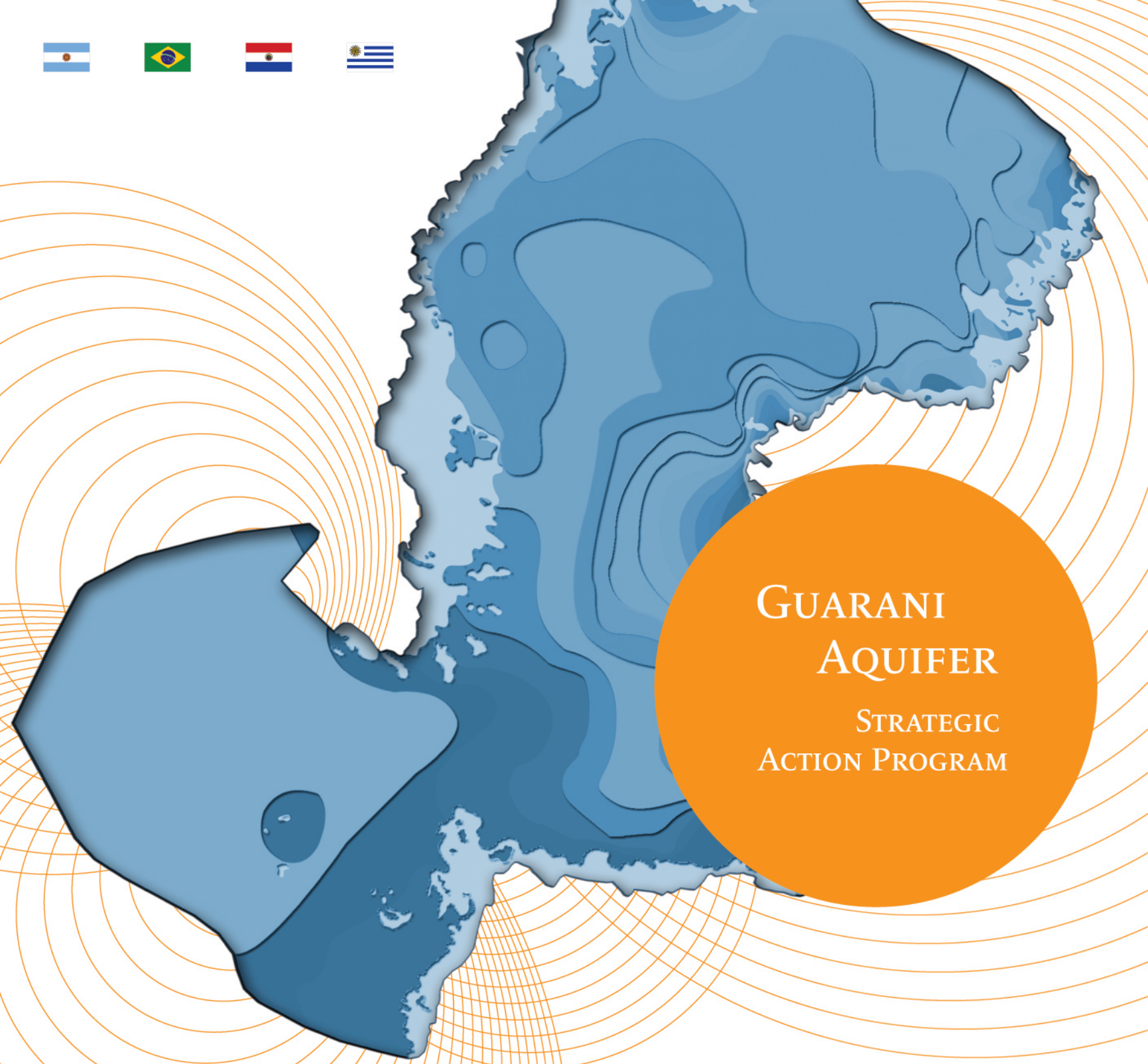
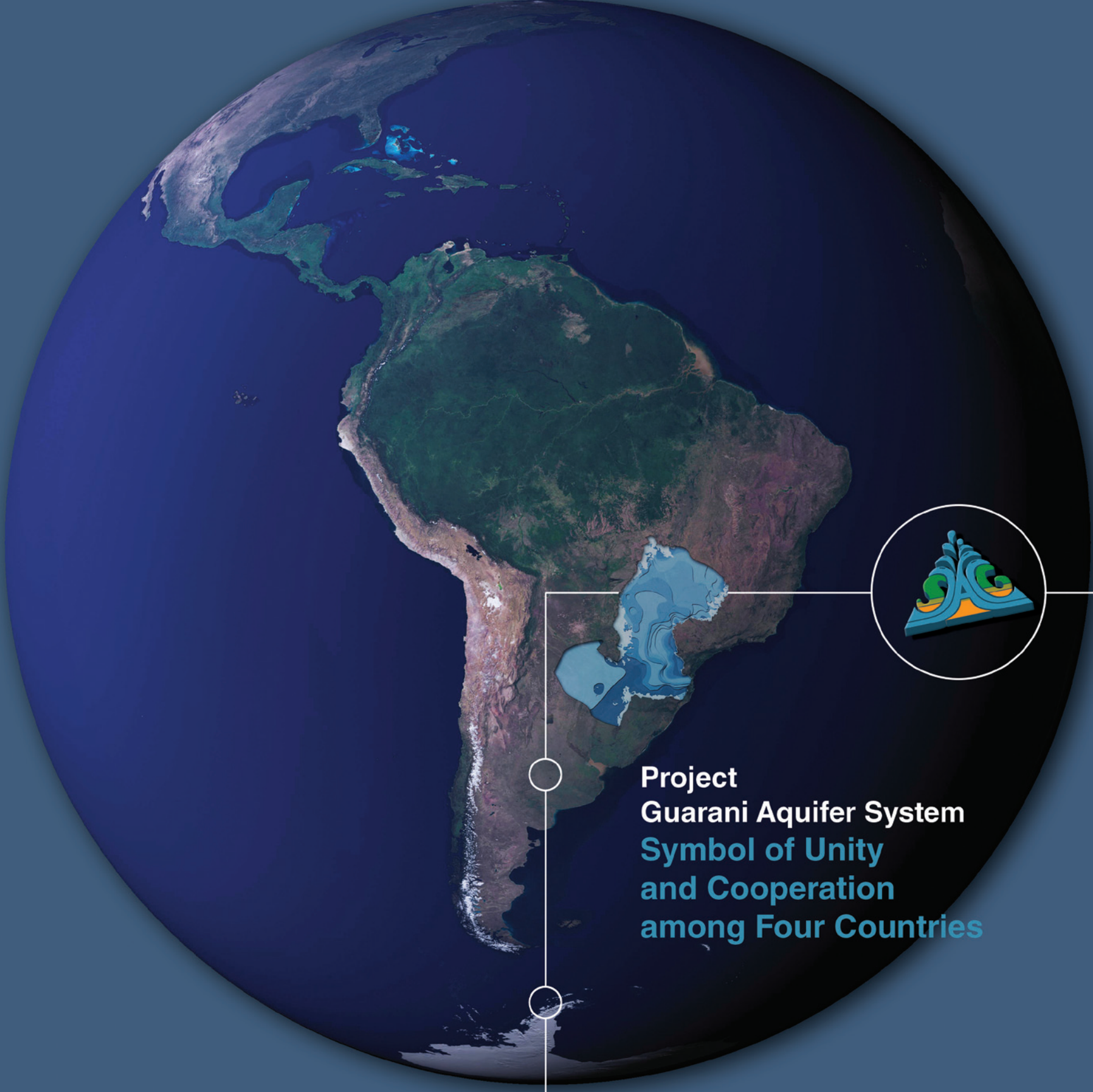


Guarani Aquifer

Strategic Action Program

Project for Environmental Protection and Sustainable Development of the Guarani Aquifer System



Project Guarani Aquifer System
Symbol of Unity and Cooperation among Four Countries

JANUARY
2009

Argentina Brasil Paraguai Uruguai
Argentina Brasil Paraguay Uruguay

RESPONSIBLE AND PARTICIPATING INSTITUTIONS

Argentina

- **Under-Secretariat for Water Resources of the Federal Ministry of Planning, Public Investment and Services (Buenos Aires)**
- Secretariat of Environment and Sustainable Development of the Nation (Buenos Aires)
- Ministry of Foreing Affairs, International Trade and Worship (Buenos Aires)
- Directorate for Living Resources of the Ministry of Ecology, Renewable Natural Resources and Tourism of Misiones (Posadas, Misiones)
- Water and Environment Institute of Corrientes (Corrientes, Corrientes)
- Directorate for Hydraulics of the Municipality of Entre Ríos (Paraná, Entre Ríos)
- Provincial Potable Water and Sanitation Service (Formosa, Formosa)
- Provincial Water Administration (Resistencia, Chaco)
- Ministry of Water, Public Services and Environment of Santa Fe (Santa Fe, Santa Fe)
- Municipality of Concordia (Concordia, Entre Ríos)

Brazil

- **Secretariat of Water Resources and Urban Environment of the Ministry of Environment (Brasilia, DF)**
- National Water Agency (Brasilia)
- Ministry of Foreing Affairs (Brasilia)
- Secretariat of Environment of the State of Mato Grosso (Cuiabá, MT)
- Secretariat of Environment, Cities, Planning, Science and Technology - Environment Institute of the State of Mato Grosso do Sul (Campo Grande, MS)
- Secretariat of Environment and Water Resources of the State of Goiás (Goiânia, GO)
- Water Management Institute of the State of Minas Gerais (Belo Horizonte, MG)
- Secretariat of Environment (São Paulo, SP)
- Superintendency of Water Resources Development and Sanitation (Curitiba, PR)
- Directorate for Water Resources of the Secretariat of Sustainable Economic Development of the State of Santa Catarina (Florianópolis, SC)
- Department of Water Resources of the Secretariat of Environment of the State of Rio Grande do Sul (Porto Alegre, RS)
- Department of Water and Electric Power (Ribeirão Preto, SP)
- Department of Water and Sewage (Santana do Livramento, RS)

Paraguay

- **Directorate General for Protection and Conservation of Water Resources of the Secretariat of Environment (Asunción)**
- Technical Secretariat for Planning (Asunción)
- Ministry of Foreing Affairs (Asunción)
- University Foundation for Agrarian Sciences of Itapúa (Hohenau)

Uruguay

- **National Directorate for Water and Sanitation of the Ministry of Housing, Territorial Planning and Environment (Montevideo)**
- National Directorate for Environment of the Ministry of Housing, Territorial Planning and Environment (Montevideo)
- Ministry of Foreing Affairs (Montevideo)
- Municipal Intendancy of Salto (Salto)
- Municipal Intendancy of Rivera (Rivera)

GEF Implementing Agency

International Bank for Reconstruction and Development (IBRD) – The World Bank

Excecuting Agency

General Secretariat of the Organization of American States - OAS

Cooperation Agencies

- International Atomic Energy Agency (IAEA)
- Federal Institute for Geociences and Natural Resources (BGR)

Financial Support

Global Environment Facility (GEF)

National Representatives and Executing Agencies

PROJECT STEERING COMMITTEE - CSDP

Argentina

WATER RESOURCES

- **Fabián López,** Under-Secretary, Under-Secretariat for Water Resources, Federal Ministry of Planning, Public Investment and Services – from 2006 to 2009; President of the CSDP – from 2006 to 2007 and from 2008 to 2009
- **Hugo Amicarelli,** Under-Secretary, Under-Secretariat for Water Resources, Federal Ministry of Planning, Public Investment and Services – from 2002 to 2006; President of the CSDP – from 2005 to 2006
- **Andrés Rodriguez,** Director, National Directorate for Conservation and Protection of Water Resources, Under-Secretariat for Water Resources, Secretariat of Public Works, Federal Ministry of Planning, Public Investment and Services (Substitute) – from 2006 to 2009
- **Claudio Laboranti,** National Directorate for Conservation and Protection of Water Resources, Under-Secretariat for Water Resources, Secretariat of Public Works, Federal Ministry of Planning, Public Investment and Services (Substitute) – from 2003 to 2009
- **Víctor Pochat,** Director, National Directorate for Conservation and Protection of Water Resources, Under-Secretariat for Water Resources, Secretariat of Public Works, Federal Ministry of Planning, Public Investment and Services (Substitute) – from 2003 to 2005

ENVIRONMENT

- **Sofía Bordenave,** National Director for Institutional Affairs, Chief of Staff for Ministers, Secretariat of Environment and Sustainable Development – from 2008 to 2009
- **Carlos Arcelli,** Secretariat of Environment and Sustainable Development – from 2003 to 2008
- **Luis Couyoupetrou,** Secretariat of Environment and Sustainable Development – from 2005 to 2006

FOREING AFFAIRS

- **María Ester Bondanza,** Ambassador Director, Directorate General for Environmental Affairs of the Ministry of Foreing Affairs, International Trade and Worship
- **Eugenio García Santos,** Minister, Director-General for Environmental Affairs of the Ministry of Foreing Affairs, International Trade and Worship (Substitute)

NATIONAL COORDINATORS

- **Miguel Ángel Giraut,** Coordinator, National Water Information System, National Directorate for Conservation and Protection of Water Resources, Under-Secretariat for Water Resources, Secretariat of Public Works, Federal Ministry of Planning, Public Investment and Services (National Coordinator) – from 2006 as 2009
- **María Josefa Fioriti,** Professional, National Directorate for Conservation and Protection of Water Resources, Under-Secretariat for Water Resources, Secretariat of Public Works, Federal Ministry of Planning, Public Investment and Services (National Coordinator) – from 2003 to 2006 and (Co-National Coordinator) – from 2006 to 2009
- **Juan José Salaber,** Advisor, National Water Institute (Deputy National Coordinator) – from 2003 to 2006
- **María Santi,** Head of Groundwater, Directorate for Hydraulics, Ministry of Governance, Justice, Education, Public Works and Services, Government of the Province of Entre Ríos – from 2006 to 2009

Brazil

ENVIRONMENT AND WATER RESOURCES

- **Vicente Andreu Guillo,** Secretary, Secretariat of Water Resources and Urban Environment, Ministry of Environment – from 2008 to 2009
- **Eustáquio Luciano Zicca,** Secretary, Secretariat of Water Resources and Urban Environment, Ministry of Environment – from 2007 to 2008
- **João Bosco Senra,** Secretary, Secretariat of Water Resources, Ministry of Environment – from 2003 to 2007

WATER RESOURCES

- **Benedito Braga Júnior,** Director, National Water Agency
- **Paulo Lopes Varella Neto,** Director, National Water Agency (Substitute) – from 2006 to 2009
- **Antônio Félix Domínguez,** Superintendent, Superintendency for Water and Soil Conservation, National Water Agency (Substitute) – from 2003 to 2006

FOREING AFFAIRS

- **João Luiz de Barros Pereira Pinto,** Director, South America Department 1 – from 2005 to 2009
- **Pedro Fernando Brêtas Bastos,** Ambassador, Head of the South America Division – from 2003 to 2005

NATIONAL COORDINATORS

- **João Bosco Senra,** Director of Water Resources, Secretariat of Water Resources and Urban Environment, Ministry of Environment (National Coordinator) – from 2007 to 2009
- **Julio Thadeu Silva Kettelhut,** Director of Programs, Secretariat of Water Resources and Urban Environment, Ministry of Environment (National Coordinator) – from 2004 to 2007
- **Fernando Roberto de Olivera,** Water Resources Specialist, Superintendency for Water and Soil Conservation, National Water Agency (National Coordinator) – from 2003 to 2004
- **Ana Luiza Sabóia de Freitas,** Specialist, Superintendency for Water and Soil Conservation, National Water Agency (National Coordinator) – 2003
- **Adriana Niemeyer Pires Ferreira,** Specialist, Secretariat of Water Resources and Urban Environment, Ministry of Environment (Substitute) – from 2007 to 2009
- **Fabrício Bueno da Fonseca Cardoso,** Specialist, Secretariat of Water Resources, Ministry of Environment (Substitute) – from 2005 to 2007

Paraguay

ENVIRONMENT AND WATER

- **José Luis Casaccia,** Minister, Secretariat of Environment – from 2008 to 2009
- **Carlos Antonio López Dose,** Minister, Secretariat of Environment – from 2007 to 2008. President of the CSDP – from 2007 to 2008
- **Alfredo Molinas Maldonado,** Minister, Secretariat of Environment – from 2004 to 2007. President of the CSDP – from 2004 to 2005
- **Luis Alberto López Zayas,** Minister, Secretariat of Environment – from 2003 to 2004. President of the CSDP – from 2003 to 2004
- **Menandro Darío Grisetti,** MMinister, Secretariat of Environment – 2003. President of the CSDP – 2003
- **Zully A. Rolón,** Representative, Secretariat of Environment (Substitute) – 2008

PLANNING

- **Carlos Sánchez,** Minister, Secretariat of Planning – from 2008 to 2009
- **Derlis Alcides Céspedes,** Minister, Secretariat of Planning – 2008
- **Rosa Miguelina Gómez de Martínez,** Minister, Secretariat of Planning – from 2006 to 2008
- **Julia Maciel, Ministra,** Secretariat of Planning – from 2004 to 2006
- **Luis Alberto Meyer,** Minister, Secretariat of Planning – 2003 (in memoriam)
- **Maria de Jesus de Molas,** Representative, Secretariat of Planning (Substitute) – from 2006 to 2007
- **Mario Ruiz Diaz,** Representative, Secretariat of Planning (Substitute) – 2003

FOREING AFFAIRS

- **Alejandro Hamed,** Minister, Ministry of Foreing Affairs – 2008
- **Rubén Ramírez,** Minister, Ministry of Foreing Affairs – from 2005 to 2008
- **Leila Rachid,** Minister, Ministry of Foreing Affairs – from 2003 to 2005
- **Raúl Cano Ricardi,** Director, Directorate General for Foreign Trade, Ministry of Foreing Affairs (Substitute) – from 2008 to 2009
- **Brigido Lezcano,** Director for the La Plata Basin, Ministry of Foreing Affairs (Substitute) – 2008
- **Nimia Torales,** Director, Directorate for Foreign Trade, Ministry of Foreing Affairs (Substitute) – 2003

NATIONAL COORDINATORS

- **Amado Insfrán,** Director-General, Directorate General for Protection and Conservation of Water Resources, Secretariat of Environment (National Coordinator) – from 2008 to 2009
- **Orlando Oporto,** Director-General, Directorate General for Protection and Conservation of Water Resources, Secretariat of Environment (National Coordinator) – 2004
- **Elena Benítez,** Director, Directorate General for Protection and Conservation of Water Resources, Secretariat of Environment (National Coordinator) – from 2003 to 2008

Uruguay

WATER RESOURCES AND ENVIRONMENT

- **José Luis Genta,** Director, National Directorate for Water and Sanitation, Ministry of Housing, Territorial Planning and Environment – from 2007 to 2009

WATER RESOURCES

- **Edi Juri,** National Director of Hydrography, Ministry of Transport and Public Works – from 2003 to 2007
- **Luis Loureiro,** National Director of Hydrography, Ministry of Transport and Public Works – 2003

FOREING AFFAIRS

- **Susana Rivero,** Minister, Director, Directorate for Environment, Ministry of Foreing Affairs – from 2008 to 2009
- **Ariel Rusiñol,** Director, Directorate for Environment, Ministry of Foreing Affairs – from 2003 to 2007

NATIONAL COORDINATORS

- **Lourdes Batista,** National Directorate for Hydrography (National Coordinator) – from 2007 to 2009
- **Alejandro Arcelus,** National Directorate for Hydrography (National Coordinator) – from 2003 to 2007
- **Juan Ledesma,** National Directorate for Hydrography (Deputy National Coordinator) – from 2003 to 2007

Representatives of National Project[1] Execution Units

NATIONAL PROJECT EXECUTION UNIT (NPEU)

Argentina

- **Andrés Rodríguez,** Director, National Directorate for Conservation and Protection of Water Resources, Under-Secretariat for Water Resources, Secretariat of Public Works, Federal Ministry of Planning, Public Investment and Services (President of the NPEU) – since 2006
- **Claudio Laboranti,** National Directorate for Conservation and Protection of Water Resources, Under-Secretariat for Water Resources, Secretariat of Public Works, Federal Ministry of Planning, Public Investment and Services (Vice President of the NPEU)
- **Sofía Bordenave,** National Director for Institutional Affairs, Chief of Staff for Ministers, Secretariat of Environment and Sustainable Development – since 2008
- **María Esther Bondanza,** Ambassador Director, Directorate General for Environmental Affairs of the Ministry of Foreing Affairs, International Trade and Worship
- **Eugenio García Santos,** Minister, Directorate General for Environmental Affairs of the Ministry of Foreing Affairs, International Trade and Worship
- **Miguel Ángel Giraut,** Coordinator, National Water Information System, National Directorate for Conservation and Protection of Water Resources, Under-Secretariat for Water Resources, Secretariat of Public Works, Federal Ministry of Planning, Public Investment and Services (National Coordinator) – since 2006
- **María Josefa Fioriti,** Specialist, National Directorate for Conservation and Protection of Water Resources, Under-Secretariat for Water Resources, Secretariat of Public Works, Federal Ministry of Planning, Public Investment and Services (National Coordinator) – from 2003 to 2006 and (Co-National Coordinator) – from 2006 to 2009
- **María Santi,** CHead of Groundwater, Directorate for Hydraulics, Ministry of Governance, Justice, Education, Public Works and Services , Municipal Administration of Entre Rios – since 2006
- **Mario Rujana,** President, Water Institute of Corrientes, Municipal Administration of Corrientes. President of the Federal Water Council

Uruguay

- **José Luis Genta,** Director, National Directorate for Water and Sanitation, Ministry of Housing, Territorial Planning and Environment – since 2007
- **Lourdes Batista,** National Directorate for Hydrography (National Coordinator) – since 2007
- **Juan Ledesma,** National Directorate for Hydrography (Alternate National Coordinator) – since 2005
- **Alfredo Altamirano,** Directorate General for Renewable Natural Resources, Ministry of Livestock, Agriculture and Fisheries – since 2004
- **Susana Rivero,** Director, Directorate of Environment, Ministry of Foreing Affairs – since 2008
- **Jorge Collazo,** Directorate for Environment, Ministry of Foreing Affairs – since 2006
- **Luis Sayagués,** Advisor, National Directorate for Environment, Ministry of Housing, Territorial Planning and Environment – since 2006
- **Walter Heinzen,** Hydrogeologist, National Directorate for Minas and Geology, Ministry of Industry, Energy and Mining – since 2005
- **Andrés Pérez,** Groundwater, State Sanitation Works – since 2005
- **Sergio Arrizcorreta,** Secretary–General of the Municipal Intendancy of Salto, National Congress of Intendants – since 2005
- **Marne Osorio,** Director de Sanitation and Higiene, Municipal Intendancy of Rivera, National Congress of Intendants – since 2005

Brazil

- **João Bosco Senra,** Director of Water Resources, Secretariat of Water Resources and Urban Environment, Ministry of Environment (National Coordinator and Chairman of the NPEU) – since 2007
- **Claudia Ferreira Lima,** Specialized Technician, Secretariat of Water Resources and Urban Environment, Ministry of Environment (Chairman of the NPEU Substitute) – since 2007
- **Adriana Niemeyer Pires Ferreira,** Specialized Technician, Secretariat of Water Resources and Urban Environment, Ministry of Environment (National Coordinator Substitute) – since 2007
- **Paulo Lopes Varella Neto,** Director, National Water Agency (Titular)
- **Fernando Roberto de Oliveira,** Manager for Groundwater, National Water Agency (Substitute)
- **João Luiz de Barros Pereira Pinto,** Minister, Director, South America Department 1, Ministry of Foreing Affairs (Permanent Member) – since 2007
- **Roger Joseph Abboud,** Secretary, Departmental Advisor, Ministry of Foreing Affairs (Substitute) – since 2007
- **Emanuel Teixeira de Queiroz,** Leader of the Inspection Group Research and Mineral Waters, National Department of Mineral Production (Permanent Member)
- **Gilberto Ruy Derze, Geologist,** National Department of Mineral Production (Substitute)
- **Paulo Choji Kitamura,** General Head for Environment, Brazilian Agricultural Research Corporation (Permanent Member)
- **Marco Antônio Ferreira Gomes,** Researcher, Brazilian Agricultural Research Corporation (Substitute)
- **José Alcides Fonseca Ferreira,** Regional Superintendant, Superintendency Regional do Rio Grande do Sul, Research and Mineral Resources Company (Permanent Member)
- **Marco Aurélio Carvalho da Silva,** Geologist, Superintendency Regional do Rio Grande do Sul, Research and Mineral Resources Company (Substitute)
- **Ninon Machado de Faria Leme Franco,** Executive Director, Instituto Ipanema, Brazilian Forum of NGOs and Social Movements for the Environment and Development (Permanent Member)
- **Andréa Carestiato,** Technical Consultant, Instituto Ipanema, Brazilian Forum of NGOs and Social Movements for the Environment and Development (Substitute)
- **Luiz Fernando Novoa Garzon,** Brazilian Network for Integration of Peoples and "Association for Taxation of Financial Transactions to Aid Citizens", Brazilian Forum of NGOs and Social Movements for the Environment and Development (Permanent Member)
- **Rubens Harry Born,** Executive and Institutional Coordinator, Vitae Civilis, Brazilian Forum of NGOs and Social Movements for the Environment and Development (Substitute)
- **Rafaela Daniella Niccola,** Director of Projects, Ecology and Action, Brazilian Forum of NGOs and Social Movements for the Environment and Development (Permanent Member)
- **Cristina Rodrigues de Melo Orphêo,** Advisor for Executive and Institutional Coordination, Vitae Civilis, Brazilian Forum of NGOs and Social Movements for the Environment and Development (Substitute)
- **Mabel de Faria Melo, Advisora,** Federation Social and Educational Welfare Bodies, Brazilian Forum of NGOs and Social Movements for the Environment and Development (Permanent Member)
- **Maria Rita dos Reis,** Legal Advisor, Terra dos Direitos, Brazilian Forum of NGOs and Social Movements for the Environment and Development (Substitute)
- **Carlos Eduardo Nascimento Alencastre,** Executive Secretary, Pardo River Basin Committee (Permanent Member)
- **Renato Crivelenti,** Deputy Executive Secretary, Pardo River Basin Committee (Substitute)
- **Suraya Damas de Oliveira Modaelli,** Deputy Executive Secretary, Médio Paranapanema River Basin Committee (Permanent Member)

1. Permanent and Substitute Representatives of the NPEUs 2009

Paraguay

- **Emílio Carlos Prandi, Coordinator,** Technical Chamber de Planning and Evaluation, Médio Paranapanema River Basin Committee (Substitute)
- **Ernani Francisco da Rosa Filho,** Associate Professor II, Federal University of Paraná (Permanent Member)
- **Osmar Sinelli, Coordinator,** Curso de Environmental Engineering, Union of Higher Education Courses COC Ltda (Substitute)
- **Everton de Oliveira, Secretary-Executivo,** Brazilian Groundwater Association (Permanent Member) – since 2007
- **Dorothy Carmen Pinatti Casarini,** 1st Vice-President, Brazilian Groundwater Association (Substitute) – since 2007
- **Cleuza Maria Gomes Viana,** Environmental Inspector, Environment Institute of Mato Grosso do Sul, Secretariat for Environment, Cities, Planning, Science and Technology, Government of the State of Mato Grosso do Sul (State Coordinator)
- **Angélica Haralampidou,** Water Resources Analist, Environment Institute of Mato Grosso do Sul, Secretariat for Environment, Cities, Planning, Science and Technology, Government of the State of Mato Grosso do Sul (Substitute State Coordinator)
- **Everton Luiz da Costa Souza,** Geologist, Superintendency of Water Resources, Secretariat of Planning and General Coordination, Government of the State of Paraná (State Coordinator)
- **Arnaldo José de Souza Abud,** Engenheiro Civil, Secretariat of Planning and General Coordination, Government of the State of Paraná (Substitute State Coordinator)
- **Gerôncio Albuquerque Rocha,** Advisor, Secretariat of Environment, Government of the State of São Paulo (State Coordinator)
- **Ricardo Vedovello,** Director-General, Instituto Geológico, Secretariat of Environment, Government of the State of São Paulo (Substitute State Coordinator) – since 2007
- **Luiz Fernando Magalhães,** Geologist, Secretariat of Industry and Trade, Government of the State of Goiás (State Coordinator)
- **Leonardo de Almeida, Geologist,** Secretariat of Environment and of Water Resources, Government of the State of Goiás (Substitute State Coordinator)
- **Maria Luiza Silva Ramos,** Manager for Development of Water Resources, Minas Gerais Water Management Institute, Government of the State of Minas Gerais (State Coordinator)
- **Maricene Menezes de Oliveira Mattos Paixão,** Environmental Analist, Minas Gerais Water Management Institute, Government of the State of Minas Gerais (Substitute State Coordinator)
- **Paulo Renato Paim, Director,** Department of Water Resources, Secretariat of Environment, Government of the State of Rio Grande do Sul (State Coordinator) – since 2008
- **Rejane Beatriz de Abreu e Silva,** Head of the Licensing and Inspection Division, Department of Water Resources, Secretariat of Environment, Government of the State of Rio Grande do Sul (Substitute State Coordinator)
- **Flávio Renê Brea Victoria, Director,** Directorate for Water Resources, State Secretariat for Sustainable Development, Government of the State of Santa Catarina (State Coordinator)
- **Marta Elisabeth Souza Kracik,** Specialist, Directorate for Water Resources, State Secretariat for Sustainable Development, Government of the State of Santa Catarina (Substitute State Coordinator)
- **Lílian Fátima de Moura Apoitia,** Environmental Analist, State Secretariat for Environment, Government of the State of Mato Grosso (State Coordinator)
- **Renato Blat Migliorini,** Deputy Professor IV, Federal University of Mato Grosso (Substitute State Coordinator)
- **Amado Insfrán, Director Geral,** Directorate General for Protection and Conservation of Water Resources, Secretariat of Environment (National Coordinator) – since 2008
- **Juan Alberto Aquino,** Representative Permanent Member, Environmental Network of Paraguay – since 2006
- **Ana María Gadea,** Professor, Faculty of Exact and Natural Sciences, National University of Asunción (Permanent Member)
- **Alejandro Blanco,** Professor, Faculty of Engineering, National University of Asunción
- **Julián Báez,** Professor of the Faculty of Science and Technology, Catholic University of Asunción (Permanent Member) – since 2008
- **Gabriela Mesquita,** Representative of the Faculty of Science and Technology, Catholic University of Asunción (Substitute) – since 2008
- **Juan Carlos Zanotti,** Professor, Faculty of Chemical Science
- **Humberto Villalba,** Specialist of the Department of Water Resources, National Environmental Sanitation Service
- **Roberto Fleitas,** Head of the Water Resources Bank, National Environmental Sanitation Service (Substitute)
- **Terencio Cáceres,** Technical Representative. Paraguayan Groundwater Society
- **Wilma Jimenez Nass,** Representative, Sanitary Services Regulatory Body (Permanent Member)
- **Olga Marecos,** Director, Directorate for Planning of the Sanitary Services Regulatory Body of Paraguay
- **Ana María Castillo**, Specialist, Vice-minister of Minas and Energy of the Ministry of Public Works and Communications
- **Raúl Cano,** Director-General, General Directorate for Foreign Trade, Ministry of Foreing Affairs – since 2008
- **Brigido Lezcano,** Director for the La Plata Basin, Ministry of Foreing Affairs – since 2008
- **Marta León,** Specialist, Project Coordinator, Technical Secretariat for Planning
- **Cristian Pascotini,** Specialist, Project Coordinator, Technical Secretariat for Planning (Substitute)
- **Virginia de González,** Director, National Atomic Energy Commission
- **José Silvero,** Director, Directorate for Hydrology and Hydrogeology, Directorate General for Protection and Conservation of Water Resources, Secretariat of Environment
- **Flavia Fiore,** Secretary of the National Coordination Committee and Directorate General for Protection and Conservation of Water Resources
- **Alicia Eisenkolbl,** Guest Technician, Local Project Coordination Unit, Local Facilitator of the Itapúa Pilot Project

LOCAL REPRESENTATIVES (PILOT PROJECTS)

Transboundary Support Committee to the Concórdia–Salto Pilot Project:

Concórdia (Entre Ríos, Argentina)

- **Mireya López Bernis,** President, Deliberative Council, Municipality of Concórdia (President of the Transboundary Support Committee Concórdia–Salto Pilot Project)
- **María Josefa Fioriti,** Professional, National Directorate for Conservation and Protection of Water Resources, Under-Secretariat for Water Resources, Secretariat of Public Works, Federal Ministry of Planning, Public Investment and Services (National Coordinator) –2003-2006 and (National Co-Coordinator) –2006-2009
- **María Santi,** Head of Groundwater, Directory of Hydraulics, Ministry of Government, Justice, Education, Public Works and Services, Government of the Province of Entre Ríos – since 2006
- **Ricardo Rosales,** Municipality of Concórdia
- **Cristian Garabau,** Municipality of Concórdia
- **Miguel Ruiz Diaz,** Administration of the Municipality of Concórdia
- **Emma Carmona,** Environmental Sanitation Technician – Municipality of Concórdia
- **Horacio Aspera,** Professional, Secretariat of Environment and Sustainable Development
- **Gonzalo Entenza,** Ministry of Foreing Affairs, Foreign Trade and Worship – Municipality of Salto (Uruguay)
- **Eduardo Zamanillo,** Technical Joint Committee of Salto Grande
- **Carlos Víctor,** Under-Secretary of Public Works – Municipality of Concórdia
- **Marcelo Vázquez,** Director of Urban Planning – Municipality of Concórdia

Municipality of Salto:

- **Sergio Arrizcorreta,** General Secretary of the Municipal Intendancy of Salto, National Congress of Intendants – since 2005
- **Carlos Cattani,** Responsible for municipal hot springs, Municipal Intendancy of Salto.
- **Eduardo Segredo,** Delegate of the Tourism Committee of Salto
- **Juan Carlos Palacios,** Representative, Universidad de la Republica

Local Support Committee to the Itapúa Pilot Project:

- **Sebald Hugo Reckziegel,** Manager Advisor, Catholic University of Itapúa. President of the Local Support Committee to the Pilot Project
- **Alfredo Servían,** Municipality of Jesús (Substitute)
- **Gilberto Garay,** Municipality of Jesús (Substitute)
- **Gustavo Acuña Centurión,** Technical University for Marketing and Development
- **Valentín Colmán,** Government of Itapúa
- **Francisco Galeano,** Government of Itapúa (Substitute)
- **Ramón Lezcano,** Government of Itapúa. Vice-President of the Local Support Committee to the Pilot Project
- **Guido Reckziegel,** Sanitation Board of Hohenau
- **Pablo Chamorro Acuña,** Municipality of Hohenau, Pro-Secretary of the Local Support Committee to the Pilot Project
- **Nelson Oliveira,** Municipality of Hohenau
- **Alicia Velásquez,** Municipality of Hohenau
- **Mariane Ott de Stierle,** Association Pró Cordilheira San Rafael (PROCOSARA) Secretary of the Local Support Committee to the Pilot Project
- **Julio Bretíz**, Catholic University "Nuestra Señora de la Asunción" Regional Offices in Itapúa
- **Víctor Dubarry,** Catholic University "Nuestra Señora de la Asunción" Regional Offices in Hohenau
- **Mónica Danieli R.,** Municipality of Bella Vista
- **Cleofe Quiñónez,** Municipality of Bella Vista (Substitute)
- **Mario Ramírez,** Sanitation Board of Bella Vista. Treasurer of the Local Support Committee to the Pilot Project
- **Esteban Kegler,** Sanitation Board of Obligado
- **Alicia Eisenkolbl,** Guest Technician, Local Project Coordination Unit, Facilitator of the Itapúa Local Pilot Project
- **Iris Riveros,** Municipality of Obligado
- **Pedro Pascual Benítez,** Municipality of Obligado (Substitute)
- **Arnaldo Sugastti,** Colonias Unidas Agrícola Ltda. Cooperative
- **Antonio Medina Netto,** Colonias Unidas Agrícola Ltda. Cooperative (Substitute)
- **Alejo Centurión,** Municipality of Bella Vista
- **Rubén Espínola,** Municipality of Jesús
- **Avelardo Vásquez,** Municipality of Jesús
- **Lucio Bogado Correa,** Municipality of Santíssima Trindade
- **Liza Hepp,** Catholic University "Nuestra Señora de la Asunción" Regional Offices in Hohenau

Guarani Aquifer Transboundary Committee (COTRÁGUA) of Rivera and Santana

Rivera (Uruguay):

- **Marne Y. Osorio Lima**, Director-General for Sanitation, Hygiene and Environment of the Departmental Intendancy of Rivera, National Congress of Intendants (Coordinator of the Guarani Aquifer Transboundary Committee)
- **José María Almada Sad,** Director of the Environment Division, of the Departmental Intendancy of Rivera – since 2003
- **Hugo Álvarez,** Technical Manager Northwest Geographic Region, State Sanitation Works – since 2003
- **Alejandro Miguel Bertón Sole,** Q.F. Head of the Municipal Laboratory, Departmental Intendancy of Rivera – since 2003
- **Ramón Lluviera,** Regional Head, Ministry of Housing, Territorial Planning and Environment – since 2003

Santana do Livramento (Rio Grande do Sul, BraZil):

- **Achylles Bassedas Costa,** Member of the Local Bi-national Committee– since 2003. Facilitator of the Rivera-Livramento Pilot Project – since 2005
- **Eloy Luft,** Department of Environment - Municipal Administration of Livramento – since 2003
- **Lorena Padilla,** Regional Head, Forestry Agency of the State Secretariat of Environment, Government of Rio Grande do Sul – since 2003
- **Fabio Decorato,** Head of Laboratory, Water and Sewage Department of Livramento – since 2007

Guarani Aquifer Pilot Project Coordination Group of Ribeirão Preto (São Paulo, Brazil)

- **Osmar Sinelli,** Coordinator, Faculdades COC –2003-2007
- **Celso Antonio Perticarrari,** Rapporteur, Water and Electric Power Department –2003-2005 (in memoriam)
- **Carlos Eduardo Nascimento Alencastre,** Rapporteur, Water and Electric Power Department –2005-2007

- **Marcos Massoli,** Coordinator, State Department for Protection of Natural Resources – 2007-2008
- **João Paulo Fonseca Correia,** Rapporteur, Water and Sewage Department of Ribeirão Preto – 2007-2008
- **Maurício Moreira dos Santos,** Local Pilot Project Facilitator – 2007-2008
- **Heraldo Campos,** Local Facilitator – 2005-2007
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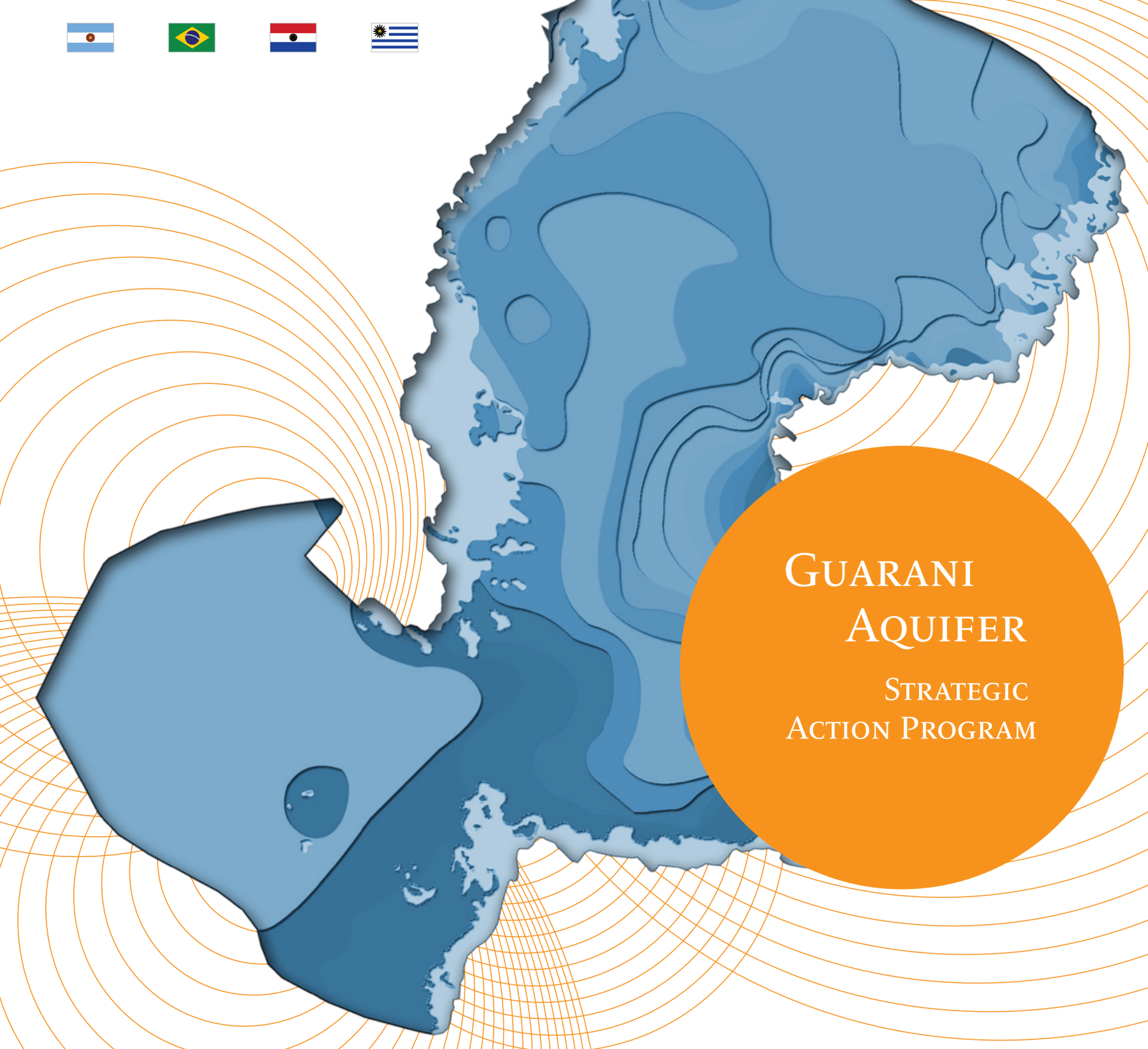

Guarani Aquifer

Strategic Action Program

Project for Environmental Protection and Sustainable Development of the Guarani Aquifer System

PREFACE

With preparation of the Strategic Action Program (SAP), the Project for Environmental Protection and Sustainable Development of the Guarani Aquifer System (PGAS) achieved its ultimate goal of creating a management framework for this important aquifer, in support of sustainable groundwater management in the countries that overlie it: Argentina, Brazil, Paraguay and Uruguay. This represented the culmination of efforts launched in March 2003, with definition of the most convenient actions to be carried out in each country, and in cooperation among the four countries, in the region overlying the Guarani Aquifer System.

Knowledge accrued on the dynamics and quality of groundwater flows and on characteristics of water use, obtained from boreholes, had led to acknowledgment that sustainable groundwater management was needed at both the regional and local levels, encompassing provinces, states, countries and transboundary regions. Regional cooperation fostered under the PGAS enabled specific advances that have benefited the GAS and the broader context of regional integration.

The SAP document was the outcome of interaction efforts on the part of sectoral, national, and provincial/state governmental bodies, contracted companies, involved sectors academics and civil society. To implement this process the Project received support from the Global Environment Facility (GEF), the World Bank, the Organization of American States (OAS), and was based on the work of the Project General Secretariat, that was comprised of renowned technical specialists of the four countries that share the GAS region. Other players, such as the Federal Institute for Geociences and Natural Resources (BGR) and the International Atomic Energy Agency (IAEA) also collaborated toward the successful attainment of goals.

Preparation of the SAP demanded full commitment on the part of the Project Steering Committee (CSDP) comprised of institutions responsible for water-resources, environmental management, and foreign affairs of the four countries. The CSDP ensured that project execution was carried out under the guidance of the respective Governments, with transparency, efficiency, and active institutional and social participation.

Argentina, Brazil, Paraguay and Uruguay can now count on the valuable outcomes of the PGAS that have emerged from this intense and fruitful regional cooperation process.

Despite these advances, we remain aware that we have merely taken the initial steps toward ensuring protection and sustainable use of this important natural resource. Subsequent steps will entail implementation of the SAP, for the benefit of society, in the awareness that this resource is a loan from future generations. The management instruments prepared, that will be further used and updated are: the Guarani Aquifer Information System (SISAG); the Monitoring Network, the regional and pilot-project area mathematical models; the training technical capacities, and the dissemination of knowledge.

As of this time, the challenges must be faced of ensuring continuity of the successful experiences developed on this path, of guiding efforts for planning follow-up for regional cooperation and incorporation, within the various national bodies, of advances achieved in the sustainable use and management of the GAS.

Finally, the advances achieved under this Project have not only led to acknowledgement of the importance of groundwater management in this region, but have also reinforced the integration processes underway among the four countries.

Fabián López
President of the Project Steering Committee (CSDP) since 2006

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FOREWORD

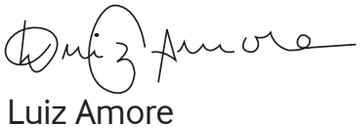
The Strategic Action Program is the outcome of six years of intense collective effort for the production of knowledge, and of a fruitful process of interaction among sectors responsible for water-resources management in Argentina, Brazil, Paraguay, and Uruguay. The goal of assisting these countries to develop a framework for protection and sustainable development of the Guarani Aquifer System (GAS) has been fully achieved, as this document describes. Today, groundwater management, an non-transferable duty of each of the countries that overlie the GAS, is equipped with technical bases for development. Moreover, the international sectors involved have fulfilled their mission of promoting cooperation among the different beneficiary countries, by means of the Project for Environmental Protection and Sustainable Development of the Guarani Aquifer System (PGAS).

Throughout the process of project execution, a common knowledge base was developed by the various players in the four countries. Based upon an acknowledged need to conduct water-resources management in each of the countries, specific groundwater management instruments have been developed. Indeed, in view of their innovative aspects, certain of the Project's outputs, such as the Basic Map of the GAS, received international awards while the process of project execution was still underway. Furthermore, the PGAS gave rise to a database on current wells and also to a number of thematic maps that have been incorporated into the Guarani Aquifer Information System (SIG). These provide support for decision-making on issues relating to groundwater at national and sub-national (state/ provincial) management bodies and can be easily accessed by the public. Management bodies also have at their disposal the monitoring network of wells and mathematical models for simulating water-use scenarios, for definition of groundwater protection measures in the four pilot areas and in the region as a whole.

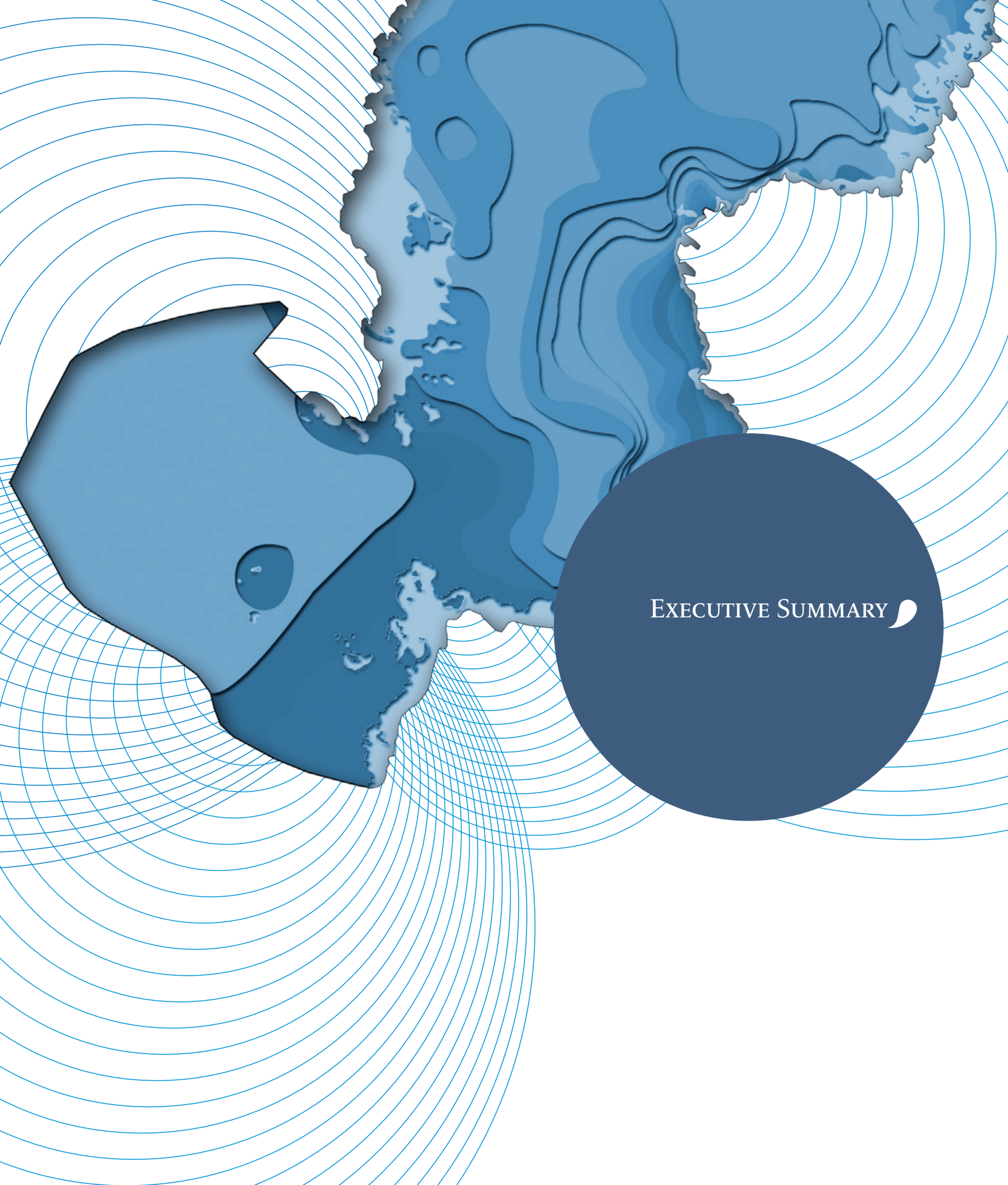
Compilation of all this technical knowledge and development of the management tools involved approximately 110 hired Consultants (mostly from within the region) and 30 trainees in various subjects. Over 150 representatives of the countries participated in innumerable meetings and technical seminars. Directly involved in development of the SAP were over 15 Consultants and, considering all phases of Project preparation, more than 300 professionals were involved. The process of managing GAS resources entailed ample interaction among national and sub-national water-resources management institutions. Having built these structures, the countries are now well positioned to develop management units at various levels to provide institutional and social support for groundwater management. At the regional level, close cooperation among the countries led to the establishment of bases for future cooperation, in support of the development of management instruments and implementation of convergent actions targeted at fostering sustainable development of the GAS.

The SAP is an important tool that will remain in effect for a long period. However, much still remains to be done to ensure sustainable management of groundwater and of the resources of the GAS. Strengthening local management so as to ensure better approaches to solving problems and implementing solutions is one of the great challenges still before us. Implementation of each of the priority actions prescribed in the SAP is of fundamental importance for each of the countries and for the region. In view of the size of the GAS and of the emerging challenges of water management throughout the world, the process that has been launched must continue to be monitored and supported by society, water users, and by the various sectors involved in water-resources management in our countries and throughout the world.

Finally, I would like to recall that implantation and development of this Project would not have been possible without support received from the technical-scientific community, civil society, educators, authorities and international bodies, all of which contributed fundamentally toward its success. I also wish to underscore the importance of work carried out in the preparation of the Project by Eduardo Mestre, Secretary General during the Preparation Stage (2000-2001), and of all the other participants involved. To the Authorities, Consultants, Collaborators and Project staff, my most sincere thanks...



Luiz Amore
Secretary General of the Project for Environmental
Protection and Sustainable Development of the Guarani Aquifer System



Executive Summary

Executive Summary

The Strategic Action Plan (SAP) summarizes the execution and joint proposals of the countries that participated in the Project for Environmental Protection and Sustainable Development of the Guarani Aquifer System (PGAS). The PGAS was requested by the Governments of Argentina, Brazil, Paraguay and Uruguay from the Global Environment Facility (GEF), as shown in Figure 1. The SAP encompasses short and medium-term strategic actions and its long-term objective is to implement coordinated and sustainable management of the Guarani Aquifer System (GAS).

The SAP establishes spaces for work and concrete actions for development of joint strategies, exchanges of information and successful experiences on groundwater management. It also promotes cooperation among stakeholders with the aim of stimulating protection and sustainable use of water of the GAS. Though based on consensual joint initiatives, the SAP acknowledges that management of the aquifer is the responsibility of each of the countries and of jurisdictions defined under their respective constitutional frameworks.

The following specific approaches were pursued during execution of the PGAS:

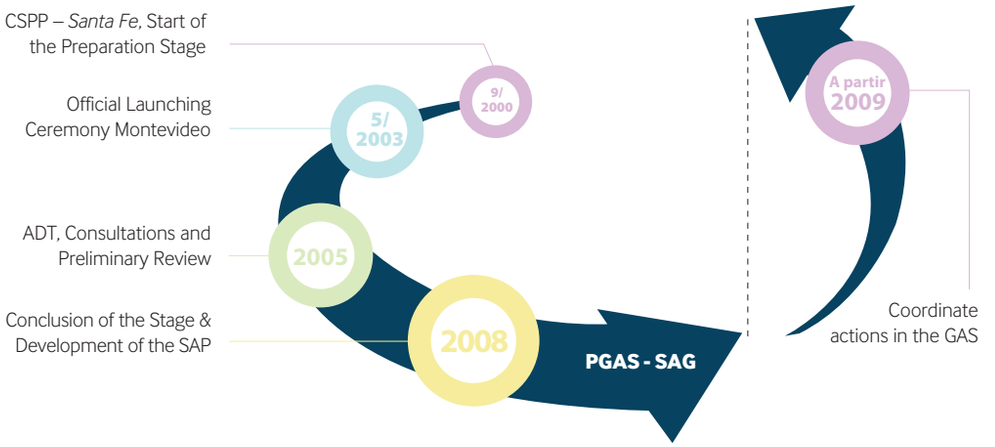
(i) Technical and scientific studies in support of management of the GAS, including diagnostic analyses, generation of new information, and creation of an information system and of a database.

(ii) Evaluation of institutional and normative frameworks relating to the theme "groundwater" at the national, sub-national, and local levels.

(iii) Execution of local groundwater management measures for the GAS in Pilot-Project areas.

(iv) Strengthening of technical capacities on groundwater related themes.

(v) Dissemination of information on groundwater and on the GAS at all levels of society.



NB: CSPP (Project Steering Committee); TDA (Transboundary Diagnostic Analysis). Fonte: Desenvolvido pela SG/SAG, 2008.

Figure 1. Execution of the PGAS and preparation of the SAP

The experience of execution of the PGAS was an exercise in cooperation among the four countries overlying the Guarani Aquifer System. One of the main characteristics of this experience was ample participation of players at different levels and of public and private academic institutions, which helped foster technical capacity building and dissemination of outcomes.

Preparation of the SAP

The SAP results from an intense process of participation within each country and in the region

overlying the GAS, involving a broad array of institutional, jurisdictional and social players concerned with protection and sustainable use of the aquifer. It is thus the outcome of cooperation among the countries, accumulated over six years of execution of the PGAS, the findings of which, along with an understanding of its regional, subregional and local scope, were determining factors for its preparation (Figure 2).

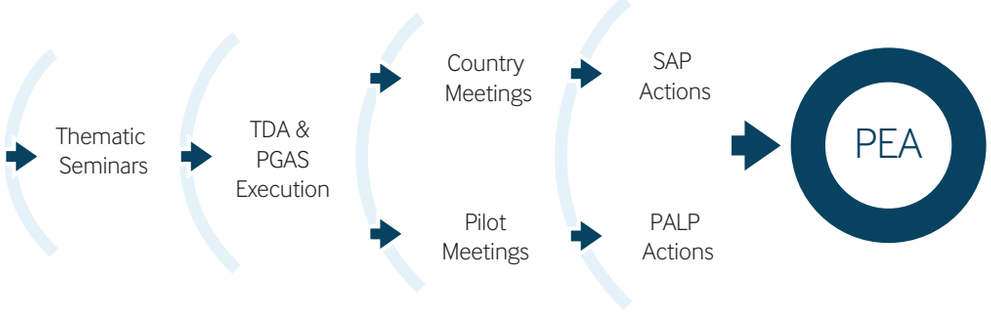
It was acknowledged that the GAS, and groundwater in general, belongs to and is under the sovereignty of the countries that overlie it, and which are responsible for its management within their territories. It was also recognized that there is a need to engage in regional coordination and cooperation, in order to implement regional and national strategic actions, regardless of whether or not the water is transboundary in scope (Table 1).

All knowledge produced was compiled and legitimated by the countries through a consensual and transparent process, respecting the competencies of the institutional hierarchies of each country.

Outcomes of the PGAS

Studies conducted under the PGAS led to the following findings:

1. The existence of the GAS was confirmed as a vast rock strata (geological formations) with aquifer characteristics, forming a vast groundwater reservoir (hydrogeological basin). New estimates calculated its area as 1,087,879 Km^2, which corresponds to 92% of the original estimate. It was also confirmed that the GAS is present in the subsoil of four countries, though certain differences were detected in relation to the original estimates.
2. The geological formation that contains the water of the GAS is a continuous structure in the four countries of the region. The water is renewable, but circulation is slow and is hampered by hydraulic barriers and natural compartments that condition subterranean flows. Generally, water quality is good. Except in a few specific areas, problems of contamination or overexploitation were not detected.
3. Though the GAS is a continuous structure, its waters present heterogeneities. Its characteristics vary from one region to another, and



Source: GS/GAS, 2008.

Figure 2. Preparation of the SAP

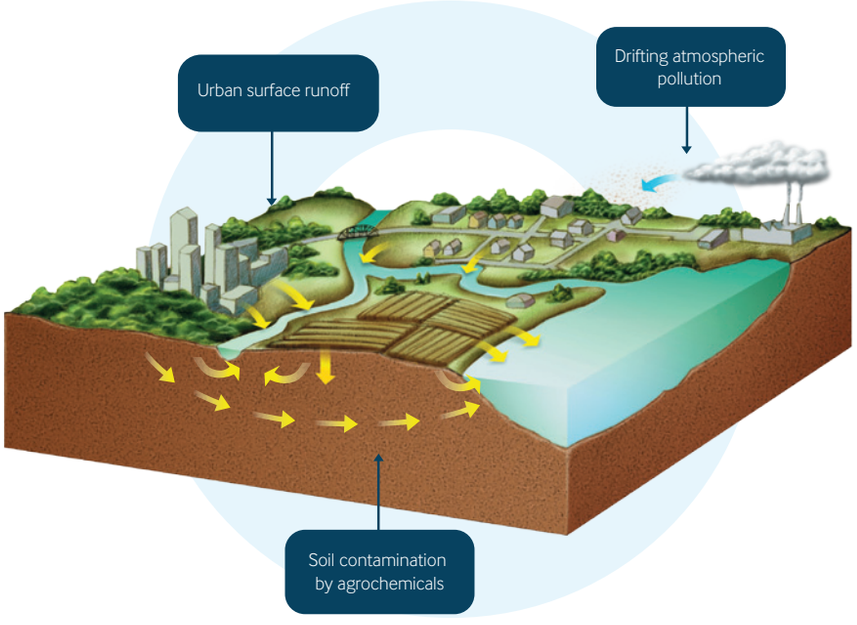
Table 1. Total estimated area and distribution of the GAS by country

Country	Original estimate		Current project estimate		% in relation to the area of the country
	Area (km^2)	% of the total	Area (km^2)	% of the total	
Argentina	225.500	19,1	228.255	20,98	8,1
Brazil	839.800	71	735.918	61,65	8,7
Paraguay	71.700	6,1	87.536	8,05	21,5
Uruguay	45.000	3,8	36.170	3,32	19,5
Total Area GAS	1.182.000	100	1.087.879	100	_

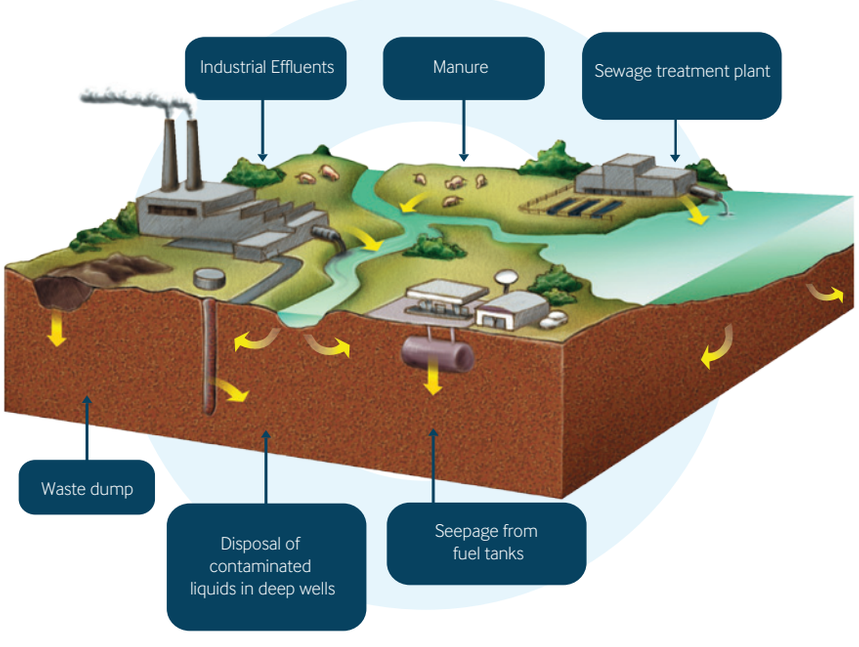
Source: GS/GAS, 2008.

well-defined areas can be identified where the dynamics of the GAS differ considerably. Such variation includes chemical differences (pH variations from five to nine and electrical conductivity between 100 and 2,500 milisiemens per cm), hydraulic differences (static levels ranging from zero to over 200 meters), differences of accessibility, and of temperature (ranging from 18 ^{o}C to 50^{o}C). Levels of use of the GAS also vary considerably. In one sector of the aquifer, equivalent to 10% of its total area, there is not a single well into the GAS or that could provide reliable information. In other sectors, within areas of 500 km^2, abstractions from the GAS amount to as much as 30,000 m^3 per day.

4. When the water of the GAS is affected by pollution, such contamination is normally detected in relatively shallow wells, and often stems from faulty well construction. Contamination may also occur in and around outcrop areas (zones with fractured basalts, through which pollution may percolate from the surface) which tend to be more vulnerable. Moreover, in areas covered by basalts, there are certain windows that expose the GAS to surface water or to flows from younger (post-GAS) geological formations. In such cases, there is considerable vulnerability. In confined areas of the GAS, vulnerability is negligible (Figure 3).
5. Studies carried out in the Pilot Projects found that current and potential transboundary effects of the GAS are restricted to a narrow strip of territory of no more than a few dozen kilometers, depending upon local specific hydrodynamic conditions. The hydraulic 'upstream' and 'downstream' effects, common in surface drainage, are not applicable to the GAS and, generally, are imperceptible. Nonetheless, for example, the lowering of the depression cone caused by extraction in the Santana de Livramento and Rivera region, though not large, crosses the border between Brazil and Uruguay, and to some degree affects local GAS groundwater flows.
6. Investigation of economic and social aspects of GAS water use led to the conclusion that certain types of activities and investments could cause impacts that go beyond strictly



A. Rivers flowing out of the GAS (outflow from the aquifer)



B. Rivers that feed the GAS (inflow to the aquifer)

Source: Adapted from Murck, W; Skinner, B.J.; Porter S.C.(1996).

Figure 3. Groundwater pollution sources

hydraulic aspects. Thus, changing land-use patterns, especially in replenishment zones, are potential areas for specific cooperation and dialogue between the countries. Among the processes of change detected by the Project are: deforestation, forestry plantations, use of high water-consumption agricultural techniques, intensive use and inadequate management of agrochemical inputs, or greater abstractions of thermal waters.

The PGAS studies led to identification of three large zones with differing characteristics for groundwater management:

a) Outcrop zones (ZA).

b) Confinement zones (ZC) in the proximity of outcrop areas (a stretch 10 to 50 km wide) and/or where the post-GAS cover is no more than 100 meters thick.

c) Highly-confined zones (ZFC).

7. Low and medium enthalpies of the GAS, especially in its more confined central portions, represent a valuable energy source. Heat from these areas is renewable energy that, under certain circumstances, could be harnessed for a variety of economic and agro-industrial activities, aside from current use for spas. In face of multiple demands (human water supply, agriculture and industry) the search for alternative uses of groundwater has intensified substantially, especially in zones where aquifers are known to contain limited resources. In such areas, GAS water assumes immense social and economic importance, and it is likely that overlapping interests will emerge as its strategic value becomes more evident. The trend toward more intense groundwater exploitation in the region could be exacerbated by climate change pressures.
8. As a consequence of efforts to disseminate themes relating to groundwater and the GAS, there have been significant increases in knowledge on the part of local, state/provincial, national and regional players.
9. Gaps exist between the provisions of legal frameworks, and deployment and enforcement of standards. Generally, the countries have developed comprehensive normative structures, in line with regional and international trends. All of them have incorporated the necessary principles and instruments for management and protection of groundwater. However, except in certain specific cases, these have not been transformed into effective advances or concrete results. Effective deployment of management instruments requires allocation of adequate financial, human and logistical resources which, generally, are scarce or unavailable.
10. In the four countries, the legal and institutional frameworks provide a sufficient basis for sustainable management and protection of the GAS. There are, likewise, conditions suitable for development of the necessary coordination between the countries that overlie the GAS and other countries. The experience acquired and outcomes of the PGAS technical studies offer each of the countries an opportunity to revise and adjust their legal frameworks and the concrete application thereof.
11. The Pilot Projects resulted in a series of applications, procedures, methodologies and legal and fiscal instruments that could be usefully employed to enhance local management, through implementation of priority actions replicated from other areas in the GAS region with similar characteristics and that face the same water-use and preservation issues.

Outcomes and impacts of the PGAS

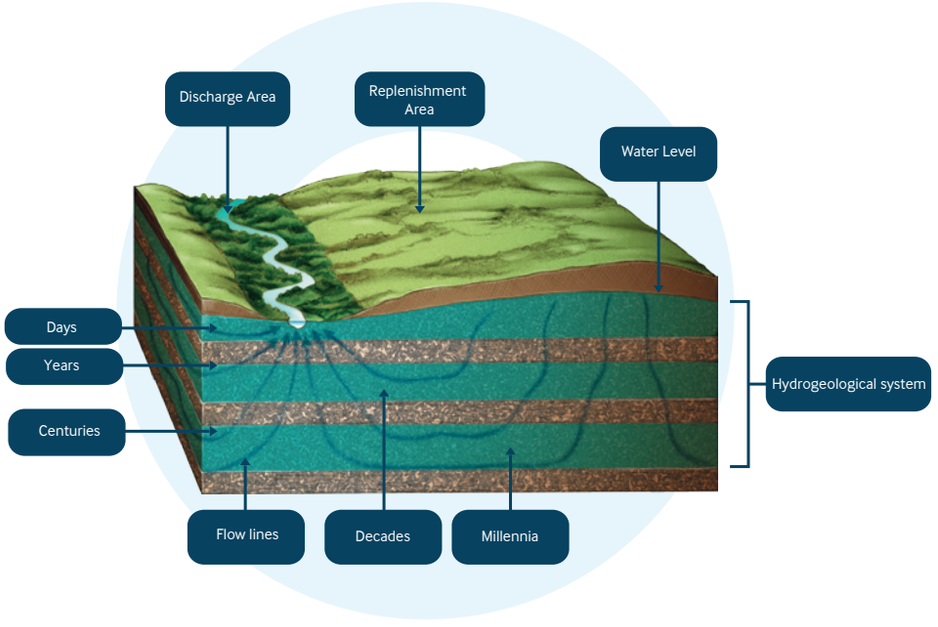
The water-resources management scenario in the four countries, when the PGAS was being prepared, proved a fertile environment for fomenting initiatives, gaining greater knowledge, and strengthening management of the GAS. Prior to the PGAS, groundwater management was rarely discussed and lacked political visibility in the region. The few initiatives that existed were in regions where, historically, groundwater had played a relevant role.

Though the term 'integrated' was used, water-resources management was generally concerned with surface water. This, in the GAS region, is due to historical factors and the vast quantities of available surface water. The importance of the role of groundwater in the maintenance of ecosystems was often neglected (Figure 4A and 4B). Very little academic literature had been produced on groundwater, as compared to the numerous studies on surface water. Moreover, there were practically no databases on tube wells or aquifers. Much of the population, including the formal schooling systems and civil society, had no access to consistent information on aquifers, groundwater and, much less, on the GAS.

This was the situation at the onset of the PGAS. The desire to protect the aquifer and a perception of the transboundary nature of this task brought the four countries together in support of the Project. During execution of the PGAS and, to a considerable degree, thanks to it, technical, legal and institutional structures were swiftly put in place to institute groundwater management. The theme 'groundwater' was definitively placed on the agendas of the four countries that overlie the GAS.

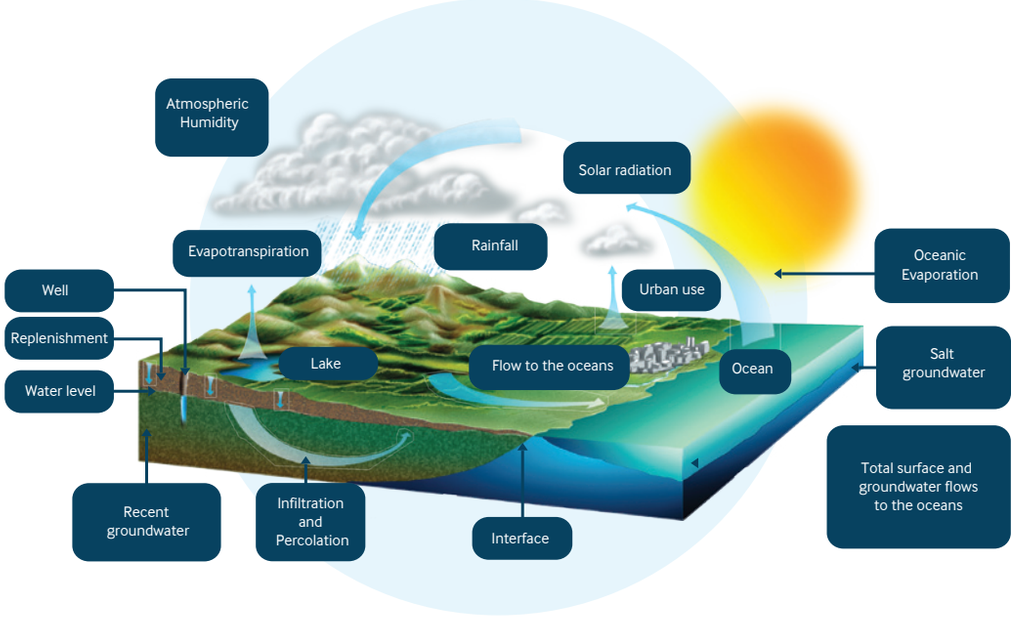
As a consequence of all these studies, joint experiences, and harmonization of knowledge, the following outcomes were achieved:

1. A great quantity of technical knowledge and a vast amount of data was produced. Manuals of procedures were prepared for managers throughout the region. Moreover, technical criteria and a regional view, so necessary for promoting sustainable groundwater management, were develop. Among the highlights of this process were :
   (I) Drafting of geological and hydrogeological maps, with details on the geometry and behavior of the GAS, based on a consensus and on correlation with stratigraphic units in the four countries.
   (ii) Establishment of a database on tube wells, available to all stakeholders and linked to all the main regional databases.
   (iii) Design of a regional monitoring network for wells, including selection of wells (in confined areas and outcrop areas) and their respective sampling protocols.
   (iv) Construction of conceptual and mathematical regional-flow models (designed to assess regional water-use scenarios including macro changes in land-use and settlement patterns) and local flow-models in Pilot-Project areas (a direct management tool for solution of local problems).
   (v) Establishment and feeding of the Information System on the Guarani Aquifer



Source: Adapted from Murck, W; Skinner, B.J.; Porter S.C.(1996).

Figure 4A. Time of residence of groundwater



Source: Adapted from Murck, W; Skinner, B.J.; Porter S.C.(1996).

Figure 4B. Hydrological Cycle

System (SIGAS), using the most modern geo-processing and information technologies.

2. One consequence of these advances was development of groundwater regulations in the four countries that overlie the GAS (Argentina, Brazil, Paraguay and Uruguay) at a higher hierarchal level and with more precise standards. The legislation has been refined to provide specific treatment for groundwater, which it did not prior to 2000.
3. Perhaps for no other transboundary aquifer in the world have such harmonization of standards and joint technical cooperation been achieved. This success results directly from cooperation between the countries, that have overcome difficulties posed by differences in their technical and institutional arrangements. Without such cooperation, progress achieved in each individual country would not have been as significant, and neither would it have been possible to share experiences and build upon lessons learned under a common management framework.
4. A Transboundary Diagnostic Analysis (TDA) was prepared, based upon a comprehensive process of consultations and participation carried out in each of the countries by the National Project Execution Units (UNEPs). All stakeholders were invited to participate in this process, including representatives of the states/provinces and municipalities involved, organizations of civil society, and local committees of the Pilot Projects. Causes of problems and information gaps were identified, and actions implemented for mitigating or resolving critical themes relating to the GAS, including quantitative and qualitative aspects of protection and management.
5. Cooperation mechanisms for fostering regional participation in decision making were tested at the various levels, including the Project Steering Committee (CSDP), the National Coordination Units (CN), the Coordination Council (CC) and the National Project Execution Units (UNEPs). Also, a Project General Secretariat (GS/GAS) was established as a regional technical body, to serve as a convergence and starting point for initiatives of each of the countries in the PGAS. It received support from the General Secretariat of the Organization of American States (GS/OAS) acting as the regional executing agency for the GEF, and the World Bank acting as the GEF implementing agency. Establishment of these spaces for discussion and exchange led to a gradual enhancement of technical and institutional capacities, strengthening ties of trust, and dissemination of lessons learned at all levels. Under the PGAS, with support from the GEF's Operational Program 8, the world's first SAP for transboundary groundwater was prepared.
6. The Guarani Universities Fund successfully implemented a mechanism for providing support for research and academic training activities on environmental and social aspects of the GAS for universities of the region. Aside from initiatives under the Fund, execution of the PGAS also served as an unprecedented stimulus for scientific initiatives relating to groundwater and to the GAS. The GAS proved to be an opportunity for generating cooperation among universities and new sources of research funding.
7. The PGAS, through the Guarani Universities Fun, provided support for actions carried out by civil society in the fields of communications, participation, and formal, informal and non-formal environmental education. Outcomes of these actions can be classified into three broad groups:
   (i) efforts to place groundwater on the public environmental and social agenda in the region;
   (ii) support for dissemination of the Project;
   (iii) activities for awakening public awareness to the importance of preservation and sustainable management of the GAS.

Knowledge relating to the Guarani Aquifer was widely publicized in the four countries. By means of the Guarani Citizenship Fund, some 2.3 million people were put into direct contact with the work of the PGAS, in the fields of environmental preservation, sustainable use, and management of the GAS.

8. In the Pilot Projects, the PGAS enlisted and fostered ample public participation. The aim was to generate increasing levels of commitment to preservation and sustainable management of the GAS at the local level. Local Project Support Committees (CLAPs) were established in each of the Pilot Projects, as a strategy for fostering more active participation in decision making on public policies that affect the aquifer. Stakeholders were offered an opportunity to intervene in the design, application, and evaluation of local actions. Based on the successful experiences of the CLAPs in Pilot-Project areas, it became clear that management-support committees have an important role to play. Such committees make it possible to adapt tools to the needs of local management, to conciliate different needs (especially municipal land-use policies and national and local water-resources policies) and to expand spaces for public participation and environmental education in areas where there are significant problems relating to the aquifer and to groundwater. Examples of progress achieved in the Pilot Projects include: the zoning of wells in Ribeirão Preto; establishment of the Capiibary Committee (Paraguay); and support for setting of minimum distances between wells in thermal areas of Concordia (Argentina) and Salto (Uruguay).
9. In line with the original project goals, a number of actions were carried out involving various indigenous groups. These helped strengthen existing institutional ties, disseminate important technical information, and enabled indigenous leaders to make specific proposals for inclusion into the SAP.

Rationale for the SAP

The SAP addresses not only environmental protection and sustainable use of the aquifer, but also the broader concept of water security. Assessments carried out under the PGAS found that issues relating to water quality, quantities, and replenishment capacity of the GAS are considered of immense

strategic importance in the regions that overlie it. Indeed, it is the GAS that provides these regions with a high degree of water security. It ensures fair access to high-quality water for local populations, thereby enabling them to engage in productive activities, providing that they conserve the integrity of this precious resource and the environment upon which it depends. For these reasons, it is essential that, at each level, measures be taken to ensure integrated management and sustainable use of the GAS.

Water security is an ambitions goal that requires convergence of strategic actions carried out in a coordinated manner by all the countries involved. Pursuit of this common goal will require attainment of harmonized technical and institutional capacities. Each of the countries needs to achieve sufficient capacities to implement management strategies at the national and sub-national levels, suitable for application to their specific circumstances and pressures of use. Water security can be achieved, provided that the sovereign States adopt compatible management principles and pledge to commit the human and financial resources necessary for sustainable management.

Fragmentation of actions, based solely on a national perspective, could pose medium and long-term risks. So limited an approach could compromise the availability of resources for management and protection of the GAS and for ensuring water security, by:

- exacerbating differences in understanding on the behavior of the GAS at the regional level;
- intensifying environmental degradation and conflicts relating to use of GAS water in border regions;
- limiting the capacity of each country to respond to challenges posed by climate change, which call for strategic coordination of actions throughout the region overlying the GAS.

Indeed, any threat to water security in one of the four countries would lead to regional imbalances. The only feasible alternative, as the SAP proposes, is strengthening of cooperation for water-resources management in general, and particularly for the strategic resource of the GAS.

Strategic actions

Implementation of the PGAS clearly illustrated benefits accruing from cooperation among countries, in a field that has been little explored worldwide. Such benefits include, for example, acknowledgment at the local-management level of the need for sustainable approaches to groundwater use; design and deployment of mathematical models for actions carried out in the PGAS Pilot-Project areas; and the structuring of technical and scientific knowledge so as to guide sustainable management. This has provided better knowledge on the aquifer and its behavior, through development of a network for monitoring wells, and of an information system installed at bodies responsible for groundwater management (countries, states/provinces) and in urban areas within the Pilot Projects (municipalities), all through close cooperation within the scope of the Project.

One of the primary tasks of the SAP is to identify strategic actions that address expectations of the countries in relation to the GAS, and that serve as a basis for regional cooperation, with a view to enhancing potential benefits of such actions, in accordance with the findings announced during preparation of the PGAS.

The identification of such strategic actions entailed intense participation of all stakeholders in the PGAS. This process was highly interactive, and culminated in decisive moments as the strategic actions began to take form. Foremost among these were:

- Preparation of the TDA, the results of which led to formulation of the SAP and outlined its main approaches, to which all other actions were aligned.
- A technical review of the outcomes of consultancies carried out during the PGAS enabled identification of priority actions and spaces for information that comprise the SAP.
- The process of consultation and discussion carried out at the Pilot Projects during development of Local Pilot Project Action Plans (PALPs).
- The presence of representatives of the UNEPs in the SAP workshops held in each of the countries. Thus, one of the outcomes of the domestic consultation process was a number of proposals for strategic actions to be incorporated into the SAP.
- The National Coordinators (CNs) and representatives of the UNEPs, with the support of national SAP articulators, developed content and form for the suggested actions and placed them on matrixes that enjoyed a high degree of consensus within each country.
- During the general UNEPs workshop, each country had an opportunity to present its matrix of actions and identify those that should have priority, in view of their common regional interest. The discussions also encompassed the issue of sustainability of regional cooperation on the GAS.

From this process, the following approaches for regional actions under the SAP emerged:

1. Development of national and sub-national capacities for groundwater management.
2. An operational structure for regional cooperation.
3. Updating and maintenance of the SIGAS.
4. Implementation and development of the GAS monitoring network and mathematical models.
5. Technical capacity building and dissemination of knowledge.
6. Development of local groundwater management.
7. Support for public participation.
8. Development of criteria for sustainable use of the GAS.
9. Implementation of technical-scientific programs linked to management of groundwater and of the GAS.
10. Preparation of technical-economic studies relating to the GAS.
11. Monitoring and evaluation of implementation of the SAP.

Details on actions under each of these approaches can be found in the SAP document, that stresses the regional ties between each and contributes specific details of an operational nature. Matrixes of actions carried out within each country complement this description, by identifying relevant players and providing cost estimates.

SAP Immediate Implementation Stage

With the aim of retaining capacities generated and building upon lessons learned under the

PGAS, just as the need for sustainable groundwater management is gaining preeminence on public agendas and in public expectations, one of the premises of the SAP is to ensure continuity and incorporation by the countries of the main management instruments developed to date.

The SAP aims to provide continuity for the Information System on the Guarani Aquifer (SIGAS) and the monitoring network, on a regional scale. It proposes to produce updates of the base map of the aquifer and of the mathematical models, to carry out capacity-building (especially at the sub-national and local levels) and to disseminate technical knowledge produced under the PGAS.

Actions for assimilation of outcomes and maintenance of current regional dynamics need to be carried out in the short and medium-term, in line with prescriptions of the SAP immediate Implementation Stage. This is a period of transition, in which the main objectives are to maintain articulation and coordination among the countries, developed within the context of the PGAS.

Once the transition has been completed, the countries may negotiate future medium and long-term regional actions. The shift from the immediate Implementation Stage to the future Implementation Stage will not be abrupt. Rather, it will be conditioned by the capacity of the countries to come up with the technical and financial resources needed to pursue national and regional priorities described in the SAP.

Arrangements for implementation of the SAP

The countries have decided to acknowledge the La Plata River Basin Treaty as the legal basis for future actions in relation to the GAS. They also acknowledge, however, that the GAS, in view of its strategic importance, merits special attention.

Best practices adopted in organizational arrangements under the PGAS offer important lessons. These have been examined and replicated with adaptations, by national executing agencies, in the light of their own experience. Existing installed institutional capacities in each country are taken into account, maintaining and adapting operational and management structures successfully deployed under the PGAS.

A Regional Cooperation Council for the GAS is to be created, similar in structure to the CSDP, comprised of members of national water-resources and environmental-management institutions, and the ministries of foreing affairs of the four countries. The UNEPs are to be acknowledged and consolidated as National Management Units (UNGs) and are to function as inter-institutional articulation bodies, comprised of relevant players in the field of water-resources management (including maintenance and strengthening of state/provincial units).

The Technical Committees created under the PGAS are to receive institutional status, and will continue to provide support for the development of management instruments during the SAP Implementation Stage. The following committees are to be set up: the Information System Committee, the Monitoring and Modeling Committee, and the Capacity Building and Dissemination Committee. Also in this context is the Group for Promotion of Local Management, with representatives of the Local Management Support Committees created under the Pilot Projects.

To provide support for implementation of the SAP, a GAS Liaison Unit is to be set up to perform the role of articulating and distributing information among the newly-created or consolidated committees and the higher decision-making and coordination bodies (National Management Units and Regional Cooperation Council). Initially, this unit will maintain a minimal technical and operational structure and will use the facilities of the GS -GAS in Montevideo, Uruguay.

Each country will assume leadership of one of the instruments installed by the PGAS and exercise regional responsibility for the functioning of the respective thematic committee. The Group for Promotion of Local Management will operate from the SAP Liaison Office.

The Information System Committee will be under the responsibility of Argentina; the Monitoring and Modeling Committee, of Brazil; the Capacity Building and Dissemination Committee, of Paraguay; and the Liaison Office will be the responsibility of Uruguay.

Each country will be responsible for one of the current Pilot Projects. Concordia-Salto will be under the responsibility of Argentina; Ribeirão Preto, Brazil; Itaipúa, Paraguay; and Rivera-Santana do Livramento will be the responsibility of Uruguay.

Figure 5 shows arrangements of the SAP for the next stage of regional activities.

Future Implementation Stage

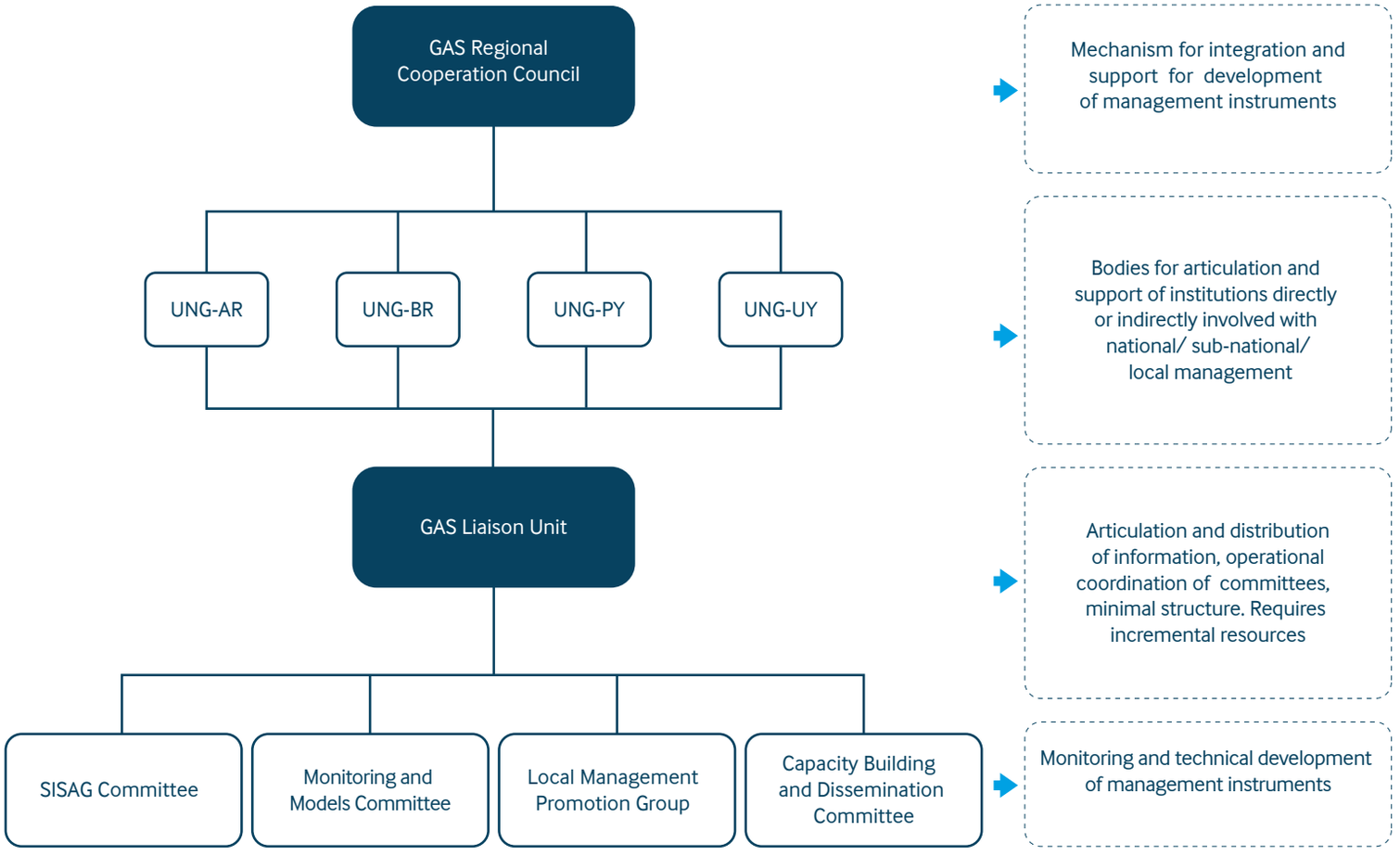
In this stage, all the agreements foreseen in the Immediate Implementation Stage will be maintained. The difference lies in the enhanced capacities of the Liaison and Operation Units and strengthening of the Technical Committees. Additional resources are to be provided for execution of previously-defined priority actions and expenses for participation in coordination meetings.

Aside from its role of promoting articulation and facilitating exchanges, the Liaison Unit will be responsible for implementation of new actions. To this end, it must be endowed with the technical capacities needed for development of new proposals, and with funding for pursuit of actions defined under the SAP that were not carried out during the Immediate Implementation Stage.

Budget

The funding agreement for the Immediate Implementation Stage foresees one hundred and eighty thousand united-states dollars (US$ 180.000). This amounts to the sum of equal contributions provided by the Governments of Argentina and Brazil, of ninety thousand dollars (US$ 90.000). As its contribution, Uruguay will provide support for the Liaison Unit in Montevideo.

These resources will be used for the purposes of promoting articulation, including scheduling of meetings, summoning of participants from the countries, maintaining the records and safekeeping of materials and documents produced under the Project, and financing of actions that the countries, meeting at the GAS Regional Cooperation Council, consider pertinent.



Source: GS/GAS, 2008

Figure 5. Institutional Agreements for regional activities under the SAP Immediate Implementation Stage

A formal proposal for application of resources is to be a part of the annual operational plan that is to be drawn up for the transition from the closing of the PGAS to launching of implantation of the SAP. This document is to be approved by the aforesaid council. Additional administrative costs for the functioning of the proposed structure, including wages for members of the various committees, national units, and the Regional Cooperation Council, and also defrayal of travel expenses, are to be funded by the bodies at which the respective appointed representatives are formally employed.

Initially, aside from the aforementioned funding sources, implementation of specific actions under the SAP proposal will depend upon national and sub-national efforts of the countries, incorporating suggestions and guidelines presented under individual and regional actions, always maintaining the highest possible degree of cooperation.

Risks stemming from non-implementation of the SAP

In the event of failure to implement SAP management tools in an integrated manner and on a regional scale in the four participating countries, a unique opportunity will have been missed. Fragmentation and loss of momentum would result in dispersion of efforts and resources and in a weakening of groundwater management institutions, at a time when new challenges must be faced.

The main risks factors relate to:

(i) the degree of effectiveness of institutional arrangements agreed to by the countries;

(ii) the capacity to mobilize financial and human resources for implementation of strategic actions;

(iii) the capacity of the Governmental bodies responsible for management and other technical institutions to assimilate and monitor deployment of actions proposed under the SAP;

(iv) technical capacities and political will in the countries to continue working

together to promote future actions for groundwater management.

More specific risks include:

- Deterioration of the committees, leading to failures of articulation and of development of management tools such as the SIGAS, the monitoring network, and mathematical models.
- Weakening of local committees of the Pilot Projects, owing to lack of institutional support and failure to define specific roles for groundwater and land-use management, and loss of interest on the part of local stakeholders.
- Dispersion and fragmentation of the technical knowledge acquired under the PGAS, if the SIGAS or other central databases are not available to store and provide specific information.
- Failure of the public to understand the scope of transboundary effects, giving rise to alarmist and technically unsound beliefs.

Sustainability

There are a series of factors that help ensure sustainability of actions carried out under the Project. Firstly, it should be underscored that the countries have expressed the political will to continue working in a coordinated manner in future stages for protection and sustainable management of the GAS (in line with the goals of the PGAS). Secondly, with respect to funding, each of the countries shall seek to allocate and ensure continuous funding for the SAP from its national budget and to manage funding sources for the SAP. Moreover, the countries shall continue working together to develop capacities and cooperation mechanisms for promoting sustainable management, through strengthening of the institutions responsible for promoting protection and rational use of the aquifer.

Based on a needs assessment for the conducting of planned basic activities (development and deployment of mathematical models, the SIGAS, and the monitoring network) and their respective levels of coordination, the following lines of action have been identified as a roadmap for full implementation of the SAP:

- Dissemination of materials produced by the Project and implementation of the SAP: this task entails disclosure of outcomes and outputs of the Project. It is of crucial importance and will result in harmonization of knowledge throughout the GAS region and will pave the way for future developments (transition packets and events for delivery of materials).
- National governments and institutions need to make available the necessary human and financial resources for conducting all activities: without such resources it will not be possible to carry out actions foreseen under the SAP.
- Deployment of SIGAS, a powerful tool for dissemination of information at all levels (local to regional): the operation of this system is of fundamental importance, since all information flows necessary for execution of the SAP are dependant upon it. A requisite for deployment of the SIGAS is the establishment of a SIGAS Committee.
- Implementation of the monitoring network: establishment and functioning of the technical coordination group will facilitate the tasks of sampling and testing under the monitoring network. With the SIGAS in full operation, all information will be available on the database.
- Implementation of local management structures: once all components are in place, it will be possible to proceed on the basis of consolidated arguments with themes relating to groundwater management on the appropriate scale, and to pursue sustainability of actions in the Pilot-Project areas and throughout the GAS region.
- Capacity to learn and to apply lessons learned, in other areas where themes relate to local management.
- Renewed updating of local mathematical models: this could strengthen arguments in favor of groundwater management, the main objective of the SAP.

At this time, as the activities are about to commence, it should be observed that implementation of the SAP will, in itself, lead to greater knowledge within the countries, through dissemination of its outputs and results

Dissemination strategies

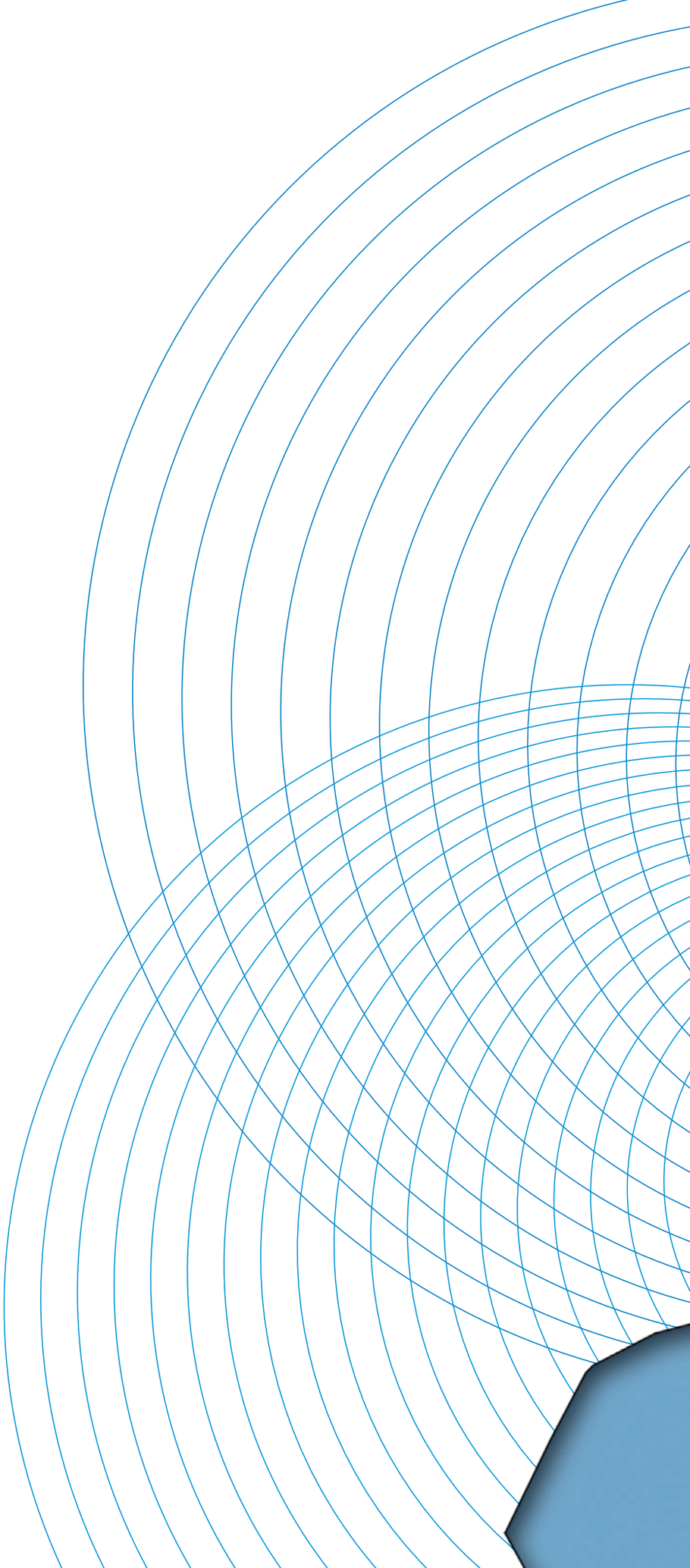
Based on experience accumulated during execution of the project, it is possible to identify three significant needs relating to dissemination of knowledge, communications, and capacity building:

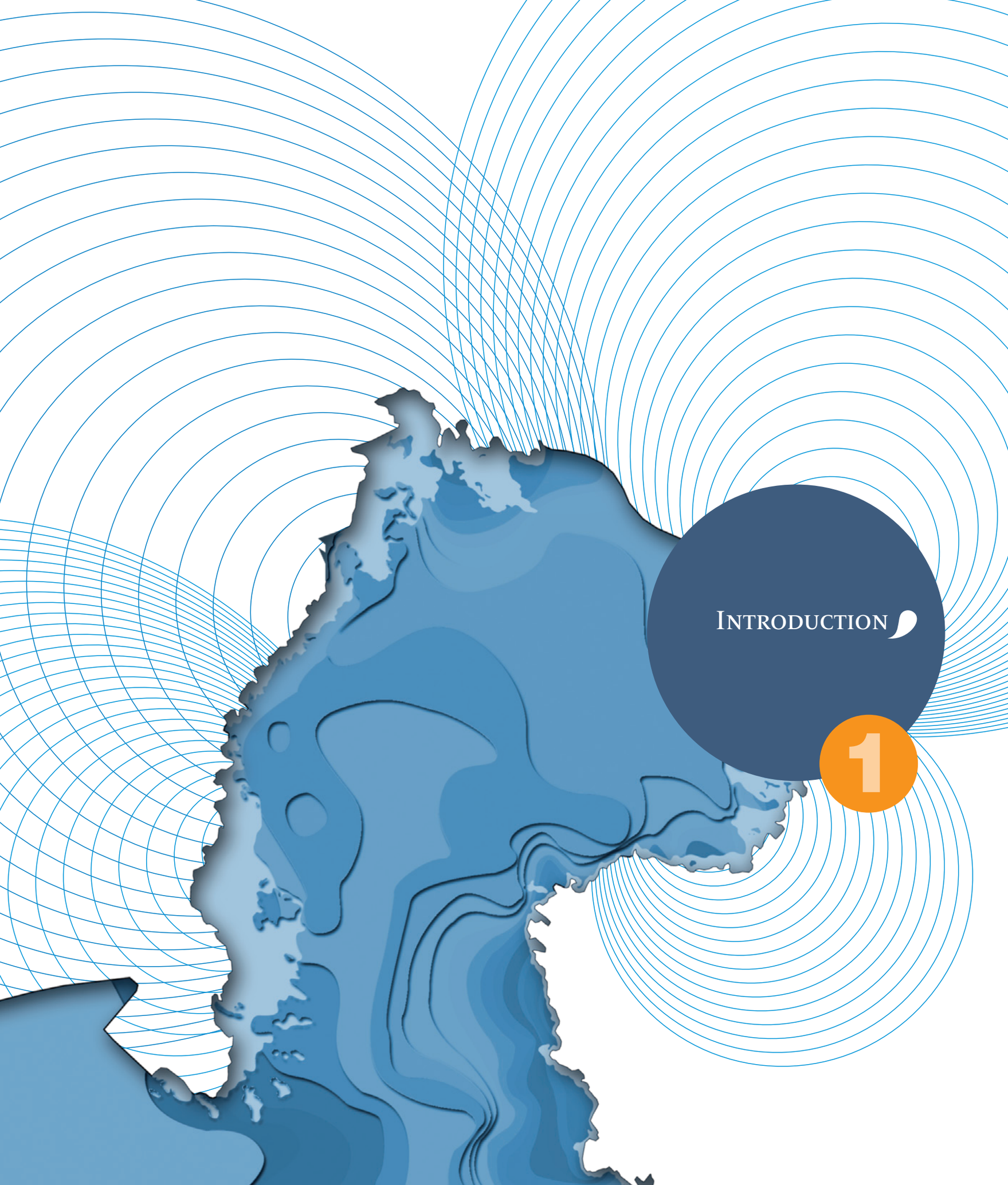
(i) management bodies need to assimilate knowledge, in order to become stronger and more effective (capacity building and assimilation of specific groundwater related themes);
(ii) dissemination instruments, developed under the PGAS, will continue to be used to raise public awareness as to the importance of groundwater and of the GAS, especially in the Pilot-Project areas, to stimulate public participation in management of aquifer resources;
(iii) technical bodies need to provide information for policy makers.

With respect to capacity building for groundwater management in general (and the GAS in particular) the top priority is to formulate national, state/provincial and municipal strategies for assimilation of technical and scientific knowledge produced by the Project. At the regional level, mechanisms need to be fostered to facilitate sharing of knowledge produced in each country. Just as the countries propose to share the management instruments that are a legacy of the Project (e.g., SIGAS, monitoring network, and mathematical models) under the coordination of Paraguay and through the Liaison Office, they are taking steps to make use of the dissemination materials complied.

A brief inventory of dissemination materials, encompassing the website, educational kits developed under the Guarani Citizenship Fund, the Project publications, and the video and TV programs, needs to be compiled and standard approaches developed for coordination and use of such materials, with the aim of providing the general public with information on themes relating to the GAS and promoting public participation in groundwater management.

Project for Environmental Protection and Sustainable Development of the Guarani Aquifer System





Introduction

1

Chapter 1

Introdution

SUMMARY

The Strategic Action Program (SAP) for protection, use, and sustainable management of the Guarani Aquiver System (GAS) is a long and short-term planning instrument for the countries where the aquifer is located (Argentina, Brazil, Paraguay and Uruguay) . The aim of the SAP is to foster coordinated and sustainable groundwater management, while acknowledging and respecting national sovereignty over the resource. Drafting of the SAP was based on a series of contributions generated under the Project for Environmental Protection and Sustainable Development of the Guarani Aquifer System (PGAS), considered the backbone of the SAP.

This report summarizes progress achieved during execution of the PSAG, highlighting technical, normative, institutional and public-participation aspects. It comprises strategic proposals for future actions to ensure sustainable management of the GAS in line with priority approaches.

Chapter 1, in particular, shows how the Project was structured, its importance within the framework of the SAP, the background, the institutional arrangements that enabled its deployment, and how it was carried out with ample public participation.

1 INTRODUTION

The Strategic Action Program (SAP) for Protection, Use and Sustainable Management of the Guarani Aquifer System (GAS) is a short and long-term planning instrument for the countries that have adopted it (Argentina, Brazil, Paraguay and Uruguay) and is based on a regionally coordinated strategic vision that acknowledges their national sovereignty over the resource.

The SAP is an expression of the desire of the countries to cooperate with each other, to strengthen convergent efforts, to continue expanding their knowledge, to foresee potential and emerging problems, and to resolve issues relating to the SAG, some of which are transboundary in nature. As a planning instrument, it was conceived by means of an intense process of participation, at the local, regional, and national levels, involving a large number of institutions, jurisdictions and social stakeholders with an interest in the protection, use, and sustainable management of this important aquifer system.

The SAP represents the high point of the Project for Environmental Protection and Sustainable Development of the Guarani Aquifer System (PGAS). This Project resulted from a request by the national Governments of Argentina, Brazil, Paraguay and Uruguay to the Global Environment Facility (GEF) and was carried out with the World Bank acting as implementing agency and the Organization of American States (OAS) as executing agency.

Based upon six years of work on the PGAS, the SAP proposes a new legal, institutional and technical framework, within which the participating countries will be able to strengthen management of the SAG. Its content not only reveals the intrinsic importance of cooperation among the participating countries, but also the arrangements necessary for maintaining the initiative.

This document is comprised of the following chapters, the content of which is described below:

- **Chapter 1:** presents the background to the PGAS, the institutional arrangements, and main outcomes achieved. It also recounts valuable contributions of public participation and the principal lessons learned.
- **Chapter 2:** presents the progress achieved in technical and scientific fields relating to the GAS, its characteristics, physical dimensions and limits, dynamics, and water quality. It also addresses water-use issues within the socioeconomic context of the region overlying the aquifer.
- **Chapter 3:** examines the bases for developing regional and coordinated approaches to sustainable management of the GAS. The chapter includes reflections on normative and institutional aspects, with the aim of enhancing groundwater management in the countries and jurisdictions, especially in relation to the GAS.
- **Chapter 4:** acknowledges, in an organized manner, the proposed strategic approaches and their respective priority actions, the logical process for assessing bases for their identification, including the Transboundary Diagnostic Analysis (ADT), taking into account outcomes of PGAS activities, and building upon discussions within the context of SAP workshops.
- **Chapter 5:** addresses the institutional and financial arrangements necessary for execution of the SAP and for sustainable management of the GAS, considering the different players and their respective responsibilities in execution of program activities. Moreover, the chapter presents conceptual and operational details of actions that comprise each of the strategic approaches.
- **Chapter 6:** summarizes the experiences of the four SAG Pilot Projects. It also presents proposals for follow up and enhancing groundwater management for each of these projects, strengthening the local focus, as one of the essential methodological contributions of the PGAS.

Lastly, there is a listing of bibliographic references consulted during preparation of this report, followed by annexes that provide complementary information for each of the chapters of the report.

1.1 GENERAL OBJECTIVE OF THE SAP

The aim of the SAP is to consolidate the process of coordinated and sustainable groundwater management for the SAG in each of the participating countries, based upon the original PSAG. This is to be achieved by means of definition of a coherent set of strategic actions, to be selected by consensus, at both the national and regional levels, in the four participating countries. These actions aim to prevent, remedy and/or resolve the causes of current and potential problems relating to the GAS, and to strengthen cooperation and coordination among the countries.

The SAP highlights areas for work and concrete actions for development of shared strategies and exchanges of information and successful groundwater-management experiences. It fosters synergistic cooperation efforts for protection and sustainable use of waters of the GAS and promotes construction of shared and consensual national initiatives that respect the principle that resources management is a responsibility of each individual country and of constitutionally-defined jurisdictions.

1.2 BACKGROUND

The first mention of the importance of the GAS as a means for promoting socioeconomic development was raised by universities of the region[1]. They called attention to the need for a regional research project, with participation of institutions of each of the governments and of such international cooperation agencies as the World Bank, the OAS, and the GEF. The existence and importance of the SAG were acknowledged by the Governments of Brazil and of Uruguay during a dialogue on the Quaraí River basin that straddles the border between the two countries. At that time, with a view to reducing the impact of drought in the region, a coordinated water resources management model was proposed that would integrate water of the SAG. This initiative was delivered by the two countries to the GEF, through

1 Federal University of Paraná (UFPR), Universidad de la República Oriental del Uruguay, Universidade do Litoral, Universidad de La Plata, and Universidad de Buenos Aires.

the OAS, at the same time as the universities initiative was submitted to the World Bank.

The scarcity and dispersion of information on the aquifer in the two countries, and differences in official terminology, posed a series of difficulties. These, in part, were resolved through a consensus on the name "Guarani[2]", suggested in 1996 at a meeting of universities of the region, held with support from the Canadian International Development Research Center (IDCR).

Following up on the work carried out by universities and under institutional agreements, the Governments of Argentina, Brazil, Paraguay and Uruguay identified the GAS as being a strategic resource for development, and agreed to work together to ensure its protection. They also acknowledged a need to accumulate more knowledge and to include all players in a mutual regional-cooperation effort.

The PGAS, originally drafted for submission to the GEF, was then converted into a tool for assisting the Governments of each of the countries to prepare a management framework for the GAS.

Execution of the PGAS began in March 2003 and ended on January 31, 2009. It was carried out in compliance with procedures and guidelines set by the donors, the GEF, the World Bank, and by the executing agency, the General Secretariat of the OAS.

Table 1 provides information on the main events that led up to preparation of the PGAS, up until its execution phase.

1.3 INSTITUTIONAL ARRANGEMENTS FOR EXECUTION OF THE PGAS

Through their respective executing agencies, the Governments of the countries involved set definitions and guidelines for the PGAS, from its preparation to its conclusion, using grant funding provided by the GEF and channeled through the World Bank.

During preparation of the PGAS, the Governments of the participating countries realized that specific arrangements were needed for project execution, and that the best approach would be to establish an ad hoc organization, with participation of each of the countries and operational support from a specialized agency. The GS/OAS was chosen toassume the role of executing agency. With a view to formalizing arrangements for execution of the PGAS, four legal instruments of similar scope were signed by the GS/OAS and the each of the Governments. These were then attached to the Project Appraisal Document (PAD)[3] drafted on the basis of proposals from the participating countries and approved by the GEF[4] . For its part, the GS/OAS, representing the four countries, signed a Cooperation Agreement with the World Bank in its role as the GEF implementing agency.

The PGAS received cooperation from the International Atomic Energy Agency (IAEA), the Federal Institute for Geociences and Natural Resources (BGR) and the Bank Netherlands Water Partnership Program (BNWPP) with the World Bank. Funding was distributed and invested in accordance with components and activities foreseen. The PGAS documents (PAD and PIP[5]) defined national counterpart funding for each country, which amounted to approximately 50% of the total resources for execution of the Project.

To oversee project activities, the countries agreed to establish a Project Steering Committee (CSDP) which received support during project execution from a Coordination Council (CC) comprised of National Coordinators (CN) appointed by the executing agencies. The CSDP was comprised of three representatives from each country, from the fields of water resources, foreing affairs, and environment, one of which also represented the national executing agency. The National Coordinators (CN) acted as Project focal points within the scope of each National Project Execution Unit (NPEU). They worked in coordination with the PGAS General Secretariat (GS-GAS)[6] to provide support for execution of activities foreseen.

The National Project Execution Units (NPEUs) served as venues for inter-ministerial and public participation of a deliberative and consultative nature for GAS-related themes in each country. The NPEUs were organized in accordance with criteria applicable in each of the four participating countries, based on a common understanding of the need to maintain broad-based institutional representation of the main players and stakeholders in GAS groundwater. In Argentina and Brazil, the NPEUs reflect the federal structure. In Brazil, aside from the NPEU, State Project Execution Units (SPEUs) were set up in each of the eight States that overlie the GAS. In Argentina, the NPEU was comprised of two representatives from each of the six Provinces that overlie the GAS, totaling 12 provincial representatives. In Paraguay and Uruguay, which are unitary states, the NPEUs were comprised of central-government officials.

Technical and administrative management of the PGAS was responsibility of the Project General Secretariat (GS-GAS) that assumed various activities, including: execution of work plans; preparation of tenders; guidance and supervision of the technical work of institutions in the countries; organization of meetings; coordination of work among countries, stakeholders, and cooperating bodies; preparation and presentation of technical and administrative project monitoring reports. The GS-GAS was also responsible for guidance, technical supervision, integration of outcomes of contracted consultancies, and establishment of the TDA and SAP.

After almost six[7] years of work, experience has demonstrated that the arrangements for execution employed resulted in advances in the agreements, and in the fulfillment of goals proposed by the PGAS.

2 The name "Guarani Aquifer System", coined by geologist Danilo Antón, reflects the fact that the area coincides with the boundaries of the Great Guarani Nation, the indigenous people of the region. The name thus pays homage to the Guarani, while at the same time signaling "a humble intention to restore humane values and the rich culture of this historic nation", one of the ancestral stocks of our mixed societies and nations"

3 Project Appraisal Document (PAD) published in May 2002, World Bank Report N. 23490-LAC.

4 According to the PAD, the PGAS received a GEF grant of US$ 13.4 million, national counterpart funding and grants from other donors (OIEA, BGR, BNWPP) of US$ 13.36 million, amounting to a total of US$ 26.76 million.

5 Project Implementation Plan (PIP) drafted during the Preparation Stage of the PGAS and approved in 2003.

6 Located in Montevideo, in offices in the Palácio Mercosul seconded by the OAS, the SG-PGAS has a specialized technical team headed by the Secretary-General and technical coordinators of the components. It is responsible for the monitoring of all routine activities of the project.

7 Initially planned to last four years, execution of the PGAS has been extended for an additional two years.

Figure 1 provides information on instructional arrangements adopted during the execution phase.

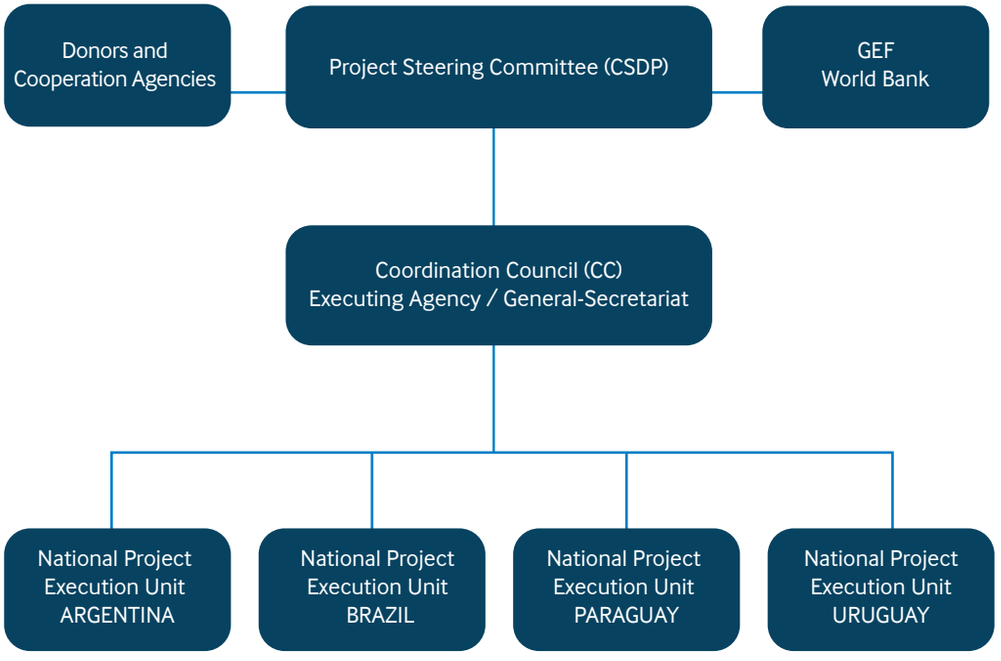
Tables 1 and 2 present a listing of meetings held within the scope of the CSDP, including a summary of resolutions approved by the Council, and a listing of CC meetings.

1.4 THE PROCESS OF EXECUTION OF PGAS COMPONENTS

From the Project preparation stage, the SAP was considered a central element for Project execution. The SAP proposal summarizes the outcomes achieved by each component, subcomponent, activity and task executed under the PGAS, the understanding of its objectives on the part of stakeholders, and the regional, subregional and local reach of its activities. The SAP is thus the outcome of mutual and cooperative efforts of the countries, performed throughout the years of execution of the PGAS. The scope and achievements of this process are to be assessed by indicators developed for each activity. Annex 3 presents tabulated information (Table 1) for each component of the PGAS, including its main outputs and stakeholders. Annex 4 summarizes the work carried out through the Guarani Universities Fund (Table 1).

The Project in many cases surpassed expectations and achieved significant results, including:

(i) Introduction and strengthening of the theme "groundwater" and activities relating to integrated water resources management in the four countries;
(ii) Production of documents, information, technical knowledge, and manuals of procedures on essential themes relating to groundwater management. This material was prepared and distributed by various players, and is available to all interested parties;
(iii) Generation of reliable information on groundwater, based on detailed technical studies;
(iv) Enhancement of exchanges of information on groundwater and on other factors relating to aquifer management in general and on the GAS in particular among countries and institutions;
(v) Raising of public awareness about the GAS and the need for sustainable management;
(vi) Creation of spaces for discussion and exchanges of views on management of the GAS;
(vii) Support for specialist studies on groundwater and related themes, by means of scholarships and training programs.
(viii) Establishment of local committees to provide support for management of the GAS at Pilot Projects, for future management of the GAS.



Source: PGAS Project Implementation Plan (PIP) 2002G.

Figure 1. Institutional Arrangements for Project Execution

A large number of people and organizations were involved in execution of the Project. News of the existence of a huge groundwater deposit known as the Guarani Aquifer System reached a television audience of 2.6 million. Execution of activities financed by the Guarani Citizenship Fund reached an additional 5 million people.

1.5 PUBLIC PARTICIPATION

Raising public awareness and involving civil society in water resources management, as expressed in the SAP, were assumed under the PGAS as a priority guideline in the four participating countries. This is in line with a worldwide trend to allow the public to play a central role in decision making on themes relating to execution of initiatives affecting the environment and natural resources. Both principle 10 of the Declaration of the United Nations Conference on Environment and Development, held in Rio de Janeiro in 1992, and the Inter-American Strategy for Public Participation (ISP) approved by the OAS in 2000, acknowledge the need for public participation in integrated water-resources management and that States have a duty to promote such participation.

Actions carried out by countries participating in the PGAS, such as the National Water Resources Plans of Argentina and of Brazil, Paraguay's Water Resources Law, and Uruguay's Constitutional Amendments are examples of this commitment. The PGAS promoted ample public participation, which

public participation and enlisting local commitment as a key requisite for sustainable development of the GAS. The strategy adopted by communities to enable participation entailed formation of Local Pilot Project Committees. The aim of such Committees is to influence public-policy decisions that affect the aquifer and to disseminate, apply, and evaluate local actions.

- The Guarani Citizenship Fund proved an important and effective public-participation tool. It was established in support of actions carried out by organized civil society in regions overlying the GAS. The fund provides support for both formal and informal actions in the fields of communications, participation and environmental education associated to the theme of groundwater and its sustainable use. It also fulfilled the need for communications with indigenous communities in the countries. For further details on the Guarani Citizenship Fund see Annex 5 (Table 1).
- The process of execution of the PGAS, especially during technical decision-making and analysis of outcome stages, entailed participation of representatives of various public and private bodies, non-governmental organizations (NGOs) and national institutions. Such participation was particularly evident during drafting of the TDA and of the SAP. In activities carried out under the PGAS, over forty non-governmental organizations were involved.
- In consonance with the original goals of the Project, a series of actions were carried out with indigenous communities of Argentina, Brazil and Paraguay. These led to strengthening of ties between national institutions that work with indigenous themes. Documents were prepared in the Guarani language, and technical information was disseminated. The SAP incorporated proposals raised during meetings and through agreements with indigenous leaders, as is recounted in Chapter 5.

1.6 GENERAL SCOPE OF PROJECT EXECUTION

Starting from a brief analysis of the historical background of water resources management in each of the countries during the Project's preparatory stage, it became clear that the proposal would be well accepted and could contribute toward fulfilling expectations and enhancing incipient management initiatives underway in each of the participating countries. Groundwater management was as yet an undefined theme in the GAS region, and prospects were still unclear. Certain isolated and limited initiatives had been attempted in areas where, historically, groundwater had played a role in fostering development.

Within the scope of national and sub-national water-resources management bodies, there were no specific standards or methodological approaches for treating groundwater. Despite use of the term 'integrated', in general, water resources management applied only to surface water. In part, the abundance of surface water in the region explains this situation. The role of groundwater in maintenance of ecosystems had received little attention.

To some extent, weaknesses in groundwater management reflected a dearth of academic literature on the theme. This became evident when comparing the production of knowledge on groundwater to studies on surface water resources. Very little systematic information can be found on quality and quantities of groundwater; few detailed studies exist on aquifers, and there are practically no tube-well databases.

It is thus understandable that much of the population, including public school systems and civil society (NGOs) simply had no information on aquifers or groundwater. This was the situation when the four countries drafted the initial proposal for the PGAS, and it was the transboundary aspect for protection of the GAS that served to cement their commitment. It was thus during execution of the PGAS, and to a great extent as a consequence of it, that a technical, normative and institutional framework for groundwater resources management was developed.

Likewise, worldwide, there was very little experience of regional cooperation among international agencies on management of transboundary aquifers. This merely underscores the pioneering nature of this Project carried out by the four countries that, within the framework of the GEF's Operational Program 8[8] for bodies of water, led to the first SAP for transboundary groundwater management.

1.6.1 International / regional scope

The experience and lessons learned during execution of the PGAS were presented, disseminated, and analyzed in various regional and international forums on water and environment. Activities of the PGAS have become a reference that transcends the borders of the four countries involved and, indeed, of South America. In view of burgeoning challenges posed by groundwater management worldwide, the lessons learned have taken on extraordinary relevance. Some of the outstandingly innovative features of the PGAS stem from experiences of its Pilot Projects, which served to test organizational tools and to enlist support for local management initiatives of crucial importance for protection of groundwater, compatible with the political context of border regions and requisites of transboundary groundwater management.

Just to exemplify, there follows a listing of some of the international and regional events at which presentations were made on the PGAS:

- World Bank Water Week - United States.
- GEF International Waters Conferences - China, Brazil and South Africa.
- Conference on Groundwater Governance and Management in Arid and Semi-arid Countries - Egypt.
- GEF International Waters Learning Exchange and Resource Network meetings and seminars (GEF IW-Learn);
- II and IV World Water Forums - Japan and Mexico;
- V and VI International Water Management Dialogues – Inter-American Water Resources Network - Jamaica and Guatemala
- Global Water Partnership (GWP) conferences and seminars;

8 The long-term objective of PO 8 is a series of projects for assistance to groups of countries to enable them, with assistance of the executing bodies, to collaborate with reform of their sectoral policies, with a view to resolving transboundary environmental problems that affect specific bodies of water.

- ExpoZaragoza - Spain;
- Water Forum of the Americas, preparatory meeting for the VI World Water Forum in Turkey - Foz do Iguaçu, Brazil;.
- United Nations Conference on Institutional Capacity Development in Transboundary Basins - Bonn, Germany;

The Base Map of the Guarani Aquifer System (scale 1:3,000,000) prepared under the PGAS with support from the Canadian Tecsult company won 2nd prize in the 'best data integration' category at the International Users' Conference of the Environmental Systems Research Institute (ESRI) - San Diego, California.

At the global level, the project was considered an innovation, in that it entailed work by four different countries for protecting a groundwater resource that in part straddles national borders, and that it led to establishment and maintenance of a regional cooperation structure capable of implementing comprehensive thematic approaches. It was thus, indeed, considered a ground-breaking experience.

The dynamic nature of the PGAS, as a regional cooperation project involving four countries targeted at producing knowledge and protecting the GAS, strengthened ties and added impetus to a process of integration already underway in the region and, in this respect, its main outcomes were:

- Strengthening of bonds of trust and exchanges of technical information among institutions in the four countries. Strong ties of technical, normative, institutional and social cooperation were established on themes relating to water resources, and especially groundwater;
- Opportunities to apply technical and financial resources for regional and local projects and actions directly and indirectly related to the GAS. This greatly facilitated establishment of a dialog among national institutions and international cooperation and financing agencies;
- Joint generation of knowledge and exchanges of information. This proved a key requisite for building trust among participants in the different countries and for fostering a shared vision of the GAS;
- Opportunities for national representatives to make presentations on the importance of the GAS at forums within the scope of the Common Market of the South (MERCOSUR), its Parliament (PARLASUR) and other regional bodies;
- Inclusion and establishment of ties among all parties committed to instituting integrated management and protection of the GAS, including universities and research foundations, social organizations and environmental journalist in the four countries, working through networks to provide technical support for the PGAS.

The PGAS also served to strengthen a variety of initiatives and projects in the fields of management and protection of natural resources in the Western hemisphere, including:

- GEF/UNEP/OAS Projects that built upon lessons learned under the GEF's DELTAmerica Project;
- International Shared Aquifer Resource Management Initiative (ISARM Americas) for transboundary aquifer management, sponsored by UNESCO and by the OAS, for which the background accumulated by the PGAS was one of the guiding elements for other such transboundary aquifers as the Yrendá - Toba – Tarijeño Aquifer between Argentina, Bolivia and Paraguay, and the Pantanal Aquifer between Brazil, Paraguay and Bolivia;
- Initiatives relating to the Inter-American Water Resources Network;
- Support for the Intergovernmental Committee of Countries that share the La Plata Basin, in the formulation of the Framework Program presented to UNEP and to the GEF;
- Meetings at forums within the scope of MERCOSUR and PARLASUR;
- The Central American Regional Committee on Hydraulic Resources (CRRH) expressed interest to the World Bank and the OAS in applying the experience of the PGAS, and especially its cooperation mechanisms, to the management of transboundary aquifers in Central America;
- Aside from support for such specific technical networks as the Environmental Communications Network of Latin America and Caribbean, support was also provided for the CAP-NET training network and the Latin-American Association of Groundwater Hydrology for Development (ALHSUD).

1.6.2 National level

In each of the countries, the scope of the PGAS at the national level was significant for the development of themes relating to groundwater management and to the GAS. It fulfilled an important role in raising public awareness as to the location and importance of the GAS, its function, potentialities, and vulnerabilities.

The PGAS served as an argument to move forward with discussions regarding environmental and water-resources themes, especially those relating to groundwater management and protection. This impact could be perceived in various public and private spaces, in social organizations, and in formal and informal networks.

The Project and its actions led to the formation of a space for dissemination of communications and ideas within institutions in each country that share responsibilities for water resources management, which in turn proved to be a key factor for placing the theme of groundwater firmly on national, regional and local public agendas in the countries.

The establishment of opportunities for national and regional coordination by the NPEUs, including an array of institutions and players that participated in the PGAS, enabled development of an integrated focus. It also entailed joint reflection on jurisdictional issues at the various levels and within governmental institutions of the countries involved.

The organizational structure encompassed a number of ministerial institutions, non-governmental organizations, and scientific and technical systems of universities. Activities of the Guarani Citizenship and Universities Funds,

aside from enabling participation of specialists in technical debates, proved to be agile, efficient and adequate mechanisms for promoting applied research, integration of regional capacities, and dissemination of public information at various levels, including actions carried out with indigenous communities in Argentina, Brazil and Paraguay.

Confirmation that groundwater management would be carried out at the local level and that it would involve local stakeholders and water users was, unquestionably, one of the strong points of the Project. Execution of Pilot Projects enabled local communities to appropriate knowledge on the GAS, and opened up significant opportunities for public participation.

Among the advances achieved were:

- Identification of critical zones for protection of the GAS in four areas encompassed by Pilot Projects.
- Installation of reference centers on the theme "groundwater", such as the one in Ribeirão Preto, Brazil.
- Debates on the GAS within existing institutional spaces, such as the Technical Chambers on Groundwater in certain Brazilian States, and the Local Committee of the Itapúa Pilot Project, in Paraguay, that provided stimulus for establishment of the Capiibary Basin Committee, with a focus on sustainable agricultural soil and water-resources use, in compliance with the Paraguayan Water Resources Law, approved in 2008.
- Numerous national and international technical and scientific publications on the GAS, stemming from studies carried out by teaching and research institutions, including a vast number of papers by young academics who were inspired by the GAS to pursue scholarships, internships, doctorates and masters' degrees.
- New graduate courses, such as Specialization in Uses of Thermal Waters, offered by the Faculty of Health Sciences of the National University of Entre Rios, Argentina.
- Building of environmental awareness in schools, in the area of the Rivera/Santana do Livramento pilot project sponsored by the Guarani Aquifer Transboundary Commission (COTRAGUA) and support for the two municipalities in raising funding to solve household sewage treatment problems.
- Stimulus for new cooperation initiatives on groundwater issues. Examples include the Pró-Rio Uruguay – Aquifer Guarani program, in the Brazilian States of Rio Grande do Sul and Santa Catarina. cooperation between the Secretariat for Environment (SEAM) of Paraguay and the German Geological Service (BGR); and aforementioned initiatives carried out under the ISARM Americas Program.

The PGAS played a role in motivating advances and improvements in groundwater management in each of the countries involved. These included:

- Approval, by the Under-Secretariat of Water Resources of Argentina, of a federal groundwater program with a component dedicated to transboundary aquifers and closer ties between Provincial authorities and the Federal Water Council (COHIFE) on themes relating to the GAS and to groundwater;
- Enhancement of Brazil's National Water Resources Plan and ensuing activities for increasing technical knowledge and capacity building on groundwater, carried out by Brazil's National Water Agency (ANA);
- Inclusion of the theme "groundwater management" and the stimulus provided by the PGAS during the process of enactment of Paraguay's Water Resources Law (Law 3.239/2007) during which outputs of the PGAS, and especially those relating to the Itapúa Pilot Project, served as national references, helping the country put the law into effect;
- Implementation of the Water Resources Law and creation of a GAS national management unit in Uruguay.

1.7 LESSONS LEARNED

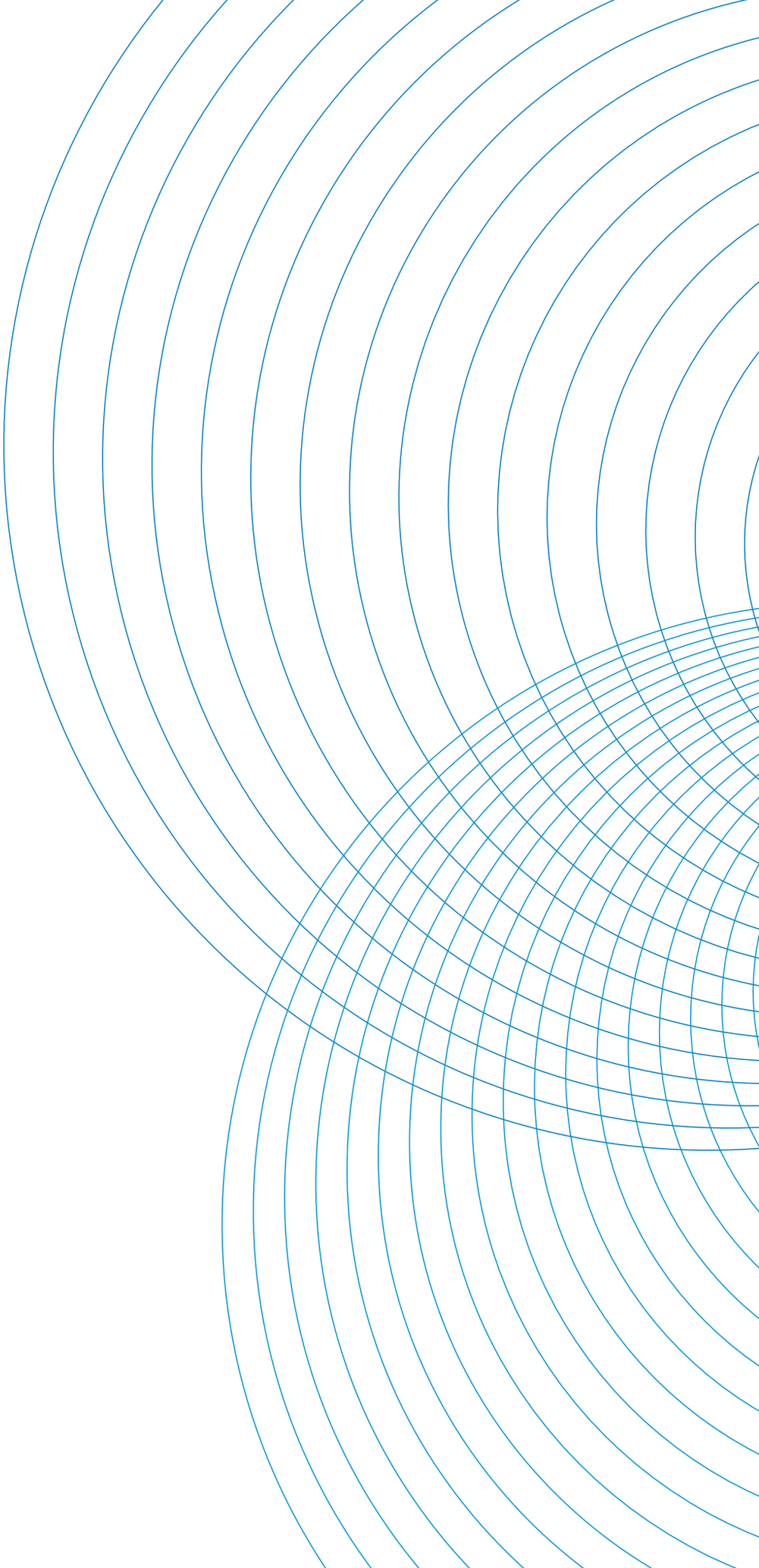
Execution of the PGAS resulted in numerous lessons learned, encompassing technical and institutional aspects. The PGAS was identified as part of the SAP preparation process, with the aim of disclosing the standpoints of representatives of the NPEUs and of National Coordination Units in each country. Among the main lessons learned were:

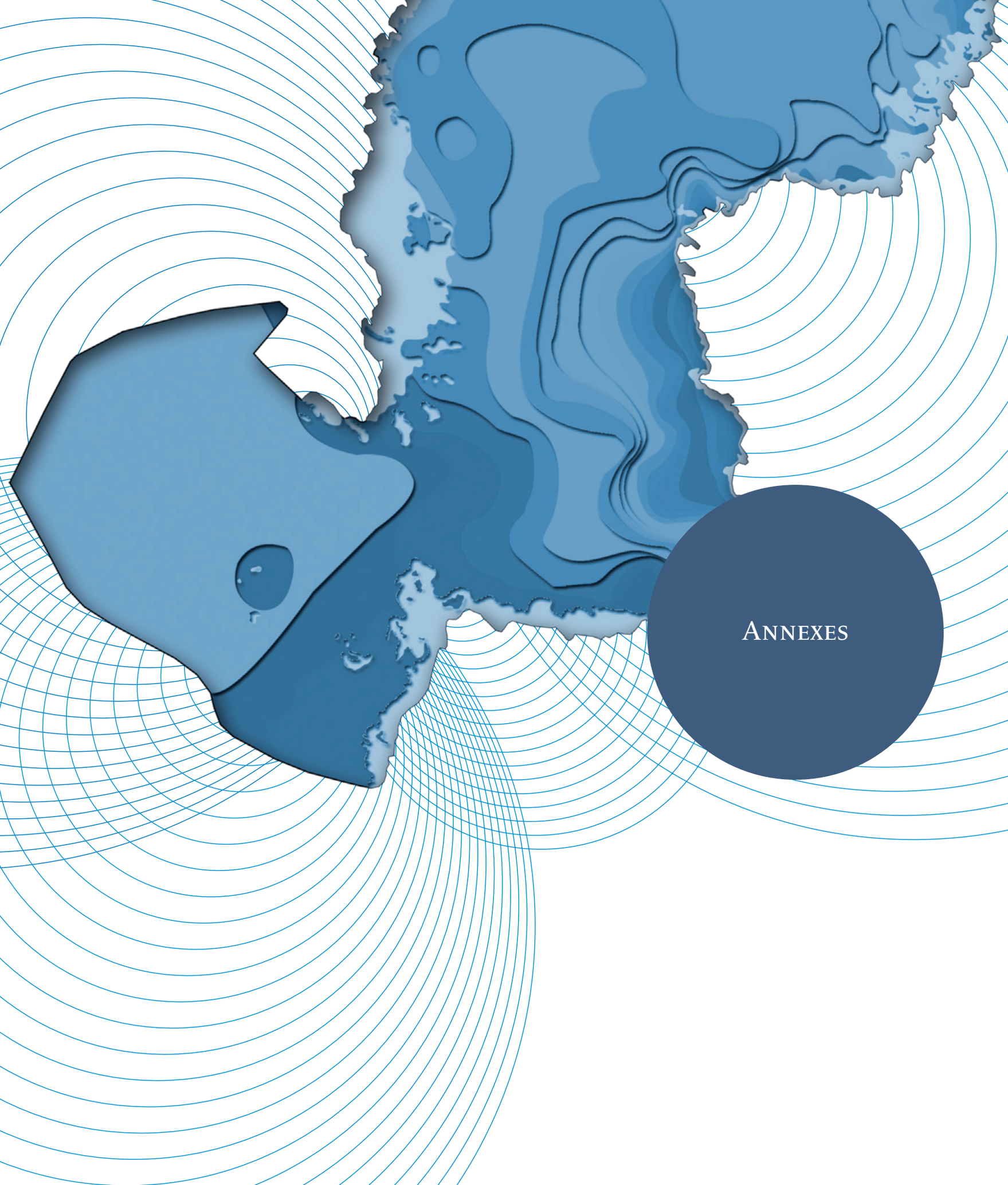
- Cooperation among the countries, without which regional coordination could not have taken place, made considerable strides and led to a sharing of preexisting knowledge on the PGAS. The PGAS proved to be an effective instrument for significantly deepening and expanding the technical and scientific knowledge needed for management of the GAS, through contributions from private companies, universities and research centers, consultants, non-governmental organizations, and local specialists.
- Mobilization of the public, the active roles played by the various players and their close involvement with technical and institutional bodies and cooperation agencies were key factors for the successful outcomes of PGAS actions. Such public participation indicates a path to be strengthened and consolidated through execution of the SAP.
- The institutional arrangements of the PGAS ensured participation of a variety of institutional players and fostered interdisciplinary approaches. The Project Steering Committee (CSDP) as the highest decision-making body for the project established by the Governments of the countries involved, proved to be an appropriate mechanism for reaching consensus on general guidelines and steps to ensure sustainable management of the GAS. The structure of the NPEUs fulfilled the need for an inter-institutional and inter-sectoral support network for assessing and evaluating information, generating exchanges, and disseminating outcomes and challenges of the PGAS.
- In certain cases it was found that the SG-GAS, as the management unit, was not fully compatible with the needs of the countries, essentially in view of structural weaknesses in the water-resources

management institutions at both the national and sub-national levels, especially where responsibilities and capacities are still not fully developed. This tended to affect the time needed for analyses, appraisals and responses to documentation produced. Furthermore, the development of formal and informal regional understandings with and among countries (success indicators) also requires time. It is important that schedules of activities for future actions included in the SAP take these difficulties and limitations into account, that the capacities of the NPEUs and National Coordination Units be improved, and that regional cooperation structures be reinforced, so as to prepare them to respond to these multiple demands.

- The attributions and responsibilities of the NPEUs, their representativeness, and real capacity to reorganize execution of programs need to be better defined at the start of projects of this type, so as to ensure ample and diversified participation. The NPEUs ought to have placed more emphasis on the users of water from the GAS.
- Execution of the PGAS occurred in stages of varying intensity. In some, great quantities of information were generated, whereas others entailed administrative tasks that elicited less motivation of players in PGAS discussion forums. In view of this, in the case of the SAP, continuous streams of new information should be generated throughout the entire SAP program-execution period as this will, unquestionably, awaken public interest and stimulate active participation.
- In projects as complex as the PGAS, involving great numbers of institutions and players, it is important to strengthen and formalize processes for exchanging messages, holding work-related dialogs, and participating in decision-making on future stages of the SAP, including meetings of the CC, the dispatch of NPEU notes, and formulation of proposals at CSDP meetings. It is essential that coordination among bodies at different levels within the NPEUs and the CSDP in each country be improved, so as to ensure the representativeness of their decision making processes.
- The willingness of the countries to advance with the PGAS and to exercise sovereignty in their management of the aquifer and in other relevant themes encompassed by the Project, should have been the focus of greater attention from the earliest stages of project preparation and execution. This could have reduced certain resistance to the participation of international agencies, which some organizations regard as an undermining of national interests.
- Despite acknowledged advances in communications and dissemination of information, owing to the size of the GAS, certain regions and communities were not reached by the Project, and this is a problem that will have to be addressed in subsequent stages of the project. The PGAS website proved to be a key tool for promoting working dialogs. User-friendly enhancements to the website could facilitate debate and awaken interest of both the public and of players directly involved in the initiative. The website proved an effective and useful communication and dissemination tool that greatly contributed toward the transparency of the PGAS.
- Pilot Projects have proven useful tools for supporting countries during joint drafting of local management initiatives for preservation of the GAS. Several of these experiences encompass areas of particular interest and could, unquestionably, be replicated in other localities overlying the GAS. These initiatives represent the combined efforts of the technical staffs of national, provincial, and local public bodies with the support of facilitators contracted under the project, NGOs, universities, and other organizations. The work encompassed a variety of aspects, including dissemination, institutional ties, and coordination activities at the local, state, national and international levels. A lesson learned from these experiences is the importance of establishing mechanisms linking the various management bodies at different levels that work in pilot zones, so as to provide institutional support for local committees. Institutional relationships should be assessed during the initial stages of project preparation, with emphasis upon project execution, with a view to enabling arrangements to mature and evolve in consonance with local expectations and demands.
- In terms of capacity building, the PGAS provided a means of significantly enhancing skills, by means of courses, technical visits to contracted companies, and internships for institutional staff working on tasks and projects at the SG-GAS. The Project innovated by fostering close relationships between staff of the institutions involved, consultants, and contracted companies. Technical staff members of national and local institutions monitored and supervised the work of consultants. Despite the capacity building offered in the fields of groundwater and aquifer management, there is still a pressing need for more skills training in the region. It is thus of crucial importance to enhance capacity-building mechanisms that have proven effective in practice and to strengthen institutional participation of management bodies, especially at the regional level, through providing training directly for permanent staff or promoting effective interaction among such bodies, so as to ensure formal and official delivery of information. Strengthening of such ties is among the main aims of SAP activities. Consolidation of agreements with institutions and with individual consultants could prove an adequate approach for strengthening institutions.

The PGAS proved to be an effective instrument for deepening and expanding technical and scientific knowledge on the aquifer system, by means of participation of players, including companies, universities, non-government organizations, and local specialists. Maintaining and deepening these relationships is one of the challenges faced by the SAP.





Annexes

ANNEX 1

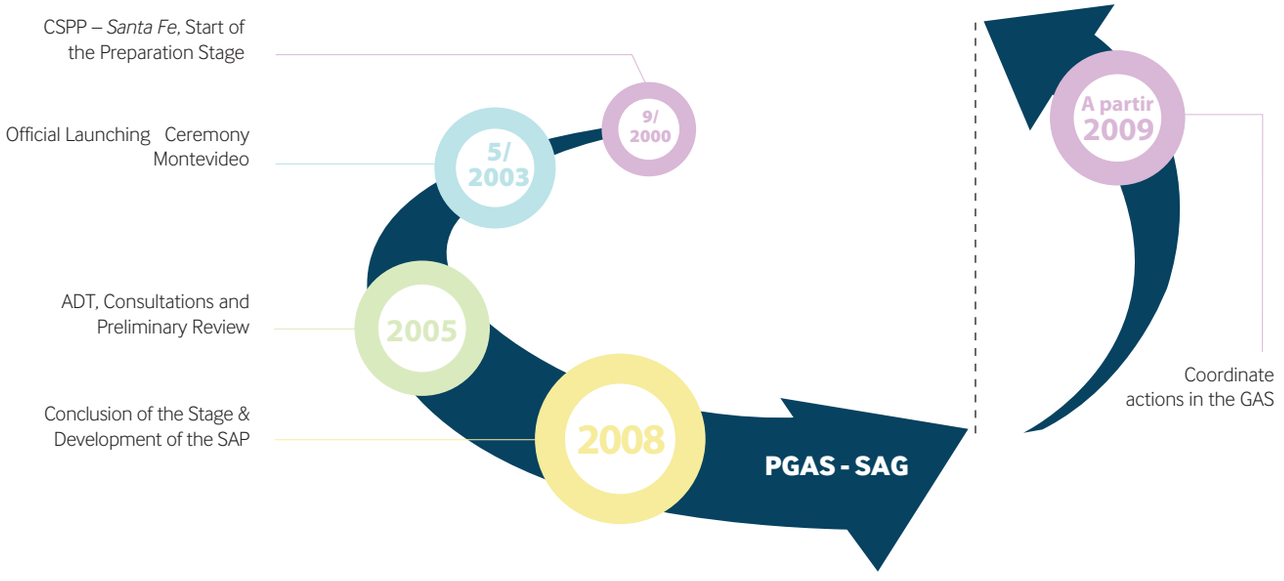
Table 1. Main events

Date	Main events
January 2000	Meeting in Foz do Iguaçu. Approval of the Project Appraisal Document by participating countries
April 2000	Approval, by the Global Environment Facility (GEF) and World Bank of a US$ 350,000 grant for preparation of Proposal PDF-Block B, for drafting of a regional project for transboundary water resources management
September 2000	Technical Seminar for Launching of the Project and 1st Meeting of the Project Steering Committee (CSPP) in Santa Fe, Argentina. Beginning of the preparation phase
December 2001	Approval of the Project Appraisal Document (PAD) by the GEF Board
May 2002	Approval of the Project by the GEF Executive Officer
June 2002	Approval of the Project by the Board of the World Bank
July 2002	Signing of the GEF Grant Agreement by the World Bank and the OAS
August 2002	Selection of the secretary-general for the Project by the CSPP
October 2002	Signing of the GAS Guarani Universities Fund agreement between the World Bank and the OAS
November 2002	Signing of the Memorandum of Understanding between the Ministry of Transport and Public Works of Uruguay and the OAS for execution of the Project
December 2002	Signing of the Complementary Adjustment between the OAS, the Brazilian Cooperation Agency (ABC) and Brazil's National Water Agency (ANA) for execution of the Project
January 2003	Signing of the Memorandum of Understanding between the OAS and the Permanent Representative of Paraguay to the OAS for execution of the Project Signing of Terms of Cooperation between the OAS and the Under-Secretariat for Coordination and International Cooperation of the Ministry of Foreing Affairs, International Commerce and Worship of Argentina, for execution of the Project Publication of calls for proposals in the four countries for Projects under the Guarani Universities Fund
February 2003	Start of effective Project execution by the OAS and the World Bank in the countries
May 2003	Official Ceremony for Launching of the project, at the MERCOSUR Building in Montevideo, Uruguay Approval of the Project Implementation Plan (PIP) and of the Project Operation Plan for 2003 (POP 2003)

Fonte: Desenvolvido pela SG/SAG, 2008.

Factors that contributed toward conclusion of all stages, approval of the proposal by the GEF, and receipt of the respective funding included (see Figure 1):

- Acknowledgement, by all of the parties, of the transcendence of the Project's goals, in view of the magnitude and importance of the GAS resource of the GAS;
- Good cooperation environment among the countries, resulting from various previous diplomatic initiatives on issues relating to water resources management;
- A relationship of trust and cooperation among the countries and international agencies involved;
- Priority awarded to the technical and procedures and formalities of the project preparation and approval processes, both by governmental bodies and international agencies;
- The great interest and technical capacity of all players that participated in preparatory meetings, and especially the representatives of governments, of national executing agencies, and public institutions responsible for use, preservation and management of natural resources;
- The great strategic importance the countries and bodies involved attributed to the Project, that is considered the first GEF Project in the field of transboundary groundwater resources.



NB: CSPP (Project Steering Committee); TDA (Transboundary Diagnostic Analysis)..

Source: Developed by GS/GAS, 2008.

Figure 1. Timeline of GAS

ANNEX 2

Annex 2 Information on the Project Steering Committee (CSDP) and Coordination Committee (CC)

Table 1. Meetings of the Project Steering Committee (CDSP) and its resolutions

Meeting nº	Date	Venue	Minutes nº	Resolutions
I	May 23, 2003	Press Room Edifício Mercosur, PB. Montevideo, Uruguay	MINUTES 01	**Resolution 01/2003:** Instituted the Guarani Universities Fund and approved its bylaws **Resolution 2/2003:** Instituted the Guarani Citizenship Fund and approved its bylaws
II	November 20 and 21, 2003	Ministry of Economy. Buenos Aires, Argentina	MINUTES 02	**Resolution 03/2003:** Approved the bylaws of the CSDP **Resolution 04/2003:** Established the Guarani Citizenship Fund **Resolution 05/2003:** Approved the Project Operational Plan for 2004
III	June 24 and 25, 2004	Palácio do Itamaraty, Sala Geminada "A". Brasília – DF, Brazil	MINUTES 03	**Resolution 09/2004:** Approved the Draft Declaration of Basic Principles and Lines of Action for the Guarani Aquifer System and determined its dispatch to the foreign ministries of the countries – members of the CSDP for their considerations
IV	December 9 and 10, 2004	Hotel Sheraton, Sala Rio Paraná. Asunción, Paraguay	MINUTES 04	–
V	June 30 and June 1st 2005	Press Room, Edifício Mercosur, PB. Montevideo, Uruguay	MINUTES 05	*Minutes of the Transfer of the Presidency from Paraguay to Argentina*
VI	June 7 and 8, 2006	Palácio San Martin, Chancellery Argentina. Buenos Aires, Argentina	MINUTES 06	**Resolution 12/2006:** Approved expansion of the project for a period of 22 months, finishing on January 31, 2009 **Resolution 13/2006:** Approved the Project Operational Plan for 2006
VII	November 23 and 24, 2006	Hotel Paraná Suíte, Curitiba, Brazil	MINUTES 07	**Resolution 14/2006:** Approved the Project Operational Plan for 2007
I Reunião Extraordinária	March 28 and 29, 2007	Edifício do Mercosur, PB. Montevideo, Uruguay	MINUTES 08	–
VIII	May 10 and 11, 2007	Hotel Sheraton. Asunción, Paraguay	MINUTES 09	*Minutes of the Transfer of the Presidency from Argentina to Paraguay*
IX	November 8 and 9, 2007	Salão de Atos of the Ministry of Transport and Public Works. Montevideo, Uruguay	MINUTES 10	–

Continues

Continuation

X	April 24 and 25, 2008	Palácio San Martin. Buenos Aires, Argentina	MINUTES 11	*Minutes of the Transfer of the Presidency from Paraguay to Argentina* **Resolution 15/2008:** Creation of the Work Group GTCR
XI	November 3 and 4, 2008	Ribeirão Preto, Brazil	MINUTES 12	–
II Reunião Extraordinária	November 25, 2008	Foz do Iguaçu, Brazil	MINUTES 13	–

Source: Prepared by GS/GAS 2008.

Table 2. Meetings of the Project Coordination Committee (CC)

DATE	VENUE
March 11, 2003	Meeting Room of the OAS in Montevideo, Uruguay
June 1 and 2, 2003	Under-Secretariat for Water Resources and World Bank Head Office in Argentina (videoconference with Washington)
May 21, 2003	Meeting Room of the General Secretariat (GS) of the Project (Dr. Didier Opertti Badan). Montevideo, Uruguay
September 5, 2003	Project Headquarters. Ed. Mercosur, 2 floor. Montevideo, Uruguay
October 30, 2003	Project Headquarters. Ed. Mercosur, 2 floor. Montevideo, Uruguay
November 10, 2003	SSRH – Ministry of Economy. Buenos Aires, Argentina
November 18, 2003	Project General Secretariat, Edifício Mercosur. Montevideo, Uruguay
June 17 and 18, 2004	Project General Secretariat, Edifício Mercosur. Montevideo, Uruguay
August 19 and 20, 2004	Project General Secretariat, Edifício Mercosur. Montevideo, Uruguay
September 23 and 24, 2004	Project General Secretariat, Edifício Mercosur. Montevideo, Uruguay
November 25 and 26, 2004	Project General Secretariat, Edifício Mercosur. Montevideo, Uruguay
June 22, 2005	Project General Secretariat, Edifício Mercosur. Montevideo, Uruguay
June 9 and 10, 2005	Project General Secretariat, Edifício Mercosur. Montevideo, Uruguay
March 30 and 31, 2006	Project General Secretariat, Edifício Mercosur. Montevideo, Uruguay
November 13 and 14, 2006	Project General Secretariat, Edifício Mercosur. Montevideo, Uruguay
February 14 and 15, 2007	Project General Secretariat, Edifício Mercosur. Montevideo, Uruguay
March 8 and 9, 2007	Project General Secretariat, Edifício Mercosur. Montevideo, Uruguay
May 9, 2007	Secretariat of Environment (SEAM). Asunción, Paraguay
October 10 and 11, 2007	Project General Secretariat, Edifício Mercosur. Montevideo, Uruguay
March 12 to 14, 2008	Project General Secretariat, Edifício Mercosur. Montevideo, Uruguay
August 28 and 29, 2008	Project General Secretariat, Edifício Mercosur. Montevideo, Uruguay

Source: Prepared by GS/GAS 2008..

ANNEX 3

Table 1. Summary of Execution of the PGAS

Component I	
Expansion and consolidation of the scientific and technical knowledge base on the Guarani Aquifer System	
Activity	**Consultant / Executing Institution**
- Inventory, sampling, geology, geophysics, Hydrogeochemistry - Isotopes and hydrogeology located in Pilot Project Areas and in the GAS - Geology and geophysics (regional and Pilot Areas) - Inventory and sampling South Zone - Inventory and sampling North Zone - Hydrochemistry South Zone - Hydrochemistry North Zone - Isotopic sampling - Hydraulic testing North and South Zone - Hydrogeology Concórdia–Salto - Hydrogeology–Itapúa - Hydrogeology Ribeirão Preto - Hydrogeology Rivera–Santana do Livramento - Numeric model Concórdia–Salto - Numeric model Itapúa - Numeric model Ribeirão Preto - Numeric model *Rivera–Santana do Livramento* - Map on use of the GAS Itapúa - Socioeconomic Concórdia–Salto - Socioeconomic Ribeirão Preto - Use of the GAS Rivera–Santana do Livramento - Monitoring Network - Frequency and Procedures – Monitoring Network NORTH - Frequency and Procedures – Monitoring Network SOUTH	SNC Lavalin International, Inc.
- General hydrogeology, thermalism and regional model of the GAS - Design and Implementation of the SIGAS Hydrogeological Database - Design of the GAS Regional Monitoring Network - Regional Hydrogeology of the GAS – Final Report - Regional Hydrogeological map of the GAS Scale 1:3.000.000 - Regional Numeric Model of the GAS - Potential geothermal resources and uses of the GAS - Drilling Manual for the GAS - Guide to Sampling and Preservation of Groundwater for Chemical and Isotopic Analyses - Manual on Stratigraphic Sampling and Laboratory Techniques - Manual of Geophysical Techniques Applied to Studies of the GAS - Manual on Pumping Tests. Execution and Interpretation - Manual for Determining Vulnerability, Risks and Calculations of the GAS Protection Perimeter - Guide to GAS Replenishment Areas with Forestry Plantations - Summary of the Regional Geology of the GAS - Socio-Demographic Evaluation of Capacity to Adapt to Changes in the Uses of the GAS - *Chaco-Paraná* Western Limit in Argentina (Salta and Tucumán Provinces) - Geology of the Northern and Eastern regions of Bolivia - Paleomagnetism and Paleocurrents - Evaluation of Hydrochemical Information	Guarani Consortium

Continues

Continuation

- Numeric Simulation of the GAS Non-Saturated Zone
- Climatology and Hydrometeorology
- Water and Hydrogeological Balances
- Land Use Maps based on Satellite Images
- Summary of the Regional Geology of the GAS – 3rd GAS Regional Geology Report
- BDH updates
- Seminars

- Final TOR on Regional and Local Studies	Albert Mente
- TOR Hydrochemical	José Lobos
- TOR Hydrochemical	André Virmond Lima Bittencourt
- TOR Geophysics	Augustinho Rigoti
- TOR Geology	Eduardo Antonio Rossello
- Quality Control RRHH Enterprises	Celina Bizzozero
Component II	
Development and instrumentation of the GAS management structure	
Activity	**Consultant / Executing Institution**
- Implementation of the Guarani Aquifer GIS Portal	Tecsult International Limitee
- TOR on Public Participation	Enrique Mazzei Sasiaím
- Consultancy to Develop a TOR for Contracting Basic Cartography for the Project	Lilián Techeira
- Consultancy to Develop Operational Regulations for Capacity Building and Institutional-Strengthening Activities	Oscar Julio López de la Fuente
- Design of the Geographic Information System for the Project, Drafting of TORs for Procurement of Equipment for Information Centers	Raquel Noemí Tardivo
- TDA Facilitator	Antonio Eduardo Leao Lanna
- PALp Facilitator - Consultancy for Drafting of the Report on Conclusion of Implementation and Project Outcomes Report	Pablo Decoud
- SAP Liaison, Argentina	Griselda Galindo
- SAP Liaison, Brazil	Márcia Tereza Pantoja Gaspar
- SAP Liaison, Paraguay	Oliva Nilsa Ocampos de Decoud
- SAP Liaison, Uruguay	Juan Carlos Canabal Menéndez
- Specialist Support for the Geographic Information System (GIS)	Edison Jorge Rosas Berton
- Legal Advisor for Drafting of the PGAS Strategic Action Program	Ana María Vidal Medeiros
- Institutional Advisor for Drafting of the PGAS Strategic Action Program	Rogério Dewes
- Economic Advisor for Drafting of the PGAS Strategic Action Program	Raymundo Garrido
- Especialista SISAG e SIAGAS	Wilfredo Pacheco Hernández

Continues

Continuation

Component III	
Public participation, education and communication	
Activity	**Consultant / Executing Institution**
- FGC Project: "A Drop of Water, a Drop of Hope for the Guarani Aquifer"	Fundation Moisés Bertoni
- FGC Project: "the Communications Power of Water"	Argentine Association of Environmental Journalists (AAPA)
- FGC Project: "The Guarani Aquifer Goes to School. Strategy for Participation, Citizenship and Environmental Education"	Fundation Ecologica Universal - FEU
- FGC Project: "Environmental Education Campaign – Guarani Aquifer System"	"Nuestra Señora de la Asunción" Catholic University
- FGC Project: "Potential Industrial Uses of the Aquifer in Misiones Province, analysis and dissemination"	Faculty of Exact, Chemical and Natural Sciences Foundation
- FGC Project: "Guarani Aquifer over the Radio Waves"	Press and Advisory Center of Rádio Criar Brasil
- FGC Project: "Shake up for the Environment" *"Mexa-se pelo Meio Ambiente"*	Latin-American Initiative
- FGC Project: "Why Protect the Guarani Aquifer System?"	Center for Protection of Nature (CEPRONAT)
- FGC Project: Workshops for Social Stakeholders. Coastal Thermal Area (Uruguay–Argentina)	Latin-American Association of Subterranean Hydrology for Development (ALHSUD)
- FGC Project: "Capacity Building for Teachers and Education on the Guarani Aquifer"	Inter-American Association of Sanitary and Environmental Engineering – Uruguay Section (AIDIS)
- FGC Project: "Dissemination and Awareness of the environmental impacts of irrational use of the Guarani Aquifer System in the eastern region of Paraguay"	Fundation Natura
- FGC Project: "A Sustainable Proposal"	Foundation for Support of Institutional, Scientific and Technological Development (UFSCar)
- FGC Project: "Environmental Education for Preservation of the Guarani Aquifer in the Planalto dos Guimarães Region"	Brazilian Groundwater Association (ABAS). São Paulo–Brazil
- FGC Project: "Environmental Education for Protection of the GAS and Groundwater in the Direct Replenishment Area of the State of Santa Catarina"	Foundation for Engineering Teaching of Santa Catarina
- FGC Project: "Guarani Aquifer on TV and in School. Democratize knowledge and awareness"	Liga Ambiental
- FGC Project: "Communications and Environmental Education on the Guarani Aquifer in Entre Rios, Argentina"	Institute of Management of Cities
- FGC Project: "Education for Knowledge and Public Participation in Protection of the Guarani Aquifer System in the Reparación and Caguazú region"	Development, participation and citizenship
- Consultancy for Drafting of the Initial Communication Bases for the Project	Eduardo Prado
- Preparation of a Documentary for Initial Dissemination of the Project	TDA – Comunicação
- TV Spot	Marcelo Sansonetti
- Specialist consultant on indigenous peoples	João Luiz Pena
- FGC Project	Universidade da Empresa (UDE)
- FGC Project: *"Minuto Água"*	Patulus Institute
- FGC Project: "Environmental Education of Leaders on Rational Use of the Waters of the Guarani Aquifer System in the Departments of Itapúa and Caazapà, in Paraguay"	Paraguayan Environmental Protection Institute (IPPA)

Continues

Continuation

- FGC Project: "Practical Dissemination on Functioning of Aquifer Systems"	Fundation Julio Ricaldoni
- FGC Project: "Pilot Project – Promotion and Environmental Education on the Guarani Aquifer System in the Itakyry and Minga Porá Districts"	*Alter Vida* Studies & Training Center for Eco-development
- FGC Project: "A Desert with Water"	Estação Ciência – Center for Scientific Technological and Cultural Dissemination of the Cultural and Extension Department of the University of São Paulo
- FGC Project: "Guarani Hydro-Solidarity"	Foundation for Fostering Research and Industrial Enhancement (FIPAI)
Component IV	
- Design and Maintenance of the Management Information System	Ikhon
Component V	
Development of management measures and mitigation in critical areas	
Activity	**Consultant / Executing Institution**
- Consulting for drafting of the Press Advisory and Education Plan	Ana Lucia Tostes De Aquino Leite
- Consulting for drafting of the Initial Plan of Action of the Concórdia–Salto Pilot Project	Jorge Montaño Xavier
- Consulting for the drafting of the Initial Plan of Action for the Itapúa Pilot Project	Enrique González Erico
- Socioeconomic Study Rivera–Santana do Livramento	Nelson Infanti Jr.
- Socioeconomic Study Itapúa	Antonio Medina Netto
- Socioeconomic Study Salto–Concórdia	Griselda Castagnino
- Socioeconomic Study Ribeirão Preto	Henrique Marinho Leite Chaves
- Consulting for the drafting of the Initial Plan of Action for the Rivera–Santana do Livramento Pilot Project	Alberto Manganelli
- Consulting for the drafting of the Initial Plan of Action for the Ribeirão Preto Pilot Project	Heraldo Sampaio Campos
- Facilitator for the Concórdia–Salto Pilot Project	Enrique Massa Segui
- Facilitator for Rivera–Santana do Livramento Pilot Project	Achyles Bassedas Costa
- Facilitator for Itapúa Pilot Project	Alicia Eisenkölbl
- Facilitator for Ribeirão Preto Pilot Project	Heraldo Campos / Mauricio Moreira dos Santos
Componente VII	
Project Coordination and Management	
Activity	**Consultant / Executing Institution**
- Valuation of counterparts in Uruguay	Laura Jimena Alonso Pontet
- Drafting of the Call for Proposals	Jose Luis Moscoso
- Consultancy for Review and Drafting of Specific Project Regulations	Luis Correa Noronha
- Maintenance of the Management Information System	Maria Eduarda Xavier Da Costa
- Consulting in support of Training for the Paraguayan National Counterpart	Humberto Raúl Costanzo García.
- Negotiation of the Lavalin contract	Luis Loureiro

Continues

Continuation

- Valuation of Counterparts in Brazil	Sergei Fortes
- Drafting of the Mid-Term Review for the World Bank SAP Facilitator	Roberto Kirchheim
- Support for the NC of Argentina	Lida Amanda Borello
- Support for the NC of Brazil	Maria Conceição Menezes
- Support for the NC of Brazil	Carolina Pedroza Gómez
- Support for the NC of Paraguay	Eduardo Dose
- Support for the NC of Uruguay	Ximena Lacués Parodi

List of trainees

Period

2008

Theme	**Name**
Regional Numeric Modeling of the Guarani Aquifer System	Stela Cota
Database	Rafael P. de Souza Luciano Brazil
Hydrogeological Map	Marcia Pressinotti Brazil
Regional Numeric Modeling of the Guarani Aquifer System	Cristian Garabau Argentina
Hydrogeology in the Pilot-Project Zone	Estela Solana Argentina

2007

Theme	**Name**
Hydrogeological Map	Marcia Pressinotti, Brazil
Status of Planted Forests in Outcrop Areas of the Guarani Aquifer System	Oscar Paniagua, Argentina
Current Status of the Arroio Capiibary Basin	Margarita Pereira, Paraguay
Status of Planted Forests in Outcrop Areas of the Guarani Aquifer System	Martina Álvarez Ausserbauer, Uruguay
Hydraulic Testing in the Ribeirão Preto Pilot Area	Ramón Leonidas Lluviera Rocha, Uruguay

2006

Theme	**Name**
Hydrogeological Aspects of the Guarani Aquifer in Mato Grosso do Sul	Antônio Carlos B. Valente, Brazil
Geophysicist (field and office)	Dora Cecilia Sosa , Argentina
Physical, Chemical and Microbiological Analyses of Water	Beatriz Esther Grulke Sommerfeld, Paraguay
Geological Activities in the Rivera–Santana do Livramento Pilot Project Area	Sergio Pena Uruguay
Monitoring and Quality Control Program	Roberto Carrión Uruguai

2005

Theme	**Name**
Gravimetric Geophysics	Maria Esther Santi Argentina

Source: Prepared by GS/GAS 2008..

ANNEX 4

ANNEX 4 SUMMARY OF IMPLEMENTATION OF THE GUARANI UNIVERSITIES FUND

The Guarani Universities Fund was developed to support universities of the region and foster academic research and capacity building activities relating to environmental and social aspects of the GAS. It's launch was made possible by a grant from the World Bank - Netherlands Water Partnership Program (BNWPP). Final selection of projects was carried out by a specially appointed board of researchers from Argentina, Brazil, Paraguay and Uruguay.

This Fund was set up to complement the PGAS, and a specific implementation plan was drawn up for it. This included regulations for presentation of proposals, selection criteria, operational procedures for deployment of activities, financial disbursements, and presentation of accounts.

Implementation of the Fund, and attainment of the goals (in terms of fulfillment of initial targets, value of technical information generated and degree of skills produced) of each of the initiatives supported were considered the most significant achievements of the PGAS as a whole. Pre-tested regulations for implementation served as a basis for its continuity and opened up the possibility of connecting it to other incentives for ongoing academic activities in the countries.

ANALYTICAL ASSESSMENT OF THE EFFECTIVENESS OF THE FUND

Nine subprojects were financed by the Fund. Four of these carried out studies in pilot areas and their outcomes were fully integrated into the respective contexts for regional and local execution of the PGAS. There follows an analytical discussion of the scope of the Fund, its

Nine subprojects were funded with support of the Fund. Table 1 presents an analytical assessment of each of these subprojects, in accordance with monitoring indicators established in the original regulations[1], and a brief account of their execution.

There follows a listing of the main outcomes of implementation of the Fund:

- *Creation and development of the Fund brought the participating universities into close contact with the Project management bodies and other research groups.*
- *The incorporation of information generated by academic subprojects in other fields of the PGAS was quite straightforward. Four of the subprojects financed by this Fund conducted studies in pilot areas and became central elements of great significance, generated technical knowledge on the GAS, and serving as a basis for formulation of Strategic Action Plans (PALPs). Technical data, and data on other subprojects of the Fund, was dispatched to the consulting companies responsible for generating primary data of a regional scope and on the pilot projects.*
- *The Fund fostered closer ties among groups that had not yet worked together and strengthened existing partnerships. The final balance was positive and helped ensure continuity of current initiatives and development of new projects by the affiliated institutions and new groundwater research groups. Other groups that had already established strong ties received additional stimulus for continuing to pursue joint projects.*
- *Many of the subprojects of the Fund were carried out by universities in the interior (in both Argentina and Brazil) and this was considered extremely positive. Information and knowledge were generated in a decentralized manner in the research groups, with a view to total consolidation.*
- *Research methodologies used are suitable for replication in other areas of the GAS. The projects achieved technical and scientific results consistent with the development of new methodologies and technologies, through application and verification of established methodologies for groundwater within the scope of the GAS.*

1 Reference to Chapter 3 of the Project Implementation Plan (PIP).

objectives, requisites, and fulfillment of targets proposed in Chapter III of the PIP.

Dissemination of academic themes relating to the GAS in regional and local water-resources policies

During implementation of the Guarani Universities Fund, GS-GAS took pains to disseminate partial and final findings among national water-resources management and decision-making bodies. At the 2nd Meeting on Environmental Geology and Territorial Zoning of MERCOSUR, held from September 8 to 10, 2004, presentations of all subprojects were made to the NPEUs and, subsequently, at management courses offered by the PGAS.

Furthermore, four of these subprojects were carried out within geographic boundaries of PGAS Pilot Projects. Thus, on various occasions, it was possible for academics to participate in local meetings at the pilot areas. The Fund fostered closer ties among universities, management bodies, and other research groups.

Participation of academic groups in PGAS regional and local activities

Participants in the subprojects established a variety of links with the Guarani Universities Fund and the teams that carried out work under contracts (in view of the limited number of hydrogeology specialists in the region overlying the GAS, and especially in regions encompassed by pilot projects). Another factor that reinforced such participation was direct transmission of data obtained during research under the Guarani Universities Fund to the GS-GAS, to the countries, and to technical personnel involved in PGAS regional activities.

For example, the Hydrogeological Monitoring Project of the Ribeirão da Onça Basin in the Outcrop Zone of the Guarani Aquifer resulted in a masters dissertation entitled Development of a numerical model for water resources management in the Ribeirão Preto Pilot Project area. This information was made available to the Lavalin company, responsible for development of the Conceptual and Numeric Model for the GAS in the pilot area.

The GS-GAS facilitated the transmission of these data by means of its database. This produced a direct benefit by providing relevant information to the research groups. The actions carried out by universities with resources from the Fund within the scope of the GAS filled in a significant gap in the execution of the PGAS, in view of the complexity of arrangements for tendering technical and scientific tasks.

Formation and consolidation of research groups and strengthening of ties among academic institutions

As was discussed in the section on results of implementation of the Fund, closer ties were established among groups that had never cooperated before and a strengthening of ties took place among those that had already engaged in cooperation activities. New initiatives emerged, such as the Project for Estimation of Regional Evapotranspiration through Remote Sensing, a joint initiative between Universidad Nacional del Centro de la Provincia de Buenos Aires (Argentina) and UNISINOS (Brazil), that have since maintained very close technical exchanges.

An example of such exchanges is the Course on Mathematical Modeling of Aquifers. Now being offered for the second time, this course is taught by technical staff of the Universidad Nacional del Centro and Universidad de Santa Fe (Argentina) at the computing center of UNISINOS (in Brazil). Specialists in hydrogeology from public and private institutions of Brazil's South Region have participated in and strengthened the initiative. After conclusion of the subproject, new researchers from the two Universities were added to the respective research groups.

Other groups that maintain strong ties, such as the Universidad de La Republica (UDELAR - Uruguay) and the Federal University of Paraná (UFPR, Brazil) for example, received additional stimulus for working together. UDELAR and the University of Mexico worked jointly on development of an electromagnetic methodology for geological and groundwater prospection. Equipment procured with resources of the Fund were used during geophysical research throughout the transboundary zone between Brazil and Uruguay.

Also worth mention is the Federal University of Santa Maria (UFSM) which, though it has a strong academic record in the field of geosciences in the central and south regions of the State of Rio Grande do Sul in Brazil, its background in hydrogeological research was still incipient. Closer ties with the UDELAR group, that has strong capacities in the field of quantitative hydrogeology, made it possible to strengthen the research group on groundwater. Today, UFSM has a standing group of students and researchers engaged in studies relating to the GAS that is prepared to address specific demands from municipalities of the region (on themes relating to excess fluorine in certain strata of the GAS, for example).

Institutional relationships were strengthened among universities and governmental research bodies, such as the National Water Institute (INA) of Argentina, that participated as an associate in two projects.

In some cases, once the subprojects of the Fund had been finalized, new institutions came in to ensure continuity of the initial lines of research. This was the case of the "Hydrogeological Monitoring of the Ribeirão da Onça Basin in the Outcrop Zone of the Guarani Aquifer", that provided follow up for

monitoring through contributions from national and state government agencies.

Replicability and assessment of outcomes

The methodologies used in this research could be directly replicated in other areas of the GAS. The projects achieved technical and scientific outcomes consistent with development of new methodologies and technologies, and with the application and verification of proven methodologies in areas of the GAS.

Among the most significant of these were isotopic monitoring, remote sensing applied to the regional water balance, geophysical prospection techniques and use of mathematical models in aquifer fracture zones, and development of methodologies for replenishment areas.

Aside from secondary information, obtained by means of bibliographic reviews, primary information was generated by mapping and surveys of geological, geophysical and hydrochemical data. All this is new information, which the GS/GAS must pass on to management bodies in the countries and disseminate as fully as possible through mechanisms of the SAP.

Summary of implementation of the Fund

The subprojects were all fully executed. Expenditures for the equipment described in Memorandums of Understanding signed by the OAS and the executing universities were fully executed, as were also all operational expenses initially proposed.

Actions for closing the Fund

Together with the editorial staff of the technical magazine ALHSUD arrangements were made for publication of the final reports of all the academic subprojects sponsored by the Fund. The format of these reports followed premises established by the magazine. An article by the secretariat provided a background summary, with special thanks to the sponsors, describing the objectives of the Fund, within the context of the PGAS and the capacity building actions of the universities. Throughout the region overlying the GAS in the four countries 2,500 copies of the magazine were distributed.

Lessons learned

- Within the framework of the PGAS, the Guarani Universities Fund proved a very valuable tool, and its success was to a great extent due to a consensus arrived at by the countries in relation to the criteria of the Fund: clear regulations; appropriate formats for presentation and monitoring; an ample period for dissemination of calls for proposals, and adequate time for preparation of proposals and formation of a scientific committee of advisors/evaluators for the selection of proposals phase.
- From the standpoint of implementation, the format of the legal contract between the OAS and academic institutions proved very effective, as it provided tools for demanding results, while at the same time granting full autonomy of execution.
- However, a lack of liquidity on the part of the academic institutions posed difficulties and meant that monitoring by managers of the Fund had to be very strict. Without exception, the groups were totally dependant upon substantial grant funding right from the onset of the project. They needed funding for procurement of essential equipment, to cover the fieldwork cost, travel expenses to gather secondary information and preparation of laboratory samples, without which the project simply could not have moved forward. Consequently, right from the start, control and monitoring were necessary and played a significant part in consolidating strong ties of trust that helped ensure smooth execution and control of counterpart activities.
- In a future version of the Fund, it is suggested that even closer monitoring be carried out, with visits to the groups and meetings among the parties. This would facilitate exchanges of experiences, data and personal contacts, and would endow the groups with greater legitimacy and visibility within their own institutions. Resources should be allocated and a clear monitoring strategy in place right from the start.
- During project development and generation of data, there should be a unified format for making both primary and secondary data available. It should be observed that the reports of the groups present information in very heterogeneous manners, which often makes it difficult to share. All information generated during studies, be it chemical, georeferenced, tabulations, images (photographs etc.) should be organized in accordance with pre-established standards for immediate sharing with institutional players in the PGAS (GS/GAS, NPEUs, Local Committees of the Pilot Projects). This would greatly add to the value of the research process, facilitating inputting into the PGAS Database and, subsequently, transmission of information, thereby avoiding duplication of efforts. Such information could also be posted immediately on the project website, thus helping maintain connections among the various websites of the groups of academics and the project website.
- The consortia model proposed by the Fund proved very worthwhile and, to some extent, fostered exchanges among groups that had previously worked in isolation from one another. In certain cases, when the bidding universities could already claim academic excellence (i.e., consolidated research groups) the new exchange mechanisms did not work as had been expected. These universities carried out their own independent projects, without any effective contributions from their co-participants. This theme should be considered when new monitoring strategies are being proposed.

Table 1. Summary of implementation of subprojects and quantification of results

Project	Universities/institutions	Products
Evaluation of water resources of the Guarani Aquifer System (GAS) in the municipality of Araguari, State of Minas Gerais, Brazil (6)	Federal University of Minas Gerais – UFMG (BR) Federal University of Mato Grosso – UFMT (BR) Nuclear Technology Development Center – CDTN (BR)	» Establishment of a database on over five hundred wells » Physical hydrogeological model » General characterization of the GAS » Map of potentialities » Water balance » Mathematical model of hydrogeological flows » Hydrochemical and isotopic analyses (^{2}H and ^{18}O) at 34 points » Monitoring and collection of samples in pluviometers » Soil sampling » Determination of the natural vulnerability of the Bauru Aquifer to contamination » Technical and academic training
Characteristics and status of water in replenishment areas of the Guarani Aquifer System in the Republic of Paraguay Physical-chemical evaluation and determination of the presence of tritium in waters of replenishment areas of the Independencia and Misiones Aquifers - Republic of Paraguay (8)	Faculty of Exact and Natural Sciences – UNA (PY) Universidad Católica de Santa Fe (AR) National Water Institute – INA (AR)	The work was carried out in basins, incorporating into the cartography, information on hydrography, topography, soils, geology, drilling and chemical analyses
Characterization of GAS replenishment and discharge areas in Rivera–Livramento and Quaraí–Artigas. Vulnerability study in the Artigas–Quaraí area of influence (10)	Federal University of Santa Maria – UFSM (BR) Universidad de La República – UDELAR (UY)	Hydrochemical, isotopic, geophysical, salination, geology and piezometry information was generated in SIG environments Digitalization of topographic charts
Methodological development for evaluation of replenishment and vulnerability of the Guarani Aquifer System in Argentina and Uruguay (12)	Universidad Nacional del Litoral – UNL (AR) National Directorate for Environment – DINAMA (UY) National Water Institute – INA (AR) Institute of Hydrology of LLanuras – Universidad Nacional del Centro de la Província de Buenos Aires – IHLLA-UNCPBA (AR)	» Piezometry » Hydrochemical » Geology » Digital model of the terrain » Land use » Hydro geological conceptual model » Replenishment
Estimate of regional evapotranspiration through remote sensing (15)	Universidade do Vale do Rio dos Sinos – UNISINOS (BR) Universidad Nacional del Centro de la Província de Buenos Aires – IHLLA-UNCPBA (AR)	» Database with basic information on the zone » Records of radiation » Data surface maps of regions, surface temperature, of albedo, and radiation » Measuring campaign; application of the Energy Balance Model; ET Map
Isotope study of the groundwater movement of the Guarani Aquifer System (SAG) in Paraná, São Paulo and Uruguay (16)	Federal University of Paraná – UFPR (BR) Universidad de La República – UDELAR (UY) University of São Paulo – USP (BR)	» Database on wells; » Physical-chemical and isotopic analyses of water samples from wells » Isotope dating » Preparation of geological profiles and hydrochemical, potentiometric and structural maps » Structural measurements of outcroppings Individualization of hydrochemical types » Qualitative hydrogeological model

Continues

Continuation

Geophysical investigation of the geological structure of the Chaco-Parana Basin in the area of the towns of Salto (Uruguay) and Concordia (Argentina) (17)	Faculty of Engineering of UDELAR (UY) Universidad Tecnológica Nacional – UTN (AR) Universidad Nacional Autónoma de México – UNAM (MX)	» Magnetic soundings » Preparation of a geological map, lithological and eletroresistance profiles » Generation of geological sections and models of the geological structure
Hydrogeological monitoring of the Pilot Basin of Ribeirão da Onça in the outcrop zone of the Guarani Aquifer (20)	University of São Paulo – USP (BR) University of Brasília – UnB (BR) Federal University of Santa Maria – UFSM (BR)	» Obtaining and processing of climatic data » Characterization of land use » Preparation of a map on land use and settlement » Analyses of the water balance in the basin » Estimate of the replenishment rate of the GAS for the basin » Conducting of drilling and lithological profiles of wells » Collection and hydrochemical analyses estimates of hydrochemical changes as a consequence of agricultural activities
Hydrogeological vulnerability and risk of the Guarani Aquifer System - outcrop area of Rivera, Uruguay (28)	Faculty of Science of UDELAR (UY) Universidad de Buenos Aires – UBA (AR)	Processing of climatic data; photo interpretation; collection and detailed study of samples of outcroppings; descriptions of drilling; survey of profiles; preparation of geological sections and maps (geological, soils, piezometric, location of wells); characterization of land use; measurement of N.E.; pumping studies; collection of water samples from wells, and physical-chemical and isotopic analyses; hydro-geological conceptual model; census of potential points of contamination

Source: Prepared by GS/GAS, 2008, based upon execution of the Guarani Universities Fund.

(AR = Argentina; BR = Brazil; PY = Paraguay; UY = Uruguay)

Project for Environmental Protection and Sustainable Development of the Guarani Aquifer System

ANNEX 5

Annex 5 Summary of Implementation of the Citizenship Fund

The Guarani Citizenship Fund was established as part of the PGAS using the GEF grant, with the aim of supporting actions carried out by civil society in the region overlying the GAS. The Fund provides support for actions in the fields of communications, public participation, and formal and informal environmental education related to groundwater, with a view to promoting public participation in the PGAS.

The objectives of the Fund are:

(i) to place the theme of groundwater and its environmental and social dimensions, onto the agenda of regional civil society;
(ii) to promote formal and informal environmental education in the region;
(iii) to disseminate the PGAS;
(iv) to build awareness of civil society as to the importance of preservation and sustainable management of the GAS.

The way in which the Citizenship Fund was implemented and its impressive outcomes (in terms of the number of people trained and lessons learned) make it an example of best practices in integrated water resources management and cooperation among non-government organizations.

Passage from the Resolution of the Project Steering Committee (CSDP) which approved operating rules of the Fund.
"Art. 1. – The Guarani Citizenship Fund is hereby instituted, within the scope of the Project for Environmental Protection and Sustainable Management of the Guarani Aquifer System, thus constituting a subcomponent of Component III of said Project."

Principal results achieved through implementation of the Citizenship Fund:

- Fairer geographic distribution of projects, an important criteria when making the final selection of proposals. The Citizenship Fund was a pioneering experience that enabled balanced regional dissemination of the central message of the PGAS.
- Support was provided for initiatives in areas in which there had formerly been no experience of projects or activities relating to the theme groundwater or to the GAS. That groups in these localities received support was in itself important for decentralization of information and of inputs.
- A great majority of the projects fulfilled the expectations foreseen in their goals and regulations. The central theme of the projects was diffusion of knowledge and training for teachers, and for the public in general. In this manner, it was possible to reach a great number of people directly.
- The Pilot Projects benefited directly from execution of the Citizenship Fund. In the initial stages of the PGAS, Projects of the Fund comprised important channels for relaying information to the public.
- Initially, the bodies involved had to compile information on the GAS and build their own capacities on themes relating to groundwater. This helped ensure the quality and consistency of subsequently disseminated information, and enabled participation of these entities in thematic exchange networks. Such capacity building of institutions was of key importance for multiplying lessons learned in subsequent initiatives.

Certain projects involved indigenous populations. Training was provided for local environmental agents and information was produced in the Guarani language. Furthermore, certain projects dealt with issues of gender and participation of women in water-related themes These were discussed on radio programs within the scope of one of these projects.

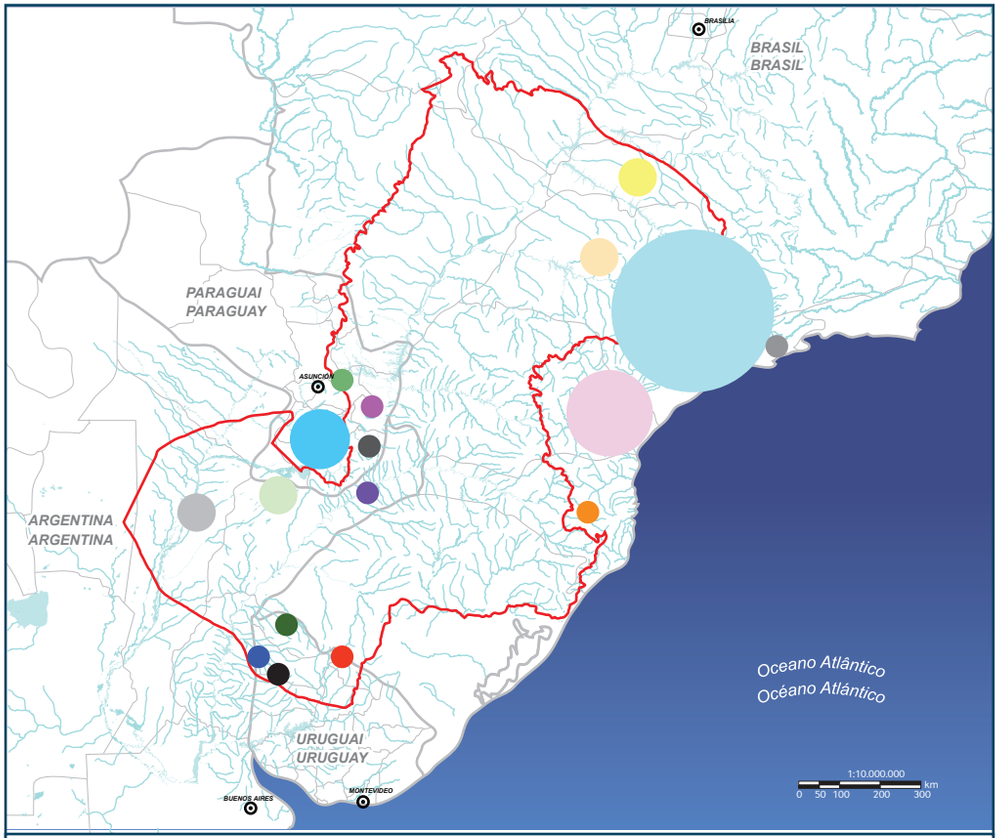
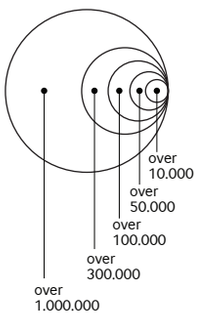


Figure 1. Guarani Citizenship Fund

Key

- Departmental, state, provincial and international boundary
- Limit of the GAS
- River basins and sub-basins
- Move for the environment - LATIN -AMERICAN INITIATIVE
- Communication, dissemination and awareness building for the public in the GAS area - UDE
- Minuto Agua - INSTITUTO PATULUS
- Teacher training and education – GAS AIDIS UY
- Environmental Education Campaign - GAS UCA PY
- Dissemination and awareness building on the implications of environmental management of the GAS – FUNDACIÓN NATURA
- Environmental education - a Sustainable Proposal Foundation for institutional support to scientific and technological development
- GAS Exhibition – a desert with water ESTAÇÃO CIÊNCIA
- Guarani Water Solidarity – FIPAI
- The GAS on radio waves - CRIAR BR
- Pilot project for fostering environmental education on the GAS - ALTER VIDA
- Moaracayu: a drop of life, a drop of hope for the GAS – FUNDACIÓN MOISES BERTONI
- The GAS goes to school - FEU
- Potential sustainable industrial uses of the GAS in the Province of Misiones - FFCEQ y N
- Environmental education for protection of the GAS
- The Guarani Aquifer on TV and in school – LIGA AMBIENTAL
- Education for knowledge and public participation in Repatriación and Caagazú – DESAROLLO PARTICIPACIÓN Y CIUDADANIA
- National capital

Number of beneficiaries



Source: PGAS Project Implementation Plan (PIP) 2002G.

Table 1. Summary of implementation of subprojects and quantification of results

Project	Entity	Specific activities	Number of beneficiaries
1) Why protect the GAS?	Center for Protection of Nature (CEPRONAT) Faculty of Engineering and Water Sciences Universidad Nacional del Litoral Argentina	» Courses for primary-school and high-school teachers » Workshops for the general community » Informative primer » Teaching manual	4.585
2) Project workshop for social stakeholders. Coastal Thermal Area	Latin-American Groundwater Hydrology for Development Association (ALHSUD), Uruguay	» General workshop (hotels, spas, trade, industry, tourist operators, communicators, NGOs, community employees) » Thematic workshops	200
3) Do something for the environment	Latin-American Initiative Uruguay, Argentina	» Workshops » Environmental projects » Didactic games	24.000
4) Communications, dissemination and awareness building of civil society in the area of the GAS, using participative methodologies that enable identification of demands and needs	Universidad da Empresa Universidad de la Empresa (UDE) Uruguay	» Primers » A one year Internet site » Electronic forum » Ideas contest » Workshops with public and private players » Case study "Functioning of the Uruguayan Advisory Board for the Guarani Aquifer"	35.000
5) Minuto água	Instituto Patulus, Brazil	» Preparation, printing and distribution of primers » Social mobilization campaigns » Competition on water and preservation of the GAS » TV Programs (30 seconds) » Weekly TV program » Local radio spots » Lectures on rational use of natural resources » International symposium » Internet page	50.000
6) Teacher training and education: Guarani Aquifer	Inter-American Sanitary and Environmental Engineering Association (AIDIS) Uruguay	» Teacher Enhancement Seminars » Informative materials » Inputting of updated information on the AIDIS website in Uruguay » Workshops, research and school competitions	32.000
7) Environmental education campaign – GAS	Catholic University of Paraguay Paraguay	» Workshops for teachers and secondary-school and university students » Production of teaching material » Workshops targeted at community leaders, justices of the peace and teachers » Fortnightly radio program with a national audience	15.000
8) Dissemination and awareness building on the environmental impacts of irrational management of the GAS in the eastern region of Paraguay	Fundación Natura, Argentina	» Courses for the university, industrial and farming communities, » Preparation of a video » Webpage » Space on open and subscriber TV » Primers » Posters » Folders	

Continues

Continuation

9) Environmental education for leaders on rational use of water of the GAS in the Departments of Itapúa and Caazapá, in Paraguay	Paraguayan Environmental Protection Institute (IPPA), Paraguay	» Workshops » Map of the GAS in Itapúa and Caazapá » Poster (46 x 65 cm)	2.000
10) Environmental education: a sustainable proposal	Science Station University of São Paulo (USP), Brazil	» Graphic material for children » Educational lectures for youths » Lectures for university students » Musical groups and recreational activities » Theater for children and the general public	70.170
11) Guarani Aquifer Exhibition: a desert with water	Science Station University of São Paulo (USP), Brazil	» Training courses for primary-school and secondary-school teachers » Production of primers » Websites » Modernization and expansion of the itinerant exhibition » Media materials for radio, TV and magazines	30.000
12) Guarani water solidarity: participation and social training in pursuit of environmental protection for the Guarani Aquifer	Foundation for Enhancement of Research and Industrial Improvement (FIPAI), Brazil	» Production of a Guide to the Guarani Aquifer » Preparation of a regional database » Meetings and photos » Creation of a group or association to continue discussions on the GAS » Websites	80.000
13)) The Guarani Aquifer on radio	Criar Brasil, Brazil	» Radio program	1.200.000
14) Environmental education for preservation of the Guarani Aquifer in Chapada dos Guimarães region of Mato Grosso	Brazilian Groundwater Association (ABAS), Brazil	» Training courses for primary-school teachers » Production of a book for students » Guidebook for teachers on the GAS Project » Guidebook for students	1.200
15) Practical dissemination on the workings of aquifer systems	Fundaci Ricaldoni, Argentina	» Preparation of a physical model for aquifers, of a manual for construction and a teaching manual » Creation of an itinerant stand » Workshops for dissemination of materials	1.000
16) Pilot Project for Promotion and Environmental Education on the GAS in the Itakyry and Minga Porá Districts	Alter Vida, Paraguay	» Sectoral workshops with representatives of civil society organizations and local authorities » Seminars to define public participation » Radio program » Dissemination primers » Workshops with three modules, with faith-based organizations, for development of environmental education journeys » Preparation of an Environmental Education Manual » Posters » Billboards » Television adverts » Articles in newspapers	45.000
17) Mbaracayú: a drop of life, a drop of hope for the Guarani Aquifer	Fundación Moisés Bertoni, Paraguay	» Radio program » Leaflets and posters » Teacher training	150.000

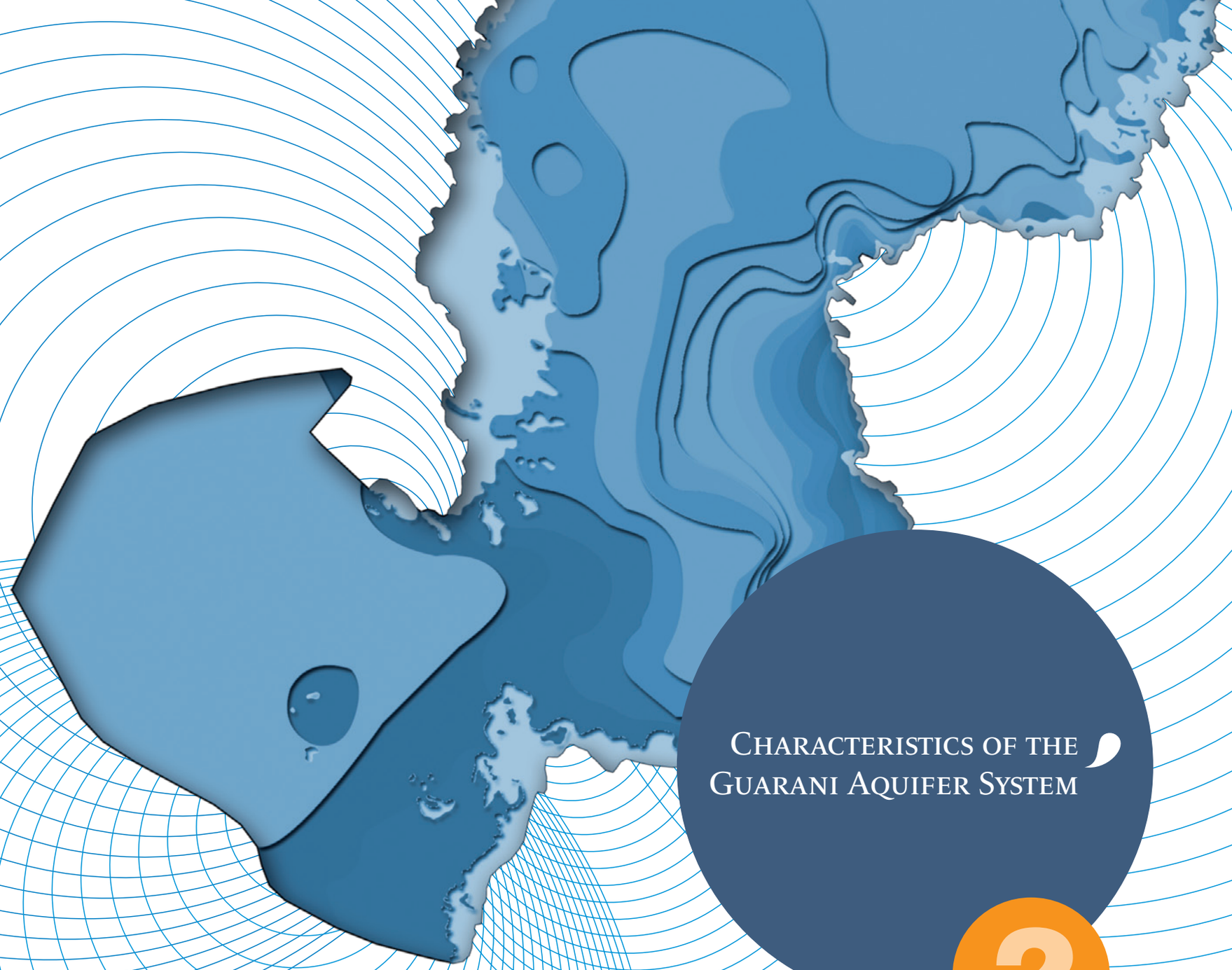
Continues

Continuation

		» Training for environmental promoters of the GAS, to carry out community projects » Visits of children to the Mbaracayú Forest Biosphere Reserve. Education on the GAS » Stickers » Bags for vehicles
18) The power of communications for water	Association of Argentine Environmental Journalists (AAPA), Argentina	» Introductory publication on the GAS and glossary of terms » Workshops during university courses in Journalism and Communications
19) The Guarani Aquifer goes to school: public participation strategy and environmental education	Fundación Ecologica Universal, Argentina	» Publication of bibliographic material for teachers » Student competition on "The Guarani Aquifer: opinion of the children". Preparation of posters » Competition for teachers "The Guarani Aquifer: role of schools" in development of environmental education activities » Meetings with teachers » Manual for organization of competitions and analysis of results
20) Possibilities for sustainable industrial use of the Guarani Aquifer in Misiones Province. Analysis and dissemination	Faculty of Exact, Chemical and Natural Sciences (FCEQYN) Universidad Nacional de Misiones, Argentina	» Workshop on groundwater resources in Misiones Province » Workshop on sustainable industrial uses of the GAS in Misiones Province » Communications work with potential industrial users of the GAS » Weekly radio program
21) Environmental education for protection of the GAS and groundwater in the direct replenishment zone in the State of Santa Catarina	Teaching and Engineering Foundation (FEESC), Brazil	» Preparation of teaching and communications materials for the Project (manuals, primers, etc.) » Seminars for dissemination in Santa Catarina » Websites » Training of managers
22) The Guarani Aquifer on TV and in school: democratize knowledge to build awareness	Liga Ambiental, Brazil	» Production of TV programs » Publication of scripts and videos » Transmission on community broadcasts » Dissemination of programs on the Liga Ambiental website » Distribution of programs on video tape in schools
23) Communications and environmental education project. Pilot project in the town of Federación, Entre Rios Province, Argentina	Cities Management Institute, Argentina	» Household surveys in two municipalities » Workshops environmental perceptions in two municipalities
24) Education for knowledge and public participation in protection of the Guarani Aquifer System, in the Repatriación and Caaguazú regions	Development, Participation and Citizenship, Paraguay	» Workshops » Short programs for local radio and TV broadcasters » Conferences » Primers » Municipal resolution

Total public reached: 2.296.955

Source: Prepared by GS/GAS, 2008, based upon execution of the Citizenship Fund.



Characteristics of the Guarani Aquifer System

2

Chapter 2

Characteristics of the Guarani Aquifer System

SUMMARY

The Guarani Aquifer System (GAS) is a transboundary body of groundwater that underlies portions of Argentina, Brazil, Paraguay and Uruguay. It represents the most important hydro-stratigraphic unit of the southern portion of the South-American continent and is associated with a set of predominantly sandy sedimentary rocks of the Paraná Basin (Brazil and Paraguay), the Chaco-Paranaense Basin (Argentina) and the Northern Basin (Uruguay).

The GAS has specific and complex physical, geological, chemical and hydraulic characteristics that were studied under the Project for Environmental Protection and Sustainable Development of the GAS (PGAS) and which provide the bases for the Strategic Action Program (SAP). It is an integral component of the ecosystem and of the socioeconomic context, in which it fulfills essential functions and by which it is directly affected.

This chapter addresses these aspects. It presents background information on physical dimensions (geological, hydrodynamic, hydrochemical, hydrothermal, etc.) of the GAS and the outcomes of isotopic studies. The chapter also examines alternative approaches for utilization of this vast reservoir of water, from a physical standpoint and within the broader context of current socioeconomic, climatic and hydrological realities and presents potential scenarios for the future.

2 CHARACTERISTICS OF THE GUARANI AQUIFER SYSTEM

The aim of this Chapter is to present the Guarani Aquifer System (GAS) including details of its physical, chemical and hydraulic characteristics. Aside from its physical aspects, this transboundary body of groundwater is an integral component of the ecosystem and of a complex socioeconomic context in which it fulfills essential functions and by which it is likewise directly affected. Knowledge of the GAS, its dynamics and the factors that place it under pressure from water users was of fundamental importance for the drafting of the Strategic Action Program (SAP).

Information on the SAP was produced and systematized within the scope of the Project for Environmental Protection and Sustainable Development of the Guarani Aquifer System (PGAS) which has been the source of current knowledge on the GAS. Such knowledge has been accumulated by means of technical reports produced under the PGAS by universities of the region through the Guarani Universities Fund; contracts with individual contractors; analytical efforts of the International Atomic Energy Agency (IAEA); contributions produced through a cooperation agreement between the Institute for Geosciences and Natural Resources of Germany (BGR) and the Government of Paraguay; the basic GIS Map of the area overlying the aquifer, prepared by the TECSULT company; technical reports prepared by the Guarani Consortium[1] ; and reports produced by the SNC Lavalin company[2] , all of which have been consolidated within the framework of the Project's General Secretariat.

2.1 BACKGROUND AND HISTORICAL ASPECTS

The Guarani Aquifer System corresponds to stratigraphic and aquifer units that were previously known in each country under such names as Misiones (Argentina and Paraguay), Botucatu and Pirambóia (Brazil), and Tacuarembó (Uruguay). In the south of Brazil, stratigraphic units such as the Caturrita and Santa Maria Formations also comprise the GAS. The current name was selected to honor the Guarani, an indigenous people who are the original inhabitants of the region overlying the aquifer.

Figures 1A and 1B present maps drafted by various specialists to illustrate the development of knowledge and regional understanding of the GAS.

The GAS has been described as "a set of water-saturated sandstones formed underlying basalt rocks in the Serra Geral Formation" (Araújo et al. 1995). Subsequently, the Hydrogeological Map of the Guarani Aquifer (Campos 2000) depicted potentiometric curves (water levels in accordance with pressure) and the main flow directions. He also identified replenishment areas associated to outcrop zones of formations that comprise the Aquifer System and discharge areas located in the regions of Entre Rios (Argentina), the Uruguay River (Santa Catarina and Rio Grande do Sul), and Pontal do Paranapanema (São Paulo, Mato Grosso do Sul and Paraná).

During the preparation phase of the PGAS, based on prior information and support from the technical and scientific community, the National Project Preparation Unit of Brazil (UNPP/BR) prepared a schematic map of the GAS. This map (Figure 1A) shows potential replenishment areas (yellow and green), discharge areas (brown), and regions where water may spring forth under artesian pressure. It should be noted that the limits of the system were not known at that time, and how far the aquifer extends into Argentine and Paraguayan territory had not yet been completely determined. Another interesting detail was the combination of hydrogeological and hydrological perspectives, expressed through identification of the limits of the La Plata Basin. The Hydrogeological Map of the GAS (last portion of Figure 1B) was produced by the Guarani Consortium, under the PGAS and represents integration of new information and knowledge from previous studies.

2.2 CURRENT OVERVIEW OF THE GAS

The GAS is the most important hydrostratigraphic unit in the southern portion of the South-American continent and is associated to a set of rocks formed by sediments originating from mechanical accumulation of detritic particles (produced from decomposition of rocks and known as siliciclasts - gravel, sand, silt and clay) of the Paraná Basin (Brazil and Paraguay), the Chaco-Paraná Basin (Argentina) and the North Basin (Uruguay).

The various geometric, compartmentalization and architectural aspects of this extensive basin and of the corresponding sediment layer are encompassed by huge structural elements, known as arcs and synclines[3] , that perform the function of physical partitions of the basin and source areas of the sediments. In this broad structural geological context, the GAS is defined as a set of sedimentary mesozoic continental clastic rocks, present in the Paraná and Chaco-Paraná Basins. Its base was stratigraphically determined by the regional permian-triassic discordance (250 million years) and its upper part, by basalt spills of the Serra Geral Formation (approximately 145-130 million years ago).

These observations are based on stratigraphic and hydrogeological premises in the region, substantiated by identification of an eroded basal surface dating from the permian-triassic era, that is to be found in a major portion of the Paraná Basin. This regional discordance surface places the GAS into contact with lithostratigraphic units that have a variety of hydraulic characteristics (in the northern portion of the basin, the Corumbataí Formation clays, and in the southern part, sandstone units of the Rio do Rasto, Sanga do Cabral, Tacuary and Buena Vista formations)[4].

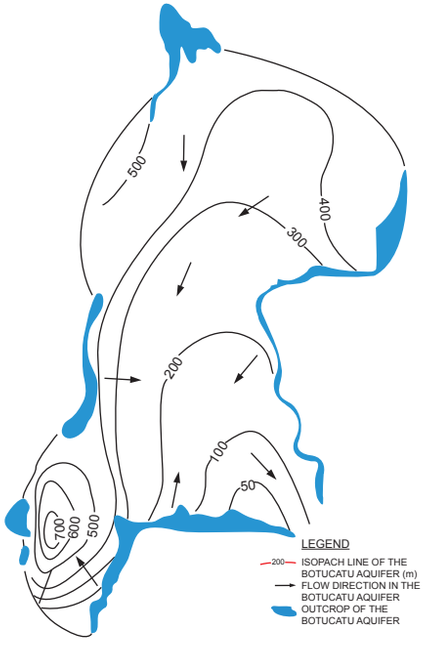
1 The Guarani Consortium was comprised of the following companies: Tahal Consulting Engineers Ltd., Seinco S.R.L., Hidroestructuras S.A., Hidrocontrol S.A. and Hidroambiente S.A. and was formalized by a contract on "General Hydrogeology, Thermalism Services and Regional Model for the Guarani Aquifer – Ref.: Tender SBCC/01/04 – 1/1018 1".

2 SNC Lavalin signed agreements with the following outsourced companies: Proinsa, Geodatos, LCV, PyT and DH Perfurações Ltda. do Brasil for total execution of field work (inventory, sampling, geology, geophysical, hydro-geochemical, isotropy and hydrogeology) in the northern and southern operational areas of the GAS.

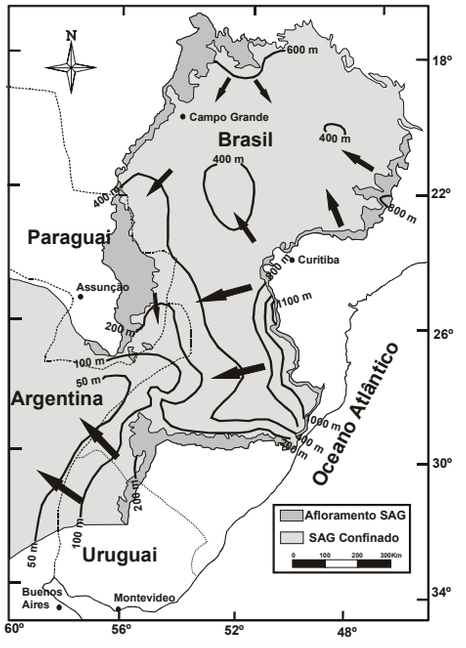
3 The main structural elements that control the various aspects of the geometry, compartmentalization and architecture of the sedimentary layer of the basin are: to the north, the Arcs of Canastra and San Vicente; to the west, the Arc of Asunción and the Arc of Pampeano/Punta; to the south, the Arc of Rio de la Plata. In the lower portion of the basin there are significant structural elements, such as the Arc of Ponta Grossa, the Arc of Rio Grande and the synclinal of Torres.

4 Wells that pass through the GAS in its entire area may tap waters from underlying units, and may experience water-quality problems (high dissolved-salt content and presence of compounds that make it unsuitable for household use).

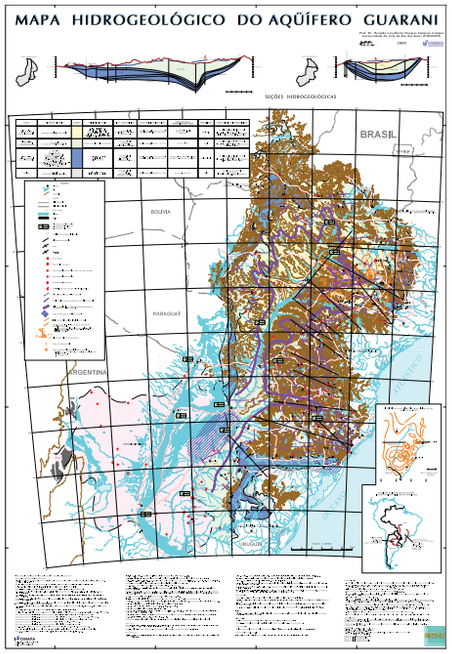
GILBOA et al. 1976



Modificado de ARAÚJO et al. 1995



CAMPOS. 2000



UNPP Brasil. 2008

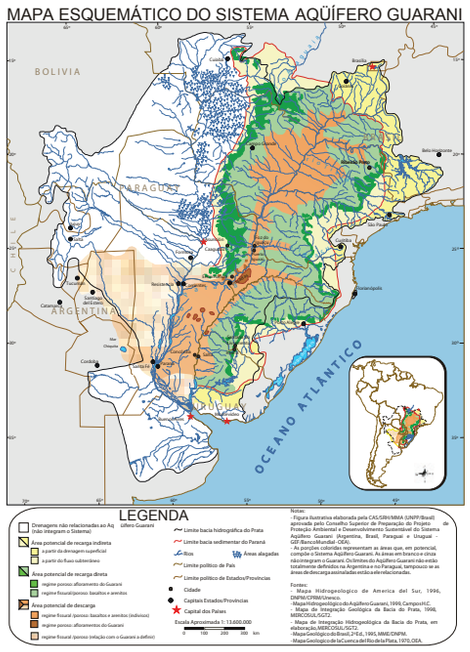


Figure 1A . Background maps of the GAS

Source: GS/GAS , Adapted from the Final Hydrogeology Report, Guarani Consortium, 2008

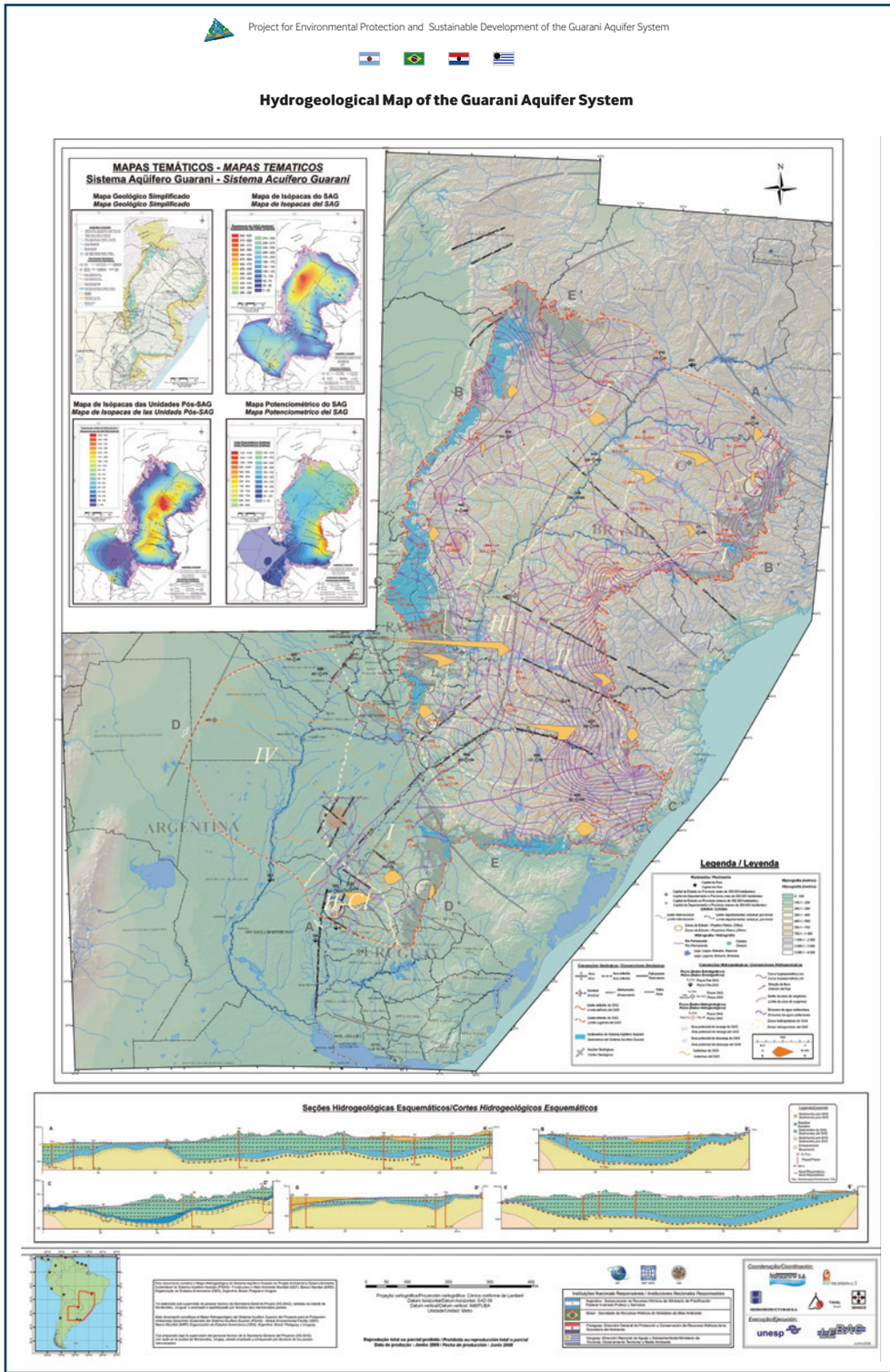


Figure 1B. Hydrogeological Map produced by the Guarani Consortium

Source: GS/GAS , Adapted from the Final Hydrogeology Report, Guarani Consortium, 2008

The GAS is a complex and heterogeneous system, in which regional and local groundwater flows are controlled by geotectonic structures (arcs, faults and dikes), by sedimentary conditioning factors (geometry, grain size, degree of digenesis, strata of which it is comprised and relationships with underlying and overlying strata) and geomorphologic conditioning factors (altimetry, declivity and relief).

Table 1 provides a lithostratigraphic account of the GAS and its relationships with adjacent units.

The map in Figure 2 presents a schematic view of the hydrogeology of the GAS.

2.3 GEOMETRY OF THE GAS AS A WATER BODY

According to previously-mentioned geological premises and system of cartographic projections used, the GAS covers an estimated area of 1,087,879 km² (table 2).

The GAS is located between parallels 16º and 32º S and meridians 47º and 60º W and its limits are determined by the area of occurrence of its component geological units. Such occurrences are located at the eastern and western extremities of the Paraná Basin. Moreover, in Brazil's South region there is an east-west outcrop strip, located in the State of Rio Grande do Sul, and a north-south outcrop strip located in northeastern Uruguay. Isolated outcrops, without connection to the main body of the GAS, such as those in the Chapada dos Guimarães in the State of Mato Grosso (Brazil) are not part of the system,

Table 1. Lithostratigraphic summary of the GAS

Paraguay	Argentina	Uruguay	Brazil (South)	Brazil (C-N)	Aquifer Units
Alto Paraná Formation	Serra Geral (Curuzú Cuatiá) Formation Posadas/Solari Formation	Arapey Formation	Serra Geral Formation	Bauru Group Serra Geral Formation	Post-GAS
Misiones Formation	Misiones Formation (Tacuarembó Formation)	Tacuarembó Formation	Botucatu/Guará Formations Caturrita Formation Santa Maria Formation	Botucatu Formation Pirambóia Formation	130 million years GAS 250 million years
Tacuary Gr. Independência Formation	Buena Vista Formation	Buena Vista Formation	Sanga do Cabral Formation	Corumbataí/Rio do Rasto Formations	Pre-GAS

NB: Brazil (South) refers to the portion of the GAS in the States of Paraná, Santa Catarina and Rio Grande do Sul. Brazil (C-N) refers to central and northern portions of the GAS in other states.

Source: Final Hydrogeological Report Guarani Consortium 2008.

Table 2. Total estimated area and distribution of the GAS by country

Country	Original estimate		Current project estimate		% in relation to the area of the country
	Area (km²)	% of the total	Area (km²)	% of the total	
Argentina	225.500	19,1	228.255	20,98	8,1
Brazil	839.800	71	735.918	61,65	8,7
Paraguay	71.700	6,1	87.536	8,05	21,5
Uruguay	45.000	3,8	36.170	3,32	19,5
GAS Total Area	1.182.000	100	1.087.879	100	_

Source: Final Hydrogeological Report Guarani Consortium 2008.

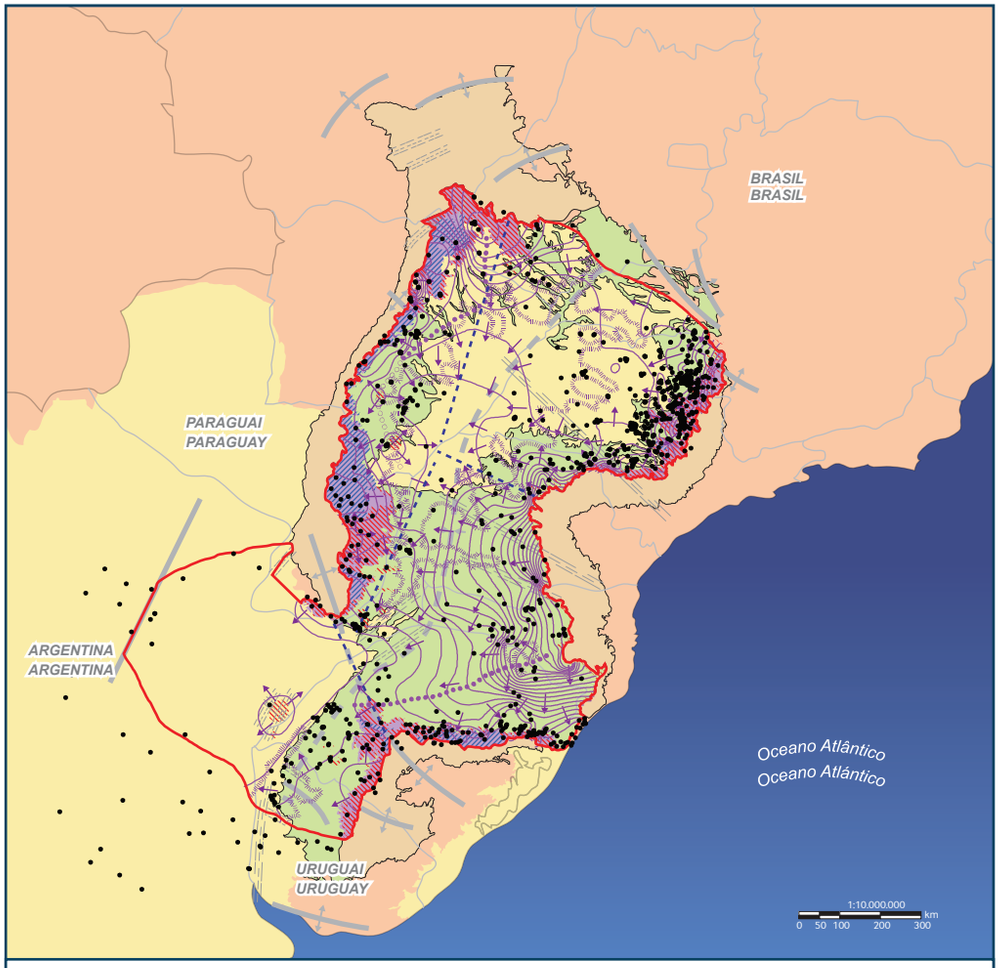


Figure 2. Schematic Hydrogeological Map with potentiometry and identification of replenishment and discharge areas

Key

- Departmental, state/provincial and international boundaries
- Limits of the GAS
- Wells
- Post-GAS sediments
- Basalts
- GAS sediments
- Pre-GAS sediments
- Base
- Replenishment area
- Discharge area

Hydrological conventions

- Water levels
- Defined underground watershed
- Undefined underground watershed
- Hydrodynamic domains
- Limit of the resurgence zone
- Direction of flow

Geological conventions

- Arc
- Suggested arc
- Fault
- Alignment
- Synclinal

Source: GS/GAS , Adapted from the Final Hydrogeology Report, Guarani Consortium, 2008

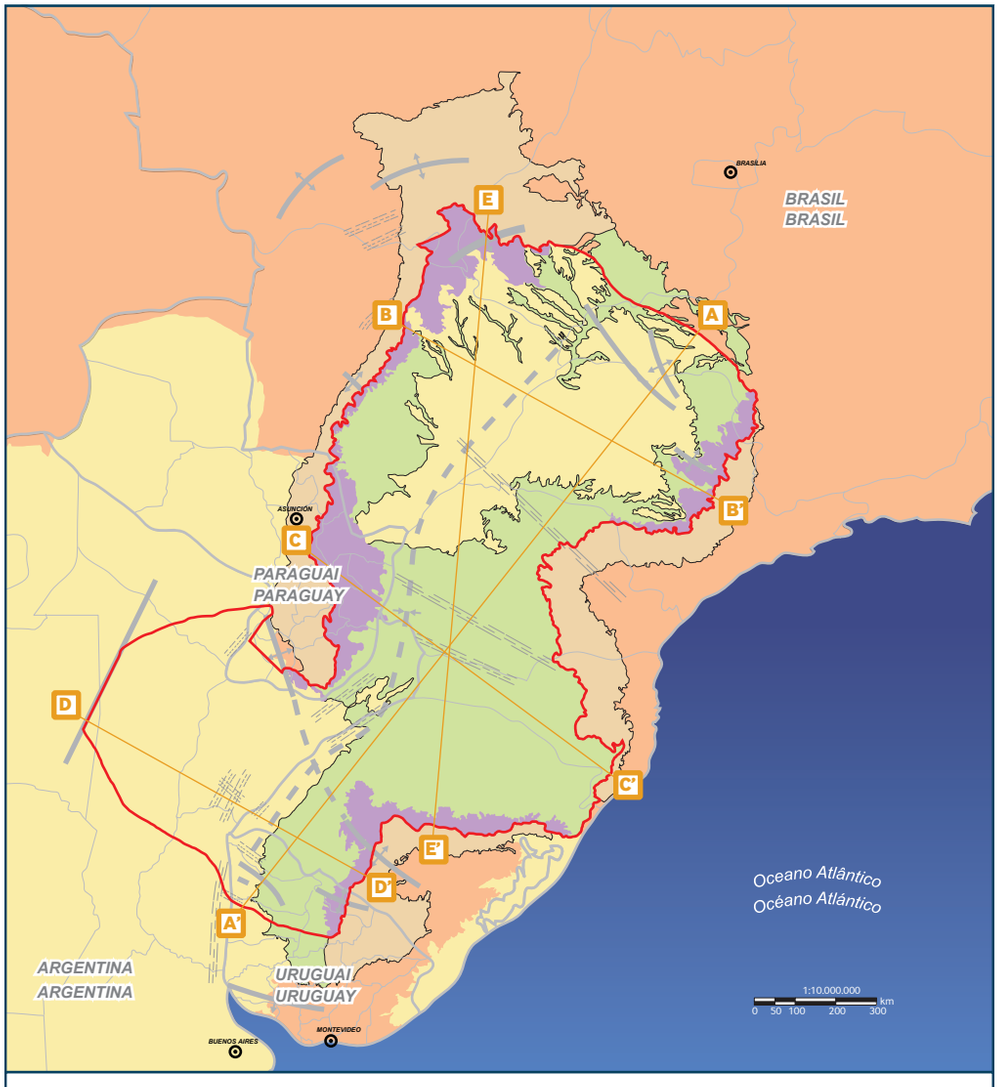


Figure 3. Simplified Geological Map showing the position of schematic cross sections

Key

- Departmental, state/provincial and international boundaries
- Limits of the GAS
- Cross-sections
- National capital
- Post-GAS sediments
- Basalts
- GAS sediments
- Pre-GAS sediments
- Base

Geological conventions

- Arc
- Suggested arc
- Fault
- Alignment
- Synclinal

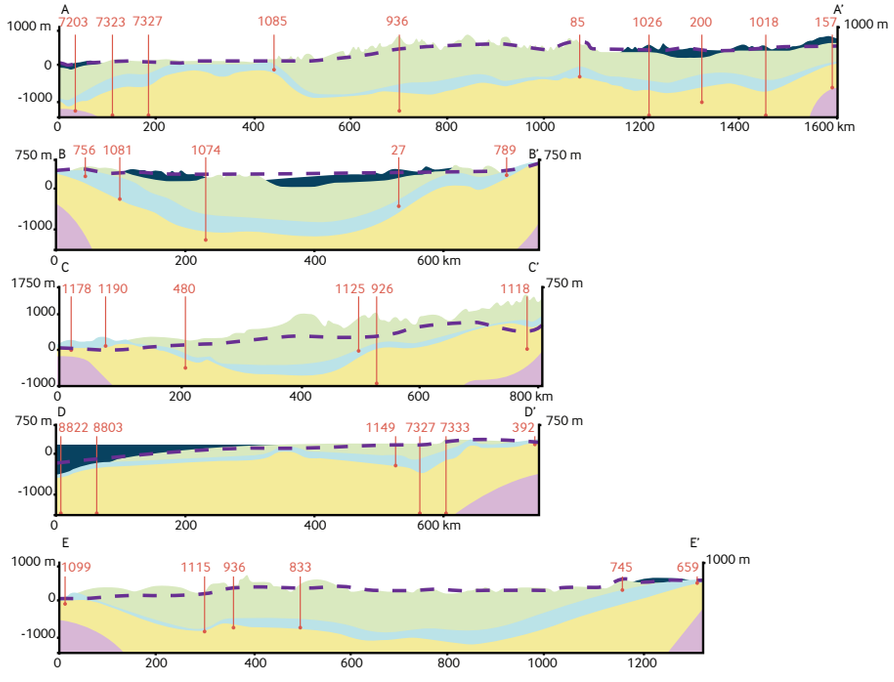
Source: Final Hydrogeology Report, Guarani Consortium, 2008

according to the Simplified Geological Map in Figure 3. The northern limit of the GAS is inferred, since there are no outcrop areas in the Brazilian states of Goiás and Minas Gerais, a region where the aquifer is covered by a layer of basalt (Figure 4, section A-A'). Data from wells drilled in the State of Goiás indicate that this limit is marked by reduced thickness of the Pirambóia and Botucatu formations. The stratigraphic limit coincides with the limits of the basin, marked by structural features at its base, responsible for its elevation. The southern part of the aquifer is also characterized by a scarcity of outcrops, especially in Argentina, where there are too few wells to enable determination of its limits (Figure 4, section A-A').

Definition of the southwestern limit of the GAS (Figure 4, section D-D') is based upon surveys of component units of the aquifer in the subsoil, principally based upon an evaluation of data from oil wells drilled in the Chaco-Paraná Basin region of Argentina. These wells were partially reassessed during execution of the PGAS and the data incorporated into the survey of the principal sismo-stratigraphic elements[5], through geophysical studies of units of the GAS (or its mesozoic equivalent) deposited on the permian-triassic discordance and petrographic studies for identification of concrete mineralogical elements for geological correlation.

2.4 HYDRODYNAMIC CHARACTERIZATION

An evaluation of the direction of GAS groundwater flows was carried out based on static water levels in wells drilled into the aquifer, and this information was subjected to systematizations using the hydrogeological database (HDB). Levels were measured when the wells were bored, though some of the data was updated during the inventory and sampling carried out under the PGAS.



Source: Final Hydrogeology Report, Guarani Consortium, 2008

Figure 4. Schematic Cross Sections (A, B, C, D, E)

Under the PGAS, a potentiometric map of the GAS (water levels and pressure) was also prepared, providing details, conditions and preferential flow directions of groundwater in replenishment and discharge zones and in artesian zones. The Hydrogeological Map of the GAS (Figure 2) shows potentiometric isolines and the main flow directions, complemented by isotopic data, to enable estimation of the ages and transit times of water (topic 2.7).

As there are no routine groundwater measurement programs in the countries overlying the GAS, mapping was carried out on the basis of non-systematic measurements taken over the years. Thus, the map can be regarded as a conceptual model of regional groundwater flows within the GAS, since current measurements could be influenced by prolonged and excessive pumping from wells. In view of this, the proposal for implementation of a GAS monitoring network is a response to the need to produce periodic and reliable information to comprise series of qualitative and quantitative data on wells, similar to the pluviometric measurements that the countries systematically gather.

The sandstones of the Botucatu Formation and of the upper strata of the Tacuarembó Formation have porosity values that vary between 20% and 30%, with high permeability of over 200 meters per day (the speed at which water flows through porous segments of the GAS), a parameter characteristic of pores with high connectivity (Figure 5).

In regional terms, from these replenishment zones to the discharge zones, GAS groundwater flows tend to move from north to south, accompanying the orientation of the Paraná Sedimentary Basin from its confluence between the States of Paraná and Mato Grosso do Sul (Brazil) and Paraguayan territory. From a hydrogeological standpoint, this axis corresponds to the so-called central channel (calha central) of the GAS (see Figure 2).

The rise in the northern compartment of the eastern part of the basin led to erosion of sedimentary sequences and formation of replenishment zones of the aquifer (Figure 4, section E-E') with a characteristic radial flow from its highest points. Examples of such rises are to be found in

5 Definition of limits is based upon the presence of sandstones (structural limits of the Alto Las Breñas-Otumpa region, in the Provinces of Chaco and Santiago del Estero, and stratigraphic limits to the north and south of these structures, where the thickness of GAS sandstones drops and finally disappears).

the northwestern extremity of the outcrop zones (on the border of the States of São Paulo and Minas Gerais), in the Arc of Ponta Grossa (Paraná) and in the Dome of Lages (Santa Catarina).

The main and most evident regional discharge and replenishment areas of the GAS are associated to outcrop zones.

Outcrop areas, however, may present their own local flow dynamics as a consequence of geo-morphological characteristics, and some zones may serve as replenishment areas, and others as discharge areas. In these areas, part of the replenishment feeds base flows of existing drainage networks. This dynamic of the GAS has an influence on Brazil's Pantanal wetlands. Isotopic studies carried out in the wetlands of Ibera (Argentina) and Ñeembucú (Paraguay) failed to confirm the presence of GAS groundwater discharges. Figure 6 provides a schematic representation of replenishment, discharge and non-flow zones.

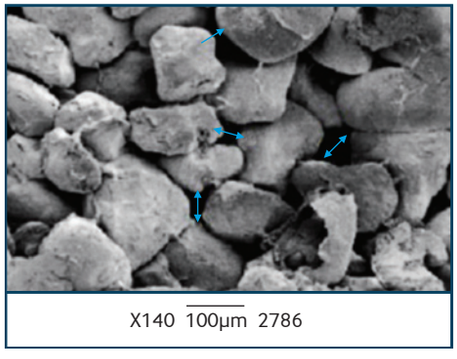
Practically the entire western limit of the GAS comprises a discharge area that feeds the drainage network that forms the Paraguay River Basin, as far as the Paraguayan Department of San Pedro (Figure 4, sections B-B' and C-C').

Four large hydrodynamic domains (northeast, east, west and south) can be identified. These relate directly to large structures within the GAS, especially the Arc of Ponta Grossa (that divides the aquifer into two potentiometric domains) and the Arc of Rio Grande–Asunción (responsible for reduced thickness of sandstones in the subsoil and for a major regional directional change in GAS groundwater flows) (Figure 6) There follows a description of these domains.

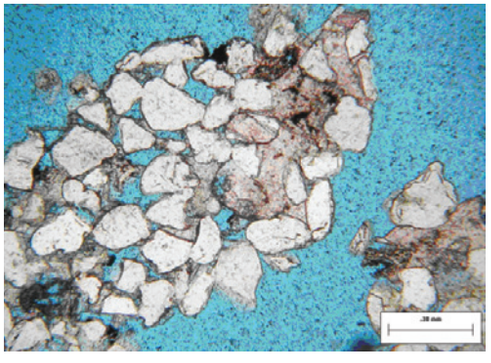
I. The first domain (northeast), located at the northeastern extremity of the area, encompasses a portion of the GAS in the Brazilian States of São Paulo and Minas Gerais, and is limited by a replenishment zone related to the GAS outcrop region, where groundwater flows run toward the Paraná River. Next to the outcrop zone, hydraulic gradients are steeper, varying from 3 to 5 meters per kilometer (m/km), with a considerable reduction in the confined zone, where gradients are no steeper than 0.1 m/km. This is directly correlated to the geometry of the GAS, since the greatest thicknesses occur in this region.

II. To the south of the northeast domain is the east domain. Both are separated by the Arc of Ponta Grossa, dikes of which serve as a huge hydraulic barrier and guide groundwater flows toward the north. Groundwater replenished in São Paulo must get around this obstacle, which extends to the channel of the Paraná River. In the east domain, flows tend to move east-to-west, principally as a consequence of a rise at the edges of the Paraná Basin and specific conditioning elements. An example of this is to be found in the State of Paraná, where the Arc of Ponta Grossa and its related dikes guide flows in an east-to-west direction, characterizing this as a region of great anisotropy. To the south of the Dome of Lages, as far as the Torres region in Rio Grande do Sul, potentiometric lines run parallel to the outcrop area, characterizing this as a non-flow region. That in this area there is neither replenishment nor discharge of GAS water is explained by features of the terrain, which forms escarpments and cliffs such as the Serra do Rio do Rasto (in Santa Catarina) that block inflows of rainwater into the aquifer. In this compartment, hydraulic gradients are quite homogeneous, varying from 2 to 3 m/km. Also in this domain is a discharge zone related to the east-west outcrop strip, that cuts through the State of Rio Grande do Sul on the left bank of the Jacuí River. Here there are discharges of water from replenishment areas, linked to higher areas of the Dome of Lages.

III. The entire western edge of the GAS, where the west domain is located, performs practically as an independent system, with replenishment and discharge



Microphotograph of a sandstone for the Upper Portion of the Tacuarembó Formation showing excellent inter-granular porosity and excellent interconnection between pores



Microphotograph of a of a petrographic slide of (fine to medium) sub-feldspatic sandstone well selected and with porosity of 21% of the Tacurembó Formation

Source: LCV, SNC Lavalin Laboratory report 2008.

Figure 5. Microphotographs (petrographic slide and sweep microscopy) of sandstone of the Tacuarembó Formation, showing good and excellent inter-granular porosity

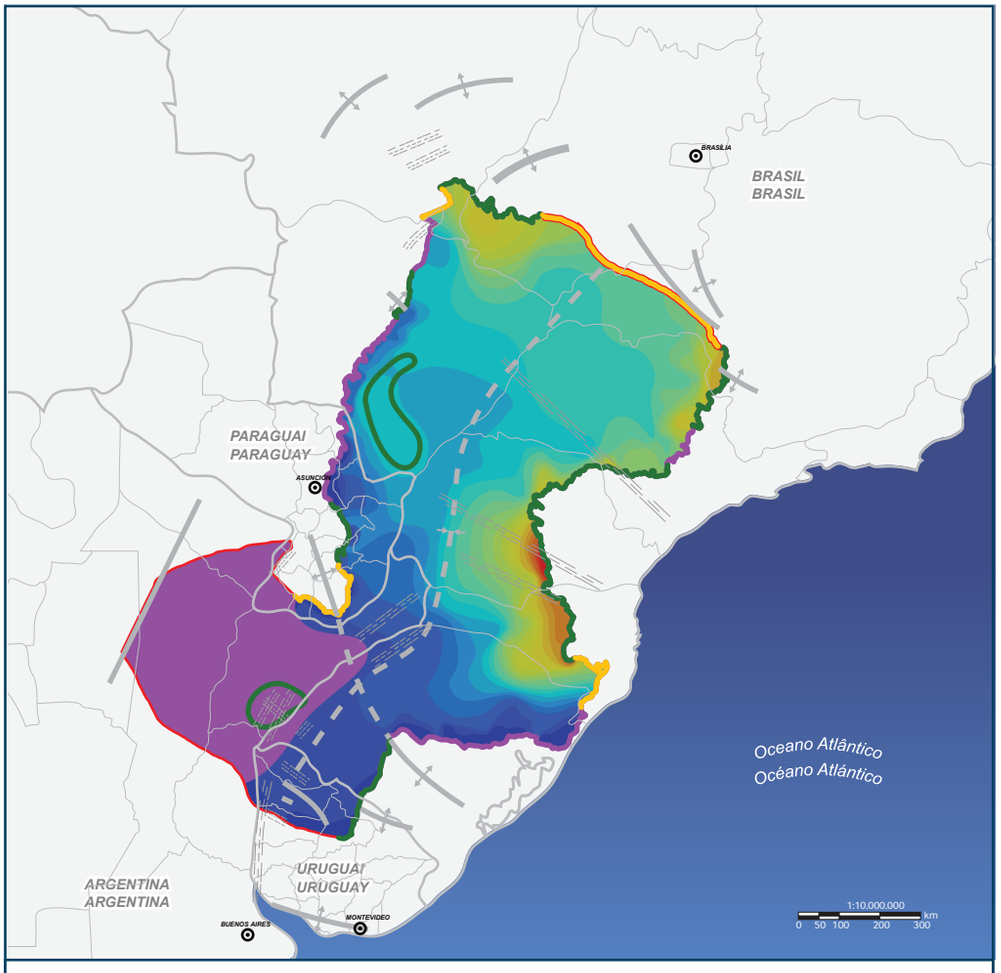


Figure 6. Outline of the GAS

Key

- Departmental, state/provincial and international boundaries
- Limits of the GAS
- Discharge or outflow (D)
- Replenishment or inflow (R)
- Non-Flow (NF)
- National capital

Cotas piezométricas

1100 - 1150	500 - 550
1050 - 1100	450 - 500
1000 - 1050	400 - 450
950 - 1000	350 - 400
900 - 950	300 - 350
850 - 900	250 - 300
800 - 850	200 - 250
750 -800	150 - 200
700 - 750	100 - 150
650 - 700	50 - 100
600 - 650	0 - 50
550 - 600	

Geological conventions

- Arc
- Suggested arc
- Fault
- Alignment
- Synclinal

Source: Numerical Modeling of the System regional Aquifer Guarani, Guarani Consortium 2008.

areas associated to outcrop strips that mark the existence of a groundwater divide. Within this domain another important replenishment zone is associated with higher terrain in the States of Goiás, Mato Grosso and Mato Grosso do Sul. Such replenishment causes radial flows, down toward the outcrop zone of the Taquari-Coxim River Basin and the central channel of the GAS. The entire western outcrop area is characterized by a discharge zone resulting from its relative low topographical position in relation to the rest of the Basin – given that the eastern limit was intensely raised, whereas the western limit that experienced influences from emergence of the Andes, underwent a much lighter raising. Associated with this local discharge zone, a groundwater divide runs parallel to the surface water divide between the Paraná and Paraguay River Basins. The watershed is the Serra de Maracaju. Near the towns of Dourados, Amambaí and Sidrolândia, in the State of Mato Grosso do Sul, numerous outcrop windows appear in the sandstone of the Botucatu Formation, breaking through the basalts and acting as local replenishment areas, which also determine the location of the divide. Hydraulic gradients in this compartment are higher in the northern portion (replenishment zone) and west of the watershed, varying from 1.5 to 2 m/km. To the east of the divide, gradients are less steep, varying from 0.8 to 0.5 m/km, and are also associated to thicker portions of the aquifer.

IV. All regional groundwater flows of the three above-described domains that do not discharge at the western edge end up converging toward the central channel of the basin along the Paraná River, in the direction of the last domain, located to the south of the Asunción-Rio Grande dorsal. Regional water balances are small or null (suggesting that there might be two compartments, one to the north of the Asunción-Rio Grande dorsal, and the other to the south, though this hypothesis has not yet been tested). It is, however, as yet unclear if this serves as a discharge area (for water coming from the north) or as a replenishment area (through mixing with the waters of the GAS). In the south domain, the main flow is toward the west. Areas of replenishment are associated with the north-south outcrop strip that begins in the Alegrete region of Rio Grande do Sul, and advances into the Rivera region and down toward the town of Tacuarembó in the center of Uruguay. In Argentine territory, despite sparse data, a small replenishment area associated with the Alto de Mercedes was identified in the Province of Corrientes. No GAS discharge zones have been confirmed in this domain, and further research is required.

Along the Paraná River, the GAS is manifested by an artesian zone (where water springs forth from tube wells). This phenomenon occurs along a 300 km strip in the States of São Paulo, Mato Grosso do Sul and northern Paraná, and in a narrower strip to the south, reaching down to the Argentine Province of Corrientes. A second region of artesianism is to be found in a narrow strip of approximately 50 km along the Uruguay River on the border between Uruguay and Argentina.

Yields from of the aquifer were assessed by means of analysis of the specific capacity of wells, carried out using information from the GAS Hydrological Database (HDB).

Full information was found on 1,348 wells. Such information encompasses static and dynamic levels and data on flows. The results show that most of the wells produce discharges of less than 50 m^3/h. Some wells, however, produce discharges of between 150 and 300 m^3/h, and are used for public water supply for large and medium-size towns, especially in the State of São Paulo.

With respect to specific discharges (flows when levels in wells is low) the majority of wells yielded less than 6 m^3/h/m, and most had specific discharges of less than 2 m^3/h/m.

2.5 HYDROCHEMICAL CHARACTERISTICS

Groundwater quality depends on interactions between water and solid and gas phases within the geological context. Moreover, it depends upon flows (speed, time of residence, hydraulic level and replenishment) and the natural climatic cycle and its variations (atmospheric pressure, rainfall patterns, etc.). In some cases, natural variations in the composition of water may be equal to or greater than variations caused by pollution[6]. For this reason, the baseline[7] can not be stated as a single value, but rather, must be expressed by a range of values, considering natural variations within the aquifer.

A lack or scarcity of historic data on water quality and hydraulic levels makes it difficult to provide a consistent statistical definition of this range of natural groundwater characteristics in different aquifers or in the GAS. For this reason, the PGAS sought to generate new data and detailed evaluations on the main hydrochemical and isotopic features of the GAS. It is essential that this process of generating basic hydrochemical information be continued, so as to enable assessment of possible effects of pollution and/or anthropogenic changes to the flow system, making it possible to detect which activities are generating harmful qualitative and quantitative impacts.

It should be stressed that the majority of the wells examined under the PGAS are being exploited with flows of over 100 m^3/h, and were built to maximize yields. Thus, samples collected may represent a mixture of waters from various levels of the aquifer, that tend to have a variety of geochemical qualities, thus making interpretation of hydrochemical data even more challenging.

6 Water is considered contaminated when its natural quality has been altered by anthropogenic and/or natural processes to the extent that it can no longer be used for the purposes for which it had previously been classified (according to standard reference parameters).

7 According to Manzano, "the natural baseline of the chemical composition (or quality) of groundwater can be defined by its physical-chemical properties, that result from purely natural processes." The European "BaSeLiNe" (Natural BaSeLiNe Quality in European Aquifers) project adopted the following definition: "the natural baseline quality of water is the level of concentration of a certain element, species, or substance present, stemming from natural geological, biological or atmospheric sources".

Generally speaking, the waters of the GAS are potable, with low levels of mineralization (indicated by conductivity of < 1.000 µS/cm) and low-speed flows. Their pH values vary considerably, from 4.5 to 11 but, in general, tend to be close to neutral. The predominant types of water and their respective electrical conductivity characteristics and pH are shown on Table 3. Certain areas display higher concentrations of sulfates and of fluorine, at levels higher than is recommended for household use. Areas where less regional flows circulate tend to be associated with greater salinity (especially in central parts of the basin, in the Brazilian States of Paraná, Santa Catarina and Rio Grande do Sul). When salinity exceeds acceptable limits, there are restrictions on the use of the water, as occurs in the extreme south of the GAS region and on its western limits in Argentina (inferred on the basis of the electrical profiles of oil prospection wells). In certain wells located in thermal areas in the southern portion of the GAS there is evidence that, aside from salinity, the water has high concentrations of other inorganic elements, such as arsenic, and must be carefully analyzed prior to being declared suitable for use.

The behavior of the main cations and anions on GAS water flow lines makes it possible to assess the principal geochemical processes underway within the GAS, including: inflows, in replenishment areas, of CO_2 from rainwater and from the soil; ionic enrichment from dissolving of sulfate, chlorate and carbonate-rich minerals with which groundwater comes into contact; ion exchanges and mixing with saline water from greater depths.

Spatial distribution of these processes depends upon such factors as:

1. Presence of ascendant salt-water flows from the pre-GAS (signifying that there are zones in which vertical flows predominate over horizontal flows). Especially relevant are the zones situated at the eastern border of Paraguay with Brazil and Argentina, along the Paraná River, on the Iguaçu River and on the border between the States of Rio Grande do Sul and Santa Catarina, along the Pelotas River.
2. Presence of the Rio Grande-Asunción structural arc. All maps of spatial distribution of soluble salts indicate that the arc acts as a barrier between the northern and southern portions of the GAS. This explains why groundwater in areas around Uruguaiana and Itaqui is quite different from the water in the zone immediately to the north. There would thus seem to be no GAS discharges on its southwestern limit, through lateral transfer toward other formations. A major portion of the discharges to the surface would appear to occur through a network of ascendant flows in zones of intense fracturing.

Information generated by the PGAS makes it possible to corroborate a model previously proposed by various authors, and the main processes responsible for chemical composition of waters of the GAS, and then to extend the model to the entire aquifer, stressing particularities of the zone to the southwest of the Rio Grande-Asunción Arc.

2.5.1 HYDROCHEMICAL DIVISION

Waters of the GAS display three main hydrochemical facets which, when related to the regional flow networks (from outcrop and replenishment areas to the confined sectors) enable hydrochemical zoning (Table 3 and Figure 7). Considering the scale of the work and its inherent simplifications, four hydrochemical zones can be identified. Despite this division, it is quite possible that mixing of waters of the GAS and those of underlying strata takes place.

2.6 HYDROTHERMAL CHARACTERISTICS

GAS water temperatures rise as a function of the depth of the aquifer's ceiling (Figure 8). In most of its confined area, temperatures vary between 35 °C and 55 °C. Maximum temperatures are approximately 65 °C, but in a few limited areas they may be as high as 80 °C. Figure 8 provides a map of temperature distribution in the form of isotherms, and its analysis may enable establishment of a classification by average temperature. Each temperature band should, a priori, be associated with certain types of potential geothermal uses (Table 4).

GAS water temperatures are within a band considered of low enthalpy. The zone of the aquifer with greatest available potential is the western region of the State of São Paulo (Brazil) where a thermal potential of some 240 kW/kg/s is available. Exploitation of this thermal potential would require mechanical pumping capacity of 1.5 kW/kg/s, assuming that the available piezometry is insufficient to pump the volume needed to fulfill the required thermal potential. In this same zone, available thermal potential is of 160 kW for each kW of mechanical potential available. It should be observed that both the thermal potential and the mechanical potential decline at the edges of the GAS.

2.7 ISOTOPIC STUDIES

Application of environmental isotopes[8] to GAS groundwater studies began in Brazil and in Argentina in the 1970s, and in Uruguay and in Paraguay in the 1980s. These analyses assessed behavior of environmental isotopes in localized areas of the GAS. Isotopic studies carried out under the PGAS, with support from the International Atomic Energy Agency (IAEA) provided an integrated regional overview of the GAS and possible explanations of isotopic processes that have taken place in its waters.

8 Isotopes are atoms, variants of a chemical element, that have the same atomic number (number of protons), but a different atomic mass (number of neutrons in the nucleus). They may be natural or artificial. The ratio of the concentration of isotopes is expressed in "parts per thousand" (‰) or "deviation per thousand" of a standard (‰).
Radioactive isotopes, such as tritium (^3H) and carbon (^{14}C) are constantly loosing their radioactivity from the moment the rocks are formed and disintegrate in an irreversible form. Velocity of disintegration is constant and varies according to the element. The period of semi-disintegration (half-life) is the time it takes the element to reduce its radioactive mass by half. As a consequence of this characteristic (half-life), radioactive isotopes make it possible to determine the age of rocks or of water that contains such elements.
Stable isotopes, such as deuterium (^2H), ^{18}O, and ^{13}C do not disintegrate, and remain constant throughout the entire period that they are present in the water. Their presence helps determine various factors and processes: history of the water, rainfall conditions, geographic factors (distance from the ocean, altitude, latitude), climatic factors (temperature, degree of condensation of cloud masses), rainfall and evaporation processes, geothermal processes, metamorphic processes, and human activities. Thus, stable isotopes make it possible to determine the origin of water.

Table 3. Hydrochemical zones

Group	Sub-groups	CE (mS/cm)	pH	Hydrochemical zone
TYPE A – Waters generally potable, calcium bicarbonated (Ca-HCO_3) and subordinately bicarbonated calcium-magnesium and calcium-sodium (CaMg- CO_3) waters. Little mineralization and low CE; little hydrochemical change and composition similar to that of replenishment waters	A1: Na>Cl	< 150	4 to 8	**ZONE I** – Located next to the outcrop area (at or near replenishment areas in the direction of the flow), around the confinement zone of the GAS. The width is variable. The narrowest part is in the eastern region. In the western region, in Mato Grosso do Sul, it is 150 km
	A2: Na≤Cl			
TYPE D – Calcium chlorates or magnesium chlorates	–	between 30 and 240	5 to 6	
TYPE B – Waters generally potable, sodium bicarbonated (Na-HCO_3), with a higher degree of mineralization and medium CE. Alkalinity rises progressively throughout the zone in which the ion transfer process (exchange of ions and dissolving of carbonate minerals) is dominant. Represents a change from type A waters. The proportion of saline water in the mixture to produce such changes observed may be ≤ 1%	B1: Cl<SO_4	between 200 and 600	7 to 10	**ZONE II** – Located in intermediate areas of the confined sector of the GAS. Type B2 is most common in the center of the basin. Probable influence in their composition of waters from aquifers underlying the GAS. Presence of waters with SO_4>Cl implies sources of SO_4 associated with ascendant flows of waters in contact with gypsum in pre-GAS formations **ZONE IIA** – Subzone located along the Uruguay River, between Argentina and Uruguay, where composition of the water is characterized by the presence of chlorine anions
	B2: Cl>SO_4			
TYPE C – Composition ranges between bicarbonates, sulfates, sodium chlorates (Na-HCO_3SO_4Cl) and sodium chlorate sodium sulfate. Mineralization medium to high. Represents a mixture of Type B waters with more saline waters, from underlying aquifers of the GAS. It is estimated that a mixture of ≤ 5% with waters of marine salinity would produce the saline concentration of these waters and change their chemical balance	C1: Cl<SO_4	> 550	7 to 9	**ZONE III** – Found where the GAS is most highly confined. C3 type waters are the most saline and are found in the center of the basin, in São Paulo and Santa Catarina, and along the Paraná River, between Paraguay, Argentina and Brazil
	C2: Cl>SO_4			
	C3: Na-Cl ou Na-SO_4			
TYPE D – Possibly, these are sodium chloride waters with high mineralization, resulting in low electrical resistance observed in geophysical profiles (< 2Ωm)		>10.000		**ZONE IV** – This zone was described by means of indirect observations of electric profiles of oil wells drilled in the Provinces of Entre Ríos, Chaco, Formosa and Santiago del Estero (Argentina)

Identification of subtypes of sodium-bicarbonated (Na-HCO^3) type waters is a new feature of studies. The same occurs with information relating to mixtures with salt waters of the pre-GAS.
Fluorine is associated with hotter, more saline waters, with a rNa/rCl (r=meq/L) ratio close to 1. This suggests that their source (or main source) is in brackish pre-GAS formations.
With respect to wells in the thermal region in Argentina, from which salt water is abstracted, isotopic ratios of ^{18}O and ^{2}H indicate an origin other than that of waters of the GAS found in other thermal wells from which fresh water is abstracted.

Source: GS/GAS Adapted from the Hydrogeology Final Report, Guarani Consortium, 2008.

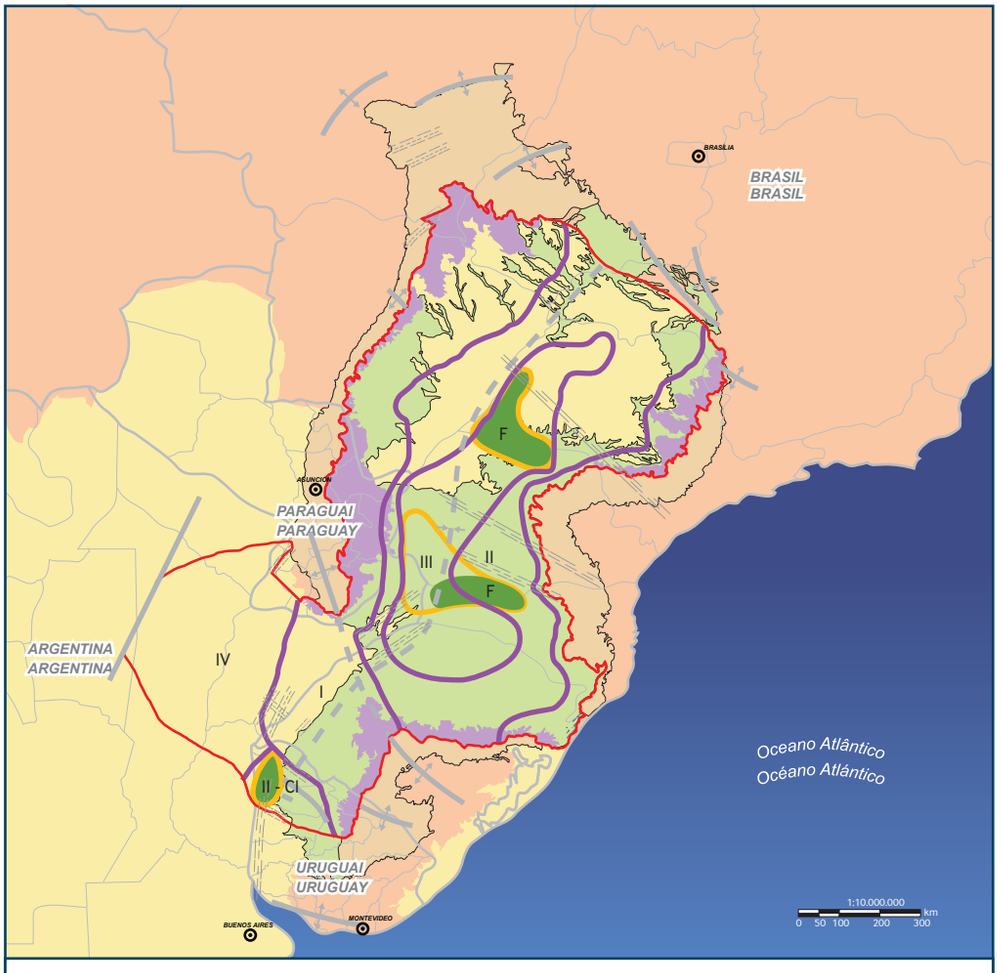


Figure 7. Hydrochemistry Map System
Guarani Aquifer

Key

- Departmental, state/provincial and international boundaries
- Limits of the GAS
- Chemical zones
- Zones with high salt content
- Zones with excessive concentration of fluorine
- Post-GAS sediments
- Basalts
- National capital
- GAS sediments
- Pre-GAS sediments
- Base

Geological conventions

- Arc
- Suggested arc
- Fault
- Alignment
- Sinclinal

Source: GS/GAS , Adapted from the Final Hydrogeology Report, Guarani Consortium, 2008.

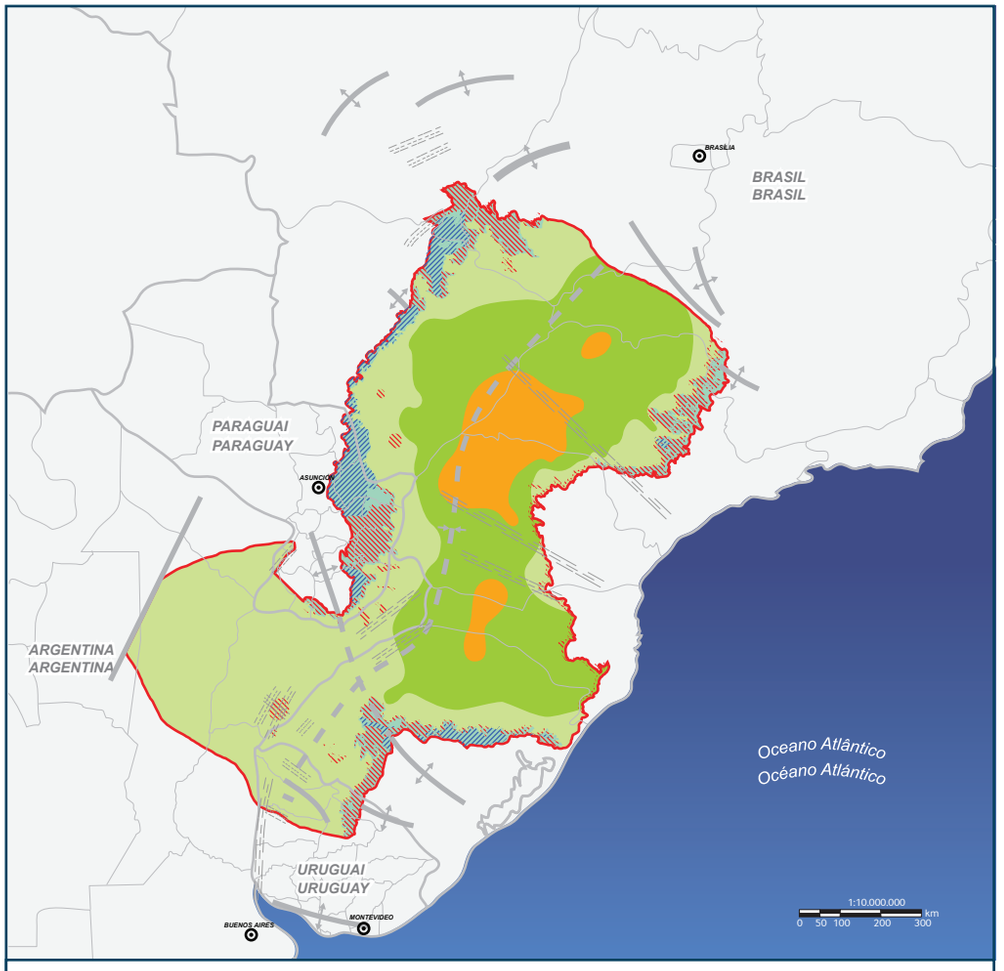


Figure 8. Hydrothermal Map of the GAS

Key

- Departmental, state/provincial and international boundaries
- Limits of the GAS
- GAS outcrop area
- Replenishment area
- Discharge area
- National capital

Temperature in degrees (°)

- Zone 1 (until 30°)
- Zone 2 (30° to 50°)
- Zone 3 (50° to 70°)

Geological conventions

- Arc
- Suggested arc
- Fault
- Alignment
- Synclinal

Source: GS/GAS, Adapted from the Evaluation Report on Potential Thermal and Non-Thermal Uses of GAS Water, Guarani Consortium, 2008.

Table 4. Identification of GAS hydrothermal zones and their potential uses

Hydrothermal zones	Current Use	Potential Use
Zone 1 (<30 ^{o}C)		Geothermal pumps, warming of the soil, aquaculture, frost control, heating and cooling of homes, heating of water, spas
Zone 2 (30 ^{o}C-50 ^{o}C)	Tourism / Salto-Concordia Hydrothermal Zone	Mushroom cultivation, carbonation of drinks, greenhouses and sterilization of soils, aquaculture, preparation of concrete, spas, frost control, heating and cooling of homes, heating of water, pasteurization and washing of poultry
Zone 3 (>50 ^{o}C)		Drying of fruits and vegetables, carbonation of drinks, greenhouses and sterilization of soils, processing of wood and paper, preparation of concrete, food processing, frost control, heating and cooling of homes, heating of water, pasteurization

NB: Depending upon the quality, water can also be used for such traditional purposes as public water supply etc.

Source: GS/GAS Adapted from the Report on Evaluation of Potential Thermal and Non-thermal uses of GAS water, Guarani Consortium, 2008.

Analyses of isotope samples collected during the project were carried out at different laboratories. Oxygen 18 (O^{18}) and deuterium (H^{2}) tests were carried out at the Environmental Isotopes Laboratory of the Chilean Nuclear Energy Commission and the Environmental Isotopes Laboratory of Ingel, in Argentina. Tritium (H^{3}) tests were carried out at the Tritium Laboratory of the Nuclear Technology Development Center of Belo Horizonte, in Brazil. Carbon 13 (C^{13}) and sulfur 34 (S^{34}) tests were carried out at the Environmental Isotopes Laboratory of the University of Waterloo, in Canada. The carbon fourteen (C^{14}) tests were carried out at the Isotrace Laboratory of the University of Toronto, in Canada.

O^{18} and H^{2} Isotopes

A broad range of isotopic values were observed in groundwater in the northern zone of the GAS. The most enriched values tend to be close to those observed in replenishment areas, whereas the poorest values are to be found in the confined and deepest parts of the aquifer. The isotopic content of waters in this part of the GAS are clustered along a meteoric line similar the world meteoric line. This indicates that such waters did not undergo significant evaporation prior to infiltration in the replenishment areas.

In the southern region of the GAS, the range of groundwater isotopic values is considerably smaller than in the north. These waters are clustered along a meteoric line that is different to the world meteoric line, that may be related to the history of air masses that brought rain to this region.

Sulfur 34 (S^{34})

Based on the results for this isotope, it can be deduced that sulfates in the waters of the GAS are of continental origin. There is no evidence of contributions of deep levels of marine origin, corroborating that sedimentation environments of the units that make up the GAS and the units of the pre-GAS, are predominantly continental.

Tritium (H^{3})

Higher values are found in replenishment zones and in waters pumped from pre-GAS formations. This implies that such waters are of recent replenishment of the aquifer. In both northern and southern portions of the GAS, tritium data behaves in similar fashion. Tritium results are in accordance with the conceptual model, and the isotope is not detected in confined areas of the GAS.

Carbon (C^{14} and C^{13}) isotopes

Carbon isotopes present a parallel evolution, in accordance with flow lines, with a lessening of C^{14} activity and enrichment of C^{13} by dissolution of environmental carbonates, exchange, and radioactive decay. The highest C^{14} values (100 pMC – percentage of modern carbon) represent more modern waters and are found in the proximity of outcrop zones. The lowest values (around 0 pMC) represent older waters and tend to be from the central and deeper part of the aquifer, as is shown in Figure 9.

In the region of São Paulo, ages calculated using C^{13} values range from modern waters to waters dating back 28,000 years. In the region of Mato Grosso do Sul, the oldest waters (according to corrected C^{14} values) are between 4,000 and 28,000 years old, even though there is a vast area close to the Paraná River in which there are no wells suitable for collection of samples. In Santa Catarina, the oldest waters have corrected radiocarbon ages of between 13,900 and 38,000 years. In Rio Grande do Sul, C^{14} values show that the waters range from modern to 11,500 years old. In Uruguay, ages of the water range from 16,000 to 28,000 years.

The C^{14} data, together with O^{18} data, serve to reaffirm the existence of 'internal' replenishment in the State of Mato Grosso do Sul, by means of basalt windows, generating the principal divider of groundwater drainage in the west-north sector of the conceptual model shown on the GAS Hydrogeological Map (Figure 2). Replenishments produced through these windows cause the waters to flow to the west (discharge area) toward the central channel.

A select number of samples was collected in the Ibera, Galarza and Luna lakes that are part of the Esteros de Ibera wetlands region. This sampling was carried out to test the hypothesis that the wetlands are GAS discharge zones. The isotopic data showed that the waters of the lakes have a homogeneous

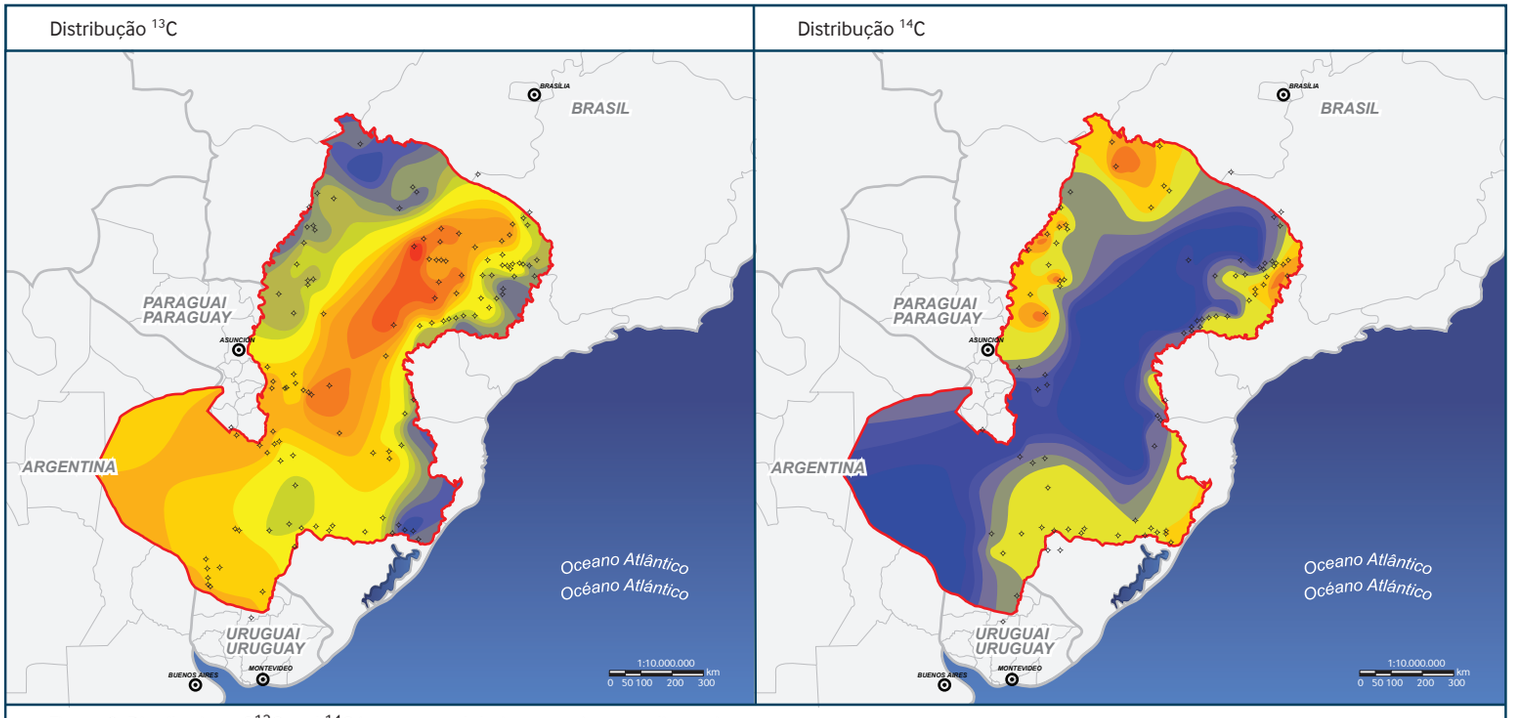


Figure 9. Distribution of ^{13}C and ^{14}C isotopes and their respective sampling points

Source: GS/GAS , Adapted from the Final Hydrogeology Report, Guarani Consortium, 2008.

isotopic composition, and present highly enriched O^{18} and H^{2} values (typical of waters that have undergone evaporation). Tritium data indicated that this water is of recent origin, and there is no evidence of earlier discharges into the wetland areas.

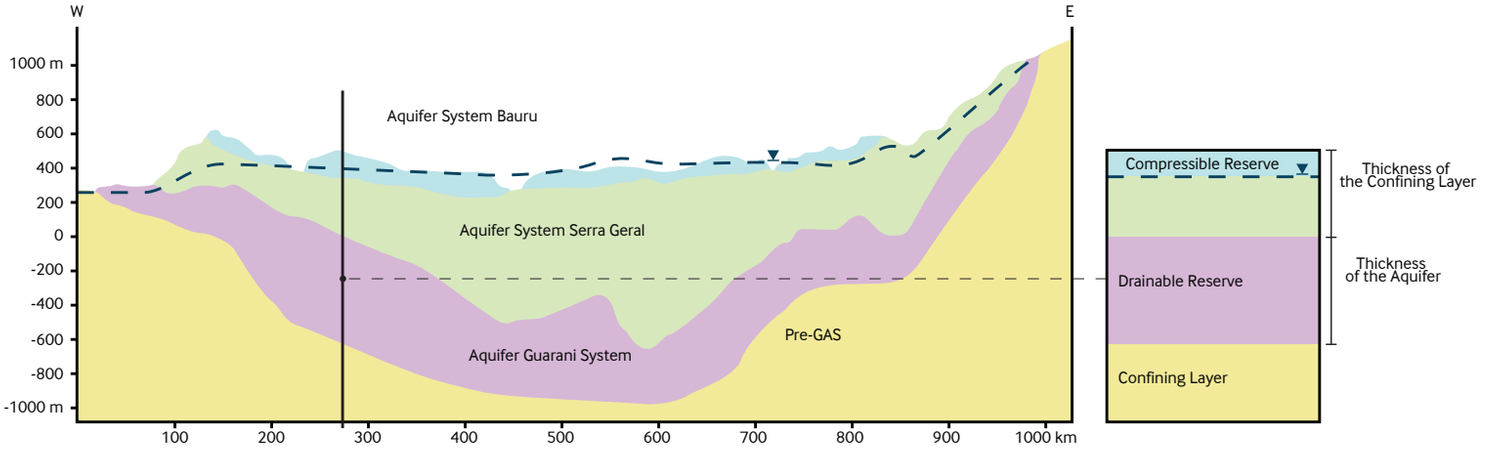
2.8 WATER RESERVES

There are two types of groundwater reserves: active reserves (dynamic resources / effective replenishment) and static reserves (permanent reserves / permanent storage). The sum of these two results in total reserves.

Active reserves are the volumes of renewable water that enter the aquifer each year. They depend directly on seasonal replenishment (rainwater infiltration and other natural sources) and are available for exploitation. They are especially important in unconfined aquifer regions and correspond to the volume of flows from confined parts of the GAS.

Static reserves correspond to the total quantity of water stored in the reservoir (in rock pores and fractures). They can be divided into two parts: those susceptible to drainage, where water can be drained by gravity; and compressed portions, where storage occurs due to compression of the aquifer and expansion of water (compressible aquifer). These amount to a non-renewable reserve (at least in human timescales) that can be exploited only up to certain circumstantial limits in which active reserves are insufficient to fulfill specific needs. Figure 10 illustrates these reserves.

Water availability (exploitable potential) in a confined aquifer of such huge dimensions as the GAS can be defined as the quantity of water available for use, obtained from wells. Such availability can be calculated on the basis of active reserves as the quantity of water that can be abstracted from a static reserve or from permanent storage,



Source: GS/GAS , Adapted from the Final Hydrogeology Report, Guarani Consortium, 2008.

Figure 10. Definition of total reserves in a confined aquifer

during a given period, without causing irreversible environmental damage.

Table 5 presents volumetric estimates of active and static reserves of the GAS, according to references prior to results generated under the PGAS.

Estimating the reserves of a regional aquifer system is subject to a series of limitations. The first of these is water balance. During the PGAS, such balances were assessed on a regional basis, although real replenishment rates had not been identified for each zone. Moreover, it was impossible, at that stage of the Project, to estimate inflows and outflows of water through the sequence of volcanic rocks of the Serra Geral Formation and others, upon which, in principle, the relationship between the potentiometric contours of both aquifers depends. This is a priority theme for investigation in subsequent studies on the GAS.

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Table 5. Volumetric estimates of permanent reserves and active regulators of the GAS

		Rebouças (1976)	Gilboa et al. (1976)	Rocha (1997)	Chang (2001)
Active Reserve	Direct Infiltration	22 km³/year	5 km³/year	160 km³/year	5,2 km³/year
	Indirect Infiltration	138 km³/year	_		
Static Reserve		48.021 km³	_	37.000 km³	
Exploitable Potential		_	_	40 km³/year	

Source: GS/GAS Adapted from the Final Hydrogeological Report, Guarani Consortium, 2008.

of the Serra Geral Formation and others, upon which, in principle, the relationship between the potentiometric contours of both aquifers depends. This is a priority theme for investigation in subsequent studies on the GAS.

2.8.1 ACTIVE RESERVE

Outcrop areas of the GAS cover 124,650 km². Roughly 80,000 km² of this total (64%) are replenishment areas, whereas an additional 3,500 km² mark the watershed between Mato Grosso do Sul in Brazil, and the region of the municipality of Mercedes in Argentina. It is in these areas that deep replenishment of the GAS occurs, in the direction of its confined zones. Surplus water in the GAS region varies from 350-450 mm/year in the northern zone, to 650-750 mm/year in the southern zone. Comparison of these values, respecting certain limits, indicates that the surplus water that provides deep replenishment of the GAS, can not amount to more than 10-20 mm/year. These values are very similar to those estimated by Gilboa et al. (1976). The resulting replenishment volumes thus range from 0.8 to 1.4 km³ of water per year.

2.8.2 STATIC RESERVE

To calculate the static reserve of the GAS it is necessary to divide it into two parts:

(i) volume of water stored within the matrix of the aquifer (permeable reserve);
(ii) volume of water stored under compression in the confined zone, for which a storage ratio [9] of 10-^{4} was considered

For sandstones of the GAS, an average porosity of 15%±2% was considered. In view of their faciological heterogeneity and intrinsic digenesis, 10% of the total volume of the GAS was presumed to be made up of impermeable sediments. To calculate the total volume of rock in the aquifer, volumes were calculated within the Geographic Information System (GIS), using cells with an area of 100 km^{2} (i.e., a grid of squares with sides of 10 km).

Table 6 provides data on static reserves, indicating that estimates of volumes of GAS water range from 29.550 km³ ±4.000 km³, to 32.830 km³ ±4.400 km³. Of these, only 50 km^{3} correspond to the compressible reserve, implying that a major portion of the water contained in the GAS is stored in its component sandstones.

This volume of water does not necessarily imply that it is all available for abstraction. In various parts of the basin, the depth of the GAS is over 400 meters, and thus, if water levels were to drop owing to excessive pumping, abstractions would become technologically and economically unfeasible.

Table 6. Calculation of static reserves stored in the GAS

	Drainable reserve (km³)	**Compressible reserve (km³)**	**General Total (km³)**
Volume total (100%)	218.527,14	506.006,18	724.533,32
Volume of water (Drainable reserve – effective porosity: 15%±2%) (Compressible reserve – storage ratio: 10^{-4})	32.780±4.400	50,6	**32.830,6±4.400**
Permeable Volume (90%)	196.674,43	506.006,18	702.680,61
Volume of water (Drainable reserve – effective porosity: 15%±2%) (Compressible reserve – storage ratio: 10-4)	29.501±4.000	50,6	**29.551.6±4.000**

Source: GS/GAS , Adapted from the Final Hydrogeology Report, Guarani Consortium, 2008.

2.8.3 EXPLOITABLE RESERVES

To calculate the volume of GAS water that can effectively be exploited, it is necessary to establish abstraction scenarios in line with the operating limits of pumping equipment and well-construction techniques. A 400m drop in water levels (below the land surface) is currently considered the critical technical and economic limitation for exploitation of the GAS. Alongside this limit, a control mechanism seeks to avoid the effect of total removal of water from the drainable saturated layer of the GAS, to the point that, by virtue of exploitation, the GAS changes from a confined to an unconfined state. In such areas, maximum lowering should not exceed 30% of this layer.

Figure 11 provides a map showing application of this hypothesis. It shows portions of the GAS that have converted from confined to unconfined state, with a central strip that remains confined. Near the borders of the States of Paraná and Santa Catarina and in part of Rio Grande do Sul, water levels are now below the critical 400m depth. According to this 400m maximum-lowering scenario, exploitable volumes amount to 2,000 km³, equivalent to 6% of current total reserves of the GAS.

Following this same logic, other criteria could be applied, or use of varying scales of maximum-lowering values (100 m, 200 m or 400 m). Estimated respective available volumes using these scales are presented in Table 7. At current levels of exploitation, of some 1.04 km^{3}/year (disregarding replenishments of the same order of magnitude as current abstractions) these reserves could be exploited for over 2,000 years.

Table 7 shows exploitable volumes over 10, 50, and 100-year pumping periods against drops in water levels of 100, 200, and 400m. It can be seen that availabilities are very low in the confined portion. In unconfined portions of the aquifer (where abstractable water is equivalent to drainable reserves) volumes are greater, and quite capable of fulfilling current and growing future demand. This information is in accordance with isotopic results, indicating that waters of the central portion of the GAS are more than 20,000 years old, reflecting extremely slow replenishment of the aquifer.

9 Storage coefficient is the volume of water that can be released by a vertical fault in the aquifer, from a unitary section and of a height equal to its saturated thickness, when a unitary reduction of the hydraulic load occurs (piezometric level or water table). For confined aquifers, water is released by the mechanical effects of compression of the aquifer and of the water. For unconfined or phreatic aquifers, ignoring relatively small effects that may introduce elasticity of the aquifer, it is clear that the storage coefficient is equivalent to the effective porosity, since in both cases it results in a quantity of water that can be extracted by gravity from a unit of volume of the saturated aquifer. In this case, the value is similar to that considered by a number of authors, and obtained from various pumping tests carried out on GAS wells.

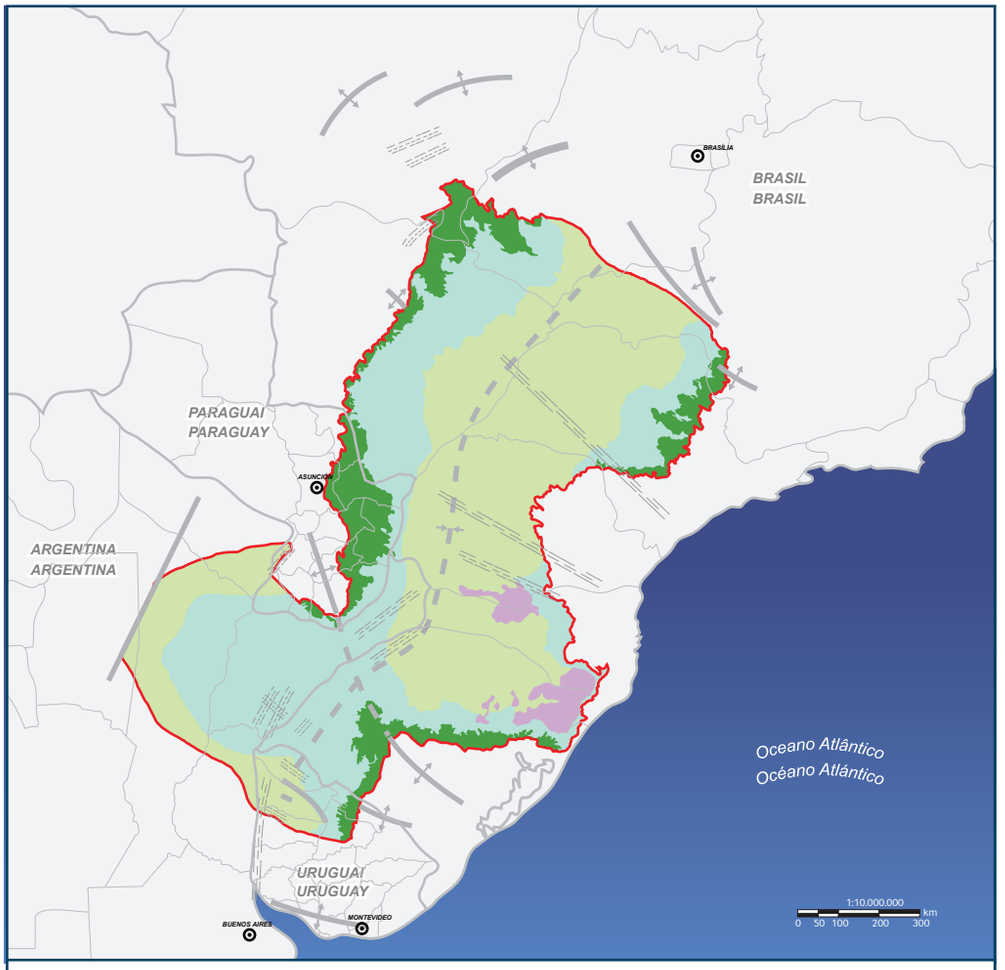


Figure 11. Map of GAS zones where water levels are dropping, taking 400m as the critical level

Key

- Departmental, state/provincial and international boundaries
- Limits of the GAS
- GAS outcrop area
- Available zone of the confined GAS
- Available zone for GAS drainage
- ZonE NE < 400 m
- National capital

Geological conventions

- Arc
- Suggested arc
- Fault
- Alignment
- Synclinal

Source: GS/GAS , Adapted from the Final Hydrogeology Report, Guarani Consortium, 2008.

Table 7. Simulations of volumes of exploitable reserves of the GAS in different scenarios

Exploitable static reserve (km³)	Lowering (m)	**400**	**200**	**100**
	Compressible	**25,21**	**12,06**	**3,83**
	Drainable	**2.014±270**	**1.660±220**	**1.610±210**
Scenarios over time (km³)				
10 years	Compressible	2,52	1,21	0,38
	Drainable	201,4±30	166,0±20	161,0±20
50 years	Compressible	0,50	0,24	0,07
	Drainable	40,28±5	33,20±4	32,20±4
100 years	Compressible	0,25	0,12	0,04
	Drainable	20,1±0,3	16,6±0,2	16,1±0,2

NB: Since active reserves (replenishments) are so much smaller than static reserves, they were not covered by this simulation.

Source: GS/GAS, adapted from the Hydrogeology Final Report, Guarani Consortium, 2008.

It is thus clear that the greatest potential for exploitation of the GAS is to be found in areas close to replenishment and outcrop zones, and that exploitation of the central part requires specific management. It is imperative to quantify real replenishment rates at the local level and, thus, to define sustainable and optimum exploitation volumes for the GAS in these zones.

2.9 CURRENT USES

Based on flow information from 2,054 wells and considering an operational regime with an average of 18 hours per day, the volume of water abstracted from the GAS was estimated at 2,847,013.5 m³/day, i.e., approximately 1.04 x 109 m³/year.

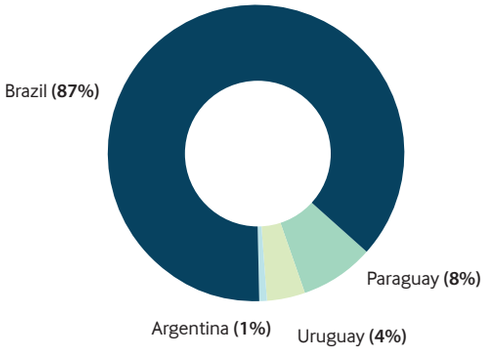
Table 8 and Figure 12A show the distribution of annual volumes of groundwater abstracted from the GAS in each country. Note that 90% of current abstractions occur in Brazil, and that the largest number of wells and volumes of water extracted are in the State of São Paulo.

GAS groundwater abstractions can be broken down by zone. There are a total of twenty abstraction zones, classified by rate of exploitation and number of wells in operation. Table 9 provides characteristics of the zones and Figure 12B shows their geographical location.

Table 8. Current volumes abstracted by country (m³/year)

Country	Annual volume (m³)	Percentage (%)
Argentina	13.421.524,5	1,3
Brazil	973.032.362,9	93,6
Paraguay	22.937.184,0	2,3
Uruguay	29.735.995,2	2,8
Total	1.039.127.066,6	100

Source: Report on Potential Uses of Thermal and Non-thermal GAS Water, 2008.



Source: GS/GAS Adapted from the Final Report on Potential Uses of Thermal and Non-thermal GAS Water, 2008.

Figure 12A. Volumetric distribution of current abstractions

Table 9. Daily volumes and number of wells in each abstraction zone

Zone	Volume (m^3/day)	Number of wells
1	84.450,78	144
2	69.066	12
3	16.180,2	49
4	50.908,32	158
5	61.305,66	76
6	56.653,11	96
7	17.676,36	16
8	54.351.36	71
9	30.976,74	160
10	23.014,8	9
11	16.956,9	23
12	86.176,26	75
13	497.013,84	78
14	537.272,82	309
15	344.090,52	133
16	73.407,24	96
17	141.355,26	78
18	158.258,7	45
19	252.500,04	181
20	275.308,56	245

Source: GS/GAS, adapted from the Report on Regional Numeric Modeling of the Guarani Aquifer System, Guarani Consortium, 2008.

In general, wells present low yields. The average volume abstracted from the set of wells examined is less than 100 m^3/h. However, certain wells used for public water supply present even higher flow volumes. The graph in Figure 13 compares flows from wells with their respective average depths in each of the countries and shows a direct relationship between higher flows and deeper wells. The main current use of water abstracted from GAS wells, both in terms of the number of wells and of flows abstracted, is public water supply. In Argentina, registered wells are exploited solely for recreational purposes. In Uruguay and Paraguay, more than 90% of the volumes abstracted are for urban water supply. In Brazil, though public water supply is the main demand, there is greater diversification of uses of water

Wells in the GAS were classified by category of use: public water supply, rural water supply, industrial, and recreational uses.

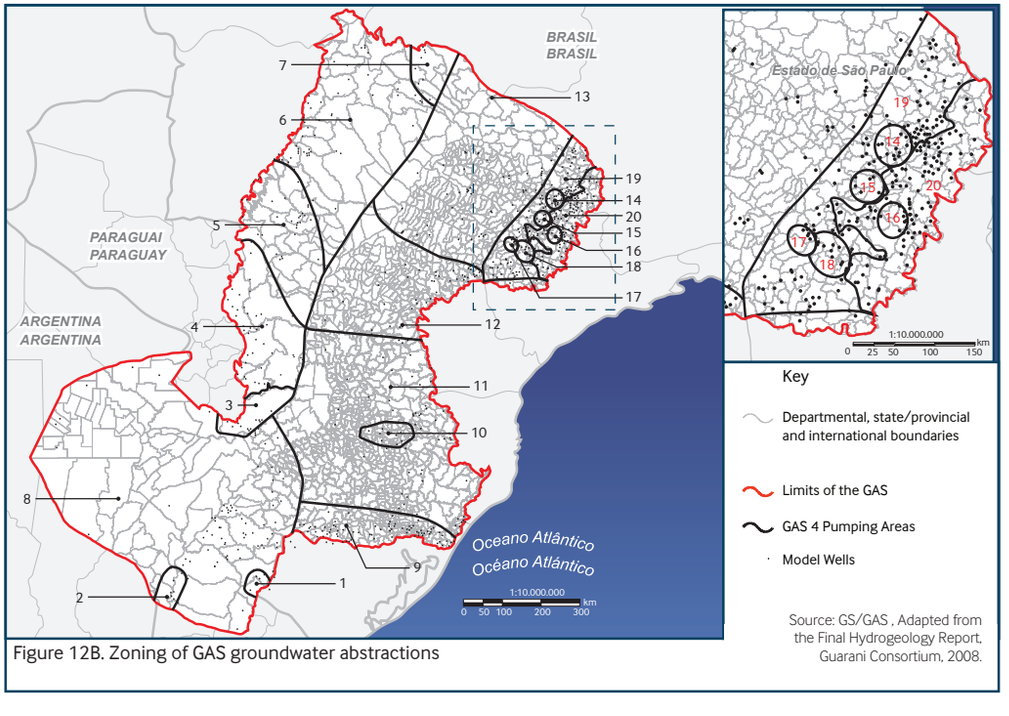
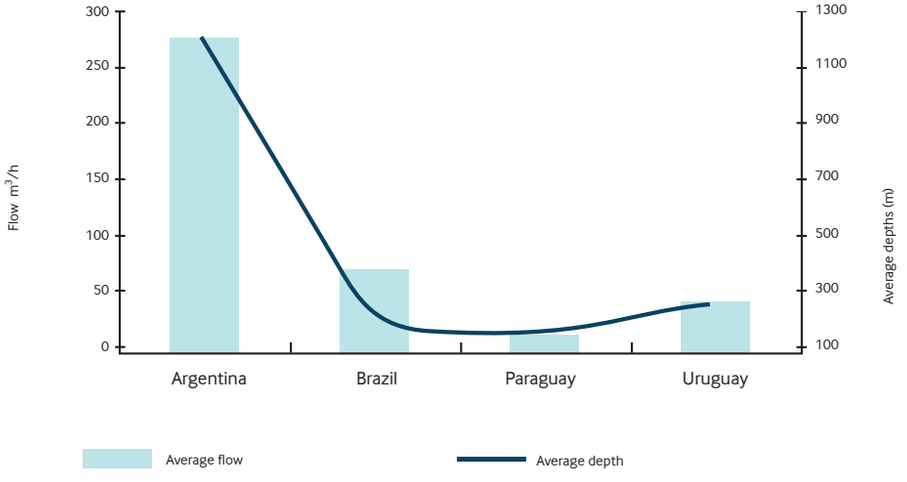


Figure 12B. Zoning of GAS groundwater abstractions

All deep tube wells from which water is abstracted to fulfill the needs of the population and operated under a concession regime fall under the category "public water supply". Under "rural water supply" are wells that fulfill needs in rural areas, including irrigation, watering of livestock and human consumption. Wells in the "industrial water supply" category serve industries in areas such as manufacturing, agro-industry, mining, textiles, chemicals and metalworks. The Map in Figure 14 shows the spatial distribution of these different uses.

2.10 CLIMATIC AND HYDROLOGICAL ASPECTS

Both climatic and hydrological studies were encompassed by the activities carried out by the Guarani Consortium during the course of the PGAS. Naturally, hydrogeological studies that culminated in the development of conceptual and mathematical flow models for the GAS were the ones that went into the greatest depth. Evaluations and results obtained from climatic and hydrological studies were less comprehensive, but pointed to approaches to be pursued in the SAP Implementation Stage. The challenge for the future will be to understand the dynamics of interactions between surface and groundwater in each specific region, and to produce fuller information for integrated water resources management. To this end, specific information available in each of the countries should be combined with hydrological studies, especially on outcrop zones of the GAS where such interaction is most apparent.



Source: Report on potential thermal and non-thermal uses of GAS water.

Figure 13. Relationship between average flows and depths of wells in each country

The principal conditioning elements of climate in southeastern South America are the almost stationary high-pressure centers of the Pacific and South Atlantic, and the low-pressure center of northwestern Argentina and southern Bolivia, caused by interaction, in the Andes, between high winds from the west and surface heating (LICHTENSTEIN, 1982). This situation, associated with two possible sources of water vapor in the southeast of South America (the Atlantic Ocean and the South-American tropical rainforest) helps explain the rainfall cycle in the area of the GAS.

The average annual cycle and average annual rainfall were calculated using data collected by 176 pluviometric stations in the region that have taken measurements over a 30-year period (1968 to 1997). Field data on annual accumulated rainfall during the period displays a rainfall gradient that declines in the direction of the Atlantic coast. There are two zones of maximums. The first lies between meridians 48° and 56° W, to the north of parallel 24° S, a region in which rainfall is over 1,300 mm per year. The second comprises the South of Brazil, the Misiones region, and Eastern Paraguay. In the latter region, annual rainfall is greater than 1,600 mm, though annual rainfall diminishes to the west and southeast (Uruguay).

Average monthly rainfall distribution over the period has certain particularities. The entire northern region of the GAS is characterized by a well-defined winter dry season, and a summer rainy season. This annual cycle is associated with the movement of the Intertropical Convergence Zone over the continent, which has a significant monsoon effect. Moving down toward the border between Argentina and Paraguay, the southwestern part of the GAS region has higher winter rainfall levels, compared to the northern part. This is also true of Brazil's South region, and even more so in Uruguay, where rainfall in winter is common. Despite this increase in winter rainfall, summer is the season with the highest rainfall levels.

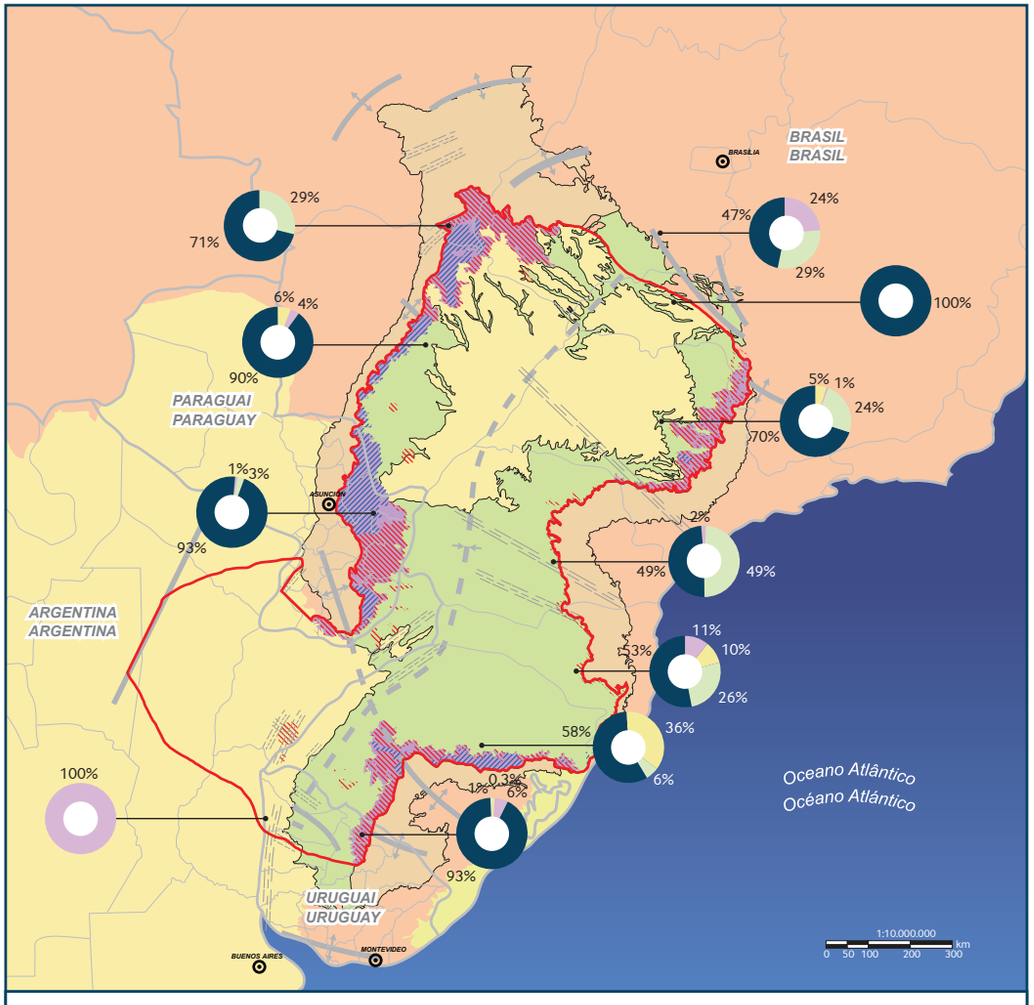


Figure 14. Map of the distribution of GAS water uses

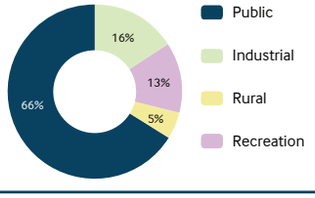
Key

- Departmental, state/provincial and international boundaries
- Limits of the GAS
- Limit of the resurgence zone
- Post-GAS sediments
- Basalts
- GAS sediments
- Pre-GAS sediments
- Base
- Replenishment area
- Discharge area

Geological conventions

- Arc
- Suggested arc
- Fault
- Alignment
- Synclinal
- National capital

Total use



Source: GS/GAS, based on reports of the Guarani Consortium, 2008.

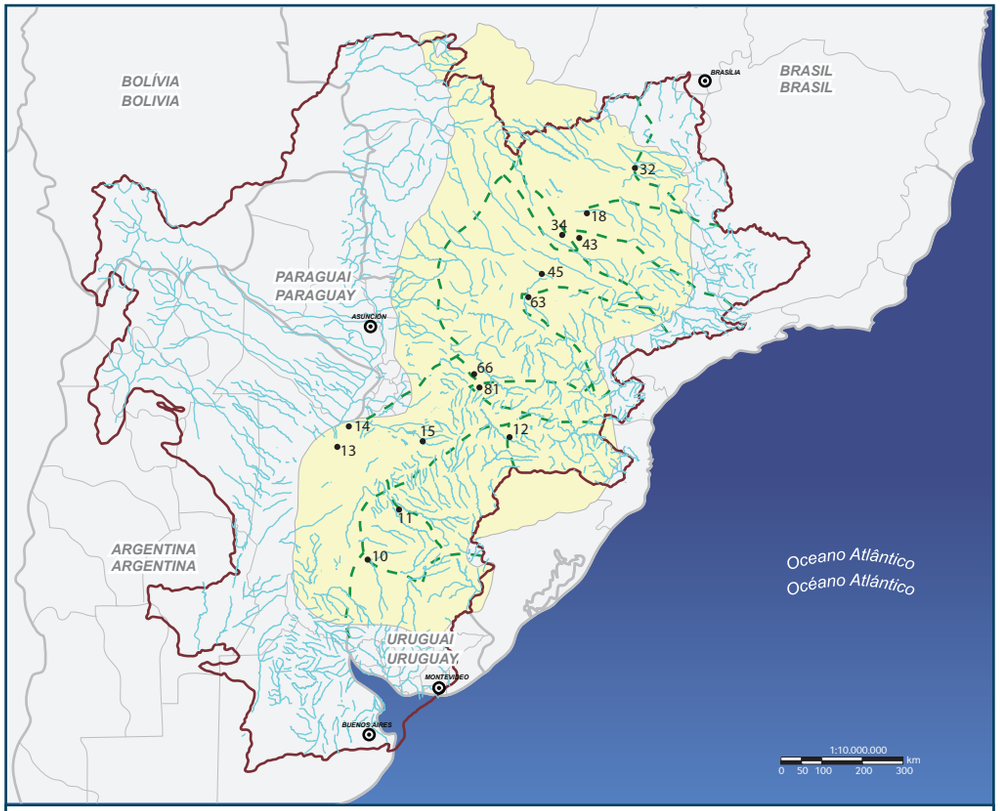


Figure 15 . Area of the hydrological study showing hydrometric stations assessed

Key

- Departmental, state/provincial and international boundaries
- Limits of the GAS
- Limit of the La Plata Basin
- Limits of sub-basins
- Hydrometric Stations
- National capital

Hydrometric Stations

10 Salto Grande (Rio Uruguai)
11 Paso de los Libres (Rio Uruguai)
12 Caxambú (Rio Uruguai)
13 Corrientes (Rio Paraná)
14 Pto. Bermejo (Rio Paraguai)
15 Posadas (Rio Paraná)
18 Água Vermelha (Rio Grande)
32 Itumbiara (Rio Parnaíba)
34 Ilha Solteira (Rio Paraná)
43 Três Irmãos (Rio Tietê)
45 Jupiá (Rio Paraná)
63 Rosana (Rio Paranapanema)
66 Itaipú (Rio Paraná)
81 Capanema (Rio Iguaçú)

Source: Area of the hydrological study with hydrometric stations assessed. Source: Report on the Water Balance and Hydrological Relations in Replenishment Areas of the Guarani Aquifer, Guarani Consortium, 2008.

Reports on average temperature variations in the GAS area (calculated on the basis of data from 181 continuous measuring stations, also for the 1968 to 1997 period) identified higher temperatures in the northwestern region of the aquifer, during the summer months, with a lowering of the temperature gradient moving toward the southeast of the aquifer, throughout the year, and toward the Atlantic Ocean. During winter months, average temperatures range between 10 °C in the southern portion of the GAS area, and 19 °C in the northern portion. During transitions seasons, average temperatures are within the middle of this range. Figure 17 shows average monthly temperatures in the GAS region.

Calculations of the water balance of the atmospheric portion of the hydrological cycle showed that, in most of the GAS area, there is an annual surplus of approximately 300 mm, and of up to 600 mm in the southern region, between Argentina and Paraguay and in the Brazilian State of Rio Grande do Sul.

From a hydrological standpoint, the GAS is associated with the basins of the Paraná and Uruguay Rivers and, to a lesser degree, the western portion of the Paraguay River Basin, i.e., the main constituents of the vast La Plata Basin. Other portions of the GAS, such as those underlying coastal basins of the South region of Brazil and the outcrop zone of the Porto Alegre metropolitan area (RS) lie outside the La Plata River Basin.

More detailed studies of areas of the La Plata River Basin that overlie the GAS were carried out within the scope of hydrological reserch based on information on flows, when the water balance was being calculated (1968-1997).

These analyses encompassed four basins on the left bank of the Paraná River, and a stretch in the vicinity of the mouth of the Paraguay River. The Uruguay River Basin was broken down into three parts: one in Brazil, another on the border of Brazil and Argentina, and a third on the border of Argentina and Uruguay. Figure 15 shows the hydrometric stations used.

These studies were of a regional and preliminary nature, and their aim was to test methodologies and enhance understanding of relationships between the GAS and other aquifers, and hydrological processes on the surface. Based on continuous monthly water-balance estimates, the potential water-availability status was calculated for each hydrological year and, more especially, what portion of the water in each of the stations assessed corresponds to a contribution toward base flows. This contribution could represent a preliminary and rough estimate of replenishment rates from outcrop areas of the GAS, for example. This study needs to be followed up, with special emphasis upon GAS replenishment areas and those of other river basins for which such information is available.

Tables 10 10.1 provide a summary of the main characteristics of these sub-basins, including average base-flow values and total surface runoff.

Table 10. Summary of base flows and total flows for sub-basins

Basin	Section	Base Flow (mm/year)	Specific Base Flow (L/s-km²)	Total Flow (mm/year)	Average Specific Discharges (L/s-km²)	Base Flow / Total Flow
Paraná River	Ilha Solteira	120-180	4-6	469	15	0.25-0.38
Paraná River	Jupiá	120-180	4-6	440	14	0.27-0.41
Paraná River	Itaipu	120-180	4-6	431	15	0.28-0.42
Paraná River	Posadas	180-300	6-10	460	15	0.39-0.65
Paranaíba River	Itumbiara	120-180	4-6	495	16	0.24-0.36
Grande River	Água Vermelha	120-180	4	496	16	0.24-0.36
Tietê River	Três Irmãos	120	4	342	11	0.35
Paranapanema River	Rosana	120	4	541	17	0.22
Iguaçu River	Capanema	120	4	839	27	0.14
Uruguay River	Caxambu	120	4	547	17	0.22
Uruguay River	P. de los Libres	120	3	735	20	0.16
Uruguay River	S. Grande	120	4	667	21	0.18

Source: Report on the Water Balance and Hydrological Relations in Replenishment Areas of the Guarani Aquifer, Guarani Consortium, 2008.

Table 10.1. Summary of annual average values

Estation	P (mm)	ETP (mm)	P-ETP (mm)	ETR (mm)	EXC (mm)	DEF (mm)
Cuiabá	1751,1	1787,2	-36,0	1427,6	322,9	-359,5
Goiânia	1377,8	1358,9	18,9	1060,0	317,8	-298,9
Araxá	1386	1122	264	963	417	-159
Londrina	1331,8	1167,9	163,8	1075,5	256,2	-92,4
Pto Casado	1242,79	1691,1	-448,3	1196,7	46,1	-494,4
Assunção	1368,8	1399,9	-31,1	1185,9	177,1	-214,0
Ciudad Este	1826,2	1285,1	541,1	1227,8	595,4	-57,4
Curitiba	1295,2	893,3	401,9	868,9	421,3	-24,4
Corrientes	1447,5	1244,9	202,6	1123,7	318,9	-121,2
Posadas	1737,0	1254,6	482,4	1174,4	557,6	-80,2
Saudade	1817,2	1254,6	564,6	1194,9	620,8	-59,7
P Los Libres	1585,2	1132,2	453,0	1058,6	521,5	-73,6
Reconquista	1253,0	1153,7	99,3	1025,4	222,6	-128,3
Salto	1322,4	1043,3	279,1	964,7	352,7	-78,6
P Los Toros	1315,2	990,2	325,0	893,5	416,7	-96,7
Mercedes	1159,4	991,7	167,7	899,0	255,5	-92,7
Colônia	1122,9	968,2	154,7	881,3	236,6	-87,0

Source: Report on the Water Balance and Hydrological Relations in Replenishment Areas of the Guarani Aquifer, Guarani Consortium, 2008.

The main findings of this analysis are:

In the Paraná River Basin, annual average water availability (EXC) varies between 350 and 400 mm, whereas annual average deficits (DEF) range between 150 and 220 mm. The highest annual water availabilities were recorded in the Iguaçu and Uruguay River Basins, with values ranging between 500 and 650 mm, whereas average annual deficits were never less than 90 mm.

In months when EXC is nil, minimum runoff in water courses stems, principally, from base flows. This runoff ranges from 10 to 15 mm per month. In view of the scale of contributions from the sub-basins examined, such hydrographic background in these water courses is significant. Indeed, the contribution of direct flows in the rainy season is not exhausted, but rather, comprises part of the minimum runoff or base flows.

In the upper Paraná River Basin (Ilha Solteira) and its principal tributaries (the Paranaíba and Grande Rivers) since 1975, an increase in minimum flows has been recorded, from 10 mm per month to 15 mm per month. On other tributaries of the Uruguay River Basin, minimum flows remained constant throughout the entire period of tests, at roughly 10 mm per month.

2.10.1 FUTURE CLIMATE SCENARIO

Two climate scenarios have been foreseen for the decade of 2081 to 2090, using numeric calculation based on regional models with an average resolution of 50 km and on possible socioeconomic scenarios. These experiments generated average annual, seasonal, monthly, and daily values for a number of variables. The A1 and B1 scenarios were defined as follows:

- A1 – Foresees a heterogeneous world, with preservation of local identities, high rates of population growth and lower regional economic development than in other forecasts. This is a critical scenario.
- B1 – Foresees a world that emphasizes local solutions, with a steady increase in population lower than in A1, and intermediate levels of economic development. This is a moderated scenario.

Variables used were rainfall, temperature, and water deficits and excesses in the soil. Their respective results are presented below:

Rainfall

Rainfall in the region of the study will increase, especially in autumn (Figure 16). Current positive rainfall trends are likely to continue.

Temperatures

In general terms, the A1 forecast scenario is of an average global temperature increase of 3°C by 2080, whereas the B1 scenario foresees an increase of 2.3°C. The greatest variations (Figure 17) are foreseen in the northern portion of the GAS (in the Brazilian States of Mato Grosso and Mato Grosso do Sul, in the central region of Paraguay, and in the northern portions of Argentina) especially in winter and spring.

Deficits and excesses

The main climatic aspects of interest for the region can be summarized as follows:

- The availability of water in the soil will diminish substantially in the northwestern

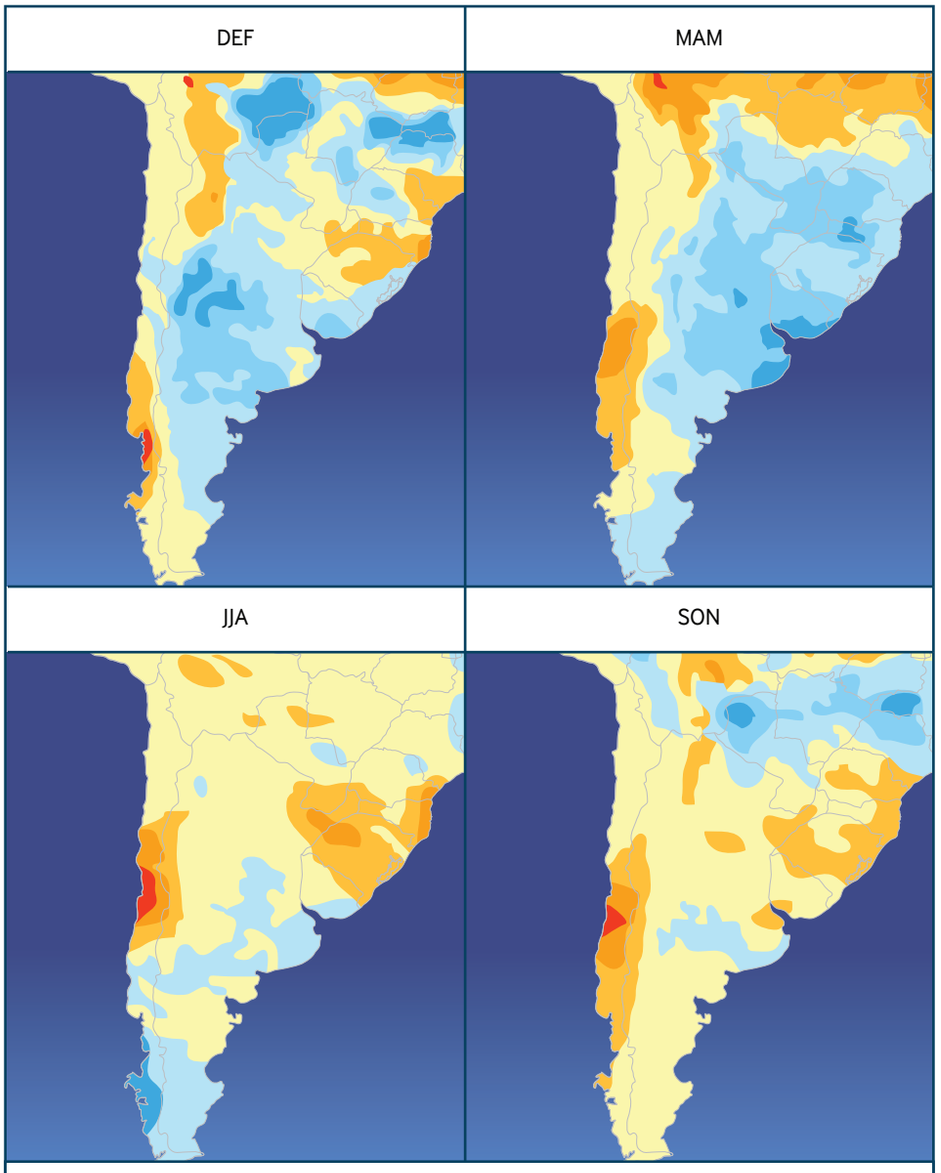


Figure 16. Rainfall change scenarios up until the end of the century
The emissions scenario is the SRES IPCC A2, and changes are expressed in millimeters per day.
Summer (DEF), autumn (MAM), winter (JJA) and spring (SON).

Key

Departmental, state/provincial and international boundaries

MM5 average precipitation
A1 (mm/dia)

- 3
- 2
- 1
- 0
- -1
- -2
- -3

Source: Modified Report on the Climatology and Hydrometeorology, Guarani Consortium, 2008.

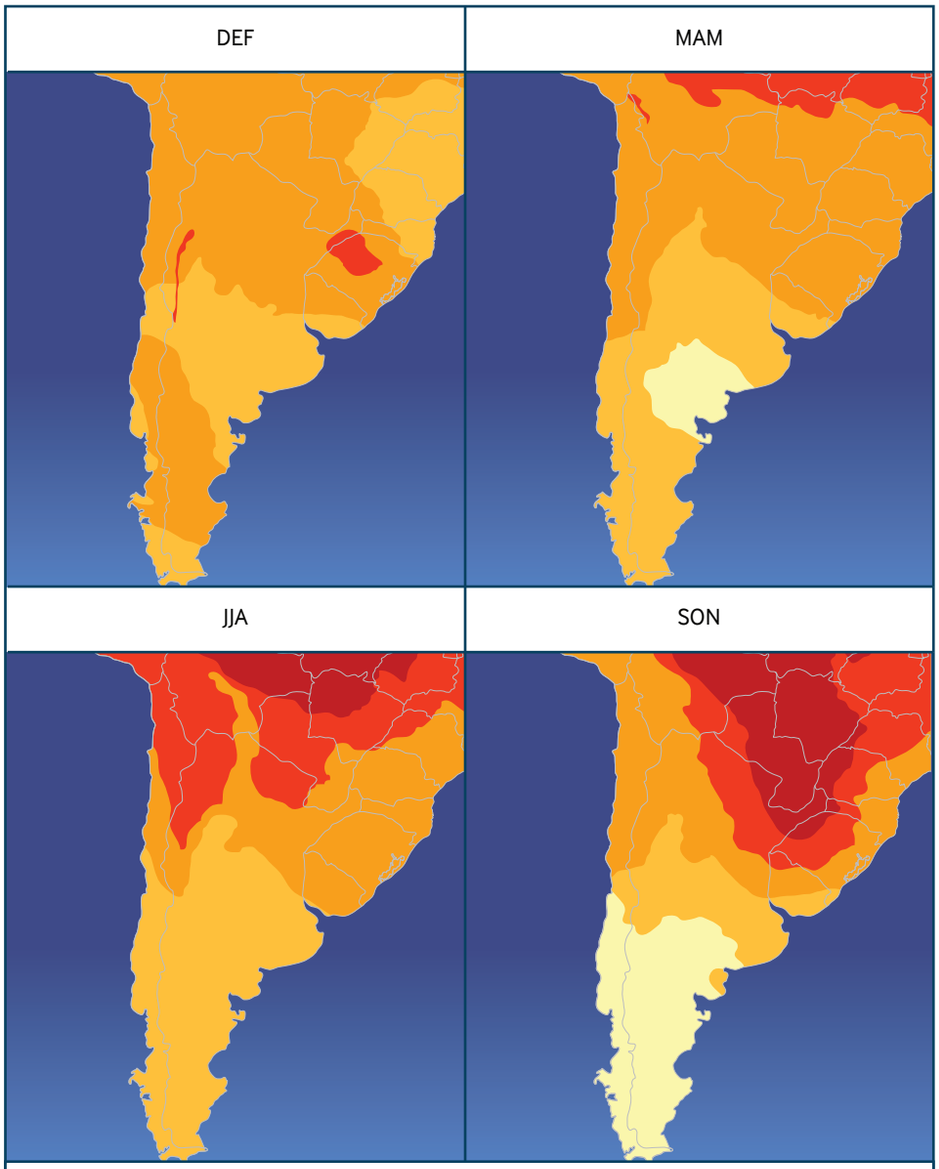


Figure 17. Temperature change scenarios up until the end of the century
The emissions scenario is the SRES IPCC A2 and changes are expressed in °C.
Summer (DEF), autumn (MAM), winter (JJA) and spring (SON).

Source: Modified Report on the Climatology and Hydrometeorology, Guarani Consortium, 2008.

zone of the aquifer, where deficits will increase, especially under scenario A1. The principal areas affected are in Paraguayan and Brazilian territory, between parallels 15º and 20º S and meridians 49º and 57º W. According to current models, this region of Brazil presents excess values of approximately 300 mm per year. Under both scenarios (A1 and B1) deficits ranging between 300 and 1,000 mm are foreseen.

- The extreme west of the study area, between parallels 23º and 30º S in Argentina, reports deficits of 300 mm per year. However, the scenarios foresee projection of the isoline to the east, with much greater depth under scenario A1, where deficits are greater than 900 mm per year. Under scenario B1, the movement is smaller, as is also the intensity of the deficit foreseen.
- Both scenarios foresee a reduction in the zone of climate excesses that encompasses the south of Brazil, the east of Paraguay, Uruguay and the entire Argentine portion, excepting the extreme west mentioned in the previous item. The A1 scenario foresees a more accentuated reduction in the northeastern part of the area of the study. Under the B1 scenario, excesses are greater (approximately 900 mm per year) in the area of Brazil located at 27º S 52º W. Under the same scenario, greater excesses are also observed in Uruguay.
- Reduced availability of water will be a feature of all seasons of the year, but will be most accentuated in spring and in summer. In summer, especially under the A1 scenario, lower availability will feature throughout the entire aquifer, with a steep reduction in the area of excesses.
- For winter, no significant changes are foreseen under the two possible scenarios. The northern part of the study area would appear to face the greatest deficits, and the Uruguay zone the greatest local excesses, under the B1 scenario.
- For autumn, changes are more evident. The current climate model presents excesses throughout the region, except in the northwest. Both scenarios show that the zone of excesses will decline substantially. Under the A1 scenario it will be limited to the region between 26º and 28º S, and under the B1 scenario it will be limited to the south of Brazil, Uruguay, and the La Plata River region.
- For spring, the area of excesses, located in the southeast under the current climate model, will decline under both scenarios. What is more significant, however, is the increase in the intensity of the deficits in the north, that will rise from 200 mm to much higher values (880 mm under the A1, and 600 mm under the B1 scenario) in the northwest portion.
- With respect to the southeast zone of the aquifer, characterized by annual excesses of water, no major changes in trends are predicted. A small reduction of the excesses is likely, especially under the A1 scenario. Even with the increases in rainfall foreseen, the balance of water in the atmosphere will depend upon temperature changes that, for this region of the aquifer, are considerable. There may be errors in this data owing to the effects of limits.
- The decline in excesses in the southeast of the aquifer are foreseen under both scenarios, for all seasons of the year except winter. Under the A1 scenario, more accentuated declines are foreseen.

2.11 LAND USE

One of the main aims of the SAP is to promote convergence and articulation between water-resources management and territorial planning, in terms of land-use and settlement patterns. This is because mechanisms and standards for the use of natural resources on the land surface have a tremendous influence on the ways in which the GAS is to be utilized. With a view to contributing toward development of this integrated outlook, land-use maps of the GAS geographic region have been drawn up, starting in the 1970s up to the current scenario.

For a given land-use category, it is possible to compare different scenarios over time, and assess the dynamics of changes at a regional level (for example, expansion of agriculture). This provides a powerful instrument that needs to be compared to regional economic assessments for the respective period. The strategic actions of the SAP have identified a need for deeper assessments of economic factors, for which such maps can provide invaluable insights.

Maps produced and the distribution of categories of use are shown in Figures 18A, 18B, and 18C.

Analysis of findings

Analysis of the aforementioned maps shows that land use in the area overlying the GAS is predominantly agricultural. Analysis of multitemporal evidence shows that, over the past thirty years, there has been significant encroachment of agriculture into areas of natural forest. The categories of land use that have undergone the greatest change are:

- Agricultural land-use, that covered 22% of the land during the 1973-1980 period, now covers 47%.
- Agro-forestry-pastoral land-use, that had covered 11% of the land area in the 1973-1980 period, covered 23% by 2007.
- Thick forest (native forest), the category that had covered 9% of the land area in the 1973-1980 period, covered only 2% by 2007.
- Degraded forests, the category that covered 33% of the land, now covers 6%.
- Uncultivated land, the category that had covered 23% of the land area in the 1973-1980 period, declined until 1990, after which it stabilized and now covers some 18% of the area.

However, if the land-use categories thick forest and degraded forest are examined together, it can be perceived that in the period between 1973 and 1980 they covered 42% of the land surface overlying the GAS. They subsequently declined to 8%, as a consequence of agricultural expansion. The second greatest change in land use was expansion of the area under agriculture (25%). Agricultural expansion generally encroached upon areas formerly covered with native vegetation.

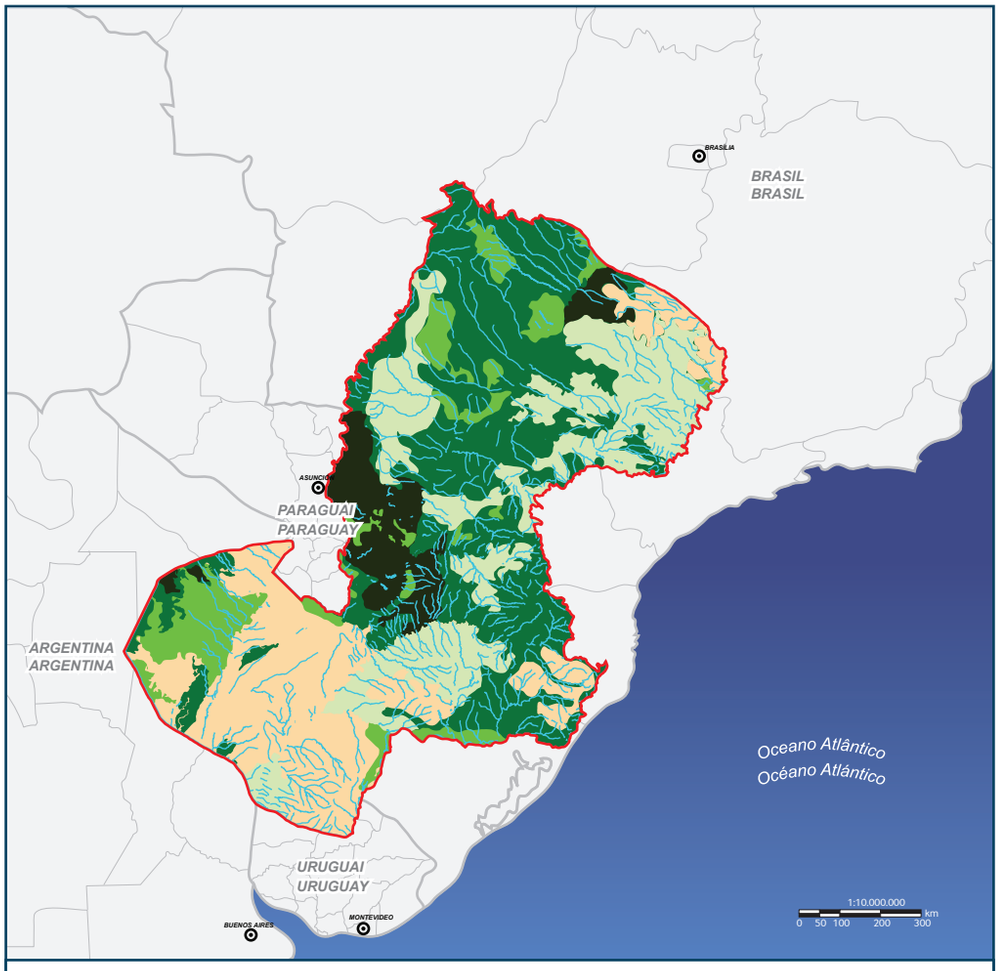
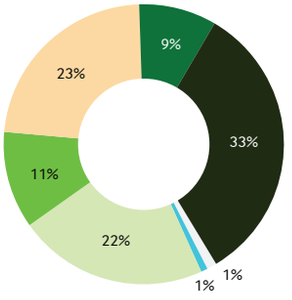


Figure 18A. Multi-temporal land-use maps and distribution by category of use. Period: 1973 a 1980

Key

- Departmental, state/provincial and international boundaries
- Limits of the GAS
- Rivers
- Agro-pastoral
- Degraded forest
- Uncultivated land
- Agriculture
- Thick forest
- Other
- National capital

Land use Categories



Source: GS/GAS, Modified Report on the Development of Maps of land use from Satellite Images - Analysis Multitemporal and the Merger SISAG, Guarani Consortium, 2008.

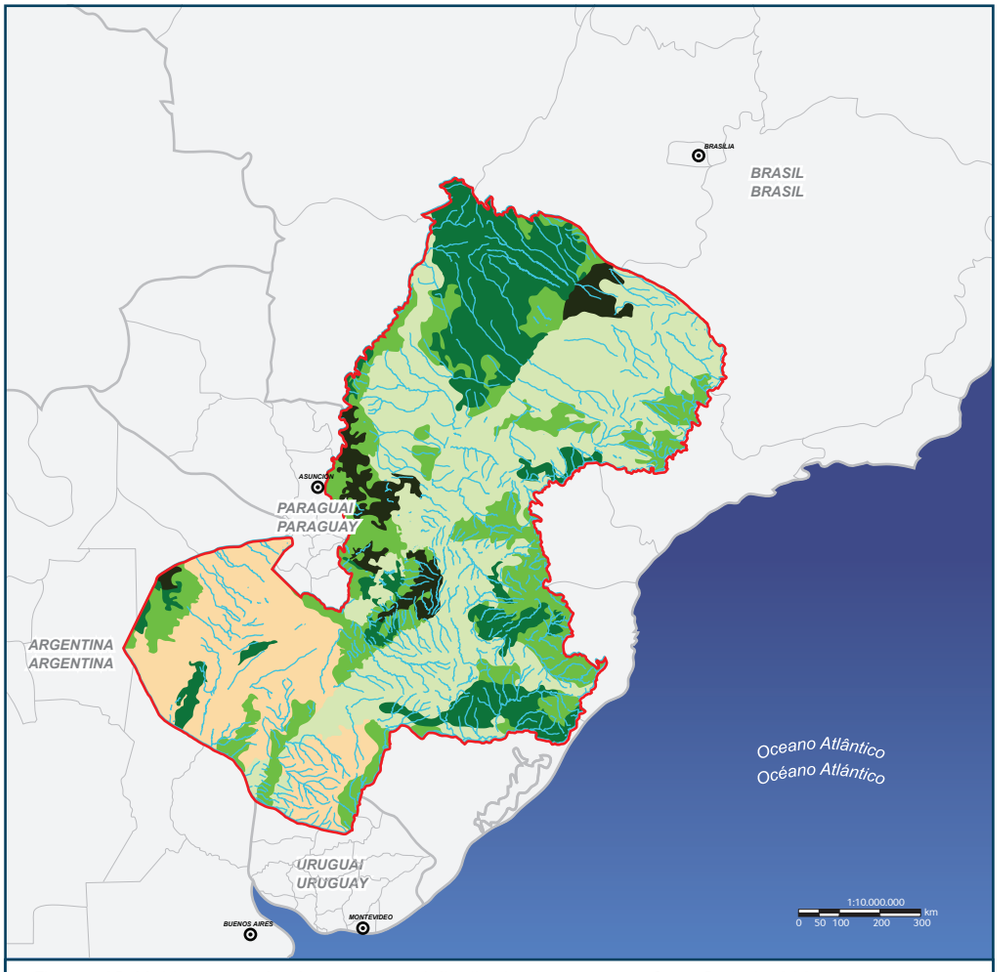
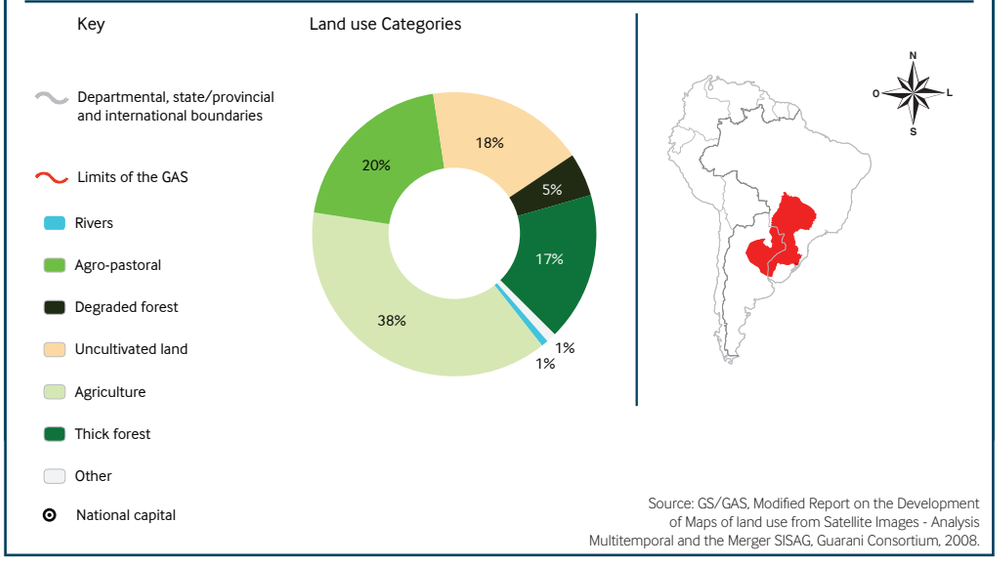


Figure 18B. Multi-temporal land-use maps and distribution by category of use. Period: 1990



Source: GS/GAS, Modified Report on the Development of Maps of land use from Satellite Images - Analysis Multitemporal and the Merger SISAG, Guarani Consortium, 2008.

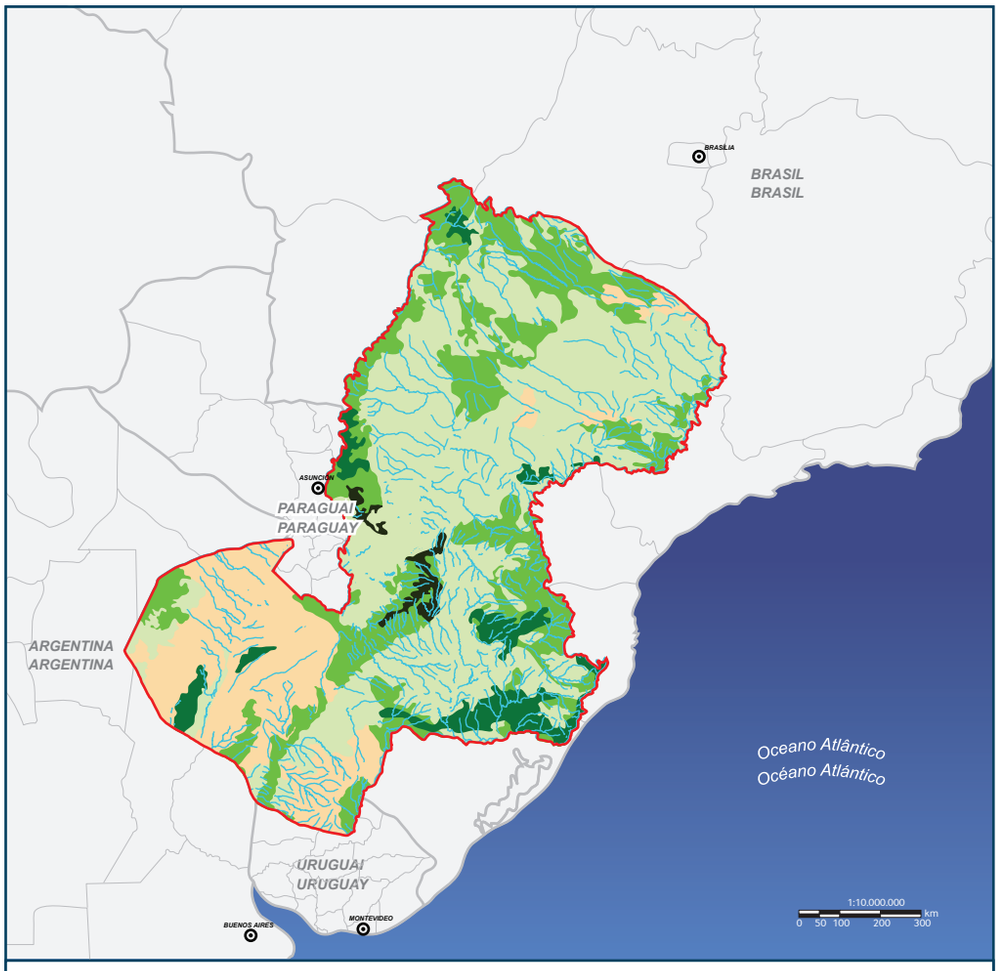
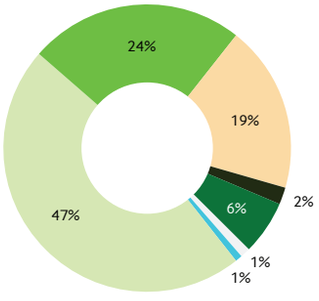


Figure 18C. Multi-temporal land-use maps and distribution by category of use. Period: 2007

Key

- Departmental, state/provincial and international boundaries
- Limits of the GAS
- Rivers
- Agro-pastoral
- Degraded forest
- Uncultivated land
- Agriculture
- Thick forest
- Other
- National capital

Land use Categories



Source: GS/GAS, Modified Report on the Development of Maps of land use from Satellite Images - Analysis Multitemporal and the Merger SISAG, Guarani Consortium, 2008.

2.12 SOCIOECONOMIC ASPECTS

Current and future utilization of the GAS depends upon a series of variables; some, of a physical nature, are intrinsic to the Aquifer System and were identified in the previous items; others, of a socioeconomic nature, depend upon population distribution and dynamics and the corresponding arrangements of productive activities within the geographic area.

Intrinsic variables are those that relate to the natural potential of the GAS, quantitative and qualitative water availability, and its dynamic responses to the effects of the various forms of use. Socioeconomic variables influence the generation of demands and the expansion or location of new sources of pollution (or cessation thereof) that could affect the natural quality of groundwater from the aquifer.

This section does not aim to conduct an exhaustive socioeconomic evaluation, but rather, to contribute with the first steps for identifying future paths in relation to the important theme.

An understanding of the social and economic dynamics at play in the GAS area is essential, and is one of the main aims of the SAP (covered in Chapter 5). Variables considered in this socioeconomic overview are: population aspects, distribution of Gross Domestic Product (GDP), aspects relating to basic sanitation (coverage of potable water supply and sewage collection) and schooling levels. The degree of disaggregation achieved in this analysis was as follows: Argentina (provincial and municipal); Brazil (state and municipal); Paraguay and Uruguay (departmental).

Specific maps were prepared for the main variables identified in the GAS region, as a means of supporting future evaluations. All the maps show replenishment and discharge areas of the GAS.

Population

The resident population of the area overlying the aquifer was estimated at approximately 92 million, corresponding to roughly half of the sum of the populations of the four countries that share the GAS (Table 11) (FERNÁNDEZ et al., 2007).

The distribution of the resident population in the area overlying the GAS varies greatly in each of the four countries. A majority (roughly 90%) of the people that reside in the area overlying the GAS have Brazilian nationality. This contingent corresponds to almost half (42.99%) of Brazil's total population. In Paraguay, more than half of the population (55.91%) lives in the area overlying the GAS, but comprises only 3.54% of the total population of the area overlying the aquifer. In Argentina and Uruguay, 21% of the total population of the two countries live in the area overlying the GAS. However, whereas the Argentine contingent of this population amounts to only 8.64% of the total population living in the area overlying the GAS, the Uruguayan contingent amounts to a mere 0.78%.

Distribution of population density in the area overlying the GAS is not uniform: it ranges from areas with practically no population, to areas with densities of over 1,500 people per km^2 (in certain towns in the State of São Paulo. The Map in Figure 19A shows population-density distribution, broken down as previously described.

In the areas of Brazil, Argentina and Uruguay that overlie the GAS, populations are overwhelmingly urban, with roughly 80% to 90% living in towns. In Paraguay, approximately half of the population lives in rural areas. This information is important for future projections on uses and demand for GAS groundwater.

Education

Schooling levels are an important factor when considering the most appropriate communications activities for dissemination of themes relating to groundwater and training approaches targeted at populations living in the GAS region. The Map in Figure 19B presents official figures on literacy (provided by each country) broken down by political/administrative unit.

Coverage of water-supply networks

This variable is indicative of the level of development and organization of potable water supply services in the region overlying the GAS.

Table 11. Demographic data on the GAS*

Country	Population of the GAS area	Percentage of the country's population	Percentage of the total population of the GAS area
Argentina	7.947.667	20,59	8,64
Brazil	80.141.415	42,99	87,04
Paraguay	3.263.318	55,91	3,54
Uruguay	724.768	21,92	0,78
Total	92.077.168	46,67	100

*Modified and compiled from Fernández et al., 2007.

Source: GS/GAS. Adapted from the Socio-demographic Report on the capacity of the Guarani Aquifer System to adapt to changes in patterns of use, Guarani Consortium, 2008.

The preliminary indicator used is the percentage of families with access to piped potable water supply in each political/administrative unit. The GAS presents an alternative low-cost source of safe water supply. Further information is thus necessary on areas in which water-supply is substandard and on locations where it is not available. It is likewise important to determine areas where water-supply services draw on groundwater sources, and particularly those that rely on the GAS, since this information is currently unavailable from official statistics in the four countries. Compilation and analysis of this information is to be carried out under the SAP. The Map in Figure 19C shows the distribution of potable water supply in each of the countries.

Coverage of sanitation services

It is important to identify zones with serious weaknesses in the provision of sanitation services. The Map in Figure 19D shows the percentage of families in each administrative unit that have access to sewage collection mains.

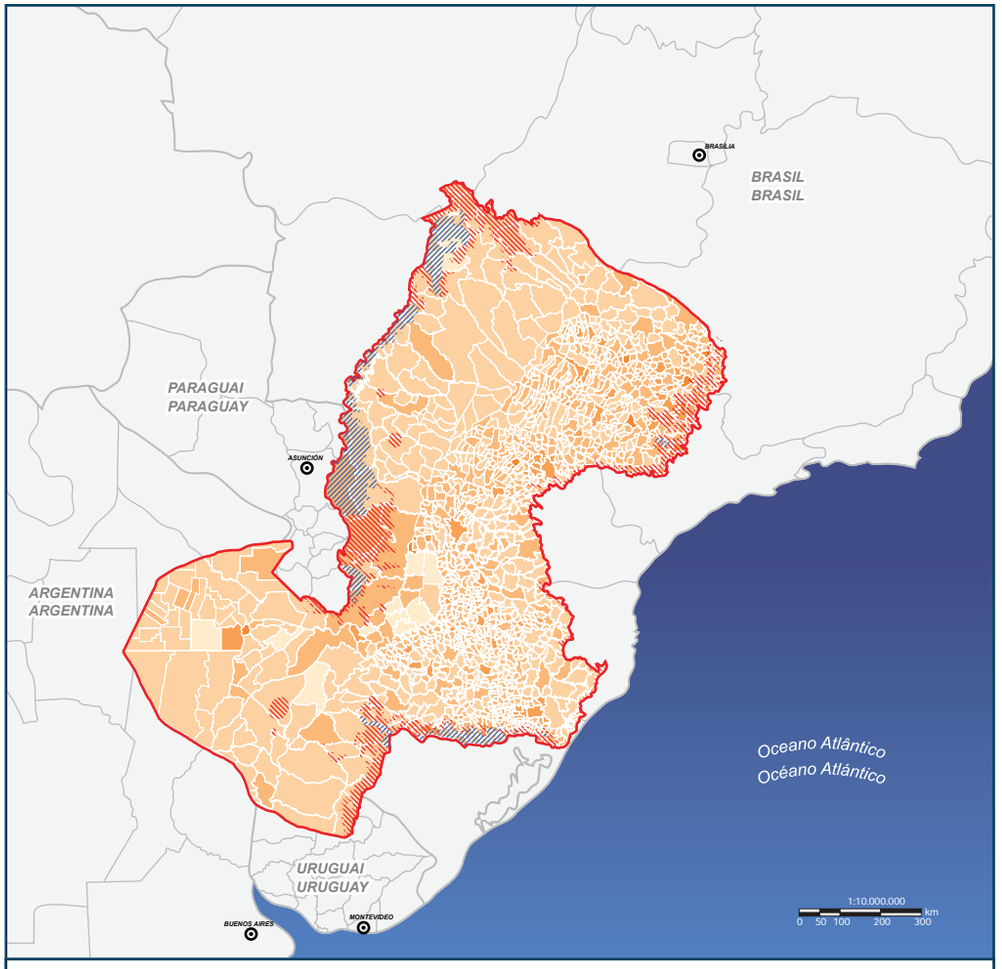


Figure 19A. Map of Population Density

Key

- Departmental, state/provincial and international boundaries
- Limits of the GAS
- Replenishment area
- Discharge area
- National capital

Population Density (hab/km²)

- No information
- < 20
- 21 - 100
- 101 - 500
- 501 - 1200
- 1201 - 2025

Source: GS/GAS based on official statistics of countries, 2008.

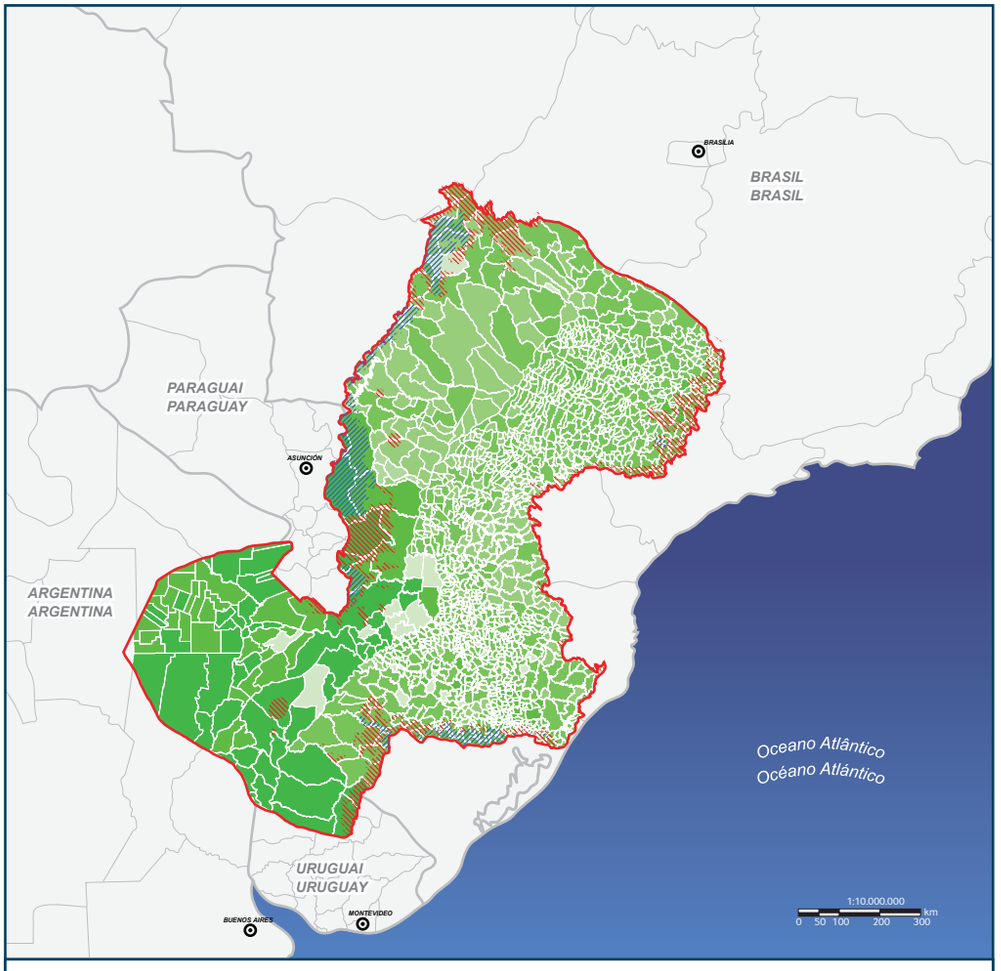


Figure 19B. Map of Percentage of Literacy

Key

- Departmental, state/provincial and international boundaries
- Limits of the GAS
- Replenishment area
- Discharge area
- National capital

Percentage of Literacy (%)

- No information
- < 60
- 61 - 70
- 71 - 80
- 81 - 90
- 91 <

Source: GS/GAS based on official statistics of countries, 2008.

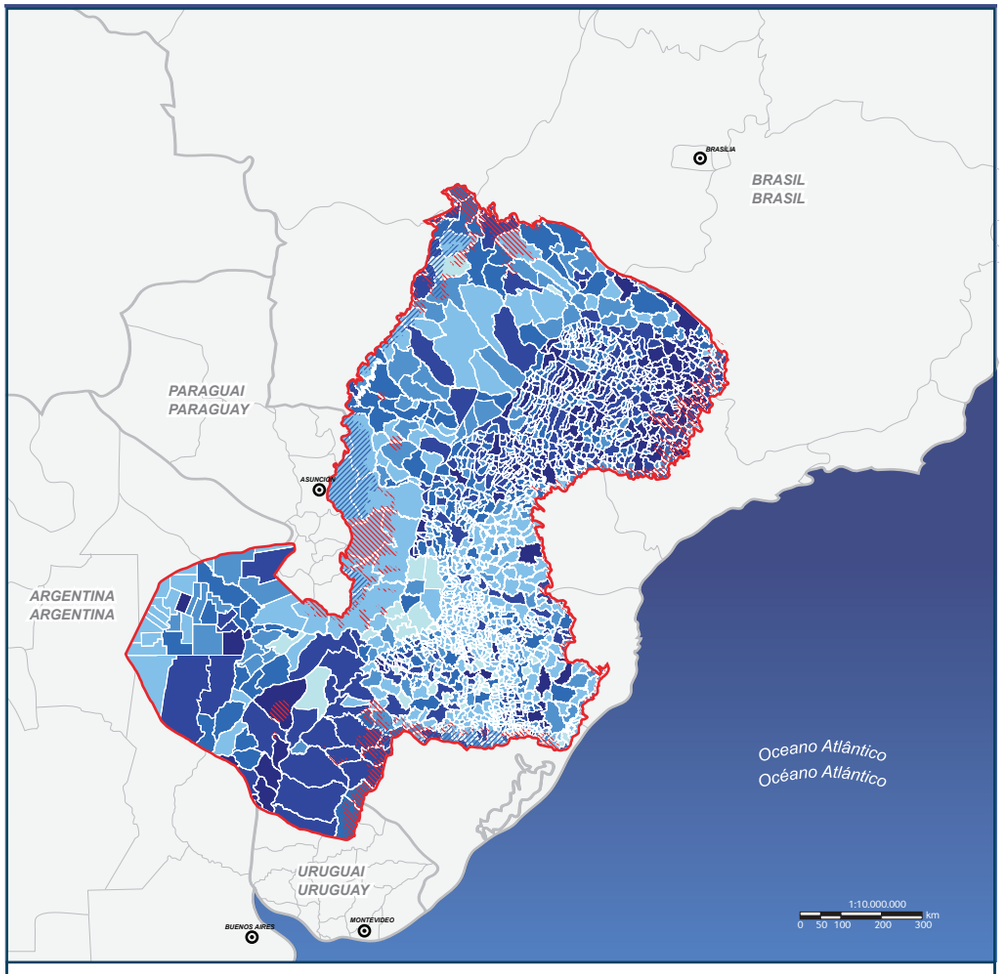


Figure 19C. Map of Network Coverage of Water

Key

- Departmental, state/provincial and international boundaries
- Limits of the GAS
- Replenishment area
- Discharge area
- National capital

Network Coverage of Water (%)

- No information
- < 60
- 61 - 70
- 71 - 80
- 81 - 90
- 91 <

Source: GS/GAS based on official statistics of countries, 2008.

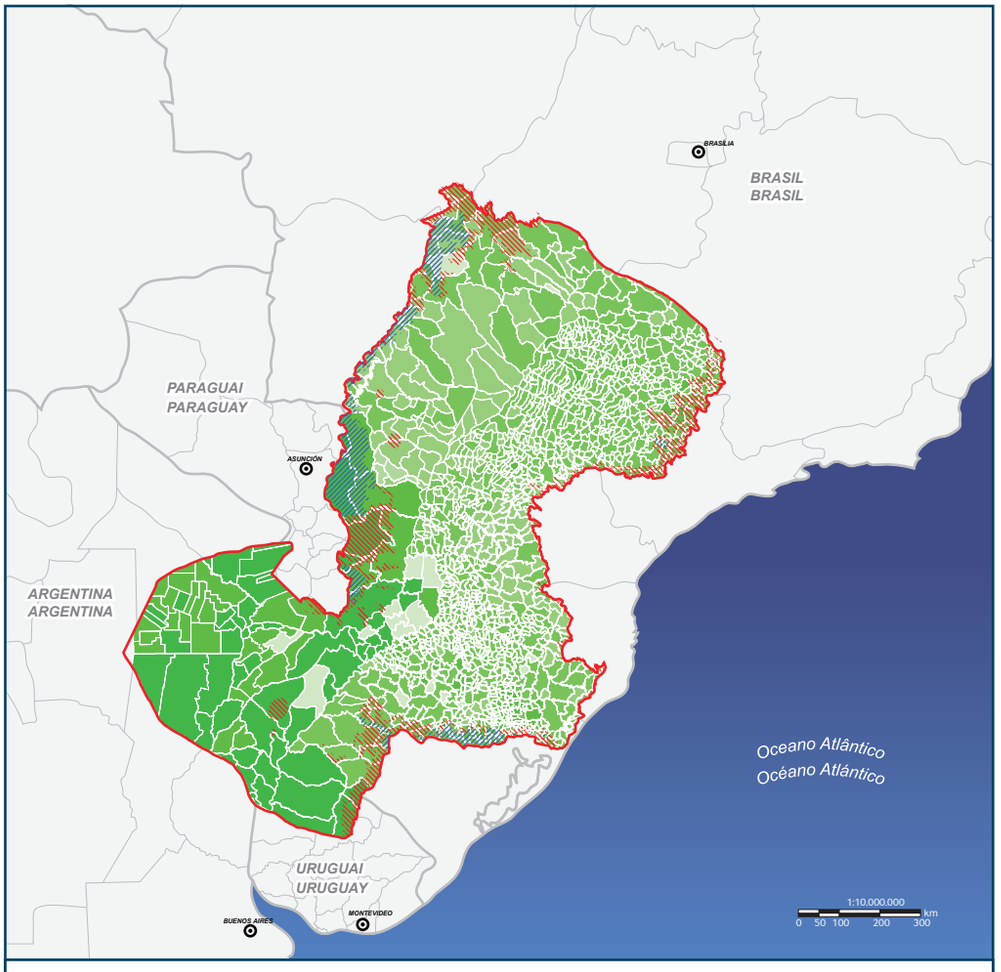


Figure 19B. Map of Percentage of Literacy

Key

- Departmental, state/provincial and international boundaries
- Limits of the GAS
- Replenishment area
- Discharge area
- National capital

Percentage of Literacy (%)

- No information
- < 60
- 61 - 70
- 71 - 80
- 81 - 90
- 91 <

Source: GS/GAS based on official statistics of countries, 2008.

Economic activities

In the countries of the region, services (tertiary sector) are responsible for generating 50% of regional wealth. In Brazil, industry (secondary sector) comes second as a share of GDP. In Paraguay, agriculture (primary sector) comes in second place (Table 12).

2.13 BASES FOR MANAGEMENT

A review and evaluation of information on hydrogeology, geometry and hydrodynamic, hydrochemical, isotopic and hydrothermal characteristics of the GAS makes it possible to identify distinct zones with similar groundwater flow and time-of-residence characteristics. These include: outcrop zones (ZA), zones of close confinement (ZC) and highly confined zones (ZFC) identified on the Map in Figure 20. Aside from their descriptive value, knowledge on these zones could provide inputs for management of the GAS. Such zoning should be regarded as a starting point and reference for national groundwater management bodies (Chapter 3). This zoning proposal is accompanied by specific information of great importance for management of the GAS in each of these zones:

- Area of the GAS: the area that overlies the GAS in the four countries. The hydrogeological map shows outcrop areas (ZA) that serve as the aquifer's regional discharge and replenishment areas, its confined zones (ZC), and highly confined zones (ZFC).
- Hydraulic characteristics: type of aquifer and the way in which water circulates and is stored in the aquifer.
- Form of exploitation: defines the maximum flow that can be abstracted from an aquifer.

Table 12. Summary of economic data on the countries overlying the GAS

Countries	GDP (US$) millions	% of GDP of the area	GDP per capita (US$)	% GDP – Primary sector	% GDP – Secondary sector	% GDP –Tertiary sectoro
Argentina	219.652	18,10	5.636	16,1	29,9	54,0
Brazil	966.827	79,66	5.085	13,6	33,2	53,2
Paraguay	8.633	0,71	1.356	24,0	23,2	52,8
Uruguay	18.591	1,53	5.345,3	11,8	28,6	59,6

Source: GS/GAS. Adapted from the Socio-demographic Report on the capacity of the Guarani Aquifer System to adapt to changes in patterns of use, Guarani Consortium, 2008..

For unconfined aquifers (ZA), calculation of the maximum flow that can be sustainably abstracted is effected by subtracting annual replenishment from a fraction of the base flow of rivers (minimum sustainable flow of the river). In confined zones (ZC) and highly confined zones (ZFC), there is no local replenishment, and flows from outcrop areas take longer to reach the confined zone (over 500 years). Thus, abstractions are taken directly from storage (S) and, as replenishment values are not of the same order, water levels gradually decline. In such situations it is necessary to plan exploitation, to determine the flow and time of abstraction, and calculate its economic feasibility. Exhaustion occurs when pumping costs exceed return on investment, or when declining water levels make abstraction impossible owing to technological limitations (depth of the dynamic level greater than 400 meters, or when the remaining saturated layer of the aquifer varies from 20% to 30%). When a confined zone is close to an outcrop area (ZC), exploitation may cause renewed replenishment of the aquifer and enhance water availability. This occurs when the flow of water stems from a steeper hydraulic gradient of the depression cone caused by exploitation. Nonetheless, the limit to exploitation should abide by limitations observed in the highly-confined zone of the aquifer (ZFC), considering a possible increase in water availability caused by pumping.

- Access to the resource: economic exploitation of groundwater from the GAS is limited by: (i) depth of the aquifer, that requires very deep wells (over 750 m) in the highly-confined zone, and (ii) depth of the dynamic level of the aquifer, that may not exceed 400 m owing to the high energy costs of abstracting water and technological limitations of pumps. In the outcrop zone, where the aquifer is unconfined (ZA), or in the zone where the aquifer has become unconfined as a consequence of a lowering of the water level, exploitation should be suspended when the available saturated layer reaches a thickness of 40 m. There are areas of the GAS in which water levels (static levels) are very deep. As will be shown, in the deepest highly-confined zone, ZFC VII, static levels are over 400 m in depth, placing a strong restriction on groundwater use.

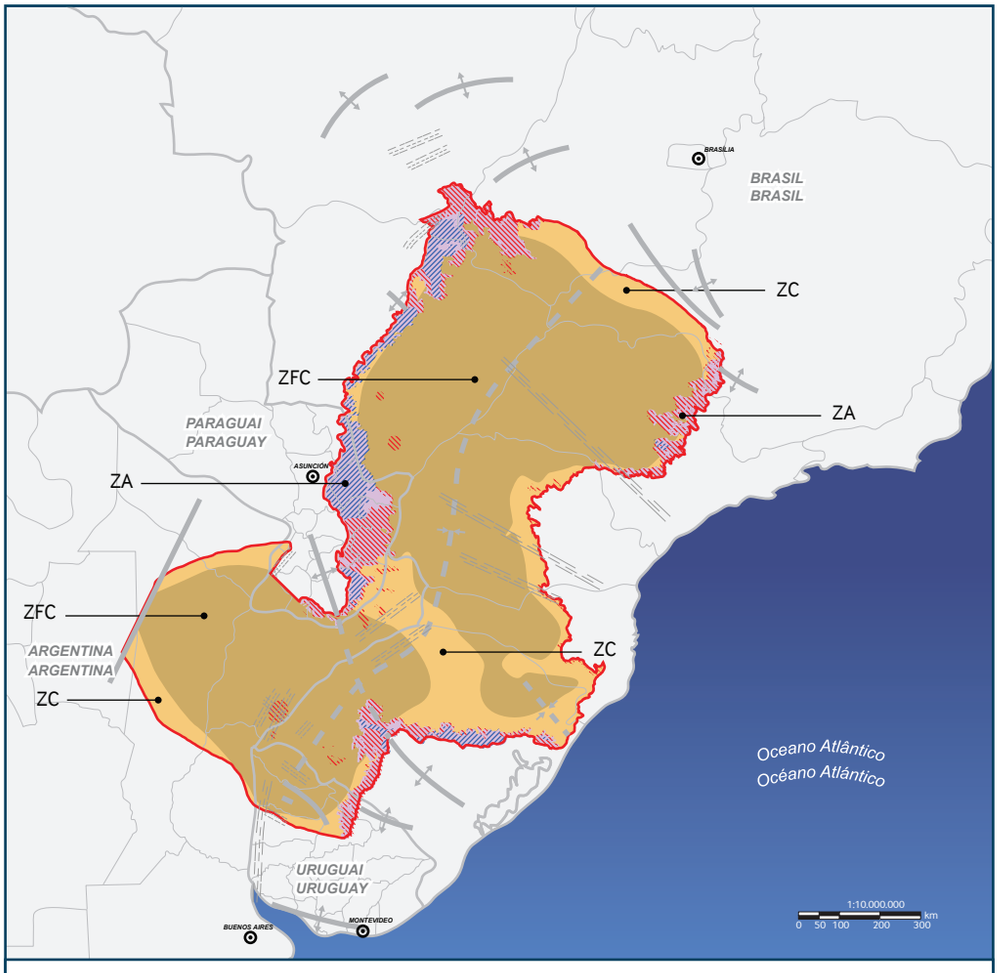


Figure 20. Proposes bases for zoning

Key

- Departmental, state/provincial and international boundaries
- Limits of the GAS
- ZFC Zone confined / strongly confined
- ZC Transition Zone / confined
- ZA GAS outcrop zone
- Replenishment area
- Discharge area
- National capital

Geological conventions

- Arc
- Suggested arc
- Fault
- Alignment
- Synclinal

Source GS/GAS. Adapted from GW-Mate and Guarani Consortium, 2008.

- Natural quality: in general, water of the GAS is appropriate for human consumption. In some places there are quality problems, such as high salinity and concentrations of fluorine. Another problem is the presence of natural inorganic anomalies, such as arsenic, cadmium, zinc, boron and nickel. The main areas where quality problems occur are shown on the Map in Figure 7. The origin of fluorine and of other inorganic elements has yet to be clarified. With respect to arsenic, cadmium, zinc, boron and nickel detected in waters of thermal wells in the southern part of the GAS (confined area V), doubts persist as to their origin and to the relationship with exploitation, since specific samples have never been collected, nor have detailed systematic motoring studies been carried out. Such chemical anomalies only occur in highly confined areas (ZFC) and, in certain cases, may be related to waters from non-isolated pre-GAS formations that may have contaminated the GAS.
- Vulnerability to anthropogenic contamination: it is possible to identify areas of greater or lesser vulnerability to contamination. Outcrop (ZA) and replenishment zones are the most vulnerable. Highly confined zones (ZFC) are not at all vulnerable. Confinement zones (ZC) are not vulnerable, provided that they are under the basalt layer (at a depth of less than 100 meters) that has no fractures that might allow access of pollutants from the surface.
- Temperature: presence of hot water is related to natural geothermal characteristics of the Paraná geological basin, and to the depth from which the water is abstracted. Highly confined zones, being some of the deepest in the GAS (confinement area IIIb) are also the hottest. Figure 8 shows the distribution of temperatures. Economic exploitation of this water as a source of thermal energy is associated with its temperature. Currently, hot water of the aquifer is used for tourism and industry, and temperatures in some cases are over 50°C.

The principle zones identified are described as follows:

2.13.1 Outcrop zones (ZA)

These correspond to areas I on the proposed zoning Map. They may act as replenishment or discharge zones. In regional discharge areas it is possible that local replenishment also occurs. There is interaction between surface and groundwater and, generally, base flows of rivers and other bodies of water are equivalent to GAS discharges. In such areas, the aquifer is unconfined (or semi-confined in certain specific situations) and the origin of replenishment water is, principally, rainfall. This is young water, that circulates rapidly, is generally potable and of a type I composition: i.e., calcium bicarbonates and, secondarily, calcium-magnesium and calcium-sodium bicarbonates. These areas are highly vulnerable to anthropogenic pollution.

2.13.2 Close confinement zones (ZC)

These correspond to areas II on the proposed zoning Map, i.e. they relate to fringes immediately adjacent to outcrop areas (10 to 50 km wide) where fractured basalt overlying the GAS is up to 100 m thick. Their existence is dependent upon vertical hydraulic conductivity of the basalt, the thickness of which varies considerably throughout the GAS, and that may act as aquitards in certain cases. Evidence exists of hydraulic connections between the GAS and post-GAS units, through these basalts (by means of geological faults and fractures). There are few specific or conclusive studies on such vertical connections (one conducted in the Ribeirão Preto region failed to demonstrate any such connection, suggesting efficacy of confinement exercised by the basalts, even when not very thick). On the other hand, in these zones, the greater the scale of observation, the more individualized the outcrop windows become, exposing areas of the GAS to an unconfined aquifer regime. This is an important theme, and the object of specific actions to be carried out under the SAP (Chapter 5).

In these areas, waters are of type I and type II, i.e., sodium bicarbonated. They are slightly vulnerable, in view of the fractured basalts, their proximity to the replenishment zone, and advective movements of pollutants through the GAS itself.

2.13.3 Highly confined zones (ZFC)

These correspond to all GAS areas confined by basalts of more than 100m in thicknesses, where available water stems from the mechanical compression of the body of the aquifer. Rates of circulation are extremely slow, leading to very low replenishment rates. They present heterogeneities that can be classified as follows:

Confined area III
Located in the western region of the GAS, in the Brazilian States of Mato Grosso and Mato Grosso do Sul, and in Paraguay, circulation of water is more dynamic in this band, as compared with other confined sectors to the east and center of the GAS. Its waters have a specific isotopic signature of O^{18}. This characteristic is probably associated with inflows from outcrop zones to the north (Goiás and Mato Grosso) and from basalt windows that serve as replenishment zones. It is not at all vulnerable and the waters are of type II.

Confined area IVa
Located in the eastern region of the GAS in the States of São Paulo and Paraná. Its waters are old, according to its O^{18} isotopic signature.. It is not vulnerable, and its waters are of types II and III. It is estimated that IVa confinement areas present the highest natural groundwater temperatures of the GAS.

Confined area IVb
Located in the northern part of the central region of the GAS, in the States of São Paulo, Mato Grosso do Sul, Paraná and Santa Catarina, along the thickest stretch of the GAS (and the thickest stretch of the post-GAS cover). Its southern limit is associated with the Asunción-Rio Grande rise (São Gabriel Arc). Like those of confined zone IVa, its waters are of high temperatures and relatively old, despite proximity to outcrop areas. It is not vulnerable. Chemical composition of its waters is predominantly of the sulfated and sodium-chlorate types (II and III) and is associated with the area of greater salinity located in the vicinity of the border between Paraná and Santa Catarina and between Paraná and Paraguay. Such high

salinity is probably associated to minor (by volume) contributions of intersticial waters from highly-saline pre-GAS rocks.

Confined area V

Beginning in the southern region of the Asunción-Rio Grande structure (São Gabriel Arc) and extending to the southern limit of the GAS in Uruguay. The vast majority of wells in this region are located on its southern limit. Its replenishment zone is related to the outcrop zone to the east of the region. Like other zones in the eastern part of the GAS, its waters tend to be very old, and despite proximity to outcrop zones, their age tends to be similar to that of waters of confined area IVb. In this area also there are thermal wells with high salinity and the presence of inorganic anomalies (high arsenic, cadmium, zinc, boron and nickel levels) that need to be assessed in greater detail.

Confined area VI

Located almost exclusively in Argentina (except for a small portion in Paraguay). As there are no wells, no information of the quality of its waters is available. It is believed that to the west of the Paraná River its waters are saline.

Confined area VII

Located on the eastern limit of the GAS in the States of Santa Catarina and Rio Grande do Sul. This is a small portion of the aquifer characterized by local flows, waters with low potentiometric levels and little replenishment. In the eastern portion, the water level is over 400 meters deep, and thus unfeasible as a water source using current technologies. Its waters are of type I (east) and type II (west) with isotopic signatures typical of recent waters.

The Map in Figure 21 proposes bases for zoning of the GAS, and Table 13 provides a summary of the predominant characteristics for protection, use, and management of the GAS in each of these zones.

2.13.4. Complementary guidelines

In view of the characteristics of the GAS, management should encompass the following aspects:

- Development of a GAS Geological Information System and of a water quality and quantity monitoring network, based on manuals and guides prepared under the PGAS. Unlike surface-water flows, groundwater flows tend to be very slow. Whereas surface-water flows are calculated in meters per second, flows within aquifers are calculated in meters per year. This has significant hydrogeological and environmental implications for groundwater management. Changes in both availability and quality of groundwater are outcomes of long processes. Nonetheless, such processes can be detected in individual wells or clusters of tube wells. For this reason, it is necessary to have a monitoring network that is attuned to potential uses and equipped with control tools. The spatial strategy of locating sampling wells is as important as the selection of relevant parameters, variables, and monitoring intervals. Preventive actions should permeate all activities targeted at groundwater resources conservation and management.
- It is important that managers bear in mind that there are other aquifers overlying the GAS. In many towns in the State of São Paulo where GAS water is exploited, there are municipal wells that abstract water from shallower aquifers. The same occurs, to varying degrees, in other Brazilian states and in the other countries that share the GAS. Regardless of whether these aquifers and the GAS are connected, exploitation should be carried out in an integrated manner that also includes surface waters.
- It is necessary to combine actions of the State with participation of water users. An example of such a participatory approach is the production of data and knowledge on wells, using contributions from user segments. Indeed, if the State does not have a good strategy for publicizing the benefits of management actions and the importance of providing inputs to management bodies, such information will not be forthcoming. One possible approach is to form alliances between the government and users, based upon clear rules, fiscal incentives and adequate training. This will stimulate water users will assume responsibility for generating data, and the government, within the limits of its institutional capacity, will simply corroborate and systematize the information. It is recommended that wells for public water supply be drilled in accordance with the PGAS Manual for Drilling Wells and that protection perimeters, both for individual wells and for clusters of wells, be delimited.
- In general, institutional and managerial capacities for management of groundwater and of the GAS are limited and uneven in the four countries. For the maintenance of water security in the region and sustainable use of the GAS, this needs to change. Aquifer management and its relationships to other national goals needs to be strengthened, through technical and programmatic consolidation, with a view to achieving integrated water-resources management, at the various jurisdictional levels that have a stake in management of the GAS.
- Overall, no major problems of over-exploitation of the GAS were detected. The effects of intense exploitation in Ribeirão Preto are local, but are already beginning to affect neighboring municipalities. Exploitation in confined areas, such as Concórdia-Salto, will cause impacts if there is a substantial increase in the number and concentration of wells. One concrete effect identified in scenarios simulated using the numeric model of the pilot project was possible interference between depression cones and their transboundary extension. In such cases, water-resources managers should promote adequate coordinated management of the aquifer, through monitoring of hydrochemical conditions and the temperatures of waters abstracted.
- Natural problems, such as high levels of arsenic, fluorine and other elements, need to be addressed by management authorities, depending upon the category of water use foreseen. It is recommended that further studies be conducted, with the aim of determining the origin of these elements and identifying areas of the GAS where such problems occur. Analysis of water from certain isolated wells

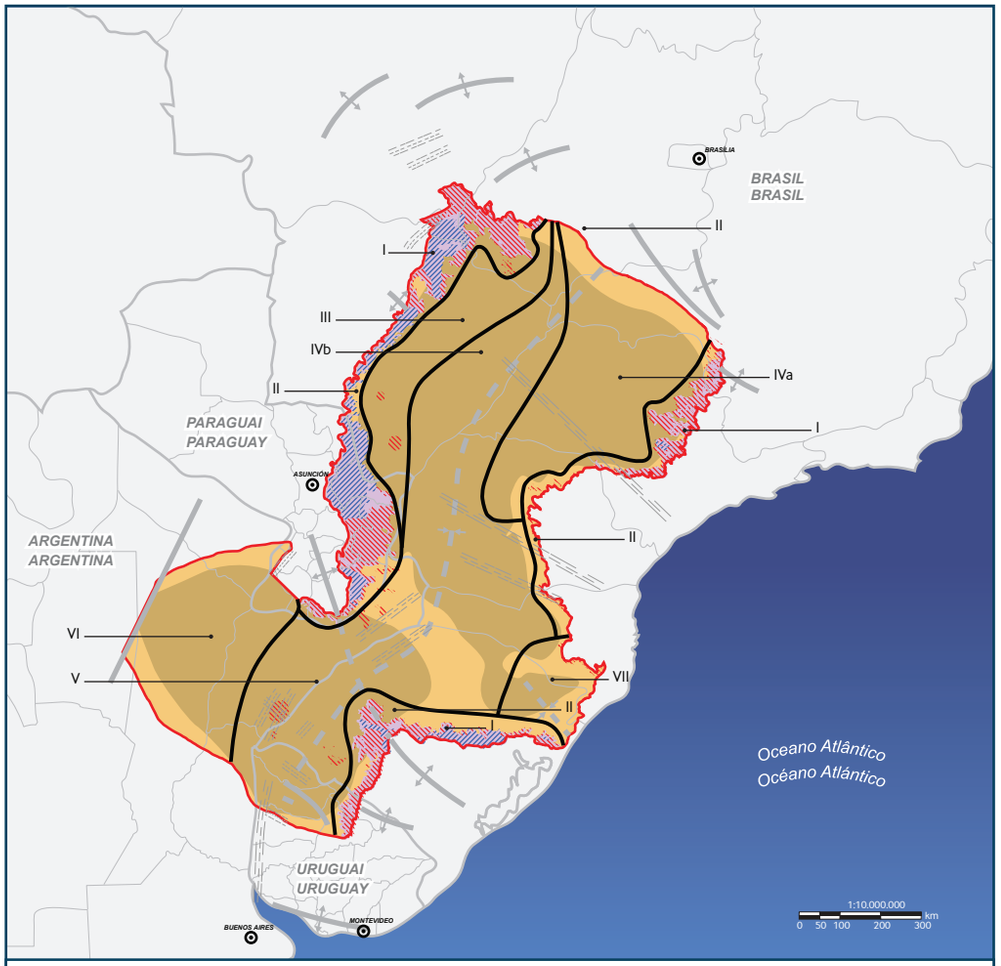


Figure 21. Proposed delimitation of GAS management zones*

Key

- Departmental, state/provincial and international boundaries
- Limits of the GAS
- Areas of homogeneity hydrogeological
- ZFC Zone confined / strongly confined
- ZC Transition Zone / confined
- ZA GAS outcrop zone
- Replenishment area
- Discharge area
- National capital

Geological conventions

- Arc
- Suggested arc
- Fault
- Alignment
- Synclinal

Source GS/GAS. Adapted from GW-Mate and Guarani Consortium, 2008.

*drawn up on the basis of flow characteristics and results of hydrochemical and isotopic tests carried out in areas I, II, III, IVa, IVb, V, VI and VII, that provide the bases for Management Zones – ZA (Area I); ZC (Area II) and ZFC (Areas III, IVa, IVb, V, VI and VII). The map also provides preliminary data on age, determined by the C^{14} and corrected by C^{13} methods.

Table 13. Summary of the characteristics of GAS zones where groundwater management should be applied*

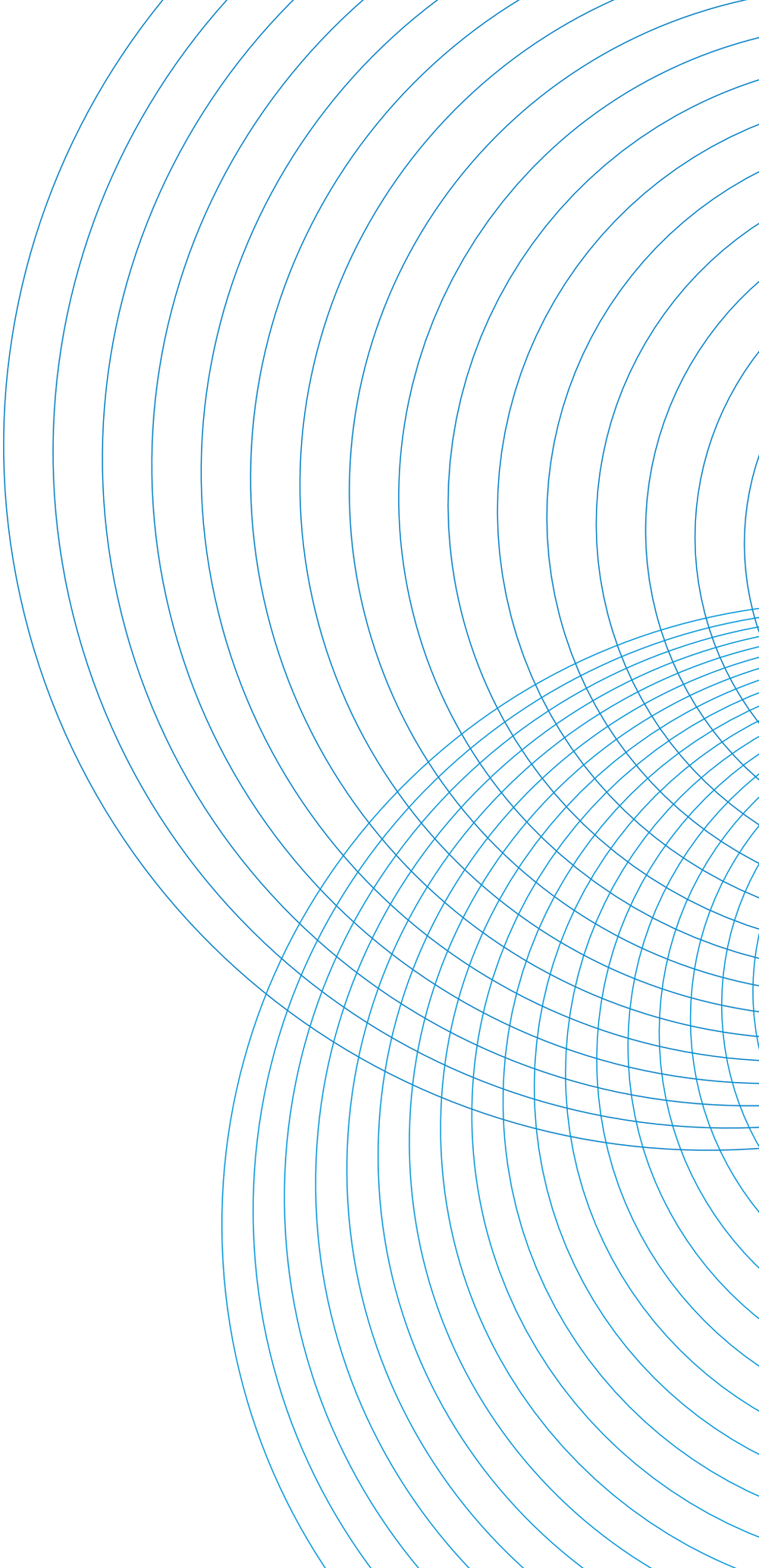
	Outcrop zone (ZA)	Confined zone (ZC)	Highly confined zone (ZFC)
Geographic situation	Outcrop area, including areas of aquitard discontinuity (windows in the basalt) (Area I)	Confined areas close to outcrops and aquitards, with thickness between 0 and 100 meters (Area II)	Highly confined area (confining aquitard > 100 meters) (Areas III, IV, V, VI, VII)
Hydraulic characteristics	Water originating from drainage of the aquifer (Neuman model). Storage of the specific yield (SY) type). Velocity of flows is relatively high. Waters are relatively modern (less than 100 years)	Confined aquifer, with possible descendent vertical drainage through the post-GAS aquitard. Exploitation may induce significant lateral flows of water from the replenishment zone, when this is close by (a few tens of kilometers) thereby increasing availability. Velocity of flows varies from low to moderately low, and the age between 200 and 500 years	Water available from the mechanical effects of compression of the body of the aquifer (Theis model) and, thus, of its storage (S). Low velocity of circulation. Ancient waters (over 500 years)
Recommended form of exploitation	Total exploitable flows (sustainable flow) is defined, for each hydrographic basin, as a function of replenishment of the GAS, its hydraulic and ecological functions, and base flow of rivers and other surface water bodies	Exploitation should be planned, as behavior of the aquifer is similar to that of the confined system. Through proximity to the replenishment area, intense exploitation (increased hydraulic gradients) may induce greater water availability for these portions of the aquifer, drawing water from outcrop areas	As there is no replenishment of water abstracted from wells (distant replenishment zone and slow flows) exploitation of these portions of the aquifer leads to a continuous decrease in the hydraulic load over time. This makes it necessary to plan for continuous exploitation. Furthermore, limits to exploitation should consider: a) interference between wells and increasing abstraction costs; b) need to deepen wells, and replace pumping equipment as a consequence of lowering water levels; c) cost of abstracting groundwater in cases of increasing manometric heights (for various reasons).
Accessibility (cost of drilling and pumping limit)	No problems of access Medium and low-cost tube wells	No problems of access Medium-cost tube wells	Exploitation per well is limited by abstraction costs. Tube wells can reach depths of 1.000 m, requiring high investments and technology. When the dynamic level of a well reaches 400 m, there are technical and (especially) economic limitations to exploitation
Natural quality	No problems detected	No problems detected	Areas with problems of high salinity and other inorganic elements, including fluorine, arsenic and others, in specific areas
Vulnerable to anthropogenic pollution	Highly vulnerable	Low vulnerability. Contamination problems through fractured basalts (thickness < 100 m). Contamination from the outcrop area induced by pumping, creating lateral flows	No vulnerability to surface pollutants. In the region of the Concórdia-Salto Pilot Project, however, hydraulic effects may lead to a risk of contamination from inflows of sub-surface salt water
Temperature	Low temperatures	Low temperatures	Temperatures of moderate enthalpy. Areas of energy, industrial, agricultural and recreational use

Source GS/GAS. Adapted from GW-Mate and Guarani Consortium, 2008.

identified the presence of nitrates. In the confined zone, this problem appears to be related to technical construction parameters of the wells, that are poorly located or out of specification. In non-confined zones and in urban areas, this problem may be related to anthropogenic influences and weaknesses of sanitation systems. systems that exercise a preventive regional focus should propose concrete actions for addressing these situations. To face up to these problems, concrete measures of a legal and institutional nature with a regional focus are needed.

- Based on studies carried out in the Pilot Projects, current transboundary effects of exploitation of the GAS would appear to affect only a limited zone, the scope of which depends upon specific hydrodynamic conditions. In general, however, such effects are restricted to a few dozen kilometers. Hydraulic 'upstream' and 'downstream' effects, so common when dealing with surface-water drainage, are imperceptible and vary in accordance with the piezometry and intensity of depression cones in the various sectors under exploitation (variations of the hydraulic gradient). In scenarios where exploitation is more intense or, for example, where one dominant economic activity affects other types of use, such impacts may go beyond strictly hydraulic issues. Future land-use changes, especially in replenishment areas (deforestation, cultivation of exotic species, crops changes, intensive use or inadequate management of agrichemicals, and increasing demand for water) or increased exploitation of GAS water from confined zones (irrigation, thermal use, and others) could lead to negative hydraulic effects and deterioration of water quality.

Project for Environmental Protection and Sustainable Development of the Guarani Aquifer System



On the Path to Sustainable Management

3

Chapter 3

On the Path to Sustainable Management

SUMMARY

Among the benefits accruing from execution of the Project for Environmental Protection and Sustainable Development of the Guarani Aquifer System (PGAS) were advances in regulations for groundwater, which thenceforth were treated with greater technical precision and at a higher jurisdictional level. This was made possible by an expansion and integration of scientific and technical knowledge, enriched by institutional and public-participation processes generated on the theme, which opened up access to such knowledge for state/provincial, national and regional stakeholders.

The four countries (Argentina, Brazil, Paraguay and Uruguay) developed their own normative structures, incorporating principles and instruments appropriate for their specific groundwater management and protection needs.

Legislation and institutional structures for groundwater management differ in each of the countries and there are asymmetries in relation to their capacities. Nonetheless, the countries have coincident principles and instruments that are favorable to adoption of measures for management and protection of the Guarani Aquifer, harmonized at the national levels and coordinated with convergent objectives at the regional level.

At the end of this chapter, a description of the actions that comprise the Strategic Action Program (SAP) aims to contribute toward promoting coordinated transboundary management which respects national realities and enhances coincident aspects.

3.1 CONTEXT AND ADVANCES

The Project for Environmental Protection and Sustainable Development of the Guarani Aquifer System (PGAS) substantially expanded knowledge on groundwater and, more especially, the GAS. It brought to the fore the local, state/provincial, national and regional interests relating to the aquifer.

During the two final decades of the 20th Century, throughout the region, environmental awareness took on greater importance and incipient advances were achieved in the field of water-resources regulation in general. However, development specifically in the field of groundwater legislation was scarce, and remained overshadowed by regulations for surface water.

Partially as a consequence of advances since that time in the region overlying the GAS, in Argentina, Brazil, Paraguay and Uruguay there has been a significant increase in groundwater regulations, characterized by a higher jurisdictional level and greater technical precision. The standards were adjusted to meet requirements of aquifer management, which had not been the case prior to 2000.

The regional joint initiative for the GAS began in 2000, which is thus the baseline year. As of preparation of the PGAS, there have been evident advances in terms of groundwater regulation, to some extent motivated by Project activities and the involvement of institutions and academics for which the Project opened the way. Subsequently, this was reinforced by dissemination of knowledge generated by the PGAS, by academic activities, by participation of NGOs, and by the consequent burgeoning of political and social awareness of the importance of this resource. Such growing awareness contrasts with weaknesses that, to varying degrees in each of the participating countries, hampered sustainable protection and management of groundwater.

In the period between 2000 and 2008, the theme of groundwater management became a permanent feature at the highest jurisdictional levels of the legal frameworks, creating a structure that legitimated subsequent development at lower hierarchical levels. These important normative advances had a direct impact on management of the GAS and originated from different circumstances, namely:

- Management institutions with responsibility for groundwater deepened the approach to regulation in two ways:
  - » standards of a higher jurisdictional level within the legal framework;
  - » increased precision by means of regulatory standards.
- Institutional bodies that had formerly lacked regulation incorporated new and more precise standards;
- As a consequence of synergies generated by the PGAS, for the first time, specific forecasts for the GAS and for Pilot Project areas began to be considered in the region.

Notwithstanding other benefits that such advances have brought to each of the countries, even more important has been the quest for implementation of regional normative convergence, compatible with the needs of the four countries, that has pointed toward coordinated management of the GAS, so as to encompass all aspects, from the base, to adequate implementation at the national and sub-national levels.

3.2 GENERAL CHARACTERISTICS OF GROUNDWATER REGULATION

The tables in Annex 6 present a summary of the available legal structures and instruments for implementation in the four countries. Annex 7 presents a table showing the international legal instruments that unite the participating countries of the PGAS initiative. Based upon this information, there follows a brief summary on how the aforementioned advances are reflected in current legislation in the four countries.

Argentina:

- In Argentina, provincial public jurisdiction over groundwater has been established. Management responsibility lies with the Provinces, although federal legislation also sets minimum management standards (under the General Environment Law 25.675 and the Environmental Management of Water Law 25.688). There is also an Under-Secretariat for Water Resources, within the Federal Ministry of Planning, Public Investment and Services.
- The six Provinces that overlie the GAS have water codes, and five of them have specific regulations for utilization and protection of groundwater. Santa Fe is the exception.
- Santa Fe and Entre Ríos have issued technical standards for drilling of wells for groundwater abstraction (Directory of Hydrology and Ministry of Water Affairs, respectively, in 2005). Entre Ríos is implementing more specific actions for management of thermal water (since the Water Law 9.172/1998 does not apply to groundwater).
- Misiones, by means of Ministry of Ecology Resolution 429/2006, issued technical standards for wells and drilling for groundwater abstraction.
- Chaco, Corrientes and Misiones have claimed the right to regulate the GAS.

Brazil:

- In Brazil, laws on the environment and water resources set national policies and state-level public jurisdiction over groundwater. Deliberations of the National Water Resources Council (CNRH) and of the state-level Water Resources Councils (CERHs) also address issues relating to regulation, management, and protection of groundwater.
- Within the scope of the National Water Resources Plan (PNRH) the National Groundwater Program (PNAS) has been proposed, under coordination of the Secretariat for Urban Environment and Water Resources of the Ministry of Environment (MMA) and of the National Water Agency (ANA). The National Groundwater Program encompasses specific subprograms for:
  - » increasing basic knowledge, including monitoring of groundwater;
  - » development of institutional and legal aspects;
  - » capacity building, communications and public participation.
- The eight States that overlie the GAS have passed laws establishing State Water

Resources Policies. Seven of them have approved specific standards relating to management, abstraction and protection of groundwater.

- In São Paulo, the State Water Resources Council has established restricted and controlled areas for abstraction and use of groundwater in the municipality of Ribeirão Preto.

Paraguay:

- Aside from environmental laws, the Water Resources Law, instituted by legislation in 2007 and currently being put into effect, establishes public jurisdiction over groundwater.
- Resolutions have provided standards for water management and drilling of wells for abstraction of groundwater.
- The Secretariat of Environment (SEAM) is responsible for water resources management, and the Sanitation Services Regulatory Corporation (ERSSAN) issues standards for water supply and sanitation services.

Uruguay:

- Environmental and water resources laws (the Water Code) have been enacted. The Constitution establishes public jurisdiction and sets management principles for groundwater (currently under implementation).
- The Management Plan for the Guarani Aquifer and technical standards for the drilling of wells for abstraction of groundwater have been issued by Decree.
- In January 2008, the powers of the National Hydrographic Board (DNH) were transferred to the National Water and Sanitation Board (DINASA) of the Ministry of Housing, Territorial Planning and Environment (MVOTMA) which has since been responsible for management and protection of the country's water resources.

3.3 EFFECTIVENESS OF NORMATIVE AND INSTITUTIONAL STRUCTURES

Generally speaking, the four countries have developed adequate normative structures, in line with regional and international trends, incorporating principles and appropriate instruments to address groundwater management and protection issues. However, except in a few cases, these advances have not been followed up by effective deployment of management instruments, entailing corresponding allocations of financial, human, and logistical resources.

Generally, the weaknesses that have hampered deployment of such management instruments are: (i) scarce or inappropriate regulations (unsubstantiated by scientific knowledge); (ii) lack of deployment instruments; (iii) poor transnational coordination; (iv) lack of mechanisms for cooperation among the countries; (v) poor institutional enforcement capabilities (lack of human and financial resources, specialized skills, etc.); (vi) ignorance of requirements on the part of water users; (vii) traditional practices and customs relating to water use; (viii) lack of public participation and dissemination; (ix) excessive centralization of management in Provincial/State and national capitals, at a distance from local problems; (x) lack of local water-quality and abstraction control bodies; and (xi) poor integration among environmental management, land-use planning and water resources management bodies.

3.4 MANAGEMENT COORDINATION AMONG COUNTRIES

As was explained in the previous section, the four countries that share the GAS have different legislative and organizational standards (presented in detail in Annex 10) with varying levels of effectiveness. Despite such differences, significant points of convergence exist, upon which coordinated management policies can be based.

The proposals at the end of this Chapter (Table 2) identify features of coordinated transboundary management that respect national differences and which, without imposing changes upon legal frameworks, can help foster convergence and cooperation, all of which contributes toward the quest for harmonized management of the GAS.

Various general principles for management and protection and several of the monitoring instruments used are similar in all the four countries. A preliminary comparison shows the following coincidences and differences among the countries:

The points of coincidence in terms of principles and management instruments are listed below.

Principles in common:

- Public jurisdiction over groundwater
- Environmental protection.
- Ensure availability of water of adequate quality for current and future generations.
- Rational, integrated, and sustainable use.
- A limited resource with an economic value.
- Multiple use.
- Priority for human water supply.
- River basins as the basic management unit.
- Territorial decentralization.
- Participation of stakeholders.

Instruments in common:

- Systems for granting of licenses for water use and discharges.
- Environmental licensing.
- Classification of water bodies.
- Basin committees or advisory boards.
- Public registry of water-use rights.
- Inventory of hydraulic engineering works.
- Information systems.
- Possibility of deploying water-use charges.
- Control and penalties for noncompliance.

Development of a future coordinated management system will have to take into consideration these important points of coincidence, and also the need to improve implementation of these legal frameworks in each country, without which further progress in joint management would be hard to achieve (see Table 1).

An analysis of these elements leads to the following preliminary conclusions:

- In each of the four countries (though there is still scope for improvement) a sufficient legal and institutional framework is in place for the development of sustainable protection and management of the GAS. Conditions are also favorable for development of the necessary coordination among the countries. It is now up to each of the countries to review and adjust its national legal framework, based on its own needs, experience, and the

results of technical studies carried out within the scope of the PGAS and other public and private research initiatives. It is, however, also necessary to point out that the effectiveness of implementation has been weak in different areas of the region.

- In view of its close links to normative aspects, the question of institutional preparedness is of key importance and inevitably arises whenever actions are proposed for this area. In countries with federative structures, articulation or integration among states or Provinces is perceived by local stakeholders as the first step toward the goal of sustainable management at the national level. In Argentina, local stakeholders have proposed establishment of a Basin Council (which would require an agreement among all of the Provinces involved, since Law 25.688, that had foreseen establishment of the Council, was declared unconstitutional). In Uruguay, there was a proposal for establishment of an Aquifer Committee, with broad powers over the entire area overlying the Uruguayan portion of the Guarani Aquifer. In Brazil, it was proposed that the existing structure and coordination mechanisms among the states should be harnessed, through bodies of proven efficacy (CNRH, CERH, and basin committees). In Paraguay decentralization of certain functions was proposed, to enable departmental governments to collaborate better with the central Government on issues relating to groundwater management.

Table 1. Legislative harmonization / main points of coincidence and difference

Nature	**Points of coincidence**	**Differences**
Normative	Basic principles for management and implementation instruments	Greater specificity in certain zones. Effectiveness of implementation
Institutional	Existence of bodies with well-defined attributions	National organization: unitary and federative states

Source: GS/GAS Adapted from the Final Report of the SAP Legal Advisors.

- Themes relating to dissemination, education and capacity building, in all of the countries, were considered central to the successful outcome of proposals. Thus, to achieve such outcomes, dissemination of information and capacity building in all areas are deemed priorities. There is a consensus among the countries that, in terms of management and protection of groundwater, public participation and involvement of all stakeholders and of civil society (including indigenous peoples) is not just a legal requirement, but an essential requisite for coordinated management.

3.5 BASES FOR A COORDINATED MANAGEMENT FRAMEWORK

There is a need to reassess the original scope of the transboundary management framework (considered the primary motive behind formulation and execution of the PGAS). The scope of the framework needs to be adjusted to encompass now-accepted groundwater management principles and newly-acquired knowledge on the dynamics of the GAS, as described in Chapter 2.

It is not merely a matter of altering jurisdictional levels, but rather, of adapting to constant challenges and strengthening of cooperation among the countries, based on the principle of subsidiarity[1], that will unquestionably lead to the strengthening of national, state/provincial and municipal management institutions.

The necessary management instruments will vary as a consequence of hydrogeological characteristics, socioeconomic pressures and specific problems in the various zones of the GAS. Unquestionably, however, formal support of the countries for this new framework will add to the sustentabilidade of the Strategic Action Program (SAP)[2].

Argentina	**Brazil**	**Paraguay**	**Uruguay**
Civil Code[3]	Federal Constitution	Civil Code	Constitution
1968	1988	2005	2004

1 The principle of subsidiarity establishes that the powers of public bodies of a higher level (State or Federal Union) should prevail over those of the municipalities only when these are not in a position to execute them effectively. In other words, the municipalities are now acknowledged by the legal framework as the main and most capable agents for social development, limited only by circumstances that require, temporarily or permanently, support in the form of funding and/or management capacities from the higher levels.
2 Implementation of the SAP will be incorporated into the Guarani Aquifer Agreement when the countries deem that the necessary conditions for its approval have been fulfilled.
3 The Civil Code dates from 1869. It was reformed in 1968, when groundwater was incorporated into the public domain (Law. 17.711). A general principle of the Code states that practically all water is within the public domain, with a few express exceptions, which define when water can be in the private domain (limited to when it is needed to fulfill the general interest)..

During development of the PGAS, the countries overlying the GAS jointly defined the following premises for coordinated and sustainable management of the Aquifer:

1. Like other groundwater deposits, the GAS is under sovereign jurisdiction of the countries that overlie it, each of which holds responsibility for its management. This increases the need for regional coordination and cooperation to ensure deployment of strategic actions at the regional and national levels, whether or not of a transboundary nature.
2. Through cooperation among national institutions, the countries defined the ultimate goal of the PGAS initiative as being protection of the GAS with a focus on prevention and sustainable use. This implies a need to identify the main vulnerabilities and propose management actions in each of the countries to be carried out jointly or individually, as the case may be. The SAP incorporates this objective and exercises the intrinsic function of fostering coordinated actions among the countries.
3. There are national frameworks, regional frameworks and international agreements capable of producing synergies in support of the process. In each of the countries, a series of initiatives and programs are underway, directly or indirectly related to groundwater management and, more specifically, to management of the GAS (regional/national/state – provincial/local). These programs need to be encompassed and strengthened by the SAP.4
4. Groundwater management needs to be focused upon prevention and incorporated into sectoral policies at the various levels. New technical knowledge acquired over the course of the Project needs to be assimilated, considering that:
   - With very few local and specific exceptions, no problems of contamination or overexploitation were detected. The legal and institutional frameworks should provide for concrete actions to face up to such local situations.
   - Studies carried out under the Pilot Projects have demonstrated that current and potential transboundary repercussions of the GAS may be restricted to a specific zone, the scope of which may be greater or smaller depending upon hydrodynamic conditions of the GAS. From a hydraulic standpoint, the effects of "upper water and lower water" so common when dealing with surface drainage, are of less significance when addressing groundwater.
   - These effects, however, may be altered or come to the fore in the aforementioned zones as a consequence of future land-use changes, especially in aquifer replenishment areas (deforestation, reforestation, changes in crops, intensive use and inadequate management of agricultural chemicals and other inputs, and increases in demand for water) or as a consequence of greater exploitation of waters of the GAS for irrigation or thermal purposes.
   - Deployment of concrete management and protection measures thus need to be based upon local experience, and upon assimilation of lessons learned from the Pilot Projects. It no longer suffices to continue enhancing local management in particular areas of the GAS and replicating them in other similar areas, it is also necessary to expand their scope to encompass adjacent areas. In brief, the proposal is to move on from the particular to the general, by adopting a pragmatic approach.

5. The realities of transboundary management of the GAS require definition of the most adequate forms of cooperation to foster and achieve:
   - monitoring of the deployment of the agreed strategic actions;
   - dissemination of materials produced under the PGAS and harmonization of the necessary knowledge for further development throughout the entire region of the GAS;
   - the work of Local Groundwater Management Committees;
   - periodic discussion of experiences for the use, management, and protection of waters of the Aquifer in the different countries, States/Provinces;
   - operation and maintenance of a groundwater quality and quantity monitoring network;
   - maintenance and updating of databases, such as the SISAG and numerical models developed under the PGAS;
   - establishment of harmonized criteria, procedures and standards in the various different zones identified in Chapter 2 (ZA, ZC and ZFC) where these are lacking.
6. Among the legacies of the Project have been development of management instruments, such as the monitoring network, the GAS geographic information system, and models prepared on a pilot and regional scale. Incorporation and use of these instruments and their continual development by the countries, will enable: 1) progress in knowledge on the GAS; 2) decision-making support mechanisms; and 3) strengthening of further ties of cooperation among the countries.
7. The importance of creating Management Support Committees is acknowledged, based upon positive experiences of Local Groundwater Management Committees in pilot areas. This is necessary in order to adapt local management instruments and enable deployment of different approaches, particularly municipal land-use policies and water-resources policies at the national or Provincial/State levels. It also provides a means of expanding opportunities for public participation and environmental education in areas where there is significant usage or problems relating to the Aquifer or to groundwater.

It is necessary to take into consideration interactions between groundwater management support committees basin committees of the respective rivers, and it is also important that opportunities for public participation include their representatives. Such public participation and the resulting exchanges of information and ideas expand the visibility of the role of groundwater within the scope of

river basins and disseminate knowledge on the economic advantages that the integrated use of groundwater and surface water can provide. The main purpose of such interaction is to seek ways of overcoming institutional, normative, and technical obstacles.

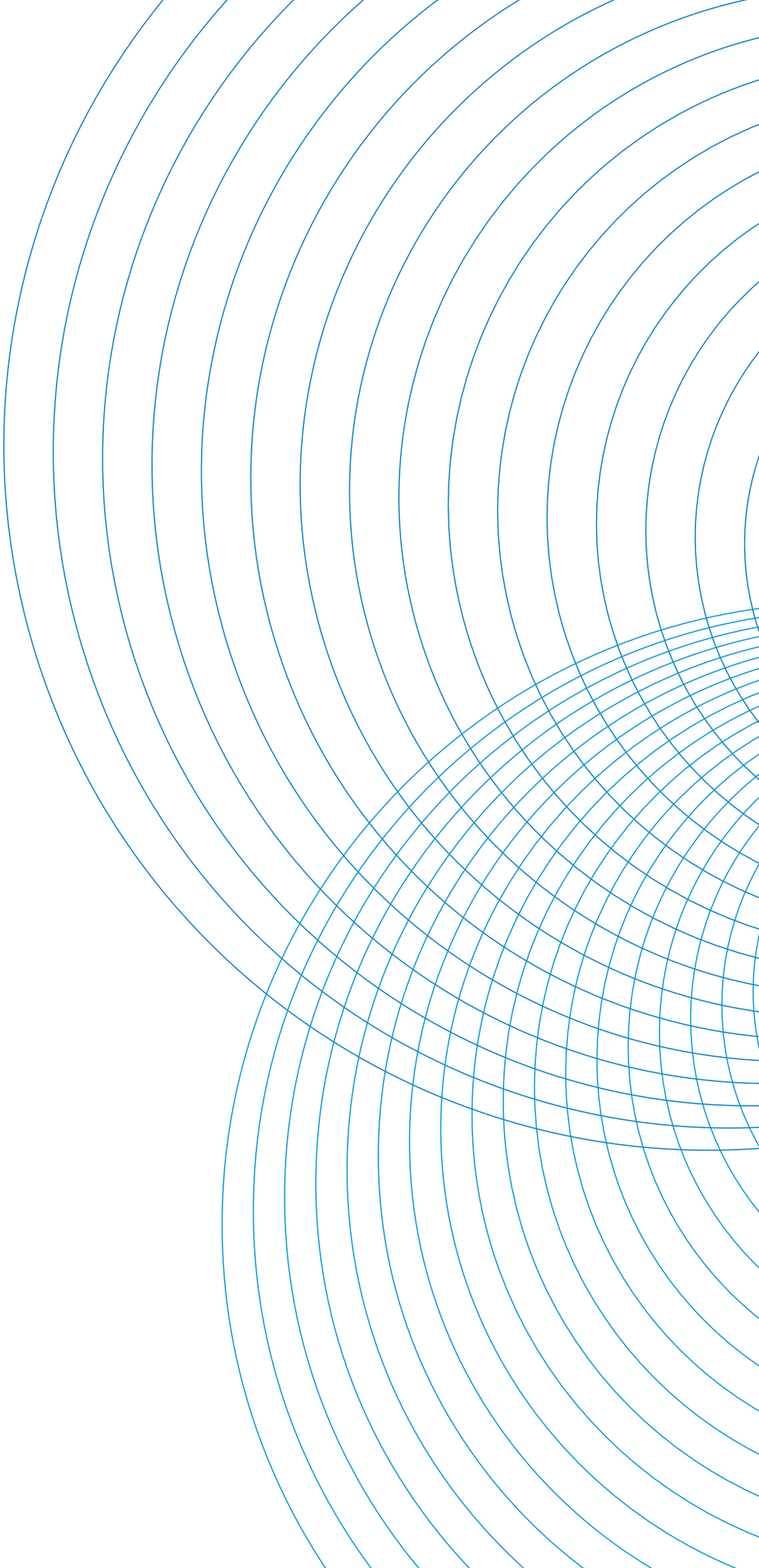
3.6 PROPOSALS OF A NORMATIVE INSTITUTIONAL NATURE

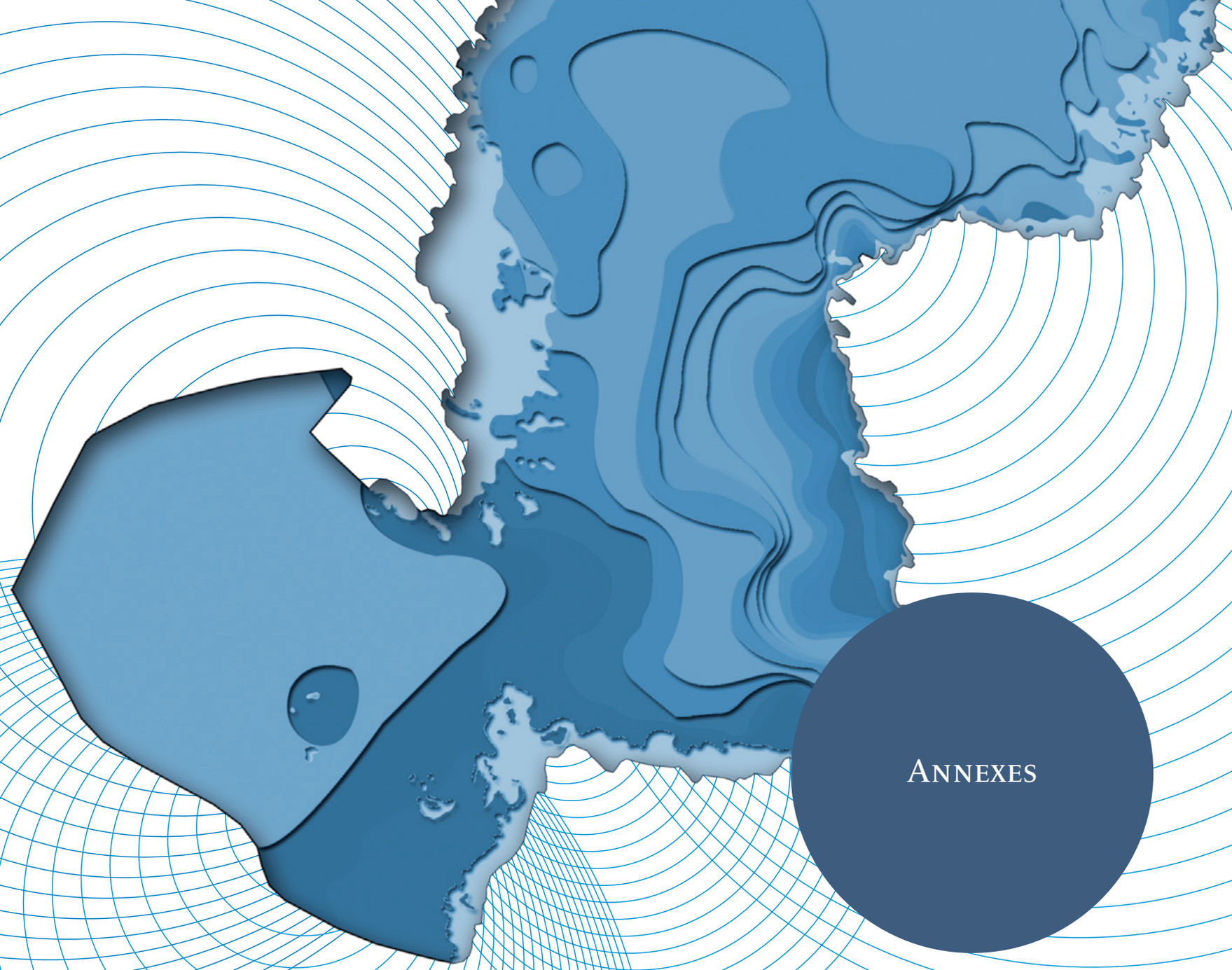
- In the four countries, meetings were held to validate the SAP, with ample participation of public and private stakeholders. These meetings provided opportunities for evaluating proposals and the technical legal measures needed to enhance the effectiveness of the current legal framework, with a view to ensuring sustainable management and protection of the GAS. These proposals have been incorporated into this report (see Table 2).
- Such participatory preparation of proposals fulfills an objective of the PGAS, in that it ensures that standards applicable to situations detected in the GAS should be duly assimilated, so that all stakeholders incorporate the respective frameworks.
- As with all issues that require compliance with legislation, unquestionably, the framework will undergo further changes in future, in response to advances of knowledge and of specific circumstances. To this end, standards should be sufficiently flexible to maintain the sustainability of the process.
- Implementation requires appropriate instruments, suggested by the countries, with differing levels of detail: drafting of manuals of best practices; delimitation of vulnerable zones and protected areas; harmonization of licensing systems; coordination between environmental licensing and licensing of the right to use water; implementation of the Register of Water Resources Users, in line with the degree of legal development and the particular circumstances of each country. All of these actions are contained in the proposals for the SAP, listed in Chapter 5.

Table 2. Actions proposed to increase normative effectiveness

Country	
	Legislation
Argentina	- Assess prospects for complementing national laws and minimum environmental and water-management standards with provincial laws
Brazil	- Adapt the standards to diagnostic studies and scientific knowledge generated by the PGAS
Paraguay	- Incorporate knowledge generated by the PGAS into regulations under the Water Resources Law
Uruguay	- Adapt the standards to scientific knowledge generated by the PGAS
	Institutional
Argentina	- Articulation among the GAS Provinces within the scope of COHIFE - Establishment of a Basin Council for the GAS Provinces
Brazil	- Intensify federal/state coordination in the CNRH, CERH, CBH, SRHU/MMA, ANA and the municipalities - Build upon compatibility with the PNAS - Integrate municipalities through basin committees - Promote establishment of Groundwater Technical Chambers within basin committees - Promote establishment of Management Support Committees for Groundwater in areas with potential problems or intensive use
Paraguay	- Decentralization of certain central Government functions to states and municipalities - Water Councils should include stakeholder sectors (agriculture, territorial planning, land use)
Uruguay	- Incorporate into the current regulatory structure an Aquifer Committee, that could be consolidated in articulation with municipalities and water users
	Tools
Argentina	- Propose a common Drilling Manual for all of the GAS Provinces - Establish a Register of Drillers
Brazil	- Harmonize water licensing systems in the GAS states, in accordance with agreed guidelines - Draft a manual of best practices for use and drilling of wells - Apply groundwater classifications - Establish protected areas - Integrate water-management and territorial, urban and rural planning, in accordance with agreed guidelines - Coordinate environmental and water-use licensing
Paraguay	- Implement the Register of Water Resources Users, dissemination and regularization deadlines - Delimit vulnerable zones and restricted areas based on knowledge generated by the PGAS
Uruguay	- Adapt the Guarani Aquifer Management Plan, update regulations on discharges of effluents and Environmental Impact Studies based on PGAS findings - Assess prospects for deploying water-use charges in certain zones and invest revenues in management improvements
	Dissemination
Argentina	- Deepen research and dissemination of results
Brazil	- Continue with training, dissemination and empowerment of Basin Committees
Paraguay	- Disseminate findings of PGAS studies - Intensify education at all levels - Translate legislation into the Guarani language
Uruguay	- IIntensify public participation, dissemination and education, utilizing spaces opened up by the PGAS

Source: GS/GAS Adapted from the Final Report of the SAP Legal Advisors, with contributions from the National Project Execution Units, 2008.





Annexes

ANNEX 6

Annex 6 Summary of Legal implementation in the four Countries

Table 1. Relevant legal standards for water resources management

	Jurisdiction
Argentina	- National Constitution (CN) of 1994: acknowledges that the Provinces have original jurisdiction over natural resources (water) existing within their territory (art. 124) - Civil Code (CC): surface waters are under public jurisdiction of the State. Reform of the code in 1968 placed groundwater under public jurisdiction (art. 2.340) - Joint interpretation of articles 124 (CN) and 2.340 (CC), places groundwater under public jurisdiction of the provincial State in which it is found
Brazil	- Federal Constitution (CF) of 1988: water is a good for common use of the people – a diffuse good (art. 225) - Law 9.433/1997 - National Water Resources Policy: water is under public jurisdiction (art. 1, I) - According to the CF/88, it is the responsibility of the (Federal) Union to legislate on general rules for water (art. 22, IV); groundwater is included among goods of the States, with exception of mineral groundwater which is under federal jurisdiction
Paraguay	- Law 3.239/2007: surface water and groundwater are under public jurisdiction of the State - Civil Code of 1985: rivers and all waters that flow naturally are goods under public jurisdiction of the State (modified by Law 2.559/2005 that extended jurisdiction over groundwater) - Municipal Organic Law nº 1.238/1987: rivers, lakes and streams are under municipal jurisdiction. Law 3.239/2007 sets restrictions to jurisdiction of banks under private ownership adjacent to water courses. It is the responsibility of the municipality, without prejudice to other authorities
Uruguay	- Art. 47 of the Constitution (reform of 2004): surface waters and also groundwater, with the exception of rainwater, that are part of the hydrological cycle constitute a unitary resource, subordinated to the general interest, and are part of the state public jurisdiction, under public hydraulic jurisdiction
	Water legislation
Argentina	- In Argentina there is no federal water law: each Province has legislation regarding the utilization and protection of the resource - According to art. 41 of the CN of 1994, there are minimum environmental budget laws: - General Environment Law 25.675/2002 - Environmental Water Management Law - nº 25.688/2002 (observed) - Law on the Right of Access to Environmental Information in possession of the State - nº 25.831/2004 - Law for Environmental Protection of Native Forests - nº 26.331/2007 - Law of the Guiding Principles for Water Policy, adopted by the Provinces by means of the Federal Water Agreement of 2003, which contains provisions referent to groundwater. Principles 1, 2, 31 and others
Brazil	At the national level: - Federal Constitution of 1988 (arts. 225, 20, III and IX; 22, IV; 23, XI; 26,I; & 170, VI) - Decree 24.643/1934 – The Water Code – arts. 96 to 101 referent to groundwater - The Mineral Water Code – Decree 7.841/1967 - Penal Code (arts. 270 and 271 – penalties for pollution of drinking water) - Mining Code – Decree 227/1967 (arts. 10,V) - Law 6.938/1981 – General rules for environmental protection - Law 9.433/1997 (National Water Resources Policy) - Law 9.984/2000 – created the National Water Agency (ANA) - Decree 4.613/2003 – issues regulations for the National Water Resources Council (CNRH) - Law 10.881/2004 (Water Agencies) - Decree 6.107/2007 (art. 23) - Law of Environmental Crimes 9.985/2000 modified by Decree 4.430/2002 on Public Forests - National Basic Sanitation Law 11.445/2007

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Paraguay	- Law 3.239/2007 on Water Resources of Paraguay – provides for sustainable and integral management of all waters and territories that produce them - Forestry Law 422/1973 - Law 836/1980 - Sanitary Code - Law 294/1993 – Law of Evaluation of Environmental Impact. Necessary for subsequent Declarations of Environmental Impact - Decree 14.281/1996 that regulates Law 294/1993 with activities subject to this law: construction and operation of water supply systems, treatment and disposal of used waters, and discharge of industrial effluents into rivers or water bodies - Law 352/1994 - Protected Wild Areas - Law 1.561/2000 - created the National Environment System, the National Environment Council and the Secretariat of Environment - Law 1.614/2000 - General regulatory and tariff framework for public provision of potable water and sewerage services in the Republic of Paraguay (relating only to the service) - Resolution 2.155/2005 – specifications for construction of tube wells for abstraction of groundwater
Uruguay	- Laws and decrees of the Executive Branch are applied nationwide Laws: - The Water Code - Law 14.589/1978 encompasses surface waters and groundwater - Law 15.239/1981 – Conservation of Soils and Waters - Law 16.466/1994 – Evaluation of Environmental Impact - Law 16.858/1997 – of Irrigation - Law 17.234/2000 – Natural Protected Areas - Law 17.283/2000 – Environmental Protection Decrees: - Irrigation Advisory Boards – Decrees 442/1970 and 128/2003 - Licensing discharges of effluents – Decree 253/1979 - Sanctions for offences against the Water Code (fines) – Decree 123/1999 - Management Plan for the Infra-basaltic Guarani Aquifer – Decree 214/2000 - Public Register of Waters – Decree 460/2003 - Technical Standards for construction of bore wells – Decree 86/2004 - Distribution of competition on water issues – Decree 335/2004 - Environmental Impact Evaluation- Decree 349/2005 - Advisory Committee on Waters and Sanitation – Decree 450/2006 - Executive Branch Resolution 769/2001 – regulates the functioning of the Advisory Board of the Infra-basaltic Guarani Aquifer
	Licensing Systems
Argentina	- In view of their public nature, to use surface or ground water it is necessary to have a license, issued by the competent public authority under certain conditions - Provincial laws or water codes determine which is the conceding authority and requisites for obtaining licenses and using water
Brazil	- Law 9.433/1997, that provides for permission to use water was implemented by CNRH Resolution 16/2001, which defines general criteria, and each State issues licenses for the right to use water within its jurisdiction (groundwater). ANA and SRHU do not license the right to use groundwater of the States and Federal District - Decree 7841/1945, art. 25 - the National Mineral Research Department (DNPM) grants permission to exploit mineral water - Resolution 76/2007 – guidelines for integration of water resources management with management of mineral, thermal, gaseous or drinking water, and for spa purposes
Paraguay	- Law 3.239/2007 – Water Resources of Paraguay: The use of water resources can only be conceded by means of a license or concession, except for domestic use and family production - Law 3.239/2007 in concordance with Law 352/1994, which establishes that: "Priority will be given to declaration of protected areas of springs and headwaters, ecosystems of wetlands, aquifer replenishment zones, and zones where environmental flows of waters must be regulated" In the case of municipalities: - Municipal Organic Law 128/1987 (the National Constitution foresees decentralized management by guidelines and the municipalities) - Art. 42: Regularization for purposes of hygiene
Uruguay	- For use of surface water and groundwater it is necessary to have permission or concession authorized by a competent authority, under certain conditions (the Waters Code) - On the Infra-basaltic Guarani Aquifer concessions are authorized for studies and extraction and use, according to decree 214/2000, subject to prior public hearings, for a given period and under certain conditions - Decree 253/1979 – Permission to discharge effluents

Source: Summary prepared during the SAP with contributions from the National Project Execution Units.

Table 2. Water resources management instruments

	General characteristics
Argentina	- Management is shared among public institutions responsible for water resources. Currently, the trend is toward integrated management including groundwater - Water management received stimulus with creation of the Federal Water Council (COHIFE). With different stages of development in each Provincial State, the current trend is toward institutional strengthening of management - The National State promotes integrated water resources management, observing sustainable development premises. The Under-Secretariat for Water Resources sets reference criteria and methodological elements to enable implementation of integrated management at the various jurisdictional levels. It also supports scientific research and capacity building, in liaison with the various jurisdictions for cooperation in scientific, technical, economic and financial fields with a view to assessing water resources, their use and protection - The Under-Secretariat for Water Resources specializes in policies, preservation, planning, information, engineering works etc., whereas the Secretariat of Environment and Sustainable Development mostly manages quality (aside from protecting the environment and promoting sustainable development and issues relating to environmental management of water) - These functions of the national institutions are essentially complementary and provide support for provincial jurisdictions that are directly responsible for the management of the resource
Brazil	- Law 9.433/1997 provides for decentralized management of water resources with the states, establishes the river basin as the basic management unit, and foresees creation of Basin Committees (art. 1, I and VI; 37 to 40) The bodies that comprise decentralized management are: - Ministry of Environment/Secretariat of Water Resources and Urban Environment (MMA–SRHU) - Decree 6.101/2007: formulated the National Water Resources Policy - CNRH - ANA: implantation of the National Water Resources Policy - State water resources management bodies - State Water Resources Councils (CERH) - Federal and state basin committees - Basin agencies
Paraguay	- Since July 10, 2007, the Positive Law of the Republic of Paraguay has included Law 3.239 on Water Resources. With promulgation of this law all articles in other legal provisions were revoked - Authority for application of the law lies with the Secretariat of Environment (SEAM) - The Water Resources Law is currently undergoing implementation. On November 20, 2007 and February 20, 2008 two inter-institutional workshops were held with representatives of similar public and private institutions and NGOs, through CONAM, SISNAM and SEAM - The National Environment System for Water Resources Management encompasses: » CONAM » SEAM – DGPCRH » Waters Councils by river basin
Uruguay	- The Executive Branch exerts national authority for Water through DINASA (management body) and DINAMA (water quality) both under MVOTMA - In 2005, Law 17.930 created the National Water and Sanitation Board (DINASA) and the Advisory Committee on Water and Sanitation (COASAS) - Law 18.172/2007 (art. 251) - MVOTMA is responsible for management , use and control of water resources. Currently, a transfer of these responsibilities is underway
	Planning
Argentina	- The Under-Secretariat for Water Resources has launched its federal planning process and is currently executing the National Federal Water Resources Plan, together with the Federal Water Council (COHIFE)
Brazil	- Law 9.433/1997, art. 5, I, created the National Water Resources Plan as an instrument of the National Water Resources Policy (arts. 6 to 8). There are now plans at the states and Federal District (DF) and river-basin levels - The National Water Resources Plan encompasses specific programs and activities for groundwater, such as Program VIII (National Groundwater Program) - CNRH Resolution 17/2001 establishes guidelines for drafting of basin plans - CNRH Resolution 22/2002 establishes guidelines for including groundwater in the Water Resources Plan

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Paraguay	- Within the CONAM framework Resolution 4/2005 - National Environment Plan - The main axis of the National Environment Policy is Integrated Water Resources Management, carried out by means of Water Councils by River Basin - Law 3.239/2007 sets, among the main goals of the National Water Resources Policy, development of a knowledge and water resources utilization planning system and promote liaison with general national planning
Uruguay	- Management Plan for the Infra-basaltic Guarani Aquifer in Uruguayan territory (Decree 214/2000) - The National Water Policy Law is being drafted to include formulation of national water resources plans
	Concession and administration of licenses
Argentina	- Although the Civil Code foresees permissions for the use of water, it is the Provinces that are responsible for licensing, registration and control, as they have the enforcement power. In practice, with rare exceptions abstractions are done without due permission, since no registration or control is in effect
Brazil	- The general system is foreseen in Law 9.433/1997 (arts. 5, III; 11 to 18) and in CNRH Resolution 16/2001 that establishes general criteria for concession of the right to use water resources - Resolution 76/2007 - guidelines for integration of water resources management with management of mineral, thermal, gaseous, drinking water and for spas - However, some States do not issue permission to use of water, but rather, an environmental license In the case of groundwater with mineral characteristics, permission is granted by DNPM, whereas for other uses it is issued by state bodies
Paraguay	- Law 3.239/2007 establishes the form and requisites for licensing permissions and concessions - To obtain permission or a concession it is necessary to have an Environmental Impact Declaration, issued by SEAM - Both permissions and concessions must be recorded on the National Water Resources Register
Uruguay	- Licensing of the right to use water by means of permissions recorded with the Public Water Register - Granting of licenses to drilling companies - Control of compliance with permissions and technical conditions for drilling companies and sanctions in cases of offenses
	Fomenting public participation, communication and education
Argentina	- The Provinces, together with the Federal Government, have established a number of Basin Committees to manage inter-jurisdictional and transboundary waters that involve more than one provincial State - Currently, a process is underway to strengthen these bodies so that careful planning can be carried out at the basin level with a view to resolving possible conflicts - This provides for democratic participation in water resources management and is the appropriate forum for communication and education on the theme
Brazil	- Creation of the CNRH, comprised of representatives of the Public Authorities, state-level water resources councils (CERHs), water users and civil society. Law 9.433/1997 (art. 34) establishes the number of representatives of the public authorities of up to 50% + 1. Decree 4.613/2003 determines the composition of the council - Basin committees act in the area of the river basin and are comprised of representatives of the Federal Union, the States and DF, municipalities, water users and civil entities. Its powers are defined in art. 38 of Law 9.433/1997. these include approving the respective basin plan - The National Water Resources Plan encompasses specific environmental education programs and activities, stimulating public participation, communication and education (Program VIII - National Groundwater Program and Program IV - Technological Development, Capacity Building and dissemination of information (GIRH)
Paraguay	- Water Councils by River Basin – Resolution 170/2006 - Law 3.239/2007 established, as one of the goals of the National Water Resources Policy, instrumentation of the utilization of water resources, with the river basin as the basic management unit
Uruguay	- Since 2003 the Advisory Board of the Infra-basaltic Guarani Aquifer has operated, comprised of public and private representatives - Participation in public hearings is compulsory, according to Decree 214/2000, for licensing of permissions and optional in other cases considered pertinent - COASAS: public participation in the National Water Resources Plan and National Water and Sanitation Plan - Irrigation Advisory Boards have been in place since 1970: their intervention is generally related to surface waters
	Water use charges and charges for residual waters
Argentina	- In Santa Fe, Law 11.220/1994 lacks standards for determining charges, which are stipulated by the Executive Branch at the time of signing of the concession contract for provision of drinking water supply and sanitation services - In Formosa, Chaco, Misiones, Corrientes and Entre Ríos, legislators have authority over setting charges that concessionaires must pay for the use of public water. Likewise, current legislation establishes parameters that must be taken into account by the authority when setting the corresponding charges - Aside from water use charges in Formosa, Corrientes and Chaco, there is a special right to a one-time concession

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Brazil	- Law 9.433/1997, arts. 5,V; 19 to 22 - CNRH Resolution 48/2005 established general criteria for charges - The States of Ceará, Rio de Janeiro and São Paulo charge for water at the state level. Federal charges are also applied in the Piracicaba, Capivari, Jundiaí (PCJ) and Paraíba do Sul River Basins
Paraguay	- Law 3.239/2007 provides for execution and permanent updating of a database - The National Water Resources Register established under Law 3.239/07 was regulated by SEAM Resolution 2194/07
Uruguay	- The possibility of applying water use charges is encompassed in the Water Code, but has not been applied so far
	Information systems
Argentina	- The National Water Information System contains data on laws, institutions and technical data - There are interconnected national, provincial and municipal networks (meteorology, population etc.)
Brazil	- Law 9.433/1997, art. 5 VI, provides for the National Water Resources Information System that is currently being developed, the first version of which was made available in August 2008 - The CPRM's Groundwater Information System (SIAGAS) could be adopted as the official database
Paraguay	- Law 3.239/2007 provides for execution and permanent updating of a database - The National Water Resources Register established under Law 3.239/07 was regulated by SEAM Resolution 2194/2007
Uruguay	- Public Registry that contains data on the right to use water, provides free information - Updated registration of water engineering works by category of use
	Surveillance and control (inspection)
Argentina	- There are none at the federal level. Actions are the responsibility of local authorities - The Provinces are primarily responsible for Surveillance and control of water resources
Brazil	- It is the shared responsibility of the Federal Union, the States and Municipalities to provide protection for the environment - Protection and inspection of water resources is the responsibility of federal and state bodies, whereas the municipalities are responsible for inspection of land use and settlement - Control and surveillance of water quality and potability standards for drinking water are encompassed by Ministry of Health Resolution 518/2004
Paraguai	- Law 3.239/2007 invests SEAM with authority for enforcement until the institutional framework has been established. It is thus also responsible for applying sanctions for offenses or noncompliance with specific standards - Sanctions: notification, suspension or cancelation of permissions or concessions, default fee and/or fine of up to forty thousand units (daily minimum wage set by the Government) for unspecified activities in the capital. Such sanctions are independent of any corresponding administrative sanctions, or civil or criminal penalties
Uruguai	- Preventative control, by means of sworn affidavits of drilling companies and water users, and as a corrective measure in response to complaints - Site inspections - In cases of failure to comply, the following sanctions may be applied: fines, cancelation of permission, removal of engineering works by court order, prior visitation, visits to the site

Source: GS/GAS Adapted from the Final Report of the SAP Legal Advisory with contributions from the National Project Execution Units, 2008.

ANNEX 7

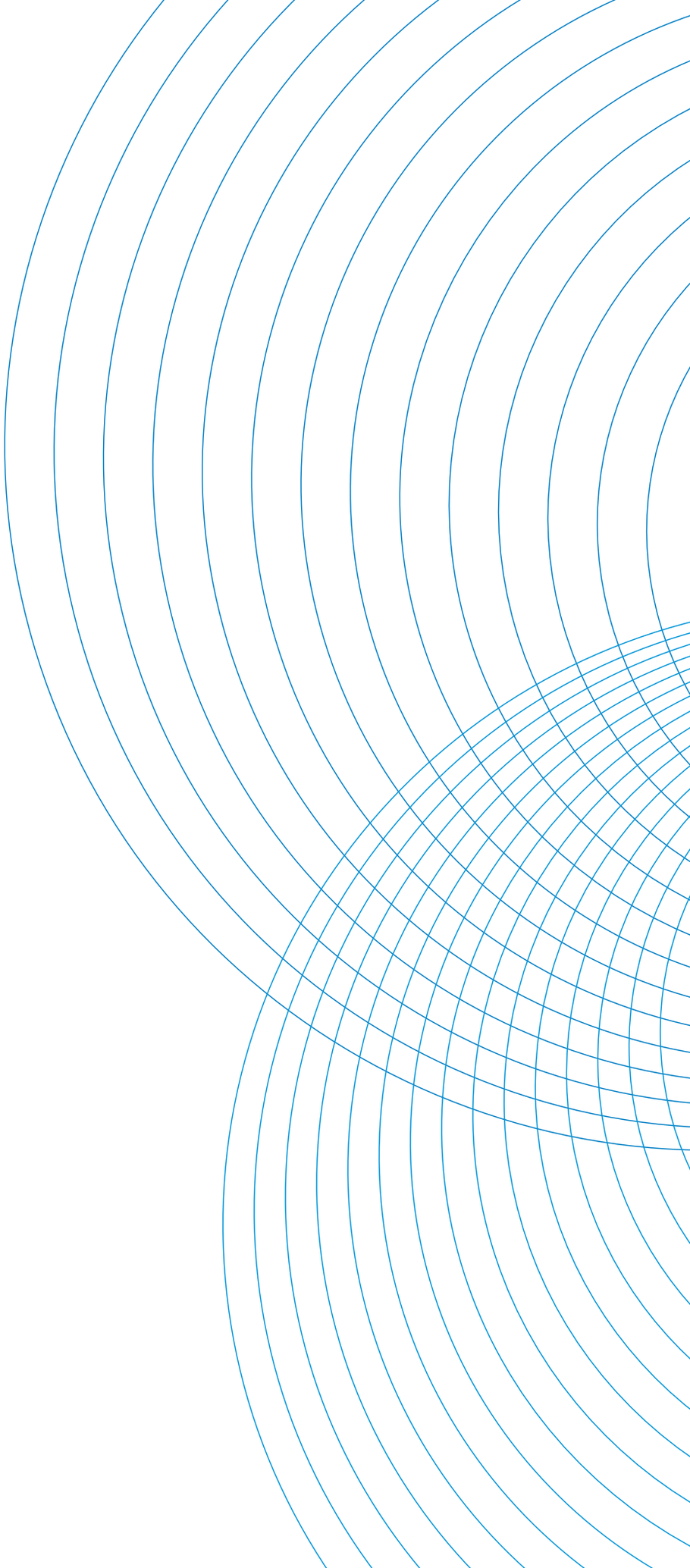
ANNEX 7 INTERNATIONAL LEGAL INSTRUMENTS UNITING THE COUNTRIES THAT SHARE THE GAS

Table 1. International agreements on water resources and transboundary water courses involving countries that overlie the gas

Year	Agreement	AR	BR	PY	UY
1933	Covenant for Legal Statute for Establishment of the Frontier		•		•
1961	Treaty of the Uruguay River for establishment of boundaries	•			•
1969	Treaty of the La Plata Basin	•	•	•	•
1973	Treaty on the La Plata River and its Maritime Front	•			•
1973	Treaty of Itaipu for hydroelectric power generation using water resources of the Paraná River		•	•	
1973	Treaty of Yacyretá for improvement of navigation conditions on the Paraná River and the level at Yacyretá Island, fomenting hydroelectric power potential	•		•	
1975	Statute of the Uruguay River	•			•
1975	Basic Scientific and Technical Cooperation Agreement		•		•
1977	Treaty of Cooperation for Utilization of Natural Resources and Development of the Lagoa Mirim Basin and Protocol for Water Resources Use on the Yaguarón River Boundary		•		•
1980	Treaty for Shared Utilization of Water Resources of stretches of the Uruguay River Boundary and of its Tributary the Pepirí-Guazú	•	•		
1991	Cooperation Agreement for Utilization of Natural Resources and Development of the Cuareim River Basin		•		•
1991	Treaty of Chuí: Cooperation agreement in the field of water resources		•		•
1992	Cooperation Agreement on Environmental Issues		•		•
2001	MERCOSUR Framework Agreement on the Environment	•	•	•	•
2002/ 2003	Agreement between each of the governments and the OAS for Execution of the Project for Environmental Protection and Sustainable Development of the Guarani Aquifer System	•	•	•	•
2004	Draft Declaration of Basic Principles and Rules for Actions of the Guarani Aquifer System approved by the Project Steering Committee (CSDP)	•	•	•	•
2006	Cooperation Agreement for Sustainable Development and Integrated Management of the Apa River Basin (awaiting approval by Brazil's National Congress)		•	•	

Source: GS/GAS Adapted from the Final Report of the SAP Legal Advisory with contributions from the National Project Execution Units, 2008.

Project for Environmental Protection and Sustainable Development of the Guarani Aquifer System



Guidelines and Actions

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Chapter 4

Guidelines and Actions

SUMMARY

Any threat to water supply in areas of the four countries that overlie the Guarani Aquifer System (GAS) (Argentina, Brazil, Paraguay and Uruguay) could lead to destabilization of water security, compromising not only water supply for the population but also prospects for regional development, which is highly dependant upon groundwater for irrigated farming and industrial activities. To prevent such a situation, inter-regional water-resources management cooperation, and particularly actions targeted at protection and management of the GAS, must be strengthened.

To address these concerns, the Strategic Action Program (SAP) goes beyond protection and sustainable management of groundwater to encompass a broader water-security approach. Essentially, the SAP seeks to identify actions that meet expectations of the countries involved and to address the challenges of managing the GAS within a regional cooperation framework, thereby enhancing benefits accruing from such actions.

This Chapter explains how the SAP was structured, based on integration, consultations, debates and studies carried out in the four countries. This participative process ensured that aspects relating to the Gurarani Aquifer System, at the local level (Pilot Projects), the sub-national level (State/Provincial Project Execution Units–SPEUs) and the national and regional levels (National Project Execution Units–NPEUs) were taken into account during preparation of the Transboundary Diagnostic Analysis (TDA). As one of the first concrete outcomes of the SAP, this process underpins the sustainability of the program.

In addition to describing conceptual and methodological aspects of the Strategic Action Program (SAP) preparation process, this chapter also describes initiatives already underway in each of the countries which, directly or indirectly, relate to sustainable groundwater management.

4. GUIDELINES AND ACTIONS

This chapter presents the structure of the SAP based upon physical, socioeconomic, legal and institutional diagnostic studies relating to the GAS and its management in the participating countries (Argentina, Brazil, Paraguay and Uruguay). The main inputs for this work stemmed from the Transboundary Diagnostic Analysis (TDA) and the technical and national consultative bodies that were subsequently instituted.

From its inception, the SAP relied upon a strong participative process in each of the countries and in the region overlying the GAS, involving an array of institutional, jurisdictional and social stakeholders concerned with protection and sustainable use of this important aquifer. The SAP was always considered a core element, to be implemented concurrently with execution of the PGAS. Indeed, the SAP was based on the outcomes and findings of each of the components, subcomponents, activities and tasks of the PGAS at the regional, subregional, and local levels (Figure 1). Thus, the SAP is the outcome of mutual cooperation among the countries.

4.1 TRANSBOUNDARY DIAGNOSTIC ANALYSIS (TDA)

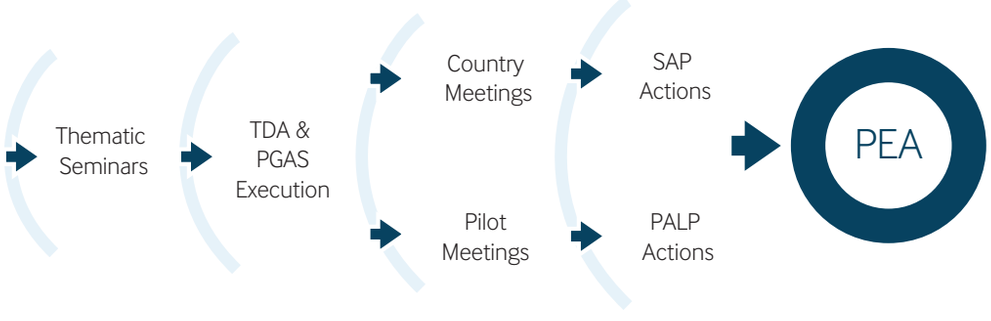
The SAP Framework Document[1] specifically states that the consultative process for development of the TDA and its respective outcomes are considered an input of fundamental importance for the SAP.

4.1.1 Conceptual and methodological aspects

Preparation of the TDA[2] was based on an ample process of consultation and participation within each country, through the NPEUs, with intensive participation of stakeholders (representatives of the states/provinces involved, civil society organizations and local Pilot-Project committees, etc). Such interaction ensured agreement over the wording of the TDA final report and, with support of the GS/GAS, a workshop was held to investigate problems identified during consolidation of the process.

This TDA workshop built upon recommendations raised at the previously held regional workshops and enhanced the structure of the TDA. These were then submitted to the Coordination Council (CC) for review, and finally approved by the Project Steering Committee (CSDP).

The participative process allowed aspects of a local, sub-national, national, and regional nature, relating to the GAS to be considered during the TDA preparation process. Thus, generating proposals for mitigation of critical issues served as a basis for elaboration of the SAP. A total of nine meetings were held: four in Pilot-Project regions, four at the national levels, and one joint meeting. In summary: during the course of the entire TDA process, individual and collective contributions



Source: GS/GAS, 2008.

Figure 1. Preparation of the SAP

were taken into consideration, in support of a joint structure, with outcomes obtained through feedback from PGAS activities.

During the course of the process, approval was secured for a solid methodology that took into account three levels: i) local (Pilot-Projects); ii) national (NEPUs); and iii) regional, in each of the four countries overlying the GAS. Activities relied on two approaches: participation within the scope of the Pilot Projects, by means of four Regional Technical-Participative Workshops; and an institution-building workshop at the national level, entailing four National Technical-Institutional Meetings and a Joint Meeting

The fllowing specific outcomes stand out:

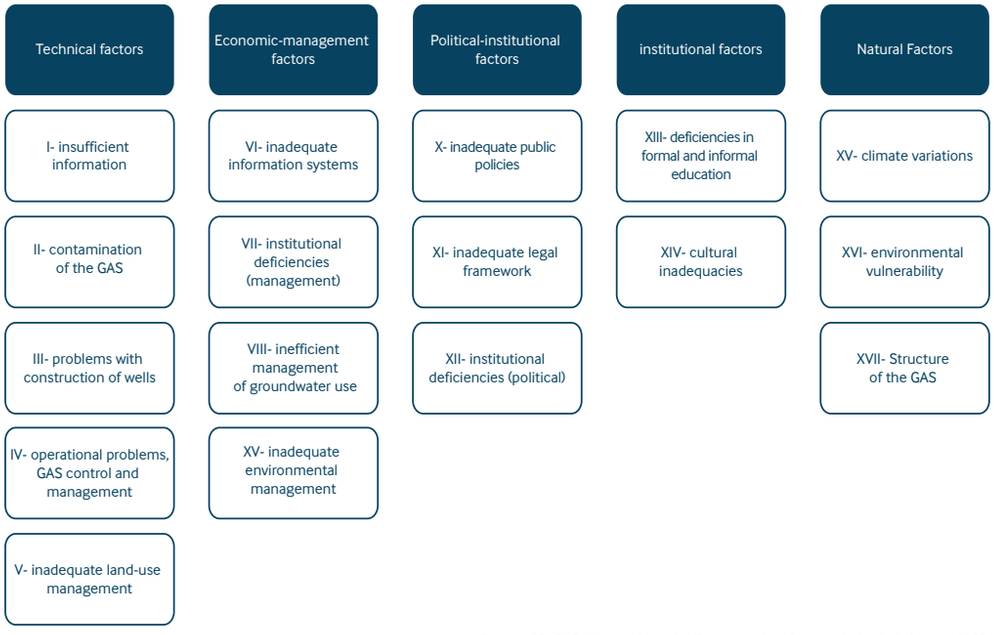
- The proposal was based on identifying concerns, gaps in information, and mitigation actions for each general category of the central theme (ranked by order of importance): contamination, overexploitation, and management. That the countries have common viewpoints in relation to these issues greatly facilitated adoption of the methodology. To date, though studies have not identified major problems of contamination or over-exploitation of the GAS, nonetheless, an assessment was made

1 General Framework for preparation of the SAP, document approved by the CSDP in April 2007.
2 Final TAD Report, draft dated February, 2007.

with a view to ensuring quantitative and qualitative protection of the aquifer and to instituting sustainable management of groundwater resources. Causal chains were developed to assess technical, economic and management, policy and institutional, socio-cultural and natural factors (Figure 2).

In addressing mitigation proposals, an appraisal was made of the priority of each of the related themes. These appraisals indicate that social players working within the GAS area understand the importance of improving public policies and strengthening institutions (management and policies). A second priority is generation and dissemination of information on wells in the GAS and improvements in the legal framework. Finally, formal and informal education, cultural mores, and awareness of these issues are perceived as being important priorities.

At the Coordination Council (CC) meeting, all actions proposed in the TDA were deemed to be of equal importance. It can be inferred, furthermore, that the countries consider it necessary to pay heed to themes relating to public policy, and to the effective strengthening of water-resources management bodies. Such themes were considered the driving force for bringing about changes in society and, consequently, in the relationship between society and the environment in general, and particularly the GAS.



Source: GS/GAS Adapted from the Transboundary Diagnostic Analysis Report, 2007.

Figure 2. TDA causal chains

4.2 RATIONAL FOR THE SAP

In accordance with project appraisals carried out under the PGAS and subsequently confirmed in the field, the quantity, quality and replenishment capacity of the GAS mean that it is of high strategic value for the overlying countries. Indeed, the Aquifer ensures the region an adequate degree of water security. Such security implies that all communities have fair access to high-quality water, enabling them to engage in productive, economic and social-development activities, provided that, at every level, they preserve the integrity of this water resource and the natural environment, through protection and sustainable use of the Aquifer.

Water-resource security is an ambitious goal, and is the underlying reason why the SAP needs to be carried out in a coordinated manner by the countries that share the GAS. All stakeholders in the region would benefit from achieving satisfactory and homogenous technical and institutional capacities that enable each of the countries to implant integral water-resources management strategies, at the national and sub-national levels, that address the specific characteristics of the various GAS zones and their respective demands for groundwater. Water-resource security can be achieved, provided the countries, while exercising sovereignty over the Aquifer, adopt common management principles and policies, based on shared knowledge on the current status and changes taking place within the GAS.

Failure to adopt a program such as the SAP and development of fragmented actions carried out in isolation in each of the countries, would pose serious obstacles to regional water-resource security that could lead to medium and long-term compromising of the availability of GAS resources in certain regions. This is because:

- Perceptions of the behavior of the GAS and the different methods and capacities needed for its management at the regional level could diverge;
- Environmental degradation and conflicts over the use of GAS resources in border regions could exacerbate, despite knowledge of its transboundary nature acquired under the PGAS (in contrast to the initial view during project preparation);
- The capacity of each country to respond to climate change could be hampered, owing to a lack of strategic and coordinated actions targeted at the aquifer as a whole.

In summary, any threat to water-resource security in any of the four countries of the GAS region would result in a regional imbalance. The only adequate response to such a challenge is strengthening of intra-regional cooperation in the field of groundwater management, and especially of the GAS.

Bearing these considerations in mind, the SAP has adopted an approach that goes beyond preservation and the sustainable use of water resources, and encompass the broader concept of water security. The strategic actions recommended involve an enormous

commitment of human and financial resources on the part of the countries concerned, and constitute an essential first step toward ensuring water-resource security. Generally, they aim to consolidate an efficient approach to cooperation developed under the PGAS for deployment of available management instruments (described in Chapter 5) for the benefit of the four countries.

Lastly, unity between regional and local spheres needs to stressed, as may be observed when strategic, pivotal questions are transformed into actions (also described in Chapter 5). Actions need to be carried out with firmness and consistency, in line with strictly methodological and analytical criteria established at the regional level. However, integration must proceed in accordance with local institutional practices and structures.

4.3 IDENTIFICATION OF STRATEGIC ACTIONS

Implementation of the PGAS was a pioneering initiative in world terms and demonstrated the benefits of cooperation between countries. These benefits include: a perception that local management is needed to deal with issues relating to sustainable use of groundwater; the deployment of management tools and mathematical models in PGAS Pilot-Project areas; and the establishment of a hierarchy of technical and scientific bodies to manage knowledge and provide guidelines for sustainable management. All this has given rise to a better understanding of the aquifer and its behavior. It led to the development of a network for monitoring of wells and establishment of an information system linking organizations involved with groundwater management (at the national, State/Provincial levels) and towns located within the Pilot-Project areas (municipalities), both developed in close cooperation within the scope of the Project.

On the other hand, effective integration and cooperation at the technical and diplomatic level, within the Steering Committee (CSDP), provided the necessary safeguards to ensure that coordinated management of the GAS would respect national sovereignties while, at the same time, fostering deployment of groundwater management instruments. One of the main features of the SAP, aside from identification of strategic actions that address the expectations of the countries in relation to challenges posed by management of the GAS, is that it provides a framework for regional cooperation, making it possible to take full advantage of benefits deriving from such actions.

Identification of strategic actions in a project of such magnitude and complexity could not be conducted in a static or rigid manner. Enormous interactivity characterized the process starting during execution of the PGAS, and there were numerous decisive moments when strategic actions began to take shape. Among the most significant of these were:

- Preparation of the TDA, developed in accordance with guidelines contained in the initial SAP document, was an important input. This imprinted upon the entire process a SAP format, that influenced all its approaches and determined the alignment of all subsequent actions;
- A technical review of the recommendations and conclusions of consultancies carried out under the PGAS led to identification of priority actions and sources of information to serve as inputs for the SAP proposal.
- Consultations and discussions carried out in the Pilot-Project areas during formulation of the Local Pilot Action Plans (LPAPs) and their summaries that became important elements of the SAP;
- The SAP Workshops were attended by representatives of the NPEU of each of the countries and resulted in fruitful internal consultations that gave rise to various proposals for incorporation into the SAP. Meetings were held in Porto Alegre (NPEU-BR) on May 12 and 13; in Asuncion (NPEU-PY) on May 20 and 21; in Montevideo (NPEU-UY) on May 27 and 28; and in Buenos Aires (NPEU-AR) on June 4 and 5, 2008. Following up on these meetings, held under the auspices of GS-GAS, each country went on to conduct its own process of internal discussions.
- The National Coordinators (NCs), supported by national SAP liaison staff, developed content and format for the identified actions, transforming these into basic plans of action and securing a high degree of internal consensus within each country prior to incorporation into the SAP document.
- From the onset, the Project Steering Committee (CSDP) guided the drafting of the work, including both aspects relating to definition of the format and to the structure of the SAP. The work of defining regional cooperation actions was conducted by the Regional Coordination Group (RCG), especially designated for this task;
- At the general NPEU meeting, held in Montevideo on September 22 and 23, 2008, each country had an opportunity to present its own basic plan of action, bearing its conception of a common regional understanding and priority areas. Discussions also encompassed the bases for sustained cooperation on themes relating to the GAS.
- It was from this process, which highlighted efforts of each of the countries to identify and systematize actions deemed to be of strategic importance, that the principle approaches for regional action within the scope of the SAP began to emerge.

There follows a list of the main approaches for regional action:

1. Development of national and sub-national institutional management capacities.
2. Fostering of an operational cooperation structure.
3. Modernization and maintenance of the SIGAS.
4 Implementation and development of the GAS monitoring network and mathematical models.
5. Technical capacity building and dissemination of knowledge.
6. Development of local groundwater resources management.
7. Support for public participation.
8. Development of sustainable use criteria.
9. Implementation of technical-scientific programs.
10. Preparation of technical-economic studies.
11. Monitoring implementation of the SAP.

Annex 8 presents a table with a summary of SAP strategic actions, based exclusively on the original SAP Country Matrixes, discussed and agreed by consensus in the NPEU of each country. A detailed description of each of these actions, based on their respective principle approaches, is presented in Chapter 5. It should be noted that, even when they are not included in this document, these original SAP Country Matrixes are important references for the SAP, and will serve as bases for future phases of the program. On a national level, they provide further details on players involved, possible sources of funding, and estimates of the scale of costs involved.

4.4 IDENTIFICATION OF INITIATIVES

In recent years, concurrently with execution of the PGAS, a series of initiatives relating to water resources (and particularly to groundwater management, including the GAS) have either been implemented in the countries involved or transformed into proposals to be implemented in the short term. Identification of these projects and initiatives has served as an important point of reference for the SAP. It is hoped that important strategic actions will be incorporated into these initiatives or used to complement and synergize other programs. Knowledge of these programs is important for reducing duplication of efforts, especially considering the scarcity of funding

As part of the SAP development process, the national coordination agencies and NPEUs[3] provided a list of initiatives and programs currently in progress or ready for immediate execution, which, either directly or indirectly, contain elements that are convergent with activities of the PGAS and future SAP. The methodology adopted for the survey was based on the following themes:

- Searches of websites of organizations involved with similar themes.
- Pre-processing of information to locate elements compatible with the SAP development process.
- Establishment of exchanges with those responsible for administrative units or bodies to evaluate information gathered.
- Identification of funding sources according to origin of funding (international, national, sub-national).

The survey comprises initiatives of a technical and policy-making nature requiring inter-jurisdictional coordination, including projects in the areas of sanitation works, drilling of deep wells, development of integrated water resources management studies within the scope of river basins or administrative management units (provinces/states), sector-specific economic development studies and, finally, international cooperation projects relating to water resources. Though not structured as a conventional baseline survey[4], which would have involved a great deal more data-collection effort and much stricter economic analysis, this information is of major value for countries that overlie the GAS and serves as a point of reference for the SAP implementation.

This survey does not aim to present the entire array of regional and local initiatives underway in the countries involved, but it does define SAP approaches and scenarios. It makes no mention of the budgetary implications of each of the recommended initiatives, of what percentage of the costs could be regarded as national counterpart funding for the SAP. A further survey should be developed at a later date, when new proposals are formulated by the countries (directly or indirectly involving the GAS) for submission to development institutions and funding agencies.

It should be noted that the Framework Program for Sustainable Water Resources Management in the La Plata Basin, in which the four countries that overlie the GAS participate (together with Bolivia) represents an important reference for the SAP. Significant synergies could emerge among these two programs.

Based on an analysis of information generated, important aspects for each of the countries involved were identified:

4.4.1 Argentina

From the standpoint of international cooperation, the Project for Management and Conservation of the Iberá Esteros, a proposal submitted to the Global Environment Facility (GEF) by the Fundación Ecos de Corrientes and channeled through the United Nations Development Programme (UNDP) is the main initiative currently underway within the GAS region.

The Federal Investment Council coordinates a variety of federally-funded programs, with special emphasis on projects for sewage treatment and increasing availability of water to meet burgeoning demand for public water supply and agricultural use. Both these aims are to be covered using surface water sources. The National Water and Sanitation Works Agency (*Ente Nacional de Obras Hídricas de Saneamento*) and the Presidential Program for Minor Sanitation Works (*Programa de Obras Menores de Saneamento da Presidencia*) are the main agencies responsible for such actions. Moreover, the Presidency's Under-Secretariat for National Water Resources and the Federal Water Council have jointly taken out a loan from the World Bank to implement integrated water resources management, under a project that could incorporate many of the actions proposed by the SAP. The National Secretariat of Tourism's Investment Promotion Program was established mainly to provide support for micro, small and medium-size businesses, including those located in the region of the GAS. Specific studies related to the thermal region of Argentina are generally linked directly to the aforementioned program.

With regard to funding of academic research projects, the roles of the University of Buenos Aires (UBA) and of the National Scientific and Technical Research Council (CONICET) merit special mention. The themes covered are varied, but climate change tends to be an increasingly significant aspect of hydrological and interdisciplinary studies. There has been growing interest in the use of geophysical techniques for geo-structural characterization

3 Gathering of this information was possible thanks to support of national SAP facilitators, duly contracted by GS-GAS and coordinated by the NCs in each country.

4 The costs of the baseline refer specifically to expenditures that countries normally effect to fulfill various aspects relating to such specific activities as protection, sustainable use and management of the GAS. Generally, funding is from public institutions, specific projects funded by the national government or external sources, and that will continue throughout execution of the SAP. Funding may also come from academic institutions or the private sector, including international agencies. In the case of the PGAS, there are some baseline activities that encompass the geographic area and specific theme of the project, and that comprise the current baseline scenario.

and environmental assessments and in studies on the hydrochemical composition of GAS groundwater in the Chaco-Pampa Basin (trace elements, arsenic, etc). Finally, studies that focus on socioeconomic aspects and governance of environmental management systems are of particular interest.

There are a vast number of initiatives related to water resources. Each province has its own program, with grants provided by the provincial treasury, development funds, or even provincial banks.

In Corrientes, there are a large number of projects for recuperation of river basins, proposed by the Corrientes Institute for Water and Environment and financed by the provincial treasury.

In the Chaco, greater emphasis is placed on supplementary works to increase the availability of potable water in various locations. These works include water-treatment stations, water mains, reservoirs and refurbishing of distribution systems. Many of these schemes are funded by Banco del Chaco. The Province of Chaco also has an Integrated Water Program, whereby the provincial water administration carries out a series of flood prevention and drainage projects. The same program encompasses geophysical studies and funding for deep boreholes for abstraction of potable water.

The Province of Entre Ríos also has a varied portfolio of projects relating to surface water resources, proposed by the Provincial Hydraulic Directorate (DPH) and the Entre Ríos Sanitation Works, and financed by federal trust funds and the provincial treasury. Significant initiatives have been carried out by the municipalities, especially Concordia, which is also a PGAS Pilot Project area where several GAS related projects are underway (territorial planning, sanitation, water resources, thermal tourism development, industrial development and capacity building).

These initiatives include: a territorial planning project with a new format for land use, developed by the municipality with the support of the Universidad de La Plata: construction of a treatment station for urban wastes prior to discharge into the Uruguay River, with support from the provincial government; creation of a municipally-funded department for integrated management of surface and groundwater resources as part of the municipal administration (as yet not in effect); drilling of a thermal borehole at Lago de Salto Grande Park for recreational and tourism, funded by the microdevelopment bank (CAFESG), by the Salto Grande Development Corporation (CODESAL) and by the Ayuí Hotel; use of thermal waters to breed lobsters for the gastronomic market, funded by the private sector; and, finally, preparation of educational materials on groundwater and the GAS, to be included in primary and secondary school curriculums.

Similarly, the Province of Formosa also has various projects relating to surface-water (flood defenses, reservoirs for potable water, bridges, etc.) many of which were proposed by the Provincial Potable Water and Sanitation Service (SPAP) and the Provincial Water Coordination Unit. Moreover, the Esmeralda Program, proposed by SPAP and funded by the provincial government, focuses on groundwater exploitation strategies, based on research carried out through deep and shallow boreholes in various locations.

In Misiones, the Directorate for Vital Resources, using funding from the provincial treasury, is engaged in drilling over 65 wells into the basalt, with a view to providing potable water supply in different locations. The Executive Council for Development and Technological Innovation, has also played a significant role in such activities. These include development of surface-water management instruments and methodologies. The Federal Investment Council is funding boreholes into the GAS, for purposes of providing public water supply.

In the Province of Santa Fe, flood-protection works in urban and rural areas, sanitation projects, water mains, and emergency drought prevention measures are among the initiatives funded by the provincial treasury, water funds, and programs of the Inter-American Development Bank (IDB). With the exception of a few studies for drilling of deep bore wells, all these projects relate to surface water.

4.4.2 Brazil

The National Water Resources Policy (PNRH) provides the framework for a number of programs and subprograms, including many of those encompassed by the SAP. Such programs are a response to the challenge of instituting integrated water-resources management. Generally, implementation of the PNRH is the responsibility of the Secretariat for Water Resources and Urban Environment (SHRU) of the Ministry of Environment (MMA) and of the National Water Agency (ANA), though a number of other organizations, secretariats, water agencies and basin committees also participate.

Funding sources vary according to the subprogram. Among the most common sources are: fiscal resources from the budgets of SRHU, ANA and other agencies; revenues from water-use charges; fiscal resources allocated in budgets of water-user organizations; revenues from charges collected and specifically channeled for support of PNRH projects and activities; lines of credit from governmental credit organizations (*Caixa Economica, Banco do Brasil* and BNDES); counterpart payments from states and municipalities; funds raised by private agents (beneficiaries); sector-specific funds (CT-Hidro, and others) and loans from multilateral funding agencies.

From the general PNRH framework, the following programs and sub-programs stand out:

- Program II – institutional development for integrated water-resources management, comprising: (II.2) support for the organization of state-level water-resources management systems (coordinated by ANA and SRHU, basin agencies and basin committees funded by CT-Hidro and the World Bank; (II.3) adjustment, complementing and harmonization of legal and institutional frameworks.
- Program III – development and implementation of water-resources management instruments, comprising: (III. 1) national register of water use and water users, coordinated by SRHU and funded by allocations from the Multi-Year Action Plan (PPA); (III. 3) processing, storage, interpretation and dissemination of water-resources information – a task force comprised of SRHU, ANA, the Geological Service of Brazil (CPRM), the National Department of Mineral Production (DNPM), the National Electric Power Agency (ANEEL), the Ministry of Science and Technology (MCT), the Ministry of Cities, Ministry of

Integration, Ministry of Health, CT-Hidro and the National Meteorology Institute (INMET); (III.4) Methodologies and licensing system for the right to use water; (III.7) application of economic instruments in support of water resources management (coordinated by ANA and SRHU with support of basin committees, water-resources sectoral funds and CT-Hidro); (III.8) national water resources information system, coordinated by ANA and SRHU;

- Program IV – technological development, capacity building, communication and dissemination of information on integrated water-resources management, comprising: (IV.1) development, consolidation of knowledge (including traditional knowledge) and technological advances in water-resources management; (IV.2) capacity building and environmental education for water resources management, with specific support from the Global Environment Facility (GEF), the Inter-American Development Bank, the World Bank and sectoral funds, including those for defense of diffuse rights, to the environment and to education. Also foreseen are partnerships with non-governmental organizations; (IV.3) communication and dissemination of information generating new channels for public participation.
- Program V – inter-sectoral, inter-institutional and intra-institutional articulation on water-resources management, comprising: (V.1) assessment of sectoral impacts on water-resources management;
- Program VI – multiple use and integrated management of water resources, comprising: (VI.2) management of water supplies, expansion, rational use and reuse of available water resources; (VI.3) demand management, resolution of conflicts, multiple and integrated use of water resources (Vi.4) integrated environmental sanitation interventions and water resources management in urban areas;(VI.5) conservation of soils and water, micro-basin management in rural areas, coordinated by ANA;
- Program VII – sectoral programs relating to water resources, comprising: (VII 2) optimization of water use in irrigation, under coordination of ANA;
- Program VIII – national groundwater program, coordinated by SRHU/ANA, targeted at expanding knowledge, developing studies and projects for (international and interstate) transboundary Aquifers and at the local level, developing monitoring programs, improving legal and institutional frameworks and capacity building.

To complement the PNRH, certain national-level programs directly related to the GAS and the SAP merit mention. The ANA Action Agenda for Groundwater, presently being implemented, encompasses the whole country and aims to trigger a set of actions for strengthening groundwater management capacities. This agenda seeks to promote hydrogeological studies on strategic Aquifers and in strategic areas (where there is potential for water-use conflicts, increasing demand, urban areas, areas of rapid economic development), development of tools and management instruments on the national and sub-national levels. CT-Hidro and *PROÁGUA Nacional* are the main sources of funding for these initiatives.

The Ministry of National Integration has a portfolio of water-infrastructure projects with which it intends to increase water availability for household use and for irrigation, by means of systems for tapping groundwater. Similarly, the Social Sanitation Action Program (PASS) of the Ministry of Cities is engaged in expanding public urban sanitation services, with priority for poorer populations living on the outskirts of large and medium-size cities.

The Ministry of Environment also has an array of programs. Aside from the PHRH, its two other main programs are: the Water Resources Development Program (*PROÁGUA*), targeted at enhancing water resources management systems at the national and state levels and modernizing the hydro-meteorological system; and the Project for Maintenance and Recuperation of River Basins (*PROBACIAS*). The budgets for both these initiatives are earmarked in the PPA.

CPRM is the executing agency for various PNRH programs and ANA actions. It is also involved with other initiatives related to the GAS, including: (i) A hydrogeological map of Santa Catarina and inventory of all wells, similar to the Project for the West of Santa Catarina (PROESC); (ii) A geochemical map of Santa Catarina; (iii) A geo-diversity map of São Paulo, Rio Grande do Sul, Mato Grosso do Sul and Mato Grosso; (iv) A hydrogeological map on a 1:1 million scale (for Paranapanema, Corumbá and Campo Grande); (v) A groundwater chart of Mato Grosso; (vi) A detailed hydrogeological map of the municipality of São Leopoldo, Rio Grande do Sul (a GAS outcrop area).

In academic terms, as a consequence of the proliferation of new information on the GAS resulting from the PGAS and other initiatives, a great many researchers are now investigating the aquifer. At all teaching and research institutions within the GAS region in Brazil, both public and private, including universities in the interior far removed from state capitals, initiatives are being developed, with funding on various different scales.

There follows a list of the most important academic research projects currently underway:

- *Study on vulnerability of replenishment areas of the Guarani Aquifer System in São Gabriel do Oeste (MS).*
- *The Serra Geral formation as a Hydraulic Connection between the Guarani Aquifer System and the Surface: Structural Analysis and in-situ Tests – a FRATASG project.*
- *Hydrogeological Zoning of the Serra Geral and Guarani Aquifers in the State of Paraná.*
- ***Study of replenishment mechanisms in the Guarani Aquifer System.***
- *Hydrological monitoring in the outcrop zone of the Guarani Aquifer.*
- *Development of a numeric model for water resources management in the Ribeirão Preto Pilot-Project area.*
- *Numeric flow model to estimate scenarios in the Guarani Aquifer in the Tieté-Jacaré Region.*
- *Geological characterization of porous aquifers in the Guarani Aquifer System in the central zone of Rio Grande do Sul.*
- *Comparative Hydrostratigraphy and geological modeling of the Guarani Aquifer System in the Santa Maria and Estância Velha-Ivoti areas, Rio Grande do Sul.*
- *Diagenetic changes and influence on hydraulics and hydrochemistry of the Gurarani Aquifer System in the State of São Paulo.*

- *Hydraulic assessment of river basins and the influence of silviculture to serve as an input for licensing proceedures.*
- *Study of the natural vulnerability of the Guarani/Serra Geral Aquifer in the State of Rio Grande do Sul/Brazil.*
- *Connectivity and magnetic-framework divisions in the Serra Geral and Guarani Aquifers in the central region of the State of Paraná.*
- *Environmental Education for Preservation of the Guarani Aquifer in the Planalto dos Guimarães region.*
- *Assessment of the current and future use of the Guarani Aquifer System in the State of São Paulo*.

Programs are currently being carried out in each of the Brazilian states overlying the GAS. The great majority of these are targeted at expansion of water supply and sanitation services, under the Growth Acceleration Program (PAC) which transfers funding to state governments and state-level sanitation companies. The following have direct implications for management of the GAS:

- Creation in the State of Minas Gerais of a center of excellence for water resources management, for providing training and technological innovation needed for implementation of programs, and dissemination of lessons learned;
- The States of Santa Catarina and Paraná maintain an awareness-building project to disseminate knowledge on the GAS and its relationship with overlying aquifers of the Serra Geral Formation basalts. This program has a strong academic component and involves institutions that participate in the Guarani/Serra Geral network and state-level science and technology foundations. The State of Santa Catarina, together with the State of Rio Grande do Sul, is also engaged in the Pro-Rio Uruguay and Guarani Aquifer Program, funded by the Inter-American Development Bank (IDB), the Japanese Trust Fund, and state counterparts. The principal objective of the program is to draw up an economic development plan for the Uruguay River basin (only within Brazilian territory) based on its surface and groundwater resources.
- The State of São Paulo has an Aquifer Project under the coordination of the State Secretariat of Environment (SMA), in which various institutions participate, including: the Geological Institute, Water Resources Coordination, Coordination for Environmental Planning (CPLA) and Forestry Institute (IF) (all of which are linked to the SMA); the Environmental Sanitation Technology Company (CETESB), Water and Electric Power Department (DAEE), Health Surveillance Center, Technological Research Institute (IPT), Institute for Geosciences of the University of São Paulo (IGC/USP), Institute of Geosciences and Exact Sciences of São Paulo State University (IGCE/UNESP), Geosciences Institute of the State University of Campinas (IGE/UNICAMP), Engineering School of the University of São Paulo in São Carlos (EESC/USP). The principal objective of this project is to promote protection of aquifers within the State, with emphasis on the Guarani and Bauru Aquifers.
- Another significant project coordinated by the Secretariat of Environment, in which CPRM and IPT participate, is the Environmental Diagnosis for the law to protect outcrop areas of the GAS in the State of São Paulo, which aims to serve as a basis for zoning of GAS outcrop areas, through a specific bill of law.

Finally, assessment of projects underway in the two PGAS Pilot-Project areas, Ribeirão Preto-SP and Santana do Livramento-RS on the Brazilian side of the border with Uruguay, has identified another dimension of such initiatives, knowledge of which will greatly contribute toward subsequent phases of the SAP.

In Ribeirão Preto and the neighboring localities of Altinópolis, Brodowski, Cajuru, Jardinópolis, Serrana and Sertãozinho, various improvements to sanitation systems are planned. The Water and Electric Power Department of Ribeirão Preto (DAERP) is engaged in a project to reduce losses from urban water mains, through procurement of equipment and capacity building. Water supply in Ribeirão Preto is entirely dependent upon abstractions from the GAS. Another initiative entails review of the Pardo basin plan, and strategic studies for deployment of water-use charges in Pardo River basin (UGRHI 04), a theme that has much in common with one of the basic premises of the SAP. With regard to the impacts of agricultural practices on the GAS, the Brazilian Agricultural Research Corporation (EMBRAPA) is conducting a series of research projects and has various publications on the theme, including a Manual of Best Agricultural Practices (BPAs).

On the border with Uruguay, within the Santana do Livramento pilot-area (RS) investments in public sanitation have also been identified. Of particular interest is the URB-AL Program, an agreement between the Municipality of Santana do Livramento and the Intendancy of Ribera with the European Union, targeted at improving living conditions for rural populations, protecting the environment by means of implantation of the Ibirapuitã–Serra do Caverá Biological Reserve, located in GAS outcrop areas.

4.4.3 Paraguay

Paraguay currently faces the great challenge of implementing Law 3.239/2007 (the Water Resources Law) that will provide a legal framework for all regional actions currently being carried out. To further strengthen water-resources management, Paraguay also aims to develop its own National Water Resources Policy. This policy will promote a program of actions, instituting river basins as the basic management units and will, with the aim of fulfilling present and future demand for water, provide a powerful planning and management tool while, at the same time, ensuring availability of water necessary for provision of goods and services, for conservation of ecosystems, and for national social and economic development.

Within the scope of these efforts are the Water Management Modernization Project, funded by the Inter-American Development Bank, which aims to support implementation of the new law; and the Project for Modernization

of the Water and Sanitation Sector, funded by the World Bank, involving the Secretariat of Environment of the Republic of Paraguay (SEAM), the National Environmental Sanitation Service (SENASA), the Sanitation Services Regulatory Agency (ERSSAN), and the Sanitation Services Company of Paraguay (ESSAP). One of the most significant initiatives aimed at facilitating enactment and implementation of the law is the Arroyo Capiibary Basin Pilot Project (involving the municipalities of Alto Verá, Obligado, Bella Vista, Hohenau, Santísima Trinidade, Jesús, La Paz, and Capitán Miranda) which encompasses the PGAS Itapúa Pilot-Project area, and which results from cooperation between the German Government and SEAM, through the Institute for Geosciences and Natural Resources (BGR) of Germany. Information generated and tools developed on a local scale will ensure that management of groundwater, and in particular the GAS, will be accomplished.

Cooperation between SEAM and BGR also resulted in the Sustainable Groundwater Management initiative that also encompasses other aquifers in Paraguay. The Ministry of Agriculture and Livestock has an environmentally sustainable agricultural production project that also has direct linkages with the GAS, especially its outcrop zones.

In compliance with Law 3.239/2007, water management organizations in Paraguay, in articulation with the main stakeholders, have helped create a GAS Management Plan, with special emphasis on the Paraná River region. River basins are the basic management units of this plan. This is a region where steady development is to be expected, in view of construction of the Corus Dam (between Argentina and Paraguay) and of a second bridge between Brazil and Paraguay. Burgeoning demand for water is yet another consequence of population growth and increasing agricultural use of land.

Aside from the aforementioned SEAM-BGR cooperation projects, a series of other initiatives relating to management of GAS water resources are underway in the PGAS pilot zone in Paraguay. In Itapúa, representatives of the Departmental Government, of the municipalities, of the Inter-American Association of Sanitary and Environmental Engineering (AIDIS), of the Catholic University (Hohenau) and Cooperatives (Colonias Unidas, La Paz and Pirapó) have reached an agreement on deployment of strategies for agricultural and livestock development, incorporating rational and coordinated land use, with management units based on river basins. The following projects and tasks were defined: (i) the community water supply project, (ii) the agrochemical management project; (iii) the project for reforestation, forestation and natural regeneration on river banks; and (iv) the management of urban wastes project (spillways).

A similar initiative is being carried out in both Itapúa and Alto Paraná Departments, under coordination of the Colonias Unidas Cooperative. Moreover, the Cooperative offers a capacity building program, known as Rincón Verde, targeted at young people. In the municipality of Hohenau, an integrated urban solid-wastes treatment station has been constructed (for reception and compression of recyclable inorganic material, recycling of organic matter through composting, and final disposal of non-recyclable materials in sanitary landfills). This initiative recently won a prize at the Development Fair. A sewage system was also installed, as part of the Rural Water Supply and Sanitation Project (World Bank IV) carried out by SENASA. The Environmental Protection Committee of Bella Vista has an innovative Pilot-Project for the selective collection of batteries, targeted at reducing potentially harmful pollution, and representing a symbolic point of reference for new generations.

4.4.4 Uruguay

An account of the initiatives currently underway in Uruguay can be broken down by thematic category. Environmental sustainability (water resources and land use in river basin) is a theme under which Uruguay has a number of interesting initiatives to present, including the following:

The Twin-Latin Program carried out in the entire transboundary Cuareim-Quaraí River Basin (Uruguay and Brazil) aims to assess the hydrological impact of changes in land-use patterns. Funding for this program was provided by the European Union and national counterparts. The Cuareim River Basin overlies a portion of the GAS, characterized by both outcrop and confinement zones. This constitutes an excellent opportunity to integrate information on surface and groundwater. Other projects underway in the same river basin include the Claris Program, also funded by the European Union; and the integrated flood-management project for the Cuareim River, carried out by the National Hydrographic Directorate (DNH) of Uruguay, and the Institute for Hydraulic Research (IPH) of the Federal University of Rio Grande do Sul (UFRGS) in Brazil.

The Office of Budget and Planning, through the DNH, carries out several projects targeted at improving water resources infrastructure and increasing environmental protection, while fostering agricultural activities in various areas, including some that overlie the GAS. Moreover, various projects proposed by the University of the Republic of Uruguay (UDELAR) aim to assess effects and develop environmental indicators to gauge productive activities in river basis in which different types of livestock and forestry management activities are underway, funded by the National Science and Technology Directorate and the National Agricultural Research Institute. In view of their economic importance, both the livestock and forestry sectors are benefited by technical assistance programs, such as the program to construct reservoirs for watering livestock, cofinanced by the World Bank, GEF, the Ministry of Livestock, Agriculture and Fisheries (MGAP) and farmers organizations.

The program for modernization of environmental management and planning institutions, within the scope of the Ministry of Housing, Territorial Planning and Environment (MVOTMA), financed by the Inter-American Development Bank (IDB) and national counterparts, represents an excellent opportunity to foster activities related to the GAS.

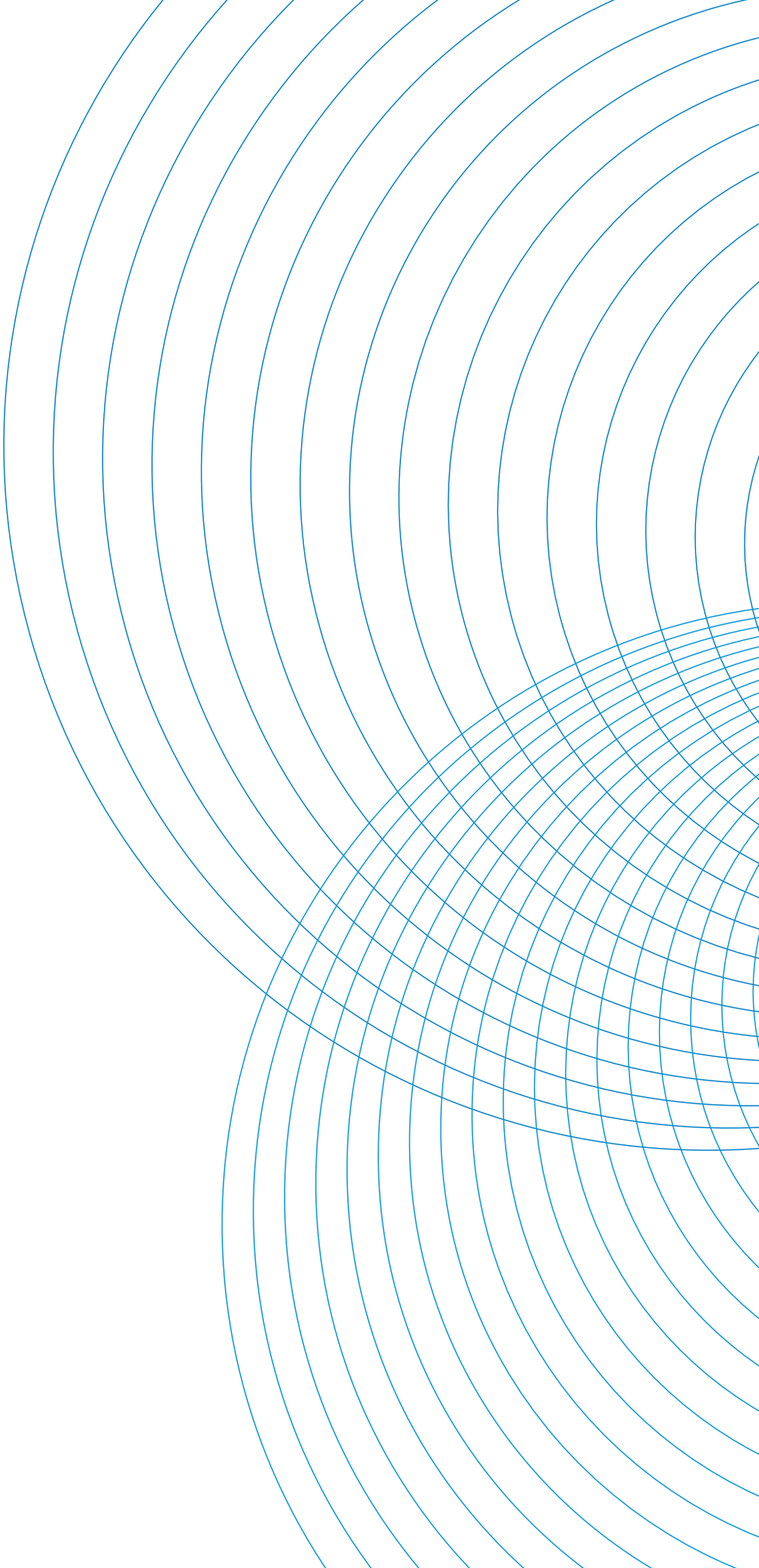
Another initiative specifically related to water resources, meteorology, and hydrology, is

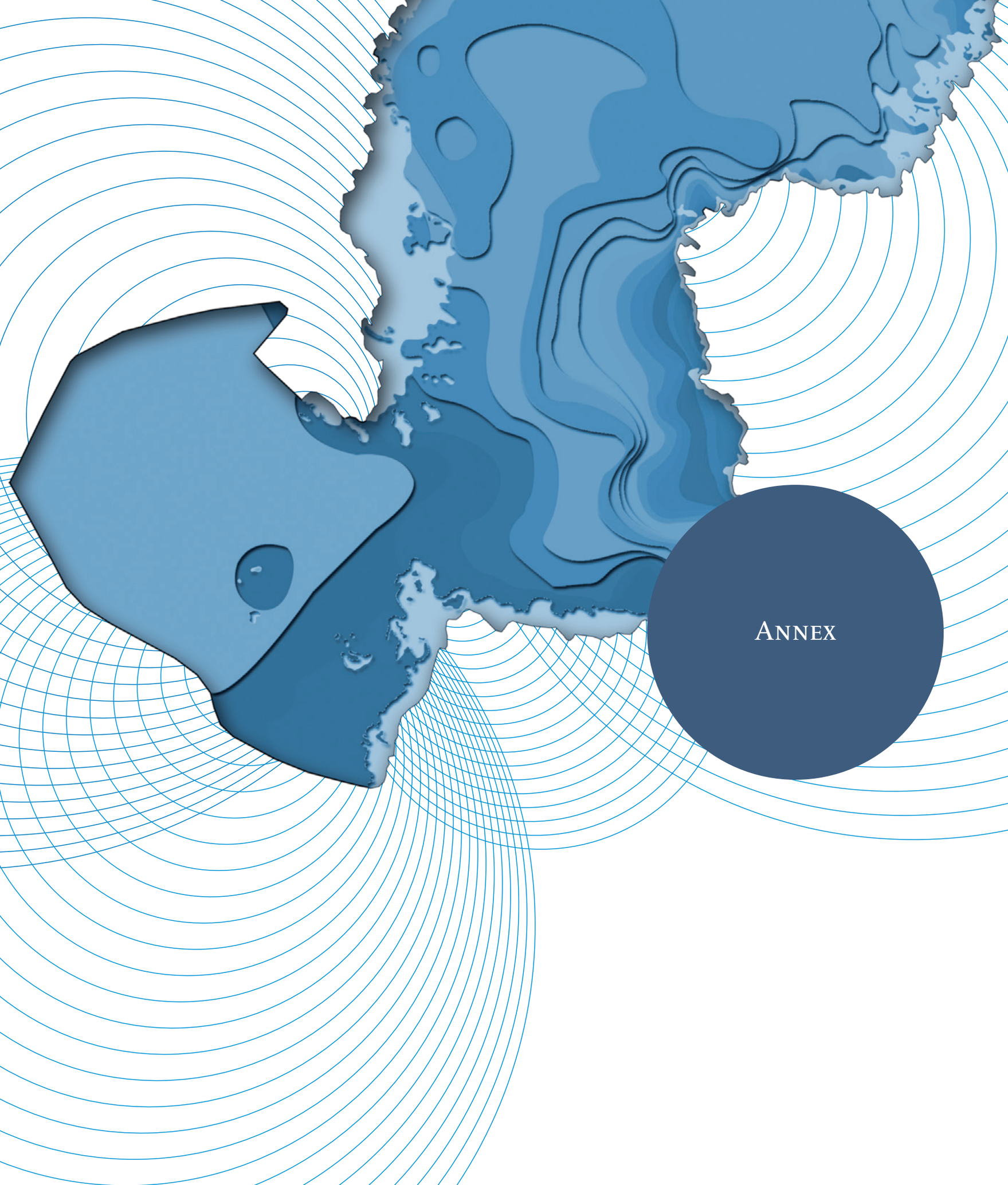
the management plan for water resources in the Negro River Basin, which aims to institute remote gathering and processing of rainfall data and hydrometric information. The United States National Oceanic and Atmospheric Agency (NOAA) and the Government of Uruguay plan to carry out a specific program, encompassing gathering of information relating to climate, installing databases, and institutional capacity building, to meet challenges imposed by climate change.

From the standpoint of expanding public water supply and sanitation services, various initiatives are being carried out by the State Sanitation Works Department (OSE) throughout the country, including in municipalities within the GAS Pilot-Project areas (Rivera and Salto) and in GAS outcrop areas (Tacuarembó). These initiatives rely on budgetary finding, or from the Interior Development Fund (linked to the Office of Planning and Budget). Some of these public works benefit from creative financial arrangements, in the form of bipartite or tripartite agreements, involving the OSE, the Municipal Intendancies, and beneficiaries. Specifically relating to groundwater, the OSE has proposed to fund and conduct hydrogeological studies and to drill boreholes in the areas of Rivera, Artigas, Tacuarembó, Salto and Paysandú, and to pursue a special program for mathematical modeling of the GAS in transboundary areas.

The Program to Implement the National System of Protected Areas, another Uruguayan initiative of special interest, which includes certain GAS outcrop areas (in the Lunarejo Valley) was proposed by the National Directorate for Environment (DINAMA) and receives support from the GEF and the UNDP. Finally, from the standpoint of regional thermal development, the Integral Tourist Development Plan for the Uruguay River region, an initiative of the Commercial Center that receives funding from IDB and the Uruguayan Government is of considerable interest.

Also relating to thermal resources, in the same geographic area as the Salto PGAS Pilot Project, a number of initiatives are being pursued: (i) OSE is investing in an urban-wastes treatment station prior to discharge into the Uruguay River; (ii) installation of a DINAMA regional office, with capacities and equipment to serve as a regional environmental reference (including water quality); (iii) drilling of a replacement borehole in Termas de Arapey, for recreational and tourism use; (iv) organization of a meeting of MERCOSUR thermal operators for an exchange of experiences and assessment of the sector, funded by the municipality; (v) in Salto, the OSE is to transfer ownership of its well to the municipality, for development of recreational infrastructure and to benefit low-income populations; (vi) creation of a water unit within the municipal organizational structure (not as yet implemented); (vii) establish an agreement between the municipality and the Geological Service of Uruguay to provide technical advice on groundwater, with municipal and national funding; (viii) conduct trials with the Thermal Hotels in Arapey in Salto, to farm lobster and breed cichlid fish (tilapia) in water tanks.





Annex

ANNEX 8

Table 1. Summary of SAP actions strategies*

Regional approaches	
1. Develop national and sub-national institutional management capacities	
Common actions	1.1. Inclusão do SAG e de seus desafios na política nacional de recursos hídricos
Actions identified for	
Argentina	Prepare a national groundwater program, within the scope of the National Water Resources Plan, coordinated by SSRH, COHIFE & COHILI
Brazil	Coordinate the GAS, within the National Water Resources Policy, by developing the National Groundwater Plan and its inter-relations with state water resources plans. Draw up an integrated management program for groundwater and surface water (ANA, PPA/OGU)
Paraguay	Draw up a Management Plan for the Guarani Aquifer System and incorporate results of the PGAS into the Water Resources Law (No. 3.239/2007)
Uruguay	Institutional recognition of the GAS, based on experiences of the Guarani Infra-basaltic Aquifer Advisory Board and through laws relating to water resources. Create a special national unit for the Aquifer
Common actions	1.2. Strengthen institutional capacities
Actions identified for	
Argentina	Enforcement of provincial legislation. Provide incentives for trained agents to remain on the staff. Implement a register of users, a register of water resources, and a register of drilling companies. Institute exploitation licenses. Technical inspections at all stages of drilling of boreholes
Brazil	Maintain state units and strengthen capacities for management of the GAS. Fund raising to carry out actions, via water-resources and science-and-technology sectoral funds (national and state funds). Foment application of CONAMA Resolution 396/2008
Paraguay	Institutional strengthening of SEAM, of municipalities, and of water councils for sustainable management of groundwater. Prepare Integrated Water-Resources Management plans for the sustainable management of the GAS. Create a Water Institute (for groundwater and surface water). Reactivate the FACEN UNA applied hydrogeology laboratory
Uruguay	Adapt existing legal instruments (Infra-basaltic Management Plan). Provide an analysis of charges foreseen in the Water Code to be applied as a tool for management of the GAS. Ensure coherence between current environmental laws and exploitation and management of the GAS. Incorporate the GAS into the national budget (Foreing Affairs Ministry and MVOTMA)
All the countries should disseminate technical materials prepared under the PGAS as practical instruments for capacity building. This material may be used at all levels of management to promote convergent strategies and criteria for groundwater management	
Common actions	1.3. Promote institutional articulation
Actions identified for	
Argentina	Create a GAS Inter-jurisdictional Committee, involving provincial representatives. Strengthen links with organizations such as COHIFE & COPHILI. Work with the Ministry of Health to coordinate epidemiological studies relating to high arsenic (As) levels

Continues

* For further details, see Chapter 5.

Continuation

Brazil	Coordinate with the Technical Chamber for Groundwater (CTAS/CNRH) and create similar bodies in all the state water resources councils. Unify and adapt procedures for licensing wells in the GAS, in accordance with environmental standards. Specific articulation with other public institutions directly linked to the GAS (INCRA, FUNASA, DNPM, among others)
Paraguay	Create local sustainable development councils. Sign a cooperation agreement between FACENUNA and SEAM on development of groundwater. Introduce the GAS within the scope of CONAM. Support the strengthening of municipal management structures, providing funding for planned actions
Uruguay	Maintain and strengthen relationships between institutions responsible for groundwater and the GAS. Maintain and strengthen the current NPEU. Strategy to involve departmental governments
All the countries shall employ their best endeavors to improve integration between water management and environmental territorial planning (including solid waste management) and regional planning policies	
Regional approaches	
2. Operational structure for cooperation	
Common actions	2.1. Maintain and support cooperation structures
Ensure continuity for management tools developed by the PGAS, maintaining national coordination through the executing agencies (SSRH in Argentina, SRHU/MMA in Brazil, SEAM in Paraguay and DINASA/DINAMA in Uruguay). Maintain and strengthen national management units. Assume responsibility for coordination and appoint technical-committee representatives. Maintain regional coordination among the four countries. Contribute funding and human resources for implementation of the SAP	
Common actions	2.2. Implement and update the SAP
Draw up and update annual operational plans for the SAP	
Common actions	2.3. Fund raising and preparation of proposals
This assignment will be part of the Liaison Unit's terms of reference, and depends essentially upon the will of the countries concerned to move ahead	
Regional approaches	
3. Update and maintain SIGAS	
Common actions	3.1. Operational maintenance of SIGAS infrastructure
Make available technical and maintenance personnel for different points of the system (in accordance with their hierarchal level). Each country will have a node, as well as subsidiary sub-national nodes in the Pilot Projects or in state organizations responsible for management. Each central node will be responsible for supervising the others and for producing geo-processed outputs	
Actions identified for	
Argentina	One main point and eight subsidiaries or workstations
Brazil	One main point and thirteen subsidiaries or workstations
Paraguay	One main point and three subsidiaries or workstations
Uruguay	One main point and four subsidiaries or workstations
Common actions	3.2. Support the SIGAS Committee
Led by Argentina (which is responsible for coordination of the SIGAS Committee) the countries shall, via their competent institutions, offer support and pass on information, queries and demands to the Committee. This information will be discussed in this forum and will serve to support joint decision making	
Common actions	3.3. Promote the flow of information to the SIGAS
The success of the SIGAS is based on continuity of the flow of information on the GAS and on the commitment of national institutions to pass them on to the nodes that comprise the chain	
Regional approaches	
4. Implement and develop monitoring networks and mathematical models of the GAS	
Common actions	4.1. Support the Monitoring Network and Modeling Committee

Continues

Continuation

	Coordination of the Monitoring and Modeling Network Committee shall be the responsibility of Brazil. This committee will be comprised of academics and water-resources institutions from each country. Implementation of this network should build upon the experiences of current representatives on issues relating to monitoring, the group of national specialists on models, and all the experience generated by the PGAS. The countries should formally appoint representatives, including those for the model sub-committees, draw up an annual program of meetings and distance exchange strategies
Common actions	4.2. Implement the GAS Monitoring Network
The GAS Monitoring Network carries out quality and quantity measurements at 180 pre-selected wells. In this first implementation phase of the SAP, the network should be adapted to using existing national and local capacities. It should make efforts to incorporate monitoring recommendations issued by environmental control organizations and by the water supply companies. Its principal task will be: to draw up an annual program of workshops and meetings; to negotiate with well-monitoring institutions and make data available to the GAS Monitoring Network; to provide technical support for selection of wells, sampling protocols and schedules	
Actions identified for	
Argentina	16 boreholes
Brazil	118 boreholes
Paraguay	28 boreholes
Uruguay	18 boreholes
Common actions	4.3. Use of the Regional Model of the GAS
Continue to improve the PGAS conceptual model and evaluate macro-trends for land use and settlement of the GAS geographic area. All discussion of the regional model represents an opportunity for continual capacity building of new human resources	
Common actions	4.4. Use of the Model in the Pilot Projects
It is important that models be constantly updated so that they can be effectively used as management tools. Such updating depends on trained human resources and production of new hydrogeological information. To improve models, the following tasks are suggested: new models should be approved by local players, with the advice of technical-operational pilot support committees; new information should be incorporated into the structure and geometry of the model; workshops should be held to define management scenarios and evaluate results; coordination of information generated, systemization and dissemination of the results among the countries and committees.	
Actions identified for	
Argentina	**The Concórdia – *Salto* Pilot Project** Draw up criteria for sustainable exploitation. Incorporate the issue of contact between fresh and salt waters into the models. Hold discussions and evaluation workshops (*this action should also be carried out by Uruguay*)
Brazil	**The *Ribeirão Preto* Pilot Project** Evaluate GAS exploitation scenarios. Support development of criteria for use and protection of the GAS (models as management tools). Hold discussion and evaluation workshops
Paraguay	***Itapúa* Pilot Project** Use of the model for management of the GAS. Territorial planning. Implement the new Water Resources Law. Evaluate possible scenarios for use of the GAS and identify areas for exploitation and protection. Hold discussion and evaluation workshops
Uruguay	**Projeto-Piloto *Rivera*–Santana do Livramento** Evaluate GAS exploitation scenarios. Support development of criteria for use and protection of the GAS (models as management tools). Hold discussion and evaluation workshops (this action should also be carried out by Brazil)
Regional approaches	
5. Technical capacity building and dissemination of knowledge	
Common actions	5.1. Support for the Capacity-Building and Dissemination Committee
	The Capacity-Building and Dissemination Committee shall be coordinated by Paraguay. It will be necessary to strengthen the preliminary committee that was created with the support of the communications areas of water resources policy institutions. During the first SAP implementation phase, the committee will begin by making use of existing capacities at different government levels, so as to take full advantage of PGAS outcomes. The starting point will be to disseminate capacity building actions and strategies and all available technical reports and publications. The main assignments will be: to draw up an annual program of workshops and meetings; establish liaisons between the countries and the Liaison Unit, develop viable strategies to incorporate capacity building strategies and incorporation of activities into national and sub-national agendas

Continues

Continution

Common actions	5.2. Development of capacity building
Formulation of national, state/provincial, departmental and municipal strategies to take full advantage of the technical-scientific knowledge generated by the Project, especially among water resources management bodies, is crucial for improving the quality of management. The objective is that management organizations should assimilate knowledge acquired during the PGAS so as to become stronger and ensure more effective actions. The principal assignments are: to provide systematic training for journalists; include the theme of "groundwater" in teacher training; provide capacity building for community leaders involved in environmental-education programs; prepare a manual of best practices for use, management, operation, and maintenance of wells	
Common actions	5.3. Disseminate information
	Disseminate promotional material developed under the PGAS. Highlights of these are: a website; educational kits about the Guarani Aquifer Citizenship Fund, television spots, Project publications (including the SAP itself), manuals, technical reports to promote greater knowledge, etc. This requires discussion of joint mechanisms that lead to common objectives, i.e., to increase knowledge about the GAS, to heighten public awareness in general, and to promote public participation in its management. Each country, through the organizations responsible for implementation of the SAP, should include the theme of the GAS in its own communications plans, emphasizing its significance, promoting rational water use and combating waste
Common actions	5.4. Promote follow up of the Guarani Citizenship Fund (see the Annex in Chapter 5)
Regional approaches	
6. Development of local management for groundwater	
Common actions	6.1. Institutional acknowledgement of local management support committees
Increase support for national and sub-national legal frameworks for effective institutional acknowledgement of the Local Management Support Committees (CLAGs). Institutional acknowledgement of the Local Support Committees of the Pilot Projects (CLAPs) is discussed in the section on legal and institutional aspects	
Actions identified for	
Argentina	Support from Secretariat of Planning and Public Works that will in turn count on support of the decentralized body responsible for municipal sanitation works and the Department of Water of the Province of Entre Ríos
Brazil	Support from the regional office of the Department of Water and Electric Power of São Paulo (DAEE-SP), the Rio Pardo River Basin Committee (CBH Pardo) and the Municipality of Ribeirão Preto
Paraguay	Establish a technical office on the theme "water" in the municipalities. Joint formulation of a local normative framework. Strengthen water councils
Uruguay	Support from the new DINASA office in Salto
Common actions	6.2. Implementation and review of action plans of local pilot projects (PALPs)
Implementation of the PALPs will entail: integration of groundwater management within the scope of urban and rural territorial planning (master plans); promotion of water re-use practices in regions with high consumption levels; and dissemination, in areas that have local management initiatives, of all technical manuals developed under the PGAS	
Common actions	6.3. Development of the local management promotion group
Lessons learned, best practices, and approaches for strengthening local groundwater management will be the subject of discussions at the Local Management Support Group	
Common actions	6.4. Characterization of potential (transboundary) pilot areas
The countries identified municipalities and frontier zones where lessons learned during the PGAS phase Pilot Projects could be applied. In each of these areas, the countries propose to carry out preliminary analyses to serve as bases for joint evaluations of future courses of action. For example, the following areas were identified: **Argentina:** It is proposed that the Province of Misiones be integrated with the Itapúa pilot initiative, in Paraguay **Uruguay and Brazil:** Both countries agree to evaluate application of PGAS Pilot Project experiences in the frontier region of Artigas (Uruguay) and Quaraí (Brazil). **Brazil and Paraguay:** Both countries agree to evaluate the application of the PGAS Pilot Project experiences in the frontier region of Ponta Porã (Brazil) and Pedro Juan Caballero (Paraguay) **Paraguay:** A study of the GAS is proposed in the section between Ciudad del Este and Encarnación, also covering zones in Brazil and Argentina	
Regional approaches	
7. Support public participation	
Common actions	7.1. Consolidation of public participation spaces
Encourage public participation in the management of groundwater resources. Prioritize efforts to create public awareness on environmental issues and the importance of groundwater, especially in relation to the GAS. This focus should be adopted by all organizations involved (NGOs in each country, local committees, river basin councils, technical councils for groundwater, etc.)	

Continues

Continution

Common actions	7.2. Effective participation of indigenous populations
Ensure that universal rights (to free, prior and informed consent) of indigenous peoples are respected within the GAS. Respect indigenous communities, their habitat, traditional territories and natural resources. Drill new boreholes to provide water supplies in indigenous areas and encourage the use of the GAS Well Boring Manual. Carry out multidisciplinary studies (in anthropology, sociology, engineering, architecture) to determine the relationship between water (surface water, groundwater and rainwater) and indigenous cultures. Promote regular regional meetings in the villages and exchanges of experiences on preserving natural resources and sustainable development in relation to indigenous societies within the GAS region. Monitor and maintain, with the participation of the Indigenous communities themselves, GAS tube wells in tribal areas. Adapt the content of informative and educational materials produced by the PGAS	
	Actions identified for
Argentina	a) Create national standing committees with participation of indigenous peoples, to guarantee that the autonomy and biodiversity of their lands are maintained, as well as their traditional cosmological conception of the world, and culture b) Train and supervise indigenous representatives to carry out surveillance and protect forest reserves within the area of the GAS
Brazil	a) Create national standing committees consisting of representatives of the indigenous peoples, of the National Indian Foundation (FUNAI), of the National Health Foundation (FUNASA) and of other government bodies b) Establish a technical chamber within the National Water Resources Council (CNRH) and in state councils, to deal with the issue of water resources in indigenous lands. Ensure that the decree that guarantees participation of indigenous peoples is approved in these councils c) Encourage training of indigenous forestry technicians d) Propose a law to enable indigenous peoples to exploit mineral water e) Develop compensatory mechanisms for restoring the environment on indigenous lands through implementation of environmental projects, such as recuperation of riparian forests
Paraguay	a) Create national standing committees consisting of representatives of indigenous communities, of SEAM, INDI and of other government bodies b) Organize decentralized meetings in indigenous communities with SEAM to discuss provisions of the new Water Resources Law c) Translate the new Water Resources Law into the Guarani language c) Promote mechanisms to ensure follow-up of wells drilled in indigenous communities d) Make available GAS conservation mechanisms in indigenous and vulnerable areas, while safeguarding land tenure rights
Uruguay	These strategies are not directly applicable to Uruguay
	Regional approaches
	8. Develop criteria for sustainable use
Common actions	8.1. Specific strategies for outcrop zones (OZ)
Map GAS outcrop areas (on a scale suitable for local management needs); evaluate and map vulnerabilities; identify potential point and non-point sources of pollution; draw up land-use and settlement criteria; criteria for use and protection of the GAS, emphasizing replenishment areas; draw up guidelines for protection of perimeters of wells and parameters for exploitation of the unconfined aquifer; draw up standard procedures for drilling of wells; incorporate the concept of groundwater when setting criteria for the use and occupation of urban land (by controlling potential sources of pollution, in relation to wells and waterproofing methods); and rural land (natural vulnerability, agricultural activities and production models); ensure greater control over major users of the GAS, encouraging them to produce systematic details about water levels, abstractions from wells and water quality. The PGAS prepared a guide on how to evaluate perimeter protection and determine vulnerabilities and risks of contamination of wells and of aquifers	
Common actions	8.2. Specific strategies for confinement zones (CZ) and for very strong confinement zones (SCZ)
	Regional approaches
	9. Implement technical-scientific programs
Common actions	9.1. Generation of data on specific areas of the GAS
Identify GAS zones with potential to generate highly significant information for the countries	
	Actions identified for
Argentina	a) Establish the western limits of the GAS and the regional and sub-regional surface fresh water and salt water boundary areas b) Foster execution of local studies and borehole drilling so as to increase knowledge about geological and geophysical structures c) Incorporate new geophysical findings from surveys conducted in Misiones, Formosa and other provinces
Brazil	a) Obtain a better definition of hydrogeological conditions on the northern boundaries of the GAS in the States of Goiás and Minas Gerais b) Increase knowledge on the GAS in the Serra do Maracaju region and in the municipality of São Gabriel do Oeste in Mato Grosso do Sul c) Survey isolated outcrops of the GAS in the Chapada dos Guimarães in Mato Grosso d) Evaluate behavior of the GAS in Paraná, with special focus on the town of Londrina (an important regional economic hub)

Continues

Continution

Paraguay	a) Carry out electro-magnetic soundings and produce additional lithological information b) Make use of information generated by mining research work undertaken in GAS regions in Paraguay
Uruguai	Make a deeper study of the central zone of the GAS, between Rivera and Salto, in areas ranging from confined to semi-confined, and estimate local distribution capacity

Common actions 9.2. Hydraulic relationships between the GAS and adjacent aquifers

The hydraulic relationships between the GAS and other aquifers are generally very complex and imperceptible on a regional scale. Nevertheless, they are important for local management of groundwater and should be studied. They occur in the four countries and some of the same features are constantly replicated. A series of technological and methodological lessons have emerged from oriented research, that offer vast possibilities for replication. In all four countries there is basalt cover above the GAS Sandstone. In surface boundary areas and under certain conditions, hydraulic and hydrochemical interaction occurs at different levels of intensity that are still not fully understood. This feature also occurs between the GAS and more recent structures, such as the Bauru Formation in Brazil, and between the GAS and rocks of paleogene and permo-triassic origin, with water that is generally of inferior quality, as occurs in the GAS confined zone in the Province of Entre Rios in Argentina

Common actions 9.3. Relevant hydrochemical aspects

In certain zones of the GAS there are restrictions on the use of water. The natural characteristics that lead to such restrictions have not yet been fully clarified and merit further investigation. Argentina and Uruguay will continue research into the high levels of salt in thermal and non-thermal waters, and the traces of arsenic and of other ions in confined areas of the GAS in the so-called "littoral" region (along the Uruguay river). Brazil and Paraguay will seek to conduct further hydrochemical studies in areas of the GAS with anomalous concentrations of fluoride (e.g. in the States of Rio Grande do Sul, Santa Catarina and Paraná). All of the countries will seek to avoid activities that could lead to contamination of the natural quality of the GAS or place its potential at risk. To this end, they will apply knowledge on areas of high vulnerability and at risk from contamination, and will improve communications among agencies responsible for environmental and territorial planning. They should also seek to control and enhance the quality of boreholes drilled into the GAS

Common actions 9.4. Integrated water resources management

One of the greatest challenges for integrated water resource management is assessment of total water availability in groundwater and surface reservoirs, quantifying their possible connections. In addition to the enormous analytical effort required to attain reliable water balances, this undertaking requires administrative tools and negotiations, entailing such mechanisms as licenses and permits. Thus, basins with reasonable levels of information should be identified

Actions identified for	
Argentina	A basin that encompasses a GAS outcrop area in the Meseta Mercedina should be selected in the Province of Corrientes
Brazil	The transboundary Cuareim-Quaraí River Basin, located between Uruguay and Brazil is the reference basin
Paraguay	The Arroio Capiibary River Basin is the reference basin
Uruguay	The Arroio Tacuarembó Chico River Basin presents ideal conditions for the purposes of these studies

Common actions 9.5. Relationship between the GAS and initiatives for protected areas

GAS outcrop areas, recognized for their function as replenishment areas, should be treated as a priority in environmental and biodiversity protection plans, since they are highly vulnerable. Certain GAS areas should be protected within other environmental and protection initiatives, as they are rich in biodiversity, could serve as ecological corridors, and contain surface-water springs. Synergies among different initiatives would make it easier to achieve legal and institutional protection and the approval of public opinion. An example of the challenges involved is provided by the project to establish an ecological protection corridor to join the localities of Lunarejo and Quebradas del Norte, in Uruguay, and the Ibuirapuitã reserve in Brazil, which covers a large swathe of GAS outcrop areas. Another example in Brazil and Paraguay is in the Miranda River Basin. The proposal to draw up an environmental protection corridor joining the Pantanal, Itaipu and Salto Grande merits attention, since this lies within the GAS region. Strategies to protect replenishment areas within the GAS, which unquestionably function as independent ecosystems, might be based on an environmental services approach. This approach is a recent development, and its applicability in the GAS area merits further investigation

Common actions 9.6. Relationship between the GAS and agricultural and forestry activities

The countries should be aware of the potential impact of these activities on the GAS, especially within outcrop areas, where sandy soils predominate. These activities may affect the quality and quantity of water available. The countries have already expressed interest in improving their understanding of the effects of agricultural and forestry practices on GAS areas. There is increasing demand for environmental certification on the part of farming and livestock operators, making it increasingly necessary to understand impacts of their activities on a variety of natural contexts. The GAS can represent an opportunity, in view of the increase of such demands. Abstraction of its waters may bring economic advantages to groundwater users in the agricultural and forestry sectors (irrigation and rural water supply). In such a scenario, criteria need to be established for sustainable use of the GAS, which are coherent with its dynamics and characteristics. Current areas of agriculture and forestry operations merit particular attention, especially with respect to their expansion into new areas and their impact on zones of greater vulnerability

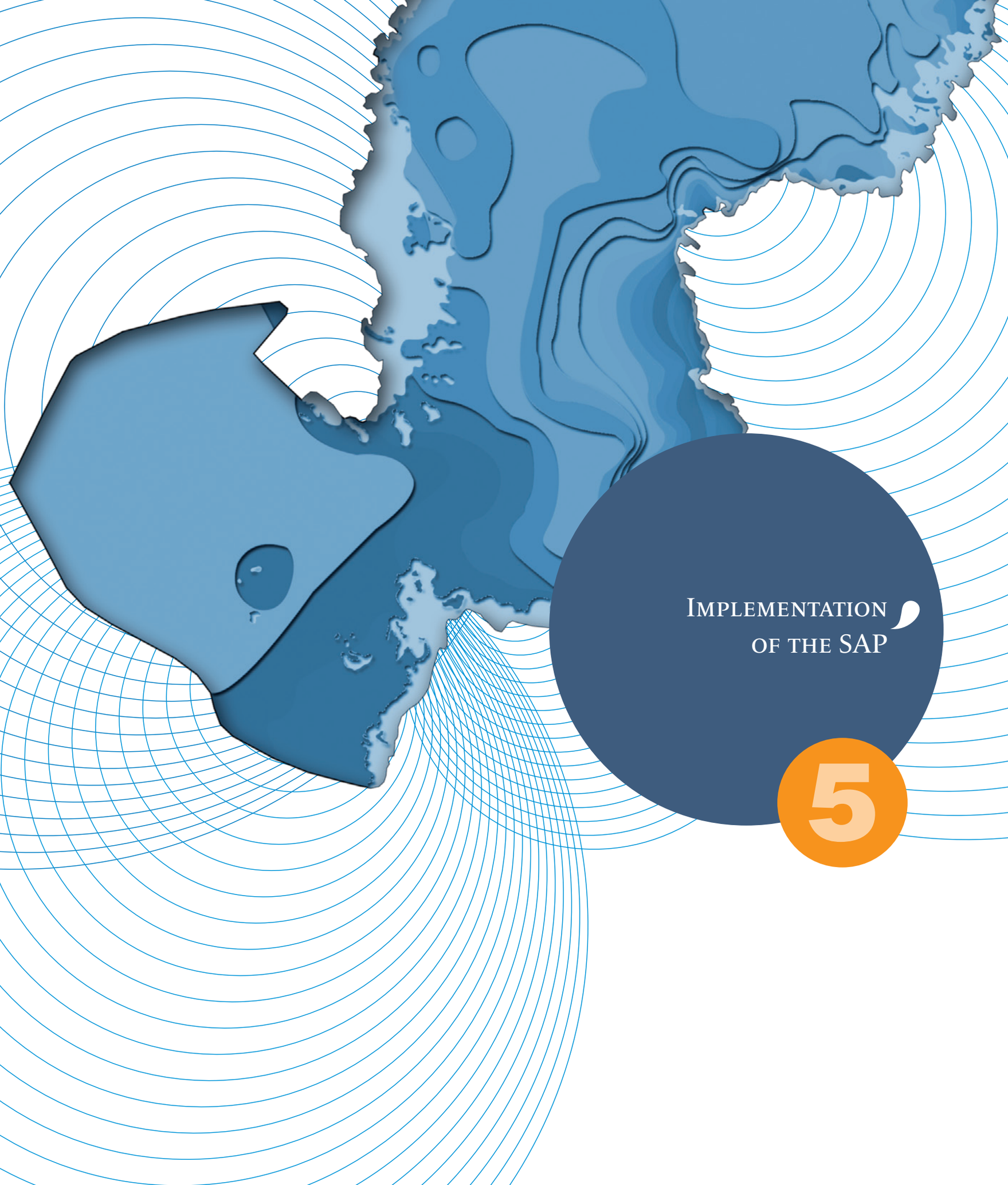
Common actions 9.7. Ensure continuity of the Guarani Universities Fund (see the Annex of Chapter 5)

Continues

Continution

Common actions	9.8. The GAS and climate change
Climate change variables should be incorporated into analyses, whenever possible. From a methodological standpoint, studies on this theme should be intensified, down to the level of river basins and regions, especially where pressures are greatest owing to changes in land use (construction of model scenarios). It is also important to consider the variety of situations and impacts of climate change in different zones of the GAS. To address the effects of climate change, possible synergies with the WWF La Plata River Basin Project should be examined	
Regional approaches	
10. Prepare technical and economic studies	
Common actions	10.1. Socio-economic overview of the GAS region
In the context of the SAP, study proposals targeted at regional social and economic issues should be included, broken down to the local level. Such studies should encompass details and regional characteristics, such as locations, territorial divisions, physical and geographic features; regional infrastructure including public sanitation, energy sources, communications and transport systems, elements relating to groundwater resources; social indexes including demographic information, human development, housing, health, education, schooling levels, culture, leisure and tourism; economic indicators showing the distribution of economic activities and regional distribution of GNP, land use, agricultural and livestock sectors, and industrial distribution	
Common actions	10.2. Studies on contributions and economic value of GAS resources
Three instruments are normally used in the assessment of GAS resources: (i) cost-benefit analyses of GAS resources use; ((ii) price-test models for groundwater use charges; (iii) consumer-product and economic-impact analyses vs. production costs. Price models for groundwater use charges, similar to those used for surface water in certain river basins could provide a valuable management instrument. Economic studies should seek to calculate optimum prices (inducing efficiency) that should be applied for groundwater use in different regions of the GAS and for different categories of use	
Common actions	10.3. Assessment of current and future groundwater use scenarios
This approach seeks to assess current and future activities involving the use of GAS groundwater, and to determine which activities exert greatest pressure on the aquifer from a quantitative and qualitative standpoint, focusing on those regions considered most propitious for economic development	
Common actions	10.4. Aprofundar estudos relacionados ao uso termal do SAG
Exploitation of GAS thermal resources produces real economic advantages, especially for the tourism sector. The principal thermal development zone lies within the Concórdia-Salto Pilot Project, in Argentina and Uruguay. Studies carried out in the region have produced important recommendations, applicable to all zones with potential for exploitation of thermal resources within the GAS region. In terms of established infra-structure and the number of wells in production, the region along the Uruguay River, on the border between the States of Rio Grande do Sul and Santa Catarina in Brazil stands out. In other states of Brazil, within the central portion of the GAS geological area (Central Channel) thermal tourism is still incipient. Despite potential economic advantages of exploiting thermal resources of the GAS certain challenges must be addressed. There is a need to increase public awareness in areas where thermal use is already consolidated, and to improve national and local capacities for sustainable management of thermal abstractions. In view of its strategic nature, it is imperative that the competent authorities deploy control mechanisms and enforce regulations established by law for exploitation of GAS thermal boreholes Territorial planning and tourism development initiatives should specifically include incentives for the reuse of thermal water and disposal of effluents. In view of the costs that such measures entail, mechanisms should be identified to make them feasible. These could be adopted by national, sub-national and local authorities interested in promoting the development of tourism From a normative institutional standpoint, guidelines for promoting sustainable use of the GAS and re-use of thermal waters should be established in each of the countries, based on current knowledge. Environmentally acceptable technical solutions should be sought for disposal of thermal effluents. This issue was raised by representatives of Argentina, but is equally relevant to all regions where exploitation of thermal waters of the GAS results in effluents with a high salt content Hydrothermal prospecting should be extended to new areas. Surveys conducted under the PGAS found thermal waters in other unexploited regions of the GAS, that could open up new opportunities for economic development. In regions where thermal water is known to exist, further prospecting could be carried out, with a view to expanding capacity. The confined GAS zone located in Salto and Artigas in Uruguay offers an example of this challenge, as does the littoral region of Argentina. Brazil would be interested in receiving details on thermal properties of the GAS in the area known as 'Calha Central'	
Regional approaches	
11. Monitoring implementation of the SAP	
Monitoring of implementation of the SAP at the regional level requires a set of suitable indicators for measuring actions under each of its approaches. These will be developed through consultations within the Liaison Unit , with support of the countries and especially their national executing bodies	

Source: SG/SAG, with contributions from the National Project Execution Units , 2008.



Implementation of the SAP

5

Chapter 5

Implementation of the SAP

SUMMARY

One of the premises of the Strategic Action Program (SAP) is to assure continuity, incorporation and deepening, on the part of participating countries, of the main management instruments developed under the Project for Environmental Protection and Sustainable Development of the Guarani Aquifer System (PGAS). To this end, it proposes that actions be carried out in two stages: the first, with duration of 12 months, is considered a transition and called the Immediate Implementation Stage. Next, comes what is described as the Future Implementation Stage, under which execution of a series of actions at the national level and a broadening of mutual regional cooperation is foreseen.

The **Immediate Implementation Stage** is characterized by initiatives of a regional nature, coordinated by countries participating in the SAP. Its two objectives are to maintain the degree of articulation and coordination developed during the PGAS and assimilate scientific and technical knowledge produced. This approach avoids fragmentation of actions. Simultaneously, the countries seek to arrive at an agreement on development of the future framework for regional medium and long-term actions. This framework will depend on the capacity of each country to generate the necessary technical and financial resources.

The **Future Implementation Stage** is a direct development from the transition phase, and provides a framework and adequate structures for carrying out future actions foreseen in the SAP. For this stage, additional institutional, technical and financial resources are foreseen.

This Chapter analyzes this proposed strategy from several angles and provides details on the two stages. It also describes the necessary institutional agreements and operational framework, funding alternatives, possible scenarios, and 11 strategic approaches that are to guide the actions.

5 IMPLEMENTATION OF THE SAP

This chapter defines and presents the organizational and institutional bases for execution of actions foreseen in the Strategic Action Program (SAP), with a view to advancing in the implementation of integrated groundwater management and sustainable use of the Guarani Aquifer System (GAS) in the region and in each of the participating countries (Argentina, Brazil, Paraguay and Uruguay). In Chapter 4, a set of actions considered of strategic importance was identified, and of these, the ones considered of regional importance and for immediate implementation were highlighted. As the latter are implemented, new stages are generated, thereby leading to selection, by the countries, of the most adequate regional scenario for execution of medium and long-term actions foreseen in the SAP.

One of the basic aims of the SAP is to assure continuity and incorporation, on the part of the countries, of the main management instruments developed under the Project for Environmental Protection and Sustainable Development for the Guarani Aquifer System (PGAS). The objective is to use the capacities generated and to exploit the experience acquired, while placing the need for sustainable development of groundwater resources and of the GAS on public agendas and raising public awareness. Isolation and fragmentation of actions could lead to the loss of technical and economic efforts already carried out.

The scale of regional actions proposed requires continuity of the Guarani Aquifer Information System (SIGAS) and of the monitoring network. It is also necessary to constantly update the base map of the aquifer and the mathematical models. Capacity building activities, especially at the sub-national and local levels, and dissemination of technical knowledge produced under the PGAS are also considered essential. During the **Immediate Implementation Stage** (topic 5.1) intense exchanges among institutions and a high degree of regional technical coordination are proposed, in order to achieve full assimilation of the work carried out in the GAS region by the countries, technicians, and decision makers. National and bi-national local-management activities in Pilot-Project areas have proven to be a key element, and have generated experiences that can be replicated when appropriate.

Inclusion into the SAP of national actions (see Chapter 4) targeted at protecting and ensuring sustainable use of the GAS transforms them into a Strategic Program. Execution of such actions, at the national, sub-national or local levels is to be carried out at the discretion of executing bodies in each country.

5.1 IMMEDIATE IMPLEMENTATION STAGE

Upon conclusion of the PGAS, the country representatives at the Project Steering Committee (CSDP) agreed to continue the work of mutual regional cooperation, while assuming direct responsibility for execution and continuity of actions initiated under the PGAS. Thus, the first stage of the SAP was defined as being a transition period, thereafter known as the **Immediate Implementation Stage**. This stage had two main goals: to maintain the articulation and coordination among the countries developed under the PGAS; and to assimilate the scientific and technical knowledge that had been produced.

During this stage, the countries aim to reach an agreement on a future institutional framework for medium and long-term regional action. No drastic change is to be expected however, since much depends upon the ability of the countries to generate the technical and financial resources necessary for pursuing national and regional goals defined in the SAP.

The knowledge accumulated and the documents prepared under the Project, alongside the management instruments, concrete experiences and lessons learned are major contributions toward understanding of the GAS. Efforts should now focus on dissemination of such knowledge and practices among institutions and key participants in each of the countries. Such material represents regional technical capital of Argentina, Brazil, Paraguay and Uruguay and will be administrated by the respective Governments.

These results could not have been achieved without intense inter-institutional cooperation efforts within each of the countries and full collaboration of the participating institutions and organizations. Arrangements for execution of the PGAS are evidence of the effectiveness of efforts to achieve convergence, at the technical and diplomatic levels, among the countries that participate in the CSDP.

Governmental leadership and the technical quality of the work carried out have convinced the public that measures to institute integrated management has respected national sovereignty while, at the same time, enhancing the instruments for groundwater management. Outcomes of the **Immediate Implementation Stage** of the SAP are reliant upon continuity of such leadership, the level of mutual cooperation achieved, and commitment on the part of the countries to take direct responsibility for execution of actions.

Execution of the Immediate Implementation Stage of the SAP assumes that the countries involved will fulfill their responsibilities as direct executors of the actions, thereby enabling definition of the bases for future agreements to consolidate the SAP proposals.

5.2 PROPOSAL FOR INSTITUTIONAL AGREEMENTS

The countries acknowledge the La Plata Basin Treaty as the legal framework under which actions relating to the GAS shall be carried out. However, in view of its strategic importance of the GAS for national development and of the transboundary nature of some of its waters, they appreciate that it requires special attention. Successful experiences accumulated under the PGAS have contributed with best practices and organizational aspects that have been examined, adapted, and assimilated for incorporation into future stages of the SAP. Options for organizational scenarios remain open, either for adaptation of existing regional institutional bodies, or as starting points for new arrangements to be implemented in accordance with the progress of experiences of execution during the Immediate Execution Stage From that point, five possible scenarios for institutional agreements were proposed (see topic 5.6).

Inspired by the five potential institutional agreements scenarios (discussed in topic 5.6) and

to avoid interruption of key activities currently underway and loss of momentum in regional cooperation, the CSDP signed ad-hoc agreements to ensure continuity of institutional actions.

During the Immediate Implementation Stage, existing institutional capacities in each country will be used. The management and operational structures successfully employed during the PGAS stage, including the CSDP, the National Project Execution Units (NPEUs) and State Project Execution Units (SPEUs), the Coordination Committee (CC), the Local Committees and Technical Committees will be maintained.

To adapt them to the needs of the new stage, small adjustments will be made in their roles and some bodies will receive new names:

- **The Regional Council for Cooperation for the GAS:** established with a structure similar to the CSDP, will be comprised of representatives of the water-resources and environment institutions and foreign-affairs ministries of the four countries.
- **National Management Units (NMU):** comprised of accredited members of the current NPEUs, that will serve as a forum for inter-institutional articulation, with participation of key players in water-resources management. In countries with a federal structure, it was suggested that state/provincial units be created to effect local articulation among, national, or sub-national groundwater management institutions.
- **Technical Committees:** are the same as they were under the PGAS. They provide support and monitoring for deployment of management instruments during the SAP implementation stage. Continuity will be ensured for the **Information Systems Committee**, the **Monitoring and Models Committee** and the **Capacity Building and Dissemination Committee**. They are to be structured with the same approach as the Technical Committees. In this context, a **Local Management Promotion Group** was included, with representatives of the Local Management Support Committees created by the Pilot Projects.
- **The GAS Liaison Unit:** established with the aim of expediting implementation of the SAP and to play the role of articulator and disseminator of information among the various committees and the higher decision-making and coordination levels (NMUs and the GAS Regional Cooperation Council). The Liaison Unit, will initially have only a minimal technical and operational structure and will use the amenities of the General Secretariat (GS/GAS) in Montevideo, Uruguay.

Each country assumes leadership in support of execution of one of the PGAS instruments and regional responsibility for the functioning of the respective thematic committee.

The Local Management Promotion Group (differently from the previous one) shall articulate with the SAP Liaison Unit. The CSDP Resolution issued at the Extraordinary Meeting held on November 24, 2008, foresees that the countries shall provide the necessary support for continuity and updating of the following instruments:

- Information System (SIGAS)–committee under the responsibility of Argentina;
- Monitoring and models–committee under the responsibility of Brazil;
- Capacity building and dissemination– committee under the responsibility of Paraguay;
- Liaison unit–structure under the responsibility of Uruguay.
- Concordia–Salto–under responsibility of Argentina;
- Ribeirão Preto–under responsibility of Brazil;
- Itapúa–under responsibility of Paraguay;
- Rivera-Santana–under responsibility of Uruguay.

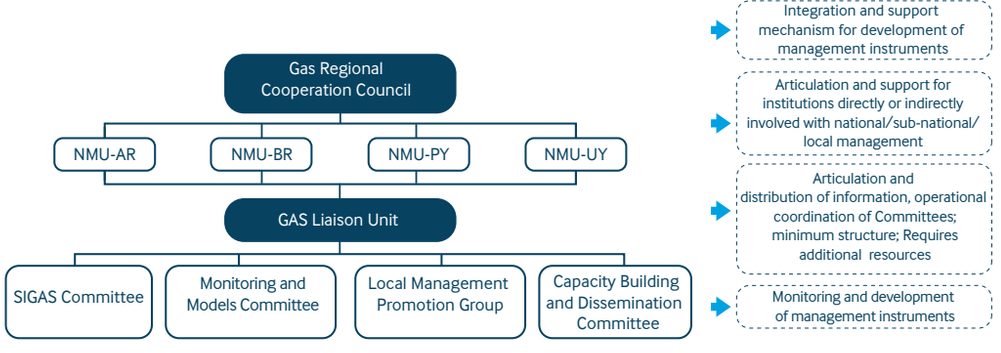
This designation of areas of responsibility to committees does not imply a weakening of sub-national structures, such as the SPEUs that operate in Brazil. The states have expressed a desire to maintain their internal articulation effort. In Brazil, for example, one possibility would be a strengthening of the state-level technical chambers for groundwater.

Figure 1 shows the agreements for the **Immediate Implementation Stage of the SAP**

5.3 OPERATIONAL CONSIDERATIONS

There follows a summary of the structure and role of each of the bodies involved in the **Immediate Implementation Stage**, including considerations on operational aspects derived from lessons learned during execution of the PGAS.

- **GAS Regional Cooperation Council:** maintains the present structure of the CSDP in terms of representation, each national representative will be responsible for leading one of the Technical Committees. Meetings of all members shall take place at least once a year.
- **National Management Promotion Units:** based in the NPEUs, these provide articulation and support for bodies for national and sub-national management institutions involved with the GAS. They consolidate with participation of private sectors and of water-users. The role of National Coordinators (NCs) will



Source: GS/GAS, 2008.

Figure 1. Institutional agreements for the immediate stage, of SAP regional actions

be maintained. The frequency of meetings will be defined according to national requirements for implementation of the SAP. In federal countries, sub-national articulation will be maintained with current bodies at the state/provincial levels.

- **Technical Committees:** each committee will be made up of national technical specialists designated by each country. Ideally, professionals who were involved with the PGAS should be maintained, so as to facilitate continuity of the work. Leadership of coordination and monitoring shall be assumed by the national executing body (topic 5.2). Each committee will have its own schedule of meetings and work plan. Initially, the proposal is to hold annual meetings, others being called if need arises.
- **Information System Committee:** made up of specialists of the Guarani Aquifer Information System (SIGAS) that is, in turn, comprised of the institutions responsible for management of information on water resources in each participating country. Each country shall be responsible for modifying and preserving data corresponding to their territory. As the system is arranged as a network, the content of each national station is replicated in the other countries. The committee of SIGAS specialists shall supply the necessary consistency for information management and shall provide advice for managers of the system (structural adjustments, hardware, software, etc.), under the responsibility and coordination of Argentina.
- **Monitoring and Models Committee:** comprised of specialists from the Monitoring Network Committee created within the scope of the Project, and will include specialists in models who may form a specific advisory sub-committee. This Committee shall be made up of academics and shall include representatives of water management institutions in the region that are to be strengthened throughout the region. Strengthening of inspection services in the countries entails a qualitative and quantitative improvement of supervision of wells and water, necessary for attaining water security in the region. Among the outputs of the PGAS are regional flow models for each of the Pilot Projects. In the Pilot Projects, the Models Subcommittee shall seek support from specialists working with the local management support committees. All sectors involved shall have access to specific software procured under the PGAS, with access to the network. Support and coordination of this Committee shall be the responsibility of Brazil.
- **Capacity Building and Dissemination Committee:** this committee shall seek the necessary support to implement a minimum agenda for institutional exchanges and capacity-building programs. It shall provide continuity for publishing of information produced, in support of opinion makers, environmental education, dissemination of best practices and public participation in groundwater management. A preliminary committee was formed with the support of communications areas of the water resources policy management institutions in the countries. Building of ties with environmental journalists during execution of the PGAS may be an appropriate approach to supporting dissemination of information.
- **Local Management Promotion Group:** enables steering of the focus of groundwater management to the local level and development and testing of management instruments. This group will be responsible for storing local management experiences developed under the Pilot Projects (Concordia-Salto, Rivera-Santana, Itapúa and Ribeirão Preto) and will foster replication of the actions implemented in other areas (still to be defined). The group will be made up of operational members of the current Local Management Support Committees in the Pilot Projects and new committees that may be created to address the various local management themes encompassed by the GAS. Articulation and systematization of exchanges will be the responsibility of the Project Liaison Unit.
- **GAS Liaison Unit:** this unit shall be comprised of a select group of professionals. The size of the group will depend upon the capacity of the countries to maintain flows of resources. At the start of activities, it shall have a technical direction unit, and administrative, IT, administration and clerical services staff. According to the resolution issued at the CSDP Extraordinary Meeting on November 24, 2008, Uruguay will be responsible for providing the facilities necessary for administration of the Unit.

During the first year, i.e., the **Immediate Implementation Stage**, the countries have agreed to define a **common framework** for convergence of actions targeted at ensuring protection and sustainable use of the GAS. The aim is to foster mutual cooperation, based on concrete requirements specified in the Program. Efforts shall seek to ensure continuity of actions and deployment of the principal management instruments developed while, at the same time, strengthening mutual cooperation.

Implementation of the SAP, in accordance with the consensus achieved among the Governments of the countries, shall be carried out within the La Plata Treaty Framework, based upon which efforts will focus upon identification of an operational support body for execution of the respective activities.

Considering that the definition and consensus of the countries on the regional cooperation framework for the GAS are themes to be defined during the Immediate Implementation Stage of the SAP, there follows a preliminary proposal for development of this framework. It is the result of the work carried out under the PGAS and is based on a process of public consultation and participation. The proposal encompasses four blocks: (a) considerations; (b) principles; (c) declaration of responsibilities; and (d) institutional agreements:

a) Considerations

The spirit of cooperation and integration underlies relations among the countries of the region and permeates actions defined in the Strategic Action Program, prepared within the scope of

the Project for Environmental Protection and Sustainable Development of the Guarani Aquifer System (PGAS) executed by Argentina, Brazil, Paraguay and Uruguay.

b) Recognition of Principles:

Acknowledge that:

(i) Management of this resource, like other natural resources, is strictly the responsibility of each of the countries and jurisdictions defined under the legal frameworks.

(ii) With the aim of fostering its protection and sustainable use, cooperation and coordination among countries that underlie the GAS shall be strengthened, through enhanced knowledge, monitoring.

(iii) Scientific outputs generated during execution of the PGAS represent the current status of knowledge on the Guarani Aquifer System, and serve as a basis for development of measures for its management and protection, with an advanced degree of certainty, efficiency and benefit.

(iv) The PGAS installed and tested management instruments necessary for maintenance and strengthening of protection of the GAS, namely: the Information System (SIGAS), the monitoring network and mathematical models, local management-support committees, and dissemination of technical knowledge. Adequate functioning of these instruments and interrelationships among them require mutual cooperation and support of the four countries. It is necessary to ensure continuity and institutionalization in the countries of the management instruments that have been developed. It will thus be possible to provide support for decision making and deepen ties of cooperation, thereby enhnacing protection and sustainable use of the GAS.

c) Statement of Responsibilities

Acknowledge the desire to establish forms of cooperation in support of the following activities:

(i) Updating and maintenance of databases (on wells and cartography) on the aquifer as part of the Guarani Aquifer Information System (SIGAS).

(ii) Operation, maintenance and development of the GAS monitoring network, based on parameters defined jointly by the institutions responsible in each of the countries and through coordinated adjustment of the corresponding mathematical models.

(iii) Deployment of local management structures that consolidate the work of the Local Management Support Committees in areas defined in the PGAS as Pilot Projects, and in other areas with the right combinations of characteristics and conditions where such experiences could be replicated.

(iv) Ample dissemination of technical materials produced and harmonization of knowledge produced under the PGAS.

(v) Monitoring of the implantation of strategic actions agreed upon at the regional level, so as to ensure continuity and deployment in the countries of management instruments developed under the PGAS.

d) Necessary institutional and financial agreements

Acknowledge that for execution of SAP activities it is necessary to establish/maintain the following bodies:

(i) **Regional Cooperation Council**, as a mechanism for integration and support for sustainable development of the GAS, with participation of the water-resources, environmental and foreign-affairs ministries of each of the four countries, and with participation of technical coordinators of the special committees created under the PGAS.

(ii) **National Management Units** in each of the countries, that will serve as forums for articulation among different institutions and to support coordination of management instruments and strategic activities, and that will function in the same way as the NPEUs of the PGAS.

(iii) **State/Provincial Management Units** may be created in countries with a federal structure, where jurisdiction of groundwater lies with the States or Provinces.

(iv) **Local Management Support Committees for the GAS**, in line with national or sub-national standards, may collaborate in groundwater management at the local level or provide assistance in the development of management instruments. In principle, such committees are the same as the current Local Support Committees for the Pilot Projects (Concordia-Salto, Rivera-Santana, Itapúa and Ribeirão Preto), but this should not interfere with the replication of actions at the regional level, implemented in other areas to be defined and which will have their own committees.

(v) The **Liaison Unit** shall facilitate coordination among the countries and distribute information to the Committees, the National Management Units, and the Regional Cooperation Council.

The countries will make provision for the funding necessary for carrying out activities and maintaining the structure required for achieving goals.

The functioning of Local Management Support Committees does not require additional agreements among the countries, but rather, local support agreements that recognize their representativeness for development of activities foreseen. Among the alternatives proposed are new agreements between countries, within the scope of MERCOSUR, the Intergovernmental Coordination Committee of the Countries of the La Plata Basin (CIC), or other relevant treaties or committees.

The theme, however, requires deep analysis which, in turn, entails adaptation of processes and deadlines. Such initiatives are by no means incompatible with securing immediate continuity of cooperation on management of the Guarani Aquifer.

5.4 FINANCING AGREEMENTS

The funding agreed upon for the **Immediate Implementation Stage** amounts to a total of US$ 180.000 (one hundred and eighty thousand dollars). This corresponds to equal contributions of US$ 90.000 (ninety thousand dollars) from

the governments of Argentina and Brazil. In addition to this funding, Uruguay will provide the amenities for the Liaison Unit in Montevideo.

This funding will be used to advance the articulation process, which includes scheduling of meetings, summoning of participants from the countries, responsibility for the records of the project and for materials and documents produced, and financing of actions that the countries (through the GAS Regional Cooperation Council) consider pertinent.

The formal proposal for investment of resources will be a component of the annual operational plan to be drawn up to cover the transition period between the closing of the PGAS and launching of the SAP implantation phase. This document will be approved by the aforementioned Council. Defrayal of additional costs for maintaining the structure proposed, including salaries of members of the various Committees, the National Management Units and Regional Cooperation Council and their respective travel expenses, will be born by the bodies at which such representatives have employee status.

Implementation of specific actions encompassed by the SAP proposal, aside from the aforementioned resources, depends upon the efforts of national and sub-national bodies in each country. Such actions should always seek to comply with suggestions and guidelines presented in the individual and regional actions, with a view to maintaining the greatest possible degree of cooperation.

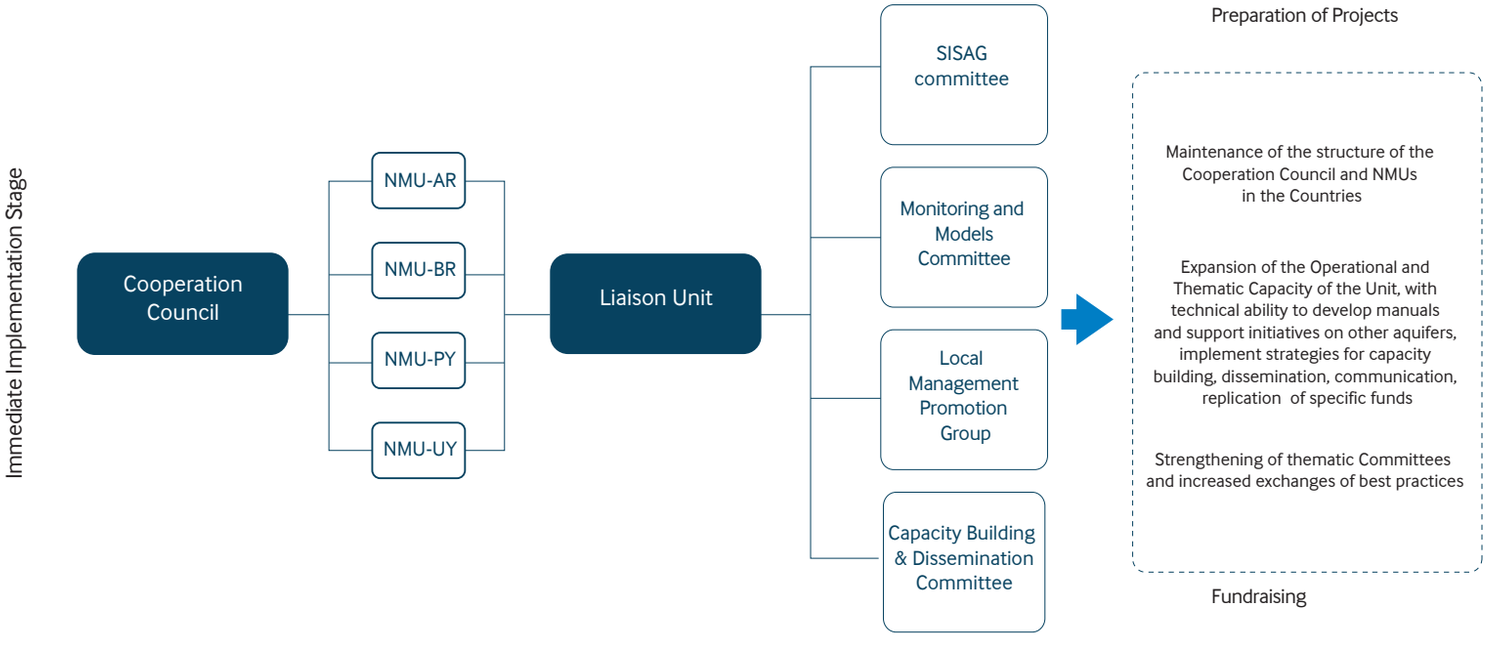
5.5 FUTURE IMPLEMENTATION STAGE

In this stage, all agreements foreseen in the **Immediate Implementation Stage** will be maintained. The difference is that the capacity of the Articulation and Operation Units will be expanded and the Technical Committees strengthened. Additional resources are also foreseen for execution of priority actions, and for fares for participants in coordination meetings.

Aside from organizing and facilitating exchanges, the Liaison Unit will be responsible for implementation of new actions. To this end, it will need technical capacities to develop new proposals and find funding for actions defined in the SAP that were not developed in the **Immediate Implementation Stage**.

For effective implementation of the SAP and achievement of the agreed objectives, the countries, through their national and sub-national water-resources management bodies, shall maintain their coordination efforts.

Figure 2 illustrates the transition from the Immediate Stage to the Future Stage of SAP implementation, with fundraising identified as being an essential task of the former, and the definitive obtaining of resources for defrayal



Source: GS/GAS, 2008.

Figure 2. Transition from the Immediate Stage to the Future Stage

of the Program as a key factor for advancing toward the future.

5.6 SCENARIOS FOR IMPLEMENTATION OF ACTIONS

For the Future Implementation Stage of the SAP, possible scenarios were presented, to guide and facilitate decision making during the Immediate Implementation Stage. The scenarios proposed offer an array of possibilities that could be implemented individually or jointly. Selection of these scenarios is directly relating to actions agreed to in the SAP. Each scenario was analyzed in terms of sustainability, risks, limitations, and funding requirements. Table 1 presents a summary of these scenarios.

Regardless of the model (or combination of models) selected, a transition period will be necessary in order to ensure full implementation of actions (such as the monitoring network, SIGAS, and models) and dissemination of technical outputs.

5.7 INVESTMENT AND FINANCING

Measures will be taken to identify potential partners for

The SAP is envisaged as a catalyst for strengthening existing ties and obtaining new sources of support from the Governments of the countries, their provinces/states, municipalities,

Table 1. Comparative summary of five scenarios for implementation of the SAP and of the PALPs*

Scenario				
Definition				
1. Countries follow up on national Pilot Projects and implement actions identified in the SAP, without a regional coordination body, but possibly with bilateral coordination. (Minimal incremental cost)	2. Same as 1, but under responsibility of SIGAS, sub-regional monitoring, and interaction with others in the implementation of trans-boundary Pilot Projects and execution of other bi-national or regional tasks. (Low incremental cost)	3. Same as 2, but with a regional structure only for updating the SIGAS and monitoring network. (Incremental cost: US$150,000 per year per country)	4. Same as 3, but with a regional support structure for the GAS and other aquifers, technical support, capacity building, institutional strengthening and international cooperation within the La Plata River Basin Treaty/ MERCOSUR. (Incremental cost: US$ 350,000 to US$ 900,000 per year per country)	5. Same as 4, but with creation or expansion of the regional organization (CIC-Plata/MERCOSUR) with the role of collective decision making, defining policies and guidelines and approving projects and programs with regional impacts. (Incremental cost: US$ 400,000 to US$ 1 million) per year per country)
Benefits				
Use of information generated by the PGAS in projects and national budgets	Same as 1, with greater possibility of implementation of PALPs/SAP1 in pilot areas and other actions of national or transboundary interest	Same as 2, with full functioning of the SIGAS and sub-regional/ regional monitoring network	Same as 3, with greater facility for coordinated regional and basin management where necessary	Same as 4, with joint management of activities with regional impacts
Weaknesses				
Risk of varying intensity that bi-national Pilot Projects might suffer deterioration Difficulty implementing support and coordination actions prioritized in the SAP Difficulties of varying intensity for regional integration, exchanges of knowledge and experience and capacity building; possible duplication of efforts			Regional coordination generates additional costs	
Risk of disintegration of SIGAS and of the monitoring network		Need generated for regional coordination with varying intensity		
Institutional Agreements				
National and Sub-national Management Units assimilated by national structures and individual strengthening of institutions that can provide technical and financial support in each country	Same as 1, with establishment of specific commitments for intra-regional cooperation to assume responsibility for the SIGAS, monitoring, models and support to the CLAPs	Same as 2, with establishment of a regional body solely to operate and maintain the SIGAS and the monitoring network; and bi-national cooperation bodies to assimilate the CLAPs	Establishment of a regional entity (Regional Cooperation Council, Technical Committees and Liaison Units) to revise and approve annual operational programs, support management of the GAS, SIGAS, monitoring, models, and current and future pilot programs	Same as 4, but adding the Council of Ministers, a National Coordinator and Sub-national Coordinator in the regional body, attributing to the Liaison Unit greater responsibility for coordination
To ensure incorporation of groundwater in sectoral and territorial policies, planning and policy bodies shall promote coordination with GAS and groundwater management bodies that, in turn, will coordinate with local bodies				

Source: GS/GAS, 2008.

* PALPs/SAP: Local Action Plans of Pilot Projects.

universities and social and water-user organizations, in order to carry out projects or actions. To complement the countries' own resources, it may be possible to count on foreign grant funding and international technical cooperation. The PGAS received significant international support from the BGR of Germany and of the IAEA, both of which are open to further cooperation in the future

In view of the visibility and international dissemination achieved by the PGAS, dialogues have been launched with other agencies, all of which offer important relationships which need to be followed up.

Activities included in the SAP that are already governed by sets of Regulations and lessons learned, such as the Guarani Guarani Universities Fund and Guarani Citizenship Fund, are examples of successful initiatives that could be opened up for financial cooperation by new partners. The countries that manage the GAS now can count on bodies, mechanisms, funds and spaces for technical or financial support. These, in turn, require management and preparation of documents for their deployment. These roles were considered in the definition of functions of the bodies responsible for execution of the SAP.

Thus, one of the main tasks of the Immediate Implementation Stage of the SAP is preparing the terrain for the identification of new partners to participate in the Future Implementation Stage.

5.8 RISKS

The main risk factors that need to be overcomes for implementation of the SAP are associated to:

(i) the degree of effectiveness and follow-up of institutional agreements signed by the countries.
(ii) the capacity for mobilization of financial and human resources for implementation of strategic actions.
(iii) the capacity for assimilation, monitoring, and continual development of actions proposed in the SAP on the part of the institutions responsible for management of the GAS at the different levels and spheres of responsibility.
(iv) the political will and technical capacity of governmental bodies in the countries to continue working together and to maintain convergent actions for protection and sustainable use of the GAS within the SAP framework.

Other more specific risks identified include:

- loss of the inputs of Technical Committees, owing to poor articulation and inadequate institutional and operational support, leading to a consequent failure of the monitoring necessary for successful deployment of management instruments, such as the SIGAS, the monitoring network, and proper use and updating of GAS Models.
- weakening of the Local Committees of the Pilot Projects owing to flaws in the institutional structure or in their specific roles of providing support for groundwater management or territorial planning, or simply lack of interest on the part of the local population;
- dispersion and fragmentation of the technical knowledge generated by the Project, in the event that the SIGAS or the central repository that stores and distributes information is dismantled;
- poor understanding on the part of key players and social organizations of the value of scientific and technical knowledge acquired, and of the importance of the transboundary and water-security dimensions (see Chapter 2) leaving room for doubts, uncertainty, and alarmist and technically-groundless discourses.

One of the greatest risks for cooperation and execution of the foreseen regional activities lies in the very real possibility of losing the momentum acquired by the four countries (not only at the national level but also at the subnational and local levels) over the six years of execution of the PGAS. This factor could lead to the loss of instruments deployed and progress achieved, and to the impossibility of moving forward with integrated management at the national levels and of convergent actions of the four countries at the regional level.

5.9 SUSTAINABILITY

The sustainability of the Project is subject to a number of factors. Firstly, the Governments of the countries involved need to demonstrate the will to continue working in a coordinated fashion to ensure protection and sustainable management of the GAS (i.e., in pursuit of the original goals of the PGAS). Secondly, there is the question of funding for activities to be carried out. Each country has provided for allocation of resources from its national budget, and has secured funding to ensure continuity of the actions foreseen in the Immediate Implementation Stage. During this transition, the countries shall seek to reach an agreement on funding sources for execution of the SAP. Also, as has been discussed in earlier sections, they have assumed responsibility for maintaining the key management instruments already deployed under the PGAS, strengthening of which is foreseen in the Future Implementation Stage of the SAP.

The following aspects are of crucial importance for full implementation of the SAP:

- **The importance of institutional and social assimilation of materials produced and disseminated:** this task entails follow-up of distribution and dissemination to be carried out in the Immediate Implementation Stage of the SAP. It is considered of key importance for harmonization of knowledge throughout the entire GAS region and vital for future development of management of the resource and of regional water security;
- **Availability of human resources and funding for SAP activities:** without the necessary human and financial resources contributed by Governments and national executing bodies at the various levels, SAP actions will lack the bases for development. Deployment of such actions depends on the degree of appropriation and of responsibility assumed by institutions during their execution;
- **Implementation of SIGAS:** SIGAS is a powerful tool for updating of knowledge, management of decision-making information, and dissemination of information at

all levels (from local to regional). Its is of fundamental importance that inputs be updated in each of the countries. The flow of information for deployment of the framework for subsequent execution of SAP actions is dependant upon the SIGAS. Its implementation is dependant upon establishment of the respective quadric-partite SIGAS Committee, that took place during the Immediate Implementation Stage, under the responsibility of Argentina.

- **Implementation of the Monitoring Network:** formation and establishment of the Monitoring and Models Committee of the four countries, under the responsibility of Brazil, will be the key factor for facilitating necessary tasks for conducting of sampling and analysis within the monitoring network established under the PGAS. As the SIGAS will then be in full operation, all information generated will be incorporated into its database and will be accessible to the countries by means of the Information System.
- **Implementation of local management structures:** having recognized the Local Management Support Committees for the GAS, it becomes possible to advance firmly on themes relating to groundwater management on the appropriate local scales. Support resulting from the reinforcement of Local Committees of the Pilot Projects and the strengthening of their capacities, with a clear definition of roles, will contribute to sustainability of actions for resolving specific problems that affect the resource in this and other areas identified as necessary.
- **Lessons learned and their application in other areas and themes coherent with the scale of local management:** this implies having available, at the local, sub-national, national and regional levels, articulated, complementary technical capacities for monitoring of the protection and sustainable use of groundwater.
- **Permanent updating of local mathematical models:** assessments of land use and settlement patterns and of groundwater abstraction scenarios need to be carried out in different zones, using models capable of detecting changes, with a view to providing inputs for management decision-making for sustainable use of the water of the Aquifer.

5.10 DESCRIPTION OF STRATEGIC ACTIONS

The main approaches and strategic actions proposed in the SAP were described in Chapter 4. The aim of this section is to provide details on each of the actions proposed, in accordance with the results of participatory processes in each country and recommendations stemming from the technical work.

The approaches that comprise the strategic actions are as follows:

1. Development of national and sub-national institutional management capacities
2. Operational structure for cooperation
3. Updating and maintenance of SIGAS
4. Implementation and development of the GAS monitoring network and mathematical models
5. Technical capacity building and dissemination of knowledge
6. Development of local groundwater management
7. Support for public participation
8. Development of criteria for sustainable use of the GAS
9. Implementation of technical-scientific programs
10. Production of technical-economic studies
11. Monitoring and evaluation of implementation of the SAP

Proposals for conduct of the **Immediate Implementation Stage** of the SAP enable coordinated execution of most of the approaches, especially those relating to monitoring of existing instruments (1 to 7 and 11). Execution of these approaches is compatible with the international agreements proposed and feasible in the light of financial resources available.

Approaches 8 to 10 require specific and intense monitoring. From the standpoint of regional articulation, such monitoring would require additional expenditure that is as yet not available. The actions proposed could, however, be executed as the countries, with support of the Liaison Unit, allocate their own resources or obtain funding from development agencies. This important challenge marks the transition from the **Immediate Implementation Stage** to the **Future Implementation Stage**. Thus, the document serves as stimulus and orientation.

There follows a description of actions under each of the approaches, emphasizing their regional importance and providing specific details. Matrixes for action, generated in each of the countries, complement this description, and identify relevant players and cost dimensions.

5.10.1 Development of national and sub-national institutional management capacities

The objective is to strengthen GAS management bodies at all levels (local, state/provincial, national and regional) for implementation of management instruments, providing the necessary financial, human and logistical resources. It is proposed that challenges posed by groundwater (specifically of the GAS) be included in national water resources policies of the countries, and that the necessary institutional articulation be stimulated. A description of the institutional context and standards in each country were presented in Chapter 3. In this case, the actions proposed and included in the SAP, generally, are more of a national nature and are presented below:

5.10.1.1 Inclusion of the Gas and its management in national water-resources policies

- **Argentina:** preparation of a National Groundwater Program, as a space for articulation among players involved in the theme and the public, within the framework of the National Federal Plan for Water Resources. To be coordinated by the Under-Secretariat for Water Resources (SSRH), with participation of the Federal Water Council (COHIFE) and the Coastal Water Council (COHILI);
- **Brazil:** articulation of the GAS within the National Water Resources Plan (PNRH) through development of the National Groundwater Plan and State Water Resources Plans, giving priority to permission for drilling and use of wells. Execution of the Program for Implementation

of Integrated Groundwater and Surface Water Management, with participation of the National Water Agency (ANA), taking into account the Multi-Year Plan (PPA) the National Budget (OGU) and the National Water Resources Development Plan (PROÁGUA);

- **Paraguay:** development of the Guarani Aquifer Management Plan and inclusion of the results of the PGAS into implementation of the Water Resources Law (3.239/2007);

Uruguay: adoption of an institutional framework for the GAS at the national level, based on its precursor, the Advisory Group for the Infrabasaltic Guarani Aquifer and the bill of the water resources law (currently before Parliament) which establishes management by hydrographic regions and the functioning of river basin committees. The law provides for incorporation of the GAS in the region of the Uruguay River and for creation of a specific national unit for the Guarani Aquifer.

5.10.1.2 Strengthening of institutional capacities

- **Argentina:** compliance with provincial legislation; maintaining of trained staff and ensuring that they remain employed; implementation of a water register; keeping of a register of wells and of professional well drillers; deployment of licensing for exploitation; updating of authorizations for drilling and technical inspections at all stages of drilling; convergence of strategies and criteria for groundwater management at sub-national levels.
- **Brazil:** maintenance of the State Units and strengthening of capacities for management of the GAS; strengthening the budget and obtaining funding for actions, by tapping sectoral funds for water resources and/or science and technology (at the national and state levels); application of CONAMA Resolution 396/2008; convergence of groundwater management strategies and criteria at sub-national levels.
- **Paraguay:** institutional strengthening of the Secretariat of Environment (SEAM), of municipalities and of Water Councils in groundwater management; development of Integrated Water Resources Management Plans for the GAS; creation of the Water Institute (for groundwater and surface water); reactivation of the Applied Hydrogeology Laboratory of the Faculty of Exact and Natural Sciences of the National University of Asunción (FACEN UNA) providing qualified human resources and the necessary facilities.
- **Uruguay:** adjust existing legal instruments for management of the GAS (adapt the Infrabasaltic Management Plan – define geographical limits of application of the current decree and/or apply the decree, expanding its scope to encompass the entire GAS; analyze prospects for taxation provided for in the Waters Code to GAS management; apply environmental standards to exploitation and management of the GAS); allocate funding from the national budget for the GAS, through the Foreign Affairs Ministry and the Ministry of Housing, Territorial Planning and Environment (MVOTMA).

Dissemination of the technical[1] manuals prepared under the PGAS as practical instruments for capacity building in water resources management at all levels is a common action proposed in the four countries.

5.10.1.3 Institutional articulation

- **Argentina:** creation of a Guarani Interjurisdictional Committee involving representatives of the six Argentine Provinces that overlie the GAS; reinforcement of ties with bodies such as COHIFE and COHILI; integration with the Ministry of Health to coordinate epidemiological studies relating to high arsenic (As) levels in some parts of the GAS;
- **Brazil:** articulation with the Technical Chamber for Groundwater (CTAS/CNRH) and creation of such chambers within the scope of all State Water Resources Councils; standardization of procedures for licensing wells in the GAS region in accordance with environmental regulations; coordination between states to establish common criteria for management instruments; specific coordination with other public institutions directly involved with the GAS, such as the National Institute for Colonization and Land Reform (INCRA), the National Health Foundation (FUNASA), the National Department for Mineral Production (DNPM), and others;
- **Paraguay:** creation of Local Sustainable Development Councils (on themes of territorial planning and land use in coordination with farmers); cooperation agreement between FACEN UNA and SEAM on development of the Nation's groundwater; placing themes relating to the GAS on the agenda of the National Environment Council (CONAM); strengthening of municipal-level management structures, making resources available for planned actions;
- **Uruguay:** strengthening of relations among institutions responsible for groundwater and the GAS; strengthening the current NPEU; development of a strategy for involving Governments of the departments.

Integration of groundwater management with territorial, environmental and regional planning policies (including solid-wastes management) is proposed as a common action for the four countries.

5.10.2 Operational structure for cooperation

The objective of this strategic approach is to bring together into a coherent whole actions for consolidation of operational structures for regional cooperation launched during the Immediate Implementation Stage of the SAP, namely, the Regional Cooperation Council, the National Management Units, the Technical Committees and the Liaison Unit, with a view to implementation of action of the SAP. The actions foreseen are as follows:

5.10.2.1 Maintenance and consolidation of cooperation structures for management of the GAS

- Provide follow up for management instruments developed under the PGAS, maintain

coordination through the national executing agencies, namely: SSRH in Argentina, ANA-SRHU/MMA in Brazil, SEAM in Paraguay and DINASA/DINAMA in Uruguay, with capacities to implement and maintain an executive unit for groundwater; maintain and strengthen an executive unit for groundwater programs; maintain and strengthen the National Management Units; assume coordination and maintain representatives at the respective Technical Committees.

- Recognize or create a regional coordination structure among the four countries that acknowledges the importance and value of the Liaison Unit as a technical space for regional support. Its main functions will be: to monitor and foster, with a balanced technical vision, execution of the SAP; support the countries in the dissemination of information on the GAS; prepare and manage projects for monitoring of agreements among the countries; articulate and provide continuity for specific management instruments such as the SIGAS, the monitoring network, the base map and models, and also the manuals, reports, updating of the website, etc. Such support must necessarily entail allocation of financial contributions and human resources.

5.10.2.2 Implementation and updating of the SAP

Transition from the **Immediate Implementation Stage** to a future institutional and operational framework for execution of the SAP in the medium and long term requires preparation of annual operational plans by the Liaison Unit, under the guidance of the countries. Although the SAP provides the agreed bases for cooperation among the countries, it is not an immutable document: its implementation entails adjustments, amendments and updating.

5.10.2.3 Search for resources and preparation of proposals

This task is essentially a responsibility assumed by the institutions of the Governments of the countries and requires:

- Inclusion of adequate funding for management of groundwater and of the SAG, for the purposes of mutual regional cooperation in the pursuit of national, sub-national and local activities, in national, sub-national and local budgets and of municipal institutions.
- Guide the Liaison Unit, in its technical role as a regional support body, in the preparation of work projects and programs to support the countries with the management of funds for smooth implementation of the SAP in the GAS region.
- Also to guide the Liaison Unit in maintaining technical institutional dialogues with agencies and cooperation organizations on the theme and the relationships of cooperation work with other similar management bodies, informing bodies of the Governments.
- Include these tasks among the functions of the Liaison Unit and provide it with the necessary technical and operational capacities.
- Updating and maintenance of the SIGAS. The SIGAS has potential to become a powerful and effective instrument for dissemination, capacity building and management of the GAS within the countries that share it. Efficient implementation of the SIGAS will facilitate consolidation of scientific and technical exchanges.
- Its installation and the training of personnel for management of the GAS marks the launching of a process, the success of which depends on the following:

5.10.2.4 Operational maintenance of the SIGAS infrastructure:

Functioning of the SIGAS requires trained institutional staff, technical knowledge and maintenance capacities, and updating of teams and programs, in order to make information available to the various nodes of the system taking into account its structure. The current structure has the following architecture: a central node in each country; and subsidiary nodes at the sub-national levels, Pilot Projects, or state bodies responsible for groundwater management. Each central node is responsible for guiding the others and each has the capability to develop geoprocessed products.

Argentina: 1 main node, 8 workstations.
Brazil: 1 main node, 13 workstations.
Paraguay: 1 main node, 3 workstations.
Uruguay: 1 main node, 4 workstations.
Support Node: Liaison Unit.

There are thus a total of four main national nodes (servers), one support node (the Liaison Unit Server) and 28 subsidiary nodes (workstations). Their distribution is described in Table 2. The servers shall be installed in institutions where logistical capacities and human resources are available to ensure functioning of the service 365 days per year. Aside from the nodes installed under the PGAS, the countries decided to install one terminal at the SIGAS coordination center (in Argentina) linked to the SIGAS Coordination Committee, and another at the CPRM in Brazil, where the greatest bandwidth is available for transmission and reception of digital data (CPRM-1Gbps) and where the maps server will be located. Thus, the 'maps service', using a web-based interface shall enable simultaneous access for the maximum number of users.

Maintaining the operational structure of the SIGAS at each node entails:

- Providing minimum support conditions for functioning of the system, especially broadband connection and telephones. Such needs vary depending upon the hierarchy and function of the node;
- Providing minimum inputs to cover expenses for operational staff in charge of operating the node. Such needs vary depending upon the hierarchy and function of the node;
- Define the types and quantity of technicians needed for operating each of the nodes. Specialists responsible for operation of the main nodes will have to be qualified in the field of water resources (emphasis on groundwater).

Inputs for the SIGAS will be supplied by water resources management institutions at the state/provincial and national levels.

Table 2. Distribution and identification of SIGAS terminals and sub-terminals

Country/number	Type	Organization	Acronym
AR – NODE	*Server*	Under–Secretariat of Water Resources (Buenos Aires)	SSRRHH
AR – T1	*Workstation*	Under–Secretariat of Water Resources (Buenos Aires)	SSRRHH
AR – T2	*Workstation*	Corrientes Institute ff Water and Environment (Corrientes)	ICAA
AR – T3	*Workstation*	Department of Vital Resources – Ministry of Ecology, Natural Renewable Resources and Tourism (Misiones)	DRV
AR – T4	*Workstation*	Water Department of the Province of Entre Rios (Entre Rios)	DH
AR – T5	*Workstation*	Special Projects Unit of Apa, Provincial Water Administration (Chaco)	UPE
AR – T6	*Workstation*	Provincial Service for Potable Water and Sanitation (Formosa)	SPAP
AR – T7	*Workstation*	Ministry of Waters, Public Services and Environment (Santa Fé)	MASPMA
AR – T8 Piloto	*Workstation*	Gas Office–Municipality of Concordia (Concordia)	MC
BR – NODE	*Server*	National Water Agency (Brasília)	ANA
BR – T1	*Workstation*	Mineral Resources Research Company (Rio de Janeiro)	CPRM/DEINF/DIINFO
BR – T2	*Workstation*	Secretariat for Water Resources and Urban Environment (Brasília)	SRHU/MMA
BR – T3	*Workstation*	State Secretariat for Environment, Cities, Planning, Science and Technology, Institute for Environment of Mato Grosso do Sul (Campo Grande)	SEMAC-IMASUL
BR – T4	*Workstation*	Minas Gerais Water Management Institute (Belo Horizonte)	IGAM
BR – T5	*Workstation*	Department of Water Resources of the State Secretariat for Environment of Rio Grande do Sul (Porto Alegre)	DRH/SEMA
BR – T6	*Workstation*	Department of Waters and Electric Power (Ribeirão Preto)	DAEE
BR – T7	*Workstation*	Directory for Water Resources – State Secretariat for Sustainable Development (Florianópolis)	DRHI
BR–T8	*Workstation*	National Water Agency (Brasília)	ANA
BR–T9	*Workstation*	Geological Institute (São Paulo)	IG-SMA
BR–T10	*Workstation*	Secretariat of Environment (Cuiabá)	SEMA
BR–T11	*Workstation*	Superintendency for Development of Water Resources and Sanitation (Curitiba)	SUDERHSA
BR–T12	*Workstation*	Secretariat of Environment and Water Resources (Goiânia)	SEMARH
BR–T13 Pilot	*Workstation*	Department of Water and Sewers (Santana do Livramento)	DAE
PY– NODE	*Server*	Secretariat of Environment (Asunción)	SEAM
PY–T1	*Workstation*	Secretariat for Environment (Asunción)	SEAM
PY–T2	*Workstation*	National Environmental Sanitation Service (Asunción)	SENASA
PY–T3 Pilot	*Workstation*	Agrarian Sciences Foundation of Itapúa	FUCAI
UY– NODE	*Server*	Ministry of Housing, Territorial Planning and Environment (Montevideo)	MVOTMA
UY– T1	*Workstation*	National Department for Water and Sanitation (Montevideo)	DINASA
UY– T2	*Workstation*	State Sanitation Works (Montevideo)	OSE
UY– T3 Pilot	*Workstation*	Salto Municipal Superintendency (Salto)	IM-Salto
UY– T4 Pilot	*Workstation*	Rivera Municipal Superintendency (Rivera)	IM-Rivera
GAS – NODE	*Support Point*	Liaison Unit (Montevideo)	UA/GAS

Source: GS/GAS, 2008.

Each will be responsible for the information it provides (data, consistency, etc.) and will enjoy total autonomy. An institution may not modify information under the domain of another. Sub-national institutions are to be integrated with their national server. For their part, national servers will mirror information to the other servers. The system shall continue functioning even if one of the servers goes down. When this server resumes operation, all the information on the others is updated.

5.10.2.5 Support for the SIGAS Committee

Under the leadership of Argentina, which is responsible for coordinating the SIGAS Technical Committee, the national institutions of each country, responsible for the nodes, shall provide support to the Committee, sending information and queries for discussion at its forum or subsequent deliberation by the coordination board. As the meeting place for the persons responsible for water resources systems in each of the countries, the Technical Committee shall provide support for the general coordination and functioning of SIGAS instruments, to accompany issues relating to hardware, software and other structural themes, under the responsibility of Argentina. The SIGAS Technical Committee shall be responsible for:

- Preparing an annual program of seminars and meetings for its members, and proposing themes to be discussed;
- Promote exchanges and technical events, in view of the constant need to develop themes relating to GIS processes and, more specifically, to groundwater. Such capacity building could be conducted by means of seminars for operators of nodes, through contracts or agreements with specialists;
- Seeking solutions for problems of implantation of the SIGAS and making adjustments when necessary;
- Maintenance of compatibility and integration between the SIGAS and the Groundwater Information System (SIAGAS) of the Brazilian Geological Institute (CPRM).

5.10.2.6 Promotion of information flows for the SIGAS

Once the SIGAS architecture has been installed, hydrogeological information generated in the region shall be available in a consistent and organized form. Success of the SIGAS depends upon a continuous flow of information, dissemination of which relies on a strong commitment on the part of national institutions.

- The PGAS collected and produced abundant additional geo-referenced information in the four countries in addition to information on wells already incorporated into the hydrogeological database. This data, which needs to be analyzed and incorporated into the SIGAS, consists of:
  - » 2,500 petroliferous determinations and of petro-fabrication of samples, control points of 3,800 km of geological profiles, and measuring stations of paleocurrents in paleodunes, according to the corresponding final reports;
  - » 140 geophysical-electrical and electromagnetic measuring stations and 1,500 km of gravimetric profiles;
  - » 17 hydrological-hydrometric stations;
  - » 17 rainfall and temperature stations;
  - » 500 coordinates of climatic stations;
  - » Documents with abundant cartography and figures (filing and management in SIGAS still needs to be defined).

Annex 9 provides details on the technical requirements of SIGAS.

5.10.3 Implementation and development of the GAS monitoring network and mathematical models

Unlike surface water flows, groundwater flows are very slow. In surface water, the velocity is usually expressed in meters per second, whereas in aquifers it is expressed in meters per year.

This has many hydrogeological and environmental implications, especially in relation to pollution and monitoring systems. Changes in both availability and quality of groundwater occur over long periods. Nonetheless, if not adequately monitored over relatively long periods, changes may affect significantly large areas without their impacts on the aquifer system as a whole being detected.

Establishment of an adequate Monitoring Network, designed to address potential uses and equipped to exercise control, is thus of importance for management of the aquifer. Location of sampling stations is as relevant as the definition of monitoring parameters, variables and frequencies. Preventive action is thus the main aim in all activities for conservation and groundwater management resources.

Unlike surface water management, groundwater management is hampered by a lack of historical data on water levels, volumes and chemical characteristics. There are no historical and systematic series of data on the GAS. Thus, for protection and adequate management of the aquifer, it is essential that such records be compiled and maintained.

Information obtained by the Monitoring Network and from new boreholes drilled into the GAS shall be incorporated into local and regional mathematical models. In this manner, these models can be permanently updated, so as to generate consistent calculation and valid contributions toward management.

5.10.3.1 Support for the Monitoring Network and Models Committee

Coordination of the Technical Monitoring Network and Models Committee, comprised of academics and representatives of water management institutions in each of the countries, shall be under the responsibility of Brazil. Similarly to the others, this Committee will direct the task of assembling the Monitoring Network, and will follow up on the monitoring and updating of current regional and local mathematical models. The establishment of this Technical Committee will seek to build upon the experience of representatives who performed the similar roles under the PGAS.

Comprised and established by the countries, the Technical Monitoring Network and Models Committee, including the members of the Models Subcommittee, will set an annual agenda of

presential meetings and remote exchange strategies. The Committee will address and resolve all queries and challenges relating to the Monitoring Network and use of models, and will orient actions necessary for enabling operation and maintenance of the Monitoring Network, adjustment and inputting/updating of the models and of the SIGAS.

5.10.3.2 Implementation of the GAS Monitoring Network

The GAS Monitoring Network is based on quantitative and qualitative measurements from 180 pre-selected wells. Approximately 70% of such wells are located in aquifer outcrop zones, but the main wells in confined zones are also monitored. The monitoring system proposed under the encompassed 16 wells in Argentina, 118 in Brazil, 28 in Paraguay and 18 in Uruguay. Sampling intervals and protocols may vary, depending upon the location of the well, the physical characteristics of the GAS, and other land-use considerations in the region.

In the initial implementation stage of the SAP, the proposed network shall be reviewed, based upon existing capacities at the national and subnational levels, so as to take maximum advantage of monitoring efforts carried out by environmental control bodies and water-supply companies.

The main tasks are:

- Drafting of an annual program of seminars and meetings for Committee members and selection of themes to be discussed.
- Establish ties and work together with the National Coordination Unit in each country and the Liaison Unit. Negotiate with institutions that monitor wells or conduct sampling and testing of the waters of the GAS, so that their information can be assimilated by the GAS Monitoring Network.
- Provide technical support in the event that the network requires further enhancement, in terms of selection of wells, sample protocols or intervals.
- Establish a quality-control mechanism for samples, to ensure consistency and parameters for hydrochemical comparison throughout the Monitoring Network.

Monitoring activities require partial agreements between countries, for example, to facilitate the dispatch of samples and technical equipment across national borders. This implies a need to seek support from the ministries of foreing affairs and customs authorities, in order to cut red tape.

Annex 10 presents technical details on the regional Monitoring Network.

In the PGAS Pilot Project areas, local Monitoring Networks are to be based on existing analytical and institutional facilities(see chapter 6 on the Pilot Projects).

5.10.3.3 Use of the GAS Regional Model

The regional flow model of the GAS is capable of responding to issues on regional scales. It can, for example, detect broad trends and possible consequences to the flow network, resulting from intense abstractions or significant changes in land use and settlement patterns in large areas within the GAS region. Its application to GAS management practices enables continual improvement of the conceptual model developed under the PGAS and evaluation of macro-tendencies. It is therefore a continuous action that requires monitoring by specialists and represents an excellent opportunity for continuous capacity building and new human resources development. There follows a set of important and necessary actions relating to use and updating of models:

(i) continuous capacity building: courses and capacity building on themes relating to modeling, for national and local technicians, in the form of consulting contracts or agreements with academic institutions.

(ii) consistency analyses and incorporation of new data: the consistency of new hydrogeological data and its incorporation into the model is assessed, in the form of consulting contracts or agreements with academic institutions.

(iii) development of scenarios: this management action brings modeling technicians together with those responsible for water-resources management and territorial planning; to be carried out under specific individual contracts for modelers.

(iv) evaluation of results and management seminars: to be carried out through meetings for discussion of the results of modeling and practical implementation of management measures.

5.10.3.4 Use of the model in Pilot Projects

The PGAS offered the management bodies responsible for groundwater and the pilot-project areas four mathematical models to be used as local management tools, one for each Pilot Project. Like the GAS regional model, these shall be constantly updated so that they can be employed as effective management instruments, and this will require human resources and new hydrogeological information. For use and enhancement of these models, the following tasks are suggested:

- Appropriation of models by local personnel, duly assisted by technical staff of the Local Support Committees of the Pilot Projects (CLAPs).
- Incorporation of new information into the structure and geometry of the model and subsequent updating.
- Organization of meetings for definition of management scenarios and evaluation of results estimated by the models.
- Coordination of information generated, organization of results and dissemination among the countries and other committees.
- The models face challenges in each Pilot Project:
  - » Concordia-Salto Pilot Project: development of sustainable exploitation criteria, incorporation of the theme of fresh/salt water contact[1] into models, and holding of discussion and evaluation seminars;
  - » Ribeirão Preto Pilot Project: evaluation of GAS exploitation scenarios, support for development of criteria for use and protection of the GAS (models as management tools) and holding of discussion and evaluation seminars;

1 Natural processes of mixing with deep salt water may become a serious problem if exploitation is not planned properly to avoid spatial concentrations of abstractions and intense and concentrated pumping. This can induce salinity in parts of the aquifer that currently have good qualities for local use and that could become spoiled, owing to mixtures from overexploitation.

» Santana do Livramento-Rivera Pilot Project: evaluation of GAS exploitation scenarios, support for development of criteria for use and protection of the GAS (models as management tools) and holding of discussion and evaluation seminars;
» Itapúa Pilot Project: use of management models for GAS, territorial planning, implementation of the new Water Resources Law, evaluation of possible scenarios for use of the GAS with identification of appropriate areas for exploitation, protection, and holding of discussion and evaluation seminars.

Annex 11 presents technical recommendations for enhancing regional models and of the Pilot Project zones.

5.10.4 Technical capacity building and dissemination of knowledge

This strategic approach of the SAP has been one of the preeminent concerns since the recommendations of the TDA under the PGAS. The technical limitations of the countries for taking on management of groundwater, and their efforts to overcome weaknesses are linked to financial constraints and political will to follow up on activities executed under the Project , with a view to improving management capacities of institutions and social organizations involved in the various levels of activity. Efforts need to focus upon ample dissemination of information and capacity building for managers.

5.10.4.1 Support for the Capacity Building and Dissemination Committee

Paraguay is in charge of coordination of the Technical Capacity Building and Dissemination Committee. To ensure continuity of actions, it is proposed that the original committee organized under the PGAS with support from the communications areas of institutions responsible for water resources management policies in each country be strengthened. The working relationship established with the Environmental Journalists Network during execution of the PGAS needs to be maintained by the Committee, so as to secure support for dissemination of precise and reliable information.

For capacity building, one approach would be to cultivate ties with institutions that provide training in water resources management (such as those that participated in the Pilot Projects within the context of CapNet). In this first stage of the SAP, the Technical Committee will base its efforts on existing capacities at the various bodies in the countries, not only at the national level but also at the sub-national and local levels, in order to make use of capacity building strategies achieved under the PGAS. The starting point for dissemination shall be all the available technical reports and publications produced under the PGAS.

The main tasks foreseen are:

- Proposal of themes for capacity building and develop an annual program of seminars and meetings for participants.
- Serve as a link between countries and the Liaison Unit, developing strategies for capacity building and dissemination to be assumed by the national and sub-national bodies within the context of their activities.

5.10.4.2 Capacity building

In order to develop capacities for groundwater management in general, and for the management of GAS in particular, the first task identified is the formulation of national state/provincial and department/municipal strategies for appropriating scientific-technical knowledge generated under the PGAS. The objective is to enable management bodies to assimilate knowledge acquired under the PGAS as a tool for strengthening their actions, developing capacities, and progressively applying effective management of groundwater. The most immediate tasks entail:

- Systematic capacity building for journalists, not restricted to those that specialize in environmental themes, through associations and networks.
- Inclusion of the theme of groundwater in the study plans of trainers.
- Training of community leaders through environmental education programs that refer to the GAS.
- Preparation of a manual on best practices for design, operation and maintenance of wells.

5.10.4.3 Dissemination of information

This strategic approach of the SAP brings together actions targeted at using instruments for communication and proceeding with dissemination of materials, developed under the PGAS, with emphasis on the website, kits of educational materials developed under projects of the Guarani Citizenship Fund, the video and TV spot, publications, manuals, technical reports for dissemination of knowledge, the SAP, etc. It is intended that:

- Instruments for dissemination developed under the PGAS continue to be used for building public awareness in general for management of the GAS and in the pilot areas.
- Results achieved through expanded dissemination of knowledge be converted into advocacy to influence decision makers;
- At the regional level, mechanisms be developed whereby the countries can share knowledge produced.

Thus, the SAP executing agencies shall receive technical support and public support that will facilitate incorporation the theme of the GAS into their respective communications plans (stressing its importance and fostering measures for rational water use).

The Technical Capacity Building and Dissemination Committee will facilitate exchanges of knowledge and information in the region, through agreements with the National Coordinators and the Liaison Unit.

5.10.4.4 Promote Continuity of the Guarani Citizenship Fund

As with the Guarani Guarani Universities Fund, follow up of the Guarani Citizenship Fund was considered worthy of continuity under the SAP. With a view to enhancing its scope, the following measures shall be pursued:

- Use the Liaison Unit to facilitate contacts/ exchanges between institutions benefited by the Fund and local management bodies and those participating in institutional agreements relating to the SAP.
- Based upon previous experience, establishment of an ad-hoc Specialist Advisory Committee to provide support in the selection of projects from organizations of civil society, comprised of representatives of the countries involved, proved indispensible.
- Adapt mechanisms and current specific regulations in order to enable a distinction between small NGOs (still in the process of being established) and more experienced and consolidated NGOs.
- Themes shall be in accordance with the management and dissemination needs of the countries. Strengthening of local natural-resources management capacities, gender perspectives, and indigenous affairs, with emphasis on groundwater resources of the GAS, are among the main themes that need to be addressed.
- Availability of financial resources to support selected projects, with special attention to their sustainability.
- The definition of profiles of eligible institutions needs to be enhanced, giving priority and encouragement to participation of NGOs with clear strategies for working with local populations.
- Monitoring of implementation of projects approved by the Fund, from a technical and financial standpoint is dependant upon the availability of time and resources on the part of the Liaison Unit, and shall encompass monitoring missions to the countries; participation of representatives of the institutions benefited; fostering of knowledge by the National Committees (NCs), and exchanges of experiences and spaces for clarification of doubts.

5.10.5 Development of local groundwater management

Management for protection and sustainable use of aquifer systems relies mainly on interventions carried out by means of drilling boreholes, and attention to human settlement and activities within replenishment areas. One of the lessons learned under the PGAS was that, as the local dimension is of key importance for management, it is necessary to count on local organizations. This strategic approach underscores the challenge of acknowledging the existence and role of Local GAS Management Support Committees in the Pilot Projects, and seeks to replicate their experiences.

5.10.5.1 Acknowledgement of the institutional status of Local Management Support Committees

Though progress has been achieved in terms of consolidating the legal status of Committees established within the scope of the Pilot Projects, it is now proposed that such acknowledgement be broadened through national and sub-national standards, so as to enable enhancement of the institutional status of Local GAS Management Support Committees (Chapter 6 provides details on institutional and legal aspects). The proposals for each country are as follows:

- **Argentina:** support of the Secretariat of Planning and Public Works to the two (national and bi-national) local levels of the Concórdia–Salto Pilot Project, through an agreement with the Ministry of Foreing Affairs, the Decentralized Entity for Sanitary Works of the Municipality, and the Department of Hydraulics of the Province of Entre Ríos.
- **Brazil:** support to the Ribeirão Preto Pilot Project through the Regional Office of the Department of Water and Electric Power of São Paulo (DAEE-SP), the Rio Pardo Basin Committee (CBH Pardo) and the Municipal Administration of Ribeirão Preto.
- **Paraguay:** establishment of technical offices for water in the municipalities; joint work with municipalities on a local legal framework, and strengthening of Water Councils;
- **Uruguay:** support for Pilot Projects through the new Regional Office of the National Water and Sanitation Board (DINASA) in Salto, and attention to local aspects of management of the GAS under the new Water Law.

5.10.5.2 Implementation and review of PALPs/SAP

Development of the Local Pilot Action Plans (PALPs) predated the SAP and was one of its main inputs. The PALP proposals included approaches for actions to be pursued in each of the Pilot Projects. Based upon these contributions, the SAP addresses each of the PALPs in greater depth and adds detail for their implementation. Key actions for implementation of the PALPs include:

- Integration of groundwater management with urban and rural land management (master plans).
- Promotion of practices for water reuse in regions with high levels of water consumption.
- Dissemination of all technical manuals developed under the PGAS in areas with local management initiatives.

5.10.5.3 Development of the local management promotion group

Lessons learned, best practices, and prospects for strengthening of local groundwater management capacities are the object of consideration by the Local Management Support Group (Section 5.3). The Liaison Unit will coordinate and assume responsibility for implementation of the actions proposed by the Group.

5.10.5.4 Characterization of potential transboundary Pilot Project areas

As part of the SAP preparation process and in recognition of the importance of providing support for local groundwater management, the countries identified new areas of the GAS that require special attention. In these areas, the countries propose to conduct preliminary diagnoses to assess needs and feasibility. Specific examination of the following areas is planned:

- **Argentina:** it is proposed that greater integration be pursued between the Itapúa Pilot Project in Paraguay and the adjacent zone

of the Province of Misiones in Argentina. The aim is to make use of information and experiences generated in Paraguay and to extend analysis and potential actions of the Pilot Program across the border with Argentina, thereby stimulating the advance of knowledge in this region (geophysics and drilling).

- **Uruguay and Brazil:** the two countries propose to evaluate application of experiences of PGAS Pilot Projects in the border areas of Artigas (UY) - Quaraí (BR). This area has a history of significant binational cooperation in the field of water resources, including studies carried out under the PGAS.
- **Brazil and Paraguay:** the two countries propose to evaluate application of experiences of PGAS Pilot Projects in the border areas of Ponta Porã (BR) - Pedro Juan Caballero (PY). Management and use of GAS resources in this region was identified as an area for cooperation between the Secretariat of Environment of Paraguay and the Federal Institute for Geociences and Natural Resources (SEAM-BGR) and previous cooperation efforts are underway in this area.
- **Paraguay:** it is proposed that a study of the GAS be conducted in the stretch between Ciudad del Este and Encarnación, also encompassing areas of Brazil and Argentina. The main objectives of the initiative are:
  (i) detailed analyses of the behavior of the GAS, its quality and potential uses;
  (ii) exchanges of experiences in management and strengthening of cooperation ties for local capacity building.

5.10.6 Support for public participation

5.10.6.1 Consolidation of spaces for public participation

Maintain support for public participation in the decision-making process relating to groundwater management and prioritize efforts that lead to raising of environmental and social awareness of the value of groundwater, especially the GAS. This approach is targeted at opportunities opened up under the PGAS, and those foreseen in national/sub-national water resources policies: (NMUs in each of the countries, Local Committees in each of the Pilot Projects, Basin Committees, Technical Chambers for Groundwater, and others).

5.10.6.2 Effective participation of indigenous populations

Meetings were held within the scope of the PGAS in Argentina, Brazil and Paraguay, with indigenous leaders and representatives of national bodies responsible for indigenous affairs[2]. A series of strategic actions targeted at fostering participation of indigenous peoples have been undertaken. Some of these address the entire GAS region, regardless of national borders:

(i) Comply, within the GAS Project, with the Universal Rights of Indigenous Peoples, with free, prior and informed consent; respect the existence of indigenous communities, their habitat, traditional territories and natural resources (especially in the territorial domain of the GAS);
(ii) Encourage use of the GAS Wells Manual in indigenous areas;
(iii) Conduct multidisciplinary evaluations (anthropology, sociology, engineering, architecture) among the indigenous communities, using material and non-material resources (oral history, music, myths, rites and representations) and recording the relation between water (surface water, groundwater and rain) and the indigenous cultures;
(iv) Promote periodic regional meetings/exchanges of experiences in villages, for the exchange of experiences on preservation of natural resources and sustainable development among the indigenous peoples on the GAS.

During meetings with indigenous communities, certain specific regional needs were highlighted, namely:

(v) Creation of national standing committees as spaces for articulation and more effective participation in decision-making on natural resources management, especially water resources, and monitoring of regional initiatives.
  » **Argentina:** creation of national standing committees with indigenous representatives, with a view to ensuring maintenance of autonomy and biodiversity of their lands, respecting their cosmological views and culture.
  » **Brazil:** a) creation of national standing committees comprising indigenous leaders, representatives of National Indian Foundation (FUNAI), the National Health Foundation (FUNASA), the Ministry of the Environment (MMA) and the Federal Public Prosecutor's Office (MPU); b) creation of a Technical Chamber on water resources in indigenous lands within the scope of the National Water Resources Council (CNRH) and, at the regional level, the State Water Resources Councils; c) approval of the right of indigenous people to participate in these councils.
  » **Paraguay:** a) creation of national standing committees made up of leaders of indigenous communities, representatives of the Secretariat of Environment (SEAM), the National Indigenous Institute (INDI), and the Ministries of Culture, of Agriculture, of Education, of Environment and of Health; b) holding of decentralized meetings (in indigenous communities) with SEAM to discuss provisions of the new Water Resources Law.
(vi) Capacity building and development of communication instruments; leadership

2 I – Meeting with indigenous peoples that live in Argentina and whose territory extends over the Guarani Aquifer System (GAS). Theme: "Live well and conserve the balance of nature". Held on June 2 and 3, 2008, in the Ojo de Água, Concepción da Sierra and Communities in the Province of Misiones, with 119 participants. The organizers were: PGAS, Under-Secretariat of Water Resources of the Federal Ministry of Planning, Public Investment and Services, Department of Vital Resources of the Ministry of Ecology, Natural Renewable Resources and Tourism of the Province of Misiones, Department of Guarani Affairs of the Ministry of Human Rights of the Province of Misiones, Council of Elders, Spiritual Guides and the Council of Caciques of the Mbya Guarani Nation, with support of the National Institute for Indigenous Affairs (INAI).
II – Meetings with indigenous peoples who live in Brazil and whose territory overlies the Guarani Aquifer System (GAS). Theme: "Water (paruda, póbo, e, magã, goió, munhâm, 'pin, úne, â, hõñe, ngoyo-ma, uni) to drink, feed, cherish, use, preserve, last, bring good health..." Held on May 29 and 30, 2008 in the Auditorium of the Museum of Contemporary Art (Marco), Parque das Nações, - Campo Grande (MS), with 36 participants. Organized by: PGAS, Secretariat for Water Resources and the Urban Environment of the Ministry of Environment (SRH/MMA), with support from the National Indian Foundation (FUNAI).
III – Meeting with indigenous peoples in Paraguay whose territory overlies the Guarani Aquifer System (GAS). Theme: "groundwater, life that comes from deep in the ground". Held on March 28, 2008, at the Patio of the Secretariat of Environment (SEAM), Asuncion, Paraguay, with 59 participants. Organized by: PGAS- General Directory for Protection and Conservation of Water Resources (DGPCRH), Secretariat of Environment (SEAM), with support from the Paraguayan Indigenous Institute (INDI) and the National Culture Secretariat.

development and sharing of technical knowledge on the GAS and natural resources in general.

» **Argentina:** a) produce capacity building material for indigenous groups; b) train and contract representatives of indigenous peoples for supervision and protection of forestry parks in the GAS area;
» **Brazil:** a) produce training material for indigenous groups and adapt educational content on the GAS for use in indigenous schools, through contacts with the Ministry of Education (MEC); b) stimulate training of indigenous forestry technicians.
» **Paraguay:** a) produce training materials for indigenous groups; b) translate the new Water Resources Law into the Guarani language;

(vii) Technical activities – assess the quality and quantity of groundwater in indigenous lands, and provide incentives for best practices for drilling, with the greatest possible involvement of local people.

» **Argentina:** monitoring of GAS water quality in wells on indigenous lands, with participation of the local community;
» **Brazil:** a) Bill of Law to allow exploitation of mineral water by the indigenous population; b) monitoring and maintenance of tube wells drilled in the GAS on indigenous lands; c) development of compensatory mechanisms to enhance the quality of indigenous lands (non-degrading activities), through implementation of environmental projects (e.g. reforestation of riverbanks with native species).
» **Paraguay:** a) drill new wells to supply indigenous areas; b) promote mechanisms for monitoring construction of wells in indigenous communities; c) deploy GAS conservation mechanisms in vulnerable indigenous areas to protect their land tenure rights (e.g. advance of soybean agribusiness).

5.10.7 Development of criteria for sustainable use of the GAS

Based on enhancements in understanding of the geometry and dynamics of the GAS (Chapter 2) it is proposed that the strategies for sustainable use be developed in accordance with the zoning proposal for the GAS: in outcrop zones (ZA); in semi-confined zones (ZC), and in highly-confined zones (ZFC) of the aquifer. In each of these zones, the GAS presents significant hydrodynamic and hydrochemical variations, and is under varying degrees of land-use and settlement pressure.

For management of the GAS, management bodies at both the national and sub-national levels need to have objective and appropriate technical criteria for disciplining ever-increasing demands for water, while safeguarding preservation of the GAS. This strategic SAP approach highlights the need for regional and sub-regional methodological coordination actions, technical exchanges, and joint dissemination of technical information. In view of the importance of these actions, in each country, the federal/national and state/provincial authorities should ensure that they are addressed by the appropriate management bodies. These actions encompass:

5.10.7.1 Specific strategies for outcrop zones (ZA)

Replenishment areas of the GAS (considering that some outcrop areas may also be discharge areas) are among the most vulnerable to surface pollution. They often coincide with areas of settlement and intense urban, industrial or agricultural land use. This places the aquifer under considerable pressure, owing to growing demand for water and potential sources of pollution. These actions encompass the following aspects:

- Mapping of GAS outcrop areas (on a scale appropriate for local management), evaluation and mapping of vulnerabilities, identification of potential sources of point or non-point pollution, and development of criteria for land use and settlement, protection and use of the GAS with emphasis on replenishment zones.
- Drafting of guidelines for establishment of protection perimeters for wells and parameters for exploitation in unconfined-aquifer areas: adequate procedures for building wells; incorporation of groundwater and of the GAS, into urban and rural land-use and settlement criteria. With respect to urban areas: control of potential pollution sources, of wells, and of soil permeability. With respect to rural areas: evaluation of natural vulnerability, capacity for agricultural use, and agricultural production models.
- Greater control over large-scale GAS water users, holding them accountable for systematic generation of data on water levels, volumes abstracted, and water quality.

Among the legacies of the PGAS are guidelines for evaluation of protection perimeters, of vulnerability to pollution, and of risks to wells and aquifers, that should be disseminated.

5.10.7.2 Specific strategies for Semi-Confined (ZC) and Highly-Confined Zones (ZFC)

The semi-confined and highly-confined zones of the GAS encompass a major portion of the area of the aquifer, and their behavior is quite distinct from that of the outcrop zones. Due to layers of overlying basalt, from the standpoint of their exposure to surface pollution, these zones are naturally better protected. However, their replenishment is subject to limitations. Building upon information generated under the PGAS, the countries will continue to expand their knowledge and develop rules for management of these zones of the GAS.

For these zones it is necessary to obtain reliable estimates of groundwater abstraction volumes, at specific points and at the regional level, while at the same time ensuring the maintenance of reasonable potentiometric levels and the natural quality of the water. It is proposed that technical guidelines be developed to ensure sustainable use of water from confined and semi-confined areas of the GAS. Management bodies should exercise greater control over large-scale users of GAS water from confined zones. Such users should be held accountable for systematic generation of data on water levels, volumes abstracted, and water quality.

5.10.8 Implementation of technical and scientific programs

Though many characteristics of the GAS remain uniform over a vast area, certain situations stemming from its geometry, dynamics,

hydraulic relationships, structures, and pressure of use vary considerably from one location or region to another. During execution of the PGAS, much emphasis was attributed to studies on the characterization of potential transboundary flows, which led to development of Pilot Projects and general enhancement of regional knowledge on the GAS.

During the SAP implementation stage, building upon experiences of the Pilot Projects and conceptual regional models, efforts are focused upon enhancing knowledge on those areas that present the greatest complexity. This strategic approach comprises a series of actions of a thematic nature or that expand knowledge on specific regions and localities. Implementation of these actions is linked to:

(i) a new call for proposals for research initiatives under the Guarani Guarani Universities Fund;
(ii) current or proposed national and sub-national development programs;
(iii) a proposal to cooperation agencies, with the support of the Liaison Unit.

Annex 12 presents complementary hydrogeological and hydrochemical recommendations compiled from recommendations contained in PGAS studies.

5.10.8.1 Generation of data in specific areas of the GAS

This action entails characterization of the various zones of the GAS. Data of this kind can not be circumscribed by national borders, but must, rather, encompass the entire area of the GAS. Both the scarcity of information and the economic and environmental importance of the GAS justify pursuit of the following actions:

- **Argentina:** a) adjust the western limit of the GAS and regional/sub-regional fresh/salt water interfaces; b) foster execution of local studies and drillings to expand existing geological and geophysical knowledge; c) incorporate new geophysical information acquired in Misiones, Formosa, and other Provinces.
- **Brazil:** a) better define hydrogeological conditions at the northeastern limit of the GAS in the States of Goiás and Minas Gerais; b) expand knowledge on the GAS in the regions of Serra do Maracaju and in the municipality of São Gabriel do Oeste in the State of Mato Grosso do Sul; c) study isolated occurrences of the GAS at Chapada dos Guimarães in the State of Mato Grosso; d) evaluate behavior of the GAS in the State of Paraná with emphasis on the town of Londrina (an important regional economic hub).
- **Paraguay:** a) take electromagnetic soundings and generate additional lithological information; b) make use of information generated by soundings within the framework of mineral research in areas that coincide with the GAS.
- **Uruguay:** conduct deeper studies of the central confined and semi-confined zone of the GAS between Rivera and Salto and local water supply capacity.

5.10.8.2 Hydraulic relationships between the GAS andadjacent aquifers

In certain zones, the hydraulic relationships between the GAS and other aquifers are often highly complex and imperceptible on a regional scale. From the local groundwater-management standpoint, however, they are of importance and require specific studies. Such relationships share common aspects that occur in various areas in the four countries. Targeted research has given rise to a series of lessons learned, in technological and methodological fields, that offer ample possibilities for replication.

In the four countries basalt strata overlie the sandstones of the GAS. Under certain conditions, varying degrees of hydraulic and hydrochemical interactions, which are not yet totally understood, occur at this interface. They also occur between the GAS and more recent aquifers, e.g., the Bauru Formation aquifer in Brazil, and the underlying rocks predominantly of paleozoic or permo-triassic origin that usually have poorer water quality, as in the case of the confined GAS region in the Province of Entre Ríos, Argentina.

It is suggested that regional initiatives be pursued for increasing knowledge on the aquifer formed by intrusive rocks overlying the GAS. This suggestion could be adopted by the Liaison Unit and the countries in their draft proposals.

5.10.8.3 Relevanthy drochemical aspects

In some zones of the GAS there are restrictions for certain uses of its waters (see Chapter 2) and in some areas the water is undrinkable. Such restrictions are due to natural characteristics of the water that have not as yet been fully explained. Definition of these characteristics is one of the main objectives of actions by the countries.

The main theme for Argentina and Uruguay is to continue assessing the high levels of salt in thermal and non-thermal waters, and also traces of arsenic (As) and other ions in confined areas of the GAS on the coastal strip. In Brazil and Paraguay, hydrodynamic studies need to be intensified in areas where the water presents fluoride anomalies (e.g., in the Brazilian States of Rio Grande do Sul, Santa Catarina, and Paraná).

All the countries are concerned with controlling and avoiding contaminants that jeopardize natural quality and pose risks to the population. This implies continuing efforts to expand knowledge on the areas of greatest vulnerability and pollution risk, seeking better articulation with bodies responsible for environmental and territorial planning policies, and encouraging control and improvement of the quality of boreholes drilled into the GAS.

5.10.8.4 Integrated water resources management

One of the challenges for integrated water resources management is assessment of the total groundwater and surface water resources available, and quantification of possible connections between them. This task entails an enormous analytical effort, the use of consolidated water balances, and adjustments to management instruments and licensing procedures. One approach is to concentrate on Pilot Basins for which a reasonable amount of hydrological information on surface and

groundwater is available. Such conditions are to be found in basins with GAS water outcroppings, and preferably where information generated by the PGAS on the local or sub-regional level is available (e.g., the Pilot Project areas).

For the conducting of such studies, potential basins have been suggested in each country. In Argentina, it is proposed that a basin that encompasses the GAS outcrop area of Meseta Mercedina in the Province of Corrientes be selected. In Paraguay, the Arroyo Capiibary River Basin presents the best potential area of reference, since it is already encompassed by the area of the Itapúa Pilot Project. The transboundary Cuareim/ Quaraí River Basin on the borders of Uruguay and Brazil is also a good potential reference area, in that is covered by a specific treaty, recent hydrological studies, and encompasses a GAS outcrop area and zones studied under projects supported by the Guarani Guarani Universities Fund. In Uruguay, the Arroyo Tacuarembó Chico River Basin, since it contains a GAS outcrop area and intense agricultural, livestock and forestry use, offers ideal conditions for the purposes of this study.

5.10.8.5 Relationship between the GAS and protected areas

GAS outcrop areas that perform replenishment functions are highly vulnerable and should be treated as a priority, in terms of environmental and biodiversity protection. The need to protect GAS replenishment areas is closely associated with other environmental protections initiatives, such as biodiversity protection areas, ecological corridors, protection of headwaters, etc. Synergies between different initiatives help consolidate the legal-institutional process and facilitate acceptance on the part of the public.

Under this approach, it is proposed that an ecological protection corridor be created, covering a large swathe of GAS outcrop areas, linking Lumarejo and Quebradas in the north of Uruguay to the Ibuirapuitã Reserve in Brazil. Another example is the region of the Miranda River Basin, between Brazil and Paraguay. Yet another proposal for development of an environmental protection corridor linking the Pantanal to Itaipu and Salto Grande has been suggested, in view of its geographic overlapping with the GAS.

5.10.8.6 The GAS and agricultural and forestry activities

In recent decades in certain zones of the GAS region there have been great changes in land-use patterns with, on the one hand, deforestation of native vegetation as a consequence of the agricultural expansion and, on the other, plantation of forests. The countries therefore have an interest in obtaining knowledge on impacts of such activities in terms of the dynamics and volumes of replenishment and the quality of water available, especially in outcrop areas with a predominance of sandy soils. It is particularly important to observe that such land use changes entail agricultural practices that are highly dependant upon the use of agricultural chemicals.

Furthermore, the has been an increasing demand for environmental certification of various agriculture and livestock systems, and this entails deeper knowledge of how products affect different natural contexts, including GAS outcrop areas.

In view of burgeoning demand for water from users in the agricultural and forestry sectors and the economic benefits accruing from irrigation and rural water-supply, complementary studies specifically targeted at the GAS are needed. The focus should be on areas of current agricultural and forestry development, and should take into account future expansion of such activities into more vulnerable zones. Of particular interest are areas in eastern Paraguay and on the western borders of Brazil, where soybean and sugarcane production is currently expanding. Paraguay is seeking support for preparation of assessments of current agrichemical and fertilizer use in the intensive agricultural region of Itapúa, including the drilling of monitoring wells in different agricultural-production areas within the scope of the Itapúa Pilot Project.

This actions proposed under this strategic approach of the SAP call for development of thematic Pilot Projects and for exchanges of studies and information already available. Under the PGAS a guide was prepared for identification of impacts of forestry projects on the water balance and water quality of the Guarani Aquifer.

5.10.8.7 Ensuring continuity of the Guarani Guarani Universities Fund

For continuity of the Guarani Guarani Universities Fund (see Annex 13) the Liaison Unit must have the technical capacity to prepare an operational plan and monitor its actions. The alternative would be to make use of existing institutional agreements and support mechanisms for academic research institutions in the countries, such as the CONICET[3] , CONACYT[4], CNPq and the state-level FAPs, with a view to establishing a specific line of project financing for fostering knowledge and management of the GAS.

In either case, the possibility of obtaining national funding from the budgets of these institutions to defray specific research initiatives targeted at the GAS can and should be the object of negotiations within the scope of the SAP. This Fund has approved bylaws and administrative manuals, and could be transformed into a package of attractive proposals worthy of funding from development agencies.

5.10.8.8 The GAS and climate change

In accordance with climate-change forecasts and the application of different scenarios to the GAS region, average rainfall levels and their distribution throughout the year, and higher average temperatures and rates of evaporation are likely to affect replenishment and determine increases in demand for GAS water and, consequently, pressure upon the aquifer, particularly when coupled with the changes in land use patterns and agricultural expansion referred to in the previous section. On the other hand, the GAS must be regarded as an

3 National Council for Scientific and Technical Research -Argentina and Uruguay.
4 National Council for Science and Technology -Paraguay.

alternative for water supply, given that its waters are naturally protected from the effects of drought and flooding.

Studies at the regional and river-basin level are needed to examine alternatives and scenarios for regions where land-use changes are placing greatest pressure on the Aquifer, bearing in mind the variety of impacts that climate-change phenomena are likely to have in different zones of the GAS.

In this regard, climate and hydrology studies, funded by the GEF, carried out in the La Plata Basin are of particular relevance.

5.10.9 Preparation of technical and economic studies

The GAS comprises reserves of water which, if managed in a rational and balanced manner, could safeguard water security (see the section on hydrogeology in Chapter 2) and is thus of key importance for the social and economic development of the nations that overlie it. Socioeconomic studies carried out under the PGAS in the Pilot Project areas have shown that demand for consumptive and non-consumptive uses of surface water is undergoing exponential growth, thus setting a scenario of increasing pressure on the Aquifer while, at the same time, such pressures are increasing as a consequence of the effects of climate change.

More in-depth studies are needed on the use and economic value of GAS water. This approach seeks to provide support for the countries by introducing the concept of water as an economic variable in discussions on current and future strategies for use of waters of the GAS. Its main actions are:

5.10.9.1 Socioeconomic overview of regions that comprise the GAS

Overall knowledge of the socioeconomic realities of the GAS region is a prerequisite for formulation of public policies and for planning of interventions relating to use of the water of the GAS.

The context of implementation of the SAP encompasses proposals for consistent studies of social and economic factors both for the region and for particular local spaces. Such proposed studies consist of:

- Detailing of regional characteristics, location, territorial division, physical and geographical aspects.
- Analysis of regional infrastructure relating to basic sanitation (especially in vulnerable zones of the GAS), power sources, communications and transport services relating to groundwater resources.
- Demographic and human-development analysis, housing, health, leisure and tourism, in relation to demand for water and pressure on the GAS, especially in zones and basins where problems of vulnerability have been detected in relation to use of aquifers in general and of the GAS in particular.
- Economic analysis of activities that are the driving forces for development, regional distribution of Gross Domestic Product (GDP), economic determination of land use, economic dynamics of sectors such as agriculture, livestock, and industry, encompassing the entire range of intersectoral relations in which water is involved.

5.10.9.2 Conduct studies on services and on economic value of uses of the GAS

Three instruments are usually applied to the GAS:

(i) cost-benefit analyses of GAS use;
(ii) water-use charge price models for waters of the GAS; and
(iii) input-output and economic-impact analyses on production values and use of GAS water.

The use of economic instruments for guiding management and protection of groundwater is inseparable from the theme of water use charges. This is a common feature of all legal frameworks for water resources management in the countries that overlie the GAS.

Price formation of charges for the use of GAS water constitutes a management instrument, as the following proposed actions make clear:

- Managing demand, influencing decisions on the location of economic activities that use water resources.
- Redistribution of social costs, applying different charges for different categories of use.
- Fostering investment for studies, projects, interventions and engineering works.
- Incorporating social and environmental dimensions into integrated management.

5.10.9.3 Evaluation of current and future use scenarios

This strategic approach aims to evaluate current activities that entail use of water from the GAS and projected future groundwater use, so as to identify those that have the greatest impact on the Aquifer. It entails a qualitative and quantitative assessment of each of the zones that comprise the GAS, with special emphasis on regions considered economic development hubs.

Such activities are closely associated with actions that guide sustainable use of the GAS (Section 8). Preparatory work on development of criteria for ensuring rational exploitation of the GAS is of special interest to Argentina. Brazil is particularly interested in obtaining further details on GAS outcrop zones. Paraguay wants to develop criteria for sustainable use of the GAS in areas of agricultural production, with a view to protecting, conserving and restoring ecosystems. Uruguay aims to expand potable water supply and sanitation coverage for populations living in areas overlying the GAS.

5.10.9.4 Conduct deeper studies on thermal uses of the GAS

Essentially, tourism is what leads to economic exploitation of GAS geothermal resources.

Most development of geothermal resources has occurred along the Uruguay River in the area encompassed by the Concordia-Salto Pilot Project which straddles the border between Argentina and Uruguay. Experience accumulated under the PGAS offers significant recommendations for application in all zones with geothermal potential within the GAS region.

A second zone with geothermal potential lies to the north of the Uruguay River, on the border of the Brazilian States of Rio Grande do Sul and Santa Catarina. Geothermal potential increases in

the central portion of the GAS Geological Basin in Brazil, in the area known as the Central Channel *(Calha Central)*. In this zone a few geothermal tourism facilities are to be found.

In order to ensure environmental sustainability and efficient exploitation of the economic potential of geothermal resources of the GAS, certain challenges must be addressed. The following actions are recommended.

- Improve knowledge on new uses of geothermal resources in zones of the GAS where they are already being exploited, and national and local capacities for ensuring sustainable management of abstractions and of thermal wells. In view of their strategic importance, stricter controls and monitoring of exploitation of GAS geothermal wells should be implemented immediately, in line with current standards imposed by national water-resources management bodies. It is imperative that adequate equipment be installed in all thermal wells to monitor such parameters as pressure, temperature, and volumes abstracted, at the required intervals. Collection and processing of information so produced needs to be carried out using adequate instruments, to serve as inputs for the SIGAS. It is proposed that estimates of future scenarios be based upon reliable information, generated by methodical monitoring, through systematic collection and analysis of data on existing wells.
- Stimulate and deploy concrete alternatives for reuse of thermal water. Use of thermal water for recreational purposes is not classified as a 'consumptive use' though it generates volumes of effluents of the same order of magnitude as the volumes abstracted from wells[5]. Territorial and tourist-development planning should seek coordination with other activities that reuse water, and economic incentives should be offered to stimulate such reuse. Given the scale of the engineering works that such reuse would entail, participation of the private sector should be encouraged, as well as that of municipal, national and sub-national authorities responsible for tourism development. Institutional standards in each country should seek to create an environment for fostering sustainable use of GAS thermal water and efficient utilization of effluent water, in the light of knowledge generated. Policies for fostering reuse of water resources should be implemented in areas of thermal exploitation, remembering that in some areas traces of toxic elements such as arsenic have been detected. Though such trace elements do not affect the use of water for bathing, they may make it unfit for certain categories of reuse. It is proposed that pilot experiences and environmental impacts of reuse of thermal effluents in economic activities, such as aquaculture, irrigation, and seasoning of wood, be evaluated.
- Seek technically and environmentally acceptable solutions for final disposal of effluents. This theme, proposed by representatives of Argentina, is considered to be of relevance to all zones of the GAS where geothermal water is exploited, especially in view of high salt content.
- Conduct prospection in zones with as-yet unproven geothermal potential. Evidence from the PGAS shows that, aside from areas where geothermal resources are already being exploited, there are other regions within the GAS where exploitation of such resources could open up new opportunities for economic development. The confined zone of the GAS between Salto and Artigas in Uruguay and the coastal zone of Argentina are prime areas for expanding thermal tourism. In Brazil, there is great interest in conducting more detailed investigation on geothermal potential in the area known as the Central Channel (Calha Central). Greater coordination is needed between thermal development and territorial planning.

5.10.10 Monitoring and evaluation of implementation of the SAP

Monitoring and evaluation of SAP is based on development of a set of indicators for measuring actions carried out under each of its strategic approaches, and is to be carried out with support from the Liaison Unit to the countries and especially their national executing agencies. Table 3 shows the indicators for each respective approach.

Table 3. Monitoring indicators

	Approaches for implementation of SAP	Indicators
1.	Development of national and sub-national institutional management capacities	• Incorporation of the GAS into actions for groundwater within the scope of water resources plans at the national and sub-national levels • Effective use of information on the GAS in the development of management instruments at the national, sub-national and local levels • Examples of successful articulation that have resulted in concrete actions for the GAS
2.	Operational cooperation structure	• Number of meetings of the National Management Units • Appointment of representatives of Technical Committees and number of meetings held • Regulation of these structures within the countries • Constant updating of the SAP • Volume of financial resources deployed for execution of regional tasks under the SAP
3.	Updating and maintenance of SIGAS	• Number of fully functioning nodes • Number of national technicians involved directly with the SIGAS • Number of meetings held by the technical committee • Quantity of information inputted into the SIGAS • Number of accesses
4.	Implementation and development of the GAS monitoring network and mathematical models	• Number of meetings held by the technical committee • Number of sample wells incorporated into the GAS monitoring network

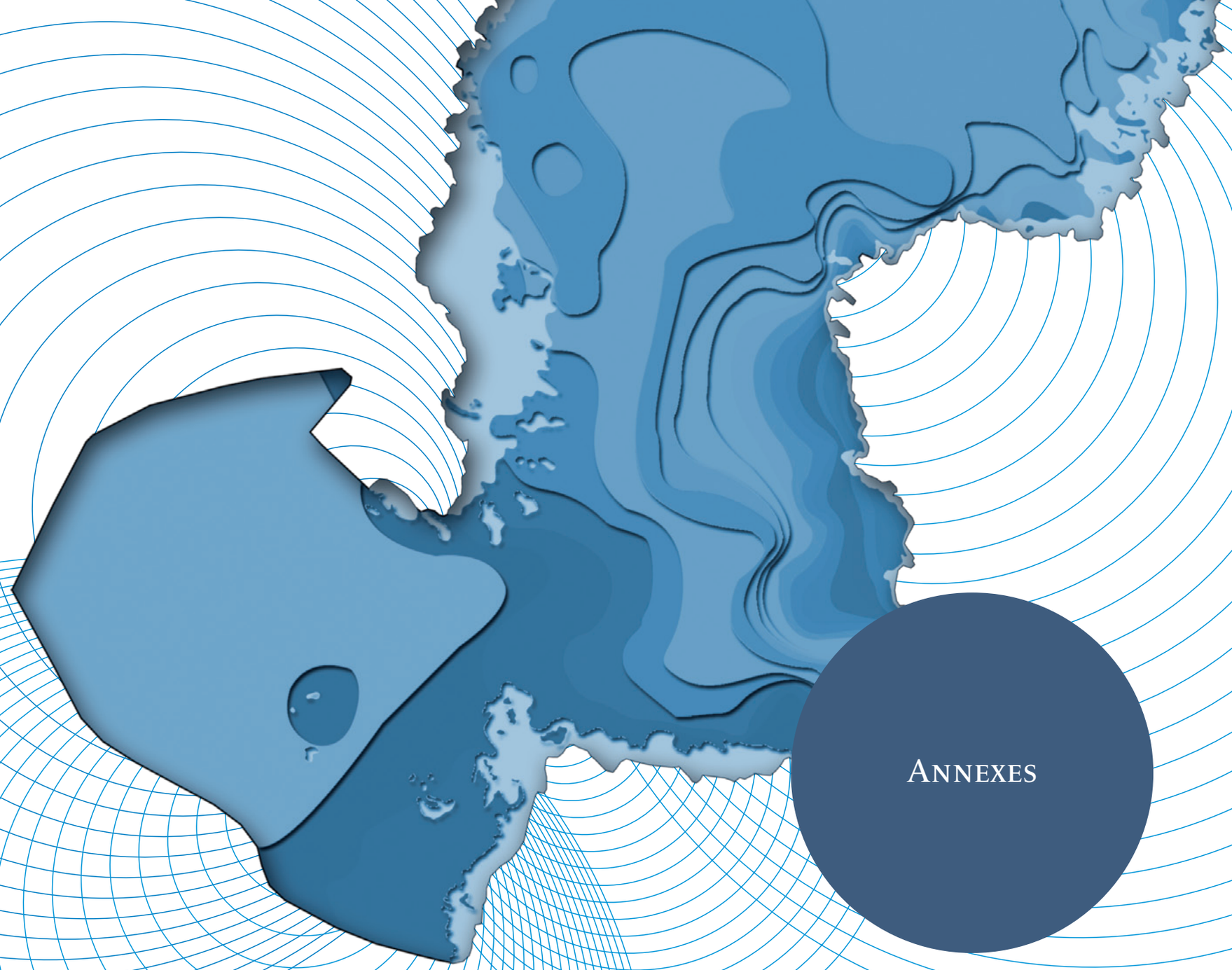
Continues

5 Studies carried out at the Salto-Concordia Pilot Project estimate that the volume of effluents is ≤ 90% of the entry volume.

Continuation

		• Formal exercises of regional models • Number of uses of models in pilot-project areas as management support tools • Technicians trained in use of models
5.	Technical capacity building and dissemination of knowledge	• Number of meetings held by the technical committee • Number of capacity-building events held • Number of people trained • Scope of distribution of capacity-building materials developed under the PGAS • Resources transferred to the Citizenship Fund • Number of dissemination campaigns
6.	Development of local groundwater management	• CLAGs duly established with technical operational support • Number of coordination meetings held by the Local Management Promotion Group • Number of meetings of the Local Management Development Group
7.	Support for public participation	• Number of participants at meetings • Number of activities relating to indigenous populations
8.	Development of sustainable use criteria	• Number of criteria agreed (vulnerability, pollution risk, zoning, quantification of sustainable extractible volumes etc.) • Percentage of zoning of entire confined area
9.	Implementação de programas técnico-científicos	• Number of academic projects and lines of research for the GAS and groundwater • Number of professionals involved in investigations on the GAS
10.	Preparation of technical and economic studies	• Percentage of the GAS social-environmental diagnosis documents completed • Number of economic studies and cost-benefit proposals, price-model tests of charges for the use of GAS water, and economic impacts on the value of GAS water use • Number of current and future use scenarios defined • Number of functioning thermal wells monitored and incorporated into the SIGAS • Preparation of the institutional framework for promotion of reuse of thermal water • Percentage of the preparation of regulations for final disposal of effluents completed • Zoning of the confined GAS in terms of its hydrothermal potential
11.	Monitoring of SAP Implementation	• Percentage of implementation of the SAP completed • Amount of national counterpart funds executed • Donors funds executed

Source: GS/GAS, 2008.



Annexes

ANNEX 9

Annex 9 Information System for the Guarani Aquifer System - SIGAS

INTRODUCTION

This document provides information on basic needs identified during development of a GIS software for the Information System for the Guarani Aquifer System (SIGAS).

This Annex briefly describes these needs and cites examples, with a view to providing a reference for analysis and a source of consensus for the countries that participate in the Project for Environmental Protection and Sustainable Development of the Guarani Aquifer System (PGAS). It will serve as the starting point for consolidation of finial adjustments relating to work carried out on the SIGAS.

Needs detected and included in this document encompass the following themes:

- Review and adjustment of the current Hydrogeological Database (HGDB).
- The current Hydrogeological Database (HGDB) versus the Hydrogeological Database furnished by the SNC-Lavalin company.
- Feeding of the database and data validation.
- Editing of data in ArcEditor.
- Processing of data in ArcEditor.
- Security of access to data and functionality.
- Remote (WEB-based) consultation of the Hydrogeological Database (HGDB).
  - » WEB Applications for consultation of the Hydrogeological Database (HGDB).
  - » WEB Applications for viewing basic maps.
  - » WEB Applications for viewing and consultation of thematic maps.
  - » WEB Applications for viewing stratigraphic profiles.
  - » WEB Applications for viewing, consulting and location of wells.

Based upon these needs, features for making the system more efficient than the previous portal will be defined.

Among the features of the new system are:

- Flexibility and dynamism, encompassing both functionality and data.
- On-line map services based on Open Geospatial Consortium (OGC) standards.
- Scalability and adaptability to enable adaptation to future needs.

Review and adjustment of the current Hydrogeological Database (HGDB)

The possibility of effecting small changes in the design and structure of the current HGDB should be confirmed by specific studies. Certain necessary structural changes have already been identified and will result in minor system adjustments.

A comparison of the original and current HGDBs when fed data reveals differences that will be integrated into the original design. The aim is to achieve a design and unified base for future use.

To differentiate the two databases, the original will henceforth be called HGDB-06, and the current one HGDB-08. The numbers used in this denomination reflect the year in which the two versions were released. More precisely, HGDB-08, the subject of this study, was released on June 12, 2008.

HGDB-06 will have to be adjusted to make it compatible with HGDB-08. Furthermore, HGDB-06 will maintain existing fields and entities within its structure, even if they have been altered in HGDB-08.

The main differences between the two versions are:

1. The "Pozoinformación" table in the HGDB-06 contains the fields CoordX, CoordY, ZoneUTM, Latitude and Longitude in degrees, minutes and seconds. These fields do not exist on HGDB-08. In the HGDB-08 version, the "Pozoinformación" table gained fields for latitude, longitude and SAG.
2. The "FisicoQuimicosCampo" in the HGDB-08 version contains a field CO2, that does not exist in the HGDB-06 version.
3. The "OrigenDeDatos" domain in the HGDB-06 version contains the element "SinDatos"; whereas in the HGDB-08 version the same domain contains the element "Outro".
4. The HGDB-08 contains certain tables that do not exist in the HGDB-06. These are:
   - » AvancePerforacion (0).
   - » BTEX (0).
   - » CompuestosOrganicosFenolicos (0).
   - » CompuestosOrganicosVolatiles (0).
   - » Herbicidas (0).
   - » HidrocarburosAromaticosPolinucleares (*).

- » HidrocarburosdePetroleo (*).
- » PCB (0).
- » PlagicidasOrganoclorados (*).
- » PlagicidasOrganofosforados (*).
- » Trihalometanos (0).

Some of these tables already contain data, whereas others are empty. The empty ones are identified with (0). Those that contain data are identified with (*). It was found that no relationship is associated to these tables.

After having effected the necessary structural changes, HGDB-06 will be the sole database for SIGAS and will be known simply as HGDB.

HGDB- vs. the Hydrogeological Database furnished by SNC-Lavalin International

There is also a Hydrological Database (HDB) furnished by SNC-Lavalin International, that has much in common with the HGDB. Though creation of a hydrographic database (BHG) that includes HDB features is beyond the scope of this project, the convenience of transferring such information to the HGDB should be examined. For this, the following tasks will have to be performed (in sequential order):

- Analyze the data that use the thematic maps furnished by SNC-Lavalin International considered of interest. These thematic maps are the same as the ones in the section "Web Applications for viewing and consultation of thematic maps".
- Evaluate whether the HGDB structure can support HDB information considered of interest for the thematic maps selected. There are two possibilities:
  - » If the HGDB structure supports the information, data should simply be transferred, maintaining the structure intact.
  - » If it does not support the information, the HGDB structure should be updated, including attributes and tables necessary for storing the new data derived from the HDB that are to be used to generate the desired thematic maps. After adjustment, the HDB data should be transferred to the new HGDB.

The first step in the above-described operation is selection of thematic maps to determine the variables involved. It will also be necessary to assess the compatibility of the database structures prior to transferring the data.

Feeding the database and validation of the data

Validation is a process of assessing compatibility of data and the model and structure of the HGDB database. In this process, it is the syntax of the dada that is important, rather than the semantics. Feeding of the database and editing of the data is carried out using ArcEditor software at the operations centers in each of the countries involved. Feeding of the database is to be distributed, using ESRI technology, so as to enable automatic control of the geographic databases, that can be viewed as if they were a single database.

Feeding of the database can be carried out in a massive form from other files, using the same software as the database. In the case of individual loading of data, ArcEditor tools will be furnished to facilitate inputting of information onto the HGDB structure. The HGDB will include standard-format metadata. Generation of metadata takes place in accordance with functionalities of the ESRI ArcCatalog software, so as to enable ease of access.

There follows a detailed description of the two processes:

- Editing in ArcEditor
- Processing in ArcEditor

Editing in ArcEditor

Editing of HGDB data is carried out using ArcEditor and not via the web. This is the mechanism used for maintenance of the database. The interface for feeding and validation of data shall be structured so that it can be used locally, and not via Internet. Maintenance and updating of data should be carried out personally at each workstation. Restrictions of access must be defined. A set of tools will be furnished, on the ArcMap Toolbar and software, under license from ArcEditor, with a simple user-friendly interface, and windows like those found in Windows or Window Forms. These are available on five main databases, one for each country and one for the center, all interconnected using ESRI automatic replication technology, with a centralized unified appearance.

Each country is to be responsible for data relating to its territory, and modification of data from the other countries is not allowed. Automatic replication of the databases ensures communication of and automatic dispatch of changes effected at any of the centers. All the centers are updated instantaneously. It is foreseen that a copy of the HGDB will be installed at each of the centers in the member countries and at the support node.

Processing in ArcEditor

This corresponds to processing of data on ArcMap, with the Geoprocessing tool supplied along with the software. Needs, in this case, should be defined by the SIGAS players, after initial implementation. For example, they can assess the feasibility of a license for drilling, simulating current conditions and other parameters, such as flows and depths, thereby obtaining of a report to justify the decision of whether or not to authorize drilling.

Security of access to data and functionalities

Access to information from the HGDB will be restricted and totally controlled in accordance with specified security levels. Such restrictions will be applied both to direct access and access by means of functionalities.

Three levels of security will be deployed. The functionality for obtaining information includes both spatial and associated descriptive criteria.

Levels of security

Three levels of security will be established:

- Level 1 – Consultations.
- Level 2 – Consultations and access to statistical documents.

- Level 3 – Consultations and downloads of data. Geometric data files can be obtained in Shapefile format. Also, reports can be obtained on consultations held.

Security of data access

The level of access to data is defined as follows:

- Basic cartography: in accordance with the content of the Project Base Map and the Pilot Maps.
- Thematic cartography: in accordance with the content of thematic maps to be deployed.
- Data and information on the HGDB: attributes can be viewed in accordance with data obtained during consultations.

Remote consultation of the HGDB

All development referent to consultations should initially be accessed via the existing GIS Portal, created by the Tecsult company and hosted at http://190.2.13.85.

With the aim of supporting data visualization and consultations, various web functionalities or applications will be deployed, including:

- Web applications for viewing base maps.
- Web applications for viewing and consultation of thematic maps.
- Web applications for viewing of stratigraphic profiles.
- Web applications for viewing, consultations and search for wells.

Web application for viewing base maps

This Web application allows viewing and handling of the map base with the following features and functionalities:

1. Visualization by country, by group of countries, by state, or by slide.
2. In the first consultation, which is predetermined, one can view the SIGAS Base Map and Maps of the (Concordia-Salto, Itapúa, Ribeirão Preto and Rivera-Santana do Livramento) Pilot Projects. It is possible to choose between viewing the map of the entire surface of the aquifer (scale 1:3.000.000), maps by country, state, province or department, or by square in accordance with SIGAS charts (191 charts) with an output scale of 1:50.000. To this end, the same templates delivered by the SAG for each of the aforementioned maps are used.
3. These will contain basic cartography and the layer of wells.
4. They will include descriptive information on wells, taken from the HGDB.
5. It is possible to provide information on coordinates, one or two radiuses, or to select wells that comply with this data. With the wells selected and associated information, it is possible to generate a variety of reports.
6. Descriptive consultations on wells can be carried out on the basis of the following information: location, characteristics of the well (contour, flow etc.), drilling method, stratigraphic profile, geological and hydrogeological profile (obtained from Table 1 (I) and Well Table Form I).
7. It will be possible to turn layers off and on.
8. It will be possible to print the map using a single template, corresponding to the scale. The map will have a key and title provided by the user. Symbols will be those defined on maps produced within the scope of the PGAS.
9. Generation of reports. The appearance of Table1 (I) and of Well Table Form I will be maintained.

Web application for viewing and consultation of thematic maps

For consultations of thematic data, different categories of thematic maps were produced by SNC-Lavalin International. It was decided that a unified template should be used, enabling changes in titles and keys in accordance with different thematic contents.

Work carried out by SNC-Lavalin International produced different categories of thematic maps.

- Unified template, enabling changes in titles and keys, in accordance with thematic contents.
- In the Pilot Projects, three different base categories were detected. Taking the Concordia-Salto Pilot Project as a reference:
  - » Key
    - Planimetry.
    - Geology - lithostratigraphic unit.
    - Thematic layer of interest (PH, TEMP, ALC).
    - Example: Concordia_Salto_In_situ_50K_Alk.pdf.
    - Comprises InSituQH, LabQH.
  - » Key
    - Planimetry.
    - Thematic layer of interest (Location Wells, Altimetry, GAS Floor).
    - Example: Concordia_Salto_V90_50K_Localización_de_Pozos.pdf.
    - Concordia_Salto_V90_50K_GAS-Floor.pdf.
    - Comprises: Location of Wells and Model.
  - » Key
    - Transport and energy infrastructure/ Transport and energy infrastructure.
    - Land use .
    - Hydrography.
    - Example: Uso do solo, Concordia_Salto_V911_3.
    - Comprises : land use.
- Others of particular interest detected during development of the Pilot Project.

The web interface to be developed will enable choice of components to generate maps. The first refers to three categories of base keys. The second enables selection of a variable or thematic layer of interest.

After configuration of the map to be viewed, the following functionalities are available:

1. Browsing.
2. Activate and deactivate layers.
3. Select an active layer.
4. Identify elements of active layers.
5. Carry out descriptive consultations on the active layer based on attributes associated either directly or otherwise, via relates.
6. Carry out spatial radius-type consultations for selection or buffer.
7. Generate maps for printout based on the template, with prior visualization, printing, and generate a PDF for later use. PDF costs and license will need to be studied.
8. The title of the printout can be user-defined.
9. The scale presented can be modified, thus altering the map.

If the user wishes to generate a map for printing, it will be based on a template that

enables, through use of a view function, confirmation that the map meets his requirements. After visualization, the map can be printed and a PDF generated for future use. Feasibility of using PDF (costs and license) requires further study.

In this functionality, the title of the printout may be user-defined. The map will be shown on its current scale, which can be altered.

The thematic maps of interest to be implemented are:

1. Geological map, keys of which include planimetry and lithostratigraphic units. Options: Concordia-Salto pilot area, Itapúa pilot area, Ribeirão Preto pilot area and Rivera-Santana do Livramento pilot area.
2. Thematic map with parameters measured "in situ", with geology, planimetry and hydrography. Option of including maps of alkalinity, conductivity, pH, and temperatures.
3. Thematic map of parameters analyzed in laboratory, with geology, planimetry and hydrography, and an option on the key for including maps of: total arsenic, chlorates, total hardness, fluorites, nitrates, total dissolved solids, and sulfates.
4. Thematic map of models, with planimetry, hydrography and the option on the key of including: specific flows, elevation of terrain, thickness of sandstones, SAG floor, potentiometry, basalt ceiling, base ceiling, ceiling of the SAG and current volumes abstracted.
5. Land-use map, with hydrography, infrastructure and a land-use key.

Web application for viewing stratigraphic profiles

Among the information produced under the PGAS are PDF files with schemes of profiles and descriptive forms on each surface point.

On the HGDB, the entity SurfaceGeology may reach these points, providing the necessary reference links to documents containing profiles, and others containing purely descriptive information. Such links will be stored in the entity GeologyOfSurface, that is related to the entity SurfaceGeology, thus facilitating access to information based on geometry.

Users may select one or more surface points. Points selected are shown on a table that lists their attributes and displays the aforementioned links. By clicking on the links, the user can access the documents. He can download or simply view them, depending on his capacity of access.

Web application for visualization, consultations and searches for wells

This application encompasses processes made available via the web for consultations and searches by attributes.

A search system will be created with fields and values for attributes (when they can be measured). The first form of consultation will be simple for each of the six cases mentioned.

Advanced consultations can also be made, i.e., by means of a concatenation of simple selections, to enable a new selection of data selected in the previous step.

Search

Carried out on the basis of attributes contained in the tables Well Form (Well Form I and II, Pumping Tests, Rate of Advance, Monitoring, Hydrochemistry etc.).

Moreover, they add:

- Wells that comply with WHO parameters (reference values for water quality). To this end, the countries should furnish parameters used, in accordance with international standards.

Having carried out searches, they will be available on paper and in the form of descriptive tables for consultation in PDF format for printing (basic cartographic content and location of selected wells).

Web applications and background

The applications described in this document emerged from analyses of information gathered under the PGAS, and from consultation of thematically similar Internet pages. Such pages will continue to be analyzed.

During preliminary consultation of these web pages, during which the internal management systems of bodies were not examined, the possibilities for visualization, consultations and access to information were assessed. In some cases the information provided to users is descriptive. In others, monitoring and further request can be forwarded. These elements will serve as a basis for development of applications and new functionalities.

In summary, the various cases mentioned can be grouped, based on their characteristics:

- With applications of Information Systems
  1. National Groundwater Information System – SIAGAS (CPRM, Brazil) http://siagas.cprm.gov.br/wellshow/indice.asp
  2. National Water Resources Information System – SNIRH (ANA, Brazil) http://www.ana.gov.br/portalsnirh/ http://hidroweb.ana.gov.br/
- With the possibility of initiating or monitoring of processes
  3. Superintendency for Development of Water Resources and Environmental Sanitation of Paraná (PR, Brazil) http://www.suderhsa.pr.gov.br/
  4. Department of Water and Electric Power of São Paulo – DAEE (SP, Brazil) http://www.daee.sp.gov.br
  5. Minas Gerais Water Management Institute – IGAM (MG, Brazil) http://www.igam.mg.gov.br/
- Applications that provide information
  6. State Water Resources System of Rio Grande do Sul – SEMA (RS, Brazil) http://www.sema.rs.gov.br/
  7. State Secretariat for Sustainable Economic Development. Water Resources Information System of the State of Santa Catarina (SC, Brazil). http://www.aguas.sc.gov.br/
  8. Corrientes Water and Environment Institute (Corrientes, Argentina). http://www.icaa.gov.ar/
- Other thematic applications
  9. SEMARH. Government of Goiás (GO, Brazil) http://www.semarh.goias.gov.br/
  10. State Secretariat of Environment. Government of the State of Mato Grosso (MT, Brazil) http://www.sema.mt.gov.br/
  11. Environment Institute of Mato Grosso do Sul - IMASUL (MS, Brazil) http://www.imasul.ms.gov.br/index.php

ANNEX 10

Annex 10 GAS Monitoring Network

1 TECHNICAL AND CONCEPTUAL ASPECTS

Development of a monitoring network for wells entails technical, political, administrative and logistical aspects.

Though participation of a great variety of public and private-sector stakeholders, ranging from well operators to water-resources managers could be perceived as being an obstacle, it can in fact be transformed into an advantage, through the harnessing of local private potential. This is exemplified by the accumulated experience of organizations and users that monitor boreholes of interest to the network.

Resources are invariably thin spread and insufficient, and are generally allocated to isolated projects. For this reason, it is necessary to maximize their impacts. Generation of information needs to be optimized and actions coordinated, in order to reduce the cost of producing data, for example, by seeking support from local stakeholders. Moreover, the existing monitoring networks need to be expanded rather than replaced. As much as possible, parameters to be measured should be simple and easily analyzed, and should employ low-cost indicators.

Measurement intervals should reflect a balance between the need to generate high-quality information and economy. Monitoring should be capable of determining normal or natural variations of the aquifer and support detection of any anomalies. Measurements should not be too frequent so as to avoid production of great volumes of data of little use for monitoring of the GAS. The design should facilitate detection of any great future changes in land or water-use patterns.

The monitoring network has broad goals, both for characterizing the aquifer (which does not require constant measurement) and for detecting possible alterations in potability, especially for wells that provide public water supply (which do require frequent measurement). In more vulnerable areas, such as outcropping and replenishment zones, there is a need to include a greater variety of parameters. However, for deep boreholes, that abstract water that has been there for millennia, only minimal variations are foreseen.

2 OBJECTIVES OF THE REGIONAL MONITORING NETWORK

The main objective of the GAS regional monitoring network is to set minimum standards for wells and basic activities that generate useful knowledge for coordinated and participative management, fostering protection and sustainable use of the entire Aquifer System.

Aside from this general objective, there are other more specific goals:

- Improve knowledge on the main characteristics of the region overlying the GAS.
- Define measuring methodologies that ensure representative and high-quality outcomes.
- Determine water quality, on a regional basis, and current levels of exploitation.
- Generate information to enable assessment, on a regional scale, of potential and hydrodynamic characteristics of the GAS, and control changes to the system over time and space.

3 ELEMENTS OF THE NETWORK

The monitoring network comprise the following elements:

- 180 wells (number defined by contract).
- Requisites recommended for inclusion of new wells into the network.
- Information of interest.
- Sampling methodology and intervals.
- Tests to be carried out and their protocols.
- Information to be stored in the database.

4 CRITERIA FOR SELECTION OF WELLS AND SOURCES OF INFORMATION

The selection of wells followed a logical process entailing assessment of candidates and generated parameters for future inclusion of new wells. There follows a description of criteria that guided selection of the boreholes that comprise the network. It should be underscored that such criteria are not mutually exclusive, but rather elements for evaluation of each particular well. Over rigorous application of all criteria would not have allowed selection of the necessary 180 wells.

The sources of data and information used in assembling the network were:

- The Hydrogeological Database (CONSÓRCIO GUARANI).
- Inventory of wells – field survey (SNC- LAVALIN).
- Hydrochemical and isotopic tests (SNC-LAVALIN).
- Prior networks in the GAS countries.
- Project GAS-PY (Government of Paraguay / German Geological Service -BGR).

General criteria (regional)

- Geographic and topographic distribution.
- Representativity of aquifer sectors: replenishment, transit and discharge.
- Distribution into particular hydrochemical sectors.
- Coverage of essential (geological and piezometric) areas of the region.
- Representativity of sectors of concentrated exploitation or at risk of anthropogenic contamination. Examples: Rivera-Santana do Livramento and Campo Grande.
- Monitoring of remote areas apart from those of intensive or concentrated exploitation. Example: Ribeirão Preto.
- Distribution and representativity of land use.
- Relevance of the well to the study or GAS hydrogeological map.

Specific criteria (wells)

- Constructive and lithological characteristics of boreholes.
- State of the well and measuring instruments on the well. Examples: pressure and temperature in artesian wells.
- Ease of measuring water levels using probes (in non-artesian wells).
- Accessibility (access to the well and permission).
- Availability and quality of background data.
- In areas with a high density of wells, those that are representative of the area and that fulfill all the above items.
- Other advantages.

5 SELECTION OF WELLS FOR THE REGIONAL MONITORING NETWORK

The GAS Monitoring Network proposal encompasses 180 wells distributed as follows (Table 2):

- **Argentina:** 16 wells were selected, ten of which were in Entre Ríos, three in Corrientes, and three in Misiones.
- **Brazil:** 118 wells were selected, distributed as follows: 12 in Goiás, 25 in Mato Grosso do Sul, 21 in Paraná, 39 in Rio Grande do Sul, 12 in Santa Catarina, 1 in Mato Grosso and 8 in São Paulo. In accordance with general criteria set during the Monitoring Network Workshop, held in October 2007, wells that currently comprise the groundwater resources monitoring network of the State of São Paulo will be incorporated into the GAS network. To the set of wells presented, eight were included in the State of São Paulo, with the aim of providing the two monitoring networks with common control points.
- **Paraguay:** in accordance with the aforementioned methodology, that includes regional and private criteria and national experiences, 28 wells were selected.
- **Uruguay:** in accordance with the aforementioned methodology, 18 wells were selected.

Figure 1 shows the regional geographic distribution of wells selected to comprise the Regional Monitoring network.

6 METHODOLOGICAL ASPECTS

Both within the scope of the monitoring network and at the national level, it is essential to incorporate guidelines that ensure representativity of the samples collected and of measurements carried out. For this reason, measuring equipment that causes little disturbance should be used, so that samples can have high representativity. Monitoring intervals should be in accordance with location of the well in the flow system and with its uses. Table 1 provides a proposal for monitoring intervals.

Table 1. Variables measured in different areas of the GAS and monitoring intervals

Variable	Outcrop zones, of high vulnerability or replenishment areas (depth < 100m)	Variable transit sectors, discharge or boreholes with abstraction depth greater than 150m
Microbiology	Monthly – Quarterly	Half–yearly
Hydraulic and operation	Monthly – Quarterly	Half-yearly – Annually
Field measurements of physical-chemical parameters	Monthly – Quarterly	Quarterly – Half-yearly
Larger species to be determined in the laboratory	Quarterly	Quarterly – Half-yearly
Toxic elements and others to be determined in the laboratory	Quarterly	Half-yearly – Annually
Isotopes	Quarterly – Half-yearly	Half-yearly – Annually
Organic pollutants and pesticides	Half-yearly – Annually	–

Source: GS/GAS, Adapted from the Report on the Regional Monitoring Network, Guarani Consortium, 2008.

Table 2. Listing of wells per country

Nº	Drilled by	HDB ID of the Well	Code	Locality	Latitude	Longitude	Country	Province / State
1	Chajari	7212	PP-A-0011-Chajari1	Chajari	-30,71787	-58,009242	Argentina	*Entre Ríos*
2	Federacion	7202	PP-A-0001-Federacion	Federacion	-31,005106	-57,92404	Argentina	*Entre Ríos*
3	Concordia 1	7203	PP-A-0002-Concordia1	Concordia	-31,294944	-58,004389	Argentina	*Entre Ríos*
4	Villa Elisa	7205	PP-A-0004-Villa Elisa	Villa Elisa	-32,132088	-58,435913	Argentina	*Entre Ríos*
5	Colon	7204	PP-A-0003-Colon	Colon	-32,210529	-58,146766	Argentina	*Entre Ríos*
6	La Paz	7213	PP-A-0012-La Paz	La Paz	-30,759563	-59,657012	Argentina	*Entre Ríos*
7	Villaguay	7209	PP-A-0008-Villaguay	Villaguay	-31,855875	-59,027217	Argentina	*Entre Ríos*
8	Basavilbaso	7210	PP-A-0009-Basavilbaso	Basavilbaso	-32,373483	-58,888263	Argentina	*Entre Ríos*
9	Maria Grande	7215	PP-A-0014-Maria Grande	Paraná	-31,659982	-59,897726	Argentina	*Entre Ríos*
10	Gualeguaychu2	7214	PP-A-0013-Gualeguaychu2	Gualeguaychu	-32,973723	-58,595712	Argentina	*Entre Ríos*
11	Guaviravi	8800	PP-A-0022	Guaviravi	-29,47	-56,92	Argentina	*Corrientes*
12	*Mercedes*	8833	PP-A-0054	*Mercedes*	-29,17	-58,08	Argentina	*Corrientes*
13	Yapeyu 1	8813	PP-A-0035	Yapeyu	-29,77	-57,38	Argentina	*Corrientes*
14	Obera 1	8794	PP-A-0016	Obera	-27,480274		Argentina	*Misiones*
15	Cerro Azul-1	8795	PP-A-0017	Cerro Azul	-27,6365	-55,4975	Argentina	*Misiones*
16	Posadas-1	8807	PP-A-0029	Posadas	-27,62	-56,47	Argentina	*Misiones*
17	PP-GO-22	7860	PP-B-7860	Santa Rita do Araguaia	-17,832267	-51,771775	Brasil	Goiás
18	PP-GO-06	754	PP-B-6757	Itajá	-19,054967	-51,546691	Brasil	Goiás
19	PP-GO-08	756	PP-B-6759	Rio Verde	-17,779884	-50,916221	Brasil	Goiás
20	PP-GO-10	758	PP-B-6761	Goiatuba	-18,010083	-49,369878	Brasil	Goiás
21	PP-GO-14	762	PP-B-6765	Itarumã	-18,589722	-51,749722	Brasil	Goiás
22	PP-GO-16	764	PP-B-6767	Rio Verde	-18,046978	-51,803922	Brasil	Goiás
23	PP-GO-01	776	PP-B-6752	Aporé	-18,685416	-51,871594	Brasil	Goiás
24	PP-GO-18	7856	PP-B-7856	Itajá	-19,186752	-51,397546	Brasil	Goiás
25	PP-GO-19	7857	PP-B-7857	Serranópolis	-18,320001	-51,961901	Brasil	Goiás
26	PP-GO-21	7859	PP-B-7859	Santa Rita do Araguaia	-17,372806	-53,153612	Brasil	Goiás
27	PP-GO-20	7858	PP-B-7858	Mineiros	-17,568306	-52,589405	Brasil	Goiás
28	GO000001514	1351	PP-B-6846-GO000001514	Aporé	-18,969722	-51,931389	Brasil	Goiás
29	PP-MS-156	7932	PP-B-7932	Caarapó	-22,498305	-54,865238	Brasil	Mato Grosso do Sul
30	PP-MS-63	8015	PP-B-8015	Jardim	-21,689002	-56,276872	Brasil	Mato Grosso do Sul
31	PP-MS-61	8013	PP-B-8013	Nioaque	-21,159294	-55,823485	Brasil	Mato Grosso do Sul
32	PP-MS-54	8006	PP-B-8006	Rio Brilhante	-21,789769	-54,556075	Brasil	Mato Grosso do Sul
33	PP-MS-42	7994	PP-B-7994	Camapuã	-19,534303	-54,033581	Brasil	Mato Grosso do Sul
34	PP-MS-38	7990	PP-B-7990	São Gabriel do Oeste	-19,252209	-54,326655	Brasil	Mato Grosso do Sul
35	PP-MS-36	7988	PP-B-7988	São Gabriel do Oeste	-19,110692	-54,636519	Brasil	Mato Grosso do Sul
36	PP-MS-28	7980	PP-B-7980	Rochedo	-19,882102	-54,627215	Brasil	Mato Grosso do Sul
37	PP-MS-24	7976	PP-B-7976	Dois Irmãos do Buriti	-20,549343	-55,366285	Brasil	Mato Grosso do Sul
38	PP-MS-23	7975	PP-B-7975	Terenos	-20,644917	-55,053764	Brasil	Mato Grosso do Sul
39	PP-MS-64	8016	PP-B-8016	Naviraí	-22,96551	-54,06994	Brasil	Mato Grosso do Sul
40	PP-MS-158	7934	PP-B-7934	Camapuã	-19,014752	-53,900843	Brasil	Mato Grosso do Sul
41	PP-MS-10	7870	PP-B-7870	Amambaí	-22,991712	-55,337624	Brasil	Mato Grosso do Sul
42	PP-MS-150	7926	PP-B-7926	Maracaju	-21,61763	-55,1615	Brasil	Mato Grosso do Sul
43	PP-MS-146	7921	PP-B-7921	Dourados	-22,085072	-55,354551	Brasil	Mato Grosso do Sul
44	PP-MS-137	7911	PP-B-7911	Camapuã	-18,675681	-53,641114	Brasil	Mato Grosso do Sul
45	PP-MS-134	7908	PP-B-7908	Douradina	-22,03446	-54,611355	Brasil	Mato Grosso do Sul
46	PP-MS-11	7881	PP-B-7881	Cassilândia	-19,12332	-51,734922	Brasil	Mato Grosso do Sul

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Nº	Drilled by	HDB ID of the Well	Code	Locality	Latitude	Longitude	Country	Province / State
47	PP-MS-07	7867	PP-B-7867	Amambaí	-23,061908	-55,207902	Brasil	Mato Grosso do Sul
48	GO000001706	1354	PP-B-6849-GO000001706	Terenos	-20,407778	-54,865556	Brasil	Mato Grosso do Sul
49	PP-MS-176	7954	PP-B-7954	Sidrolândia	-20,914066	-54,956824	Brasil	Mato Grosso do Sul
50	PP-MS-66	8018	PP-B-8018	Alcinópolis	-18,323653	-53,713347	Brasil	Mato Grosso do Sul
51	PP-MS-65	8017	PP-B-8017	Cassilândia	-19,18483	-51,408375	Brasil	Mato Grosso do Sul
52	PP-MS-01	7861	PP-B-7861	Inocência	-19,73335	-51,92772	Brasil	Mato Grosso do Sul
53	PP-MS-190	7970	PP-B-7970	Três Lagoas	-20,859537	-51,741436	Brasil	Mato Grosso do Sul
54		1405	PP-B-0035	Prudentópolis	-24,954444	-51,357778	Brasil	Paraná
55		1380	PP-B-0010	Inácio Martins	-25,578333	-51,069167	Brasil	Paraná
56	PP-PR-58	8109	PP-B-8109	Ribeirão do Pinhal	-23,403511	-50,363149	Brasil	Paraná
57	PP-PR-08	8059	PP-B-8059	Matilândia do Sul	-25,284941	-53,932857	Brasil	Paraná
58	PP-PR-71	8122	PP-B-8122	Tamarana	-23,715066	-51,092296	Brasil	Paraná
59	PP-PR-59	8110	PP-B-8110	Ribeirão do Pinhal	-23,391891	-50,549098	Brasil	Paraná
60	PP-PR-50	8101	PP-B-8101	Londrina	-23,340861	-51,02297	Brasil	Paraná
61	PP-PR-49	8100	PP-B-8100	Londrina	-23,242242	-51,10186	Brasil	Paraná
62	PP-PR-35	8086	PP-B-8086	General Carneiro	-26,426858	-51,32111	Brasil	Paraná
63	PP-PR-28	8079	PP-B-8079	Cruz Machado	-25,864802	-51,262625	Brasil	Paraná
64	PP-PR-25	8076	PP-B-8076	Cruz Machado	-26,080718	-51,253515	Brasil	Paraná
65	PP-PR-24	8075	PP-B-8075	Cianorte	-23,655082	-52,613062	Brasil	Paraná
66	PP-PR-15	8066	PP-B-8066	Andira	-23,053711	-50,222734	Brasil	Paraná
67	PP-PR-14	8065	PP-B-8065	Foz do Iguaçu	-25,567024	-54,554274	Brasil	Paraná
68	PP-PR-13	8064	PP-B-8064	Foz do Iguaçu	-25,584722	-54,527778	Brasil	Paraná
69	PP-PR-45	8096	PP-B-8096	Jardim Alegre	-24,172542	-51,690444	Brasil	Paraná
70	PP-PR-04	8055	PP-B-8055	Cornélio Procópio	-23,186394	-50,637486	Brasil	Paraná
71	PP-PR-66	8117	PP-B-8117	Santo Antônio da Platina	-23,260813	-50,093302	Brasil	Paraná
72	PP-PR-09	8060	PP-B-8060	Pinhão	-25,825648	-51,591393	Brasil	Paraná
73	PP-PR-07	8058	PP-B-8058	Maringá	-23,410359	-51,837503	Brasil	Paraná
74	FB	8876	PP-B-8876	Francisco Beltrão	-25,97305	-53,3275	Brasil	Paraná
75	DAE H10	9117	PP-B-9117	Santana do Livramento	-30,8957603	-55,5239998	Brasil	Rio Grande do Sul
76	Quarai (Qua 001)	9116	PP-B-9116	Quaraí	-30,401633	-56,437765	Brasil	Rio Grande do Sul
77	HIDROGEO1530	8276	PP-B-8275	Novo Hamburgo	-29,661307	-51,935276	Brasil	Rio Grande do Sul
78	HIDROGEO1283	8223	PP-B-8222	Montenegro	-29,841453	-50,598234	Brasil	Rio Grande do Sul
79	HIDROGEO1382	8243	PP-B-8242	Restinga Seca	-29,825881	-53,36827	Brasil	Rio Grande do Sul
80	HIDROGEO1440	8251	PP-B-8250	Santana do Livramento	-30,867083	-55,54328	Brasil	Rio Grande do Sul
81	HIDROGEO1466	8263	PP-B-8262	Paraíso do Sul	-29,769779	-53,072925	Brasil	Rio Grande do Sul
82	HIDROGEO1517	8274	PP-B-8273	Santa Maria	-29,698234	-53,797736	Brasil	Rio Grande do Sul
83	HIDROGEO1554	8288	PP-B-8287	Campo Bom	-29,649971	-51,039511	Brasil	Rio Grande do Sul
84	HIDROGEO1487	8265	PP-B-8264	Gravataí	-29,840402	-50,868988	Brasil	Rio Grande do Sul
85	HIDROGEO1221	8201	PP-B-8200	Cacequi	-29,909482	-54,771665	Brasil	Rio Grande do Sul
86	HIDROGEO1196	8196	PP-B-8195	Santo Antônio da Patrulha	-29,933513	-50,519741	Brasil	Rio Grande do Sul
87	HIDROGEO1193	8194	PP-B-8193	Santa Cruz do Sul	-29,708562	-52,419066	Brasil	Rio Grande do Sul
88	HIDROGEO1182	8192	PP-B-8191	Igrejinha	-29,564201	-50,791393	Brasil	Rio Grande do Sul
89	CORSAN Registro 3	9118	PP-B-9118	Santana do Livramento	-30,8636594	-55,5461536	Brasil	Rio Grande do Sul
90	HIDROGEO1043	8158	PP-B-8157	Gravataí	-29,832877	-50,915857	Brasil	Rio Grande do Sul
91	HIDROGEO1583	8296	PP-B-8295	Bom Retiro do Sul	-29,663819	-51,94122	Brasil	Rio Grande do Sul
92	HIDROGEO1120	8172	PP-B-8171	Dilermando de Aguiar	-29,869248	-54,248012	Brasil	Rio Grande do Sul
93	HIDROGEO1092	8167	PP-B-8166	Novo Hamburgo	-29,662538	-51,131577	Brasil	Rio Grande do Sul
94	HIDROGEO1132	8173	PP-B-8172	Santa Maria	-29,704439	-53,799035	Brasil	Rio Grande do Sul
95	HIDROGEO1882	8374	PP-B-8373	Santa Maria	-29,711713	-53,845752	Brasil	Rio Grande do Sul

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Nº	Drilled by	HDB ID of the Well	Code	Locality	Latitude	Longitude	Country	Province / State
96	HIDROGEO1088	8165	PP-B-8164	Portão	-29,725962	-51,257115	Brasil	Rio Grande do Sul
97	IK142	4010	PP-B-1727-IK142	Santa Cruz do Sul	-29,821111	-52,361111	Brasil	Rio Grande do Sul
98	HIDROGEO1019	8152	PP-B-8151	Triunfo	-29,852371	-51,698965	Brasil	Rio Grande do Sul
99	HIDROGEO138	8430	PP-B-8429	Nova Santa Rita	-29,818367	-51,275442	Brasil	Rio Grande do Sul
100	HIDROGEO1912	8385	PP-B-8384	Rosário do Sul	-30,260354	-54,898086	Brasil	Rio Grande do Sul
101	HIDROGEO1674	8321	PP-B-8320	Cachoeira do Sul	-30,014824	-52,909918	Brasil	Rio Grande do Sul
102	HIDROGEO1877	8372	PP-B-8371	Presidente Lucena	-29,536398	-51,205928	Brasil	Rio Grande do Sul
103	HIDROGEO1803	8358	PP-B-8357	Montenegro	-29,651683	-51,562028	Brasil	Rio Grande do Sul
104	HIDROGEO1731	8348	PP-B-8347	Montenegro	-29,705685	-51,560467	Brasil	Rio Grande do Sul
105	HIDROGEO1719	8345	PP-B-8344	Igrejinha	-29,595919	-50,812477	Brasil	Rio Grande do Sul
106	HIDROGEO1692	8332	PP-B-8331	Venâncio Aires	-29,640638	-52,15442	Brasil	Rio Grande do Sul
107	HIDROGEO1681	8324	PP-B-8323	Igrejinha	-29,541391	-50,767774	Brasil	Rio Grande do Sul
108	HIDROGEO1677	8322	PP-B-8321	Santana do Livramento	-30,883021	-55,520653	Brasil	Rio Grande do Sul
109	IR285	5260	PP-B-2977-IR285	Paraíso do Sul	-29,769444	-53,072778	Brasil	Rio Grande do Sul
110	CPRM-4300002695	8651	PP-B-8651	Santo Antonio das Missões	-28,516388	-55,227222	Brasil	Rio Grande do Sul
111	Poço Aventura	8966	PP-B-8966		-28,776389	-51,520833	Brasil	Rio Grande do Sul
112	DCM-CESA	8892	PP-B-8892	Caxias do Sul	-29,169556	-51,211333	Brasil	Rio Grande do Sul
113	Frig. PRENDA	9004	PP-B-9004	Santa Rosa	-27,916667	-54,583333	Brasil	Rio Grande do Sul
114	PP-SC-21	8143	PP-B-8143	Piratuba	-27,423342	-51,77945	Brasil	Santa Catarina
115	PP-SC-20	8142	PP-B-8142	Monte Alegre	-27,30834	-50,41945	Brasil	Santa Catarina
116	HIDROGEO27	8179	PP-B-8178	Ponte Alta do Norte	-27,159086	-50,466632	Brasil	Santa Catarina
117	HIDROGEO1164	8185	PP-B-8184	Lages	-27,788236	-50,266766	Brasil	Santa Catarina
118	PP-SC-25	8147	PP-B-8147	Tangará	-27,081952	-51,250556	Brasil	Santa Catarina
119	PP-SC-23	8145	PP-B-8145	São João do Oeste	-26,731683	-53,527724	Brasil	Santa Catarina
120	PP-SC-13	8135	PP-B-8135	São Cristovão do Sul	-27,261111	-50,442778	Brasil	Santa Catarina
121	PP-SC-08	8130	PP-B-8130	Piratuba	-27,423611	-51,779444	Brasil	Santa Catarina
122	PP-SC-01	8123	PP-B-8123	Treze Tílias	-26,992212	-51,404525	Brasil	Santa Catarina
123	PP-SC-02	8124	PP-B-8124	Chapecó	-27,195288	-52,668194	Brasil	Santa Catarina
124	PP-SC-04	8126	PP-B-8126	Curitibanos	-27,289722	-50,579722	Brasil	Santa Catarina
125	PP-SC-07	8129	PP-B-8129	Ita	-27,2778	-52,334715	Brasil	Santa Catarina
126	PP-BR-6961	7702	PP-B-7702	Santa Lúcia	-21,686538	-48,086987	Brasil	São Paulo
127	PP-BR-6319	105	PP-B-6319	Marília	-22,246524	-49,992094	Brasil	São Paulo
128	PP-BR-6828	7569	PP-B-7569	Auriflama	-20,691766	-50,550611	Brasil	São Paulo
129	PP-BR-6909	7650	PP-B-7650	Jales	-20,287811	-50,532633	Brasil	São Paulo
130	PP-BR-6933	7674	PP-B-7674	Paraguaçu Paulista	-22,416747	-50,574998	Brasil	São Paulo
131	PP-BR-6241	27	PP-B-6241	Fernandópolis	-20,269457	-50,203762	Brasil	São Paulo
132	PP-BR-6915	7656	PP-B-7656	Jardinópolis	-21,014397	-47,769278	Brasil	São Paulo
133	PP-BR-6949	7690	PP-B-7690	Presidente Epitácio	-21,752579	-52,100001	Brasil	São Paulo
134	GO000001444	1349	PP-B-6844-GO000001444	Alto Taquari	-17,826111	-53,279722	Brasil	Mato Grosso
135	SP-P0058	1809	PP-P-0470-SP-P0058	Nueva Germa	-23,599913	-55,98458	Paraguay	–
136	SAGPY003MS	1542	PP-P-0203-SAGPY003MS	*Santa Rosa Misiones*	-26,886709	-56,85117	Paraguay	–
137	AM-P0073	1864	PP-P-0526-AM-P0073	P.J.Caballero	-22,523109	-55,841574	Paraguay	–
138	SAGPY021MS	1560	PP-P-0221-SAGPY021MS	San Cristobal	-26,658069	-57,201741	Paraguay	–
139	CG-P0083	1885	PP-P-0547-CG-P0083	Caaguazu	-25,510488	-56,022757	Paraguay	–
140	SAGPY034IT	1573	PP-P-0234-SAGPY034IT	Bella Vista	-27,039287	-55,578408	Paraguay	–
141	SAGPY071IT	1610	PP-P-0271-SAGPY071IT	Trinidad	-27,134296	-55,705425	Paraguay	–
142	SAGPY078IT	1617	PP-P-0278-SAGPY078IT	Coronel Bogado	-27,168013	-56,230779	Paraguay	–
143	CG-P0040	1973	PP-P-0635-CG-P0040	San Joaquin	-25,108379	-56,062018	Paraguay	–
144	CG-P0112	1690	PP-P-0351-SAGPY151IT	*Itapúa*	-26,985696	-56,20552	Paraguay	–

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145	SAGPY134AP	1673	PP-P-0334-SAGPY134AP	Santa Rita	-25,801361	-55,08224	Paraguay	–
146	SAGPY145AP	1684	PP-P-0345-SAGPY145AP	*Ciudad del Este*	-25,517297	-54,622908	Paraguay	–
147	SAGPY146AP	1685	PP-P-0346-SAGPY146AP	Minga Guasu	-25,452428	-54,801094	Paraguay	–
148	SAGPY147MS	1686	PP-P-0347-SAGPY147MS	Yabebyry - San Ignacio	-27,380038	-57,165858	Paraguay	–
149	SAGPY171AP	1710	PP-P-0371-SAGPY171AP	Colonia Yguazu	-25,456391	-55,008486	Paraguay	–
150	GR-P0035	2096	PP-P-0758-GR-P0035	Fassardi	-25,887214	-56,0838	Paraguay	–
151	AM-P0015	1862	PP-P-0524-AM-P0015	P.J.Caballero	-22,714318	-56,013841	Paraguay	–
152	SP-P0124	2292	PP-P-0954-SP-P0124	Tacuati	-23,515852	-56,758454	Paraguay	–
153	SP-P0151	2296	PP-P-0958-SP-P0151	Gral.Aquin	-24,343729	-56,737991	Paraguay	–
154	SP-P0353	2311	PP-P-0973-SP-P0353	San Pedro D	-23,910656	-56,989379	Paraguay	–
155	AP-P0010	1901	PP-P-0563-AP-P0010	Juan E. Ole	-25,405024	-55,376	Paraguay	–
156	CG-P0028	1962	PP-P-0624-CG-P0028	Mcal. Lopez	-25,237108	-55,074952	Paraguay	–
157	CG-P0041	1974	PP-P-0636-CG-P0041	Vaqueria	-24,993729	-55,82857	Paraguay	–
158	IT-P0040	2138	PP-P-0800-IT-P0040	Alto Vera	-26,753089	-55,770037	Paraguay	–
159	AP-P0018	1907	PP-P-0569-AP-P0018	Itakiry	-24,984957	-55,143915	Paraguay	–
160	MS-P0012	2242	PP-P-0904-MS-P0012	San Ignacio	-26,894214	-57,03178	Paraguay	–
161	SP-P0068	1880	PP-P-0542-SP-P0068	Yrybucua	-24,481486	-56,086842	Paraguay	–
162	CG-P0038	1971	PP-P-0633-CG-P0038	Juan M.Fru	-25,431344	-55,861154	Paraguay	–
163	Ose Salto	7325	PP-U-0003-OSE	*Salto*	-31,376477	-57,962003	Uruguay	–
164	Arapey	7323	PP-U-0001-Arapey	*Salto*	-30,949325	-57,517959	Uruguay	–
165	Dayman	7324	PP-U-0002-Dayman	Paysandu	-31,458327	-57,908624	Uruguay	–
166	Colonia Viñar	7341	PP-U-0020-Colonia Viñar	Colonia Viñar	-30,467274	-57,616346	Uruguay	–
167	Artigas OSE 410	7339	PP-U-0018-Granja Cornelius	Artigas	-30,416556	-56,454775	Uruguay	–
168	Artigas OSE 1.4.012	7387	PP-U-0066-1.4.012	Artigas	-30,399233	-56,473494	Uruguay	–
169	Rivera 10.4.018	7355	PP-U-0034-10.4.018	*Rivera*	-30,87271	-55,600117	Uruguay	–
170	Rivera 10.4.036	7358	PP-U-0037-10.4.036 Polo fondo	*Rivera*	-30,876587	-55,604343	Uruguay	–
171	Tranqueras 16.1.002	7373	PP-U-005216.1.002	Tranqueras	-31,19766	-55,754443	Uruguay	–
172	Tacuarembo 25.3.005	7376	PP-U-0055-25.3.005	Tacuarembo	-31,685182	-55,949566	Uruguay	–
173	Paguero	7347	PP-U-0026-Paguero	Paguero	-30,6318	-56,7759	Uruguay	–
174	Peralta	1284	PP-U-0516-853	Peralta	-32,498274	-56,355782	Uruguay	–
175	San Nicanor	7337	PP-U-0016-Termas San Nicanor		-31,545294	-57,801655	Uruguay	–
176	Guaviyu	7334	PP-U-0013-Quebracho	Quebracho	-31,841654	-57,886924	Uruguay	–
177	Javier de Viana OSE	7411	PP-U-0119-27		-30,431447	-56,783841	Uruguay	–
178	Guichon	7326	PP-U-0004-Almiron		-32,357724	-57,269356	Uruguay	–
179	16.1.010	7446	PP-U-0164-16.1.010	Tranqueras	-31,197732	-55,754716	Uruguay	–
180	Paso Ullestie	7338	PP-U-0017-Paso Ullestie	Paso Ullestie	-32,59555	-57,77535	Uruguay	-

Source: GS/GAS, Adapted from the Report on the Regional Monitoring Network, Guarani Consortium, 2008..

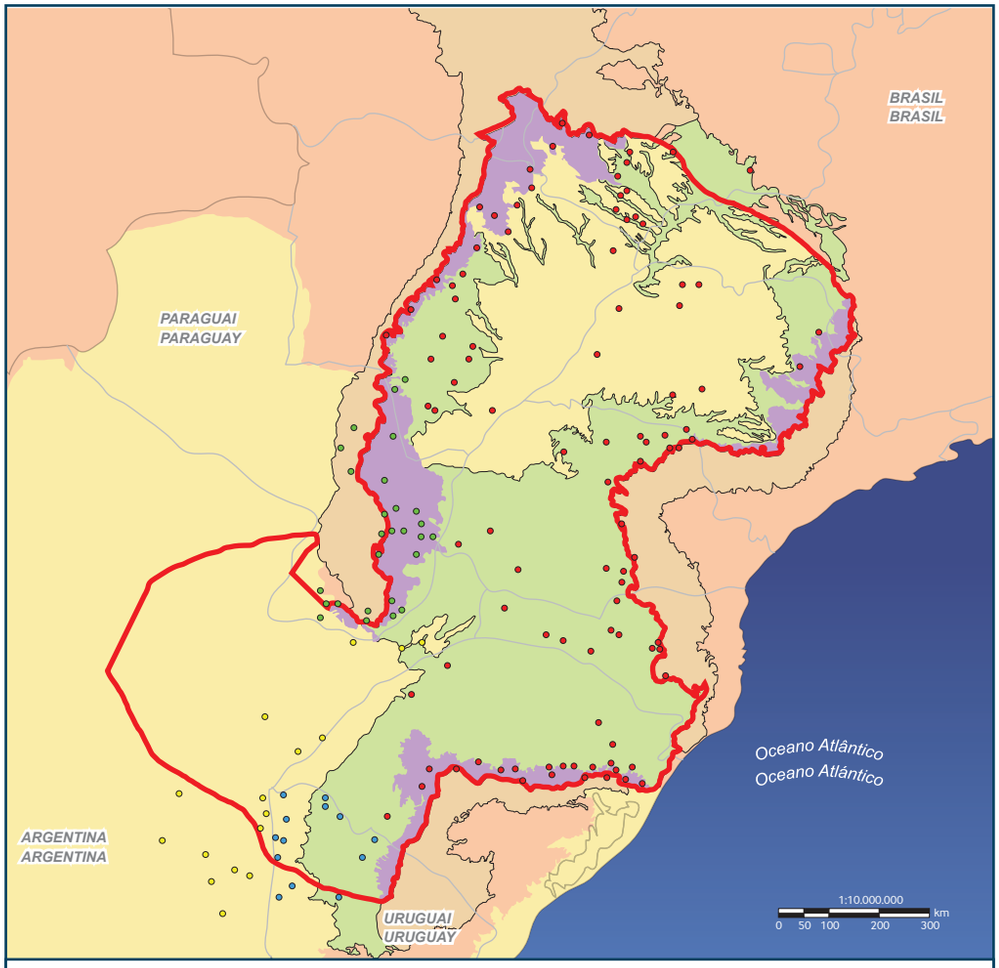


Figure 1. Location of selected wells

Key

- Departmental, state/provincial and international boundaries
- Limits of the GAS
- Post-GAS sediments
- Basalts
- GAS sediments
- Pre-GAS sediments
- Base

Abstract

- Argentina
- Brazil
- Paraguay
- Uruguay

Source: GS/GAS - Adapted from the Report on the Regional Monitoring Network, Guarani Consortium, 2008.

Regional model

In strictly technical terms, there is a need to calibrate the numeric model with the transit (variations over time of the aquifer's storage capacity) of water through the aquifer, principally owing to the slowness of groundwater flows. Such calibration could determine in which regions storage might be affected, a factor of crucial importance for sustainable management of groundwater resources in aquifers with low rates of replenishment.

To this end, the following suggestions were made:

- Analyze some of the smaller structures of regions not included in the GAS operational structure, where it is hypothesized that a continuous structure exists.
  N.B.: this will lead to reproduction of some piezometric and hydrochemical anomalies.
- Analyze how formations prior to the GAS could affect piezometry and flows.
- Prepare a map of the thicknesses of the Serra Geral Formation, including its regional characteristics. Analyze the possibility of horizontal flows of water through the basalt layer, and also of vertical changes.
- Prepare a map of the distribution of hydraulic conductivities or transmission to calibrate the numeric model.
- Determine, with greater precision, flows of water, especially replenishment in outcrop and extraction zones, with a view to quantifying basic flows of water courses and of deep replenishment.
  N.B.: based on local balances in river basins it is possible to estimate these components.
- Measure, with greater precision, interaction between the GAS and the Paraná and Uruguay Rivers.
  N.B.: applying chemical and isotopic methods it is possible to measure interaction between surface and groundwater flows.
- Study possible interaction between the GAS and waters located upstream from the Itaipu dam.
  N.B.: one swift and simple approach for conducting this study would be periodic measurement of flows or river levels and comparison of the data obtained from hydrograms of wells in the local area. This should be done for several years.
- Study ways of determining interactions between fresh and brackish water in the south region of the GAS.
- Collect, at selected wells of the project, data on water levels, flows and pumping, so as to attempt to model the GAS in a transitory regime.

Models in pilot areas

Ribeirão Preto

With a view to improving and complementing knowledge on the area of the study, implementation of a program for collection of information that encompasses the entire pilot area is recommended. This program should include the following procedures :

- Measures to ensure that owners of wells in pilot areas keep good records of abstractions and that they dispatch them regularly to the central agency. Monthly water use should be recorded by water meters.
- Drilling of a series of small-diameter wells to collect geological and hydrogeological information, both within the fields of existing wells and in other pilot-area zones, especially between towns where the majority of the wells are located .
  N.B.: samples from the main well should be collected and registered geologically, with a view to determining with greater exactitude the stratigraphic contacts between different units of the Guarani Aquifer. Packer testing should be carried out on the main well to determine the permeability profiles of the various different units of the aquifer. Intermediate bore holes should be drilled alongside the first well, with a view to creating a base for piezometric monitoring. There is no need to collect samples or conduct packer tests on these intermediate boreholes since this information is already available for the main well. The three boreholes should be lined with filters of PVC 50 millimeters in diameter.

ANNEX 11

ANNEX 11 TECHNICAL ASPECTS OF THE MODELS

- Identification of existing wells and abandoned boreholes that could be incorporated into the piezometric monitoring network, together with the previously-described boreholes.
  N.B.: static water levels should be measured at least one a month. If possible, transducers should be installed in some wells for continual monitoring of the water level.
- Conducting of a hydrological study to obtain a better appreciation of surface water flows in the entire area of the study.
  N.B.: if no measuring stations exist, they should be set up on the principal water courses and rivers, with a view to measuring flows . This would enable estimation of base flows.
- Updating of the numeric model of the area can only be effected through implementation of the previously-mentioned programs and collection of a sufficient quantity of new information.

Rivera–Santana do Livramento

Weaknesses in the information found in the present modeling study include:

- Lack of detailed and reliable information on characteristics of the aquifer in the principal abstraction area.
- Lack of substantial hydrogeological information on a major portion of the study area, i.e., aside from the group of wells in and around the main towns.
- Lack of hydrogeological information on surface drainage within the area.
- Lack of reliable information relating to certain private wells in the region, especially with respect to annual abstraction rates.
- Lack of historical and seasonal time series with information on water levels.

Based on this situation, implementation of a program for collecting data throughout the pilot area is recommended. This program should include the following procedures:

- Drilling of a series of small-diameter wells to collect geological and hydrogeological information both within the fields of existing wells and in other zones of the pilot area, especially between the towns where the majority of wells are located.
  N.B.: samples of the principal well should be collected and recorded geologically, with a view to determining with greater exactitude stratigraphic contacts between the various different units of the Guarani Aquifer. Packer testing should be carried on the principal well to determine permeability profiles of units of the aquifer. Intermediate boreholes should be drilled alongside the first well, with a view to creating a base for piezometric monitoring. There is no need to collect samples or conduct packer tests on the intermediate boreholes since this information is already available for the main well. The three boreholes should be lined with filters of PVC 50 millimeters in diameter.
- Identification of existing wells and abandoned boreholes that could be incorporated into the piezometric monitoring network, together with the previously-described boreholes.
  N.B.: static water levels should be measured at least one a month. If possible, transducers should be installed in some wells for continual monitoring of water levels.
- All owners of wells should use meters to registrar the quantity of water abstracted each month.
- Conducting of a hydrological study to obtain a better appreciation of surface water flows in the entire area of the study.
  N.B.: if no measuring stations exist, they should be set up to measure the greatest possible number of water courses and rivers, with a view to measuring flows. This would enable estimation of base flows.
- Incentives for water-supply companies to drill and conduct abstraction tests in areas removed from those that have been excessively exploited .
  N.B.: all new wells should undergo an exhaustive battery of hydraulic testes.
- Updating of the numeric model for the area can be carried out after implementation of the aforementioned programs and collection of sufficient quantities of data.

Itapúa

Surface water in the Itapúa pilot area has been relatively little exploited. In view of potential increases in exploitation, it is recommended that studies be carried out for development of long-term monitoring strategies and that data be collected on existing wells. These two measures taken together would enable analyses and forecasting of alternative scenarios.

Furthermore, the following procedures are recommended:

- Development of a monitoring network for groundwater levels in the basalt and sandstone, that could be comprised of existing wells.
  N.B.: regular (monthly) monitoring of the water level in each well is important. For the present analysis, it is presumed that one water-level measurement for each well will provide reliable data on long-term trends. This hypothesis can not be proven with the available data
- Wells should be selected from among those for which specialists have developed geological profiles.
  N.B.: a survey of the geographic coordinates and altitude of the wells should be carried out. If any of them provide potable water, the water level should be measured in static conditions, i.e., some six hours after pumping.
- Selected wells should be equipped with transducers, for continuous water level measurement.
  N.B.: monthly data on long-term water levels are insufficient. It is necessary to have knowledge on short-term variations. Transducers should be graded and monitored by remote access.
- It is necessary to identify the main hydraulic tests used in the area of the study with a view to obtaining knowledge on wells in active use, to appraise the quantity of water that can be abstracted in the long term, and identify the hydro-stratigraphic units from which water is abstracted.
  N.B: hydraulic testes should be adapted to local conditions so that more precise interpretations can be obtained, as there are no reliable independent assessments of hydraulic conductivity (transmisability). In future, hydraulic testes should be designed according to the category of use of wells for which geological profiles and construction details are available. On another occasion, more widely distributed wells in the study area may be used.

Information obtained from complementary wells is potentially valuable, as it may help supplement existing data and corroborate the calibration method. Provided resources are available for further drilling, the following is recommended :

- The well should be installed at a location close to coordinates E623000 m, N698000 m.
- The well should be located in a zone where the basalt is relatively thick. The model is sensitive to properties of the underlying basalt and, thus, a good location could be the area where sandstones of the Misiones Formation are covered by a lower and a higher layer of basalt.
- The well should be located in a zone where the water level in the Misiones Formation is significantly higher than the level of the surface topography. In such zones, future pumping needs will be smaller, and the aquifer is protected from contamination and isolated from surface sources.
- The well should be located in a zone where wells are widely distributed. If sufficient resources are available, hydraulic tests should be conducted during throughout the drilling stage.

Salto–Concordia

All spas ought to obtain and disseminate information, as follows:

- Monthly dispatch to a central body of data on daily abstraction volumes, including the number of hours of operation and discharge rates. *N.B.: precise piezometric measurements should be taken at least once a week and, if possible, recorded during pumping and rest periods. For example, if a pump operates for 16 hours and rests for eight hours per day, the pressure readings should be taken immediately prior to interruption and start of pumping.*
- Each installation should be visited by a qualified inspector and procedures revised to confirm that information is being correctly collected.
- Once a year (or twice, if possible) all thermal wells in the pilot area should be shut down for 48 hours.
  N.B.: piezometric loads should be measured immediately prior to the 48-hour shut down, and prior to start up. Demand for spas is seasonal. Thus, half-yearly shutdowns should occur at the beginning and end of the off season. Shut-down and recording of data should be the responsibility of a qualified inspector. Additional tests on the aquifer should be carried out during periods of shut-down and start up of pumping, and should also be supervised by a qualified inspector. These measures should be introduced gradually, until all of the wells have been tested.

If possible, a test well should be drilled, specifically for collecting scientific data relating to the GAS. In view of problems related to high artesian loads in the pilot area, it is suggested that drilling be carried out at a point between the Rivera-Tacuarembó region (a replenishment area) and the Concordia-Salto area. In this case it is important to remember that:

- After careful selection, drilling could be carried out in an area where the piezometric load is close to ground level. To solve the problem of lack of data, drilling could also be carried out in a zone where there are no deep boreholes and, consequently, little information is available.
- Drilling should at least reach the Buena Vista Formation and sequential samples of GAS structures (including the Buena Vista Formation)should be taken. Samples should be made available to academic institutions and duly recorded. Moreover, drilling should include tests to determine permeability profiles. Best practices for obtaining water samples from different depths and for complementing drilling should be adopted. If possible, multilevel sample collectors should be installed.
- It is recommended that, at some point, the scope of the model be extended to enable inclusion of a greater array of natural limit conditions. To this end, the possibility of developing a sub-regional model that encompasses the entire replenishment area and the Concordia-Salto area should be studied. Potentially, this initiative could provide a more realistic simulation of the groundwater regime, especially if data collected during experimental drilling is included. This would also enable incorporation of findings from the Concordia-Salto and Rivera-Santana do Livramento pilot areas.

ANNEX 12

Annex 12 General Hydrogeological Recommendations

The PGAS enabled a deepening of knowledge on the Guarani Aquifer System and its hydrogeological and hydraulic workings. However, some doubts persist and have generated a series of recommendations (taken from PGAS technical consultancy reports), many of which have been incorporated into the strategic actions listed in Chapter 5. Others are listed below:

- To underpin deployment of groundwater management policies, it is necessary to raise awareness of water-resources managers as to the need for specific knowledge. The only direct means of observation and data gathering on groundwater are bore wells. It is essential that each new well drilled provide all possible information, including geoelectrical profiles and pumping tests. Such information should be incorporated into the SIGAS and disseminated. A continuous program of registry and control of wells should be set up, to determine locations and calculate volumes, and the uses of abstracted water .
- All wells drilled into the GAS should abide by recognized design and construction methodologies and technologies, in accordance with standards provided by the PGAS drilling manual. All environmental protection measures should be observed during drilling of wells. Geological formations that cover the aquifer should be insulated using tubes and cement structures, so as to maximize efficiency and working lives.
- If possible, measurement of water levels should be carried out in wells that are not being used. This would make it possible to overcome current limitations of surveys performed under the PGAS. There is a need to carry out a greater number of pumping tests, with observations of interference between wells, with a view to characterizing such significant parameters as transmissibility and storage coefficients. This would enable quantification of flows and reserves.
- Definition of replenishment and discharge volumes of the GAS poses an enormous challenge. The water balances carried out are insufficiently conclusive and need to be complemented by more detailed studies on the basins and specific replenishment and discharge areas. These studies require use of adequate equipment and methodologies. Only based upon sound data at the local level can regional patterns be established.
- A regional (general) overview of the GAS contributes toward local knowledge, but can not detect certain conditions nor resolve local problems. Local studies are needed, on a scale of at least 1:50.000, or of no more than 1:100.000, to define more precisely such problems as the scope of interferences, the risks of contamination and the connections between flows over larger distances.
- It is recommended that future hydrogeochemical studies quantify discharges of the surface water network, determine the composition and age of pre-GAS brackish water, confirm the origin of fluorine and the contributions of the pre-GAS, identify processes of contamination in urban and rural zones, and prepare prevention and recuperation plans.
- With respect to application of environmental isotope tests to the GAS, it is recommended that data on time of residence be improved, using carbon 14 (^{14}C) methodology. Correction is necessary because the emergence of old carbon from dissolution of carbonates. Correction methods should be based on geochemical alterations in the groundwater. It is also recommended that new isotopic tools be used to determine the time of residence of water, since this information can not be obtained by means of the ^{14}C methodology. To this end, chlorine 36 (^{36}Cl) and cryptonym 81 (^{81}Kr) tools can be used. There was an experience of using ^{36}Cl that revealed the complexity of applying this methodology to the aquifer. However, this experience also demonstrated that a more careful selection of test wells could enhance results produced by the tool.
- Another important aspect that merits deeper study is the influence of tectonic structures that affect the hydraulics of the GAS, such as slippage and discontinuity faults, sealed by intrusive diabase sills. It is necessary to gain a better understanding of the influence of the Arco de Ponta Grossa on the flow system of the GAS. One view is that this type

of structure compartmentalized the aquifer. This view questions the continuity of the flow system among the different blocks. Another process that requires further study is possible discharges of the GAS through the basalts. There is evidence that this is occurring in certain parts of the aquifer, but such compartmentalization needs to be confirmed and its geological causes understood.

- The isotopic study also leads to postulation that, in the GAS replenishment zones, a considerable portion of the replenishment serves to supply the local drainage system, thus implying a low rate of replenishment of the regional aquifer. In view of its importance for management of the aquifer, this aspect needs to be studied in greater depth so as to assess the relationship between local and regional replenishment. Isotopic data obtained from this study show that the lakes of Estero de Ibera are fed by recent water (rainwater). To understand the role of groundwater in these lakes, it is recommended that a hydrogeological study be carried out in wells drilled specifically for this purpose. This would enable a study of the flow system and of the chemical and isotopic composition of the waters that feed the lakes.
- Obtain a better understanding of characteristics of the lower limits of the GAS sandstones, their discordances and discontinuities, and the type of sediments that support them (degree of separation of Permian sediments from salt water, for example). Carry out detailed studies on the Pirambóia Formation in Brazil, its stratigraphic relations and its age.
- Assess the existence of contemporary geological Mesozoic sub-basins that are independent of the GAS.
- Carry out complementary geophysical evaluations that encompass the geometry, structure, and hydraulics of deep sectors of the Central Channel of the sedimentary basin in the countries. Stimulate the search for information in areas for which no data is available on the subsoil.

ANNEX 13

Annex 13 Strategies for ensuring continuity of the Guarani Universities Fund

Continuity of the Guarani Universities Fund, as proposed in this document, requires that there be a Liaison Unit with technical and financial capabilities to deploy its operational plan and ensure follow up of its actions. One alternative would be to use the structures and institutional arrangements for support of scientific research in the countries (CONICET[1], CONACYT[2] CNPq, CAPES and state-level FAPs[3]) and to create a special line of financing for studies on the GAS. In either case, the possibility of specific research on the GAS being carried out using national resources from the budgets of these institutions should be the object of specific negotiations within the scope of the SAP.

In order to ensure continuity of the fund, the following recommendations are made:

1 Thematic axes

Starting from an academic fund with a wide scope of thematic approaches, it is proposed that a second fund (or continuation of the present one) foster multidisciplinary participation, and that it be restricted to specific and strategic themes. For example:

- » Socioeconomic aspects: few research groups are assessing economic possibilities for using groundwater or the threats posed to water quality and quantity. Foremost among these are thermal uses of the aquifer.
- » Aspects related to management and planning (including legal aspects): groundwater management initiatives in the GAS region have yet to be assessed. Implementation of specific standards and laws for groundwater tend to draw reactions from the public. Management weaknesses (lack of technical knowledge, poor systematization of information among management bodies, lack of training for technical staff and consultants, poor public participation, political timeliness, etc.) and the effects of such reactions are themes that need to be investigated in future research initiatives.

2 Selection criteria

Based on relationships of mutual trust between stakeholder groups and the Project, it is suggested that resources be allocated in a targeted fashion for fomenting ongoing technical and scientific initiatives, by means of submission of new proposals that highlight subsequent stages of research.

Furthermore, it is recommended that funds be created that are open to any group wishing to submit research proposal, in accordance with conditions published in calls for proposals that should clearly state which are the priority themes.

3 Geographical aspects

Equitable representativeness should be fostered among the countries. Regions that have no consolidated research groups should receive funding to establish them. Such new groups should receive support from the liaison unit, which is responsible for establishing contacts and providing information. Closer ties should also be fostered among universities of the region. The strategy of targeting the focus on Pilot Projects has proven appropriate, as it has enabled universities in the interior to become involved with research themes relating to groundwater and led them to generate information of great importance within the context of the GAS. Formation of consortia should remain a requisite when considering proposals for studies on technical scientific themes. Funding should be made available to as yet non-consolidated groups, with a view to stimulating their growth.

4 Allocation and execution of the fund

As was stated earlier, allocation of resources should be based upon presentation of a minimum, simple and feasible strategy for close-up monitoring. Presentation formats for legal agreements between liaison offices and universities should be replicated. An external scientific evaluation group, holding of symposia for presentation of

1 National Scientific and Technical Research Council – Argentina and Uruguay.
2 National Science and Technology Council – Paraguay.
3 National Scientific and Technological Council, Coordination for Personnel Enhancement at the Higher-Education Level and State Research Support Foundations – Brazil.

research papers, and creation of a cash award would add academic prestige to the process and stimulate analysis of data generated by project consultants. This award is merely a suggestion, and its creation and management still needs to be discussed and approved by decision makers in each country.

5 Financial aspects of the Fund

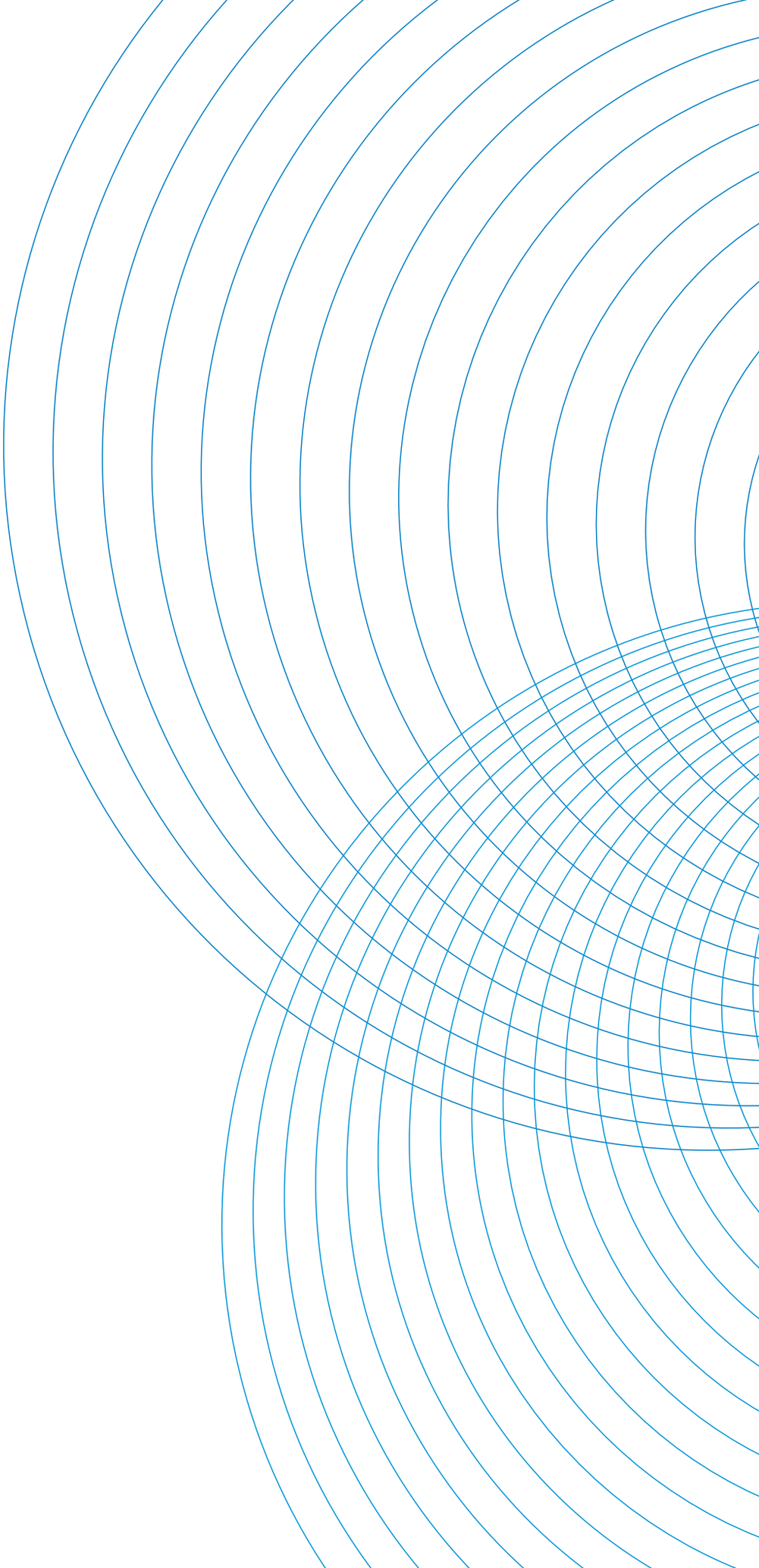
In line with the new thematic approaches of the SAP and following-up on technical and scientific research, the liaison office should unbundle the funding, to make it compatible with actions under the earlier fund. This should be determined by the executing countries and donor institutions. The 25% counterpart could be raised to 50%, thereby stimulating greater commitment on the part of the universities. It should, nonetheless, vary depending upon the modality of the fund (targeted or open).

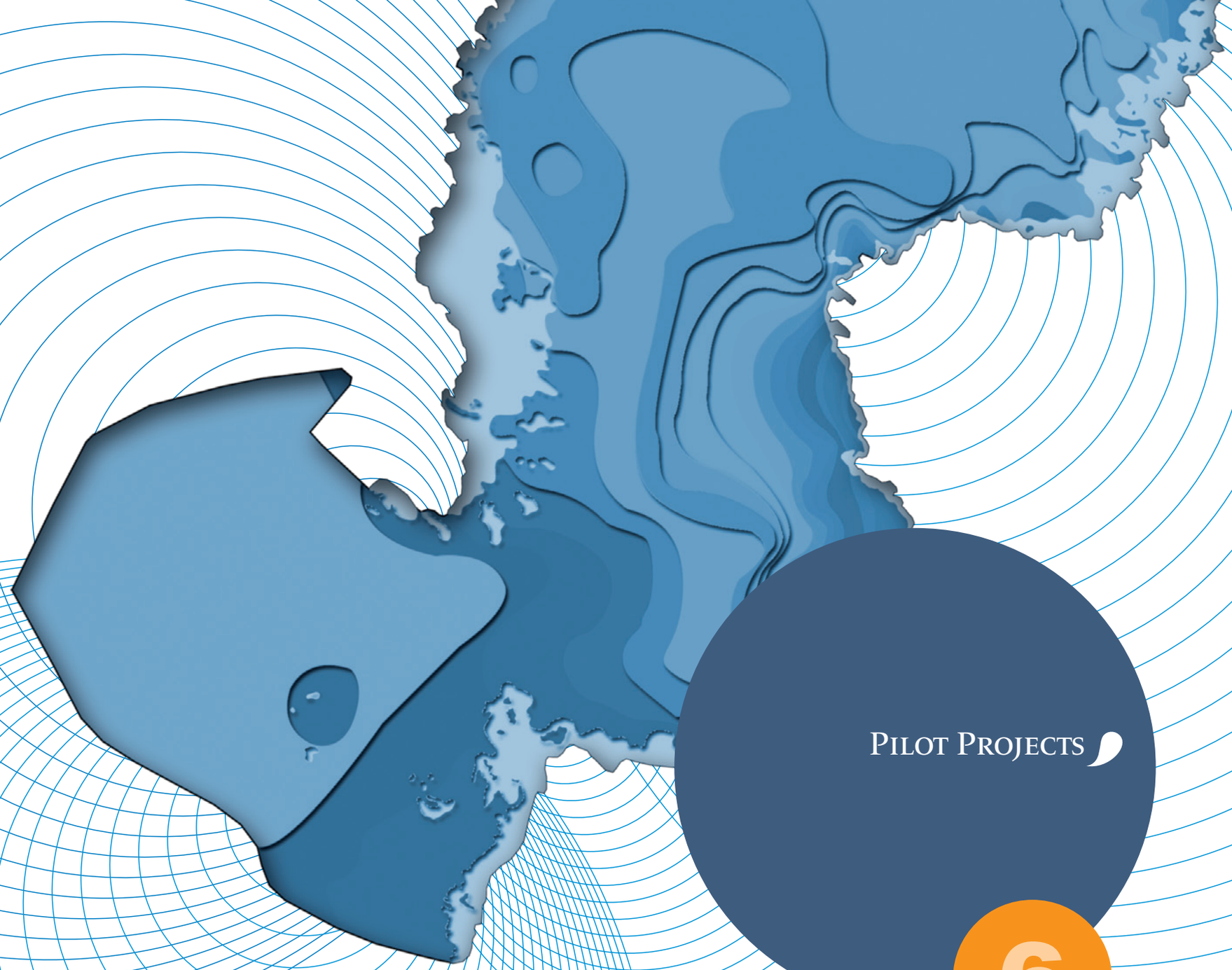
6 Publicity (calls for proposals and outcomes)

Differently to what has happened in the past, the executing body should engage in specific prior dissemination, especially when seeking partners to work in areas where institutional weaknesses have become apparent. During meetings held to present new strategies, the liaison office could not only seek to build capacities and stimulate presentation of new projects, but also promote participation of other universities in the GAS region, eligible to form consortia. Calls for proposals should be specifically addressed to federal, state, and municipal universities in the region. New thematic approaches could be announced in the same way as in the previous fund.

Publication of calls for proposals should abide by normal public-tender and competitive-examination procedures, (internet, major newspapers, etc.). Publication of results should be commiserate with funding allocations provided by donors. It is recommended that publication of such results be in the form of a book, or in renowned scientific publications.

Project for Environmental Protection and Sustainable Development of the Guarani Aquifer System





Pilot Projects

6

Chapter 6

Pilot Projects

SUMMARY

With a view to launching concrete experiences in sustainable management for subsequent replication, Pilot Projects were established in four areas identified as being under current or potential threat of conflict over land-use or use of groundwater from the Guarani Aquifer System (GAS). Two of these Pilot Project areas, namely, Santana do Livramento/Rivera (Brazil-Uruguay) and Concordia Salto (Argentina-Uruguay)are located in transboundary areas. whereas the other two, Itapúa (Paraguay) and Ribeirão Preto (Brazil) are located totally within a country. However, in view of the relevance of the themes addressed by these four Pilot Projects, their experience is of interest to all four countries that share responsibilities for management of the GAS.

These Pilot Projects entailed preparation of diagnostic studies of each area and the opening of opportunities for public participation in activities relating to decision making and management of the GAS. They enabled the preparation of measures for fostering rational and sustainable use of GAS waters, addressing issues relating to interdependence with social, economic and environmental factors and enhancing the effectiveness of normative standards for protection and management of the Aquifer. This chapter describes the situation in each of the Pilot-Project areas and recommends specific approaches, under the Strategic Action Program (SAP) for short, medium and long-term management of the GAS.

6 PILOT PROJECTS

During execution of the Project for Environmental Protection and Sustainable Development of the Guarani Aquifer (PGAS) four pilot areas were delimited. The aim was to generate concrete local management experiences in areas with potential conflicts relating to use of groundwater or changes in land use patterns, and that could be considered representative of the Guarani Aquifer System (GAS) as a whole. These local experiences are referred to as Pilot Projects.

Two of these pilot areas straddle international borders and encompass the municipalities of Santana do Livramento in Brazil and Rivera in Uruguay. and of Concordia in Argentina and Salto in Uruguay. The other two, Itapúa in Paraguay and Ribeirão Preto in Brazil, are totally within those respective countries (Figure 1).

In each of the Pilot Projects, Local Project Support Committees (CLAPs) were formed and, with the assistance of technical advisors, Local Action Plans (PALPs) were prepared and carried out.

The experiences and lessons learned during this process are of fundamental importance for future management of the GAS, and were considered during preparation of the Strategic Action Program (SAP).

Establishment and organization of the CLAPs stemmed from a need to enhance participation in decision making at the local level, in order to face up to the challenges of implementing groundwater management.

6.1 DIAGNOSTIC ANALYSIS OF THE PILOT-PROJECT AREAS

There follows criteria and challenges were considered in the selection of Pilot Project areas:

(a) *Itapúa* (Paraguay): an aquifer replenishment zone in an flourishing agricultural area formerly covered with forest, where the main challenge is to obtain a better understanding of the relationship between settlement and land-use patterns and the GAS. The aim of the Pilot Project in this zone is to identify ways of ensuring protection and sustainable use of the GAS. As a consequence of outcomes already achieved by the PGAS and implementation of future actions, this Pilot Project is likely to become an important reference for effective implementation of the new Water Resources Law throughout Paraguay.

(b) *Concordia* (Argentina)/*Salto* (Uruguay): an intensely exploited hydrothermal confined-aquifer zone of the GAS. A great number of boreholes are used by a socially and economically important tourism industry, the expansion of which could, potentially, give raise to conflicts and issues of sustainability. Evidence of interference between wells is already apparent. According to zoning activities carried under the Project, this is a highly-confined zone (ZFC) of the GAS, where replenishment of abstracted water is very slow. In view of these characteristics, it is essential that standards for rational use and reuse of thermal waters of the GAS be implemented in this Pilot Project area.

(c) *Ribeirão Preto* (Brazil): a town (population 600,000) in the interior of the State of São Paulo, located in a rapidly developing area overlying the GAS. Drinking-water supply for this important development hub is intensively abstracted from the GAS. Studies predating the Project had detected considerable drops in GAS piezometric levels in certain neighborhoods of the town. The Pilot Project provided an opportunity to generate concrete experiences of groundwater management under conditions of intensive use, in an outcrop zone (ZA) and highly-confined zone (ZC), where the GAS receives direct replenishment.

(d) *Rivera* (Uruguay)/*Santana do Livramento* (Brazil): an unconfined aquifer zone coincident or in close proximity to outcrop and replenishment areas that are highly vulnerable to contamination, overlying which lives an urban population of over 200,00, divided roughly in half by the border between Brazil and Uruguay. On both sides of the border, water abstracted from wells drilled into the GAS is mostly for household use. Potential interference between wells and pollution caused by poor urban sanitation pose significant problems. Protection of the GAS is closely associated with issues relating to land-use, territorial planning of human settlements, and the rapidly changing dynamics of productive activities.

Table 1 summarizes the main characteristics of the Pilot-Project areas.

6.2 NORMATIVE AND INSTITUTIONAL EVALUATION

Under the PGAS, specialists on legal and institutional themes relating to water resources from the four countries conducted an analysis of current legislation in each of the Pilot-Project areas. The main points highlighted in this analysis were as follows:

- All of the countries have the necessary legislation to carry out priority short and long-term strategic actions for enhancement of local management of the GAS in the four Pilot-Project areas.
- In transboundary Pilot-Project areas, the path for achieving local coordinated groundwater management starts with a clear definition of the common objectives (problems and their respective solutions), followed by implementation of actions, based upon current legislation of each country. In the transboundary Pilot-Project areas, there are sufficient normative standards and tools to achieve the common goal of instituting local groundwater management. To this end, institutional cooperation is indispensible.
- Spaces for local coordination between the countries should be ensured, principally between the various technical departments of groundwater-management and territorial-planning institutions. Exchanges of ideas and experiences will lead to advances in local management that will in turn enable the necessary adjustments for fomenting rational use and adequate protection of the aquifer in the Pilot-Project areas.
- In non-transboundary Pilot-Project areas, i.e., Itapúa and Ribeirão Preto, current legislation allows the adoption of strategic actions to enhance local management. This can be effected by means of integrated

Figure 1. Map GAS - Pilot Areas

Key

- Departmental, state/provincial and international boundaries
- Limits of the GAS
- Argentina
- Brazil
- Paraguay
- Uruguay

Pilot Areas

- Concordia / Salto
- Ribeirão Preto
- Itapua
- River / Santana

Source: GS/GAS, 2008.

Table 1. Summary of characteristics of the Pilot-Project areas

	Ribeirão Preto
Location and population	- Six municipalities - 2.500 km^2 - Population of 720,000 in the Pardo River Basin (70% in Ribeirão Preto) - Population forecast for 2020 - over 1 million-
Socioeconomic development and water use	- Extensive sugarcane and citrus plantations - Brazil's agribusiness capital, with the world's greatest sugar and alcohol production - GAS water the only source of public water supply - Household consumption 350-450 liters/person/ day
Characteristics and hydrogeological problems	- 137 km^2 of GAS sandstone outcrops and GAS regions covered by basalts - Evidence of excessive exploitation in the municipality of Ribeirão Preto - Potential risk of contamination in outcrop areas - Abstractions greater than replenishment and increasing demand for water - Expectation of reduced replenishment owing to climate change
Legal framework	- State laws and municipal ordinances useful for management and protection, but greater integration and stricter enforcement are required
Main institutions involved in local groundwater management	- Municipal Secretariats - Department of Water and Sewage of Ribeirão Preto (DAERP) - Pardo River Basin Committee(CBPH) - State Secretariat of Environment (SMA/SP) - Department of Water and Electric Power (DAEE) - Geological Institute of São Paulo (IGSP) - State Sanitation and Environmental Technology Company (CETESB) - The Local GAS Committee is linked to the Pardo River Basin Committee
Priority actions of a technical nature	- Maintain restrictions on drilling of wells in urban areas (in force in Ribeirão Preto) - Stimulate location of new wells outside the most exploited perimeters - Promote territorial planning so as to protect replenishment zones and potable water sources, based on GAS thematic maps (including the map on vulnerabilities) - Promote strategies for reducing household consumption (metering, tariffs and awareness-building campaigns) - Implement protection measures for current public water supply sources located in vulnerable areas - Promote studies of alternative sources for future mixed water supply (surface waters and rainwater) - Promote installation of local quality monitoring networks for GAS water and the use of models as management instruments-
Guidelines for management	- Consolidate the Local GAS Committee within the Pardo River Basin Committee - Promote coordination between the Local GAS Committee and the Technical Chamber for Groundwater (CTAS) of the Pardo River Basin Committee - Build capacities in the municipality to operate the GAS Information System (SIGAS) - Support efforts of the Department of Water and Electric Power (DAEE) to operate and expand the local monitoring network for wells
General actions and implementation	- Continually expand local knowledge on the GAS through the local committees - Implementation of mechanisms for dissemination of local knowledge through coordinated actions between Local Committees and municipalities - Promote balanced integration and representation among public and private bodies in the local committees - Create spaces for public participation in local committees - Facilitate coordination among institutional players within each country and between countries for implementation of proposed actions - Enlist commitment and support from Governments for local management - Seek to improve the availability of human and financial resources
	Rivera (Uruguay)/Santana do Livramento (Brazil)
Location and population	- 750 km^2 of land border between the two countries - Population 170,000 in the two towns
Socioeconomic development and water use	- Intensive agriculture and livestock raising - Good potable water coverage, with the GAS as the main source of water supply - Poor sanitation (with projects and works for expanding coverage in the two towns) - Growing forestry development in peripheral areas of the Pilot Project

Continues

Continuation

Characteristics and hydrogeological problems	- Important GAS outcrop area - 60% of abstractions located in the urban zone of the Pilot Project - Possible nitrate contamination in wells of the region owing to lack of sanitation (coverage under expansion) - Insufficient inclusion of the themes groundwater and the GAS in territorial planning - Lack of protection of GAS outcrop and replenishment zones - Restrictions to installation of potentially polluting activities (landfills, metalworks and gasoline stations)	
Legal framework	- National legislation on management and protection in the two countries (state-level legislation in Brazil) requires stricter enforcement - Need to guide local management and to promote coordination and convergence in the two countries - Existing environmental and scientific cooperation agreements between Brazil and Uruguay could serve as a basis for local actions	
Main institutions involved in local groundwater management	**Brazil** - Secretariat of Agriculture and Water and Sewage Board (municipal) - Secretariat of Environment of the State of Rio Grande do Sul (SEMA) - Department of Water Resources of the State of Rio Grande do Sul (DRH) - State Environmental Protection Foundation (FEPAM) - Santa Maria, Ibicuí and Quaraí River Basin Committees - Secretariat of Water Resources and Urban Environment of the Ministry of Environment (SRHU/MMA) - Ministry of Foreing Affairs (MRE)	**Uruguay** - Rivera Municipal Intendancy (Health, Hygiene, Environment and Laboratories Board) - Ministry of Housing, Territorial Planning and Environment (MVOTMA) - National Water and Sanitation Board (DINASA) - National Environment Board (DINAMA) - State Sanitation Works Department (OSE) - Guarani Infra-basaltic Aquifer Advisory Board
	Bi-National - Guarani Aquifer Transboundary Committee (COTRAGUA)	
Priority actions of a technical nature	- Support expansion of the sanitation network in the two towns - Establish groundwater protection areas with restrictions on such activities as urban growth and intensive agriculture - Stimulate installation of new sources in protected areas and outside urban areas - Promote territorial planning so as to protect potable water sources located in outcrop areas - Deepen studies on the water balance, replenishment and groundwater availability - Assess impacts of expansion of forestry activities - Universal census of wells, registered or not requiring registration - Promote installation of local quality monitoring networks for GAS water, and use of models as management instruments	
Guidelines for management	- Consolidate the Local GAS Committee with support from the two municipalities, the Santa Maria, Ibicuí and Quaraí River Basin Committees (Brazil), the Guarani Aquifer Advisory Board (Uruguay) and the Uruguay-Brazil Joint Committee for development of the Cuareim/Quaraí River Basin and its areas of influence - Analyze sources of funding for the Guarani Aquifer Transboundary Committee (COTRAGUA) - Harmonize territorial planning of the two towns in relation to local management of groundwater	
General actions and implementation	- Continually expand local knowledge on the GAS through the local committees - Implementation of mechanisms for dissemination of local knowledge through coordinated actions between Local Committees and municipalities - Promote balanced integration and representation among public and private bodies in the local committees - Create spaces for public participation in local committees - Facilitate coordination among institutional players within each country and between countries for implementation of proposed actions - Enlist commitment and support from Governments for local management - Seek to improve the availability of human and financial resources	
	Itapúa (Paraguay)	
Location and population	- Region of agro-livestock activity, covering 800 km^2, encompassing five municipalities in the Capiibary Basin of southwestern Paraguay - Population 45,000	
Socioeconomic development and water use	- Extensive land surface for agricultural production (soybeans and seasonal crops) - Agriculture encroaching on outcrop areas - Low volume and disperse abstractions for public water supply - Possible socioeconomic changes caused by the Corpus Reservoir	
Characteristics and hydrogeological problems	- 50% of GAS outcrops (municipalities of Trinidad and Jesús) and the remainder under a basaltic cover of varying thicknesses (in the municipalities of Bella Vista, Hohenau and Obligado) - Changes in land-use patterns may lead to higher risk of contamination of the GAS	

Continues

Continuation

Legal framework	- National legislation adequate for management and protection, but new standards still need to be instituted, integrated and strictly enforced
Main institutions involved in local groundwater management	- Secretariat of Environment (SEAM), General Directory for Protection and Conservation of Water Resources - Sanitation Environmental Service (SENASA) and Water and Sanitation Boards - Capiibary Basin Council - The Local GAS Committee is linked to the Capiibary Basin Council
Priority actions of a technical nature	- Protect sources of public water supply - Include measures targeted at protection of productive and replenishment areas of the GAS into territorial planning - Assess potential contaminants in the non-saturated zone and conduct hydrochemical monitoring of the quality of GAS water - Diffusion and control of compliance of technical standards for drilling of wells - Use of mathematical models as management support instruments
Guidelines for management	- Consolidate the Local GAS Committee within the Capiibary Basin Council - Train and support Fundación Universidad Católica de Itapúa (FUCAI) to operate the Information System SIGAS - Establish a research center at FUCAI to assess the relationship between agricultural land use and the GAS - Assess impacts in the area of influence of the Corpus dam and effects on the aquifer (new uses and replenishment)
General actions and implementation	- Continually expand local knowledge on the GAS through the local committees - Implementation of mechanisms for dissemination of local knowledge through coordinated actions between Local Committees and municipalities - Promote balanced integration and representation among public and private bodies in the local committees - Create spaces for public participation in local committees - Facilitate coordination among institutional players within each country and between countries for implementation of proposed actions - Enlist commitment and support from Governments for local management - Seek to improve the availability of human and financial resources
	Concórdia (Argentina)/Salto (Uruguay)
Location and population	- 500 km^2 on both banks of the Uruguay River - Population 200,000 evenly distributed between the two countries
Socioeconomic development and water use	- Citriculture and horticulture in expansion - Principal thermal tourist hub in the GAS region - Principal use of the GAS is for recreation - Public water supply of the towns is from surface-water sources
Characteristics and hydrogeological problems	- GAS covered and protected by 800 to 1,000m of basalt, with artesianism and geothermal potential (temperatures ranging from 44 ^{o}C to 48 ^{o}C) - Upper portion of the basalt and sandy strata of the cover are a source of potable water for household use, principally in rural areas - Potential interference between clusters of geothermal wells - Risk of contamination from abstractions of water from deeper aquifers (more brackish water)
Legal framework	- National legislation for management and protection in the two countries (provincial legislation in Argentina) - Legislation of acceptable effectiveness, few users identified - Within the scope of the Pilot Project, local standards were developed in the two countries - Legislations in the two countries serve as the platform for developing a set of coordinated and convergent actions for local management
Main institutions involved in local groundwater management	**Argentina** - Municipal Administration of Concordia - Hydraulic Directory of Entre Ríos - Secretariat of Environment and Sustainable Development - Regulatory Council for Water Sources (CORUFA) - Regulatory Body for Thermal Resources (ERRTER) **Uruguay** - Municipal Intendancy of Salto - Ministry of Housing, Territorial Planning and Environment (MVOTMA) - National Water and Sanitation Board (DINASA) - National Environment Board (DINAMA) - Guarani Infra-basaltic Aquifer Advisory Board - State Sanitation Works Department (OSE) Bi-National - Local Support Committee for the GAS - Pilot Project Concordia/Salto (CLAP): acts as the local committee for the country and as a transboundary committee
Priority actions of a technical nature	- Promote local coordinated groundwater resources management - Prevent conflicts caused by interference between wells - Preserve artesian flows, conserve water temperatures and minimize salination - Promote efficient use of thermal water - Apply and control technical standards for design, construction and operation of thermal wells - Maintain continuous monitoring of wells (changes in parameters) principally to prevent changes in quality owing to salinity - Control land use, especially in thermal complexes - Use and enhance mathematical model as a management support instrument

Continues

Continuation

Guidelines for management	- Consolidate the Local Committee for the GAS, with support from the two municipalities, the Guarani Aquifer Advisory Board and the bi-national Salto Grande Technical Joint Committee - Strengthen municipal, provincial and national bodies to operate and expand the local monitoring network of wells and of the SIGAS - Analyze sources of funding for the Pilot Project Support Committee
General actions and implementation	- Continually expand local knowledge on the GAS through the local committees - Implementation of mechanisms for dissemination of local knowledge through coordinated actions between Local Committees and municipalities - Promote balanced integration and representation among public and private bodies in the local committees - Create spaces for public participation in local committees - Facilitate coordination among institutional players within each country and between countries for implementation of proposed actions - Enlist commitment and support from Governments for local management - Seek to improve the availability of human and financial resources

Source: GS/GAS, GS/GAS, adapted from GW-MATE and PALP, with contributions from the Project Execution Units, 2008.

water-resources management through basin committees and councils. In such cases there are no obstacles to implementation of concrete actions.

Ensuring the success and sustainability of the Pilot Projects is an essential step toward instituting management of GAS groundwater. Lessons learned in other areas of the GAS with similar characteristics and their general applicability are of special importance. It is the Pilot Projects that provide procedures, methodologies, and legal and fiscal instruments for enhancing local management in these and other areas of the GAS.

6.3 SUSTAINABILITY OF MANAGEMENT IN PGAS PILOT-PROJECT AREAS

Table 2 provides proposals for promoting sustainability and normative effectiveness of management in PGAS Pilot-Project areas

6.4 ITAPÚA PILOT PROJECT (PARAGUAY)

The Itapúa Pilot Project encompasses areas used predominantly for agriculture and livestock, that were formerly covered by forest ecosystems. The main crop is soybeans, but there are also fields of wheat, corn (maize), erva-mate, and other crops. The area covers 800 km^2 in the extreme southeast of Paraguay, and encompasses the districts of Bella Vista, Jesús, Trinidad, Hohenau and Obligado (Figure 2). Annual average rainfall in this area is 1,600 mm/year. The population is approximately 45,000.

The Itapúa Pilot Project area is located on a sequence of mesozoic sedimentary formations, covered by non-continuous layers of basalt (the Alto Paraná volcanic formation) which extend across the central and northeastern zone of the Pilot-Project area, but not the southern part. The GAS outcrop zone corresponds to 40% of the area. The cross-sections in Figure 3 show the hydrogeological context.

Table 2. Proposals for promoting sustainability of management in PGAS Pilot-Project areas

Promote involvement of the Local Groundwater Management Committee (CLGAS) in water resources management	
Riberão Preto, Brazil (with financial impact)	- Ensure continuity of the Pilot Project Coordination Group of Ribeirão Preto (GCPPRP) established in 2003 as part of the Pardo River Basin Committee
Concordia, Argentina – Salto, Uruguay (with financial impact)	- Establishment of two Local Groundwater Management Committees (CLGAS) - ***Concordia:*** a formal unit within the Hydrology Board of Entre Ríos (DHER). Acknowledgement, by the DHER, of the CLGAS as the local groundwater-management support body, and signing of an agreement between DHER and the Municipal Administration of Concordia to provide technical and operational support to the CLGAS - ***Salto:*** a formal unit within the Municipal Administration of Salto. Acknowledgement, by the DINASA, of the CLGAS as the local groundwater-management support body, and signing of an agreement between DINASA and a Municipal Administration of Salto to provide technical and operational support to the CLGAS
Rivera, Uruguay – Santana Do Livramento, Brazil (without financial impact)	- Formalization of two Local Groundwater Management Committees (CLGAS) - ***Rivera:*** a formal unit within the Municipal Administration of Rivera. Acknowledgement by DINASA of CLGAS as the local groundwater-management support body, and signing of an agreement between DINASA and the Municipal Administration of Rivera to provide technical and operational support to the CLGAS

Continues

Continuation

	- **Santana do Livramento:** transformation of the current CLGAS into a Technical Chamber for Groundwater within the scope of the Santa Maria River Basin Committee. the Secretariat of Environment of the State of Rio Grande do Sul (SEMA) is to sign an agreement with a university to provide technical and operational support to the CTAS **Bi-national:** Within the scope of current cooperation agreements between the two countries, create a Local Transboundary Groundwater Management Committee (a Bi-national CLTGAS) with participation of the CLGAS, of the Ministry of Foreing Affairs, and of the Secretariat of Water Resources and Urban Environment of the Ministry of Environment
***Itapúa*, Paraguay** (without financial impact)	- Establishment of a Committee for the Pilot Project of Itapúa (CCPI) within the Capiibary Basin Water Council, as a consultative body, and Fundación Universidad Católica de Itapúa (FUCAI) as the technical and operational support body - Technical support agreement between a FUCAI and the Secretariat of Environment (SEAM)
	Technical support: studies, models of the aquifer, SIGAS, water quantity and quality monitoring
Ribeirão Preto, Brazil (with financial impact)	- Department of Water and Electric Power (DAEE), with support of universities that participate in the GCPPRP
Concordia, Argentina – Salto, Uruguay *(with financial impact)*	- The Municipal Administrations of Salto and Concordia have expressed their intention of creating "water units", in support of the CLTGAS
Rivera, Uruguay – Santana Do Livramento, Brazil (without financial impact)	- ***Rivera:*** Municipal Administration (partial) and State Sanitation Works Department (monitoring) - **Santana do Livramento:** Universidade Federal do Pampa (total) and Department of Water and Sewage of the Municipal Administration of Santana do Livramento (DAEPS) (total)
	Cooperation instruments
Riberão Preto, Brazil (with financial impact)	- Pardo River Basin Committee Resolution 007/2003
Concordia, Argentina – Salto, Uruguay (with financial impact)	- ***Concordia:*** an Ordinance of the Hydrology Board of Entre Ríos (DHER) is needed - ***Salto:*** an Ordinance of the National Water and Sanitation Board is needed - **Uruguai e *Entre Ríos:*** an agreement needs to be signed between Uruguay and the Province of Entre Ríos based on the 2006 agreement between the municipalities of Salto and Concordia - Enlistment of a commitment on the part of parks and thermal complexes is indispensible
Rivera, Uruguay – Santana Do Livramento, Brazil (without financial impact)	- ***Rivera:*** an Ordinance of DINASA is needed - **Santana do Livramento:** an agreement needs to be signed between the Government of the State of Rio Grande do Sul and Universidade Federal do Pampa (UNIPAMPA) - **Uruguai e Rio Grande do Sul:** continue informal support for the municipalities of Rivera and Santana do Livramento/Santa Maria River Basin Committee (CCSM) and subsequently formalize this relationship on the basis of current bilateral agreements
Itapúa, Paraguay (without financial impact)	- The 2008 SEAM-FUCAI Framework Agreement needs to be expanded to formalize CCPI and FUCAI
	Potential funding sources
Ribeirão Preto, Brazil (with financial impact)	- Department of Water and Electric Power (DAEE) - State Water Resources Fund (FEHIDRO) - Water supply companies of the municipality
Concordia, Argentina – Salto, Uruguay (with financial impact)	- Charges for the use of water, foreseen in the legislation of Uruguay and of Entre Ríos - Public research and environmental funds
Rivera, Uruguay – Santana Do Livramento, Brazil (without financial impact)	- **Rivera and Santana do Livramento:** public research and environmental funding - ***Rivera:*** *technical services of the State Sanitation Works Department (OSE) and environmental quotas for potentially polluting activities* - **Santana:** technical services of the DAEPS
***Itapúa*, Paraguay** (without financial impact)	- Fundos públicos, de pesquisa e ambientais e serviços a entidades públicas e privadas

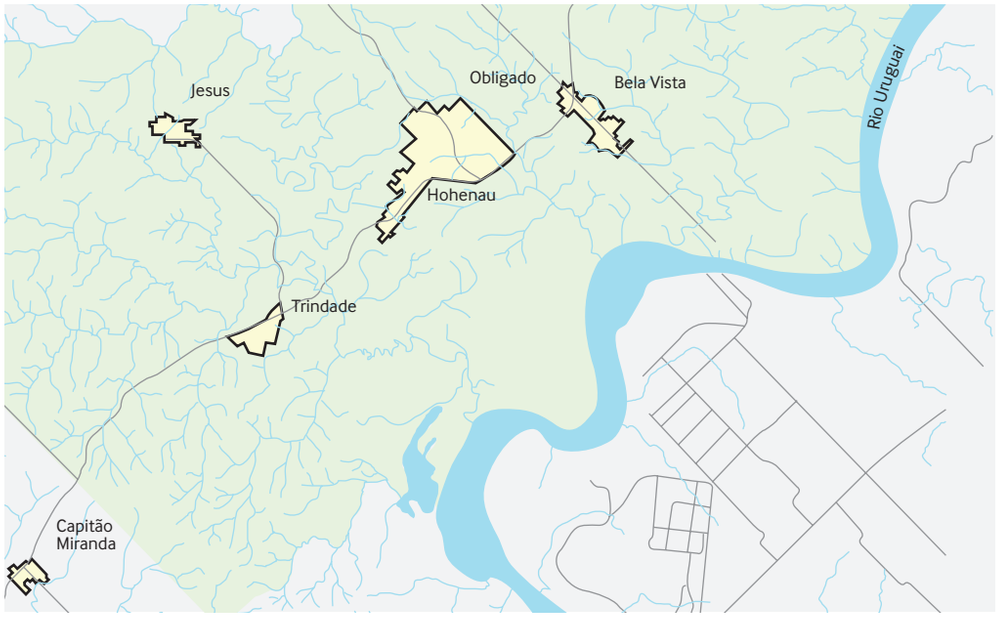
Source: GS/GAS, GS/GAS, adapted from GW-MATE and PALP, with contributions from the Project Execution Units, 2008.

Some 60 wells were registered by the National Water and Sanitation Service (SENASA) and inspected by the project under a partnership with German technicians (BGR) and the Secretariat of Environment (SEAM). Depths of the wells ranged from 70 to 120 m, and up to 300 in areas where the basalt covering is thicker.

Most groundwater abstracted in this region of the GAS is for public water supply and for rural and agricultural activities, and demands are currently low. The greatest use of groundwater is for irrigation and watering livestock (beef and dairy cattle). Water supply in the urban areas of Bella Vista, Hohenau, Obligado, Trinidad and Jesús is from wells bored into the GAS, with demands of approximately 30,000 m^3/day. Total consumption may reach 50,000 m^3/day, considered a low level of use of GAS water. Thus, the region has sufficient reserves for current use and for potential future uses. Potential flows of wells in the Pilot-Project areas are greater than 100 m^3/h, and the volumes currently pumped are significantly lower. Approximately half of the wells in activity have flows of less than 15 m^3/h.

From a quality standpoint, water of the GAS is potable and suitable for a great variety of uses. Table 3 provides values for the main indicators assessed under the PGAS. The results of tests on the water of wells in Itapúa display a variety of geochemical signatures, ranging from calcium-magnesium bicarbonated to calcium-magnesium chlorate. Tests on the two deep sub-basaltic wells revealed water with sodium bicarbonated signatures.

As a consequence of the proximity of replenishment zones, time of residence of GAS groundwater is short, as isotopic studies have shown. Potentiometric surfaces are highest in the north and extreme northwest of the region, and tend to decline to the southeast, flowing to discharge zones on the Paraná River. In view of these conditions, the GAS is quite vulnerable, with risks of contamination varying as a function of the basalt cover and land-use patterns. The risk of contamination is low in the basalt-covered areas of the north, and range from moderate to high in sandstone outcrop zones. The principal potential sources of groundwater contamination are fluids produced by landfills, residues from poor sanitation, poorly maintained septic tanks and, use of agrochemicals in areas under cultivation. Some of the shallower wells show incipient traces of nitrate contamination.



Source: GS/GAS, 2008

Figure 2. Pilot projects Itapúa (Paraguay)

Table 3. Water Quality Tests

Alkalinity (mg/l)	CE (µS/cm)	pH	T (ºC)
0 - 181,1	28 - 350	4,81 - 10,24	20,5 - 30
Ca (mg/l)	**Na (mg/l)**	**Mg (mg/l)**	**K (mg/l)**
2,9 -29,3	0,33 - 71	1,3 - 51,3	0,3 - 3,3
Cl (mg/l)	**F (mg/l)**	**$N\text{-}NO_3$ (mg/l)**	**SO_4 (mg/l)**
2,5 - 29,3	0,03 - 0,6	0,16 - 21,93	2,3 - 6,1

Source: GS/GAS, 2008

6.4.1 Institutional and normative assessment

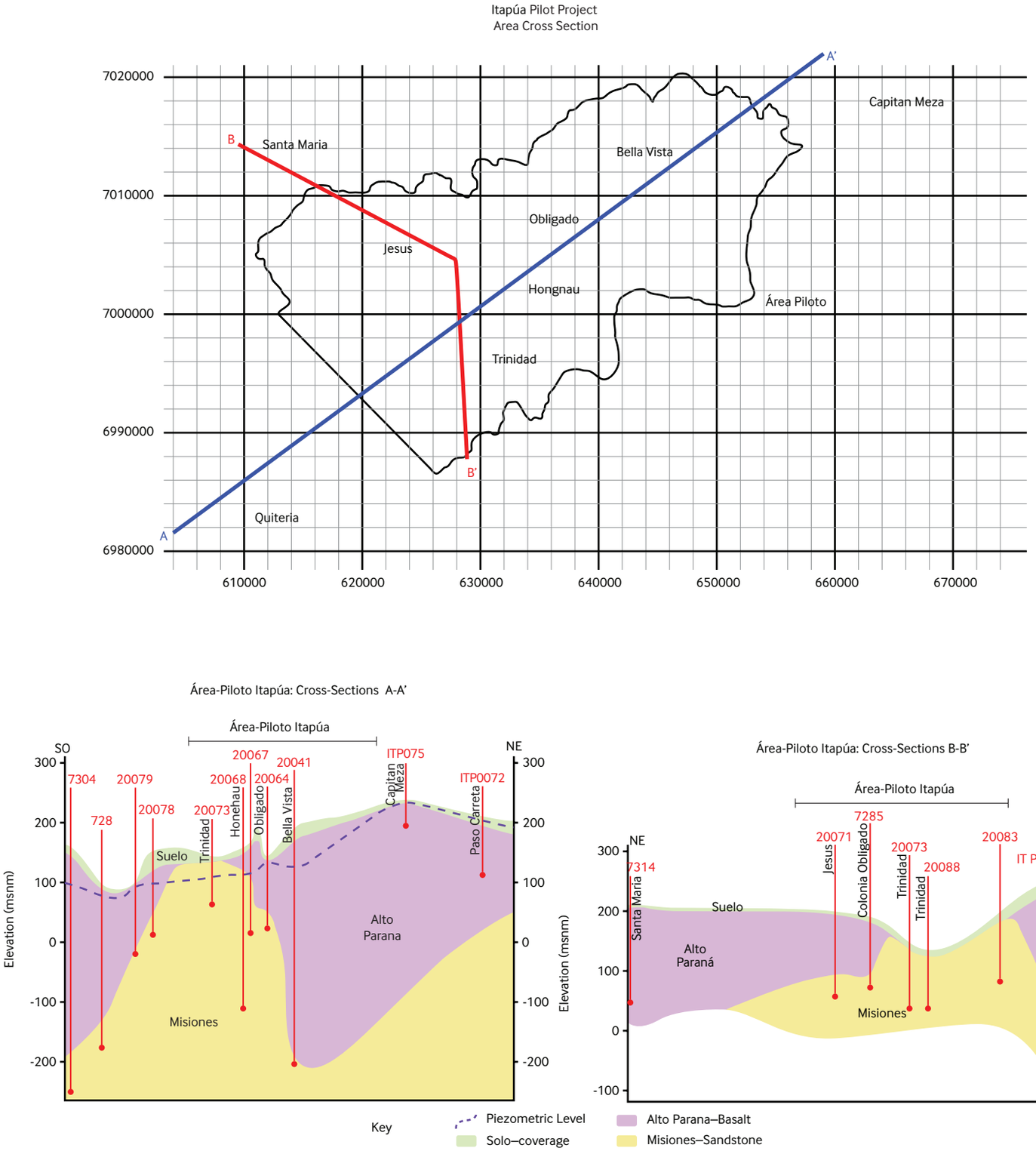
An analysis of the normative situation in Paraguay (Chapter 3) provides a number of points for consideration:

(i) Paraguay's Water-Resources Management Policy encompasses both surface water and groundwater.

(ii) Law 3.239/2007, on water resources, went into effect in July 2007.

(iii) Paraguayan legislation covers conditions of abstraction and standards for protection of groundwater, that provides 80% of the country's water supply. Moreover, there are environmental laws for protection of water resources.

(iv) SEAM Resolution 170, of February 8, 2006, provided for creation of water councils for



Source: SNC Lavallin, 2008.

Figure 3. Geological cross-sections showing the hydrogeological context of the Pilot Project zone

river basins, under a policy of decentralized and participative water-resources management. Under the formats established by this resolution, six water councils were created, including the Capiibary River Council located within the Pilot Project zone. Table 4 provides a summary of the normative situation in Itapúa.

6.4.2 Bases for management

Activities carried out under the PGAS, the process of providing support to local players, and the multiple discussions carried out during development of the PALP in Itapúa and Paraguayan portions of the GAS, have made it possible to draw conclusions and set the following bases for future actions to be included into the SAP:

- The Itapúa Pilot Project expanded discussions on the theme "groundwater" and on the importance of the GAS in Paraguay.
- It facilitated the process of approval of the Law 3.239/2007(the Water Resources Law) and of SEAM resolutions 2.155/2005, 50/2006, 170/2006 and 2.194/2007 on the same theme. Moreover, in the light of the technical background provided by the PGAS, the Pilot-Project zone represents an excellent laboratory for testing the new Law and transforming it into a concrete and efficient management instrument. Efforts and participation of the CLAP should thus be channeled toward implementation of the new law and its dissemination among the public (for example, stimulating water-use registration).
- Law 1.561/2000 authorized decentralization of SEAM's control and inspection functions. Decentralization of the system for issuing environmental licenses is now underway, whereby the Government of Itapúa is responsible, together with SEAM, for evaluation of environmental projects. The Municipal Administrations of Obligado and Hohenau have proposed that inspection and control functions be exercised by municipal secretariats of environment, at a level where the CLAP could provide assistance.

Table 4. Summary of the normative situation in Itapúa

	Groundwater
Normative framework	- Civil Code and Law 2.559/2005 (public jurisdiction over groundwater) - Law 1.561/2000 (policy and environmental management) - Law 3.239/2007 (water resources) - currently under implementation, sets standards for protection of water resources that take precedence over other territorial planning measures. SEAM Resolutions: - Law 2.155/2005 (technical specifications for construction of wells for abstraction of groundwater) - Law 50/2006 (water-resources management standards) - Law 170/2006 (Water Councils) - Law 2.194/2007 (National Water Resources Register) **Itapúa** - Cooperation agreement between SEAM and FUCAI, signed on April 11, 2008, for implementation of the PGAS, conducting of studies, monitoring and inspection in the Pilot Project zone
Effectiveness of the normative framework	- Public jurisdiction over groundwater (2005) led to regulations governing its use - The Water Resources Law has not yet been implemented and there is a five-year deadline for its implementation . Major portions of the law have not been put into effect - Currently, environmental licenses are issued, but not authorizations for use - Inspection of compliance with existing standards (SEAM resolutions) is contingent upon filing of complaints
Causes of poor effectiveness	- Centralized management in the nation's capital hampers effectiveness - Lack of technical knowledge on water bodies hampers implementation of the new law - Users fail to comply with environmental standards owing to lack of knowledge or because they consider them excessive - Themes such as concession and authorizations for use, controls and sanctions have not yet been fully implemented

Source: Adapted from the SAP and PALP Legal Advisory Final Report, with contributions from the National Project Execution Units, 2008.

- The Local Committee of the Pilot Project has adopted a forward-looking vision, offering support to local management of the GAS in coordination with the Water Council of the Capiibary Basin, within the current legal framework.
- A cooperation agreement was signed between SEAM and FUCAI (headquarters of the local committee) on April 11, 2008, with the aim of promoting field studies on the GAS, using monitoring and inspection tools developed under the PGAS (SIGAS, mathematical model and local monitoring network).
- Municipalities in the Pilot-Project areas want to proceed with implementation of GAS projects.
- Based on water samples taken in the Pilot-Project areas and on test results, certain recommendations for local management can be made, with a view to conserving the aquifer and preventing possible contamination problems.
- The local committee needs to be consolidated by means of specific tasks in support of GAS management in the area.

- It is important to consider the opinion of the local population and of local institutions, and to support their projects and actions for protection of the GAS.

6.4.3 Priority strategic actions for the Pilot Project

I - Technical aspects

a) Protect the municipalities' potable water sources (sanitation boards) and the more vulnerable and strategic areas of the GAS:
   - » Define guidelines for compliance with technical standards for construction of wells for abstraction of waters of the Guarani Aquifer.
   - » Protect sources of public water supply by means of structural surface measures for wells.
   - » Establish protection perimeters for wells used for public water supply, observing land-use restrictions defined in municipal master plans.
   - » Make the system for issuing authorizations to use water more strict in vulnerable areas identified in zoning under the PGAS.

b) Concrete tasks for sustainable groundwater resources management:
   - » Enhance capacities at the FUCAI laboratory for conducting of analyses of water samples for various purposes.
   - » Assess potential of the GAS for supplementary irrigation of crops, considering current water availability and sustainable flows.
   - » Develop test in demonstration areas to assess levels of local contamination.
   - » Conduct monitoring in the Pilot Project area, as part of the agreement between FUCAI and SEAM (monitor nitrates and heavy metals, take surface samples to identify sources of diffuse contamination in agricultural areas, construct a pollution-dispersion model, and establish laboratories and train staff to conduct chemical analyses of water).
   - » Use the model for GAS management and for territorial planning.

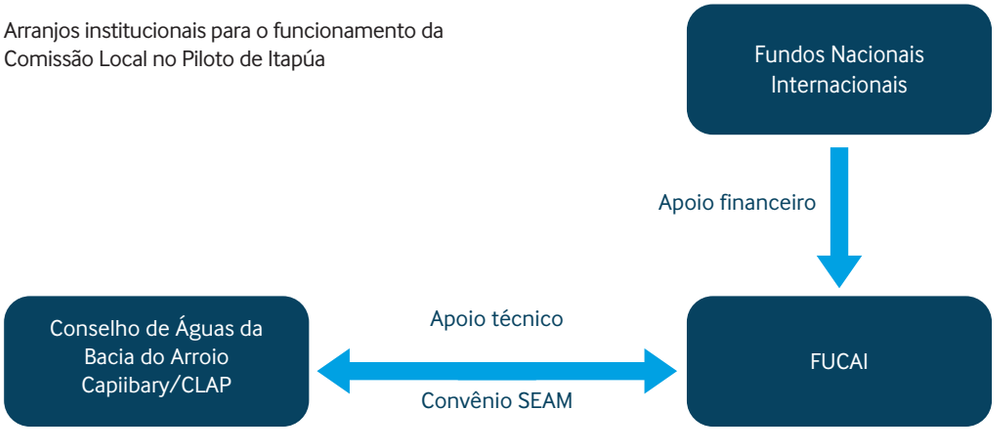
II - Legal and institutional aspects

a) Consolidation and institutional strengthening of the GAS Local Committee:
   - » Signing of a term of amendment to the SEAM/FUCAI Agreement for: (a) establishment of a Consultative Committee of the Pilot Project within the scope of the Water Council of the Capiibary Basin. (b) designation of FUCAI as the technical and operational support body for activities of the respective Consultative Committee.
   - » Provide the Local Committee with a stable structure, with annual appointment of representatives of component organizations.
   - » Define a work program that encompasses support for maintenance of management instruments deployed and developed during the execution phase of the Project for Environmental Protection and Sustainable Development of the Guarani Aquifer System.
   - » Prepare a program of annual targets to be achieved by the Local Committee and define the terms of contracts for human resources.
   - » Seek funding sources that include local budgets to defray operational expenses of the Local Committee.

It is suggested that this committee be comprised of representatives of the Water Councils of all basins within the Pilot-Project area. This committee, composition of which should reflect the representation of the Water Councils, is to assume the following responsibilities: (i) submitting to SEAM and FUCAI demands for studies, investigations and proposed practical actions referent to groundwater within the scope of Water Councils. (ii) issue opinions on proposals for projects to be carried out by FUCAI, and to bring them to the attention of the Water Councils of river basins within the Pilot-Project area. (iii) support SEAM in the monitoring of actions carried out within the scope of the Agreement (Figure 4):

b) Strengthening of local institutions:
   - » Develop a coordinated program for increasing scientific knowledge and provide support to management of the GAS, together with local public and private institutions.
   - » Strengthen FUCAI to operate and update the SIGAS.
   - » Consolidate articulation mechanisms of the Local Committee of the GAS, in the Capiibary Basin and in other basins in the Paraguayan portion of the GAS region.

Arranjos institucionais para o funcionamento da Comissão Local no Piloto de Itapúa



Source: GS/GAS, 2008.

Figure 4. Institutional Arrangements for functioning of the Itapúa Local Pilot-Project Committee

III - Social and public participation aspects

a) Continual expansion and dissemination of local knowledge on the GAS:
   - » Support the Local Committee in the establishment of a scientific subcommittee to update knowledge.
   - » Support the Local Committee in the establishment of a communications subcommittee, to provide information for the various different segments of the public, using multimedia tools.
   - » Support public communications by means of a continuous local dissemination plan.

b) Development of a local reference center for the GAS to facilitate public participation:
   - » Support the Local Committee in the establishment of a subcommittee responsible for promoting public participation.
   - » Promote the establishment of local university courses (under-graduate and graduate levels).

Source: GS/GAS, 2008

Figure 5. Pilot-Project Concórdia/Salto

6.5 CONCORDIA -SALTO PILOT PROJECT (ARGENTINA AND URUGUAY)

The Concordia-Salto Pilot Project covers an area of 500 km^2 located on both banks of the Uruguay River that marks the border between Argentina and Uruguay (Figure 5). Unlike the other Pilot Project areas, the GAS in this area is at a depth of between 800 and 1,000m, and is covered by layers of volcanic basalt. Groundwater in this region has artesian characteristics and great geothermal potential, with temperatures ranging from 44 °C to 48 °C. Yields from geothermal wells range between 100 and 300 m^3/h, and boreholes are up to 1,400m in depth. Geological cross-sections of the Pilot-Project zone show the hydrogeological situation (Figure 6).

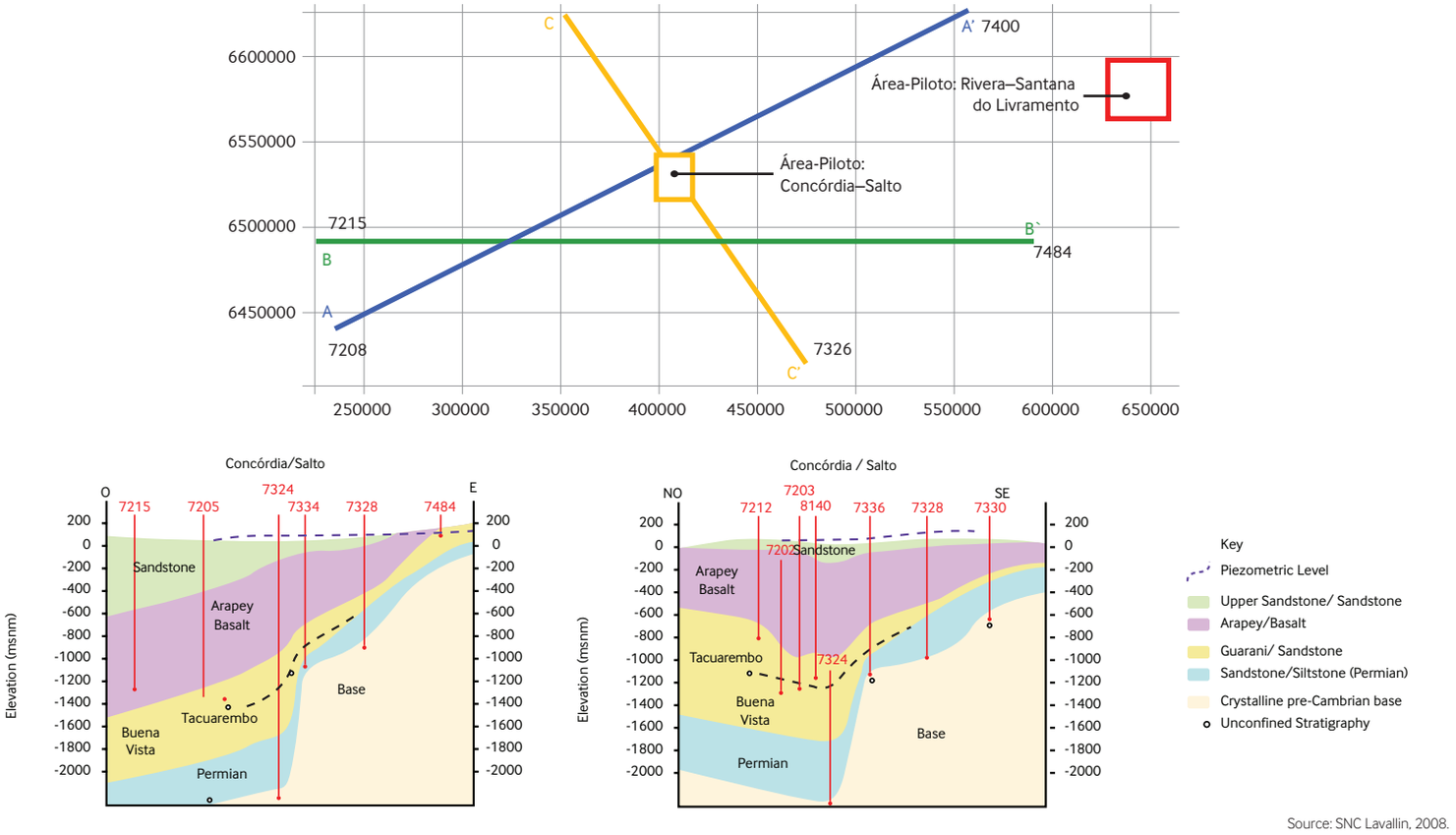
The Pilot Project encompasses the most densely populated part of the border region between Argentina and Uruguay, with some 200,000 people distributed fairly equally on either side. The main livelihoods in the region are industries relating to citriculture and horticulture. In Salto, Uruguay, MERCOSUR's best developed spas tap thermal waters of the GAS.

In this zone, the GAS is not a significant source of drinking water. Public water supply generally relies on treatment stations that abstract water directly from the Uruguay River. Also, certain shallow wells drilled into the Tertiary and Quaternary layers and the upper fractured layers of the Serra Geral basalts serve as a water source for small-scale public water-supply and irrigation.

GAS waters in the Concordia-Salto area have a long time of residence. Over the years, they have absorbed calcium and released sodium, in a process that explains their high sodium bicarbonate content. Such waters are predominantly characterized by the presence of sodium bicarbonate and magnesium bicarbonate. They bear little calcium and even lower levels of chlorates and sulfates. As no replenishment takes place in the Pilot-Project areas, the GAS is not vulnerable to contamination from external sources, excepting from poorly constructed wells. The presence of nitrates (still at minimal levels) would appear to be from surface-water contributions, and merits further research.

In environmental terms, the GAS is well protected by thick layers of basalts and its high degree of confinement. The main potential problems in the region are: (i) hydraulic interference between neighboring wells. There are currently nine geothermal wells in a relatively small area. (ii) intrusion of salt from the south and southeast, where there are thermal wells with highly saline water from pre-GAS formations. This situation merits further investigation under the SAP.

Many thermal spas do not as yet exercise adequate management of demand and use of water. Thus, more efficient management practices need to be developed and disseminated, including recycling of water for gardening, for heating of hotel facilities, and for greenhouses and aquiculture. It is also necessary to build safe reservoirs for used water, especially when it has a high salt content. Furthermore, the combination of thermal water and groundwater



Source: SNC Lavallin, 2008.

Figure 6. Geological cross-sections illustrating the hydrogeological context of the Pilot-Project zone

from lesser depths for uses other than in spas should be examined.

6.5.1 Institutional and normative assessment

In the two management units[1] the normative framework provides the main instruments for management and protection of groundwater. However, poor integration among local institutions, such as water agencies and the decision makers responsible for policies in such fields as agriculture, tourism, territorial planning and land use in urban and suburban areas hampers deployment of regulations.

No significant divergences exist between legislation on water in the Province of Entre Ríos and in Uruguay (Table 5). The legislative bases and guidelines are the same:

» Groundwater under public jurisdiction.
» Authorization for the use of water is issued by competent authorities.
» Priority for human water supply and watering livestock.
» Compulsory registration of water use and inventory of engineering works.

Entre Ríos

- Law 9.172/1998 (the Water Law) provides regulations for use, after technical studies on provincial aquifers have been concluded.
- Law 9.678/2006 (the Thermal Resources Law) decentralized management by separating management of thermal water from protection of water resources. This has not as yet been implemented by the ministries responsible.
- There are currently no standards on environmental impact assessments.
- Law 9.757/2007 established a system of Basin Committees, that has not as yet been fully deployed.
- There has been little investment in technical personnel, specialized human resources, or studies and infrastructure for implementing management.

Uruguay

- Management does not cover qualitative and quantitative aspects. Neither does it integrate management of surface waters, groundwater, land use and territorial planning.
- The Management Plan (Decree 214/2000) was prepared based on outdated knowledge accumulated prior to execution of the PGAS.
- The Advisory Board intervened in implementation of the Management Plan to mediate conflicts. Later, its participation was

1 In Argentina, a federated state, the Government of the Province of Entre Ríos is responsible for groundwater management. In Uruguay, a unitary state, the National Executive Branch is responsible

weakened owing, among other things, to a lack of qualified human resources.
- Lack of control and information of dispersion of effluents, that is the responsibility of the Municipal Administration of Salto and not of the environmental management body.
- The rule for prevention of environmental pollution by means of control of water (Decree 253/1979) establishes classification of water bodies that receive effluents and limits to pollution parameters. However, such classification has not been effected, and the executive order that allows discharge of effluents remains in effect.
- Regulations on location, distance between wells, technical responsibilities, licenses for drilling and aspects relating to construction of wells are generally observed in the region. However, inspection of abstraction flows is rarely carried out. This information is reported each month by the permission holders.
- Environmental impact assessments are carried out only when groundwater abstraction values exceed 50 liters per second.

Concordia-Salto:
- In December 2005 it was decided that the bill containing technical standards for construction of deep wells would be approved by both Governments (Hydraulics Division of Entre Ríos and the Ministry of Transport and Public Works of Uruguay). At the present time, however, these standards have not been incorporated into the legal framework of Entre Ríos, and neither have they been introduced in Uruguay. Under this standard, all projects for drilling would be subject to prior environmental authorization. The current decree only required such authorization for flows greater than 50 liters per second.
- On January 6, 2006 a cooperation agreement was signed between the Municipal Administrations, with a view to controlling drilling, water quality and reuse. This agreement was not implemented (Table 6).

Table 5. Normative situation in the Pilot-Project area with respect to groundwater

Legal framework	**Argentina:** - National Constitution (ref. 94) and Civil Code (ref. 68): provincial public jurisdiction over groundwater - Law 25.675/2002 (General Environment Law) - Law 25.688/2002 (minimum resources necessary for preservation and use of water) **Entre Ríos:** - Law 9.678/2006 (Thermal Resources) - Law 9.757/2007 (Basin Committees and Water Consortia) - Law 9.172/1998 (The Water Law) **Uruguay:** - Constitution (ref. 2004): public jurisdiction over groundwater and Law 14.859/78 (Water Code) - Law 16.466/1994 (Environmental Impact Evaluation) - Law 17.283/2000 (Protection Environmental) - Decree 214/2000 (Management Plan of the Infra-basaltic Guarani Aquifer) - Decree 86/2004 (technical standards on drilling of wells) - Decree 253/1979 (dispersion of effluents) - Decree 349/2005 (Environmental Impact Evaluation) **Concórdia–Salto:** - The technical standard for construction of deep wells is currently being examined for approval by the two Governments - Agreement between Intendancies, of January 6, 2006, for control of drilling, water quality and reuse
Effectiveness of the regulatory framework	**Entre Ríos:** - Law 25.688/02, on Water Management, as yet not in effect - Law 9.678/2006, on the Thermal Resources of Entre Ríos, decentralized management of thermal water, removing it from the sphere of environmental management bodies. Implementation is just starting - Law 9.172/1998 (The Water Law) not yet been implemented. **Uruguay:** - The Management Plan is applied to concessions for authorization of use and studies, but later inspection is weak - Environmental impact assessments are applicable to wells with abstractions in excess of 50 liters per second and systematic quality control is not carried out **Concórdia–Salto:** - The bill drafted jointly by the Province of Entre Ríos and Uruguay on technical standards for drilling of wells (2005) has not been formally incorporated into the legislation of Entre Ríos - The Management Plan is applied to concessions for authorization of use and studies, but later inspection is weak - Environmental impact assessments are applicable to wells with abstractions in excess of 50 liters per second and systematic quality control is not carried out

Continues

Continuation

Causes of poor effectiveness	**In the two management units:** - Management is centralized in the capitals - Weak presence of local bodies responsible for quality control of thermal water and its exploitation - Institutional difficulties for effecting abstraction controls **Entre Ríos:** - Disagreements between the Provinces and the National Government caused by application of the National Groundwater Management Law. - Fragmentation of management caused by the Thermal Water Law of Entre Ríos - Poor integration between quality and quantity management. Lack of coordination among bodies - Lack of a provincial environmental impact law **Uruguay:** - Poor integration between quality and quantity management. Lack of coordination among bodies - Priority given to regularization and inventory of engineering works rather than to control of requisites for issuing of water use licenses - Outdated standards for discharges of effluents. Lack of information

Source: Adapted from the SAP and PALP Legal Advisory Final Report, with contributions from the National Project Execution Units, 2008.

Table 6. Standards applicable to solution of specific problems in the Concordia-Salto Pilot Project

Control of drilling of wells and abstraction of groundwater	**Entre Ríos** - Provincial Law 9.678/2006 (Thermal Resources) - The Water Law 9.172/1998 **Uruguay** - Law 14.859/1978 (Water Code) - Decree 214/2000 (Management Plan of the Guarani Aquifer) - Decree 86/2004 (Technical Standards for Construction of Deep Wells) **Concordia–Salto** The Governments of Entre Ríos and of Uruguay decided to include a standard for drilling of deep wells for abstraction of groundwater in their legal frameworks
Control of discharges of thermal and saline effluents into the aquifer	**Entre Ríos:** - Law 9.678/2006 (Thermal Resources, article 9: establishment of quality quantity control mechanisms and diversity of Thermal Resources) **Uruguay:** - Law 14.859/1978 (Water Code) - Law 16.466/1994 (Environmental Impact Evaluation) - Decree 253/1979 (Discharge of effluents)

Source: Adapted from the SAP and PALP Legal Advisory Final Report, with contributions from the National Project Execution Units, 2008.

6.5.2 Bases for management

Activities carried out under the PGAS, the entire process of support to local players, and multiple discussions conducted during the process of development of the PALP of the Concordia-Salto Pilot Project and of the SAP in Argentina and Uruguay, make it possible to identify the following bases for future actions under the SAP:

- The aquifer straddles the international border between Argentina and Uruguay. Any excessive increase in abstractions could cause interference on the other side of the border, owing to loss of pressure and lowering of potentiometric levels, that would have repercussions on the operation of thermal wells. Aspects relating to construction and use of wells could also generate the same effects.
- Synergies generated by the project led to approval, by the Municipal Administrations of Concordia (Argentina) and Salto (Uruguay) of a cooperation agreement for establishment of a register of infra-basaltic boreholes, and a system for measuring water quality and discharges of reused water and effluents.
- The provincial and national Governments decided to include technical standards for drilling of deep wells in their legal frameworks, but these have not yet been implemented.
- The Pilot Project collaborated with the signing of an agreement between the municipalities for coordination of actions to promote Sustainable Development of the current tourist thermal corridor of the Uruguay River, thereby fostering conditions for both technical and social integration.
- It will be necessary to accompany the future development of demand for water. Moreover, it will be necessary to deepen knowledge on efficient utilization of thermal water and subsequent reuse or other environmentally sustainable alternatives.

One of the major challenges faced by the transboundary Pilot Project stems from the fact that the countries have not moved at the same pace. This is due to social, cultural and legislative processes that respond to the different realities of each country and require time to achieve acceptance.

Only by means of sustainable management of the GAS, based on cooperation between the two countries and both municipalities will it be possible to maintain current levels of use and of economic activities, or to expand them, as is the express desire of all the parties.

6.5.3 Priority strategic actions for the Pilot Project

I - Technical aspects

a) Hydraulic and hydrochemical monitoring of the GAS: operation and maintenance of the local GAS monitoring system and of the SIGAS (a document containing proposals for local monitoring and basic instruments such as metering).
b) Promote efficient use of thermal water, rational water use and reutilization of effluents of thermal water from GAS wells (see Chapter 5 for details on actions for conducting deeper studies on uses of thermal water of the GAS).
c) Promote appropriate management based on environmental criteria for current and future utilization of the GAS.
d) Increasing use of mathematical models for development of criteria for sustainable exploitation and incorporation of the theme of freshwater/ saltwater contact (Chapter 5 Annex 11).
e) Continue to evaluate high levels of salt in thermal and non-thermal water, and high levels of arsenic (As) and other ions in the confined stretch of the GAS in the coastal area.

II – Legal and institutional aspects

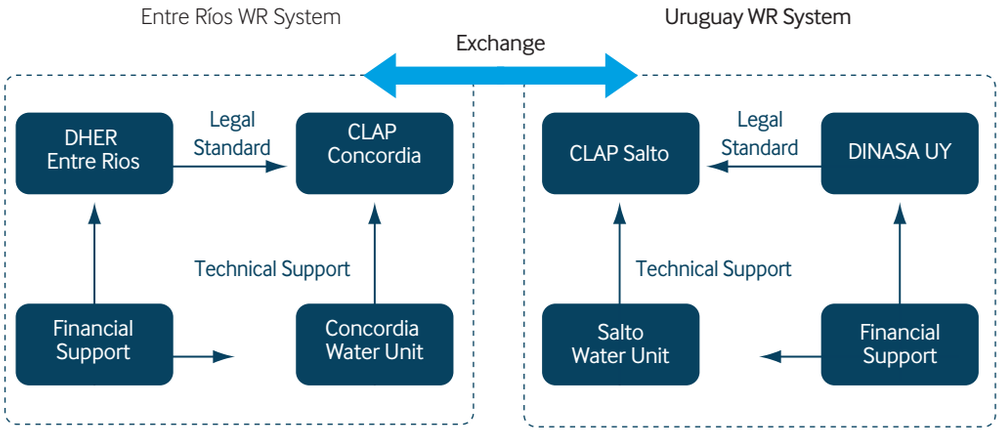
a) Consolidate the Local Committees and Transboundary Committee:
   » Endow them with legal status (municipality, province, department and/or country) and a stable structure, through periodic appointment of representatives of the component organizations with capacity to draw up a program of goals, and to define terms for contracting of human resources.
   » Staff them with a coordinator and an assistant that reside in the area.
   » Seek sources of funding, from the municipal budgets of the two towns and from the national and provincial budgets to defray operational costs of the Transboundary Committee. National funding sources (representatives of water users, academics, social organizations, and public municipal, departmental, provincial and national institutions). An agreement needs to be signed between the respective management bodies and the municipalities to formalize their operational support to the CLAPs, carried out (as the diagram shows) by water units to be established in each of the municipalities. Participation of water users and operators of thermal parks is indispensable.

b) Strengthening of local, groundwater and land-use management institutions:
   » Strengthening of local institutions in the two countries for operation and updating of management instruments installed and developed under the PGAS.
   » Strengthening of the provincial water management resources body of Entre Ríos and contracting of a hydro-geologist.
   » Strengthening of regional bodies such as DINASA and DGRNR and contracting of a hydro-geologist.

c) Actions for enhancing local institutional effectiveness of groundwater management:
   » Entre Ríos: (i) create a unified body for sustainable management of water resources. (ii) include standards for groundwater in the Urban Planning Code (currently under review). (iii) foster enforcement of the Agreement on Technical Standards, incorporating it into legislation. (iv) draw up standards for Environmental Impact Evaluations.

play an important role in consolidation of the projects.

The organizational flow chart in Figure 7 shows the suggested institutional arrangements for consolidation of the Local Committees within the Pilot Projects. The chart itself provides a guide to enhancing their organization. The management bodies of both CLAPs should be formally acknowledged (in accordance with their bylaws) as local groundwater management support bodies and with specific competencies and composition



Source: PSAG of PIP

Figure 7. Institutional Arrangements of local committees

- » Uruguay: (i) based on outcomes of the PGAS, update the Management Plan to be applied in different zones of the aquifer. (ii) update standards on effluents based upon information in the PGAS. (iii) establish a committee for the Guarani Aquifer with national competencies and local representation. (iv) propose inclusion into the water policy law of a national committee for the Guarani Aquifer.
- » Concordia-Salto: (i) implement agreement between the municipal administrations for implementation of concrete measures, such as sampling, testing protocols, use of equipment donated under the project (spectrophotometer, pH measurements, temperature etc.), testing intervals, etc.. (ii) analyze the application of charges for discharges of effluents, by means of local management.

III - Social and public participation

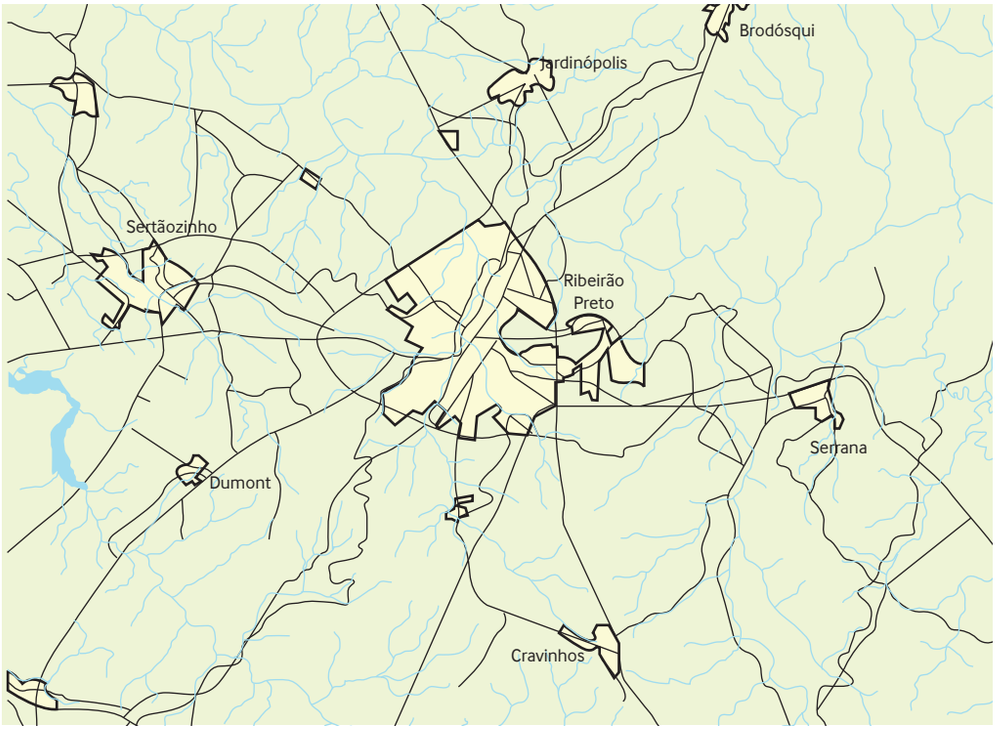
a) Continuous accumulation and dissemination at the local level of knowledge on the GAS, by means of advisory committees that contribute with ideas and suggest joint activities with the Transboundary Committee:
   - » Create, within the Transboundary Committee, an advisory subcommittee for updating scientific knowledge.
   - » Create, within the Transboundary Committee, an advisory subcommittee to carry out dissemination activities, using multimedia tools.
   - » Create and deploy educational and dissemination programs.

b) Create a reference center on the GAS to facilitate public participation:
   - » Create, within the Transboundary Committee, a subcommittee for public participation to propose community activities together with the Transboundary Committee.

6.6 RIBEIRÃO PRETO PILOT PROJECT (BRAZIL)

The Ribeirão Preto Pilot Project is located in the eponymous municipality in the northwest of the State of São Paulo (Figure 8). The project area has a population of approximately 500,000 and covers some 2,500 km^2, including portions of the neighboring municipalities of Jardinópolis, Sertãozinho, Dumont, Serrana, Serra Azul, Cravinhos and Brodósqui. Pilot Project activities are concentrated on an area of 651 km^2, of which 137 are GAS outcrop areas. The remaining land surface is covered by basalts of the Serra Geral Formation.

The GAS sandstones are confined to the western parte of the Pilot-Project areas by a layer of basalt of up to 200m in thickness that emerges in the eastern portion. The aquifer is under a layer of permian rock (a sequence of clays, sandstone and fine silts) that store water, although they are less permeable than the aquifer. Paleozoic rocks cover crystalline rocks of low permeability of the pre-cambrian layer. The cross-sections in Figure 9 display the hydrogeological context.



Source: GS/GAS, 2008.

Figure 8. Pilot-Project Ribeirão Preto

Replenishment of the aquifer is predominantly from rainfall on outcrop areas. It has been estimated that rainfall in this area is approximately 135 mm/year. On the regional level, groundwater appears to flow from east to west, with depression cone in the urban area.

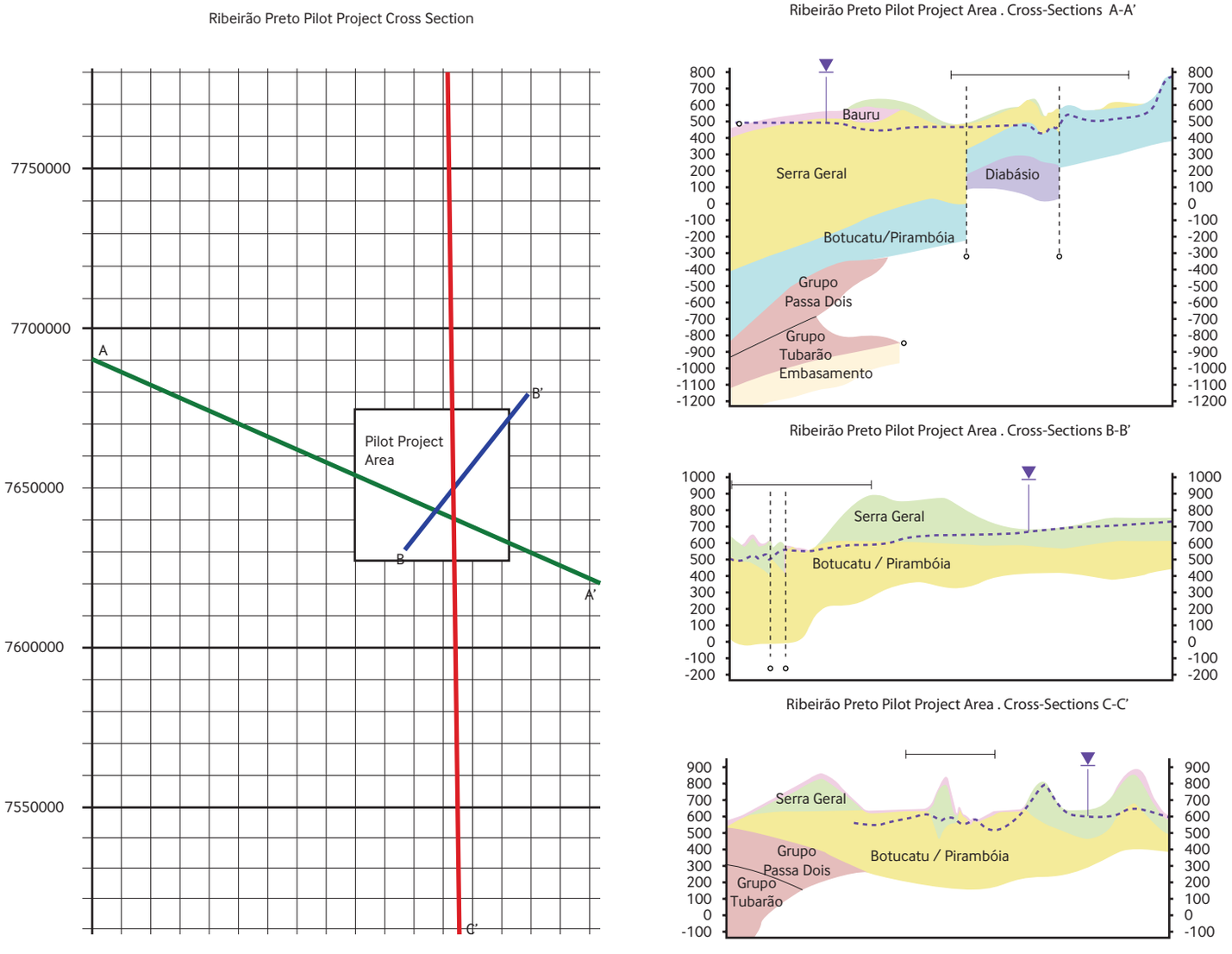
The region is an agricultural hub, and the world's largest producer of sugar and alcohol, with extensive sugarcane plantations and a few orange groves. The region also has industries for processing soybeans and coffee, food-processing and fertilizer plants. Due to rapid urban growth, with intensive agricultural and industrial activities, demand for groundwater resources has increased, placing pressure on the Guarani Aquifer. Such demand has led to a significant lowering of groundwater levels, principally within the town of Ribeirão Preto. The water table has dropped by as much as 30 or 40m since the 1970s.

Among the side effects have been: (i) increased operational cost for drinking water supply, owing to lowering of the water table

and reduced yields from wells, upper sections of which no longer produce. (ii) loss of confinement of groundwater in certain wells. (iii) some water courses that used to receive water from the aquifer now contribute to it, thereby increasing the risk of groundwater contamination.

The Water Department of Ribeirão Preto (DAERP) has 95 wells in operation, with potential yields of approximately 3,700 liters per second. Estimated current production is 65 mm^3/year, most of which is for urban household use. Considering other uses and the neighboring towns, abstractions for Ribeirão Preto amount to some 5.1x105 m^3/day.

The results of analyses of water from wells in Ribeirão Preto are coherent with the geochemistry of the local geology. With respect to the chemistry of cations, samples taken from eight wells show water with calcium, and 15 with a mixture of calcium sodium and magnesium waters. With respect to the chemistry of anions, most of the wells have bicarbonated water (as might be expected in a hydrogeological context of shallow wells located in or near a replenishment area, i.e., with relatively recent groundwater). By combining the results for cations and anions, the water can be characterized as calcium-magnesium bicarbonated. According to studies carried out under the PGAS, the quality of



Source: SNC Lavallin, 2008.

Figure 9. Geological Cross-Sections showing the hydrogeological context of the Pilot-Project zone

groundwater from deep wells located both within and outside central urban areas is generally good (except a few low pH values, associated with replenishment areas).

Of the 677km^2 of GAS replenishment areas identified in the region of the Pilot Project, 29.6% present high vulnerability associated to shallow, permeable soils with low clay content, whereas 39.5% present low vulnerability. A major portion of this area is within the urban-expansion zone, defined by a Resolution of the Pardo River Basin Committee, where there is a lack of adequate sanitation. There are risks of contamination associated with leaching from landfills and unlicensed waste dumps in zones that have no solid-waste collection services, which correspond to less than 5% in the major portion of the Pilot-Project area (less than 1% in Ribeirão Preto), but as much as 16% in Altinópolis.

6.6.1 Institutional and normative assessment

- Generally, federal and state legislation on groundwater management and protection is consistent, and its implementation has been swift and efficient (Table 7).
- The main problems in Pilot-Project areas are contamination caused by inadequate sanitation, agricultural activities, inadequate construction of wells and intensive water use. Some management and control measures have been deployed to mitigate these problems (Table 8).
- Coordination of the Ribeirão Preto Pilot Project is under control of the Pardo River Basin Committee, where measures for regulating and controlling abstractions from the Guarani Aquifer in the town and its surrounding areas are discussed.
- System for issuing licenses for exploitation:
  - » The procedure for obtaining a license is not a mere formality and depends upon prior inspection and entails liability to sanctions.
  - » Tube wells require a license from the municipal planning authority. To apply for a license to use water, first a permission to build a well must be granted by the municipality, along with a land-use and settlement certificate (urban or rural).
  - » In the past, between 20 and 30 licenses were granted per month in the area with restrictions. After its delimitation, only two have been granted, both for public water supply.
- Federal Law 11.445/2007 (the Basic Sanitation Law) presents problems of interpretation. It is unclear whether it is forbidden to abstract groundwater in places where public water supply is available, or if it forbidden to mix water from public water mains with water from alternative sources. In view of this flaw, each state enforces the law differently.
- The recent CONAMA Resolution 396/2008, on the classification of groundwater, has provided a powerful tool for the State of São Paulo in the process of granting licenses and charging for the use of groundwater. It will also help with zoning and planning of aquifer protection areas, that are so necessary for sustainable development.

6.6.2 Bases for management

Activities carried out under the PGAS enabled identification of future actions for the SAP stage, based on evaluation of the process of support to local players, the work carried out, and multiple discussions held during development of the PALP of the Ribeirão Preto Pilot Project.

The Ribeirão Preto Pilot Project area represents an excellent opportunity to combine territorial planning and water resources policies. The main instruments for deployment of national territorial planning legislation (Federal Law 10.257/2001) are Territorial Master Plans and Local Master Plans. Drafting of such plans necessarily entails ample public participation, and they ought to encompass aspects relating to groundwater, but rarely do. Another efficient mechanism for integration entails participation in the State Water Resources Council (CERH) and in the Pardo River Basin Committee (CBRP). Here also, however, inclusion of the theme groundwater in regional and municipal guidelines is incipient. Management and inspection of land use and settlement at the municipal level tends to be weak and should be one of the focuses for institutional capacity building.

From a management standpoint, Ribeirão Preto has several initiatives that will serve as starting points for future actions in the Pilot Project area.

Table 7. Legal Status of the Pilot Project

	Groundwater
Legal framework	**Brazil** - Federal Constitution (ref. 1988: public jurisdiction over groundwater) - Law 6.902/1981 (National Environment Policy) - Law 6.938/1981 (Environmental Protection Areas) - Law 9.433/1997 (National Water Resources Policy, Management System) - Law 10.257/2001 (Statute of the Cities) - Law 11.445/2007 (Basic Sanitation) - CNRH Resolution 76/2007 (guidelines for integration of water-resources management with management of mineral, thermal, gaseous and potable water, and water for use in spas) - CONAMA Resolution 396/2008 (classification, prevention and control of groundwater pollution) **São Paulo:** - Constitution (ref. 2005: water resources management) - Law 6.134/1988 (preservation of groundwater, implemented by Decree 32.955/91) - Law 7.663/1991 (State Water Resources Policy) - Decree 41.258/1996 (licensing of the right to use water)-

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Continuation

	- CERH Deliberation 52/2005 (areas with restrictions and control of abstraction and use of groundwater) - DAEE Order 1594/2005 (delimits the area of temporary restriction and control of uses and interference with groundwater) **Ribeirão Preto:** - CBHP Resolution 7/2003 (coordination of the RP-PGAS Pilot Project with the Pardo River Basin Committee) - CERH Deliberation 65/2006 (ratifies CBHP Deliberation 04/2006: areas with temporary restrictions and control of abstraction and use of groundwater in the municipality of Ribeirão Preto, criteria for drilling of wells)
Effectiveness of the regulatory framework	- National and state-level standards for management and protection of groundwater were swiftly implemented in the area of the GAS - Coordination of the Pardo River Basin Committee, a deliberative and democratic forum, fosters effective management - There is articulation between land use and water use. Authorization for use requires prior licensing from the municipality, with a certificate of rural or urban land use and settlement - CONAMA Resolution on recently approved classifications of groundwater has not yet been implemented - Municipal legislation on land use and settlement and municipal plans and guidelines do not consider inter-relations between waters in their master plans
Causes of poor effectiveness	- Lack of inspection land use and settlement standards, owing to weaknesses of infrastructure and lack of specialized personnel - Since the municipal authorities face difficulties in implementing water resources management, Territorial Planning is implemented in each municipality with no consideration for water - Differing interpretations of Federal Law 11.445/2007 (the Basic Sanitation Law) owing to lack of clarity on the scope of limitations it imposes

Source: Adapted from the SAP and PALP Legal Advisory Final Report, with contributions from the National Project Execution Units, 2008.

Table 8. Applicable standards for solving specific problems of the Ribeirão Preto Pilot Project (Brazil)

Control of drilling of wells and abstraction of groundwater	- Law 7.663/1991 (State Water Resources Policy, art. 3) - State Decree 41.258/1996 (licensing of the right to use water) - CERH Deliberation 52/2005 (areas with restrictions and control for abstraction and use of groundwater) - CERH Deliberation 65/2006 (ratifies CBHP Deliberation 04/2006, on areas with temporary restrictions and control for abstraction and use of groundwater in the municipality of Ribeirão Preto)
Local control of land use and discharges of effluents to protect groundwater	- State Law 61.34/1988, art. 6 (requires hydrogeological studies for industrial districts and large-scale irrigation, colonization and other projects) - CBHP Deliberation 52/2005 (on areas with restrictions and control for abstraction and use of groundwater) - CONAMA Resolution 303/2002 (on declaration and conservation of protected areas) - CONAMA Resolution 396/2008 (on classification, prevention and control of groundwater pollution)
Protection of groundwater in the planning of land use and of agricultural and urban development	- Federal Law 10.257/2001 (Statute of the Cities) - Decree State 32.955/1991 (on areas of protection, restriction and control of wells and other abstractions. In areas of maximum protection, industries with high environmental risk and agricultural activities that jeopardize groundwater are forbidden) Ribeirão Preto: - CRH Deliberation 65/2006 (ratifies CRH Deliberation 04/2006, on areas with temporary restrictions and control for abstraction and use of groundwater)

Source: Adapted from the SAP and PALP Legal Advisory Final Report, with contributions from the National Project Execution Units, 2008.

CBHP Deliberation 04/2006, approved during execution of the Pilot Project, implemented a plan that delimits areas in which drilling of wells is forbidden and establishes protection areas for replenishment zones. CERH Resolution 65, of September 4, 2006, which ratified this deliberation, establishes that areas with temporary restrictions and control shall be subject to review after conclusion of the Project for Environmental Protection and Sustainable Development of the Guarani Aquifer System (PGAS) and development of a numeric model for the Ribeirão Preto Pilot Project area. The Technical Chamber for Groundwater of the Pardo River Basin Committee is the ideal venue for establishing a Local Committee. Acting as a standing advisory group on the GAS, this committee could be responsible for articulating the competent institutional structure for groundwater management in the Ribeirão Preto area. It is important that local institutions (DAEE, DAERP, municipality, CBHRP, FEHIDRO) provide funding for defraying actions of the Local Committee. Local institutions have created a Reference Center on Groundwater and on the Guarani Aquifer in the Pilot-Project area.

It has been estimated that the population of the Pilot-Project area will in crease to 1,330,000 by 2050. Such robust population growth will lead to a significant increase in demand for drinking water, which is set to rise from a current 13.4 million m³ per month to 22 million m³ per month. Demand for public water supply is the most critical issue relating to the GAS in this area. In view of this situation, the vulnerability of the GAS in this area justifies priority local-management actions targeted at ensuring sustainability and reliability of future water supplies. One proposal for fulfilling future

demand entails drilling of wells in zones with high potential yields, outside the replenishment areas, which would reduce pressure on the system, since most wells are currently concentrated in the urban area. Climate-change scenarios should be assessed, principally in relation to reduced excess water in the region, and consequent decreases in replenishment. One current aspect that needs to be addressed is high per-capita water consumption in the town of Ribeirão Preto, that currently amounts to some 400 liters per person per day.

6.6.3 Priority strategic actions for the Pilot Project

I - Technical aspects

a) Adoption of management measures targeted at maintenance of GAS groundwater availability and quality:
   - » Reduce high rates of loss from the distribution system.
   - » Implement measures for reducing per capita water consumption.
   - » Seek management alternatives for water supply and demand.
   - » Management of tariffs.
   - » Establish protection perimeters for wells, with restrictions on land use.
   - » Maintain the three aquifer protection zones in the urban area of Ribeirão Preto, with restrictions on new wells.
   - » Determine that sources of public water supply be from favorable areas, in terms of protection and of the quality and quantity of water.
   - » Assess the possibility of instituting payment for environmental services as a possible management instrument in vulnerable areas of the GAS, taking into account high property values in the Pilot-Project areas. This tool could reduce costs of protection of these areas.
   - » Assess and propose land-use restrictions in outcrop areas of the aquifer, within the scope of municipal plans.
   - » Operation and maintenance of the local network of monitoring wells of the GAS.
   - » Study possible processes of contamination in outcrop areas of the aquifer and compile a full inventory of unregistered wells.
   - » Assess the feasibility of future alternatives for supply from mixed water sources (surface and groundwater).
   - » Evaluate scenarios for exploitation of the GAS, foster development of criteria for use and protection of the GAS, using the mathematical model as a management tool and incorporating new variables and transport of contaminants (Chapter 5 Annex 11).

II - Legal and institutional aspects

a) Consolidate the GAS Local Committee:
   - » Endow it with a stable structure, with annual appointment of representatives of the component organizations.
   - » Prepare a program of annual targets for the Local Committee and define conditions for contracting the necessary human resources.
   - » Seek funding from within municipal budgets to defray operational costs of the Local Committee.

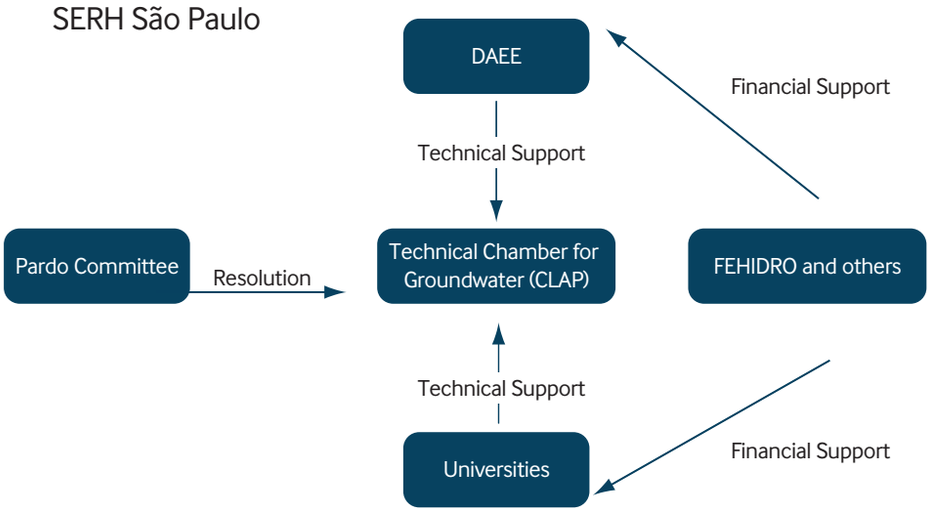
In October 2003, Pardo Basin Committee Resolution 007 instituted the Pilot Project Coordination Group, within the scope of the State of São Paulo water-resources management system. The composition and attributions of this Coordination Group are evidence that this is an area of special interest for groundwater-resources management and consolidation of local management. The Coordination Group thus takes on functions formerly exercised by the Local Project Support Committee (CLAP). Technical support is to be provided by the Department of Water and Electric Power (DAEE) which is the water-resources management body of the State of São Paulo, either directly, or through support from Universities that comprise the Coordination Group. With respect to the financial resources necessary for follow up of the Pilot Project, besides operating expenses to be covered by DAEE, the State of São Paulo may provide support for other activities by means of the State Water Resources Fund (FEHIDRO), with support from the Municipal Public Water Supply Company of Ribeirão Preto (DAERP).

The organizational flow chart in Figure 10 illustrates the relationships for local management of the GAS described earlier.

b) Strengthening of local groundwater management and land-use agencies:
   - » Strengthening of municipal institutional capacities for operation and updating of the SIGAS, and territorial, environmental and water-resources management.
   - » Strengthening of local water resources institutions, to enable them to operate, maintain and expand the local monitoring network of wells.
   - » Consolidate mechanisms for articulation of the Local GAS Committee with the Technical Chamber for Groundwater of the Pardo River Basin Committee.
   - » Define, through the Technical Chamber for Groundwater of the National Water Resources Council (CTAS/CNRH) the scope of the Basic Sanitation Law (Law 11.445/2007).
   - » Stimulate classification of groundwater, in accordance with CONAMA Resolution 396/2008, based on vulnerability maps.
   - » Decentralize certain DAEE activities, transferring competencies to offices in other towns.
   - » Strengthen inspection with the support of the Pardo River Basin Committee, through dissemination, debates, etc.

III - Social aspects and public participation

a) Continual local expansion and dissemination of knowledge on the GAS:
   - » Create, within the Local Committee, a scientific subcommittee together with DAEE to contiunually update scientific knowledge on the GAS at the local and regional levels.
   - » Create, within the Local Committee, an advisory subcommittee to carry out dissemination activities using multimedia tools.
   - » Establish a reference center on the GAS to facilitate public participation.
   - » Create, within the Local Committee, a subcommittee for public participation to organize events for strengthening of community participation.



Source: GS/GAS, 2008.

Figure 10. Inter-relations for local management

6.7 RIVERA-SANTANA DO LIVRAMENTO PILOT PROJECT (URUGUAY - BRAZIL)

The Rivera-Santana do Livramento Pilot Project encompasses an area of 759 km^2 on the border between Uruguay (Department of Rivera) and Brazil (State of Rio Grande do Sul). This border coincides with a surface-water watershed in a zone overlying the Guarani Aquifer which, in this area, is relatively close to the surface (Figure 11).

Together, the towns of Rivera and Santana do Livramento have a population of approximately 200,000, equally distributed on the two sides of the border. This rapidly growing population behaves as if the two were a single town.

The main economic activities are agriculture and livestock (wool, meat, hides, vineyards, corn (maize) and, increasingly, soybeans). On the Uruguayan side there a number of sawmills. Aside from poor basic sanitation, the most significant potential sources of pollution are slaughterhouses and sawmills.

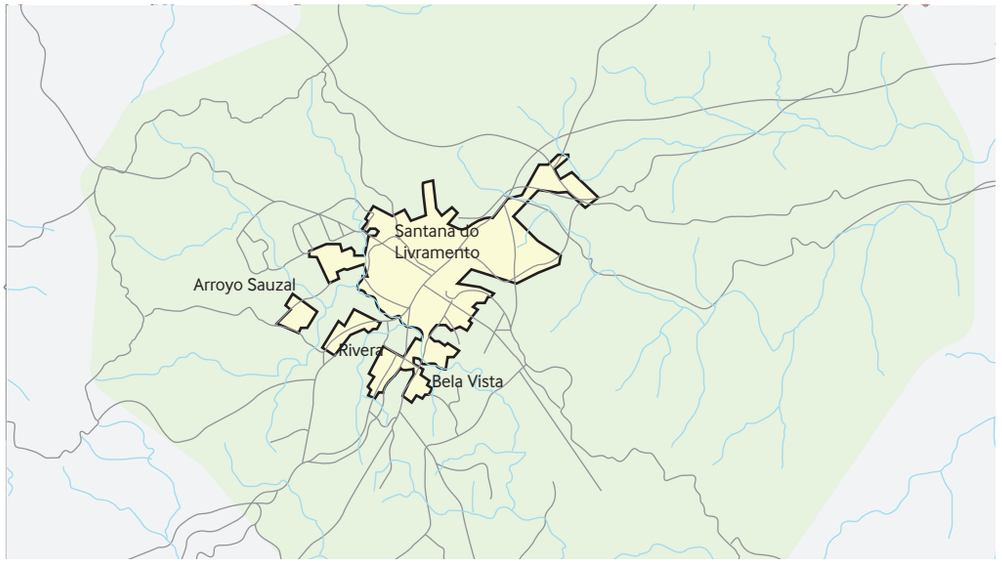
Much of the Pilot-Project area consists of outcrops of GAS sandstone and the remainder is a thin covering of basalts of the Serra Geral Formation. The GAS is the main source of water supply and is exploited by wells drilled by the State Sanitation Works Department (OSE) of Rivera, and by the Water and Sewage Department (DAE) of Santana do Livramento. The volumes extracted from these wells correspond to roughly 80% and 100%, respectively, of public water supply for these two towns. The water supply network serves over 95% of the population. Estimated total consumption, including suburban areas and nearby rural zones, varies between 50,000 and 60,000 m^3 per day (between 25,000 and 30,000 m^3 of water is consumed in Santana do Livramento, and 14,000 to 15,000 m^3 in Rivera).

Groundwater flows in the area are mostly concentrated in the more permeable horizons of the aquifer, in a layer of variable thickness (between 40 and 80 meters). The natural flow is toward the northeast, but has been altered due to abstractions, which have lowered groundwater levels by approximately 5 meters over the past 10 years.

GAS water in the Pilot-Project area is predominantly characterized by calcium-magnesium bicarbonate and secondly, by calcium-magnesium chlorates, always with an absence of sodium and low concentrations of chlorates. Rivera and Santana do Livramento are part of a replenishment area where water has a short time of residence. Ionic exchanges clearly explain this type of water rich in calcium-magnesium bicarbonate and with a lack of sodium. The quality of groundwater from deep wells located in central urban areas is good, except for that of certain wells with a depth of less than 100 meters where pH is low, and some wells where magnesium, cadmium and borax are present in higher than standard concentrations.

The main groundwater quality management problems are associated with flaws in the sewage-collection network. Sewage collection services reach only 30% of the population in the town of Rivera, and 40% in Santana do Livramento, with the result that there are significant sub-surface discharges from septic tanks in many areas of the town.

Both OSE and DAE own groups of wells with yields of over 100 m^3/h, located in protection zones to the west of the towns, in the region where the basalt layer begins to appear. These zones, that lie outside the urban area, are suitable for drilling of new wells and for establishment of special protection areas for abstraction of groundwater for public water supply. They represent potential water security for the towns, as they offer an opportunity to reduce dependence upon various wells spread throughout the urban zone. Wells in the urban zone are subject to greater risk of contamination, even if the sewage network is expanded.



Source: GS/GAS, 2008.

Figure 11. Pilot-Project Rivera–Santana do Livramento

6.7.1 Institutional and normative assessment

The legal frameworks of the two countries have many similarities, especially in terms of water-resources management principles and goals, the value placed upon such resources, and the aim of promoting appropriate management.

Legal framework applicable to the Pilot-Project area

In the two management units[2] there is a legal framework that encompasses the main management tools for protection of groundwater. There follows an assessment of the degree of effectiveness of these standards.

Legislation on water in Rio Grande do Sul and in Uruguay present no significant differences (Table 9) and the essential principles and guidelines are similar:

- » Groundwater under public jurisdiction.
- » Authorization for the use of water is issued by competent authorities.
- » Priority for human water supply and watering livestock.
- » Compulsory registration of water use and inventory of engineering works.

In both management units, international scientific and technical cooperation agreements have not been implemented in the Pilot-Project area. To date, the environmental cooperation committee, foreseen in an agreement signed in 1992, has not been established.

Rio Grande do Sul

- The system for issuing licenses for use of groundwater was implemented in 2001, but many wells in the region and in the state have not been regularized, owing to a lack of technical staff at the management body.
- For provision of public water supply services (regarded as a priority) licenses are issued for a period of 10 years. For other categories of use, unlimited licenses are issued, since the limits to availability of the resource are unknown. Decision-making support systems, such as the database, register of water users, the hydrometric network and Information System, are currently in the implementation phase.
- No strategy has been prepared for regularization of existing wells. It is, however, compulsory to obtain a license for the drilling of new wells. At present, regularization must be requested by the water user, for example, renewal of environmental licenses for industrial projects (Table 10).
- The management body lacks inspectors to ensure compliance with standards. Inspections are carried out by the State Environmental Patrol (PATRAM) that responds to complaints. PATRAM lacks specialized personnel to assess technical conditions of wells.
- Licenses for drilling wells for exploitation of mineral and thermal water are issued by the National Department for Mineral Production (a federal body). To date, no coordinated procedures with the state management body have been implemented, and neither is there an adequate exchange of information on wells that have been regularized.
- Law 11.445/2007 (the Basic Sanitation Law) makes regularization of wells and use of any alternative sources conditional upon non-availability of the public water supply network, but it is unclear just how this will be applied.
- The State's environmental licensing procedures are not specifically for wells, but rather for their associated economic ventures.

Santana do Livramento

- The Territorial Plan of the Municipality of Santana do Livramento, approved in 2006, does not encompass groundwater. It is currently under review, and will be altered in the light of outcomes of the PGAS.
- The aquifer underlies more than one river basin, and the master plans for each basin are approved by their respective committees. For this reason, different concession criteria and differing priorities may hamper management.

Uruguay

- The qualitative and quantitative aspects of water management have not been integrated. Neither has the relationship between surface and groundwater, nor land-use and territorial planning.

2 In Brazil, a federated state, the Government of the State of Rio Grande do Sul is responsible for groundwater management. In Uruguay, a unitary state, the National Executive Branch is responsible.

Table 9. Situation in the Rivera-Santana do Livramento Pilot Project

Regulatory framework	**In the two countries** Cooperation agreements on scientific and technical (1975 and 1991) and environmental (1992) matters **Brazil:** - Federal Constitution (ref. 1988: public jurisdiction over groundwater) - Law 6.902/1981 (National Environment Policy) - Law 9.433/1997 (National Water Resources Policy. Management System) - Law 11.445/2007 (Basic Sanitation) - CONAMA Resolution 396/2008 (classification, prevention and control of groundwater pollution) **Rio Grande do Sul:** - State Constitution (ref. 2007: water resources management) - Law 10.350/1994 (State Water Resources Policy) - Decrees 37.033/1996 (water-use licenses), 37.034/1996 (Basin Committees) and 42.047/2002 (management and conservation of groundwater). **Uruguay:** - Constitution (ref. 2004: public jurisdiction over groundwater) and Water Code (1978) - Law 16.466/1994 (Environmental Impact Evaluation) - Law 17.283/2000 (Environmental Protection) - Law 17.234/2000 (Natural Protected Areas) - Decree 214/2000 (Management Plan for the Infra-basaltic Guarani Aquifer) - Decree 86/2004 (Technical standards on drilling of wells) - Decree 253/1979 (Discharges of effluents) and Decree 349/2005 (Environmental Impact Evaluation) **Rivera–Santana do Livramento:** - Joint resolution of the two Municipal Administrations, of 2003, creating the Pilot-Project Support Committee
Effectiveness of the regulatory framework	**In the two countries** The cooperation agreements were not implemented during development of GAS projects **Rio Grande do Sul:** - The system for issuing licenses has not yet been fully implemented - Environmental licensing covers the venture, rather than groundwater use **Uruguay:** - The Management Plan for the Infra-basaltic Guarani Aquifer is not applied in this zone - Environmental impact assessments are applied to wells with flows of over 50 liters per second
Causes of poor effectiveness	**In the two management units** - Management is centralized in the state capital and national capital, respectively - Lack of specialized personnel at management bodies and resident in the region - Poor integration between environmental management and land and water use **Rio Grande do Sul:** - The licensing system lacks information for decision making, competencies are fragmented, according to the groundwater characteristics and there is no harmonized procedure among the different bodies - The scope of limitations set by the Basic Sanitation Law has not yet been determined **Uruguay:** - The Management Plan does not contain provisions applicable to shallow zones of the aquifer - Parameters for licenses to discharge effluents are outdated - Environmental impact assessments are not required for most wells **Rivera–Santana do Livramento:** - Municipal land use and settlement legislation and municipal plans and guidelines do not consider interrelated aspects of water in their master plans

Source: Adapted from the SAP and PALP Legal Advisory Final Report, with contributions from the National Project Execution Units, 2008.

Table 10. Standards applicable to solution of specific problems of the Rivera-Santana do Livramento Pilot Project

Control over drilling of wells and abstraction of groundwater	**Rio Grande do Sul:** - Law 10.350/1994 (State Water Resources Policy) on issuing of licenses - Decree State 42.047/2002, on groundwater management and conservation **Uruguay:** - Law 14.589/1978 (Water Code) - Decree 86/2004 (Technical standards for construction of deep wells)
Local control of land use and discharges of effluents to protect groundwater	**Rio Grande do Sul:** - Decree 42.047/2002, on groundwater management and conservation. Article 26, on projects with a risk of groundwater pollution that require environmental studies - CONAMA Resolution 303/2002, on declaration and conservation of protected areas - CONAMA Resolution 396/2008, on classification, prevention and control of groundwater pollution **Uruguay:** - Water Code of 1978 - Law 16.466/1994, on Environmental Impact Evaluation, and the enabling decree - Law 17.234/2000, on Natural Protected Areas - Decree nº 253/1979, on discharges of effluents

Source: Adapted from the SAP and PALP Legal Advisory Final Report, with contributions from the National Project Execution Units, 2008.

- Technical requisites established in the Management Plan for the Guarani Aquifer (Decree 214/2000) are not applicable in the zone. Thus, no parameters have yet been set for granting of licenses.
- Since the Management Plan is not applicable, the Advisory Board has no power to intervene in management of the aquifer in the outcrop zone.
- Regulations on prevention of environmental pollution by means of control of water, approved by Decree 253, of May 5, 1979, establish classifications for water bodies that may receive effluent flows, and the limits of contamination parameters. They also determine the procedure for obtaining the right to discharge effluents and set sanctions for noncompliance. In practice, such classification has not been implemented, so there is no enforcement of the decree, and thus the provisions of the executive order that allows discharges of effluents remain in force.
- Environmental impact assessments are only required for wells with abstraction capacity of over 50 liters per second. In view of the characteristics of the wells in the zone, this standard is not applicable.
- No regular quality control is carried out, and technical control of drilling operations is rare.
- The Law of Natural Protected Areas (Law 17.234/2000) was implemented by Decree 52/2005. One of the zones declared part of the National System of Protected Areas is Vale do Lunarejo, which encompasses part of the Uruguayan portion of the Pilot-Project area.

Rivera

- The Master Plan for the Intendancy of Rivera encompasses the Guarani Aquifer, while leaving space for further adjustments, based upon information generated under the PGAS.

6.7.2 Bases for management

Activities carried out under the PGAS make it possible to identify the bases for future actions under the SAP. Local stakeholders participated in many discussions held during the entire process of development of the PALP and of the SAP in Rivera-Santana do Livramento.

- From a hydrogeological standpoint, most favorable areas outside the urban perimeters of the two towns were defined, where future sources of public water supply could be tapped with new wells, to replace those in urban areas that are more susceptible to contamination.
- Land-use plans, both in Santana do Livramento and in Rivera, could be used as instruments for declaring and conserving protected areas, both in highly vulnerable zones of the aquifer and in areas where wells for urban public water supply are located.
- The inherent difficulties of integrated management do not derive from legal or institutional weaknesses, but rather from flaws in the implementation of mechanisms foreseen, both at the national and bi-national levels.
- Requisites for applications for licenses for utilization of water resources are similar. In both countries there are instructions and forms specifying licensing requisites for uses of surface and groundwater, depending upon the category of use. The same is true for information on water-related engineering works.
- There are, in both countries, institutions with clearly-defined powers responsible for water-resources management. Differences exist in the organizations of each of the countries, that reflect the federative structure of Brazil and Uruguayan unitary state. This need not, however, impede establishment of coordination mechanisms necessary for articulation between the respective bodies.
- Mere establishment of the Local Transboundary Committee is not enough. it will also be necessary to endow it with financial, human, and technical resources. The

Local Committee must have legitimacy to follow through with its actions. To this end, it is essential that it be acknowledged by the municipal authorities (mayor's offices and municipal councils) and by state and national authorities (state institutions and national groundwater management bodies).

- One of the key features of execution the PGAS in the Pilot-Project area was intense public participation in the various activities, demonstrating increasing levels of public interest in the region for issues relating to water resources.

6.7.3 Priority strategic actions for the Pilot Project

I - Technical aspects

a) Hydraulic and hydrochemical monitoring of waters of the GAS in the urban area:
   - » Operation and maintenance of the local GAS monitoring network (with emphasis on detection of traces of nitrates and heavy metals).
   - » Inventory and inspection of existing and unregistered wells throughout the Pilot-Project area. To carry out this task, in the medium term, it would be worthwhile to install local laboratories and provide training for local human resources in gathering of samples and chemical analyses of water.

b) Aquifer protection and management measures:
   - » Detailed studies to assess and confirm that the protected areas selected are capable of producing large-scale flows. Such studies should also define potential abstraction yields from these zones.
   - » Propose to the State Sanitation Works Department (OSE) that new wells be constructed in protected areas of Grã-Bretanha Park.
   - » Propose to the Water and Sewage Department (DAE) that new wells be constructed in protected areas in the Northeast Sector of Santana do Livramento (Retiro).
   - » Establish protection perimeters for wells, with restrictions on land use.
   - » Use a mathematical model to simulate scenarios for use of the GAS, incorporating possible transport of contaminants (details in Annex 11).

c) Expansion of sanitation in the two towns:
   - » Propose collaboration between the state and national Governments and companies that provide sanitation services, to ensure continual increases of coverage in the two towns.
   - » Propose joint efforts of the two towns to improve sanitation coverage.

II - Legal and institutional aspects

Considering that COTRAGUA will need to have the support of two committees, one linked to the water-resources management system of Uruguay, and the other to the management system of the State of Rio Grande do Sul, the following proposals are submitted:

Uruguay: (i) formal acknowledgement, by DINASA (by means of an order) of the Rivera Local Management Support Committee (CLAG) as the local groundwater management support body responsible, duly comprised of representatives of users, social organizations, and public municipal, departmental and national bodies). (ii) signing of an agreement between DINASA and the Municipal Administration of Rivera on technical and operational support to the CLAG and COTRAGUA.

Brazil: (i) formal acknowledgement, by SEMA/DRH (by means of an order) of the Santana do Livramento CLAG as the local groundwater management support body responsible, duly comprised of representatives of users, social organizations, and public municipal, state and national bodies). (ii) formation of a Technical Chamber for Groundwater within the scope of the Santa Maria River Basin Committee which, by means of a Committee resolution, shall be based on the CLAG. (iii) the state management body should sign an agreement with a local university to provide technical and operational support for the Santana do Livramento CLAG.

At the bi-national level, and within the framework of current agreements between the two countries, propose creation of a bi-national COTRAGUA with participation of both committees and representatives of the respective Ministries of Foreing Affairs and national management bodies.

The following organizational flow chart (Figure 12) illustrates the suggested institutional arrangement.

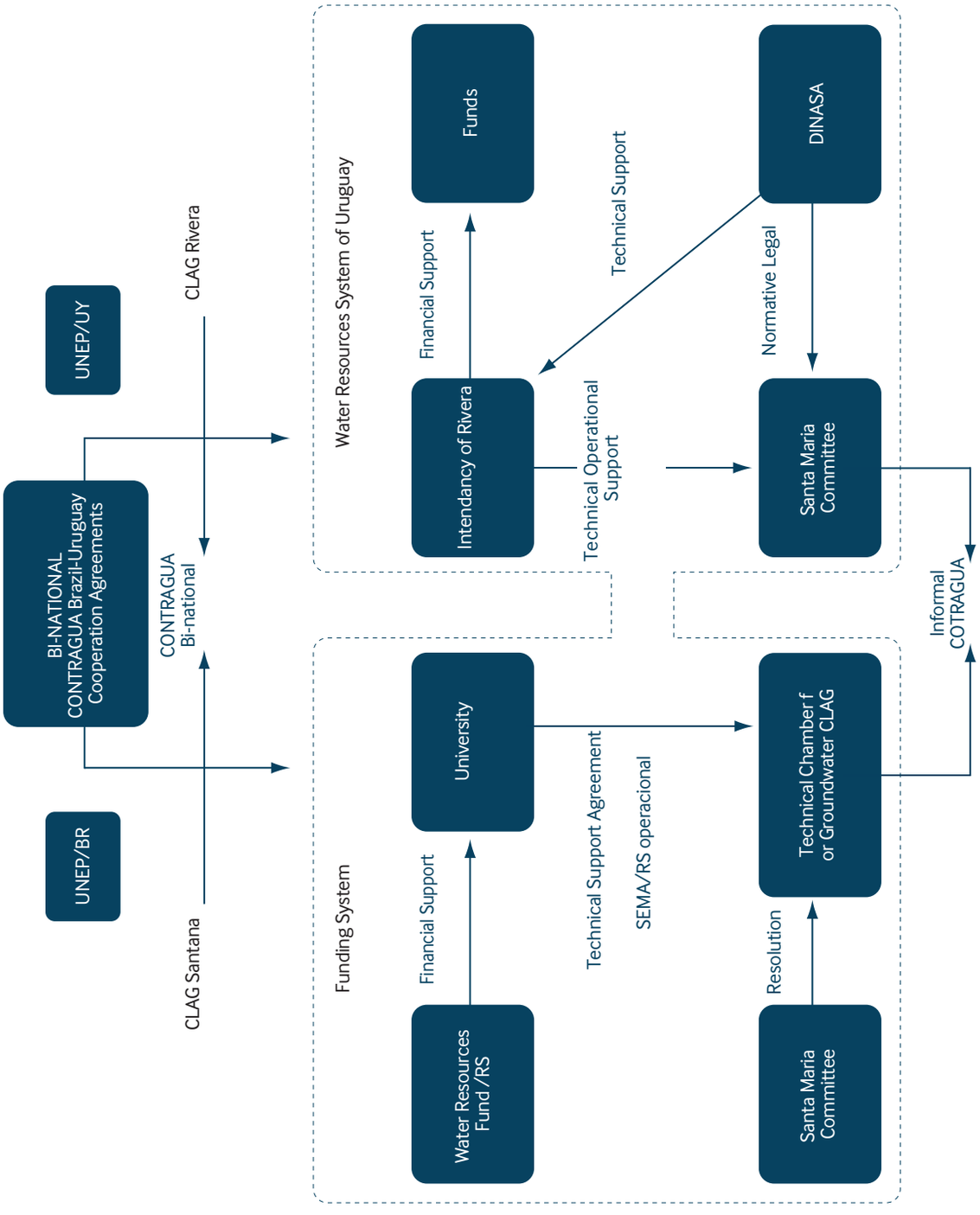
a) Consolidate the Local COTRAGUA Committee:
   - » Endow it with a stable structure, with periodic appointment of representatives of the component organizations, including water users.
   - » Contract a consultancy to prepare a program of annual targets to be attained by COTRAGUA and define terms for contracting of human resources.
   - » Seek funding from municipal budgets to defray COTRAGUA operational costs. National sources may also play an important role in its consolidation.

b) Institutional strengthening of groundwater management and land-use agencies:
   - » Strengthening of local capacities for operation and updating of the SIGAS.
   - » Strengthening of the State Water Resources Department of the Secretariat of Environment of Rio Grande do Sul and contracting of hydro-geologists.
   - » Strengthening of the regional offices of the National Water and Sanitation Board (DINASA) and of the General Directory for Natural Renewable Resources (DGRNR) and contracting of hydro-geologists.

c) Actions to enhance the effectiveness in the two management units:
   - » Implement cooperation agreements by means of concrete and specific actions, such as exchanges of information on wells, that need to be regularized by the respective authorities.

Rio Grande do Sul

- » Harmonize the system for issuing licenses, by applying CNRH Resolution 65.



Source: GS/GAS, 2008.

Figure 12. Suggested Institutional Arrangement for functioning of COTRÁGUA

» Improve the system for issuing licenses.
» Involve authorities at all levels in the basin committees (especially on issues relating to land use) and of the municipality, and formulate classifications for groundwater in accordance with CONAMA Resolutions.
» Clarification, by the Technical Chamber for Groundwater (CTAS) and through the National Water Resources Council (CNRH), of the scope of Law 11.445/2007 (the Basic Sanitation Law).

Uruguay

» Update the Management Plan, based on outcomes of the PGAS, incorporating adjustments so as to make it applicable to the various zones of the aquifer.
» Propose inclusion, within the Water Policy Law, of a committee on the Guarani Aquifer with nationwide powers.

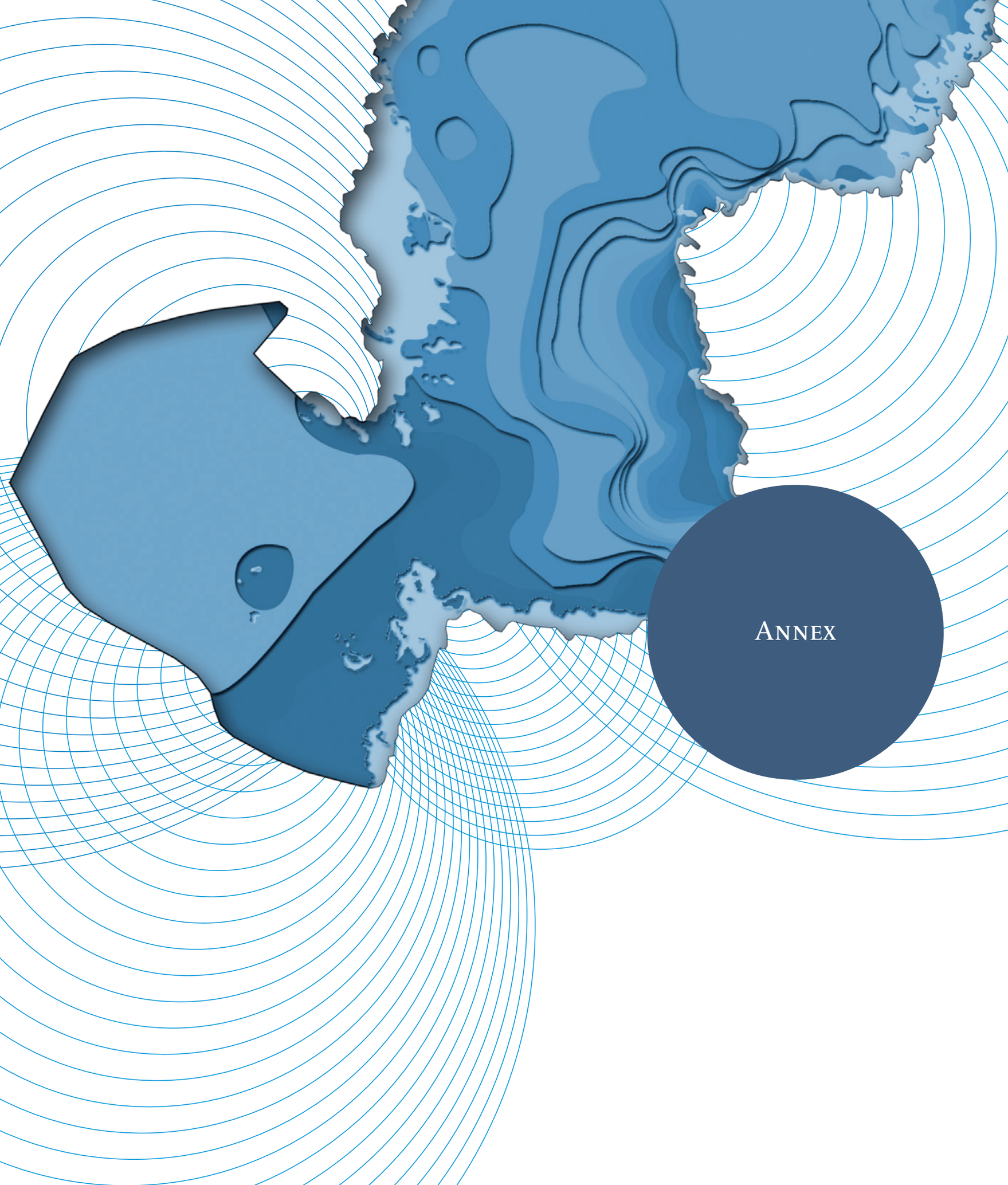
Rivera-Santana do Livramento

» The Local Management Support to Committee (COTRAGUA) could propose changes in the master plans of the municipalities and foster greater coordination between water-resources and land-use management, based on information produced under the PGAS.
» The Master Plan of the Intendancy of Rivera encompassed the Guarani Aquifer, leaving scope for future changes, based on information produced under the PGAS.

III - Social aspects and public participation

a) Continual local expansion and dissemination of knowledge on the GAS:
   » Create, within COTRAGUA, a scientific subcommittee for updating scientific knowledge.
   » Create, within COTRAGUA, a subcommittee for dissemination of public information, using multimedia tools.
   » Prepare a continuous public communications and local dissemination plan.

b) Create a reference center on the GAS to facilitate public participation:
   » Create, within COTRAGUA, a subcommittee for public participation to organize events for strengthening community participation.



Annex

ANNEX 14

Annex 14 Preparation of Local Action Programs of the Pilot Projects (Palps)

PREPARATION OF LOCAL ACTION PROGRAMS OF THE PILOT PROJECTS (PALPS)

The Local Action Programs of the Pilot Projects (PALPs) were prepared based on an Initial Local Management Plan (PGL) and on the Transboundary Diagnostic Analysis (TDA) that identified the most critical problems relating to the Guarani Aquifer System in specific areas. This preparation process entailed active participation of the local community, and made it possible to rank actions into a management program aimed at protection and sustainable use of the aquifer. A summary of each of the PALPs can be found in the chapter on the Pilot Projects.

Preparation of each of the PALPs considered:

- The outcomes of scientific studies carried out by the SNC-Lavalin International company and the Guarani Consortium[3].
- The results of the Universities Fund (knowledge on the structure and geometry of the system, flows, and water quality).
- The results of the Citizenship Fund (experiences in the fields of information, dissemination and community participation).
- Studies carried out by consultancies of private projects on the GAS.
- Internships by legal and institutional specialists of the countries.
- Socioeconomic consultancies (information on socioeconomic, gender, cultural and water-use aspects).
- Experiences of dissemination, public participation and lessons learned by the PGAS Secretariat in each Pilot Project.
- Valuable contributions of the local committees and facilitators (PGAS technical staff) at each of the Pilot Projects.

In 2003, implementation of the PGAS began in the Pilot-Project areas. From the very beginning, the projects carried out a variety of activities based on the Initial Local Management Plan (PGL) and on the Transboundary Diagnostic Analysis (TDA). Workshops were held on public participation, scientific projects of the universities (Universities Fund) and citizenship building initiatives (Guarani Citizenship Fund) and a series of studies geological, geophysical, hydrogeological, social and economic studies.

Findings of the Transboundary Diagnostic Analysis were deepened and revised during preparation of the PALPs. Contributions and points of view of the various institutions and social stakeholders were collected through a comprehensive process of public participation and incorporated into the PALP document. Between 2003 and 2007, meetings, workshops and events were held in the Pilot-Project areas to disseminate information on the GAS and collect suggestions and opinions.

In view of the nature of the GAS, the following guidelines oriented actions foreseen in the PALPs:

- Strengthen the common understanding on the GAS and promote sustainable use and management.
- Enable the four countries to benefit from "services" of the GAS, and reduce negative impacts as much as possible.
- Reinforce opportunities for sustainable use of the GAS, based on a common understanding and on pragmatic cooperation mechanisms.
- Anticipate potential conflicts and propose a strategy for resolving or managing them.
- Make use of and build upon public and stakeholder support.

Content of the PALPs

Each PALP comprised:

- Technical aspects
- Legal and institutional aspects
- Social and public participation aspects

Based on these aspects, short and medium-term strategic and priority actions were launched in each of the Pilot-Project areas. From a scientific standpoint, the technical consultancies carried out by SNC-Lavalin International and the Guarani Consortium increased local knowledge on the aquifer and its dynamics, filled in information gaps, and

3 Argentina contests the findings of pumping tests at the Concórdia-Salto pilot project.

helped build a solid basis in support of the proposed actions. Local action programs resulted in preparation, by each of the Pilot Projects, of a document to reflect the specificities of each area. These documents provided working instruments to be used to enhance local management and promote sustainable development of the GAS.

Lessons learned

During the design and execution phases of the PGAS in the Pilot-Project areas, there was initially resistance to the focus on preserving the environment and natural resources, in view of cultural biases in favor of immediate exploitation prevalent in each of the countries. This proved the necessity of redoubled awareness-building efforts when executing projects aimed at preventing environmental damage and avoiding disputes caused by scarcity or conflicting uses of resources.

The communications strategies of the Pilot Projects had to consider two challenges:

- one relating to characteristics of project design which, in view of its preventative nature, made explicit the importance of its goals, but failed to express the urgency of fulfilling them. Indeed, the communications strategy treated the Pilot Projects as a seed that would produce fruits at some future date.
- and another relating to the physical characteristics of the resource that it aims to protect. Unlike surface water, groundwater is not immediately visible to the public eye.

A common element in all four Pilot Projects is the need to strengthen local institutions. Though needs vary in accordance with the specific characteristics of each of the Pilot-Project areas, it is necessary to invest in institutional capacities (equipment and human-resources training) for both groundwater and land-use management. Trained technical staff are needed to carry out actions at the local level. The shortage of trained technical staff at the local-management level is a limiting factor that often hampers attainment of the desired results, either owing to insufficient monitoring or lack of resources for management training.

The PGAS Pilot Projects demonstrated that there is great public interest in the Guarani Aquifer. Such interest is an indication of the potential for public participation, that could be harnessed to enhance local management on the part of authorities responsible for water-resources and land-use management. Throughout the period of the Pilot Projects, local committees in support of the PGAS demonstrated interest and capacity to work synergistically. The countries should acknowledge the value of such participation and, looking to the future, ensure that these committees have secure enough institutional structures guaranteed by national legislative provisions. Though national frameworks vary, there are laws in each of the countries that acknowledge participation of such committees and their important role in local management of the aquifer.

The composition of local committees should ensure a reasonable balance between stakeholder sectors (state and society) and enable their members to assume roles as legitimate representatives. With this in mind, all stakeholder segments should be encouraged to participate, through regular elections for representatives.

It should be explicitly stated that the purpose of such local committees (whether or not they are transboundary) is to provide support for local management of the aquifer. The legacy of the PGAS in each of the Pilot Projects (the well monitoring networks, SIGAS, and local mathematical models) provides significant initial guidance for the work of these local committees. As time passes, other elements that can contribute toward the routine management duties of these committees in each Pilot Project can be added.

It is essential that the local management support committees of the GAS be provided with a budget and sufficient funding to defray their operating needs, i.e., that they can cover the costs of equipment, office supplies, human resources and operational expenses. Such funding could come from a variety of sources. In the short term, however, it is up to local, state/provincial and national governments, through their own budgets or using funding from international agencies, to provide the necessary support for local committees, beginning in 2009, and to ensure that they are in a position to provide support for management of the aquifer in the Pilot-Project areas.

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Chapter 2

Characteristics of the Guarani Aquifer System

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Units of measurement used in the SAP (in order of appearance)

km²	square kilometers – measurement of area
m/d	meters per day – permeability of the GAS
m/km	meters per kilometer – hydraulic gradients of the GAS
m³/h wells	cubic meters per hour – flows / abstractions from
m³/h/m	yield per unit of lowering – specific flow, a hydraulic characteristic of the well-aquifer system
µS/cm	micro simens per centimeter – measure of the electrical conductivity of GAS waters
pH	measure indicating acidity, neutrality or alkalinity of a liquid solution
m – Ohm metro – RE	electrical resistance of GAS waters (opposite of conductivity)
meq/L	milliequivalent per liter – a measure of the concentration of a solute in solution; obtained by dividing the concentration in milligrams per liter by equivalent weight of the ion
°C	degrees Celsius - a measure of temperature
kW/kg/s	kilowatts per second per kilo – specific mechanical or thermal power (per unit of mass)
pMC	measure of the concentration – percentage of modern carbon
km³	cubic kilometer - a measure of volume
km³/year	cubic kilometer per year – flow of water
mm/ano, **mm/month**	millimeter per year, millimeter per month – flow of water (indicating annual rainfall, water excesses or deficits, base flows, flows of rivers, surface runoff)
m³/h, m³/dia, m³/year	cubic meters per hour, cubic meters per day, cubic meters per year - measures of volumes of water abstracted from the GAS
L/s-km²	specific base flows – measure of flows per unit of area

List of acronyms

TDA – Transboundary Diagnostic Analysis (PGAS)
AIDIS – Inter-American Association of Environmental and Sanitary Engineering
IAEA - International Atomic Energy Agency
ALHSUD – Latin American Association of Underground Hydrology for Development (Brazil)
ANA – Agência Nacional de Águas (Brasil)
ANEEL – National Electric Power Agency (Brazil)
APA – Provincial Water Administration (Chaco - Argentina)

IDB - Inter-American Development Bank
BGR – Federal Institute for Geociences and Natural Resources
World Bank
BNDES – Brazilian Development Bank
BNWPP – Bank-Netherlands Water Partnership Program

CACAC – Capiibary River Basin Council
CBH – River Basin Committee
CC – Coordination Committee (PGAS)
CERH – State Water Resources Council (Brazil)
CCRP – Pardo River Basin Committee
CCSM – Santa Maria River Basin Committee
CCPI – Itapúa Pilot Project Committee
CETESB – Environmental Sanitation Technology Company (SP – Brazil)
CIC – Intergovernmental Coordinating Committee for the La Plata Basin
CLAG – Local Management Support Committee (PGAS)
CLAS – Local Support Committee for Pilot Projects (PGAS)
CLGAS – Local Groundwater Management Committee
CLAP – Local Support Committee to the PGAS
CN – National Coordination
CNRH – National Water Resources Council
CODESAL – Salto Grande Development Corporation (Uruguay)
COHIFE – Federal Water Council (Argentina)
COHILI – Water Council of the Littoral (Argentina)
CONAMA – National Environment Council (Brazil)
CONICET – National Scientific and Technical Research Council (Argentina)
COTRAGUA – Guarani Aquifer Transboundary Committee
CPLA – Environmental Planning Coordination Unit
CPRM – Brazilian Geological Service
CLTGAS – Local Transboundary Groundwater Management Committee
CNs – National Coordination Units
CORUFA – Water Sources Regulatory Council
CSDP – Project Steering Committee (PGAS)
CTM – Salto Grande Joint Technical Committee
CRRH – Regional Water Resources Committee
CSDP – Project Steering Committee (PGAS)
CSPP – Project Preparation Steering Committee (PGAS)
CTAS – Technical Chamber for Groundwater (Brazil)
CRC – Regional Cooperation Council (SAP – GAS)

DAE – Water and Sewage Department
DAEE – Water and Electric Power Department (SP – Brazil)
DAERP – Water and Sewage Department of Riberão Preto (SP – Brazil)
DGRNR – Directorate General of Renewable Natural Resources (Paraguay)
DHER – Water Department of Entre Ríos (Argentina)
DINAMA - National Directorate of Environment (Uruguay)
DINASA – National Directorate of Water and Sanitation (Uruguay)
DNH – National Directorate of Hydrography
DNPM – National Department of Mineral Production (Brazil)
DPH – Provincial Water Directorate
DRH – Department of Water Resources of the State of Grande do Sul (Brazil)
DRV – Directorate of Living Resources - Ministry of Ecology, Renewable Natural Resources and Tourism (Misiones, Argentina)

EESC/USP Engineering School of São Carlos - University of São Paulo (Brazil)
ERSSAN – Sanitation Services Regulatory Company (Paraguay)
ESSAP – Sanitation Services Company of Paraguay
ERRTER – Thermal Resources Regulatory Body

FACEN UNA – Faculty of Exact and Natural Sciences of the National University of Asuncion
FEPAM – Henrique Luiz Roessler State Environmental Protection Foundation
GEF – Global Environment Facility
FUCAI – Catholic University of Itapúa
FEHIDRO – State Water Resources Fund (Brazil)
FUNAI – National Indian Foundation (Brazil)
FUNASA – National Health Foundation (Brazil)

GEF - Global Environment Facility
GCPPRP –Ribeirão Preto Pilot Project Coordination Group (PGAS)

IWRM – Integrated Water Resources Management
GTCR – Regional Technical Coordination Group

GTCR – National Water Institute (Argentina)
IR/IMR – Municipal Intendance of Rivera (Uruguay)
IS/IMS – Municipal Intendance of Salto (Uruguay)
ISARM – Internationally Shared Aquifer Resources Management of the Americas
ISP – Inter-American Strategy for Promoting Public Participation
IF – Forestry Institute (SP - Brazil)
IGCE/UNESP – Institute of Geosciences and Exact Sciences of Universidade Estadual Paulista
IGe/UNICAMP – Institute of Geosciences of the State University of Campinas (São Paulo - Brazil)
IGSP – Geological Institute of São Paulo (Brazil)
INAI – National Institute for Indigenous Affairs (Argentina)
INCRA – National Institute for Colonization and Agrarian Reform (Brazil)
INMET – National Meteorology Institute (Brazil)
IPH – Hydraulic Research Institute (RS – Brazil)
IPT – Technological Research Institute (SP – Brazil)
IGc/USP – Institute of Geosciences of the University of São Paulo

MCT – Ministry of Science and Technology (Brazil)
MERCOSUR – Common Market of the South
MMA – Ministry of Environment (Brazil)
MVOTMA – Ministry of Housing, Territorial Planning and Environment (Uruguay)

NOAA – National Oceanic Atmospheric Administration (United States)

OAS – Organization of American States
OSE – Sanitation Works Department (Uruguay)
NGO – Non-Government Organization
OGU – Federal Budget (Brazil)

SAP – Strategic Action Plan (PGAS)
PAC – Growth Acceleration Program (Brazil)
PAD – Project Appraisal Document (PGAS)
PALP – Local Pilot Project Action Plan (PGAS)
PARLASUR – MERCOSUR Parliament
PASS – Social Action Program in Sanitation (Brazil)
PATRAM – State Environmental Patrol (RS – Brazil)
GDP – Gross Domestic Product
PIP – Project Implementation Plan
PNAS – National Groundwater Program (Brazil)
PNRH – National Water Resources Plan (Brazil)
UNDP – United Nations Development Programme
UNEP – United Nations Environment Programme
Proágua – National Water Resources Development Program (Brazil)
PPA – Multi-Year Plan (Brazil)
PGAS – Project for Environmental Protection and Sustainable Development of the Guarani Aquifer System
PSL – Municipal Administration of Santana do Livramento (RS, Brasil)

RENARE – Renewable Natural Resources

GS – Project General Secretariat (PGAS)
GAS – Guarani Aquifer System
SEAM – Secretariat of Environment (Paraguay)
SEMA – Secretariat of Environment of the State of Rio Grande do Sul (Brazil)
SENASA – National Environmental Sanitation Service (Paraguay)
GS/OAS - General Secretariat of the Organization of American States
SHRU – Secretariat of Water Resources and Urban Environment (Brazil)
SIAGAS – Groundwater Information System
SIGAS - Information System on the Guarani Aquifer System (PGAS)
SPAP – Provincial Potable Water Service (Argentina)
SSRH – Under-Secretariat for Water Resources (Argentina)
SNIRH – Information System on Water Resources

UBA – University of Buenos Aires (Argentina)
UDELAR – University of the Republic of Uruguay
UEEP – State Project Execution Unit (PGAS – Brazil)
UFRGS – Federal University of Rio Grande do Sul (Brazil)
UNEP – National Project Execution Unit (PGAS)
UNG – National Management Unit (SAP, PGAS)
UNCED – United Nations Conference on Environment and Development
UNIPAMPA – Federal University of Pampa

ZA – outcrop zones
ZC – close confinement zones
ZFC – highly confined zones

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