Numerical Modelling Approach for Supporting Groundwater Management in an Industrial Complex in Bahia, Brazil

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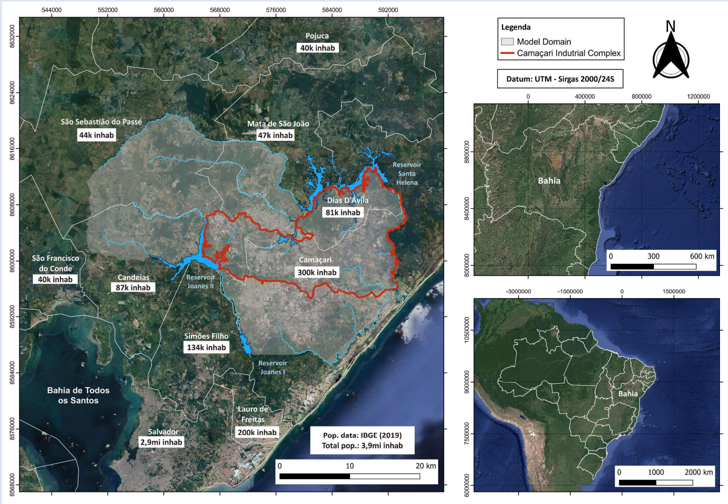
1) Introduction

The **Camacari Industrial Complex** is the largest industrial complex in South America, located in the NE part of Brazil. About the site:

- In operation since **1978**
- **235 km²** in an area
- Over **50 companies** (megasite)
- Located in a highly populated area (**~4 mi inhabitants**)

Water resources are a key aspect for the site environmental management, mainly due to:

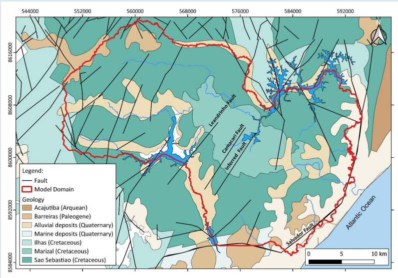
- **Water quantity issues:** requiring a balance between industrial and urban water demands
- **Water quality issues:** requiring the monitoring of industrial impacts and remediation measures
- **Water policy issues:** requiring the definition of policies and guidelines for sustainable water use.



2) Site Hydrogeology

The site is located within a Cretaceous rift basin oriented in the NNE-SSW direction, filled with sedimentary deposits up to 7-10 km in thickness (Tamura et al. 2016). The sediments were deposited under different environments, such as lacustrine, deltaic, fluvial deposits and alluvial fans. The model domain encompasses the top three main sedimentary units: Quaternary deposits, Marizal and Sao Sebastiao formations.

- **Quaternary deposits** were highly modified by earthworks (cut and fill areas).
- **Marizal formation** is comprised of fluvial deposits with marine incursions, ~50m thick in the area of interest. It is defined by coarse-grained sandstones and discontinuous siltstones with conglomerates, shale and cross bedding.

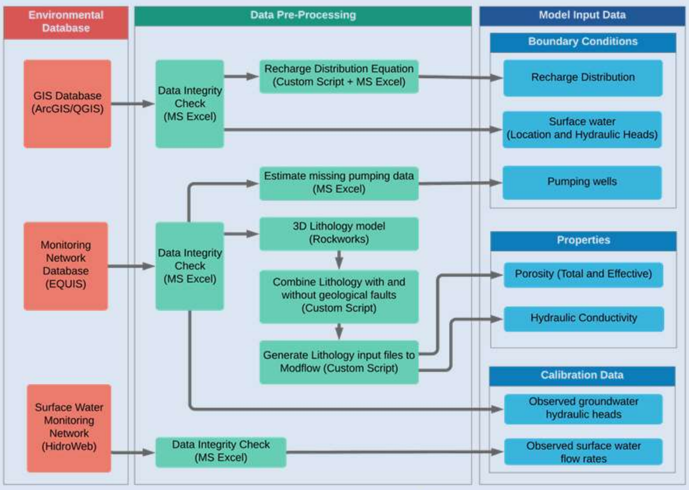


- **Sao Sebastiao formation** consists of fluvial deposits, with thickness up to 3km (Ribeiro, 2013), extending beyond the bottom of the domain (thickness = 500m). It consists of finer-grained sandstones, siltstones and shales, crossed by a system of faults. It is the main water supply to production wells that supply water to the Industrial Complex and nearby communities.

The resulting hydrogeology is comprised of a very thick aquifer, with discontinuous aquitard units and with the presence of geologic faults.

3) Groundwater Model as a Management Tool

A groundwater model (~1500 km² in area and ~500m in domain thickness) was built in 2002 and is periodically updated as part of the water resources management of this site. For this latest update, a new workflow was proposed to integrate existing environmental databases with the required model inputs. This integration is an important aspect to improve model usefulness and allow easier and more frequent model updates.

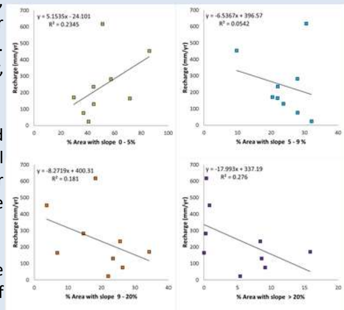


4) Groundwater Recharge

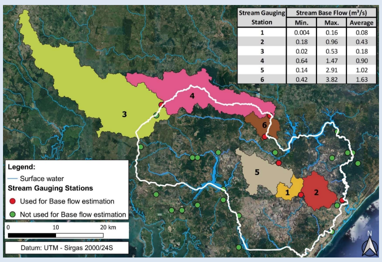
Recharge is an important element for this study, as it influences the overall groundwater dynamics and how fast aquifers are replenished. Its distribution was derived from base flow, estimated from surface water data.

The relationship between different aspects and base flow was evaluated, namely: land use, soil properties and ground surface slope. Higher correlations with recharge distribution were observed for ground surface slope.

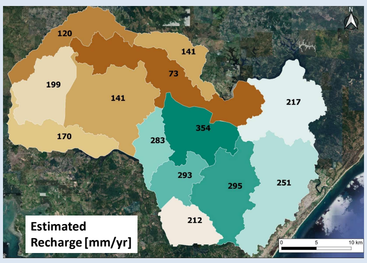
An equation was developed to estimate recharge using slope data, weighted by the coefficient of determination (r^2). The resulting equation is:



$$R = 1.34 \cdot [(1.21 \cdot A_{5\%}) + (-0.35 \cdot A_{5-9\%}) + (-1.50 \cdot A_{9-20\%}) + (-4.97 \cdot A_{>20\%}) + 181.36]$$



Stream Gauging Station	Stream Base Flow (m³/s)		
	Min.	Max.	Average
1	0.004	0.16	0.08
2	0.18	0.96	0.43
3	0.02	0.53	0.18
4	0.64	1.47	0.90
5	0.14	2.91	1.02
6	0.42	3.82	1.63



5) Data Quality Check and Filling Data Gaps

Two important aspects to integrate environmental databases and the revised model are:

- **Data quality checks**: Data entries may be affected by different types of error (typing, field forms, field equipment, data manipulation and number format). Logical checks were stablished to screen for errors.
- **Procedure to fill data gaps**: When data problems were identified or when data was missing, some procedures were adopted to fill the existing data gaps. For example: an existing correlation between well depth and pumping rate was used to estimate missing pumping rates.

6) Conclusion

- Models that require constant updates can benefit from an explicit workflow, connecting databases and the model inputs.
- An equation was proposed to estimate spatial recharge distribution, using existing surface water data. This equation can be later checked using other recharge estimation techniques.
- Clear procedures for identifying data errors and inconsistencies (data quality checks) and for filling data gaps are also important. The absence of important information should trigger data gathering efforts.

Tamura, L. N. et al (2016). Ground Penetrating Radar investigation of depositional architecture: the Sao Sebastiao and Marizal formations in the Cretaceous Tucano Basin. Brazilian Journal of Geology, 46(1), 15-27.
Ribeiro (2013) Aspectos Hidrogeológicos da Bacia do Recôncavo Norte – Bahia. UFBA: Salvador, 2013.
Roedel, R. M (2017). Proposição de critérios técnicos para outorga de águas subterrâneas. Estudo de caso: polo industrial de Camaçari. 2017. Dissertação de Mestrado (MEAU). UFBA: Salvador, 2017.

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