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ECOMANAGE

Integrated Ecological Coastal Zone Management System

Deliverable 2.8

Groundwater modeling of the sedimentary aquifer on Santos Estuary basin using GIS mapping of hydrogeologic parameters

(Deliverable 2.8– 1st Part: Santos Estuary - Quantity)

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Study developed for the European Commission DG Research INCO-CT Programme under contract number INCO-CT-2004-003715

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GROUNDWATER MODELLING OF THE SEDIMENTARY AQUIFER ON SANTOS ESTUARY BASIN USING GIS MAPPING OF HYDROGEOLOGIC PARAMENTERS (DELIVERABLE 2.8 – 1st PART: SANTOS ESTUARY QUANTITY)

ABSTRACT

This report aims the presentation of the conceptual model, the mathematical model, and the computed results that allowed the quantification and mapping of the groundwater flow discharge, per kilometre of coastal line, towards Santos Estuary, in Brazil.

The physical data of the Santos Estuary watershed is presented in terms of geology, hydrogeology, altimetry and precipitation.

From the results it can be concluded that groundwater discharge to Santos Estuary depends on the watershed location, area and land use. Flow discharge is lower on a well drained basin, because groundwater contributions are mainly to the drains. There is a high fresh water discharge to the Atlantic Ocean, from Praia Grande and Santos area. Lower values are related with crystalline rock outcrop and small islands. Total groundwater discharge to the land-Estuary boundary from precipitation is about 8%, besides, other 17% flows as base flow to the drains.

From the simulation it can be concluded that Boturoca watershed, São Vicente and Santo Amaro Island are the main contributors of fresh water from the sedimentary aquifer to the estuary. The results showed important groundwater discharges, higher from January to May. Lower discharges to the estuary were observed in Cubatão watershed. In this basin groundwater from the sedimentary aquifer flows to the drains and, afterwards as surface water, to the estuary.

MODELAÇÃO NUMÉRICA DO AQUIFERO SEDIMENTAR NA BACIA DO ESTUARIO DE SANTOS UTILIZANDO MAPEAMENTO EM SIG DOS PARÂMETROS HIDROGEOLÓGICOS (1ª PARTE: ESTUÁRIO DE SANTOS - QUANTIDADE)

RESUMO

Este relatório visa a apresentação do modelo conceptual, do modelo matemático e dos resultados obtidos que permitiram a quantificação e o mapeamento da contribuição das águas subterrâneas, por quilómetro de linha de costa, para o estuário de Santos, no Brasil.

Apresentam-se os dados de base físicos da área terrestre drenante para o estuário, em termos de geologia, hidrogeologia, altimetria e precipitação.

Dos resultados obtidos pode concluir-se que a descarga de águas subterrâneas para o estuário depende do aquífero, da sua localização e do uso do solo. A descarga é menor em aquíferos bem drenados, porque a descarga se faz directamente para as valas urbanas ou para a rede de linhas de drenagem naturais. Há elevada descarga directamente para o Oceano Atlântico nas áreas de Praia Grande e de Santos. Os menores valores obtidos para a descarga foram nas áreas do cristalino e nas ilhas de menor dimensão.

A descarga total de águas subterrâneas para o estuário, em termos de percentagem da precipitação, foi calculada em 8%. 17% escoam adicionalmente como escoamento de base em redes de drenagem superficial.

Neste relatório conclui-se que as bacias de Boturoca, e a ilha de São Vicente e de Santo Amaro são as áreas de maior contribuição de águas doces do aquífero sedimentar para o estuário. Os resultados mostraram descargas importantes e mais elevadas de Janeiro a Maio. Descargas para o estuário, mais reduzidas, foram observadas na bacia do Cubatão. Nesta bacia a água subterrânea escoa para a rede de drenagem superficial e daí para o estuário.

ACKNOWLEDGEMENTS

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Alexandra Sampaio (UNISANTA) for collecting groundwater level data of the sedimentary aquifer.

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1 Introduction

The purpose of this Deliverable is to report on the groundwater flow modelling of the sedimentary aquifer system for Santos Estuary basin, developed within ECOMANAGE project. That allowed the evaluation of the contribution of fresh water from the aquifer system to the Estuary, on steady state conditions. The model calibration was used as initial condition for a monthly flow simulation of the aquifer (transient condition) and for the evaluation of critical conditions (extreme recharge data).

The modelling work included the analysis of geological, hydrogeological and climate data by Malva Mancuso during her mission to LNEC, May to July 2006.

The groundwater model was developed using the following softwares: Ground Water Modelling System – GMS, with the modules BOREHOLES, TIN, SOLIDS, MAP and MODFLOW, ArcView and ArcInfo.

2 General Description

2.1 Location

The Estuary Basin area is located in the "*Unidade de Gerenciamento de Recursos Hídricos*" (Water Resources Management Unit) nr 7, called "*Bacia Hidrográfica da Baixada Santista*" ("*Baixada Santista*" Hydrographic Basin). This Hydrographic Basin covers an area of 2788.82 km^2 (CETEC, 1999).

The study area includes the land area that contributes with fresh water (flows at the surface or underground) to the Santos Estuary. This are will hereinafter be called **Land Santos Estuary area** (Fig. 1). It is comprised of several small watersheds, listed in Table 1.

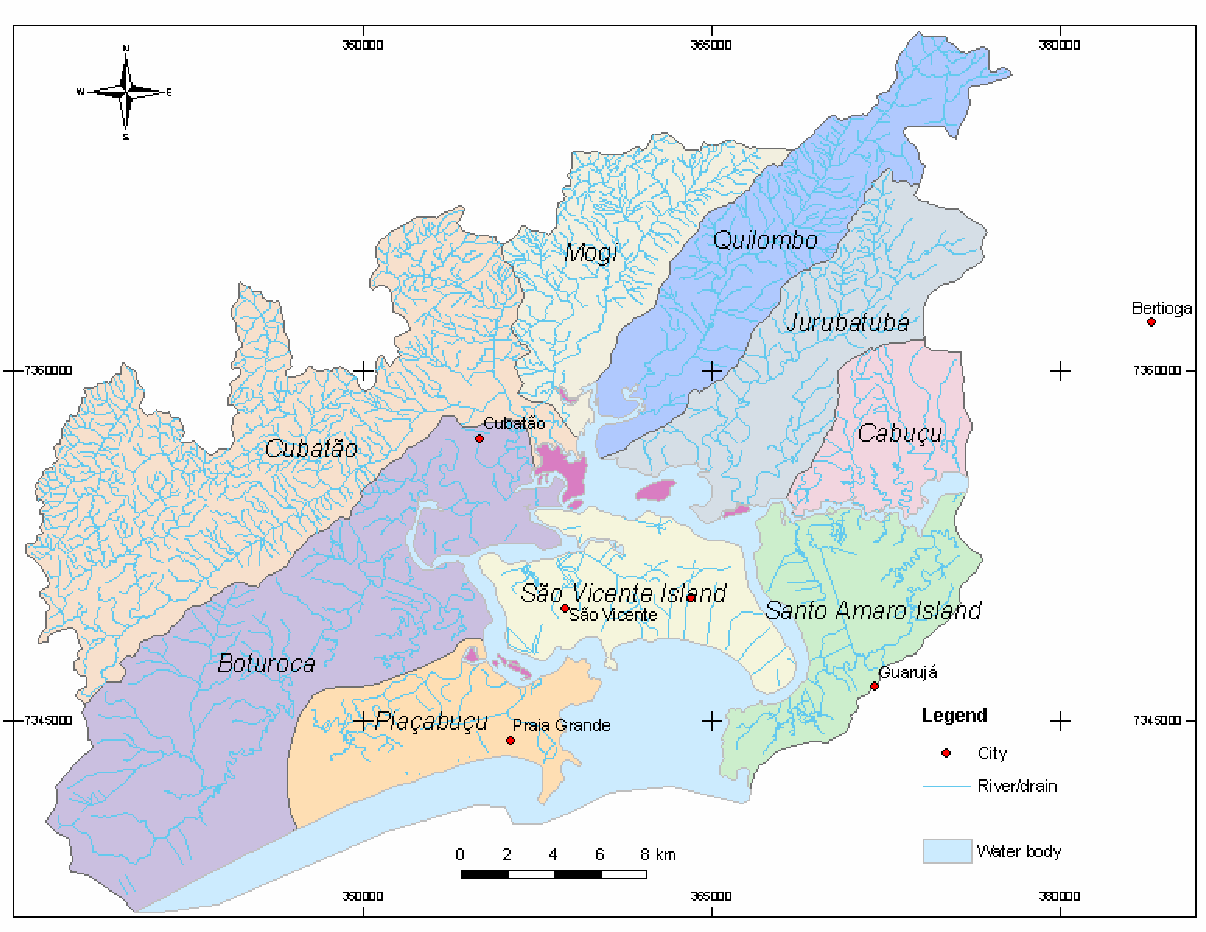
Only the western part of the Santo Amaro Island and Cabuçu basin contributes with fresh water to the Santos estuary. The water flows directly to the Bertioga channel that separates the Santo Amaro Island from mainland. So the study area is about 834.6 km^2.

Table 1 – Land Santos Estuary area watersheds

Watershed	Area (km²)
Boturoca stream	182.8
Cubatão stream	185.5
Piaçabuçu stream	57.1
S. Vicente island	58.5
Mogi stream	67.9
Santo Amaro island (*)	68.6 (*)
Cabuçu stream (*)	41.0 (*)
Jurubatuba stream	82.0
Quilombo stream	86.6
Islands	4.9
Total	834.6

(*) Only the area that contribute with surface water to the estuary

Source: the watersheds were defined using IGGSP topographic map (IGGSP, 1971 and 1972) scale, 1:50.000



Source: watersheds limits were defined based on topographic map (IGGSP, 1971 and 1972)

Fig. 1 – The watersheds in Land Santos Estuary area

3 Groundwater Conceptual Model

A groundwater flow model was developed for the sedimentary aquifer. The conceptualization was based on the physical system, its geometry, geology and hydrogeology. The conceptual model also comprises groundwater recharge estimation and water budget understanding.

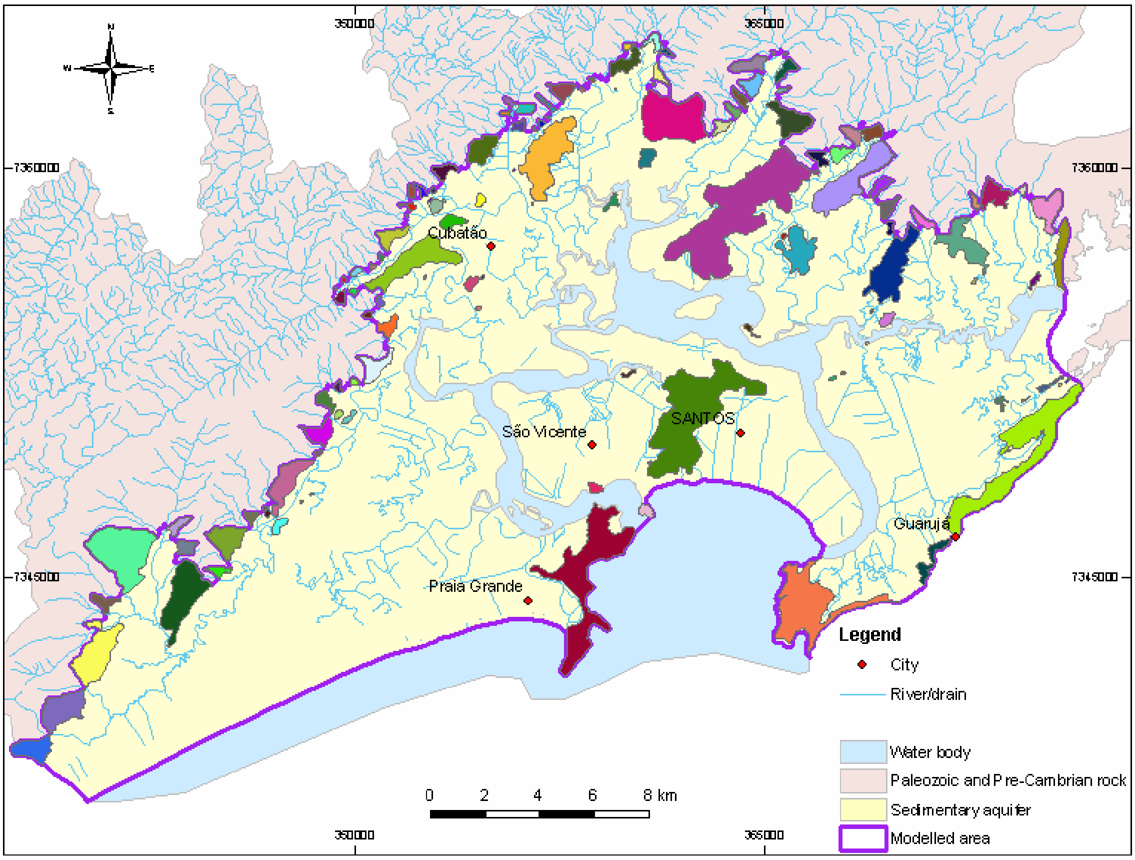
The area for modelling was defined in ArcView, using geological map from SUGUIO & MARTIN (1978, in DAEE, 1979), to delimitate the Cenozoic sediments, and PERROTA, *et al.* (2004) and IPT (1981) for the geological characterization of this formations.

As a boundary condition for the sedimentary aquifer, on the crystalline interface, it was considered that the soil covering the basement rocks, produced by the weathering of the bedrock, is capable of retaining water from precipitation. That water, as recharge, flows into rivers and, on the interface between the aquifers, to the sedimentary formation. As a result the modelled area was the sedimentary aquifer plus small basins from the crystalline aquifer (Fig. 2).

The main basins were defined by consulting topographic data from IGGSP (1971 and 1972) for elevations higher than 20 m, lakes and rivers, and elevation data points available in the NASA web site (ftp://e0mss21u.ecs.nasa.gov/srtm/South_America/) for elevations below 20 m. That data points were transformed to the Universal Transverse Mercator (UTM) projection coordinate system using the software <ConvertToXYZ.exe> developed by the Maretec (Instituto Superior Técnico) ECOMANAGE partner (OLIVEIRA, *et al.* 2005).

To calculate recharge from the crystalline aquifer (weathering rock) to the sedimentary aquifer an interface boundary between the aquifers was considered, consisting on areas, on crystalline rock, without surface drainage.

To delimitate this basins without surface drainage a topographic map was used (elevation curves from 20 to 1160 m) (IBGE, 1:50.000). A drainage map (stream coverage) was used for the crystalline geologic formation. The data was used to produce a grid with 50 m x 50 m cell representing the elevation surface. From this base the flow direction for each cell was calculated to its steepest down slope neighbour. The results were applied to create a new grid delineating all drainage basins within the analysis window. All cells in that grid belong to a basin, even if that basin is a single cell. The result, edited, can be seen at Fig. 2.



Source: cenozoic formation limit after SUGUIO & MARTIN (1978)

Fig. 2 – Modelled area in Land Santos Estuary area. Sedimentary aquifer and basins from crystalline aquifer that contribute with the groundwater flow to the porous aquifer

3.1 Geology and hydrogeology

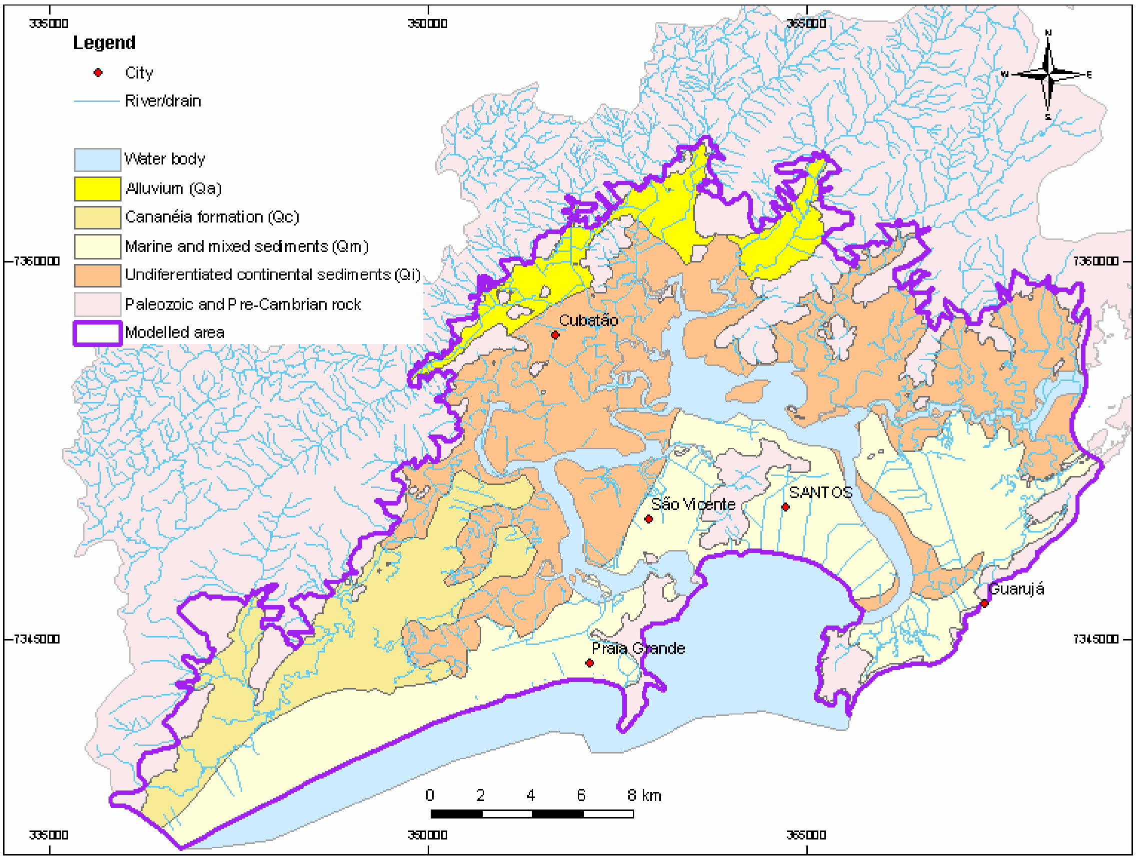
The geological description is based on CETEC (1999), and the geological map based on the SUGUIO & MARTIN (1978, in DAEE, 1979, scale 1:100.000), to delimitate the Cenozoic sediments, and PERROTA et al. (2004) (scale 1:750.000), IPT (1981) (1:500.000) and DAEE (1979) for the geological characterization of this formations (Fig. 3).

The geology of the area may be grouped into the basement formations (Paleozoic and Pre-Cambrian) and cenozoic cover (alluvium, marine and mixed sediments, undifferentiated continental sediments and *Cananéia* formation) (Fig. 3).

The basement formations are the result of several tectonic phases, responsible for deformation, faulting, foliation, besides metamorphism and magmatic processes, combined with variations of sea level and climate. Inland, several faulting and epeirogenesis have produced the escarpment of the actual *Serra do Mar*.

In the Cenozoic, the main events may be summarized in topography modelling, tropical humid climate, sea transgression and deposition of the sedimentary sequences.

The geological description of the Cenozoic formations is summarized in Table 2.



Source: PERROTA et al. (2004); SUGUIO & MARTIN (1978)

Fig. 3 – Geology of the sedimentary formation of the Land Santos Estuary area

The sedimentary Cenozoic coverage is formed of unconsolidated sediments, located in the plain and low areas of the Coastal Plain and in the foot of the hills (Table 2). They are represented by four geological units: Qa – alluvium sediments; Qm – marine and mixed sediments; Qi – undifferentiated continental sediments; and Qc – *Cananéia* formation.

Table 2 – Geology of the sediment formations of Land Santos Estuary area

Period (Age)	Geological formation	Lithology
Cenozoic	Qa - Alluvium	Unconsolidated sands of variable texture, associated clays and gravels
	Qm – Marine and mixed sediments	Sands, marine, sandy-siltic-clayey terms and mangroves deposits
	Qi – Undifferentiated continental sediments	Continental deposits
	Qc – Cananéia formation	Unconsolidated thin marine sands

Source: Geological Map of São Paulo State, in IPT (1981)

The *Cananéia* formation (Qc) is composed of old marine sandy deposits (thin sands) with sparse clayey layers, often limonited, with average thickness of 30 m.

Externally to the *Cananéia* formation, extensive portions of Marine and Mixed Sediments (Qm), include sands from beaches, marine deposits locally subject to fluvial and/or eolic action, sandy-silted-clayey terms from fluvio-marine-lacustrine deposition and mangroves deposits. The thickness of these sediments (sandy to clayey, mud with high content of biodetritical organics from mangrove) may be more than 50 m deep.

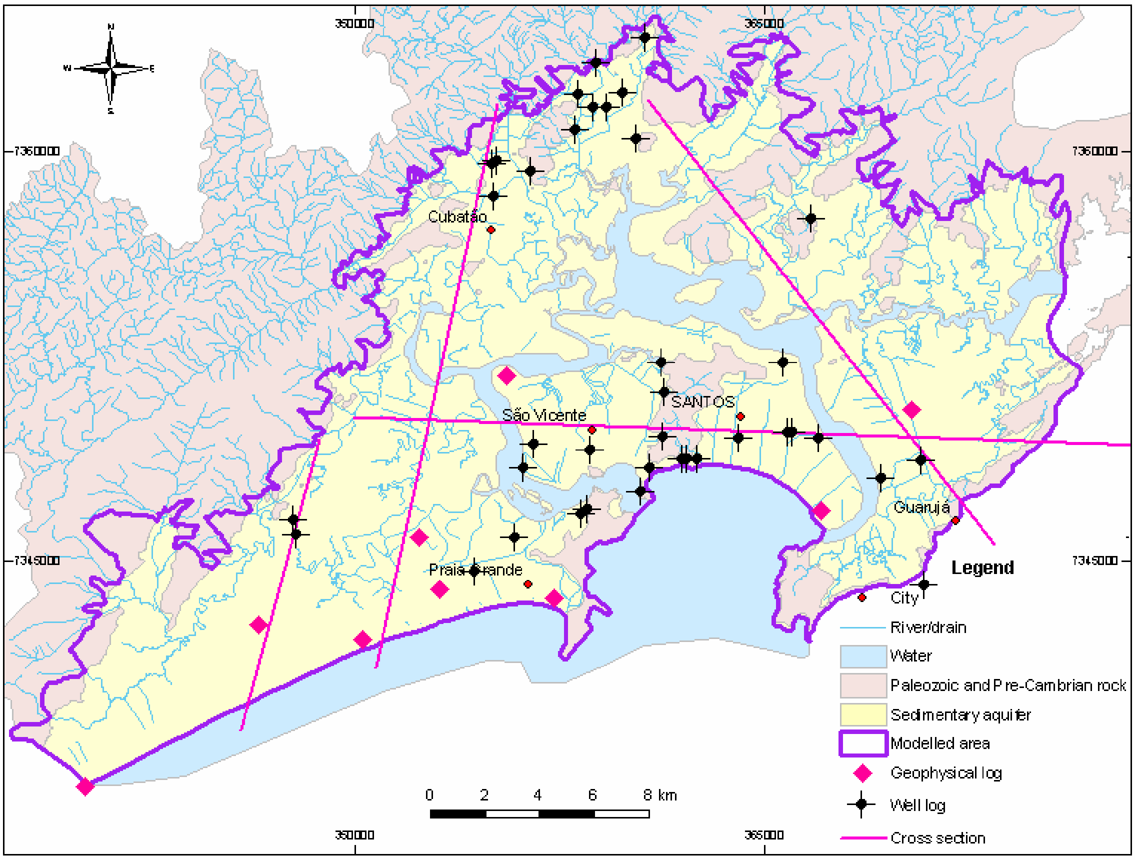
The detrital deposits mainly located in the basal portion of the hills and half hillside (Undifferentiated continental sediments – Qi), are mainly composed of immature sediments, poorly sorted and often coarse material from colluvium's material. They are formed of gravels, sands and clays in variable proportions sometimes comprising numerous blocks.

The alluvium sediments (Qa) comprise unconsolidated sands of variable granulometry, as well as clay and fluvial gravels, also found in terraces.

In the Paleozoic and Pre-Cambrian rocks the soils cover the basement, having been produced from the weathering of bedrock, and whose granulometry, mineralogy and thickness vary accordingly with the basement rock lithology.

The characterization of the bottom of the sedimentary aquifer and the sediments stratification is based on the following data:

1) geological maps: SUGUIO & MARTIN (1978), PERROTA et al. (2004), and IPT (1981);
2) 4 geological cross sections (DAEE, 1979);
3) 42 well logs (DAEE, 1979); and
4) 10 geophysical logs (DAEE, 1979) (Fig. 4).

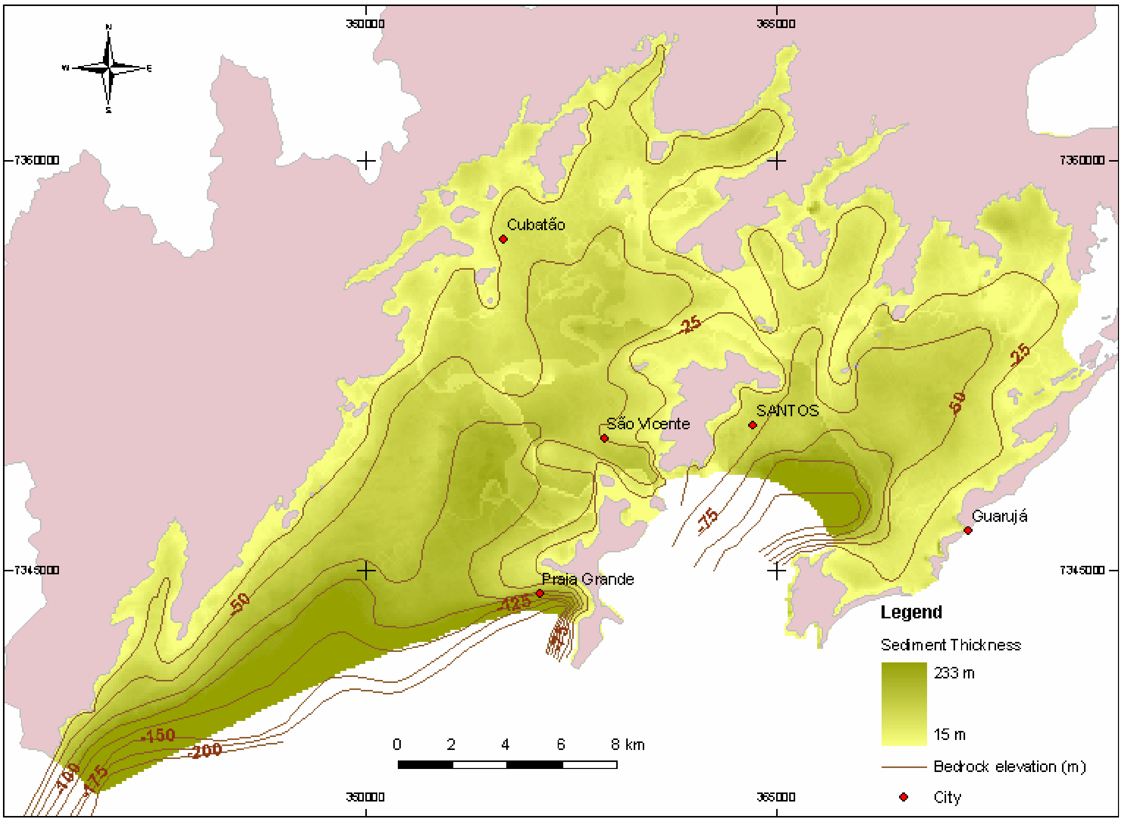


Source: DAEE (1979)

Fig. 4 – Information of the sediments in the porous aquifer

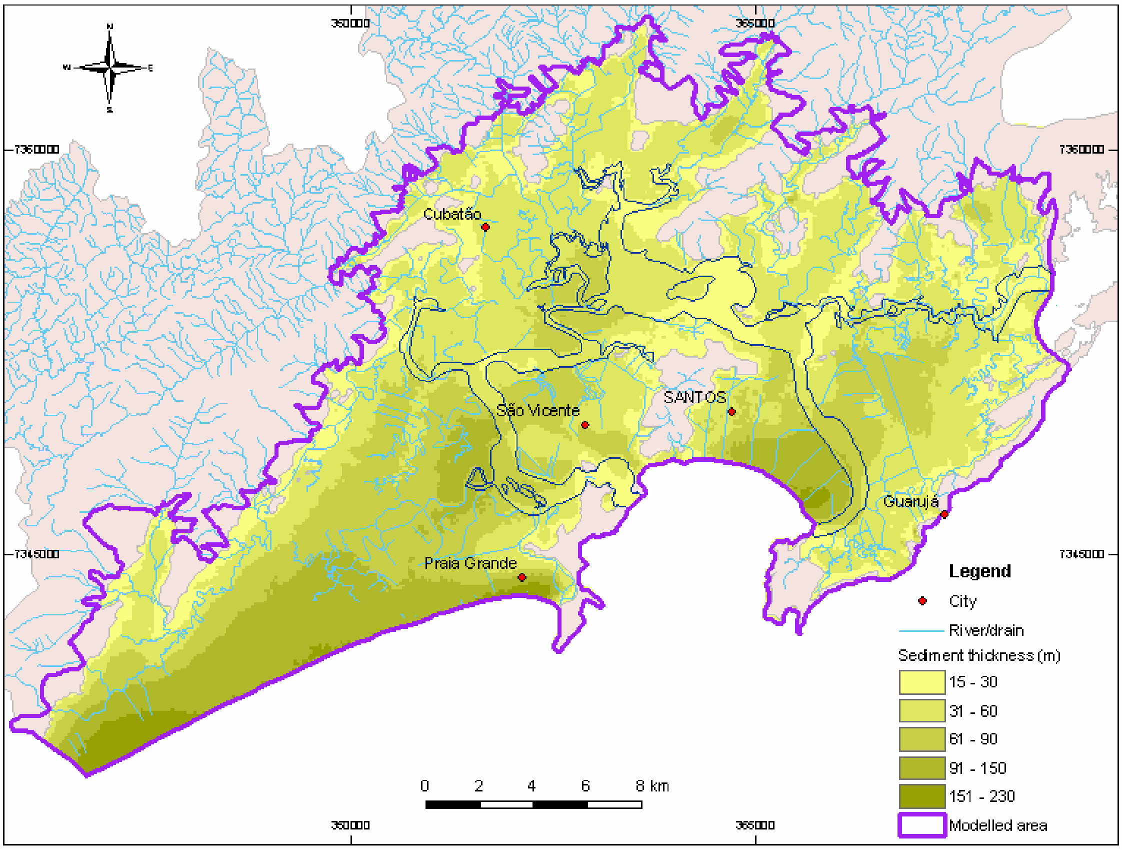
According to the collected information, the bottom of the aquifer (top of crystalline rock) varies from -25 m close to the hard rock, disappearing where the hard rock formations outcrop, and increase up to -230 m at the southwest part of the basin, close to the ocean and up to -125 at southeast of São Vicente Island. On the Santos Estuary channel the bottom of the aquifer varies mostly from -50 to -75 m, with the higher levels at north of the island are up to -25 m (Fig. 5).

The sediments thickness in Praia Grande, close to the ocean, is mostly around 100 m, increasing to 230 m southwest. North of Santos the thickness goes up to 30 m but southeast it is around 150 m (Fig. 6).



Source: Bedrock elevation modified from DAEE (1979)

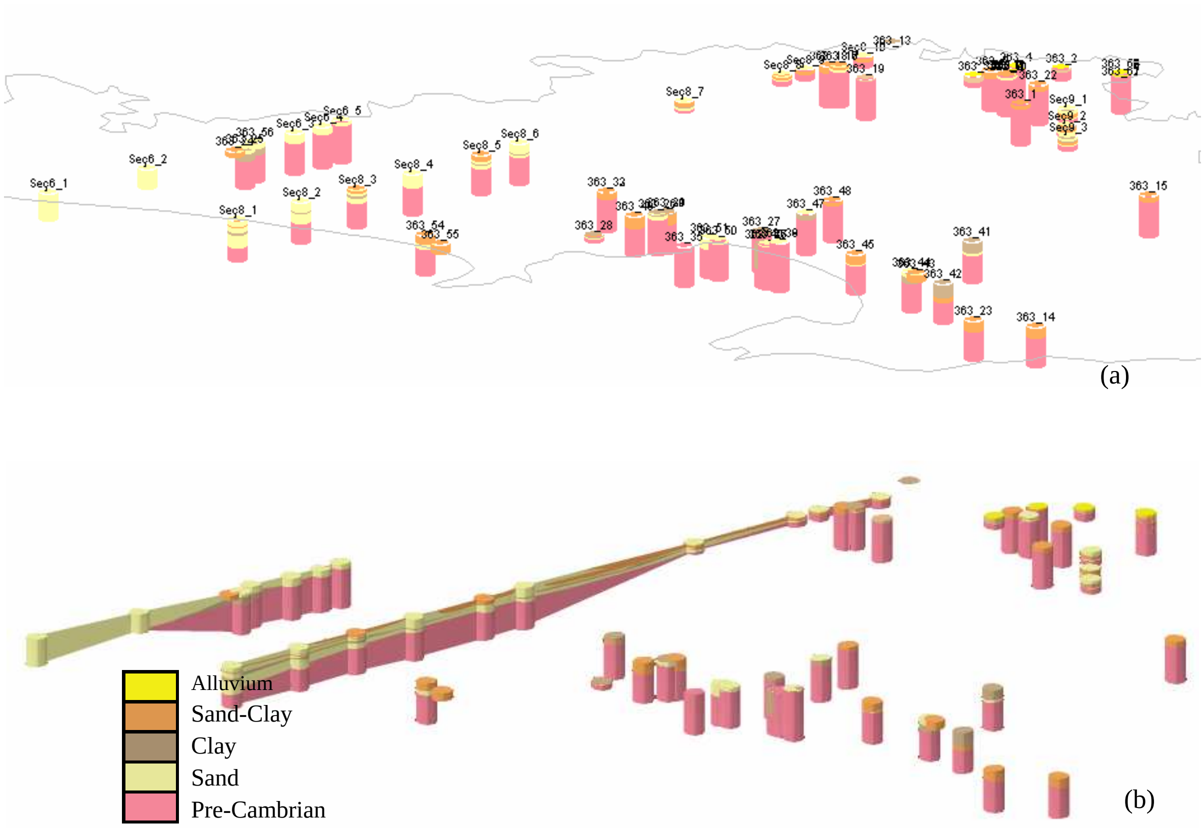
Fig. 5 – Bedrock elevation and thickness of the sediments in the porous aquifer



Source: sediment thickness calculated from DAEE (1979)

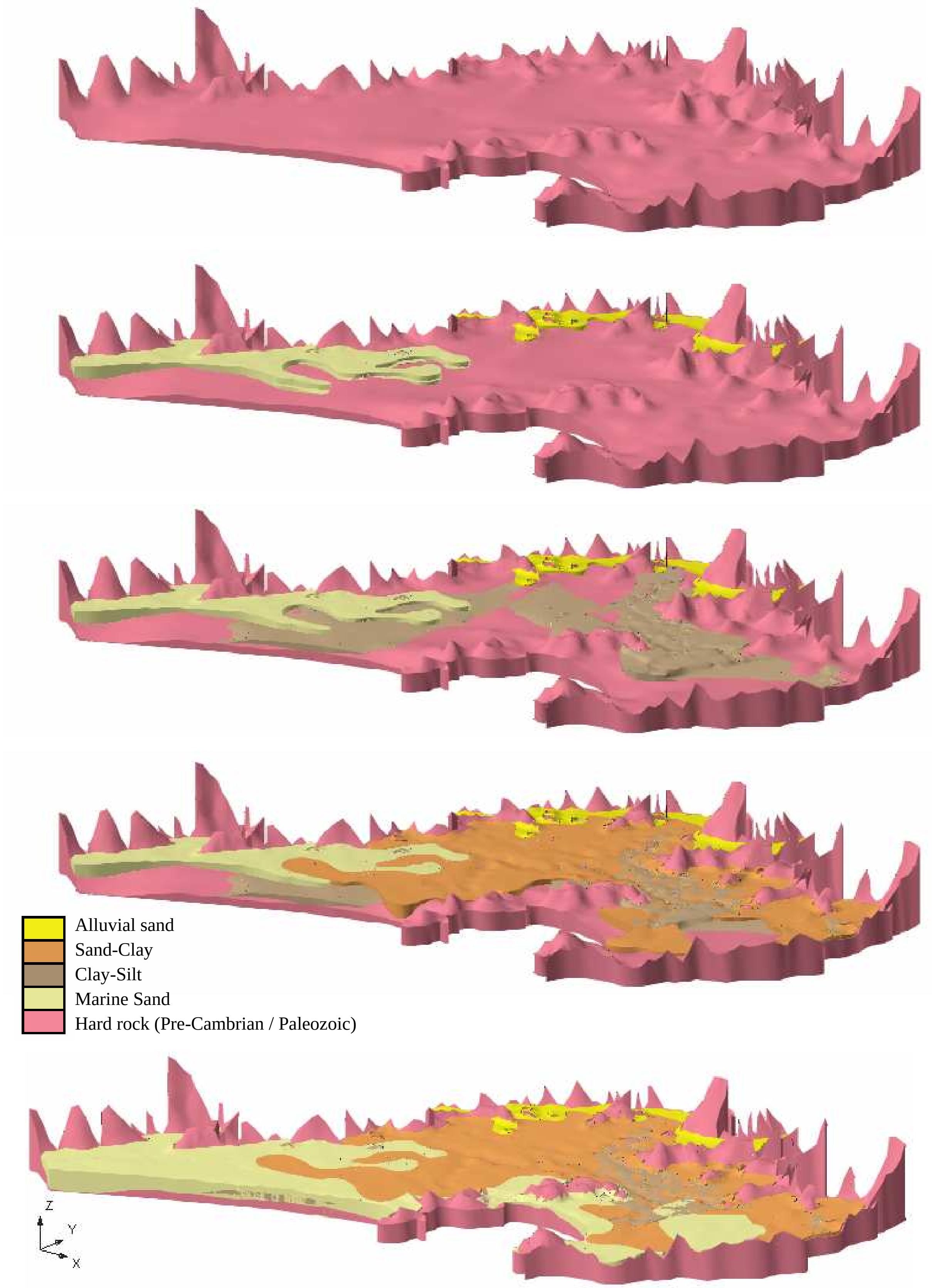
Fig. 6 – Thickness of the sediments in the porous aquifer

The hydraulic conductivity is the ability of the aquifer to transmit water, the higher the conductivity, the higher the flow rate. Data from hydraulic conductivity in the sedimentary aquifer of Santos Estuary basin was estimated from bibliography, considering the geological formation data. A 3D view of the sediments in the porous media was build, based on geological maps (SUGUIO & MARTIN, 1978; PERROTA *et al.*, 2004; and IPT, 1981), geological cross sections, well logs and geophysical logs (DAEE, 1979). The process and final result is show in Fig. 7 and Fig. 9.



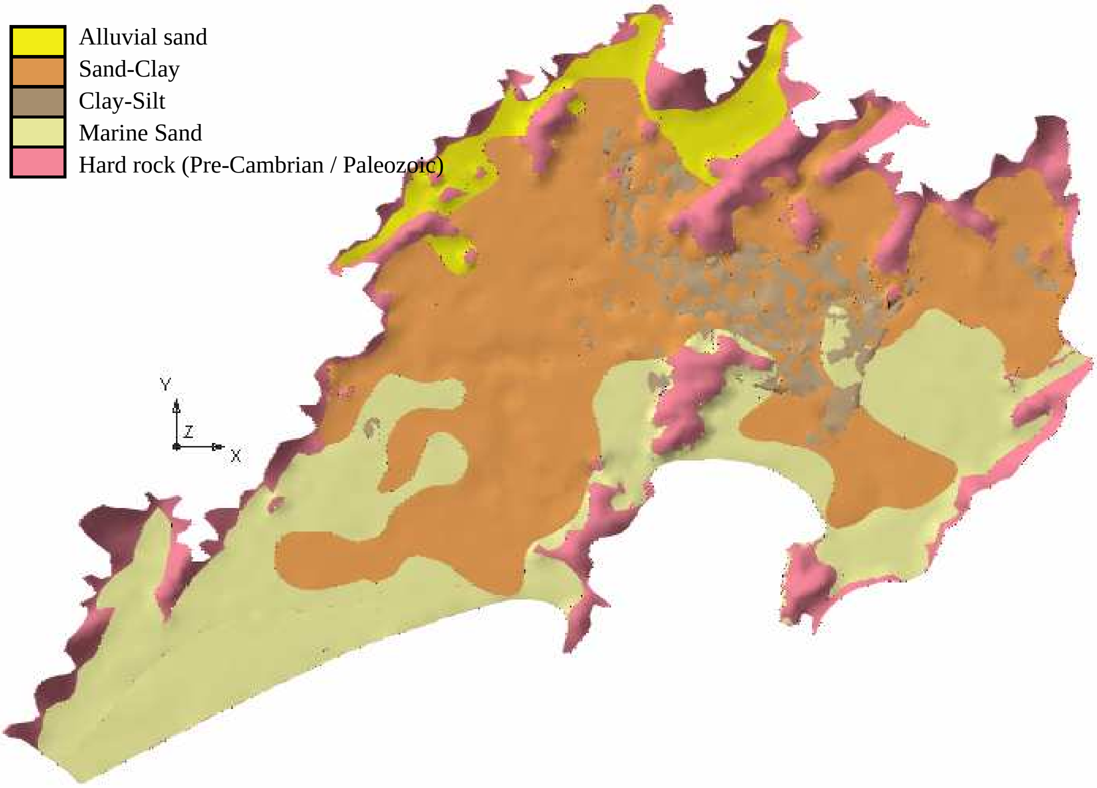
Source: DAEE (1979)

Fig. 7 – Logs (a) and cross section (b) of the sediments in the sedimentary aquifer



Source: after DAEE (1979), SUGUIO & MARTIN (1978), PERROTA et al., (2004) and IPT (1981)

Fig. 8 – Steps of a 3D view build for the sedimentary formations in the porous media



Source: geology after DAEE (1979), SUGUIO & MARTIN (1978), PERROTA et al., (2004) and IPT (1981)

Fig. 9 – Plan view of the sedimentary formations in the Santos Estuary basin

The geological approach was used for the estimation of the hydraulic conductivity (K) parameter for each geological formation of the sedimentary aquifer, as a function of the lithology. The hydraulic characterisation of the aquifer media was based on the 3D geological map (Fig. 8), elaborated base on SUGUIO & MARTIN (1978), PERROTA *et al.* (2004), IPT (1981), well logs, geophysical logs, geological cross sections and hydrogeological data from DAEE (1979). Also, the characterization of this parameter is based on recovery test of monitoring wells performed by CONSULTORIA PAULISTA (2004) and MKR (2003).

For the formations the following hydraulic conductivities values have been assigned:

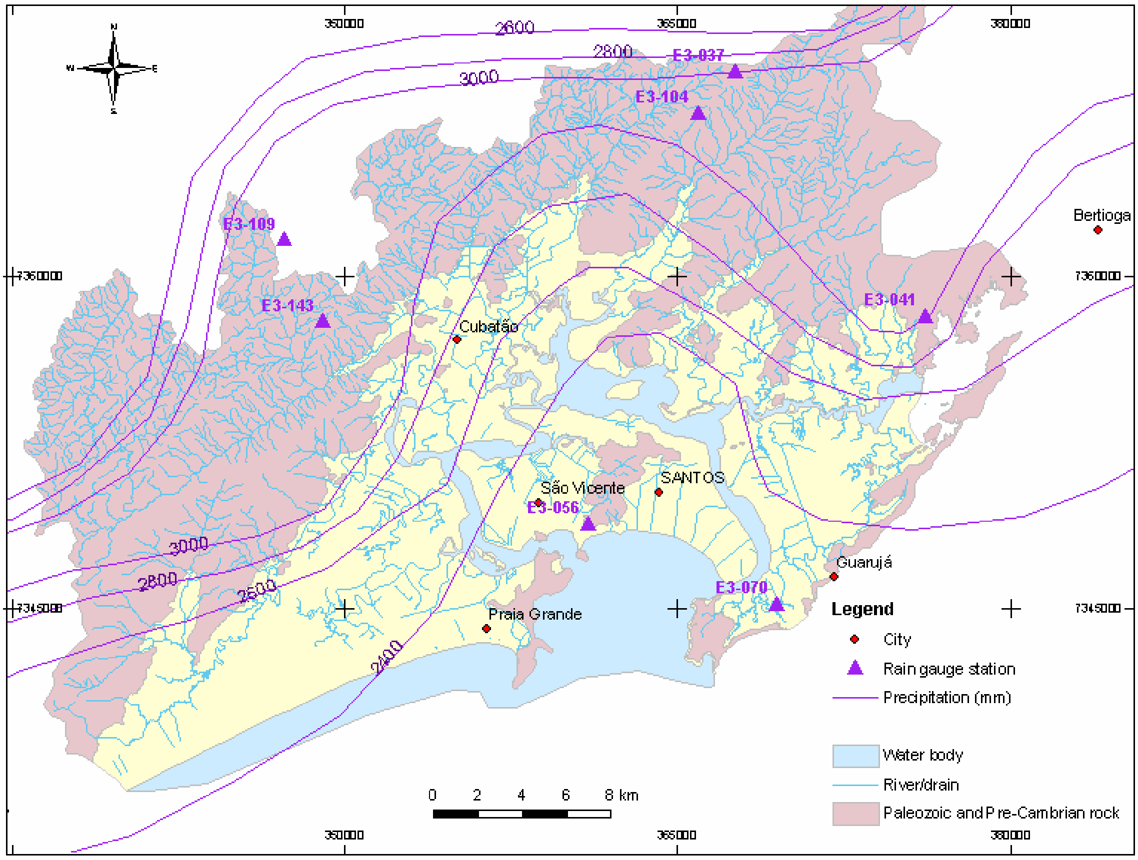
1) Alluvium (Qa) (alluvial sand): k_x and k_y = 1 m/d (1.16 10^{-3} cm/s), k_z = 0.01 m/d (1.16 10^{-5} cm/s);
2) *Cananéia* formation (Qc) and Marine and mixed sediments (Qm) (marine sand and sandy-siltic-clayey terms and mangroves deposits): k_x and k_y = 0.5 m/d (5.79 10^{-4} cm/s), k_z = 0.005 m/d (5.79 10^{-6} cm/s);
3) Undifferentiated continental sediments (Qi) (sand-clay and silt also mangroves deposits): k_x and k_y = 0.5 m/d (5.79 10^{-4} cm/s), k_z = 0.005 m/d (5.79 10^{-6} cm/s) and

4) Weathering rocks from Pre-Cambrian / Paleozoic formations was assigned: k_x and k_y = 0.009 m/d (1.16 10^{-5} cm/s), k_z = 0.0001 m/d (1.16 10^{-7} cm/s).

Groundwater levels have been monitored for the mapping of the regional piezometry. Bibliography from DAEE (1979), CONSULTORIA PAULISTA (2004) and MKR (2003) helped on this approach. Groundwater levels are almost at subsurface and vary from 0 to 5 m elevation in Praia Grande and up to 8 m in the west part of São Vicente Island.

3.2 Recharge

To compute the recharge for Santos Estuary basin area, precipitation data from 8 rain gauge station (SIGRHI - Information System for Water Resources Management of São Paulo State) (http://www.sigrh.sp.gov.br) (DAEE site, access in 2006) have been used as point data source (Table 3), and curves (Fig. 10). According to the data the precipitation in the plain area is 2131 mm close to Guarujá up to 3000 mm close to the escarpment area.



Source: geology after DAEE (1979) and SIGRHI (http://www.sigrh.sp.gov.br)

Fig. 10 – Precipitation in Santos Estuary basin

Table 3 – Annual precipitation data for rain gauge stations at Land Santos Estuary

County	Prefix	Name	X (m)	Y (m)	Z (m)	Watershed	Annual P (mm)
Sao Vicente	E3-056	Sao Vicente	46°22'	23°58'	10	Vertente Atlantica (bs)	2 212.07
Guarujá	E3-070	Ponta da Praia	46°17'	24°00'	3	Vertente Atlantica (bs)	2 131.22
Itanhaem	F3-008	Banaurea	46°45'	24°02'	20	Branco	3 013.77
Cubatão	E3-143	Rodovia Anchieta	46°29'	23°53'	400	Cubatao	3 245.21
Sao Bernardo do Campo	E3-109	Alto da Serra	46°30'	23°51'	760	Cubatao	3 498.08
Santo Andre	E3-037	Paranapiacaba	46°18'	23°47'	820	Moji	3 127.28
Santos	E3-041	Caete	46°13'	23°53'	200	Vertente Atlantica (bs)	3 3 86.30
Cubatão	E3-104	Terceiro Plano S. Nova	46°19'	23°48'	670	Moji	3 015 .75

Source: Precipitation data from (SIGRHI) (http://www.sigrh.sp.gov.br)

The recharge was calculated based on mass balances between water coming in, going out or being stored in the water system. This balance was made for Cubatão watershed by DAEE (1979). The results were used as base for estimating recharges on the others watersheds of the modelled area (Table 4) (Fig. 11).

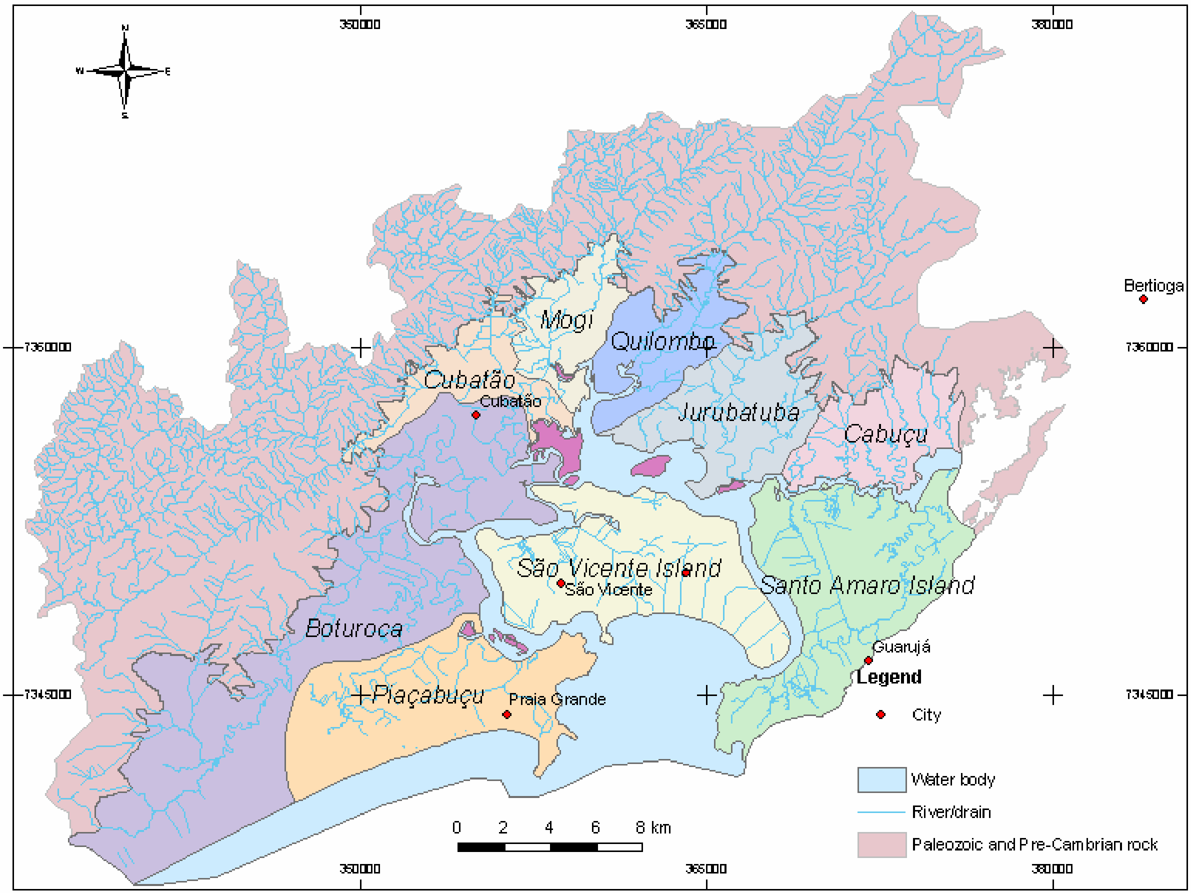
Table 4 – Precipitation and potential recharge at Land Santos Estuary watersheds

Watershed	Santos Estuary Basin			Modeled Area			
	Area (km^2)	P (mm/year)	P (MMC/year)	Modeled Area (km^2)	P (mm/year)	P (MMC/year)	Potential Recharge[1] (mm/year)
Boturoca stream	182.8	2709	495.07	128.1	2640	338.21	744
Cubatão stream	185.5	2917	540.90	21.0	2863	60.09	807
Piaçabuçu stream	57.1	2405	137.20	57.1	2405	137.22	678
S. Vicente island	58.5	2291	133.94	58.5	2291	133.96	646
Mogi stream	67.9	2884	195.69	20.5	2704	55.47	763
Santo Amaro island (2)	68.6[1]	2402	164.84	68.6	2376	163.04	670
Cabuçu stream (2)	41.0[1]	2827	115.81	28.4	2771	78.74	781
Jurubatuba stream	82.0	2793	229.01	36.3	2539	92.06	716
Quilombo stream	86.6	2828	244.82	25.0	2619	65.56	739
Islands	4.9	2409	11.77	4.9	2410	11.77	680
Total	834.6		2269.04	448.3		1136.13	

Source: Precipitation from SIGRH (http://www.sigrh.sp.gov.br). Recharge calculation after DAEE (1979).

(1) 28.2% from precipitation, considering urban areas and mangrove (DAEE, 1979)

(2) Only the area that contribute with surface water to the estuary



Source: watersheds limits based on topographic map (IGGSP, 1971 and 1972)

Fig. 11 – Watersheds in the modelled area. Land Santos Estuary basin

For modelling purpose the total recharge was estimate as 28.2% from precipitation (DAEE, 1979), considering urban areas and mangrove. Mean recharge value was then 0.0019 m/d at start for modelling condition.

Real evapotranspiration is 38% of precipitation in Cubatão Watershed (DAEE, 1979), according to the water balance calculated from the year 1949/1950. But total discharge for the same watershed on the period of 1955 to 1976 was calculated to be 67% of the precipitation; the results also showed that 43% of the surface discharge is due to groundwater base flow.

The water budget calculation was made using the regionalization hydrological method for São Paulo State available on the Management of Water Resources Information System for São Paulo State at http://www.sigrh.sp.gov.br. Results shows that minimum discharge from base flow, observed in 7 consecutive days in 10 years, is considered to be 24% of the total discharge (Table 5). That indicated a minimum value for base flow during the hydrogeological year.

OLIVEIRA, *et al.* (2005) assed also for ECOMANAGE project groundwater recharge for the evaluation of DRASTIC parameter "D". Groundwater recharge in that study was estimated using the hydrograph separation technique (*cf.* OLIVEIRA, 2006). The methodology behind this technique did not prove to be the most adequate as rainfall amounts are very large and do not allow for the best application of the technique. Obtained values were about 900 mm/yr for precipitations in the order of around 3300 mm/yr. Considering 3000 mm of precipitation close to the escarpment area and 28.2% as the percentage from precipitation that corresponds to recharge a value of 846 mm/y is evaluated, that is in the order of magnitude of the 900 mm/y mentioned above.

As far as potential evapotranspiration, land use and soil information are available for the area, also daily sequential water balance models, *e.g.* BALSEQ model (*cf.* LOBO-FERREIRA, 1982), may be used to estimate recharge.

Table 5 – Surface discharge at Land Santos Estuary watersheds from the regionalization hydrological method for São Paulo State (http://www.sigrh.sp.gov.br)

Watershed	Santos Estuary Basin			Modeled Area			
	Area (km^2)	P (mm/year)	Q (m^3/s)	Modeled Area (km^2)	P (mm/year)	Q (m^3/s)	$Q_{7/10}$[1] (m^3/s)
Boturoca stream	182.8	2709	10.212	128.1	2640	9.815	2,397
Cubatão stream	185.5	2917	11.578	21.0	2863	1.275	0.311
Piaçabuçu stream	57.1	2405	2.643	57.1	2405	2.643	0.646
S. Vicente island	58.5	2291	2.498	58.5	2291	2.498	0.610
Mogi stream	67.9	2884	4.167	20.5	2704	1.142	0.279
Santo Amaro island (2)	68.6[1]	2402	3.169	68.6	2376	3.113	0.760
Cabuçu stream (2)	41.01[1]	2827	2.443	28.4	2771	1.642	0.401
Jurubatuba stream	82.0	2793	4.798	36.3	2539	1.833	0.448
Quilombo stream	86.6	2828	5.162	25.0	2619	1.326	0.324
Islands	4.9	2409	0.227	4.9	2410	0.227	0.056
Total	834.6			448.3			

[1]Minimum discharge from 7 consecutive days in 10 years
[2] Only the area that flows to the estuary

4 Groundwater Mathematical Model

The total modelled area is 448.3 km^2 (406 km^2 of land area approximately) and comprises part of the following watersheds: Piaçabuçu, Boturoca, Cubatão, Mogi, Quilombo, Jurubatuba, Cabuçu, Santo Amaro Island and São Vicente Island.

The mathematical groundwater flow model used in this study was MODFLOW model. MODFLOW was first published by MCDONALD and HARBAUGH (1988). The flow model was developed considering flow as a steady state, with lakes and the channel considered as constant head cells. Rivers were simulated as drains.

A 2 layers model was elaborated. Both layers on porous aquifer, the first one is an unconfined layer and the second confined/unconfined layer. This division intended to evaluate the real groundwater flow rate discharging to the estuary, considering a total penetrating channel on the first layer. So, the first layer has a mean thickness of 20 m, and the second layer has variable thickness according with the bedrock elevation.

4.1 Grid

The 3D model grid starts at the World Coordinates X = 337,080 m, Y = 7,336,560 m and Z = -230 m, ending at X = 377,080 m, Y = 7,365,560 m and Z = 1,070 m. The model has two layers subdivided into 116 rows by 160 columns. Each cell is 250 m by 250 m along the xx and yy directions (Table 6). The zz direction varies according to the layer to which each cell belongs and to the x and y coordinates of that cell. The thickness for the first layer was calculated as 30% of total thickness of the sediments, between topographic level and hard rock, specifying a minimum thickness of 25 m. The total thickness was calculated from topographic grid and hard rock top elevation grid (the lower elevation for the base of the sedimentary aquifer system was observed in -230 m). The thickness of the first layer varies from 70 m to 25 m and the elevation of the second layer, on the sedimentary aquifer, varies from -5 m to -230 m.

Table 6 – Grid characteristics for Santos Estuary groundwater model

Grid	Dimension		
	x	y	z
Origin	337080	7336560	-230
Length	40000	29000	1300
Number of cells	160	116	2
cell size	250	250	

4.2 Layer attributes

The qeology attributes, in a layer format, were used as an input data for the Modflow model. The hydrogeological characterization was accomplished using the geometry and hydraulic data from the geological formations (Fig. 12 and Fig. 13).

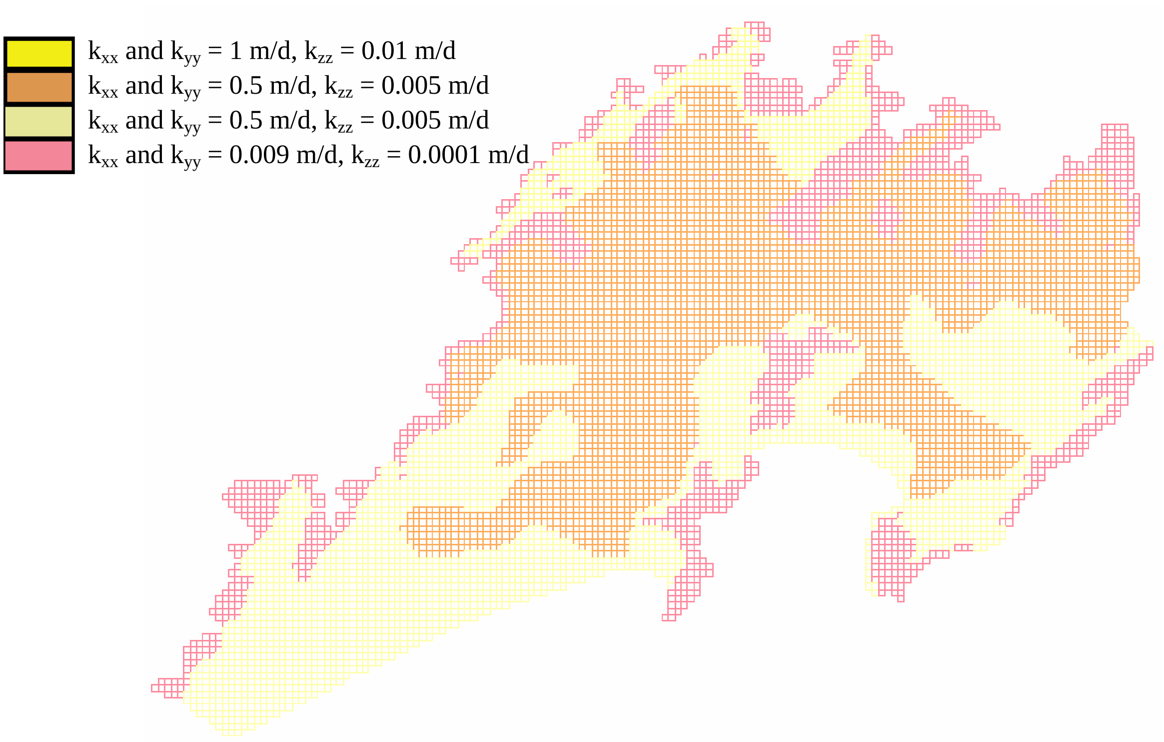


Fig. 12 – Hydraulic Conductivity (k) (m/d) for layer 1. Land Santos Estuary sedimentary aquifer

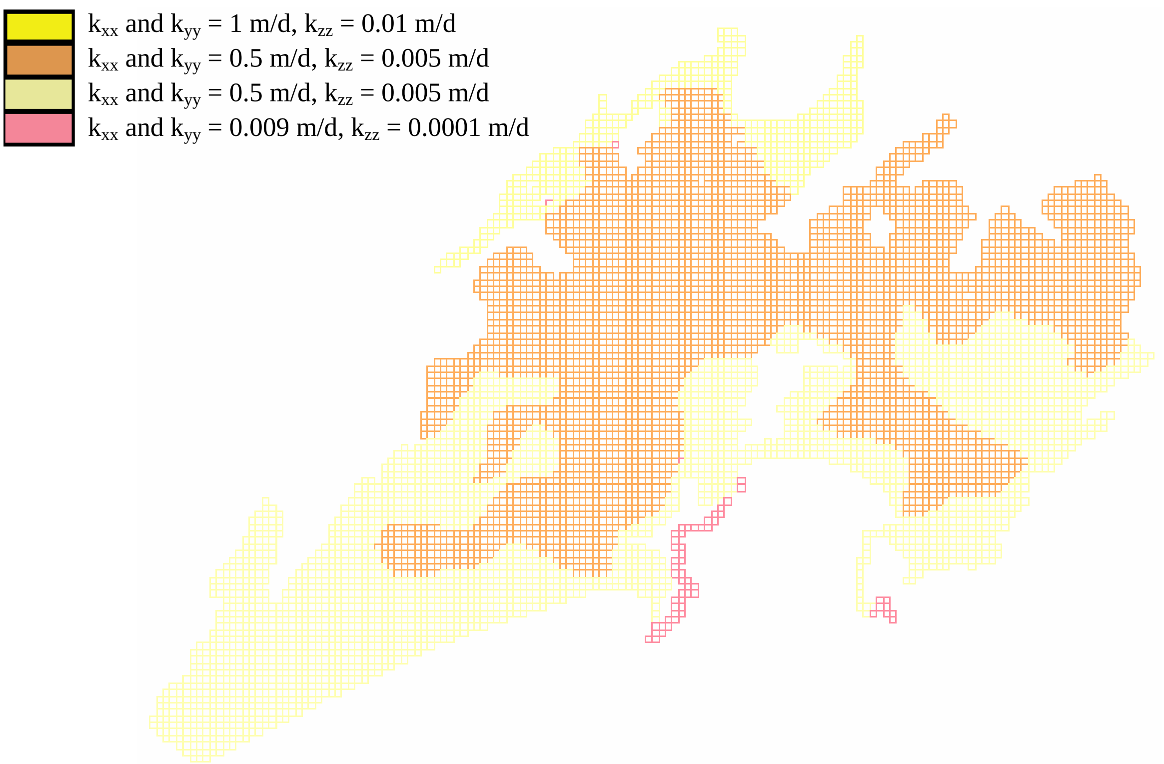


Fig. 13 – Hydraulic Conductivity (k) (m/d) for layer 2. Land Santos Estuary sedimentary aquifer

4.3 Source/Sinks Attributes

Surface water from rivers, drains, Santos estuary and the Atlantic Ocean were represented as drains and constant head on Modflow model. On the first layer (Fig. 14) were represented the rivers, drains and channels, as a partially penetrating water system. The Atlantic Ocean has been represented as a constant head and a fully interception system for groundwater flow (Fig. 15). Considering the purpose of this work, It was not simulated groundwater and sea water interaction. The constant head boundary at 0 m allowed quantifying mean groundwater discharge from the sedimentary aquifer.

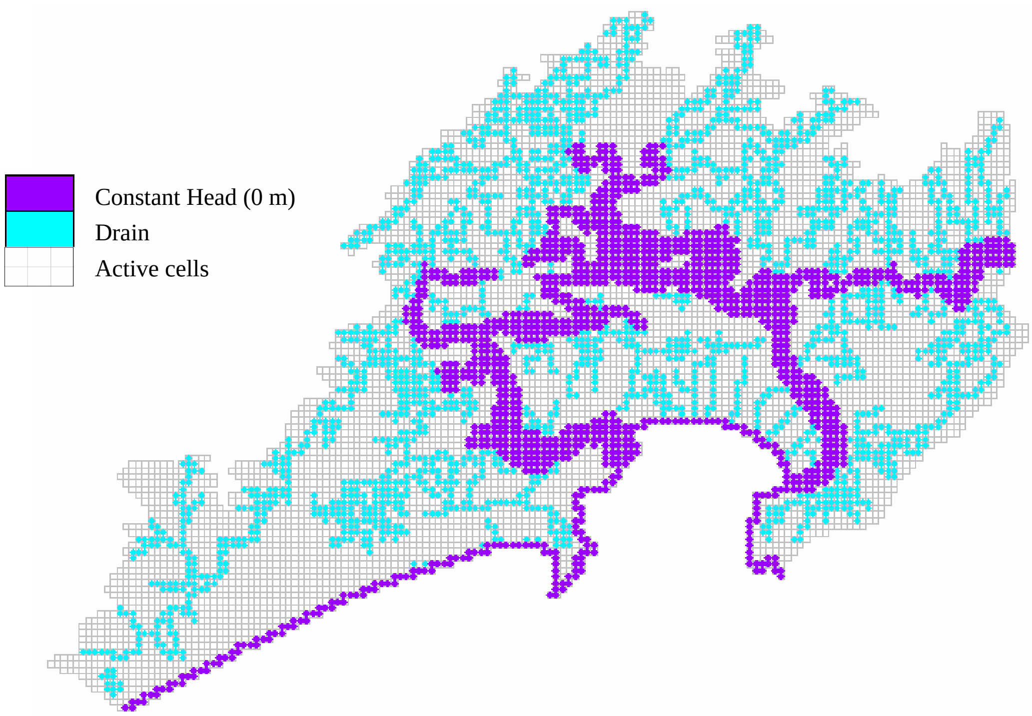


Fig. 14 – Source/Sink for layer 1 shows rivers as drains and constant head cells at ocean boundary and Santos Estuary channel

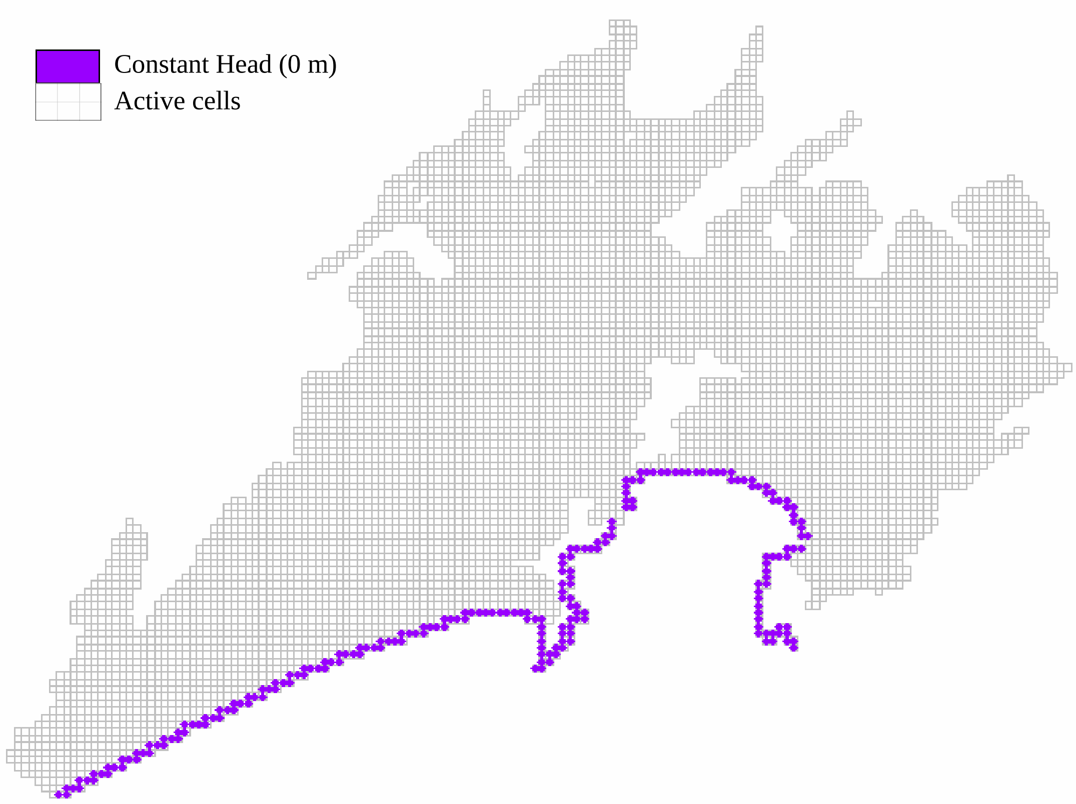


Fig. 15 – Source/Sink for layer 2 shows a constant head cells at ocean boundary

4.4 Recharge

Calibration was obtained using recharge values from each watershed (*cf.* Table 7).

Table 7 – Resulted recharge from calibration at Land Santos Estuary watersheds

	Santos Estuary Basin			
Watershed	**Modeled Area (km^2)**	**P (mm/year)**	**Potential Recharge[2] (mm/year)**	**Potential Recharge (m^3/d)**
Boturoca stream	128.1	2640	744	261,282
Cubatão stream	21.0	2863	807	46,451
Piaçabuçu stream	57.1	2405	678	106,098
S. Vicente island	58.5	2291	646	103,547
Mogi stream	20.5	2704	763	42,827
Santo Amaro island (*)	68.6	2376	670	125,929
Cabuçu stream (*)	28.4	2771	781	60,801
Jurubatuba stream	36.3	2539	716	71,207
Quilombo stream	25.0	2619	739	50,586
Islands	4.9	2410	680	
Total	448.3			868,728

[2] 28,2% from precipitation, considering urban areas and mangrove (DAEE, 1979)

4.5 Results

Model calibration is an on going process (2006-2007). The information here presented is the initial data resulting from the runs of the model during the first author stay in Lisbon at LNEC (Table 8).

Table 8 – Groundwater parameters resulted from the initial model calibration

Parameter	Condition
Hydraulic Conductivity (k)	k_{xx} and k_{yy} = 0.009 m/d to 1 m/d, k_{zz} = 0.005 m/d to 0.0001 m/d
Drain Conductance	0,2 to 2 L (m)
Recharge	1,8 x 10^{-3} to 2,2 x 10^{-3} m/d
Inicial head	0 m to 10 m

The objective of the model calibration is to obtain piezometric surface compatible with observed heads, or the piezometric surface of DAEE (1979). In a general way, at Santos Estuary sedimentary aquifer groundwater flows locally towards the rivers, and the drains opened according to the urban development. Regionally groundwater flows towards the sea as may be observed from piezometric values and flow direction maps shown in Fig. 16, Fig. 17 and Fig. 18.

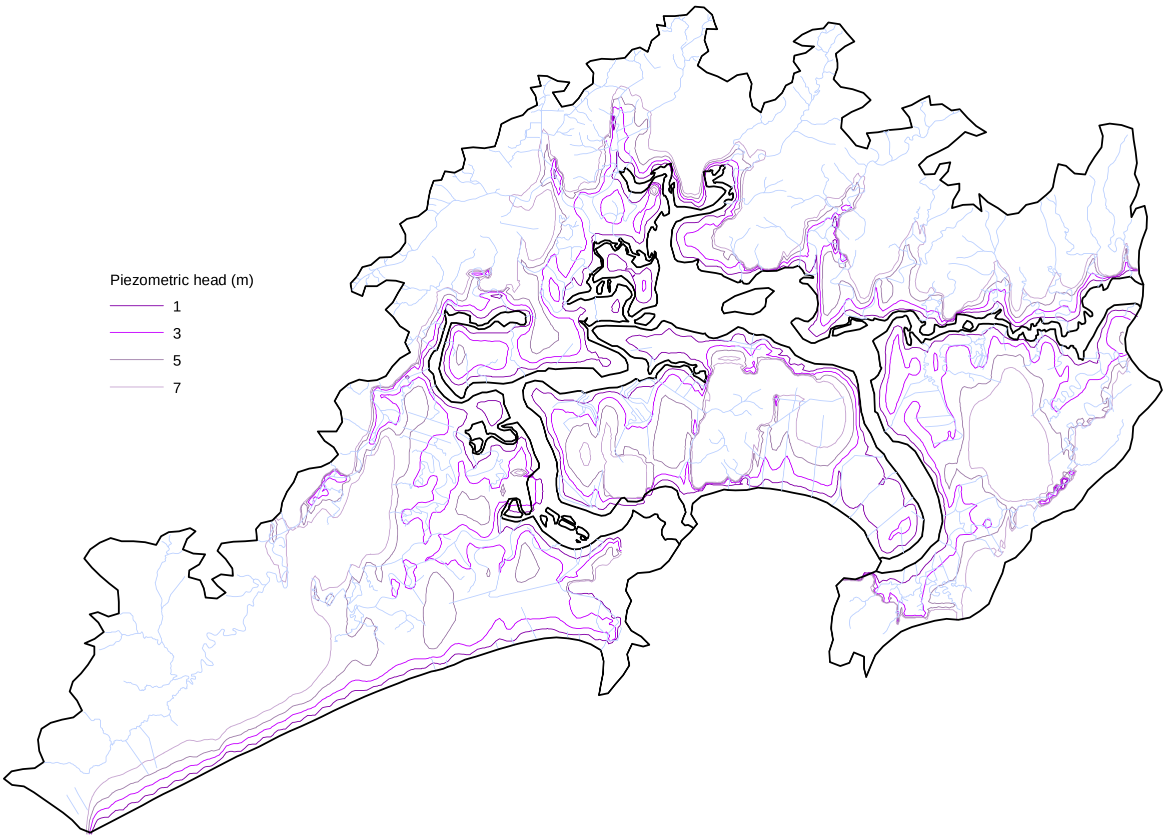


Fig. 16 – Piezometric head for Land Santos Estuary sedimentary aquifer resulted from Modflow model

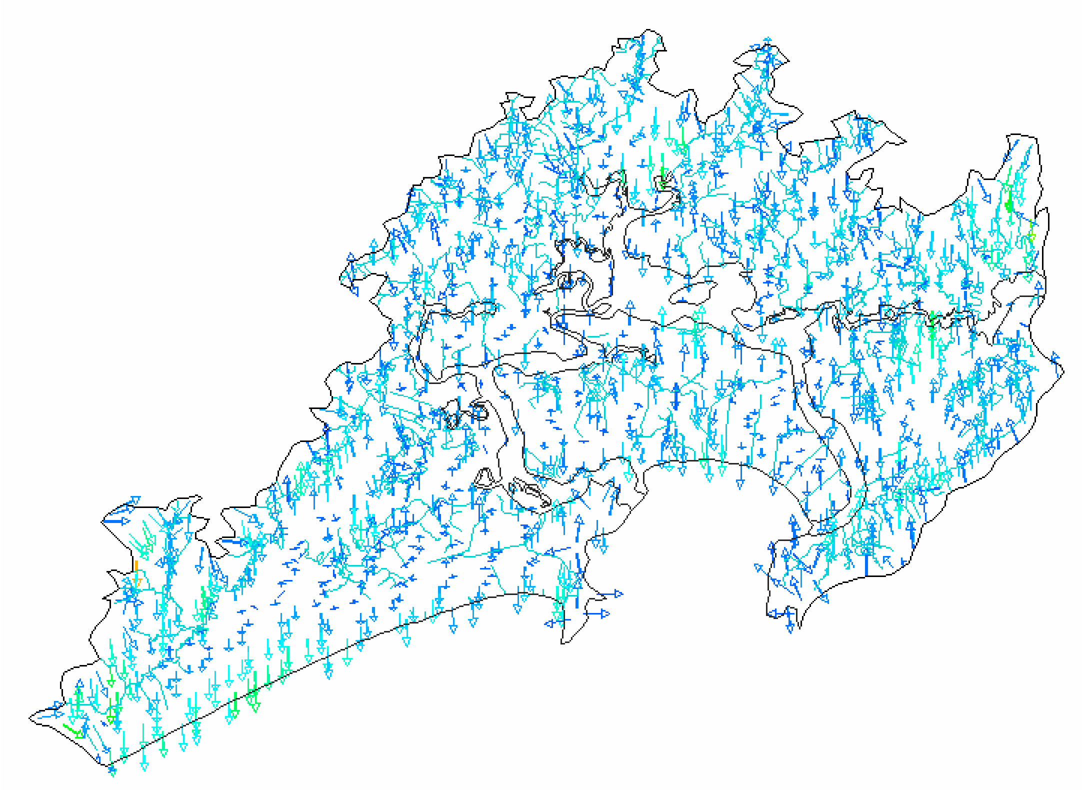


Fig. 17 – Flow direction for layer 1. Land Santos Estuary sedimentary aquifer

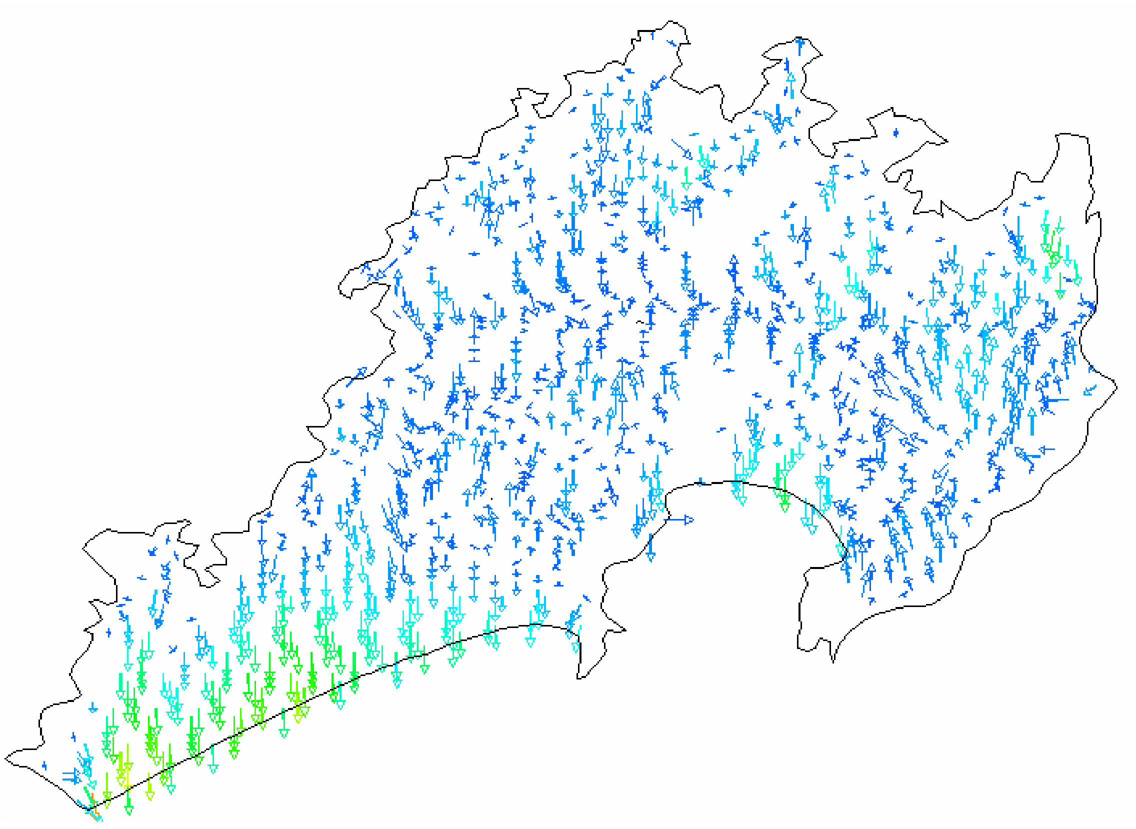


Fig. 18 – Flow direction for layer 2. Land Santos Estuary sedimentary aquifer

Water budget showed that flow in and out from the system are almost the same, with a discrepancy of 1%. According with the model results, total discharge from groundwater is 877x10^3 m^3/d, 208x10^3 m^3/d (24%) flows to the Estuary and 493x10^3 m^3/d (56%) to the drains, part of groundwater flows to the Atlantic Ocean (20%) (Table 9). Total discharge from precipitation through the sedimentary aquifer to the Estuary is about 8%. Flow depends on the watershed location (Fig. 19), area and land use, but mean flow from groundwater to the Estuary boundary is around 1 $m^3/m/d$.

Table 9 – Estimated groundwater discharge to the Estuary System resulting from a year groundwater simulation

Watershed	Modelled Area (km^2)	Estimated Recharge (m^3/d)[2]	Numerical Model Result				
			Discharge to the Estuary (m^3/d)		Discharge to the Atlantic Ocean (m^3/d)		Total Discharge (m^3/d)
			Groundwater	Surface	Groundwater	Surface	
Boturoca stream	128.1	261,282	-43,815.76	-147,097.50	-58,805.41	-	-249,718.67
Cubatão stream	21.0	46,451	-4,599.56	-45,890.46	-	-	-50,490.02
Piaçabuçu stream	57.1	106,098	-13,910.20	-38,002.28	-67,396.35	-647.35	-119,956.18
S. Vicente island	58.5	103,547	-40,091.87[1]	-23,798.46	-32,286.62	-13,361.37	-109,538.32
Mogi stream	20.5	42,827	-8,580.46	-30,282.50	-	-	-38,862.96
Santo Amaro island (*)	68.6	125,929	-25,825.09	-74,350.03	-2,826.13	-	-103,001.25
Cabuçu stream (*)	28.4	60,801	-24,164.612	-43,301.68	-	-	-67,466.29
Jurubatuba stream	36.3	71,207	-21,716.69	-56,260.08	-	-	-77,976.77
Quilombo stream	25.0	50,586	-19,940.51	-33,603.98	-	-	-53,544.49
Islands	4.9		-5,035.99		-	-	-5,035.99
Santos Estuary line					-1,531.28		-1,531.28
Total	448.3		-207,680.74	-492,586.97	-162,845.79	-14,008.72	-877,122.22

[1]To the Estuary

[2] 28,2% from precipitation, considering urban areas and mangrove (DAEE, 1979)

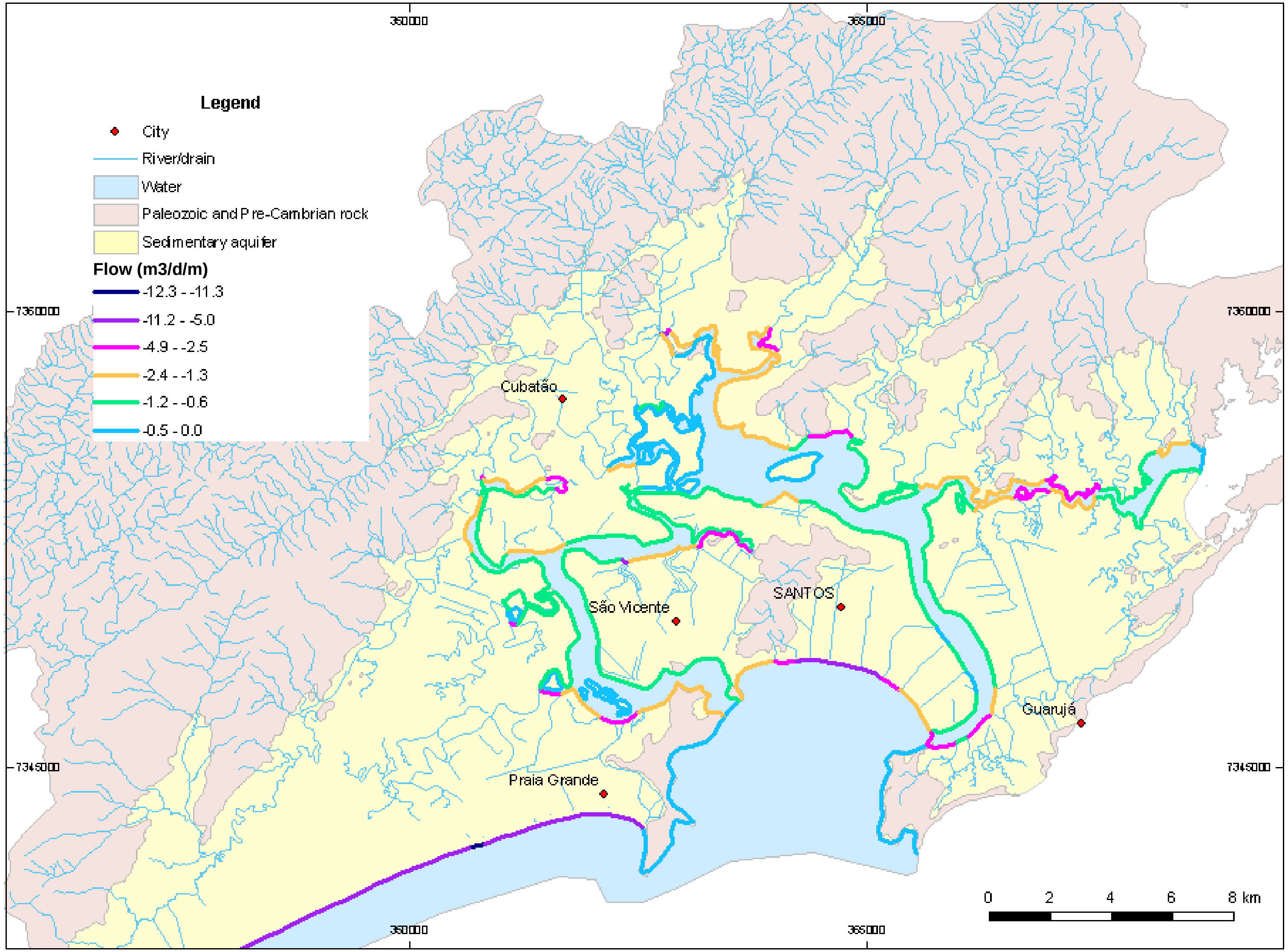


Fig. 19 – Flow discharge from the sedimentary aquifer. Land Santos Estuary basin

5 Simulation of monthly groundwater discharge to the estuary

The monthly groundwater discharge to the estuary was calculated considering monthly precipitation data for the counties mentioned in Table 10. As initial conditions for the simulation, *e.g.* starting heads and aquifer parameters, we have considered the values resulting from model calibration.

Table 10 – Monthly precipitation (mm)

County	Station Prefix	Data Interval	Month											
			J	F	M	A	M	J	J	A	S	O	N	D
Sao Vicente	E3-056	1938-2004	284.57	273.57	290.59	201.69	140.83	106.18	104.41	86.01	142.55	171.52	177.67	232.47
Guarujá	E3-070	1937-2004	280.29	253.26	266.44	178.13	151.16	115.01	105.25	91.81	133.88	173.50	160.35	222.15
Itanhaem	F3-008	1969-1968	408.11	341.01	394.56	274.03	172.49	126.23	132.53	115.23	235.41	265.12	272.03	277.02
Cubatão	E3-143	1950-1994	423.81	361.19	375.15	289.81	172.90	116.46	114.89	118.92	242.76	341.62	320.11	367.58
Sao Bernardo do Campo	E3-109	1944-1998	394.20	391.52	408.48	293.01	198.91	125.99	137.72	150.66	273.04	386.34	337.18	401.05
Santo Andre	E3-037	1936-1998	384.97	339.10	331.93	272.32	174.06	140.68	147.35	173.06	231.15	295.53	286.64	350.48
Santos	E3-041	1937-2004	402.75	422.45	387.77	293.70	216.82	163.02	168.61	154.64	243.09	301.65	284.51	347.27
Cubatão	E3-104	1960-1982	403.52	322.52	339.37	265.28	147.28	119.02	127.05	144.44	210.82	278.56	291.78	366.13

Source: Precipitation from SIGRH (http://www.sigrh.sp.gov.br) (access 07/2006)

Associated with the variation of the precipitation during the year (Table 11), different rates of monthly recharge can be observed in Table 12. This has been considered so that we could obtain more appropriate recharge values for the model. Other factors such as urban areas, mangroves, losses from pipes lines of water supply, eventual pumping rates from sedimentary aquifer, etc. may be incorporated. New values of monthly recharge per watershed were applied.

Table 11 – Percent of precipitation (mm) per month

County	Station Prefix	Month											
		J	F	M	A	M	J	J	A	S	O	N	D
Sao Vicente	E3-056	0.13	0.12	0.13	0.09	0.06	0.05	0.05	0.04	0.06	0.08	0.08	0.11
Guarujá	E3-070	0.13	0.12	0.13	0.08	0.07	0.05	0.05	0.04	0.06	0.08	0.08	0.10
Itanhaem	F3-008	0.14	0.11	0.13	0.09	0.06	0.04	0.04	0.04	0.08	0.09	0.09	0.09
Cubatão	E3-143	0.13	0.11	0.12	0.09	0.05	0.04	0.04	0.04	0.07	0.11	0.10	0.11
Sao Bernardo do Campo	E3-109	0.11	0.11	0.12	0.08	0.06	0.04	0.04	0.04	0.08	0.11	0.10	0.11
Santo Andre	E3-037	0.12	0.11	0.11	0.09	0.06	0.04	0.05	0.06	0.07	0.09	0.09	0.11
Santos	E3-041	0.12	0.12	0.11	0.09	0.06	0.05	0.05	0.05	0.07	0.09	0.08	0.10
Cubatão	E3-104	0.13	0.11	0.11	0.09	0.05	0.04	0.04	0.05	0.07	0.09	0.10	0.12
Mean		**12.62**	**11.45**	**11.83**	**8.75**	**5.82**	**4.29**	**4.39**	**4.38**	**7.25**	**9.37**	**9.02**	**10.85**

Source: Precipitation from SIGRH (http://www.sigrh.sp.gov.br) (access 07/2006)

Table 12 – Precipitation (mm) per month on watershed and islands

Watershed	P (mm/year	Precipitation (mm/month) J	F	M	A	M	J	J	A	S	O	N	D
Boturoca stream	2640	333.19	302.17	312.19	231.04	153.56	113.13	115.95	115.61	191.35	247.34	238.00	286.48
Cubatão stream	2863	361.33	327.69	338.56	250.56	166.53	122.69	125.74	125.37	207.51	268.23	258.11	310.68
Piaçabuçu stream	2405	303.53	275.27	284.40	210.48	16.01	103.06	105.63	105.32	174.32	225.32	216.82	260.98
S. Vicente island	2291	289.14	262.22	270.92	200.50	133.26	98.17	100.62	100.33	166.05	214.64	206.54	248.61
Mogi stream	2704	341.26	309.50	319.76	236.64	157.28	115.87	118.76	118.41	195.99	253.33	243.77	293.42
Santo Amaro island (*)	2376	299.87	271.95	280.97	207.94	138.20	101.82	104.35	104.05	172.21	222.60	214.20	257.83
Cabuçu stream (*)	2771	349.72	317.16	327.68	242.51	161.18	118.74	121.70	121.35	200.84	259.61	10.94	300.69
Jurubatuba stream	2539	320.44	290.61	300.25	222.20	147.68	108.80	111.51	111.19	184.03	237.88	228.90	275.52
Quilombo stream	2619	330.53	299.77	309.71	229.20	152.34	112.23	115.03	114.69	189.83	245.37	236.11	284.20
Islands	2410	304.16	275.85	284.99	210.91	140.18	103.27	105.85	105.54	174.68	225.79	217.27	261.52

Source: Precipitation from SIGRH (http://www.sigrh.sp.gov.br) (access 07/2006)

Recharge calculation considered the water budget developed for Cubatão watershed for a year period (1949/1950) (Table 13) and total recharge for the Estuary area was calculated as 28.2% from precipitation, considering urban areas and mangrove (Table 14) (DAEE, 1979) (MENEGASSE-VELÁSQUE, 1996).

Table 13 – Recharge per month in Cubatão watershed (water budget from 1949 to 1950)

Month	P (mm)	ER (mm)	R (mm)	R (%P)	Recharge for the Estuary watersheds (%)
October	194.3	90.3	43.8	0.23	0.15
November	104.6	95.6	50.4	0.48	0.33
December	313.2	58.4	113.0	0.36	0.24
January	337.1	53.3	193.2	0.57	0.37
Fevruary	182.1	97.1	124.6	0.68	0.46
March	302.7	96.6	120.2	0.40	0.27
April	206.1	56.9	103.0	0.50	0.34
May	90.0	58.0	76.3	0.85	0.57
Jun	70.7	72.9	29.7	0.42	0.28
July	30.4	50.5	8.9	0.29	0.20
August	24.5	32.2	2.4	0.10	0.07
September	238	45.1	36.2	0.15	0.10
Total	2 093.7	806.9	901.7	0.42	**0.28**

Source: DAEE (1979)

Table 14 – Estimated recharge (mm) per month on watershed and islands

Watershed	P (mm/year)	Recharge (mm/month) J	F	M	A	M	J	J	A	S	O	N	D
Boturoca stream	2640	123.28	139.00	84.29	78.55	87.53	31.68	23.19	8.09	19.13	37.10	78.54	68.75
Cubatão stream	2863	133.69	150.74	91.41	85.19	94.92	34.35	25.15	8.78	20.75	40.23	85.17	74.56
Piaçabuçu stream	2405	112.30	126.63	76.79	71.56	9.13	28.86	21.13	7.37	17.43	33.80	71.55	62.63
S. Vicente island	2291	106.98	120.62	73.15	68.17	75.96	27.49	20.12	7.02	16.61	32.20	68.16	59.67
Mogi stream	2704	126.27	142.37	86.33	80.46	89.65	32.44	23.75	8.29	19.60	38.00	80.44	70.42
Santo Amaro island (*)	2376	110.95	125.10	75.86	70.70	78.78	28.51	20.87	7.28	17.22	33.39	70.69	61.88
Cabuçu stream (*)	2771	129.40	145.90	88.47	82.45	91.87	33.25	24.34	8.49	20.08	38.94	3.61	72.17
Jurubatuba stream	2539	118.56	133.68	81.07	75.55	84.18	30.46	22.30	7.78	18.40	35.68	75.54	66.12
Quilombo stream	2619	122.30	137.89	83.62	77.93	86.83	31.42	23.01	8.03	18.98	36.81	77.92	68.21
Islands	2410	112.54	126.89	76.95	71.71	79.90	28.92	21.17	7.39	17.47	33.87	71.70	62.76

Table 15 and Table 16 show the groundwater discharge from the sedimentary aquifer to the estuary system, resulting from the simulation.

Table 15 – Estimated monthly groundwater discharge to the Estuary System resulting from a year groundwater simulation

Watershed	Groundwater discharge to Santos Estuary (m^3/d)											
	J	F	M	A	M	J	J	A	S	O	N	D
Boturoca stream	56,282	61,952	54,517	52,504	52,143	44,055	40,415	36,341	37,057	39,678	48,136	46,146
Cubatão stream	6,160	7,116	5,586	5,364	5,552	4,275	3,957	3,598	3,605	3,954	5,021	4,820
Piaçabuçu stream	17,747	19,963	17,644	17,015	17,307	15,184	14,312	13,305	13,107	13,677	15,488	15,428
S. Vicente island	51,287	57,783	49,306	47,226	47,600	39,005	35,959	32,832	34,035	36,083	43,265	42,270
Mogi stream	14,360	15,226	14,059	13,814	13,914	12,883	11,943	11,473	11,666	12,016	13,153	12,967
Santo Amaro island (*)	37,324	40,783	37,570	36,960	37,117	33,575	31,619	29,560	29,555	30,155	33,049	33,040
Cabuçu stream (*)	27,341	29,097	26,587	26,016	26,317	24,128	23,358	22,610	22,839	23,527	22,792	24,678
Jurubatuba stream	25,661	27,867	25,080	24,386	24,643	22,183	20,737	19,700	19,942	20,583	23,016	22,671
Quilombo stream	22,870	24,603	22,734	22,327	22,459	20,573	19,821	18,407	18,456	19,664	20,809	20,681
Islands	17,608	20,393	15,661	15,028	15,563	11,740	10,801	9,756	10,372	11,330	14,381	13,820

Table 16 – Estimated groundwater discharge to the Estuary System resulting from a year groundwater simulation

Watershed	Line Discharge Length (m)	Mean Discharge (m^3/d)	Total Discharge ($m^3/year$)	Discharge ($m^3/d/m$)
Boturoca stream	43,970.51	47,338	17,278,398	1.08
Cubatão stream	5,803.59	4,903	1,789,635	0.84
Piaçabuçu stream	10,697.25	15,821	5,774,804	1.48
S. Vicente island	40,878.49	42,957	15,679,301	1.05
Mogi stream	10,449.15	13,108	4,784,500	1.25
Santo Amaro island (*)	25,201.78	34,148	12,464,029	1.35
Cabuçu stream (*)	13,865.76	24,918	9,094,924	1.80
Jurubatuba stream	14,183.19	23,007	8,397,411	1.62
Quilombo stream	9,223.80	21,095	7,699,550	2.29
Islands	29,544.22	13,828	5,047,343	0.47
Total		241,123	88,009,895	

According with the groundwater model developed in this work, the discharge from the sedimentary aquifer directly to the Estuary is approximately 8% of the precipitation.

6 Conclusions

This Report presents the characterisation of the sedimentary aquifer of Santos Estuary area. Also quantified is the mean flow and monthly groundwater discharge to the estuary, on the interface aquifer-channel.

This work was a first approach for the evaluation of the groundwater discharge from the sedimentary aquifer into Santos Estuary. Discharge from fractures of the crystalline aquifer (hard rock) has not been considered. From the results it can be concluded that groundwater discharge to Santos Estuary depends on the watershed location, area and land use. Flow discharge is lower on a well drained basin, because groundwater contributions are mainly to the drains. This base flow discharge is counted on the rivers flow rate. There is a high fresh water discharge to the Atlantic Ocean, from Praia Grande and Santos area. Lower values are related with crystalline rock outcrop and small islands. Total groundwater discharge to the land-Estuary boundary from precipitation is about 8%, besides, other 17% flows as base flow to the drains.

Monthly recharge values for each watershed were considered as an input for model simulation in the study area, as well as the influence of urban areas and mangroves on the recharge rate. The rate of recharge from precipitation was based on bibliography studies. One can observe differences between groundwater recharge rates on forest land use, as published by OLIVEIRA, *et al.* (2005) for the Cubatão watershed, and groundwater recharge on urban areas, as calculated in this work for Santos and São Vicente. The computation didn't consider losses from water supply pipes.

From the simulation it can be concluded that Boturoca watershed, São Vicente and Santo Amaro Island are the main contributors of fresh water from the sedimentary aquifer to the estuary. The results showed important groundwater discharge, higher from January to May. Lower discharges to the estuary were observed in Cubatão watershed. In this basin groundwater from the sedimentary aquifer flows to the drains and, afterwards as surface water, to the estuary.

This work was based on existing data and on field trips. It's important to collect new groundwater data to improve this first modelling approach. The physiographic of the area, the land use and mainly the large amount of rainfall, increasing the availability of water, at least in quantity terms, may be responsible for the inexistence of groundwater studies. The available information exists in small scales.

The authors do suggest this research work to be further improved. This requires additional detailed field information, becoming available in terms of piezometry, inventory of wells, monitoring data, geophysical data and hydraulic characterization.

Complementing the studies presented in this report, during 2007, the main ECOMANAGE project groundwater research will be target on pollution problems due to industry development. According to OLIVEIRA *et al.* (2005) a high vulnerability class is associated to Cenozoic formations, having sedimentary aquifers, while low to medium vulnerability classes are associated to basement formations. Groundwater detailed models can help quantifying possible contamination from sedimentary aquifers to the estuary. The groundwater flow model presented in this report is being complemented during 2007, with a three-dimensional transport model that will allow the simulation of advection, dispersion, and chemical reactions processes of dissolved constituents in the aquifer system. The final aim is the quantification of diffuse pollution loads, discharging to selected area of the Santos Estuary.

Lisboa, Laboratório Nacional de Engenharia Civil, July 2007

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ANNEX 1 - Groundwater discharge to the Atlantic Ocean and Santos Estuary, on the interface groundwater-surface water, for segment of land. Results from Model calibration.

Name	BEGINLAYER	ENDLAYER	Flux (m^3/d)	Length	Flux ($m^3/m/d$)
chdf43	1	1	-4380.00	3676.80	-1.19
chdf49	1	2	-1240.00	834.72	-1.49
chdf60	1	1	-1050.00	859.34	-1.22
chdf75	1	1	-978.00	1413.93	-0.69
chdf83	1	1	-435.00	860.74	-0.51
chdf92	1	1	-1000.00	1012.65	-0.99
chdf101	1	1	-345.00	754.45	-0.46
chdf111	1	2	-4610.00	752.68	-6.12
chdf5	1	2	-5750.00	1038.25	-5.54
chdf21	1	2	-3600.00	729.18	-4.94
chdf30	1	1	-329.00	29.07	-11.32
chdf37	1	2	-1740.00	898.31	-1.94
chdf41	1	2	-3420.00	2262.01	-1.51
chdf42	1	2	-3290.00	710.26	-4.63
chdf44	1	2	-3480.00	464.99	-7.48
chdf45	1	2	-3260.00	644.20	-5.06
chdf46	1	1	-11.70	745.44	-0.02
chdf47	1	1	-8000.00	6629.72	-1.21
chdf48	1	1	-1900.00	628.10	-3.03
chdf50	1	1	-4080.00	6035.63	-0.68
chdf51	1	1	-1010.00	610.28	-1.65
chdf52	1	1	-1020.00	616.61	-1.65
chdf53	1	1	-6790.00	7048.69	-0.96
chdf54	1	1	-4730.00	1702.17	-2.78
chdf55	1	1	-1160.00	1963.10	-0.59
chdf56	1	1	-86.50	964.20	-0.09
chdf57	1	1	-102.00	1712.46	-0.06
chdf59	1	1	-2860.00	3073.74	-0.93
chdf61	1	2	-2890.00	6328.80	-0.46
chdf62	1	1	-1210.00	4360.73	-0.28
chdf63	1	1	-1120.00	1122.61	-1.00
chdf69	1	1	-2580.00	1403.82	-1.84
chdf70	1	1	-7180.00	6809.06	-1.05
chdf71	1	1	-1770.00	2815.13	-0.63
chdf72	1	1	-1020.00	943.67	-1.08
chdf73	1	1	-3510.00	1266.34	-2.77
chdf74	1	1	-1290.00	359.78	-3.59
chdf76	1	1	-12.60	798.70	-0.02
chdf77	1	1	-5310.00	7400.04	-0.72
chdf78	1	1	-4990.00	2104.62	-2.37
chdf79	1	1	-6370.00	6644.99	-0.96
chdf80	1	1	-13400.00	8825.55	-1.52
chdf81	1	1	-8420.00	5964.80	-1.41
chdf82	1	1	-1770.00	978.65	-1.81
chdf84	1	1	-4400.00	7521.81	-0.58
chdf85	1	1	-4310.00	1425.54	-3.02
chdf86	1	1	-669.00	146.78	-4.56
chdf87	1	1	-1410.00	239.50	-5.89
chdf88	1	1	-1110.00	821.31	-1.35
chdf89	1	1	-537.00	1315.91	-0.41
chdf90	1	1	-2010.00	1578.14	-1.27
chdf91	1	1	-5540.00	7325.64	-0.76
chdf93	1	1	-827.00	1767.60	-0.47
chdf94	1	1	-1530.00	1052.22	-1.45
chdf95	1	1	-616.00	2419.75	-0.25
chdf96	1	1	-652.00	242.83	-2.69
chdf97	1	1	-1860.00	1348.67	-1.38
chdf98	1	1	-1230.00	644.60	-1.91
chdf99	1	1	-1700.00	2705.64	-0.63
chdf100	1	1	-613.00	551.12	-1.11
chdf102	1	1	-1040.00	720.79	-1.44
chdf103	1	1	-1160.00	711.90	-1.63
chdf104	1	1	-966.00	1851.53	-0.52
chdf105	1	1	-1560.00	650.23	-2.40

chdf106	1	1	-2300.00	741.80	-3.10
chdf107	1	1	-3360.00	1791.72	-1.88
chdf108	1	1	-664.00	251.78	-2.64

Name	BEGINLAYER	ENDLAYER	Flux (m^3/d)	Length	Flux ($m^3/m/d$)
chdf109	1	1	-6260.00	4249.96	-1.47
chdf110	1	2	-78869.58	12949.06	-6.09
chdf112	1	1	-1630.00	494.92	-3.29
chdf113	1	1	-1150.00	239.99	-4.79
chdf114	1	1	-1510.00	357.37	-4.23
chdf115	1	1	-781.00	1319.28	-0.59
chdf116	1	2	-2760.00	9319.62	-0.30
chdf117	1	2	-5170.00	420.82	-12.29
chdf0	1	2	-10800.00	1836.42	-5.88
chdf1	1	2	-4040.00	546.00	-7.40
chdf2	1	1	-5710.00	10515.45	-0.54
chdf3	1	2	-4340.00	786.80	-5.52
chdf4	1	2	-5390.00	1068.08	-5.05
chdf6	1	2	-3330.00	399.53	-8.33
chdf7	1	2	-4920.00	794.00	-6.20
chdf8	1	1	-2600.00	1246.98	-2.09
chdf9	1	1	-1030.00	172.59	-5.97
chdf10	1	1	-127.00	1500.17	-0.08
chdf11	1	1	-118.00	1377.27	-0.09
chdf12	1	1	-224.00	1164.98	-0.19
chdf13	1	1	-212.00	1278.36	-0.17
chdf14	1	1	-193.00	553.42	-0.35
chdf15	1	1	-69.60	344.56	-0.20
chdf16	1	1	-25.00	1127.81	-0.02
chdf17	1	1	-351.00	936.65	-0.37
chdf18	1	1	-3370.00	2834.93	-1.19
chdf19	1	1	-309.00	250.04	-1.24
chdf20	1	1	-3580.00	1457.43	-2.46
chdf22	1	1	-6890.00	3801.06	-1.81
chdf23	1	1	-201.00	522.80	-0.38
chdf24	1	1	-2530.00	2992.74	-0.85
chdf25	1	1	-3680.00	1535.17	-2.40
chdf26	1	1	-1200.00	512.45	-2.34
chdf27	1	1	-1510.00	1373.25	-1.10
chdf28	1	1	-5090.00	2087.82	-2.44
chdf29	1	1	-8580.00	3190.60	-2.69
chdf31	1	1	-6370.00	7608.03	-0.84
chdf32	1	1	-1560.00	1216.24	-1.28
chdf33	1	1	-4020.00	3149.55	-1.28
chdf34	1	1	-3490.00	1284.11	-2.72
chdf35	1	1	-2030.00	575.16	-3.53
chdf36	1	1	-2580.00	994.39	-2.59
chdf38	1	1	-2520.00	784.50	-3.21
chdf39	1	1	-1170.00	261.84	-4.47
chdf40	1	1	-6800.00	8316.59	-0.82
chdf58	1	1	-4910.00	2476.17	-1.98
chdf64	1	1	-1555.91	500.02	-3.11
chdf65	1	1	-3467.00	1017.77	-3.41
chdf66	1	1	-343.57	393.69	-0.87
chdf67	1	1	-2789.00	1107.42	-2.52
chdf68	1	1	-1603.74	840.42	-1.91
TOTAL			**-397 323**		