United Nations
Educational, Scientific and
Cultural Organization

International
Hydrological
Programme

UNESCO GRAPHIC Project
"Groundwater Resources Assessment under the Pressures of Humanity and Climate Change"

Launching of Andros Case Study

Nassau, March 17-19, 2008

FINAL REPORT

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2. Presentation of objectives and expected outcomes of the meeting
3. Overview of Andros Aquifer and related global and regional initiatives
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UNESCO GRAPHIC Project
"Groundwater Resources Assessment under the Pressures of Humanity and Climate Change"

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FINAL REPORT

1. Opening session

The Meeting was held in Nassau, Bahamas, on March 17-19, 2008. It was organized by UNESCO International Hydrological Programme (IHP) with the support of the Water and Sewerage Corporation of the Bahamas Environment, Science and Technology (BEST) Commission.

The representative of the Water and Sewerage Corporation, Mr. John Bowleg, was designated Chairman of the meeting. In the opening session, Mr. Bowleg welcomed the participants to the Bahamas and wished them all a fruitful meeting. On behalf of the BEST Commission, Mr. Miles Brennen, expressed the support of the Commission for this initiative and indicated their willingness to contribute to its development. Ms. María Concepcion Donoso, UNESCO Regional Hydrologist for Latin America and the Caribbean (LAC) thanked the local organizers of the meeting and briefly introduced the main aims of the event, after which the Chairman declared the workshop officially opened. The agenda of the event is attached under Annex 1.

The participants introduced themselves by indicating their professional expertise relevant to the GRAPHIC project. The list of participants is attached to this report in Annex 2.

2. Presentation of objectives and expected outcomes of the meeting

The Regional Coordinator, Mr. Henrique Chaves, made a brief presentation of UNESCO's GRAPHIC programme, its scope, objectives, and methodologies, as well as the activities developed to date within GRAPHIC at the regional and global level.

Moreover, the Regional Coordinator provided an overview of the situation of GRAPHIC in LAC, including the ongoing pilot studies as agreed to at the launching meeting in Belize, in 2007, and the potential incorporations of other groundwater systems to this group of aquifers, such as Artibonito-Masacre (Haiti-Dominican Republic).

Finally, Mr. Henrique Chaves presented the objectives and expected outcomes of the workshop and the expected outcomes of this new case study in the Caribbean. The Andros Aquifer System case study is to serve as a global GRAPHIC initiative. The concept note of the Andros Aquifer System case study is presented in Annex 3.

3. Overview of Andros Aquifer and related global and regional initiatives

The representatives of the Water and Sewerage Corporation of the Bahamas, Mr. John Bowleg, Mr. Richard Cant, and Mr. Michael Swann, provided a comprehensive report on the situation of the Andros aquifer, its hydrogeological characteristics, uses and present management. They also referred to the existing concerns about the sustainable use of the aquifer resources, presently being used to provide drinking water to the island of New Providence. Another aspect of concern was the fact that the system had been seriously affected by storm surge inundation in the past years, and could be impacted again. The threshold and dynamics of these impacts are not well understood.

Following this presentation and the questions of the participants in relation to this overview, the invited experts provided their view point on the situation in Andros from their institutional perspective.

First, Mr. Armando Hernandez from Cuba, presented examples of common situations of coastal aquifers and their vulnerability to overexploitation and climate impacts. Within these scenarios, he focused on sea water intrusion problems and the need to assess and prevent these impacts.

The second presentation was made by Mr. Michael Taylor from the University of West Indies in Jamaica. Mr. Taylor presented the research and activities his group is developing in the Caribbean that could serve the proposed case study. These activities include understanding mechanisms responsible for the mean state and extremes in climate and using this to predict climate on a seasonal and annual basis. Moreover, the group is investigating climate change and its impact in the Caribbean, promoting awareness of global change and renewable energy resources, and investigating and promoting the advantageous uses of climate prediction in socio-economic sectors.

Ms. Diana Allen from the Simon Fraser University of Canada presented the work being developed at her university to model recharge and the impact of climate change in the dynamics of aquifer systems. In her presentation, Ms. Allen highlighted the importance of undertaking the Caribbean case study that encompasses potential climate change impacts and groundwater management, and how the GRAPHIC group can provide assistance by utilizing data and models currently available.

After this presentation, Ms. Lucila Candela from the Universidad Politécnica de Catalunya in Spain, presented her experience under similar characteristics while working in the Balearic islands. The experience presented included many of the features involved in this Caribbean situation, such as the strong dependence on groundwater resources and the increasing demand due to tourism. She presented the different climatic scenarios used to predict the future situation of water resources and how they could provide information for its future management.

The presentation of Mr. Breton Bruce of the US Geological Survey was devoted to reporting the activities the USGS is developing on groundwater and climate change in the US, especially in the High Plain Aquifer. Mr. Bruce presented the different tools they are utilizing to monitor the groundwater situation and use, as well as to predict global change impacts. Mr. Bruce offered that some of these tools and expertise could be used to accomplish the Andros case study objectives. Mr. Bruce provides access to the broad range of expertise within the 4,000+ employees of the US Geological Survey.

On behalf of OAS, Mr. Jean Marc Racine reported on the activities that the Division of Sustainable Development is developing in the field of climate change, and expressed the interest of his institution in supporting the UNESCO GRAPHIC programme and in particular this case study.

4. Consolidation of background document

The presentations were followed by a discussion session based on the concept note consolidated by the group of experts in advance. The concept note is annexed to this document (Annex 3).

5. Field trip to Andros Island

The second day of the meeting was devoted to the field visit to the Andros Island. The objective of the trip was to obtain information *in situ* on the present situation of groundwater exploitation in the island and to further expand the information presented by the Bahamian representatives in their presentation.

During the field visit, the old and new wellfields that provide water to New Providence Island were visited, and comprehensive information was provided on the operation and management of these wellfields. Many of the trenches were visited, providing the opportunity to visualize the system and its conditions and management.

Furthermore, the storage tanks and the system used to take the water to the shipment point were also visited during this trip.

The participants agreed on the usefulness of this fact finding mission to clarify many of the design questions and concerns expressed by the local experts in their presentation, as well as to identify potential aspects of research to be considered in the future case study development.

6. Planning of future activities

The Chairman, who led the planning session of the meeting, transmitted to the participants the interest of the Bahamas in carrying on such a study in the Bahamas and confirmed the institutional and technical support of his country to this initiative.

The participants identified the key issues that need to be taken into account for the case study and the potential contribution of each invited institution and their personal commitment to the project.

The summary of the planning is presented in Annex 4.

7. Review of agreements, conclusions and recommendations

During the third day of the meeting, the representatives of the Member States confirmed their interest in supporting the Andros case study as a global GRAPHIC initiative and agreed on taking the necessary actions to develop this study.

The Bahamas representatives expressed their commitment in contributing to this case study with the available human and financial resources, as well as with the available information and data.

On the other hand, the UNESCO representatives expressed support to the Bahamas and to the group in order to facilitate the process of developing the study and to explore different funding opportunities within and from out of the Organization, to develop the project.

In this sense, UNESCO representatives together with the GRAPHIC Regional Coordinator and the representatives of The Bahamas will work towards the development of a proposal to circulate among the group of experts.

8. Closure of the meeting

Mr. John Bolweg thanked UNESCO/IHP for their support and expressed on Behalf of the Bahamian experts their willingness of working in this initiative. Moreover, UNESCO representative thanked the organizers for their support during the development of the workshop and the participants for their contributions. She ended by wishing those travelling a safe return to their countries.

The workshop was formally closed by the Chairman at noon on March 19, 2008.

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Annex 1

Case Study Launching – North Andros Aquifer
-UNESCO/GRAPHIC Project for Latin America and the Caribbean-

March 17-19, 2008
Nassau, The Bahamas

DRAFT AGENDA

Monday, March 17

01.30 PM – 01.45 PM	Opening session - *Water and Sewerage Corporation* - *BEST Commission* - *UNESCO/IHP*
01.45 PM – 02.15 PM	Presentation of GRAPHIC Programme / objectives of the meeting and presentation of case study background document - *Henrique Chaves, GRAPHIC-LAC Regional Coordinator*
02.15 PM – 02.45 PM	Bahamas presentation - *Water and Sewerage Corporation*
02.45 PM – 03.15 PM	Coffee-break
03.15 PM – 04.45 PM	Invited participants presentations: - *Armando Hernandez, CUJAEE, Cuba* - *Michael Taylor, UWI, Jamaica* - *Diana Allen, Simon Fraser University, Canada* - *Lucila Candela, U. Politécnica de Catalunya, Spain* - *Breton Bruce, USGS, USA* - *Jean Marc Racine, OAS*
04.45 PM – 06.00 PM	Brainstorming session / discussion on background document

Tuesday, March 18

7.00 AM – 5.00 PM	Field trip to North Andros Aquifer

Wednesday, March 19

08.30 AM – 10.30 AM	Brainstorming / consolidation of background document
10.30 AM – 11.00 AM	Planning of future activities
11.15 AM – 11.30 AM	Coffee-break
11.30 AM – 12.30 PM	Financial / budgetary issues
12.30 PM – 01.00 PM	Review of agreements / closing session
01.30 PM – 02.30 PM	Lunch

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Annex 2

Case Study Launching – North Andros Aquifer
- UNESCO/GRAPHIC Project for Latin America and the Caribbean -

March 17-19, 2008
The Bahamas

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Annex 3

CONCEPT NOTE

Understanding Climate Change and Linked Human Impacts on Groundwater Resources of the Caribbean Region: A Collaborative GRAPHIC Case Study in the Bahamas

UNESCO's GRAPHIC Programme

In order to address the impacts of human activities and climate change on global groundwater resources, UNESCO-IHP initiated the GRAPHIC (Groundwater Resources Assessment under the Pressures of Humanity and Climate Change) programme. GRAPHIC seeks to improve our understanding of how groundwater interacts within the global water cycle, supports ecosystems and humankind, and in turn, responds to complex and coupled pressures of human activities and climate change. To successfully achieve these objectives within a global context, the GRAPHIC project was developed to incorporate a collaborative effort and umbrella for international research and education. The GRAPHIC project has outlined areas of desired international investigations covering major geographical regions, groundwater resource topics, and methods to help advance the combined knowledge needed to address the science and social aspects.

GRAPHIC provides a platform for exchange of information through case studies, thematic working groups, research, and communication. GRAPHIC serves the global community through providing scientifically-based recommendations that are policy relevant. GRAPHIC uses regional and global networks to improve capacity to manage groundwater resources.

Specific activities and case studies will be organized and implemented at the regional level, with the aim of meeting the needs and specificities of the regions. Each region will identify a coordinator that will work in close cooperation with the IHP regional hydrologist and field offices. The regional component of GRAPHIC in Latin America and the Caribbean (LAC) was launched in Belize in November 2007 and is coordinated by the UNESCO Office in Montevideo (IHP-LAC) and the designated regional coordinator Henrique Chaves of the University of Brasilia, Brazil.

Conceptual Proposal for a Collaborative GRAPHIC Case Study

Overview

The proposed research case study project is intended as a collaborative effort between regional and local groundwater experts and a team of international groundwater – climate change experts to explore the potential impacts of climate change and human activity on groundwater resources in the Caribbean region, specifically in the Bahamas. The project will serve as a Case Study for UNESCO's Groundwater Resources Assessment under the Pressures of Humanity and Climate Change (GRAPHIC) programme and, more importantly, provide a scientific knowledge base to be used by local water management agencies for preparing for the impacts of climate change. Such preparations require information on projected changes to groundwater conditions, both in terms of water quantity and quality, as well as recommendations for establishing a monitoring network and management alternatives under scenarios of human impact and climate change. The scientific contributions and management strategies developed during this effort are expected to global transfer value to other island nations with similar physiographic and hydrologic settings. These types of island nations are considered to be some of the most vulnerable settings to the effects of global climate changes

Background

Freshwater resources of island nations are particularly vulnerable to climate change and human impacts. The Caribbean Region, which relies on relatively shallow fresh groundwater lenses for much of their water use needs, is no exception. The Caribbean groundwater resources are sensitive because of the limited land areas and quantities of groundwater safe for drinking. Growing demand over supply because of population growth, salt water intrusion, and pollution from human and animal waste are a few of the human stresses on these limited resources. Such problems may be exacerbated in response to climate variability and change, such as severe hurricanes and potential rising sea levels. Changes in the position of the distribution of fresh, brackish and saline groundwater might be anticipated due to rising sea level, possible reductions in groundwater recharge, as well as increased abstraction. Because of such concerns, the Caribbean Region is ideally suited as a GRAPHIC case study to better understand the overall quantity of available freshwater and its potential for being strongly impacted by climate change and population growth.

At the UNESCO-GRAPHIC 5th Expert Group meeting held in Estes Park, Colorado, USA in September 2007, the expert group discussed their interest in developing a case study in the Caribbean region. This region was specifically identified because islands in such a region are particularly sensitive to climate change and human impacts. Suggestions for a potential island case study site included Jamaica and Trinidad and Tobago, or possibly a smaller island. A brief concept proposal was prepared by Dr. Diana Allen with contributions from the GRAPHIC expert group, and presented at the 1st GRAPHIC LAC meeting held in Belize in November 2007. The concept proposal was discussed by the representatives of the Member States and UNESCO staff, and it was agreed to pursue opportunities for such a collaborative

project. The case study area identified by the Caribbean Member States representatives is North Andros Aquifer, located in Andros Island, the Bahamas.

Description of the Study Area

In the Bahamas, climate change as it relates to rising sea levels, and storm surges associated with tropical storms are of great concern to the sustainability of the freshwater resources. The archipelago is made up of over 2,000 islands, cays and rocks. Many of the islands are carbonate shelf structures with very little relief resulting in minimal surface runoff and little opportunity to develop surface-water catchments. The average height of Andros Island above sea level is less than six feet (1.83-meters). The coastal area is predominantly of gently sloping shoares.

This type of land formation is particularly vulnerable to sea level rise. Any sea level rise would quickly reduce the size of the island and push the water lenses nearer the surface promoting its loss through greater evaporation. Lower Smaller land surface area and/or lower annual rainfall would cause a reduction in the sizes of the lenses due to the lower recharge ratevolume.

All freshwater in the Bahamas is only available as groundwater, which comes about as a result of rainfall. The freshwater resources occur as three-dimensional lens-shaped bodies, which overlies brackish and saline waters at depth. The size, shape and orientation of the island, the subsurface geology and the amount of rainfall control the shape size and thickness of the freshwater bodies. In excess of 90 percent of the freshwater lenses are within five feet of the surface.

The selected study site, the North Andros aquifer of the Bahamas, provides freshwater to the city of Nassau and neighbouring areas. The North Andros Water Resources, specifically the Barging Scheme Wellfields, comprises the 'Old' and 'New' Wellfields . The maximum annual average for rainfall is 1,500-mm (Northern Bahamas). The wet season is from May to October. The target production salinity for the area is 600-mg/L chloride, and corrective measure of trench isolation commence at 450-mg/L chloride.

In March-2004, production from the North Andros Water Resources system was 4.57 million imperial gallons per day (MiG/Day). Approximately 2.71-MiG/Day was abstracted for the Old Wellfields, and 1.86-Mig/Day from the New Wellfield.

Together, all the barging scheme wellfields are approximately 12,000-Acres (4,858-Hectares), with an available freshwater supply of 6,000,000-GPD (22,712-m3/Day). The maximum abstraction from the area by WSC is approximately 4,800,000-GPD (18,170-m3/Day).

In May-2004 average composite salinities from the Barging Scheme wellfields were 330-mg/L chloride, compared to 260-mg/L chloride in March-2000. Following the storm surge associated with Hurricane Frances, chlorides in all trenches increased. The detected chloride range was 1,300 to 15,000-mg/L chloride for 80% of the trenches in the North Andros Wellfield.

The groundwater lens was not compromised beyond repair, but this incident affected daily imports into New Providence. Proof that the resources have not been

lost is indicated by chloride readings of 114-mg/L, down to minus eleven feet (3.35-meters) below ground level in the monitoring wells. However, the overall impact to the freshwater resources that are subject to seawater inundation is not sustainable, particularly if global climate change results in an increase in the frequency and intensity of tropical storms. In 1999, the Grand Bahama Wellfields were also subjected to storm surge, as a result of the passing of Hurricane Floyd, and again during Hurricane Frances.

Additional environmental and water quality concerns that exist for North Andros and the water resources of the Bahamas are:

- Over-extraction of groundwater lenses;
- Waste disposal in landfills and septic tanks, which are unlined;
- Industrial and commercial effluents, and their disposal;
- Agricultural and landscaping concerns with regards to the construction and irrigation of golf courses;
- Land & coastal development, including the excavation of Wetland Areas.

Research Team

The research team would be comprised of experts from Latin America and the Caribbean region, local researchers from the Bahamas and international researchers and their associates that contribute to the GRAPHIC Expert Group. This project will be implemented under the coordination and with the support of UNESCO/IHP-LAC and UNESCO/IHP Secretariat at Headquarters. Financial resources for this project will be explored at the international and regional (LAC) donors community level.

Objectives

The objective of the study will be to identify and forecast potential impacts of climate change on groundwater resources in the North Andros Aquifer of the Bahamas, and to make recommendations for groundwater management schemes under such changing conditions. An integral component of the project will be to develop local and regional expertise through joint external supervision of university students and training of water management personnel through workshops, field studies, training courses, and model use.

The scope of work for the study will include:

- Compiling geologic, hydrologic (water levels, streamflow, etc.), geochemical, soils, climate, water use, and other relevant geospatial data;
- Assessing current status of groundwater resources and developing a revised conceptual model of groundwater system (water use, water budget, groundwater movement, current and past groundwater conditions, including water quantity and quality);
- Assessing past climate data and influences on groundwater conditions, including the response of groundwater resources to natural climate variability on seasonal (ie., Hurricane season) to multi-decadal time scales;
- Characterizing the distribution of fresh, brackish and saline groundwater using geophysical (e.g., electrical resistivity imaging or Continue Vertical Electrical Soundings - CVES, T-EC probe), and geochemical and isotopic methods;

- Developing a calibrated density-dependent groundwater model to represent current groundwater conditions, including distribution of fresh, brackish and saline groundwater;
- Estimating groundwater recharge and evapotranspiration using a variety of methods, including historic groundwater level-climate interactions, in-situ instrumentation, geochemical tracers, and numerical modelling;
- Analysing predicted shifts in climate, based on raw (or downscaled) Global Circulation Model (GCM) data and/or RCM simulations (several models);
- Using current and future predicted climate (and sea level) data as input to recharge models, and subsequently groundwater flow models;
- Generating scenarios for future land-use change, and changes in water use;
- Using remote sensing (GRACE Satellite and/or others) to define present and potential climate change impact;
- Modelling potential future human impacts on groundwater resources;
- Evaluating model outputs for generating recommendations for groundwater monitoring and management under scenarios of human impact and climate change.
- Implementing and testing innovative techniques (e.g. artificial recharge, salt-fresh scavenger wells, trench design, desalination techniques, etc.) at favourable sites, if applicable.
- Compare major findings of the Bahamas case study to other GRAPHIC case studies that are assessing groundwater resources of Small Island Developing States (SIDS).

Funding

Funding for the project will be sought from international funding sources in a subsequent stage after agreeing on the general aims and structure of the pilot project.

First Project Planning Meeting - Bahamas

The 1st Project Planning Meeting will be held in Nassau, Bahamas, on March 17-19, 2008. The purpose of this meeting is bring together groundwater and climate change experts from the LAC region, local researchers and partner agency representatives from the Bahamas, as well as GRAPHIC experts to discuss the conceptual project proposal as described above, and to establish a working plan for implementing the project.

To this end, a group of regional and international experts leaded by Mr. Henrique Chaves (Latin America and Caribbean GRAPHIC Coordinator) were invited by UNESCO to act as scientific advisors and collaborators for the project. Representatives from the Bahamas include Dr. Richard Cant (Water & Sewerage Corporation- WSC), Mr. Philip Weech (BEST Commission – BEST), Mr. Mike Swann (WSC), and Mr. John Bowleg (WSC). In addition, representatives of UNESCO/IHP include Maria Concepción Donoso (LAC Regional Hydrologist), Jose Luis Martin (IHP Secretariat) and Zelmira May (IHP-LAC).

The conceptual project proposal will be discussed with the following objectives:

1. Approving the overall scope of the project. Does the conceptual proposal meet with the overall objectives of GRAPHIC and the local needs of the Bahamas?

2. Identifying potential partners including GRAPHIC experts, local university researchers, and government representatives.

3. Discussing the availability of data that will be required to meet the proposed objectives.

4. Finalizing the objectives of the study, and development of a scope of work, timeframe to achieve project objectives, and funding requirements.

5. Determining potential sources of funding and identification of project leaders for preparing and submitting a proposal.

6. Planning follow-up activities.

The names of the experts and institutions at the international, regional and local level that will participate in this project will be proposed and discussed during the 1st Project Planning Meeting in Nassau (17-19 March 2008).

Expected outcomes

- Contribute to the development of indicators to evaluate and assess the impacts of human activities and climate change on groundwater resources.

- Support the development of guidelines for the establishment of appropriate groundwater monitoring systems and databases.

United Nations Educational, Scientific and Cultural Organization

International Hydrological Programme

Annex 4

Summary of GRAPHIC Andros Case Study

1. **Goal:** Assess the sustainability of groundwater resources in island settings under climatic and human stressors.

2. **Objective:** Identify and forecast the potential impacts of climate variability, climate change, land-use, and human demand scenarios on groundwater resources in North Andros Island, and make recommendations for groundwater management schemes.

3. **Define a conceptual model of the North Andros aquifer system.**
    a. Compile and make digitally accessible all available data sets
        i. Devise method for sharing data and GIS resources
            1. geologic
            2. hydrologic (original water lens isopach map)
            3. meteorological data
            4. geochemical
            5. soils
            6. vegetation cover
            7. elevation (surveys of trench designs, topography)
            8. aquifer properties
            9. land-use/land-cover data
            10. water use
            11. sea-level records and tidal changes
    b. Literature search on similar studies applicable to problem
        i. Other case studies of storm surge.
        ii. Relation between storm surge, hurricanes, and salinity.
        iii. How other trench systems have been modelled.
        iv. Review existing numerical models – define potential applicability

4. **Collect additional data required for modelling efforts**
    a. Establish and instrument a research site assessing:
        i. Surveying
        ii. Geophysics
        iii. Precipitation
        iv. Evapotranspiration
        v. Recharge
        vi. GW levels
        vii. Trench water levels
        viii. Tidal fluctuations

ix. Water quality

5. **Develop mathematically based models**
    a. Determine which numerical code is applicable.
    b. Construct and calibrate model of the predevelopment (baseline) system. (This is the substantial effort under this research)
        i. develop representative historical climate time series
        ii. estimation of recharge
        iii. distribution of aquifer and soil properties
        iv. how to incorporate trench system and function (likely will require finite-element modelling effort)

6. **Impose the important climatic and human stresses**
    a. Primary threats
        i. Storm surge
        ii. Sea-level rise/reduction in land-surface area
        iii. Human demand
        iv. Increase/decrease precipitation

7. **Evaluate the potential management responses to these stressors**

8. **Products**
    a. Publish conceptual model
    b. Recommend long-term monitoring approach
    c. Predictive transient numerical model
    d. Model documentation and final written reports

9. **Responsibilities and capabilities**
    a. Water and Sewerage Corp. – provide and quality assure existing data (original construction, water production, hydrogeologic information, meteorological, GIS resources, etc.)
    b. USGS – groundwater modelling expertise, remote sensing (LANDSAT), instrumentation of research sites, development of data sharing template, evapotranspiration, water-level monitoring, recharge measurement, geophysics, geochemistry/paleohydrology
    c. International Center of Hydroinformatics – hosting and maintenance of data base
    d. University of West Indies – climate data, climate variability and change, coordination with CIMH
    e. Simon Frasier University – recharge and GW modeling expertise, student supervisory support, downscaling GCM data, geological framework development, geophysics (immediate possible post-doc)
    f. Hydraulic Research Center of Havana – GW modeling expertise, seawater intrusion, hydrogeological assistance
    g. College of the Bahamas – student support,
    h. BEST Commission – wetlands, climate change, biodiversity, science and technology, Met. Service
    i. University of Brasilia – hydrology, drainage/recharge, remote sensing,
    j. Organization of American States – funding search

k. Technical University of Catalonia – GW hydrology expertise, geochemistry (isotopes)
l. Ramsar Regional Wetlands Training Center – biological and ecological training
m. Local NGOs – BNT, TNC,

10. **Timeline:** (Suggested 5-year timeframe)
    a. White paper/proposal writing – 6 months
    b. Project implementation
        i. Data compilation and development – years 0 – 0.5
        ii. Develop preliminary conceptual model – years 0.5 – 1.0
        iii. Identification of potential scenarios for modelling – years 1.0 – 1.5
        iv. Additional data collection – years 1.0 – 3.0
        v. Finalize conceptual model and construct baseline (steady-state) numerical model – years 2.0 – 3.0
        vi. Create transient model and run forecast scenarios – years 3.0 – 4.5
        vii. Define alternatives for mitigation and adaptation – years 3.5 – 4.5
        Develop written products – years 4.0 – 5.0