

Pedro Juan Caballero – Ponta Porã

A Groundwater Transboundary Situation between Paraguay and Brasil

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ABSTRACT

As one of the largest groundwater reservoirs with estimated water resources of 30.000 km³ the Guaraní aquifer covers an area of some 1.1 million km² and lies underneath Argentina, Brasil, Paraguay and Uruguay. Growing industrialisation and urbanisation in the region lead to rapidly increasing groundwater production and also to increasing contamination of the resources.

Until 2009 the multinational project “Environmental Protection and Sustainable Development of the Guaraní Aquifer System” – executed by the Organisation of American States and responsible to the World Bank and GEF - supported the four countries in jointly elaborating and implementing a common institutional and technical framework for managing the Guaraní Aquifer System (SAG, Sistema Acuífero Guaraní). On behalf of the German Ministry for Economic Cooperation and Development (BMZ) the Federal Institute for Geosciences and Natural Resources (BGR) supported the SAG-GEF project through assisting Paraguay to meet the requirements in the fields of hydrogeology and groundwater resources evaluation and prognosis.

In the north-eastern edge of the oriental region of Paraguay Pedro Juan Caballero, capital of the Department of Amambay, borders the Federal State of Mato Grosso do Sul in direct neighbour ship to the Brazilian city of Ponta Porã. The twin municipalities form a bi-nationally characterised region with a good potential for future development. The investigation area involves a predominantly agricultural cropping (on the favoured lateritic soils of the basalts) and livestock-rearing area. The Brazilian part of the area is already dominated by farming at an industrial scale.

In Ponta Porã a first deep borehole has been drilled down to the SAG. As there are uncertainties about the interactive impact from the development of the Guaraní aquifer (more deep well locations are under study), this region has been identified as a real transboundary situation with the risk of conflicts. A common water policy is needed and should lead to an integrated transboundary water resources management in a regional and bi-national context on base of updated hydrogeological and socio-economic information.

Key words: Guaraní Aquifer System, Paraguay, transboundary groundwater resources, modelling

1. INTRODUCTION

1.1. The Guaraní Aquifer System

The Guaraní Aquifer consists of a sequence of (mainly weakly cemented) sandstone beds and was formed during Triassic-Jurassic age (250-145 million years BP). The aquifer is overlain by Cretaceous basalt flows (145-130 million years BP), exceeding a thickness of 1000 m in the central parts of the sedimentary basin which is affected by tectonic structures and crossed by volcanic dykes. Despite these local features the Guaraní Aquifer is considered as a continuous groundwater body across the entire region with a mean thickness of about 200 m (Gastmans et al. 2008). In homage to the indigenous population of the area the aquifer system has been named “Guaraní”, generalising different regional names for the same geological formation (Botucatu in Brasil, Misiones in Paraguay, and Tacuarembó in Argentina and Uruguay).

The subtropical to tropical climate (annual rainfall of 1300 to 2000 mm) provides favourite groundwater recharge conditions for the outcrop areas along the boundary zones of the SAG and for areas of weathered and fractured basalt cover of moderate thickness. An annual groundwater recharge of 45 to 55 km³ is considered as reasonable estimation of a mean rate. This quantity is less than 0.2 %

of the freshwater storage. The natural drainage of the SAG takes place along the boundary zones and as baseflow via rivers and probably also via swampy areas on both sides of the Parana River at the southern edge of Paraguay and in Argentina (Esteros del Iberá). At the central parts of the SAG the groundwater is highly confined and shows elevated values of mineralisation and temperature.

Both in terms of population and groundwater production Brasil has a dominating role in the SAG region: 87% of the SAG population of 92 million inhabitants live on the Brazilian territory, and about 93% of the recent groundwater production (1040 million m³ in 2007) happens in Brasil, mainly in the federal state of São Paulo (PSAG, 2009).

Starting in 2003, the SAG-GEF project has elaborated an extensive study on hydrogeological and many other aspects of the entire Guaraní aquifer region. Detailed investigations have been carried out in four pilot areas, e.g. in Itapúa).

After the finalisation of the SAG-GEF project in 2009, international agreements have been approved to promote future SAG groundwater initiatives, including the creation of a regional groundwater institute by the Mercosur Parliament in November 2009 (INRA-Mercosur) with specific reference to the shared management of the SAG. And consequently, in August 2010 the agreement about the responsibility for a common and sustainable management (acuerdo sobre el Acuífero Guaraní) has been signed by the four SAG participating countries Argentina, Brasil, Paraguay and Uruguay.



Figure 1: General location map

1.2. The Guaraní Aquifer System in Paraguay

In close connection to the SAG-GEF project the SAG in Paraguay has been analysed and brought into a conceptual and numerical groundwater simulation model, including neighbouring zones of Argentina and Brasil (SAG-PY, Schmidt G. & al., 2009).

About 8% of the total SAG area belongs to the Paraguayan territory (87,500 km² in the eastern region of the country). Basically, two main groundwater flow directions are identified. In the northern part groundwater flows from Brasil into Paraguay and discharges finally into the Paraguay River in the west via a number of its tributaries which have their origin within the SAG outcrop area. The southern situation is characterised by a distinct recharge area from where the groundwater flows mainly to the east and directed to the Paraná River.

The relatively shallow movement of the groundwater is controlled by a rather fast exchange between groundwater recharge from rainfall and discharge to the drainage system of small rivers nearby. Calculated water paths in the model reflect this general flow behaviour, which is partially approved by hydrochemical and isotope studies. In total, the SAG represents a more or less "stagnant" groundwater reservoir. The Guaraní Aquifer as well as other hydrogeological units of different age, e.g. the cretaceous basalt (see also table), are included in the three-dimensional numerical model. The calibrated model results form the basis for the resource quantification and for prognostic simulations.

Referring to the Paraguayan territory, the groundwater system receives 9.12 km³ of groundwater recharge annually, from which 6.47 km³ (about 160 mm) infiltrate into the SAG, representing 13% of the total SAG recharge. As the second important recipient the basalt aquifer receives about 2.18 km³ (roughly 70 mm). A vertical leakage of up to 0.24 km³ (8 mm at a maximum) is calculated to flow from the basalt into the Guaraní Aquifer.

The groundwater budget shows that (under a regional aspect) there is almost no problem to guarantee future water supply. Following the official regulations for a complete and safe water supply (150 litres per day and consumer) 0.05 km³ of clean groundwater from deep wells will be needed annually for all communities in the Paraguayan SAG region in future (about 1% of the recent recharge).

However, the model results show also clearly that there might be some consequences on a long term. The local concentration of production wells will create water-level depressions in the range of 2 and 10 metres. For the shallow aquifer system (Basalt) in Pedro Juan Caballero depressions of about 30 metres are to be expected.

Table: Hydraulic conductivity and groundwater recharge as results from the calibrated simulation model.

Period	Formation / Group	Hydraulic conductivity [m/d]		Recharge [mm/year]
		horizontal	vertical	
Quaternary	Fm. Chaco	8	0.001	40
Cretaceous	Fm. Acaray	2	0.0005	30
	Fm. Alto Paraná (Basalt)	1	0.0005	70
Triassic	Fm. Misiones (SAG)	<i>shallow</i>	0.006	160
Jurassic		<i>deep</i>	0.002	~ 8 (from Basalt)
Permian	Gr. Independencia	0.2	0.002	10
Carboniferous	Gr. Cnel. Oviedo	0.08	0.0012	2

2. TRANSBOUNDARY GROUNDWATER FLOW BETWEEN PARAGUAY AND BRASIL

Along a certain run in the south-eastern part of Paraguay the Paraná River forms the political border to Argentina and Brasil. In the hydraulic sense, this river has a dominant drainage effect on the groundwater flow in the basalt as well as in the sandstone aquifer on both sides. A transboundary groundwater flow between the countries seems to be of minor importance. A quite different situation is given in the north-eastern part of Paraguay: the groundwater passes the border of Paraguay and Brasil in a westwards direction and is under use from both sides.

2.1. Pilot area: Pedro Juan Cabllero / Ponta Porã

The Pedro Juan Caballero/Ponta Porã pilot straddles the border of Paraguay and Brasil and covers the environs of these frontier towns, which have a combined population of about 135,000 growing at over 1%/a and about 2%/a respectively. The urban ‘frontier economy’ is dominated by the trade and service sector, which has good potential for further development, set in a flourishing agricultural region of good soils and an annual rainfall averaging about 1,200 mm/a. On the Brazilian side, the land use and agricultural production of Mato Grosso do Sul State is already dominated by intensive soya bean - cereal rotations coupled with livestock rearing, whilst on the Paraguayan side deforestation for these purpose has come later and is still occurring.

2.2 Hydrogeological situation and water supply

Over most of the area the SAG is covered by 100 m or more of basalts (and outcrops only in the extreme west of the pilot area), and its groundwater exhibits a confined (but not artesian overflowing) condition (Figure 2) - with the frontier following the surface-water divide of the Serra/Sierra de

Amambay. The top part of the basalt is sufficiently fractured and weathered to form a semi-independent aquifer across much of the area, which provides recharge through leakage to the SAG with groundwater flow westwards from Brasil to Paraguay under hydraulic gradients of 6-7 m/km.

Groundwater from the basalts is currently the main source of urban water supply with over 100 water wells (mainly 70-120 m deep), including those of the Empresa de Servicios Sanitarios del Paraguay (ESSAP) and Servicio Nacional de Agua y Saneamiento (SENASA) around Pedro Juan Caballero and the Empresa de Saneamento de Mato Grosso do Sul (SANESUL) in Ponta Porã, which can produce a total of 1,200 m³/hour or more. However, there is no main sewerage system in Pedro Juan Caballero/Ponta Porã, with all urban wastewater disposals to the ground via in-situ sanitation units, and the basalt aquifer is showing signs of pollution with the abandonment of some water wells.

The most satisfactory solution would be to develop a small number of soundly-constructed water wells into the semi-confined SAG and protect their wellhead areas carefully against contamination. SANE-SUL has recently completed the construction of the first deep (750 m) borehole which alone can produce an additional 260 m³/hour, and further development is under preparation.

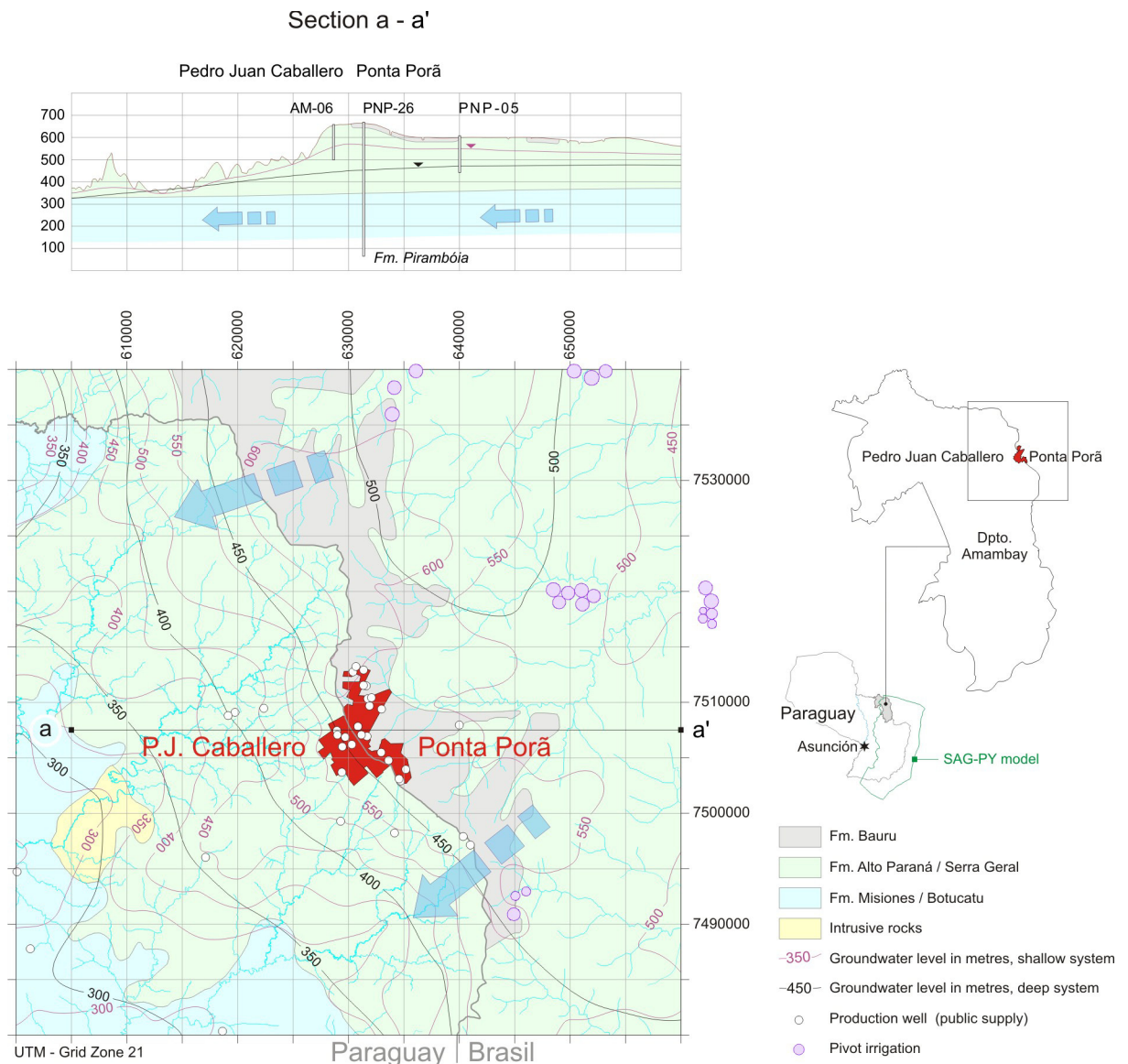


Figure 2 Locations, drainage system and hydrogeological features in the pilot area.

2.3. Preliminary simulation results

In addition to the comprehensive simulation model SAG-PY under a regional scale, selected groundwater production scenarios have been calculated at a local scale by mean of an analytical model. This well field model calculates the drawdown of groundwater pressure heads in the Guaraní aquifer during 20 years of pumping hypothetical quantities of groundwater.

Based on a uniformly spread transmissivity of 300 m³/day and a storage coefficient of 5x10⁻³ (confined aquifer conditions assumed), and on a continuous groundwater abstraction of about 3 million m³/year, the model calculates a mean drawdown of 10 metres after 20 years, whereas the well drawdown is estimated to be in the range of 50 metres. The affected area of depression below 10 metres amounts to roughly 30 km², and extends to 750 km² respectively to 1800 km² when the annual groundwater abstraction rate in the model increases to 9 and to 15 million m³.

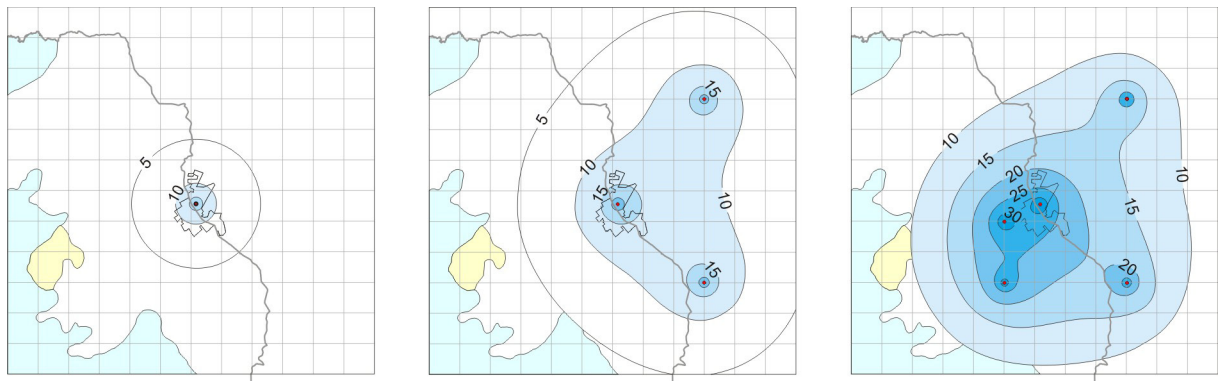


Figure 3 Simulated drawdown in metres after 20 years of continuous pumping 3, 9 and 15 million m³/year from the SAG.

3. CONCLUSIONS and RECOMMANDATIONS

At a first glance, the estimated groundwater budgets of the entire SAG and also of the SAG part in Paraguay give the impression that the groundwater resource might be almost inexhaustible during the near future and under the recent climatic and recharge conditions. However, under local considerations the stress on the groundwater resource is already remarkable high, either by groundwater production (e.g. as in the Ribeirão Preto SAG-GEF pilot area or as in Pedro Juan Caballero / Ponta Porã) and/or by pollution hazards.

The first transboundary workshop on water and environmental management was held in February 2009 and attended by groundwater specialists and stakeholder representatives from both sides of the frontier in which it was concluded that a political mandate is needed for a bi-national transboundary commission in order to promote commonly future groundwater development.

Furthermore:

Completion of the water well inventory and hydrogeological database is required, with establishment of a conceptual and numerical model of the local SAG and an improved monitoring network for groundwater levels, quality and use.

Further development of SAG resources for public water supply will require a feasibility study and water well siting plans, and a common policy approach is needed to rationalize such development.

Measures are needed to reduce the contaminant load on the basalt aquifer, especially in those parts of the urban area where it is was likely to continue as the ‘sole source’ of water supply

Public information and awareness campaigns were required to gain support for stricter application of relevant existing environmental laws and regulations, and to facilitate the implementation of future groundwater protection measures.

Findings of the second workshop to be held in November 2010 in Pedro Juan Caballero/Ponta Porã and further model results from a new numerical simulation model of the pilot area are to be reported in December this year.

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BIBLIOGRAPHY

Foster S. & al. (2009): GW-MATE case profile collection no. 9: The Guaraní aquifer initiative – towards realistic groundwater management in a transboundary context.

Gastmans, D., Chang, Hung K., Sineli, O., de Paula e Silva, F., Nogueira Pressinotti, M. M., (2008): Avanços no Conhecimento - Mapa Hidrogeológico, Modelo Conceitual e Cálculo de Reservas, Laboratório De Estudos De Bacias – Lebac - Unesp – Rio Claro, Ribeirão Preto, 03 de novembro de 2008.

PSAG (2009): Proyecto para la Protección Ambiental y Desarrollo Sostenible del Sistema Acuífero Guaraní - Programa Estratégico de Acción, Montevideo, ISBN 978-85-98276-07-6.

Schmidt G. & al. (2009): SAG-PY - Uso Sostenible del Sistema Acuífero Guaraní en la Región Oriental del Paraguay, Asuncion, Hannover. Página web: www.sag-py.org.