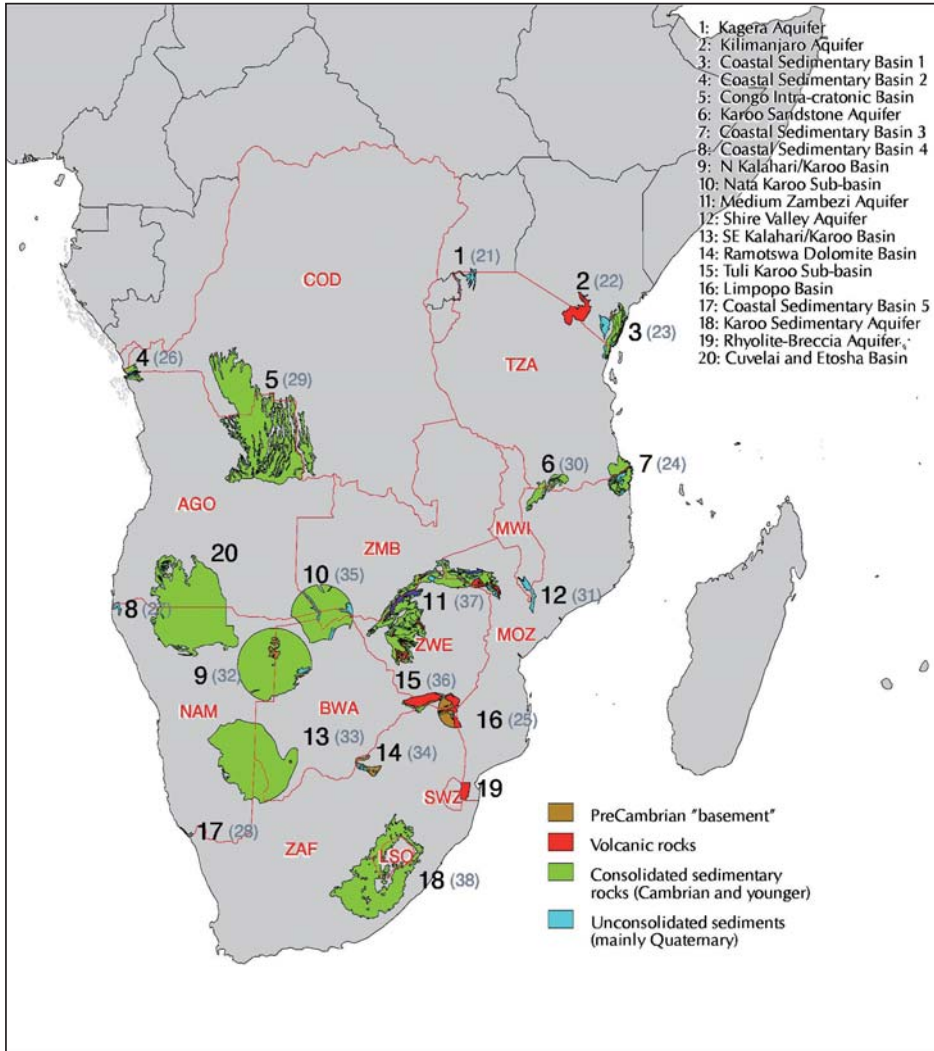
- ISARM, 2004 (International Workshop in Libya, 2001): 18 transboundary aquifers.
- IGRAC, 2005: in order to refine the original ISARM delineation, IGRAC used sources already available in the public domain and produced a provisional map of transboundary aquifers in the SADC region (see next page).
- WHYMAP, 2006: WHYMAP Transboundary Aquifer Systems map. Similar to the Tripoli ISARM map of 2004, circles or ellipses symbolize the location and approximate size of regionally important transboundary aquifer systems (see below).

In 2007, ISARM-SADC was launched in cooperation with national experts and regional institutions with the aim of improving knowledge on transboundary aquifers of the region. Harmonization of new and existing information will be crucial and will be the next step undertaken in cooperation with UNESCO Member States.

#### **Transboundary Aquifers of Southern Africa: WHYMAP Inventory 2006**



**Transboundary aquifers of Southern Africa: IGRAC inventory 2005**



**Transboundary Aquifers of Southern Africa**

Provisional boundaries based on information available to IGRAC (still to be confirmed by SADC experts)

- 12** IGRAC aquifer number
- (31)** SADC aquifer number (from the Tripoli 2002 conference)
- MOZ** ISO\_3DIGIT country code



Version: 29-JUN-2005

Delineation and names are based on the information available in the public domain. Provisional boundaries of individual aquifers are mainly based on surficial extent of geological formations (litho-logical transitions) and/or surface water divides (catchments). If such basic information is lacking, the aquifers boundaries remains in the shape of original circles and ellipses.

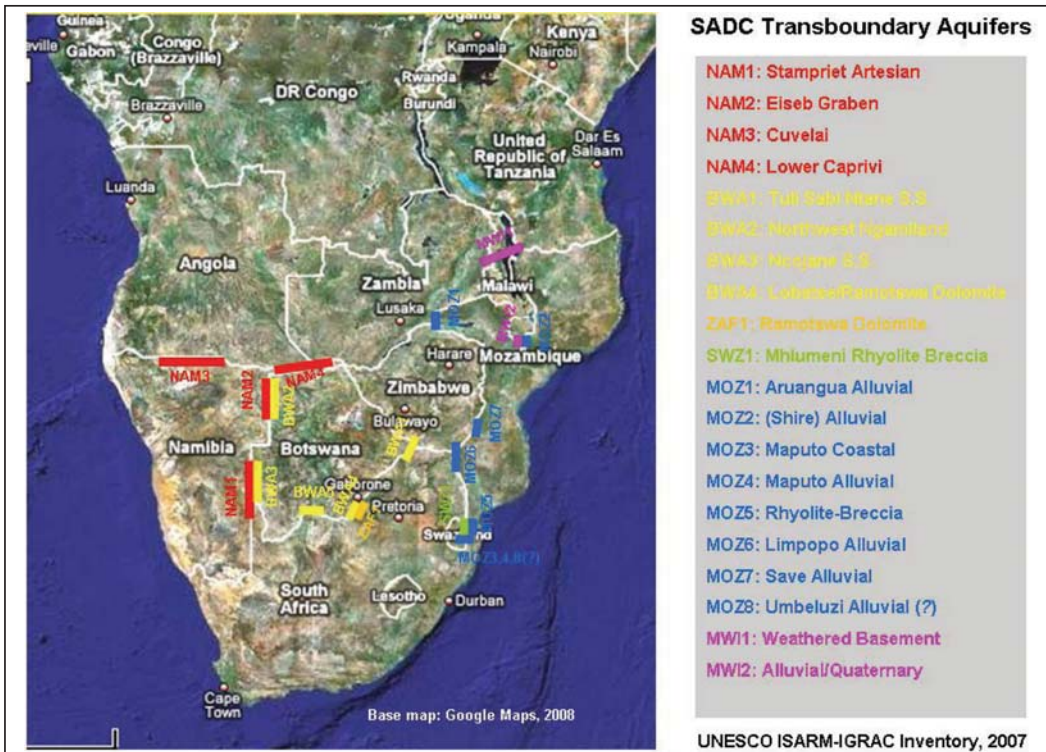
## SADC: Recent developments

Launching meeting of ISARM-SADC was held in Pretoria, South Africa in March 2007. Based on the national presentations and related discussions, transboundary aquifers were identified for six participating countries (Namibia, Botswana, Zimbabwe, Mozambique, Swaziland and South Africa).

As of August 2008, an evaluation of questionnaires and forms yielded information on aquifers located in these countries.

Next figure indicates approximate positions of these aquifers along the boundaries of sharing countries. Evaluation of information gaps will define necessary actions for additional data collection, and harmonization of information will lead to a consistent link with aquifers identified in previous inventories.

### **Aquifers identified as transboundary in six SADC countries: UNESCO-ISARM-SADC/IGRAC local inventory 2007**

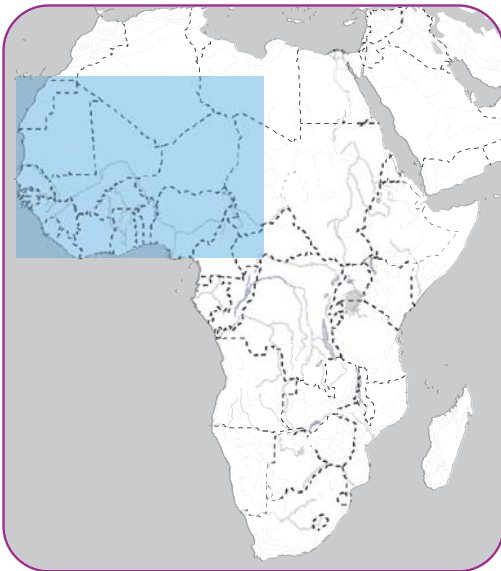


Source: Vasak, 2008.

## WESTERN AFRICA

### Towards a regional inventory

The first West African ISARM Workshop devoted to the development of an inventory of trans-boundary aquifers in the region was held in Cotonou, Benin, from 30th May to 1st June 2007. This workshop followed on from the regional ISARM Workshop, held in Tripoli in 2002, which had discussed shared aquifers in Africa and recommended that a sub-regional approach to the inventory be adopted.



The main objective of this initial workshop was to collect data on the different shared aquifers; a task shared by ten expert hydrogeologists from Benin, Burkina, Ghana, Côte d'Ivoire, Mali, Mauritania, Niger, Nigeria, Senegal and Togo

It came out, from the discussions about gap The workshop concluded that there existed a gap in information within this particular field. It was felt that it was necessary, for example, to make the distinction between shared basins, which is a geological phenomenon, as opposed to shared aquifers which is related to the field of hydrogeology. It was also decided that for some aquifers in the region, uncertainties still remained as to the nature of their transboundary status and that research was still required to determine this, in particular concerning those aquifers located within certain coastal basin zones.

The principle shared aquifer basins (geology) containing aquifers that are both shared are as follows:

- Iullemeden (Mali, Niger, Nigeria, Benin);
- Senegalo-mauritanian (Mauritania, Senegal, Gambia, Guinea-Bissau);
- Lake Chad (Niger, Nigeria, Chad, Cameroon);
- Taoudeni (Burkina Faso, Mali, Mauritania, Algeria);
- Basin of Tano (Côte d'Ivoire, Ghana);
- Basin of Keita (Ghana, Togo, Benin, Nigeria)
- Volta (Burkina Faso, Benin, Togo);
- Tindouf (Mauritania, ...);
- Djado-Mourzouk (Niger, Libya);
- Bilma-Agadem (Niger, Chad).

During the ISARM Workshop participants agreed to reinforce cooperation between the specialists from Western Africa in an aim to harmonise their use of terminology to describe shared basins and to grant efforts for the implementation of tools needed for a better knowledge of the basins.

The group selected two case studies, those of Tano and Keta, which corresponded to the set criteria regarding pollution, the pressure exerted on the aquifer as well as its characteristics.

Finally, the participants of the workshop agreed to prepare a proposal for the Global Environmental Facility (GEF) which deals with the shared Senegalo-Mauritanian Basin. This particular basin shares the same dynamics as those under existing GEF projects, such as the Iullemeden, Lake Chad or the coastal basins.



# AFRICA

## Case studies

1. **lullemeden Aquifer System**, studied in the framework of 'Management of Transboundary Hydrogeological Risks in the IAS' OSS project.
2. **North-Western Sahara Aquifer System**: studied in the framework of 'Concerted Management of a Transboundary Water Basin' OSS project.
3. **Nubian Aquifer Project**, a joint initiative of IAEA/UNDP/GEF to improve the information base as a first key step for a better understanding of the complexities of the aquifer.
4. **Stampriet Kalahari/Karoo Artesian Basin**, ISARM-SADC pilot project for transboundary aquifer management in Southern Africa.  
The three ISARM-SADC meetings led to a study proposal concerning Stampriet Kalahari/Karoo Basin, formulated by the three sharing countries (Namibia, Botswana and South Africa). The project will include data exchange and will concentrate on recharge assessment, water quality issues, harmonising legal and technical regulations regarding drilling and water use and establishment of a common monitoring network. A Technical Task Team represents the three countries at the relevant ORASECOM (Orange-Senqu Basin Commission) meetings and serve as a mechanism to drive the project.

### lullemeden Aquifer System (Mali/Niger/Nigeria)

#### Project 'Managing Hydrogeological Risk in the lullemeden Aquifer System'

The lullemeden sedimentary groundwater basin (IAS) is located in Mali, Niger and Nigeria with minor, non-connected sections in Algeria and Benin. The aquifer system, which covers an area of 525,000 km<sup>2</sup> with 31,000 km<sup>2</sup> in Mali, 434,000 km<sup>2</sup> in Niger and 60,000 km<sup>2</sup> in Nigeria, represents one of the major freshwater reservoirs of West Africa and is linked to many humid areas and ecosystems.



Source: ESA TIGER Aquifer Project, 2007

With high demographic growth (from 6 million in 1970 to about 15 million in 2000 towards 30 million in 2025) and impacts of climatic change and variability with regional drought over the last several decades, the lullemeden aquifer system is being increasingly exposed to environmental stress. The annual water withdrawals, of about 50 million m<sup>3</sup> in 1970 increased to about 170 million m<sup>3</sup> in 2004 and the IAS is changing from a strategic regional resource to an increasingly used aquifer system. Total abstractions now exceed the annual aquifer recharge and there are consequent visible impacts of water table decline, loss of artesian pressure and local aquifer pollution in local hot spots and border areas. The IAS interacts with the regional Niger River with seepage inflows that support the river water body during periods of low flow and extended drought.

The following categories of environmental threats to the aquifer and the related ecosystems have been identified: (a) land use change in recharge areas and humid zones of the IAS, (b) climatic change, and (c) over-extraction and human-induced water pollution and water and land salinization. These threats/risks are addressed by the project through the establishment of joint mechanism and cooperative frameworks for: (a) identification of transboundary risk and uncertainty issues, (b) formulation of joint risk mitigation and sharing policy; and (c) joint policy implementation through a joint IAS legal and institutional cooperative framework. The scope for management of transboundary risk and conflict in the IAS is constrained by the scientific uncertainty on the aquifer system and by the impacts of climatic change.

In order to address transboundary risks associated with these threats in a strategic manner, a GEF/UNEP/OSS project adopts a risk-based management approach. The project is aimed at establishment of a joint mechanism and cooperative framework for: (a) identification of transboundary risks and uncertainty issues; (b) formulation of joint risk mitigation and sharing policy; and (c) joint policy implementation through a joint IAS legal and institutional consultative mechanism. These components will be supported by awareness raising, public participation and communication.

The main achievements are: 1) major transboundary risks identified, 2) common data base elaborated (more than 17,000 boreholes), 2) Geographic Information System developed, 3) Groundwater model developed, 4) lullemeden website elaborated, and 5) a clear consensus on the need for, and on the structure and mandate of, the consultative mechanism, and on the approach to be followed for its establishment.

The perspectives are: 1) formulating the Strategic Action Programme, 2) improving data and information, 3) assessing and managing surface water and groundwater, and 4) implementing the regional consultative mechanism.

The project is managed through the project steering committee by the three governments with the Sahara and Sahel Observatory as the Executing Agency.

## North-Western Sahara Aquifer System (Algeria/Tunisia/Libya )

The North-Western Sahara Aquifer System (NWSAS) – *Système Aquifère du Sahara Septentrional* (SASS) in French – covers a total area of over one million km<sup>2</sup>: 700,000 km<sup>2</sup> in Algeria, 80,000 km<sup>2</sup> in Tunisia and 250,000 km<sup>2</sup> in Libya. It contains sedimentary deposits which, from bottom to top, have two main levels of aquifers, the Intercalary Continental (IC) and the Terminal Complex (TC).

The three NWSAS countries embraced an approach of joint management. This approach is based on an in-depth knowledge of the aquifer, including projections and simulations of the impacts intensive withdrawal will have.

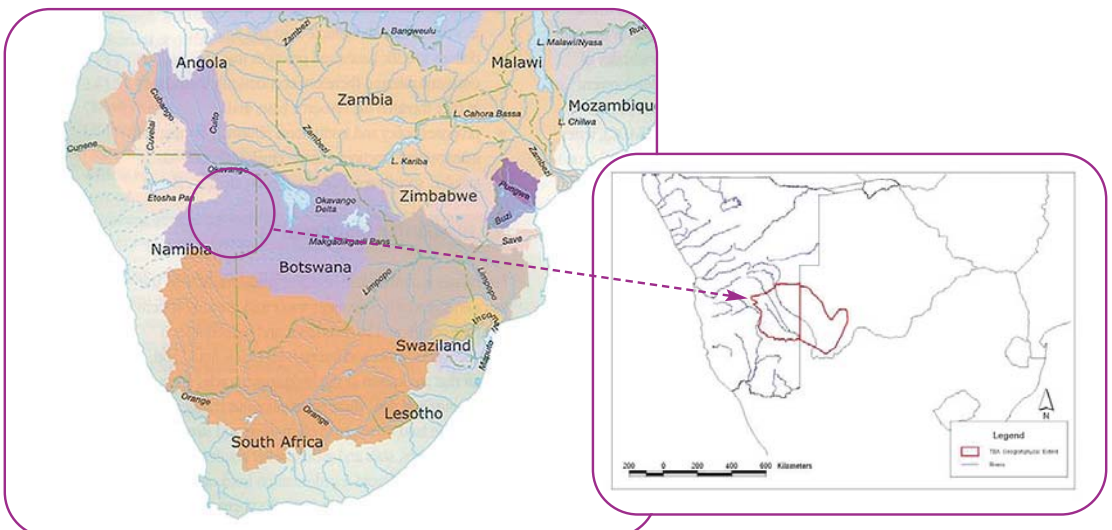


Source: ESA TIGER Aquifer Project, 2007

NWSAS is crucial to development in the WSAS is crucial to development in the North-Western part of the Sahara

desert. NWSAS water will now be crucial to secure food for a growing population close to, and even far beyond its borders, and to meet the demands of agriculture, industry and construction.

## Stampriet Kalahari/Karoo Artesian Basin (Namibia/Botswana/South Africa)



The groundwater potential of the Stampriet Kalahari/Karoo Artesian Basin (SKKAB) found within Namibia Botswana and South The two sandstone members of the Prince Albert Formation (Pp), the Nossib and Auob Sandstone Members have strong sub artesian aquifer characteristics.

Aquifer type:

- All Sedimentary – Semi-consolidated primary aquifer (T-Qk) and weathered and fractured sediments (C-Pd + Pp). The two sandstone members of the Prince Albert Formation (Pp), the Nossib and Auob Sandstone Members has strong sub artesian aquifer characteristics.
- Local fractured zones where dolerite sills and dykes and younger Kimberlite pipes have intruded into the Karoo Supper group formations does exists in the Rietfontein-Boksputs area.

This project is structured in three phases and is currently on the first phase. All three phases will be conducted in close cooperation and under equal contributions from Botswana, Namibia and South Africa.

This joint project will establish the information necessary for transboundary groundwater security that will furthermore promote better long-term management to the benefit of all three countries.

***The purpose of the intended study will look into the whole groundwater system that extends into all three countries, from a transboundary perspective.***

***This can be seen as case study for Transboundary Aquifers (TBAs) for the rest of SADC that is necessary for sound management of Strategic Transboundary Groundwater Resources.***

### FINAL OUTPUTS

- Establishment of a groundwater management model and a Transboundary Groundwater Management Plan for all three participating countries
- Compile technical and socio-economic recommendations for key users and the population at large
- Conduct a water awareness campaign among the stakeholders in the transboundary areas

## Nubian Sandstone Aquifer System (Chad/Egypt/Libya/Sudan )

### Geographical location

The Nubian sandstone aquifer system (NSAS) is one of the largest regional aquifer resources in Africa and in the world. It consists of a number of aquifers laterally and/or vertically connected, extending over more than 2 million square kilometres in the eastern part of the Libyan Arab Jamahiriya, Egypt, north-eastern Chad and the northern part of the Sudan. The Nubian aquifer is a strategically crucial regional resource in this arid region, which has only few alternative freshwater resources, a low and irregular rainfall and persistent drought and is subject to land degradation and desertification. Under current climatic conditions, the Nubian aquifer represents a finite, non-renewable water resource.



### The aquifer system

The Nubian sandstone aquifer system can be differentiated into two major systems:

- The Nubian aquifer system

This part of the system occurs all over the area and constitutes an enormous reservoir of water of excellent quality in its southern part and of hyper-saline water in the north. The calculated storage capacity of the Nubian aquifer system in both its unconfined and confined parts, within the four sharing countries, exceeds 520,000 cubic kilometres. The total volume of fresh groundwater in storage is approximately 373,000 cubic kilometres. The economically exploitable volume, estimated at 150,000 cubic kilometres, represents the largest freshwater mass and one of the most important groundwater basins in the world.

- Post-Nubian aquifer system

This part of the system is located to the north of parallel 26 in the western desert of Egypt and the north-eastern part of the Libyan Arab Jamahiriya, and is under unconfined conditions. Its cumulative thickness is about 5,000 metres. The total volume of groundwater in storage in the post-Nubian aquifer system is 845,000 cubic kilometres, while the amount of fresh groundwater is 73,000 cubic kilometres. Low permeability layers separate the two systems.



## Groundwater extraction

Groundwater from the Nubian sandstone aquifer system has been utilized for centuries from the oases all over the area through springs and shallow wells. However, as a result of population growth, food demand and economic development, pressure on the supply of groundwater in the region has increased rapidly over the past decades. It is estimated that 40 billion cubic metres of water were extracted from the aquifer over the past 40 years, in Egypt and the Libyan Arab Jamahiriya alone. No historical data is available for Chad and the Sudan where the present extractions and socio-economic uses are limited. Most of the present water extracted from the system is used for agriculture. A drop of the water table has already occurred and reaches 60 metres in some places.

## International cooperation

Since the early 1970s, Egypt, the Libyan Arab Jamahiriya and the Sudan have expressed their interest in regional cooperation in studying and developing their shared resource. In July 1992, a joint authority was established between Egypt and the Libyan Arab Jamahiriya, subsequently joined by Chad and the Sudan. Among other things, the Authority is responsible for collecting and updating data, conducting studies, formulating plans and programmes for water resources development and utilization, implementing common groundwater management policies, training technical personnel, rationing the aquifer waters and studying the environmental aspects of water resources development. An integrated regional information system was developed with the support of the Center for Environment and the Development of the Arab Region and Europe. In 2006, the four countries embarked on a GEF funded medium size project 'Formulation of an Action Programme for the Integrated Management of the Shared Nubian Aquifer' implemented by UNDP, and executed by IAEA in cooperation with UNESCO-IHP.

The project's four immediate objectives are: identify priority transboundary threats and root causes; fill key gaps; prepare a Strategic Action Programme (SAP); and establish the framework to implement the SAP.

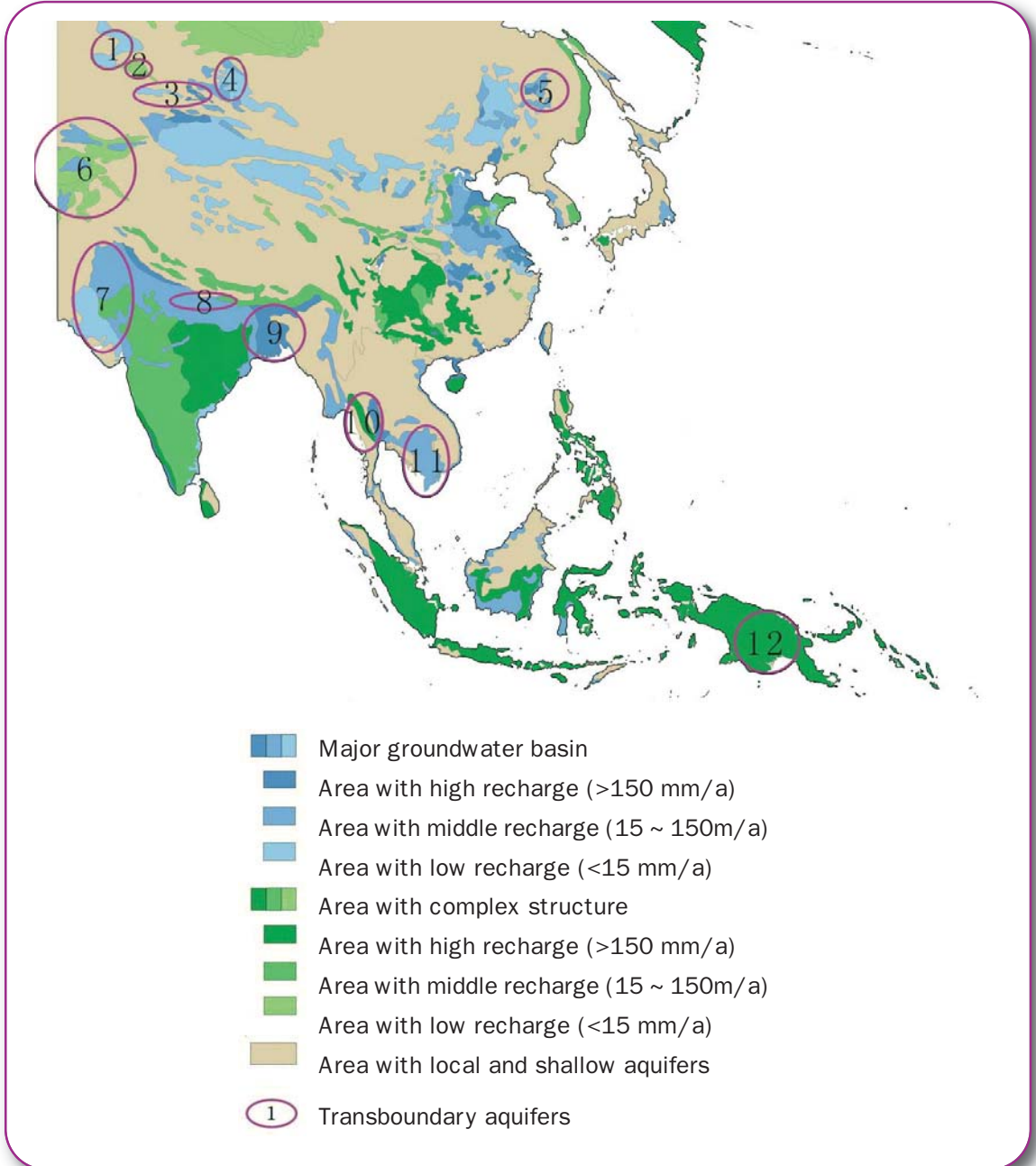
***The overall expected results of the Nubian project would contribute to strengthening the institutional, legal and analytical frameworks for the sustainable management and use of NSAS.***

***The long-term goal of the project is to establish a rational and equitable management of the NSAS for sustainable socio-economic development and the protection of biodiversity and land resources.***

# ASIA

## TRANSBOUNDARY AQUIFERS INVENTORY

### OVERVIEW



Source: UNESCO, 2006.

Asia		
1	Ertix River Plain	Russia, Kazakhstan
2	West Altai	Russia, Kazakhstan
3	Yili River Plain	China, Kazakhstan
4	Yenisei Upstream	Russia, Mongolia
5	Heilongjiang River Plain	China, Russia
6	Central Asia	Kazakhstan, Kyrgyzstan, Uzbekistan, Tajikistan, Turkmenistan, Afghanistan
7	India River plain	India, Pakistan
8	Southern of Himalayas	Nepal, India
9	Ganges River Plain	Bangladesh, India
10	South Burma	Myanmar, Thailand
11	Mekong River Plain	Thailand, Laos, Cambodia, Vietnam
12	New Guinea Island	Indonesia, Papua-New Guinea

### Types of aquifer

(for Aquifers details on next two pages)

Type 1: porous

Type 2: fissured/fractured

Type 3: karst

## ASIA: Aquifers details

### Ertix River Plain

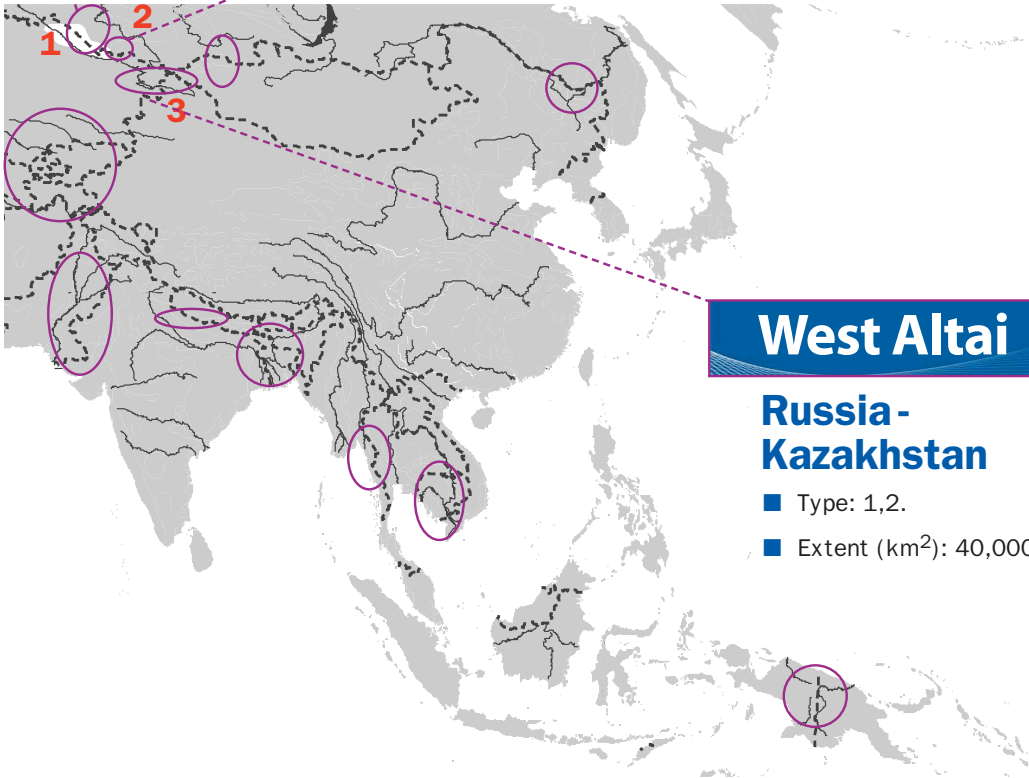
#### Russia - Kazakhstan

- Type: 1.
- Extent (km<sup>2</sup>): 120,000.

### Yili River Plain

#### China - Kazakhstan

- Type: 1.
- Extent (km<sup>2</sup>): 53,000.



Rayy Lake and Zhalanash  
pumping plant, Kazakhstan  
© UNESCO/Zhanat Kulenov





Virgin Komi Forests,  
Russian Federation  
© UNESCO

## Yenisei Upstream

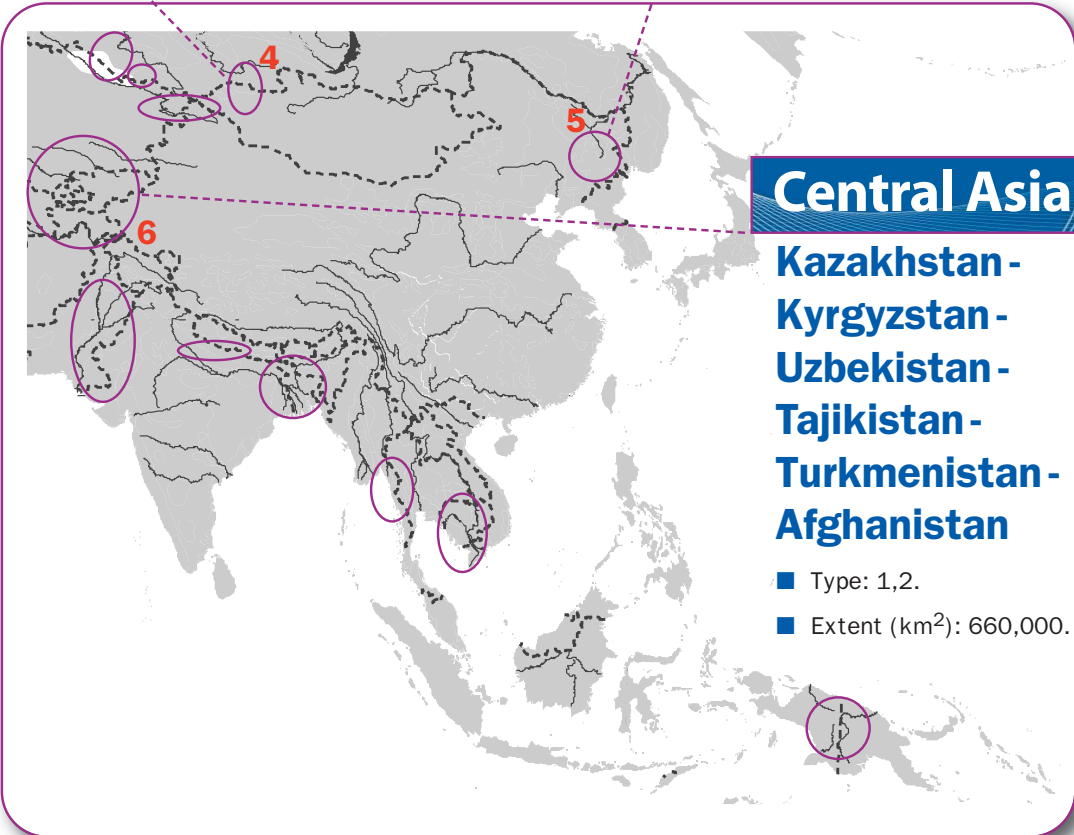
### Russia - Mongolia

- Type: 1,2.
- Extent (km<sup>2</sup>): 60,000.

## Heilongjiang River Plain

### China - Russia

- Type: 1.
- Extent (km<sup>2</sup>): 100,000.



## Central Asia

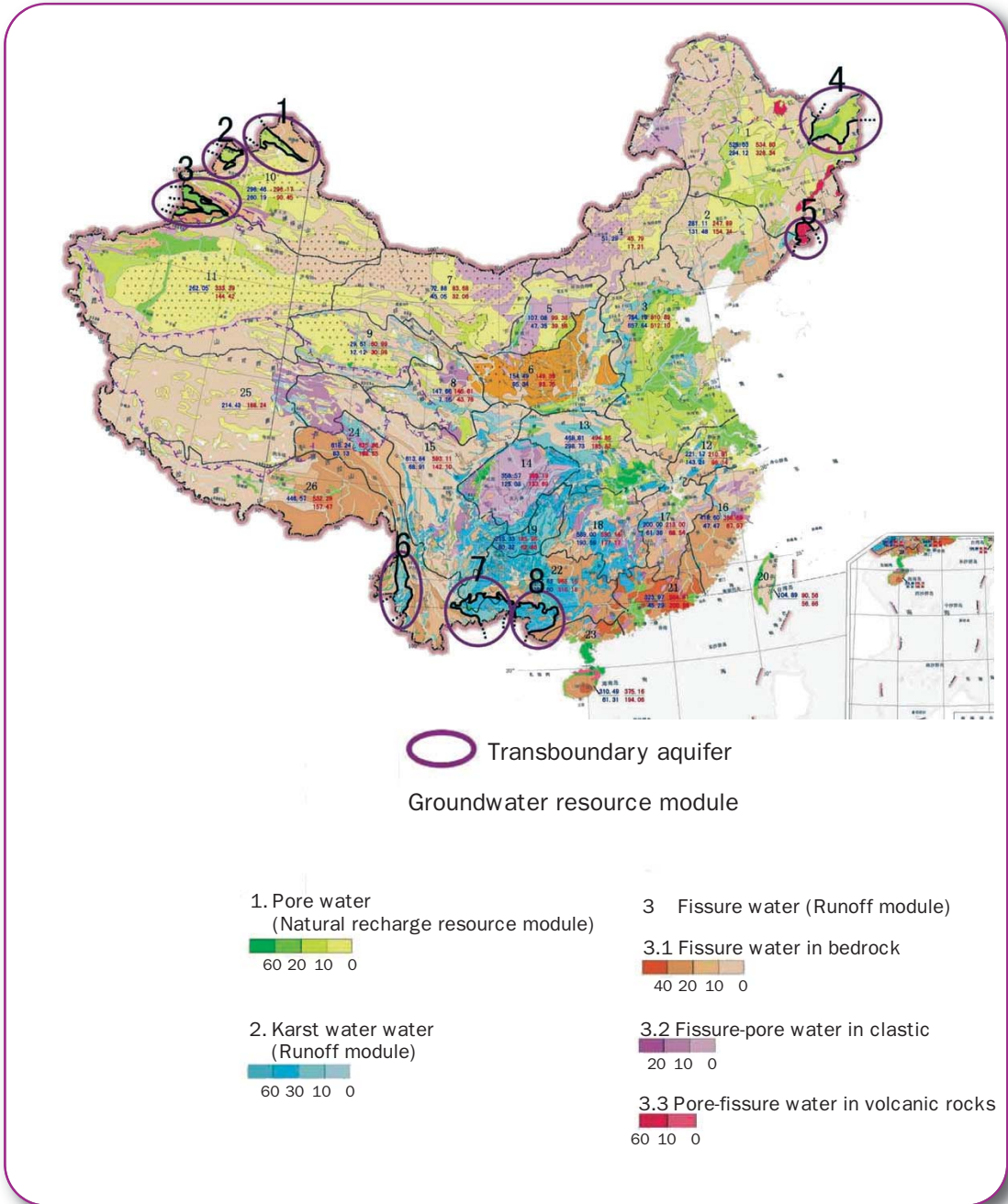
### Kazakhstan - Kyrgyzstan - Uzbekistan - Tajikistan - Turkmenistan - Afghanistan

- Type: 1,2.
- Extent (km<sup>2</sup>): 660,000.



# CHINA TRANSBOUNDARY AQUIFERS INVENTORY

## OVERVIEW



Source: UNESCO, 2006.

China		
1	Ertix River Plain	China, Kazakhstan
2	Tacheng Basin	China, Kazakhstan
3	Yili River Valley	China, Kazakhstan
4	Middle Heilongjiang-Amur River Basin	China, Russia
5	Yalu River Valley	China, Korea
6	Nu River Valley	China, Burma
7	Upriver of Zuo River	China, Vietnam
8	Beilun River Basin	China, Vietnam

### Types of aquifer

(for Aquifers details on next two pages)

Type 1: porous

Type 2: fissured/fractured

Type 3: karst

## CHINA: Aquifers details

### Yili River Valley

#### China - Kazakhstan

- Type: 1.
- Extension in China: 26,000 km<sup>2</sup>.

### Tacheng Basin

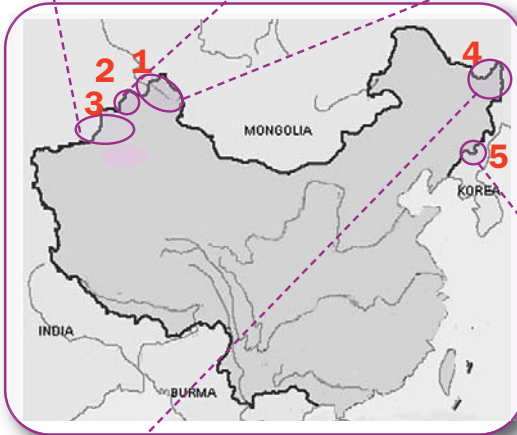
#### China - Kazakhstan

- Type: 1.
- Extension in China: 11,721 km<sup>2</sup>.

### Ertix River Plain

#### China - Kazakhstan

- Type: 1.
- Extension in China: 16,754 km<sup>2</sup>.



### Yalu River Plain

#### China - Korea

- Type: 2.
- Extension in China : 11,210 km<sup>2</sup>.

### Middle Heilongjiang-Amur River Basin

#### China - Russia

- Type: 1.
- Extension in China: 45,000 km<sup>2</sup>.

*Rayy Lake and Zhalanash, pumping plant, Kazakhstan  
© UNESCO/Zhanat Kulenov*



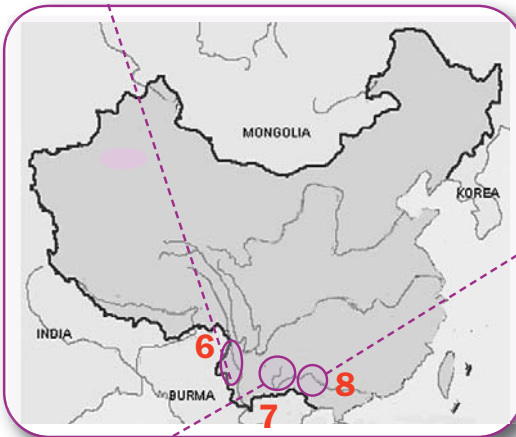


Himalaya Mountain Range,  
Yunnan, China  
© SXC

## Nu River Valley

### China - Myanmar

- Type: 3.
- Extent: 35,477 km<sup>2</sup>.



## Beilun River Basin

### China - Korea

- Type: 3.
- Extension in China:  
30,170 km<sup>2</sup>.

## Upriver of Zuo River

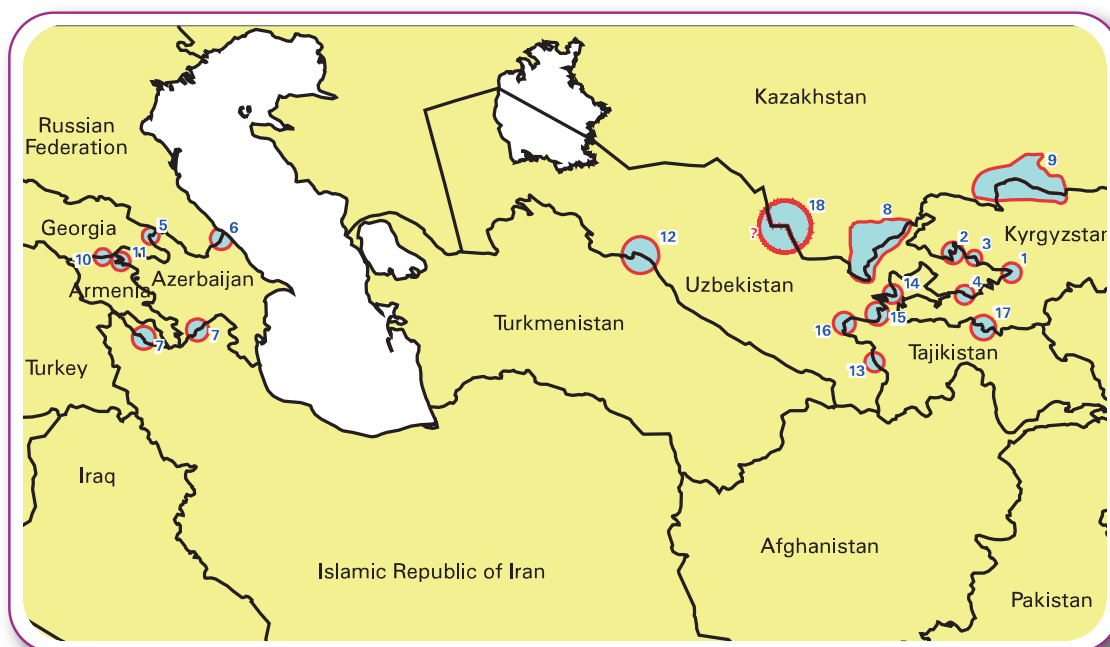
### China - Vietnam

- Type: 3.
- Extension in China:  
32,227 km<sup>2</sup>.

# CAUCASUS and CENTRAL ASIA

## TRANSBOUNDARY AQUIFERS INVENTORY

### OVERVIEW



#### Caucasus and Central Asia

1	Osh Aravoj	
2	Almoe-Vorzin	Uzbekistan-Kyrgyzstan
3	Moiansuv	
4	Sokh	
5	Alazan-Agrichay	
6	Samur	Azerbaijan-Russian Federation
7	Middle and Lower Araks	Azerbaijan-Islamic Rep. of Iran
8	Pretashkent	Kyrgyzstan-Uzbekistan
9	Chu Basin	Kyrgyzstan-Kazakhstan
10	Pambak-Debet	Georgia-Armenia
11	Agstev-Tabuch	Armenia-Azerbaijan
12	Birata-Urgench	Turkmenistan-Uzbekistan
13	Karotog	Tajikistan-Uzbekistan
14	Dalverzin	Uzbekistan-Tajikistan
15	Zaforoboi	Tajikistan-Uzbekistan
16	Zeravshan	
17	Selepta-Batkin – Nai-Icfor	Kyrgyzstan-Tajikistan
18	Chatkal-Kurman	Kyrgyzstan-Uzbekistan

Source: UNECE 2008.





Lake Issyk Kul, Kyrgyzstan  
© UNESCO/Peter Coles



## Uzbekistan-Kyrgyzstan

### Osh Aravoij

- Lithology: Sandy gravel.
- Pressure factors: Agriculture, industry, waste disposal (Uzb.) Agriculture (Kyrg.).
- Future trends: Expected pressure on the water resources due to economic growth and climate change.

### Sokh

- Expected pressure on the water resources due to economic growth and climate change.

### Almoe-Vorzin

- Pressure factors: Agriculture, ore mining, waste disposal (Uzb.) Agriculture (Kyrg.).
- Future trends: Improvement of the monitoring of groundwater quantity and quality (Kyrg.)

### Moiansuv

- Area: 1,760 km<sup>2</sup> (Uzbekistan).
- Lithology: Boulders pebble, loams, sandy, loams.
- Pressure factors: Industry (Uzb.) Agriculture (Kyrg.).
- Future trends: Improvement of the monitoring of groundwater quantity and quality.



## Middle and Lower Araks

### Azerbaijan-Islamic Rep. of Iran

- Extent: 1,480 km<sup>2</sup> (Azerbaijan).
- Lithology: Gravel-pebble, sand, boulder.
- Thickness mean-max: 60 -150 m.
- Water uses and functions (% of total abstraction)(Azerb.): Irrigation (55-60%), drinking water (40-45%).

## Samur

### Azerbaijan-Russian federation

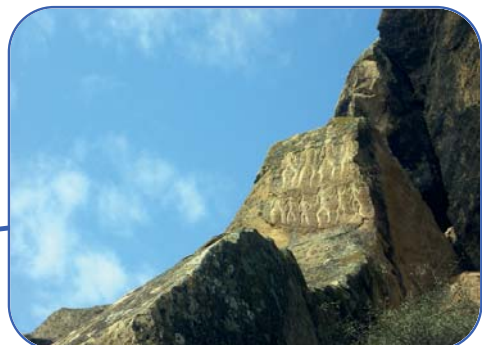
- Extent: 2,900 km<sup>2</sup> (Azerbaijan).
- Lithology: Gravel-pebble, sand, boulder.
- Thickness mean-max: 50 -100 m.
- Future trends: Increased use of water due to economic growth. (Azerbaijan).

## Alazan-Agrichay

### Azerbaijan-Georgia

- Extent: 3,050 km<sup>2</sup> (Azerbaijan).
- Lithology: Gravel-pebble, sand, boulder.
- Thickness mean-max: 150 -300 m.
- Future trends: Increased water demands.

Gobustan, Azerbaijan  
© UNESCO/Liz Wade





Aral Sea Region, Kazakhstan  
© UNESCO/Zhanat Kulenov



## Chu Basin

### Kyrgyzstan-Kazakhstan

- Extent: 200-350 km<sup>2</sup>.
- Lithology: Sand, clay, loams.
- Thickness mean-max: 150 -300 m.
- Pressure factors: Water abstraction.
- Problems related to groundwater quantity: Degradation of ecosystems, salt water upcoming (Kyr.).
- Problems related to groundwater quantity; Salinization (Kyr.).

## Pretashkent

### Uzbekistan-Kazakhstan

- Extent: 20,000 km<sup>2</sup>.
- Lithology: Sand, clay.
- Thickness mean-max: 200 -320 m.
- Water uses: Mineral water and partly as drinking water source (Uzb.); Drinking water supply (Kazak.).
- Transboundary impacts: Decline of the groundwater levels were observed (Kazak.).
- Prospects: Increased economic activities and climate change can have a pressure on the groundwater resources.



## Agstev-Tabuch

### Armenia-Azerbaijan

- Extent: 500 km<sup>2</sup>.
- Water uses: Drinking water up to 75%, irrigation up to 25% and mining industry (Arm.); Irrigation 80%, drinking water 15%, industry 5% (Azerb.).
- Pressure factors: Mining industry and waste disposal (Arm.); Mining industry (Azer.).

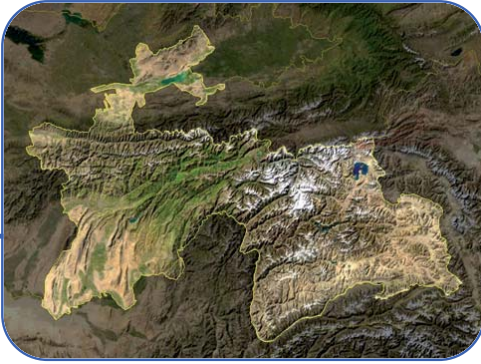
## Pambak-Debet

### Georgia-Armenia

- Lithology: Sand, clay, loams.
- Water uses: Drinking water supply 100% (Geor.); Drinking water up to 90%, irrigation and mining industry (Arm.).
- Pressure factors: Mining industry and agriculture (Armenia).
- Future trends: Increased use of water as consequence of the economic growth.

Lake Sevan, Armenia





Satellite photo of Tajikistan  
(Source: NASA)



## Birata-Urgench

### Uzbekistan-Turkmenistan

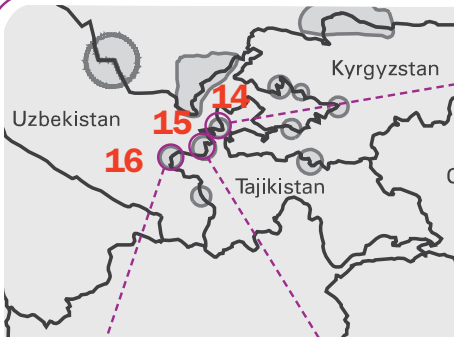
- Extent: 60,000 km<sup>2</sup>.
- Lithology: Sand, loams.
- Thickness mean-max: 10-50 m.
- Water uses: Drinking water supply.
- Pressure factors: Water abstraction.
- Problems related to groundwater quantity: Widespread/moderate reduction of borehole yields, widespread/serious reduction of base flow, spring flow.
- Problems related to groundwater quality: Salinization (natural origins and irrigation) as results of waste water and drainage waters.

## Karotog

### Tajikistan-Uzbekistan

- Extent: 328 km<sup>2</sup>.
- Lithology: Sand, loams.
- Thickness mean-max: 10-50 m.
- Water uses: Drinking water supply.
- Pressure factors: Water abstraction.
- Problems related to groundwater quantity: Widespread/moderate reduction of borehole yields, widespread/serious reduction of base flow, spring flow.
- Problems related to groundwater quality: Salinization (natural origins and irrigation) as results of waste water and drainage waters.





## Dalverzin

### Uzbekistan- Tajikistan

- Water uses: Irrigation (Uzb.); Drinking water supply and irrigation (Taj.).
- Pressure factors: Water abstraction.
- Problems related to groundwater quantity: Water resources are recharged in the course of year.
- Problems related to groundwater quality: Moderate increase in mineralization and hardness.

## Zeravshan

### Tajikistan- Uzbekistan

- Extent: 88 km<sup>2</sup> (Tajikistan).
- Water uses: Drinking water supply (Taj.); Drinking water and technological water (Uzb.).
- Pressure factors: Moderate water abstraction.
- Problems related to groundwater quantity: Change of water resources on the edge of natural sustainability.
- Problems related to groundwater quality: Significant effect of the industrial activities (Taj.).
- Groundwater management measures: Need to organize complex monitoring programme (Taj.); Existing monitoring programme of the groundwater (Uzb.).

## Zaforboi

### Tajikistan- Uzbekistan

- Water uses: Drinking water and irrigation.
- Pressure factors: Water abstraction.
- Problems related to groundwater quantity: Natural resources are recharged in the autumn and winter period.
- Problems related to groundwater quality: Moderate pollution (Uzb.).
- Groundwater management measures: Improvement of existing monitoring network of groundwater programme.



Pavlodar, Kazakhstan



## Chatkal-Kurman

### Kazakhstan-Uzbekistan

- Extent: 20,000 km<sup>2</sup> (Kazakhstan).
- Lithology: Sand, clay.
- Water uses: Drinking water (100%).
- Pressure factors: Water abstraction.
- Problems related to groundwater quantity: Reduction of borehole yields, decline of groundwater level.
- Problems related to groundwater quality: Salinization (natural origins and irrigation) as results of waste water and drainage waters.

## Selepta-Batkin – Nai-Icfor (Syr Darya)

### Kyrgyzstan-Tajikistan

- Extent: 891 km<sup>2</sup> (Tajikistan).
- Water uses: Irrigation and drinking water (Kyr.); Irrigation, drinking water and technological water (Taj.).
- Pressure factors: Water abstraction (Taj.).
- Problems related to groundwater quantity: Over exploitation (Kyr.); Water abstraction (Taj.).
- Problems related to groundwater quality: Contamination by nitrates and salinization (Kyr.); Increased mineralization, hardness and sulphates (Taj.).
- Groundwater management measures: Special monitoring is not performed (Kyr.); Monitoring is done partly (Taj.).

# MIDDLE EAST

## TRANSBOUNDARY AQUIFERS INVENTORY

### OVERVIEW

#### Middle East Transboundary Aquifers/Groundwater Units

Western Asia		
1	Upper Jezira / Mesopotamia	Iraq, Syria, Turkey
2	Eastern Mediterranean	Israel, (Jordan), Lebanon, Palestine, Syria
	Western Mountain Aquifer	Israel, Palestine
	Northern Anti-Lebanon Jurassic	Lebanon, Syria
	Southern Anti-Lebanon Jurassic	
	Northern Anti-Lebanon Cretaceous	
	Southern Anti-Lebanon Cretaceous	
	Hasbani-Ouazani Aquifer catchment	Israel, Lebanon
	Northeastern Mountain Aquifer	Israel, Palestine
	Eastern Mountain Aquifer	
	Gaza Strip Aquifer	Israel, Palestine
3	Hauran and Jabal Al-Arab	Jordan, Saudi Arabia, Syria
4	Syrian Steppe	Iraq, Jordan, Saudi Arabia, Syria
5	Disi, Saq	Jordan, Saudi Arabia
6	Eastern Arabian Peninsula	Bahrain, Qatar, Saudi Arabia, UAE
Not assignable		
	Aruma Deep Aquifer*	Bahrain, Iraq, Kuwait, Saudi Arabia
	Neogene Deep Aquifer*	
	Wasia-Biyadh Deep Aquifer*	Oman, Saudi Arabia, Yemen
	Wajid Deep Aquifer*	Saudi Arabia, Yemen
	Wasia-Biyadh Deep Aquifer*	Qatar, Saudi Arabia, UAE
	Saq and Tabuk Deep Aquifers*	Jordan, Saudi Arabia, Syria
	Upper Jordan River Quaternary	Israel, Syria
	Lower Jordan River quaternary	Israel, Jordan, Palestine

Source: Klingbeil, 2006.

\* See detailed maps for Arabian Peninsula and Saudi Arabia (pages 298 and 299).

## Eastern Mediterranean

**Israel, (Jordan), Lebanon, Palestine, Syria**

- Type: 1, 2, 3
- Extent (km<sup>2</sup>): 48,000

## Upper Jezira / Mesopotamia

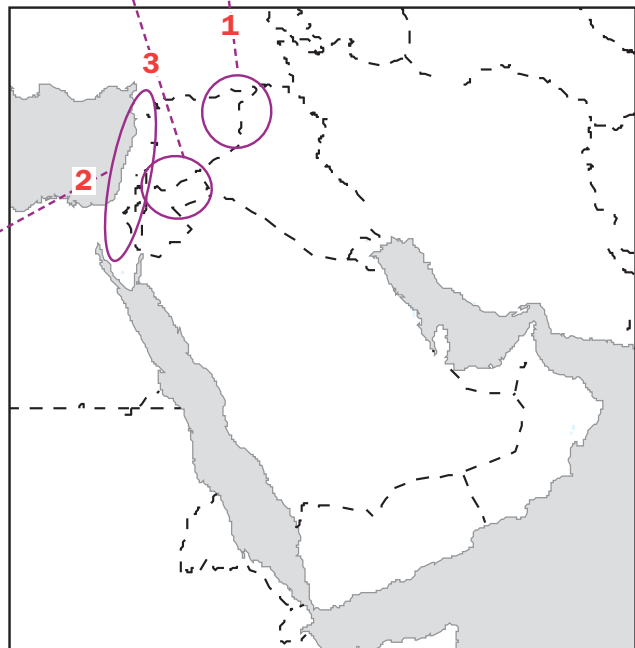
**Iraq, Syria, Turkey**

- Type: 1, 2
- Extent (km<sup>2</sup>): 100,000

## Hauran and Jabal Al-Arab

**Jordan, Saudi Arabia, Syria**

- Basalts, Neogene to Quaternary
- Type: 2
- Extent (km<sup>2</sup>): 15,000



### Types of aquifer

Type 1: porous; Type 2: fissured/fractured; Type 3: karst

Source: WHYMAP, 2006.

## Syrian Steppe

**Iraq, Jordan,  
Saudi Arabia,  
Syria**

- Type: 1, 2
- Extent (km<sup>2</sup>):  
1,600,000

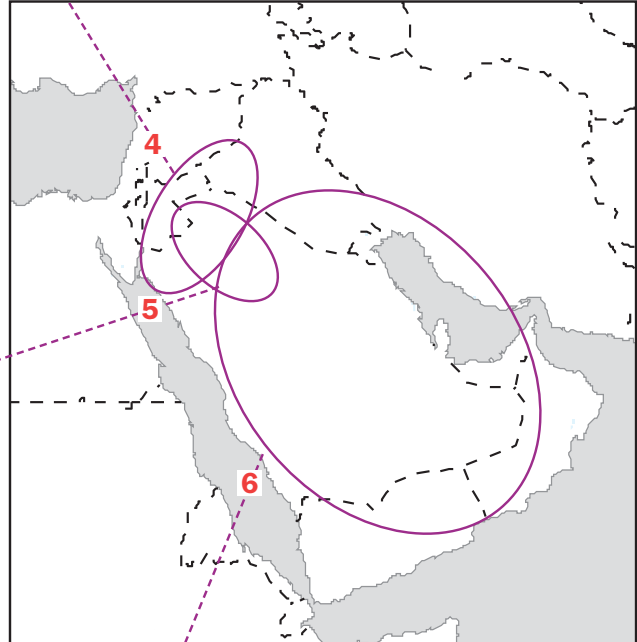
## Disi Aquifer

**Jordan,  
Saudi Arabia**

- 250 km long, 50 km wide,  
1 km deep.
- Fossil aquifer,  
dated 30,000 years ago.
- Non-renewable.

### Types of aquifer

Type 1: porous; Type 2: fissured/fractured; Type 3: karst



## Eastern Arabian Peninsula

**Bahrain, Iraq, Kuwait,  
Oman, Qatar, Saudi  
Arabia, UAE, Yemen**

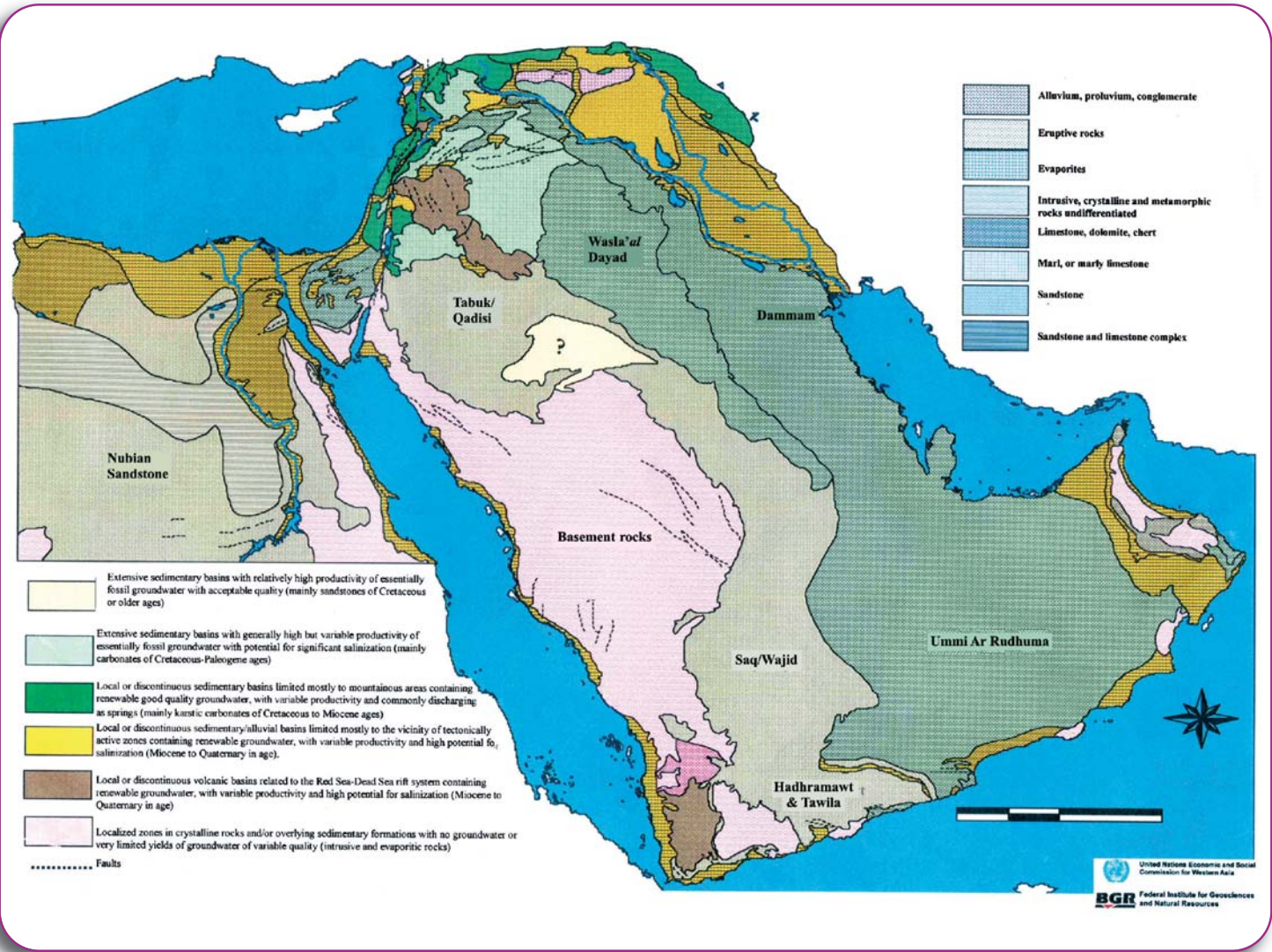
- Paleogene
- Type: 1, 2
- Extent (km<sup>2</sup>): 1,600,000

Source: WHYMAP 2006, Ferragina and Greco 2009.

## LOCAL INVENTORIES

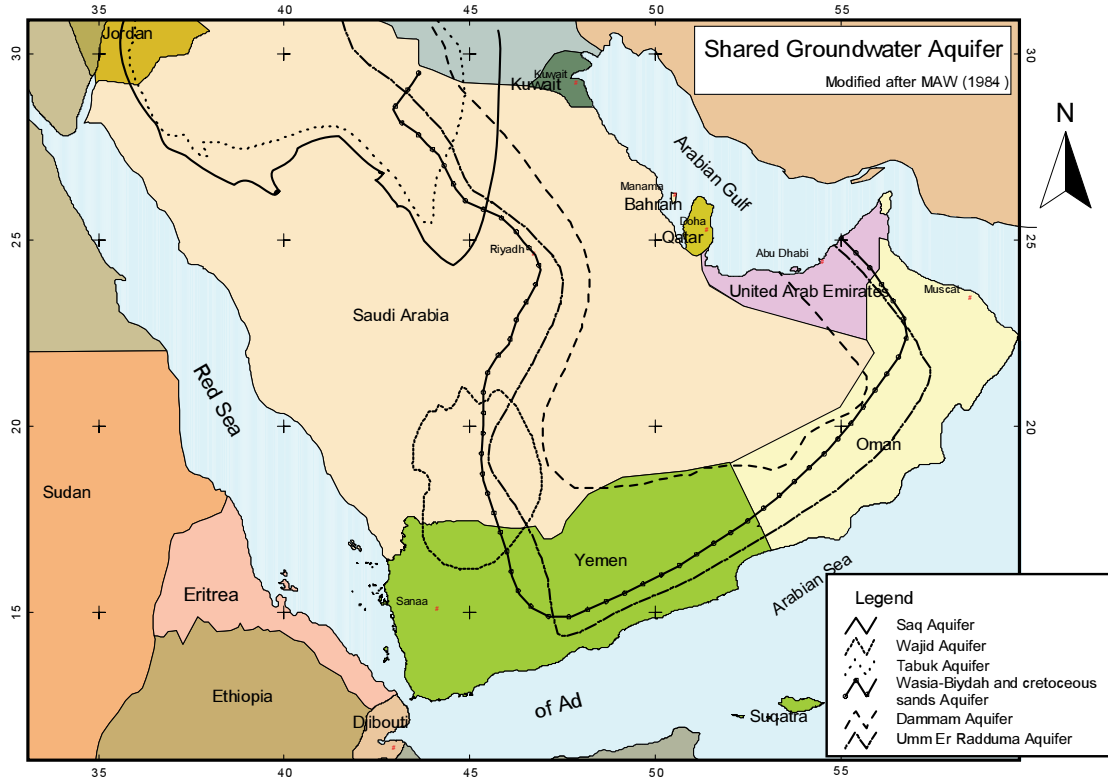
Additional transboundary aquifers in the Middle East are not and could not be accommodated in the WHYMAP due to the scale and their maps are presented separately in next pages.





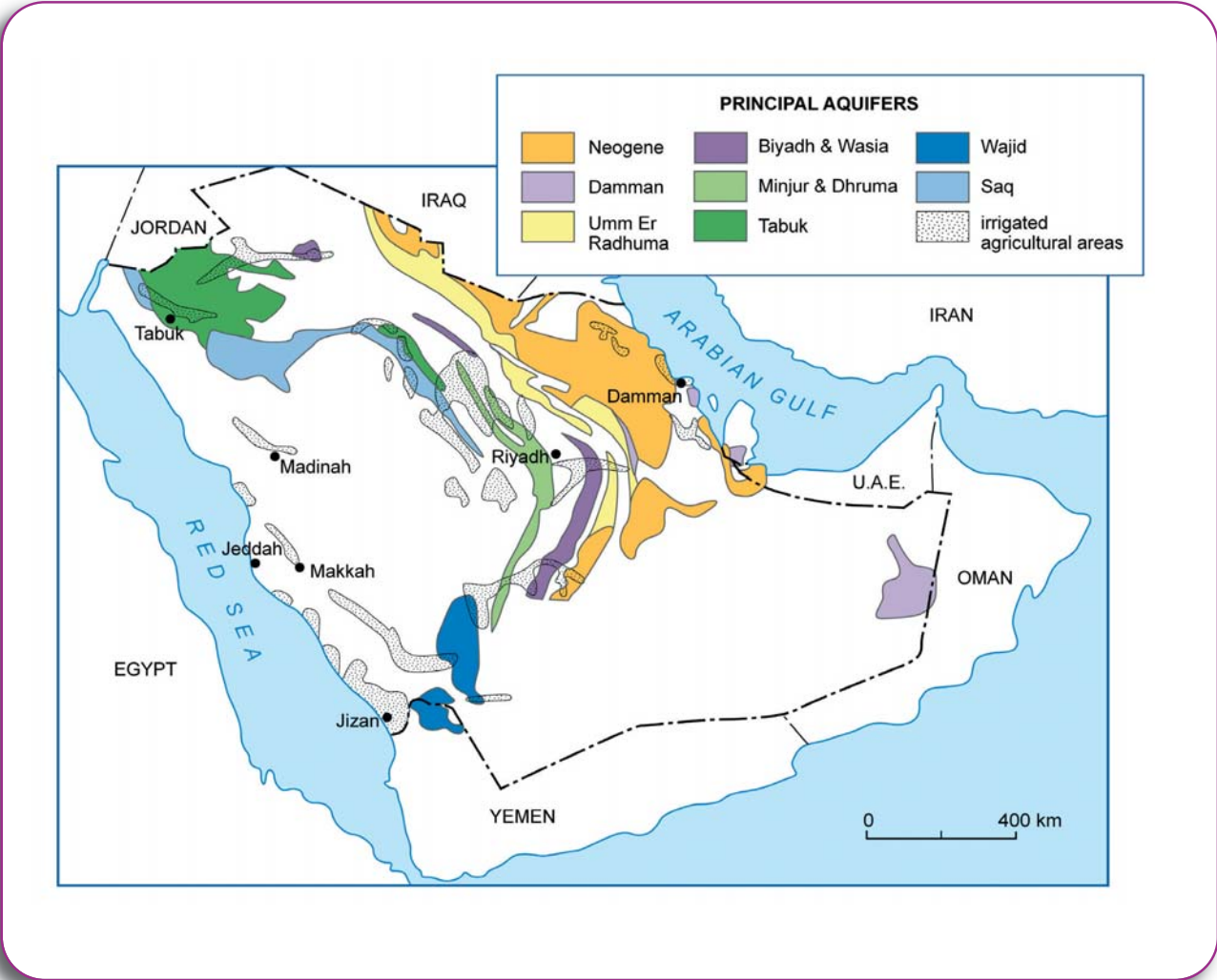
Source: UN-ESCWA/BGR, 2000 (modified from ACSAD, 1990).

ARABIAN PENINSULA: Shared groundwater aquifers



Source: UNESCO/WA/BGR, 2000 (modified after MAW (SA), 1984).

SAUDI ARABIA: Detail of principal aquifers



Source: Adapted from Foster and Loucks, 2006.

## Shared aquifers between Yemen and Oman

Age	Formation		Lithological characteristics	Maximum thickness	Groundwater characteristics and occurrences
Neogene	Lower Fars	Yemen	<i>Shihr</i> : Limestone, marl, shale	3,000	Low permeability
		Oman (Dhofar interior)	<i>Lower Fars</i> : Gypsiferous marls, minor dolomites (Dhofar) <i>Shihr</i> : (Dhofar)		Artesian, very saline water  Aquiclude or poor aquifer
Lower and Middle Eocene	Damman	Yemen	<i>Habshiya</i> : Shale, marls, limestone		Low permeability
		Oman (Dhofar interior)	Damman: Limestone and chalk (Dhofar)	150	Good aquifer, cavernous, fissured, unconfined; good quality
	Rus	Yemen	Jeza marl		
		Oman (Dhofar interior)	Massive gypsum (Dhofar)	100	Aquitard
Paleocene and Lower Eocene	Umm Er-Raduma	Yemen	<i>Medi-zir series</i> : Sandstone, siltstone; dykes <i>Saiun Limestone</i> : (Umm Er-Raduma)	120 180	Low permeability
		Oman (Dhofar interior)	Limestones, shales (Dhofar)	350	Upper part fair-poor aquifer. At depth good aquifer – confined, cavernous. Water quality fair-good
Upper Cretaceous	Aruma	Yemen			
		Oman (Dhofar interior)	Limestone, conglomerates, marls <i>Semali</i> ; serpentinite and gabbro	3,000	Water of variable salinity  In fractures groundwater may be present

Source: Stratigraphic column and hydrogeological characteristics of the shared aquifers between Yemen and Oman (modified after FAO, 1979)

# INWEB Database

INWEB presents a database including descriptive information and an interactive map on shared aquifers of the East Mediterranean Region.

East Mediterranean Region shared aquifers		
1	Eocene -Helvtia	Syria, Turkey
2	Bazalt-Azraq	Syria, Jordan
3	Nahr el Kabir (Cenemonian-Turonian)	Lebanon, Syria, Israel
4	Western Aquifer	Israel, Egypt, Palestine
5	Northeastern Aquifer	Israel, Palestine
6	Coastal Aquifer	Israel, Palestine



Source: <<http://www.inweb.gr>>.







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# Legal issues

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As mentioned earlier, despite the importance of transboundary aquifers and the increasing dependency on them for water resources, they have received, until recently, little attention in international law. While regulations for transboundary surface waters are quite well developed, this is still not really the case for transboundary groundwaters.

### At the global level

At the global level, the UN Convention on the Law of Non-Navigational Uses of International Watercourses (1997) (UN Doc. A/RES/51/229) (known as the UN Watercourse Convention) represents the latest authority in international water law. It includes groundwater in its coverage but in a very limited way. In article 2 on the 'Use of terms', the Convention defines a watercourse as 'a system of surface waters and groundwaters constituting by virtue of their physical relationship a *unitary whole and normally flowing into a common terminus*' (article 2 paragraph a). An international watercourse is defined as 'a watercourse, parts of which are situated in different States' (article 2 paragraph b). Regarding groundwater, the Watercourse Convention appears limited in its scope. It only considers groundwater when it is related to surface water, flowing to a common terminus. For instance, groundwater unrelated to surface water is excluded. This leaves out important transboundary aquifer systems located in different regions of the world, containing great amounts of freshwater resources. On the other hand, groundwater and surface water, even when they are related, do not necessarily 'share' a common terminus. In reality, surface water and groundwater don't always flow to a common terminus.

As a result, transboundary aquifers received limited coverage in international law. Furthermore, the provisions are tailored for a surface water body and do not cover the specific hydrogeological characteristics of aquifers.

The work of the ILC achieved in 2008 with the adoption at second reading of the draft articles on the law of transboundary aquifers and its recent recognition by a Resolution of the UN General Assembly on the law of transboundary aquifers (A/RES/63/124) (December 2008) mark an important step forward in the development of international law in the field of transboundary aquifers. The Resolution is a non-binding legal instrument, offering guidance for States sharing a transboundary aquifer in reaching an agreement. The text acknowledges the importance of the subject of the law of transboundary aquifers in the relations among States. It encourages the States concerned to make appropriate bilateral or regional arrangements for the proper management of their transboundary aquifers, taking into account the provisions of these draft articles, which are annexed to the Resolution.

### At the regional level

The UN ECE Convention on the Protection and Use of Transboundary Watercourses and International Lakes (or UNECE Water Convention) applies to all transboundary waters meaning 'any surface or ground waters which mark, cross or are located on boundaries between two or more States;' (article 1§1). This definition is broad and includes transboundary aquifers. The Convention is guided by the equitable and reasonable use principle, the precautionary principle and the sustainable development.

The UN ECE Water Convention provides that Riparian States shall enter into agreements, and establish joint bodies, which will have the responsibility, inter alia to collect and compile data and to elaborate joint monitoring programs.

Another instrument worth mentioning in Europe is the EU Water Framework Directive<sup>1</sup>. The EU WFD extends its provisions to provide transboundary or international river basins. According to the Directive groundwater is assigned to the most appropriate river basin. Each Member State will have to find and set the most appropriate administrative arrangements at the level of the river basin. In case of international river basin districts, whether shared by two or more Member States, or extending beyond the territory of the EU, each Member State has the obligation to ensure the administrative arrangements within the portion of his territory that comply with the rules of the Directive. Member States are required to coordinate with non Member States, when it is the case, for meeting the requirements of the Directive.

The revised Protocol on Shared Watercourses in the Southern African Development Community (2000) adopts the same definition for a watercourse as the UN Convention, which was described earlier as limited regarding groundwater. The Revised Protocol promotes cooperation on shared watercourses in the SADC region, the sustainable, equitable and reasonable utilization and the obligation not to cause significant harm.

## State practice

State practice over transboundary aquifers is also evolving. While until a recent period, transboundary aquifers were only covered within the larger framework of co-operation in the management and protection of border rivers, and in a marginal role, a little but notable change is occurring.

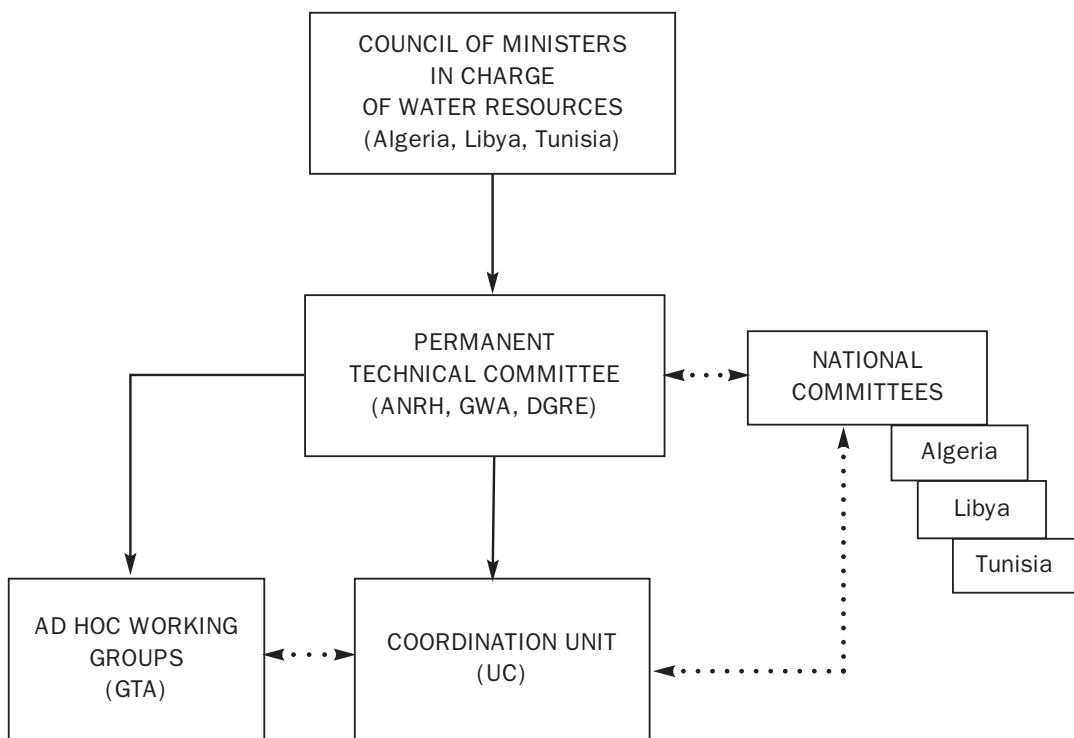
The case of the agreement on the Genevese aquifer, shared between France and Switzerland, remains an exception. A first convention on the protection, utilisation and recharging of the aquifer was concluded in 1977. In 2008, a new Convention entered into force replacing the previous one, keeping globally the same arrangement for the management of the aquifer.

Agreements on transboundary aquifers have appeared in the last years. For example, the riparian countries (Chad, Egypt, Libya and Sudan) of the Nubian Sandstone Aquifer System have established a joint authority among them. The agreement was first signed in July 1992 between Egypt and Libya. Sudan and Chad joined later. Amongst other things, the Authority is responsible for collecting and updating data, conducting studies, formulating plans and programmes for water resources development and utilization, implementing common groundwater management policies, training technical personnel, rationing the aquifer waters and studying the environmental aspects of water resources development.

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1. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (OJ L 327, 22.12.2000, p. 1)

In the same way, a first temporary institutional mechanism was established in 2002 among the three States of the North Western Sahara Aquifer System (Algeria, Libya and Tunisia). The structure of the mechanism included a steering committee composed of the national water authorities in the three countries, a coordination unit hosted by the Observatoire du Sahara et du Sahel, and an *ad hoc* scientific committee for evaluation and orientation, of which UNESCO-IHP is a member. The mechanism was in charge of managing the tools developed for the system (a common data base and a model) and the exchange of information, the establishment of monitoring indicators and promoting studies. In 2008, a permanent structure is agreed upon by the countries (figure below).



*Structure of the permanent consultation mechanism of the SASS  
(Latrech, oral presentation, Tripoli 2008)*

*Notes:*

ANRH = Agence Nationale des Ressources Hydrauliques (Algeria)

GWA = General Water Authority (Libya)

DGRE = Direction générale des Ressources en Eau (Tunisia)

GTA = Groupes de Travail ad hoc

UC = Unité de Coordination



The responsibilities of the permanent mechanism are:

- The development of indicators on the water resource and water demand
- The development and the updating of the common data base
- The development and the management of common monitoring systems.

## Emerging projects

Projects on transboundary aquifers are emerging, and often include a legal and institutional component. It is worth mentioning here the achievements under two projects, even if still not in force and application.

In the frame of the GEF project on the environmental protection and sustainable development of the Guarani Aquifer System (Argentina, Brazil, Paraguay, Uruguay), the four States have adopted a draft declaration on the basic principles and lines of action for the Guarani aquifer system. The draft declaration includes the following :

- Recalls the sovereignty of each State on the part of the aquifer in its territory
- Use of the water resource in a reasonable and sustainable way
- Respect of the rules of international law related to the activities which could have an adverse effect in another State,
- Enter into cooperation in defined 'hot spots

([http://www.sg-guarani.org/index/pdf/proyecto/docbas/acuerdos/Declaracion\\_Principios\\_Basicos\\_SAG.pdf](http://www.sg-guarani.org/index/pdf/proyecto/docbas/acuerdos/Declaracion_Principios_Basicos_SAG.pdf) )

In the frame of the project on the Lullemeden Aquifer System (Mali, Niger and Nigeria) 'Managing transboundary hydrogeological risks in the IAS', the three States agreed on the principle of setting up a consultation mechanism, and a draft proposal was prepared.

It is clear from the evolving State practice that awareness on the necessity of developing legal tools and mechanisms for cooperation has been reached. The new Resolution on the law of transboundary aquifers is today at useful guide for States, for entering into agreements in view of the proper management of their transboundary aquifers.



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# Appendices

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# I. Partners of the ISARM Programme

## ■ The International Groundwater Resources Assessment Centre (IGRAC)



The assessment of global groundwater resources is one of the core activities of International Groundwater Resources Assessment Centre (IGRAC). Next to the assessment, IGRAC – as UNESCO/WMO groundwater centre – facilitates and promotes global sharing of information and knowledge. In both activities, transboundary aquifers take a very prominent place.

IGRAC participates in the ISARM project and maintains the ISARM portal at <<http://www.isarm.net>>. Nevertheless, the main IGRAC contribution so far is one to the ISARM regional activities. Together with OAS (Organisation of American States) and UNESCO-IHP, IGRAC has played a major role in creating a data set of transboundary aquifers of America's. Results of a preliminary delineation of transboundary aquifers that IGRAC conducted in Southern Africa are available on-line in IGRAC's GGIS (Global Groundwater Information System).

Finally, IGRAC contributed to an initial assessment of transboundary aquifers in South-Eastern Europe. In the framework of GEF IW LEARN project, IGRAC compiled lessons learned from various transboundary projects.

UNESCO has also engaged IGRAC in development of ISARM transboundary aquifers course material.

More information on IGRAC and its activities can be found at <<http://www.igrac.nl>>.

## ■ International Association of Hydrogeologists (IAH)



IAH is a scientific and educational organisation whose aims are to promote research into and understanding of the proper management and protection of groundwater for the common good throughout the world. The IAH has over 3,500 members in 135 countries.

More information on IAH and its activities can be found at <<http://www.iah.org>>.

### ■ UN Food and Agriculture Organisation (FAO)



In the face of increasing water scarcity, and the dominance of agricultural water use, FAO is in the forefront to enhance global agricultural performance while promoting the sustainability of water use for food production.

Specific targets are integrated water resources management, water harvesting, groundwater, use of non-conventional water, modernization of irrigation systems, on-farm water management, water-quality management, agriculture-wetlands interactions, drought impact mitigation, institutional capacities, national water strategies and policies, river basin and transboundary waters management.

FAO maintains an extensive multi-scale information base on water for use at global, national and local levels, AQUASTAT, and FAOLEX, FAO's global information system of water and agriculture, monitors and reports on water resources and agricultural water use in member countries.

More information on IGRAC and its activities can be found at <http://www.fao.org>.

### ■ UN Economic Commission for Europe (UNECE)



The United Nations Economic Commission for Europe (UNECE) is one of five regional commissions of the United Nations.

Its major aim is to promote pan-European economic integration. To do so, UNECE brings together 56 countries located in the European Union, non-EU Western and Eastern Europe, South-East Europe.

The UNECE has negotiated the Convention of the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention), intended to strengthen national measures for the protection and ecologically sound management of transboundary surface waters and groundwaters.

In 2008, with the support of UNESCO ISARM among other institutions, UNECE published the first Assessment of Transboundary Rivers, Lakes and Groundwaters, carried out under the auspices of the Water Convention. The Assessment is the first comprehensive analysis of transboundary rivers, lakes and groundwaters in the UNECE region. It covers 140 transboundary rivers and 30 transboundary lakes in the European and Asian parts of the region, as well as 70 transboundary aquifers located in South-Eastern Europe, Caucasus and Central Asia.

More information on UNECE and its activities can be found at <<http://www.unece.org>>.

### ■ Organisation of American States (OAS)



The Department of Sustainable Development (OAS/DSD) supports OAS member States in the design and implementation of policies, programs and projects oriented to integrate environmental priorities with poverty alleviation, and socio-economic development goals. Translating sustainable development and environmental protection goals into concrete actions, DSD supports the execution of multiple-country projects in such diverse areas as integrated water management, renewable energy, natural hazards-climate change adaptation and land use planning, biological diversity and environmental law and policy. The UNESCO/OAS ISARM Americas Programme results from the joint effort by UNESCO-IHP and DSD/OAS to set up the ISARM Programme in the American hemisphere. As the leading agency in coordinating the American Programme, OAS has focused its efforts on helping American countries become involved in carrying out the programme's tasks.

More information can be found at <[http://www.oas.org/dsd/isarm/ISARM\\_index.htm](http://www.oas.org/dsd/isarm/ISARM_index.htm)>

### ■ International Network of Water-Environment Centres for the Balkans (INWEB)



INWEB was created in 1999 and in July 2003 was appointed as a UNESCO Chair for 'Sustainable Management of Water and Conflict Resolution'.



INWEB's objectives are, among others, to facilitate the exchange of information in the fields of water and environment by establishing an international, open network in the Balkan region; to raise public awareness in the fields of water resources and environmental protection; to promote training and professional development in the Balkan region by providing distance learning; to develop inventories of existing transboundary monitoring systems, to create and maintain databases on water and the environment by use of official, validated national data compatible to European Union standards and mainly related to transboundary water bodies.

UNESCO Chair/INWEB has prepared and maintains databases of South-Eastern Europe, available on its website <<http://www.inweb.gr>>: Balkans region, South Mediterranean countries and East Mediterranean countries. The inventories include, for each aquifer, an interactive map using Google Earth technology, aquifer data and descriptive information.

### ■ The Sahara and Sahel Observatory (OSS)



OSS is an independent international organisation based in Tunis, Tunisia, founded in 1992 to improve early warning and monitoring systems for agriculture, food security and drought in Africa.

Ever since, its main objective has been to give impetus to the combat against desertification and the mitigation of drought by providing member countries and organisations with a forum where they can share experiences and harmonise the ways in which data is collected and processed to feed into decision-support tools.

The OSS Water programme focuses on groundwater and promotes the joint management of shared water resources with a view to underpinning sustainable development and economic integration in circum-Saharan Africa. Its ultimate goal is to help safeguard water resources for the benefit of the peoples sharing them.

In two projects OSS has been the executing agency of the project and UNESCO/IHP the scientific partner: North-Western Sahara Aquifer System (NWSAS) project, aiming to contributing to sustainable development in the area, and Lullemeden Aquifer System (IAS) project, aiming to provide favourable conditions for the emergence of an integrated joint management approach to the shared IAS water resources. Published synthesis of both projects are available on OSS website, <<http://www.oss-online.org>>.

### ■ UN Economic and Social Commission for West Asia (UNESCWA)



ESCWA comprises 13 Arab countries in Western Asia: Bahrain, Egypt, Iraq, Jordan, Kuwait, Lebanon, Oman, Palestine, Qatar, Saudi Arabia, the Syrian Arab Republic, the United Arab Emirates and Yemen.

ESCWA provides a framework for the formulation and harmonization of sectoral policies for member countries, a platform for congress and coordination, a home for expertise and knowledge, and an information observatory. UNESCWA and UNESCO have signed an agreement for the development of the ISARM activities in the region.

The subprogramme 'Integrated management of natural resources for sustainable development' aims to improve the sustainable management of natural resources in the region, with particular emphasis on the water, energy and production sectors, always taking environmental considerations into account. The subprogramme includes The Water and Environment Issues Team, which carries out a number of activities with a view to enhancing regional integration and cooperation for the sustainable management of water resources; in particular, to build the capacity of member countries in integrated water resource management (IWRM), devise national policies and plans, and develop the institutional and legal frameworks needed for IWRM.

More information on UNESCWA can be found at <http://www.escwa.un.org/>.

### ■ Bureau de recherches géologiques et minières (BRGM)



BRGM is a France's public institution involved in the Earth Science field for the sustainable management of natural resources and surface and subsurface risks.

Water is one thematic areas of BRGM, among others. As supplying water to the Earth's

population is a major concern for the 21st Century, rational and strict management is essential if the available resource could well prove insufficient in many regions of the world. For countries in the temperate zone, the priority will lie in preserving water quality.

BRGM is involved in prospecting, locating and evaluating groundwater resources. Other efforts are devoted to understanding the mechanisms behind the deterioration of groundwater quality. These notably include a study of its chemical properties, whether natural (background geochemistry) or man-induced (e.g. diffuse pollution from agricultural sources), as well as the potential for natural remediation.

In 2008, BRGM and UNESCO-IHP have published jointly *Les eaux souterraines dans le monde* [Groundwater in the world], written by Jean Margat, as a contribution to the everybody's awareness of potential but fragility of groundwater. More information on BRGM and its activities can be found at <<http://www.brgm.fr>>.

#### ■ Federal Institute for Geosciences and Natural Resources (BGR)



In order to contribute to the world-wide efforts to better study, manage and protect freshwater resources the World-wide Hydrogeological Mapping and Assessment Programme (WHYMAP) was launched by UNESCO in 1999 and BGR and UNESCO are the lead agencies.

BGR is the central geoscientific authority providing advice to the German Federal Government in all relevant groundwater aspects, like management, resources assessment, and protection. The WHYMAP programme aims at collecting, collating and visualising hydrogeological information at a global scale. Maps are convenient tools to convey groundwater related information in an appropriate way to groundwater experts as well as to non-experts or politicians. WHYMAP thus brings together the huge efforts in hydrogeological mapping, at regional, national and continental levels.

WHYMAP products include world maps on groundwater resources, additional global maps, geographic information system (GIS) with supra-national, continent-wide, groundwater related data, and a web mapping application with embedded World-wide Hydrogeological Map Information System (WHYMIS). Some products are available for download and the information can be found at <<http://www.whymap.org>>.

### ■ **The GEF International Waters Focal Area**



The UNESCO-IHP has set up a close cooperation with the Global Environment Facility (GEF) International Water programme. In the course of three technical workshops jointly organized by UNESCO-IHP and the Scientific Technical Advisory Panel of the GEF, the ISARM Initiative has become a centre point for facilitating projects and technical discussions as regards transboundary aquifers. The scientific network of the ISARM Programme has provided the hydrogeological basis for considering approaches for sustainable use and management so that global environmental gains can be achieved. Several transboundary aquifer systems identified in the course of the national and regional inventories have been adopted as projects financed through the GEF International Waters focal area – not able among them are the Iullemeden Aquifers System, the North West Sahara Aquifer System, the Dinaric Karst Aquifer Systems and the Nubian Sandstone Aquifer System. These are all described in the case Studies Section of this atlas.

### ■ **African Ministers' Council on Water (AMCOW)' African Groundwater Commission**



UNESCO is supporting the recently adopted African Groundwater Commission by the AMCOW. The ISARM Programme is very attentive to build partnerships with sub-regional initiatives such as those promoted by SADC, ECOWAS, Senegal River Basin Organisation, Niger Basin Authority, Chad Basin Commission continue for participate in. Support will be provided to the SADC Region and the Senegal Basin authority to consider how the ILC's draft Articles on the use of transboundary aquifers could be incorporated into the existing regional instruments.

### ■ ***The UN International Law Commission***



The 67th Plenary meeting of the UN General Assembly decided to include in the provisional agenda of its sixty-sixth session 'an item entitled 'The law of transboundary aquifers' with a view to examining, inter alia, the question of the form that might be given to the draft articles.' As stated previously the articles are not as yet a binding instrument to Member States and further experience is needed to build up customary legislative support for any future legally binding instruments. The ISARM Programme is committed to supporting those Member States that wish to consider the applicability of such Articles, supported by capacity strengthening and institutional development. In course of such actions in the coming years, the ISARM Programme will again provide its support support trough its network of scientists and water law specialists.



## II. RESOLUTION XIV-12

### International Initiative on Transboundary Aquifer Resources Management (TARM)

Adopted during the 14th Session of the Council of UNESCO's International Hydrological Programme (UNESCO-IHP), Paris, 5-10 June 2000

The Intergovernmental Council of the International Hydrological Programme of UNESCO,

*Recognizing* that transboundary aquifer systems are an important source of fresh water in some regions of the world, particularly under arid and semi-arid climatic conditions,

*Also recognizing* that due to a lack of reliable scientific knowledge and information conflicts may arise,

*Recalling* that at the fifth UNESCO/WMO International Conference on Hydrology (Geneva 1999) concern was raised on the lack of monitoring and assessment of the key aquifer resources,

*Noting* that the Tripoli Statement of November 1999 and the Ministerial Declaration of The Hague (March 2000) drew attention to the problems of managing shared water resources,

*Endorses* the recommendations of the experts meeting organised by UNESCO and IAHR in co-operation with FAO and UN/ECE (UNESCO, Paris 27-28 March 2000),

*Decides* to launch an inter-agency initiative to promote studies in regard to transboundary aquifers (TARM),

*Requests* the Director-General of UNESCO to take necessary actions to conclude a Memorandum of Understanding with UN/ECE and FAO,

*Invites* Member States to facilitate regional co-operation and provide their support to this initiative,

*Encourages* UN Agencies to provide their support and funding institutions to contribute financially to this initiative.

## III. RESOLUTION A/RES/63/124

### Law on transboundary aquifers

Adopted during the 63th Session United Nations General Assembly,  
New York, 11 December 2008

The General Assembly,

*Having* considered chapter IV of the report of the International Law Commission on the work of its sixtieth session,<sup>1</sup> which contains the draft articles on the law of transboundary aquifers,

*Noting* that the Commission decided to recommend to the General Assembly

(a) to take note of the draft articles on the law of transboundary aquifers in a resolution, and to annex the articles to the resolution; (b) to recommend to States concerned to make appropriate bilateral or regional arrangements for the proper management of their transboundary aquifers on the basis of the principles enunciated in the articles; and (c) to also consider, at a later stage, and in view of the importance of the topic, the elaboration of a convention on the basis of the draft articles,<sup>2</sup>

*Emphasizing* the continuing importance of the codification and progressive development of international law, as referred to in Article 13, paragraph 1 (a), of the Charter of the United Nations,

*Noting* that the subject of the law of transboundary aquifers is of major importance in the relations of States,

*Taking note* of the comments of Governments and the discussion in the Sixth Committee at the sixty-third session of the General Assembly on this topic,

1. *Welcomes* the conclusion of the work of the International Law Commission on the law of transboundary aquifers and its adoption of the draft articles and a detailed commentary on the subject;

2. *Expresses its appreciation* to the Commission for its continuing contribution to the codification and progressive development of international law;

3. *Also expresses its appreciation* to the International Hydrological Programme of the United Nations Educational, Scientific and Cultural Organization and to other relevant organizations for the valuable scientific and technical assistance rendered to the International Law Commission;<sup>3</sup>

1 Official Records of the General Assembly, Sixty-third Session, Supplement No. 10 (A/63/10).

2 *Ibid.*, para. 49.

3 *Ibid.*, para. 51.

4. *Takes note* of the draft articles on the law of transboundary aquifers, presented by the Commission, the text of which is annexed to the present resolution, and commends them to the attention of Governments without prejudice to the question of their future adoption or other appropriate action;

5. *Encourages* the States concerned to make appropriate bilateral or regional arrangements for the proper management of their transboundary aquifers, taking into account the provisions of these draft articles;

6. *Decides* to include in the provisional agenda of its sixty-sixth session an item entitled 'The law of transboundary aquifers' with a view to examining, inter alia, the question of the form that might be given to the draft articles.

67th plenary meeting  
11 December 2008

Full text of Articles included in:

- Part one* Introduction  
*Article 1* Scope  
*Article 2* Use of terms
- Part two* General principles  
*Article 3* Sovereignty of aquifer States  
*Article 4* Equitable and reasonable utilization  
*Article 5* Factors relevant to equitable and reasonable utilization  
*Article 6* Obligation not to cause significant harm  
*Article 7* General obligation to cooperate  
*Article 8* Regular exchange of data and information  
*Article 9* Bilateral and regional agreements and arrangements
- Part three* Protection, preservation and management  
  
*Article 10* Protection and preservation of ecosystems  
*Article 11* Recharge and discharge zones  
*Article 12* Prevention, reduction and control of pollution  
*Article 13* Monitoring  
*Article 14* Management  
*Article 15* Planned activities
- Part four* Miscellaneous provisions  
*Article 16* Technical cooperation with developing States  
*Article 17* Emergency situations  
*Article 18* Protection in time of armed conflict  
*Article 19* Data and information vital to national defence or security

can be consulted at the General Assembly of the United Nations website,  
<<http://www.un.org/ga>>.

## IV. Tripoli Statement

### International Conference on 'Regional Aquifer Systems in Arid Zones – Managing Non-Renewable Resources' Tripoli, November 1999

More than 600 hundred participants from more than 20 countries and regional and international organizations and associations attended the International Conference on

#### **'Regional Aquifer Systems in Arid Zones – Managing Non-Renewable Resources'**

Tripoli, 20–24 of November 1999

#### **We the Participants of the Conference recognize that:**

1. In most arid countries the scarcity of renewable water supplies implies a serious threat to sustainable coupled and balanced socio-economic growth and environmental protection. This threat is clearly more pronounced in the less wealthy countries.
2. In many arid countries, however, the mining of non-renewable groundwater resources could provide an opportunity and a challenge, and allow water supply sustainability within foreseeable time-frames that can be progressively modified as water related technology advances.
3. The Conference marks a milestone in the discussion of the emerging concept of planned groundwater mining.

#### **We the Participants consider that:**

1. Adoption of this concept at national level could have international repercussions;
2. A national integrated water policy is essential with, where feasible, priority given to renewable resources, and the use of treated water, including desalinated water.

#### **We recommend that:**

- a. Groundwater mining time-frames should account for both quantity and quality with criteria set for use priorities, and maximum use efficiency, particularly in agriculture;
- b. Care should be exercised to minimize the detrimental impact to existing communities;
- c. Consideration should be given to the creation of economical low water consuming activities.

*We the participants further consider that in situ development, or development based upon transferred mined groundwater, depend upon many non-hydrogeological factors outside the scope of this Conference. Nevertheless, hydrogeological constraints need to be defined for both planners and the end users.*

*We recommend the participation of the end users in the decision making process and the enhancement of their responsibility through water use education and public awareness. We believe that for efficient water-use, cost recovery could eventually be necessary.*

In recognition of the fact that:

- a. some countries share aquifer systems;
- b. international law does not provide comprehensive rules for the management of such systems as yet, and
- c. clearly groundwater mining could have implications for shared water bodies;

We the participants draw the attention of Governments and International Organizations to the need for:

- a. rules on equitable utilization of shared groundwater resources,
- b. prevention of harm to such resources and the environment,
- c. exchange of information and data.

We also encourage concerned countries to enter into negotiations with a view of reaching agreements on the development, management, and protection of shared groundwater resources.



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## IV. Acronyms and abbreviations

<b>AUTH</b>	Aristotle University of Thessaloniki
<b>AMCOW</b>	African Ministerial Conference on Water
<b>AWF</b>	African Water Facility
<b>BGR</b>	Federal Institute for Geosciences and Natural Resources, Germany
<b>BRGM</b>	Bureau de recherches géologiques et minières, France
<b>FAO</b>	Food and Agriculture Organization
<b>GEF</b>	Global Environment Facility
<b>IAEA</b>	International Agency for Atomic Energy
<b>IAH</b>	International Association of Hydrologists
<b>IGRAC</b>	International Groundwater Resources Assessment Centre
<b>INWEB</b>	International Network of Water - Environment Centres in the Balkans
<b>IHP</b>	International Hydrological Programme
<b>ISARM</b>	International Shared Aquifer Resources Management
<b>MEDA</b>	Euro-Mediterranean Partnership
<b>OACT</b>	Organisation Africaine de Cartographie et de Télédétection
<b>OAS</b>	Organization of American States
<b>OSS</b>	Observatoire du Sahara et du Sahel
<b>TBA</b>	Transboundary aquifer
<b>SADC</b>	Southern Africa Development Community
<b>UN</b>	United Nations
<b>UNECE</b>	United Nations Economic Commission for Europe
<b>UNEP</b>	United Nations Environment Programme
<b>UNESCWA</b>	United Nations Economic and Social Commission for West Asia
<b>UNGA</b>	United Nations General Assembly
<b>UNILC</b>	United Nations International Law Commission
<b>UNESCO</b>	United Nations Education Science and Culture Organization
<b>WHYMAP</b>	World-wide Hydrogeological Mapping and Assessment Programme
<b>WWAP</b>	World Water Assessment Programme
<b>5WWF</b>	Fifth World-Water Forum

### *Abbreviations for countries*

<b>FYROM, the FYR of Macedonia</b>	The former Yugoslav Republic of Macedonia
<b>Laos</b>	Lao People's Democratic Republic
<b>Libya</b>	Libyan Arab Jamahiriya
<b>Russia</b>	Russian Federation
<b>Syria</b>	Syrian Arab Republic
<b>Tanzania</b>	United Republic of Tanzania
<b>UAE</b>	United Arab Emirates
<b>USA</b>	United States of America

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