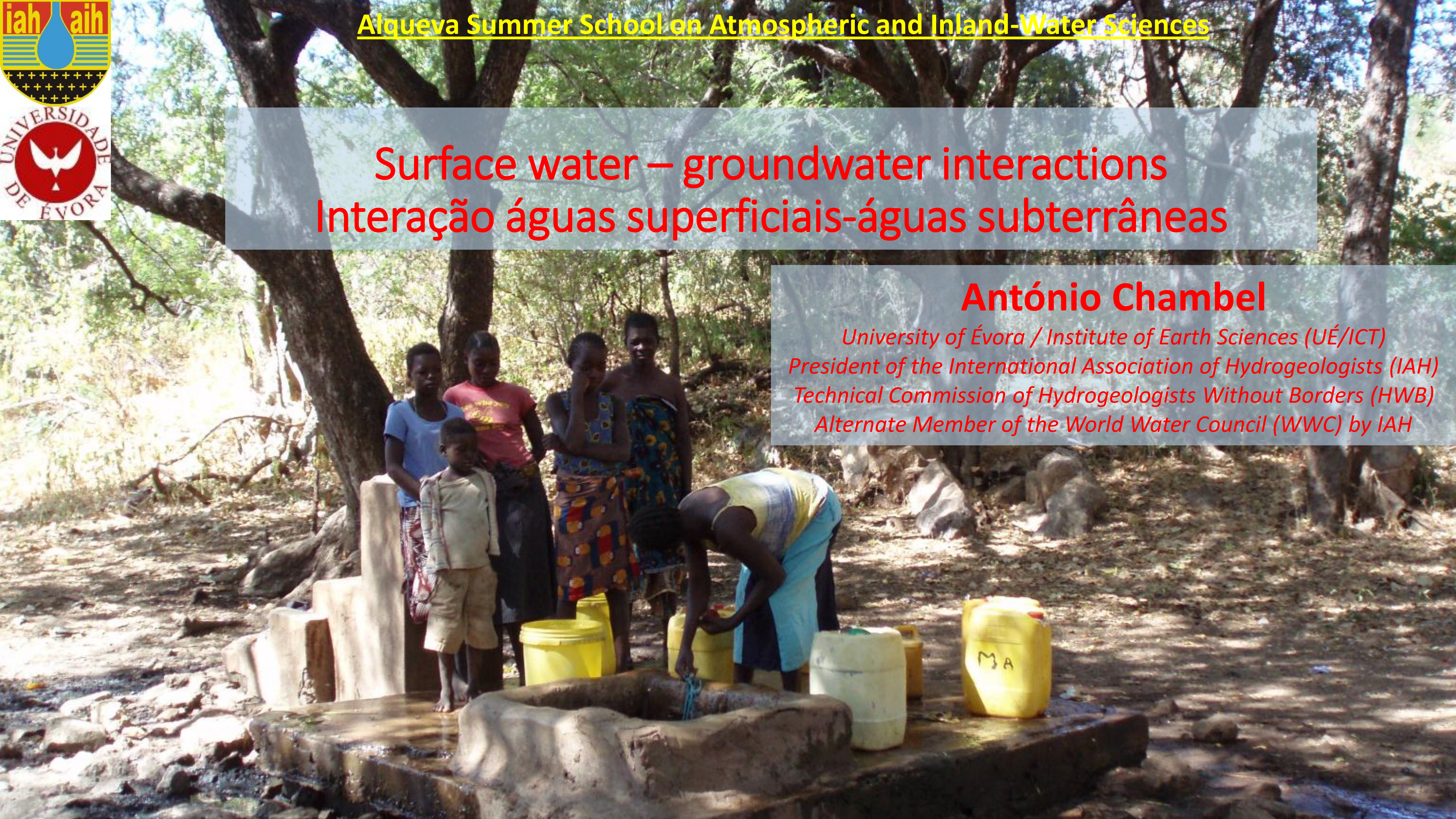


Alqueva Summer School on Atmospheric and Inland-Water Sciences

Surface water – groundwater interactions
Interação águas superficiais-águas subterrâneas

António Chambel

University of Évora / Institute of Earth Sciences (UÉ/ICT)
President of the International Association of Hydrogeologists (IAH)
Technical Commission of Hydrogeologists Without Borders (HWB)
Alternate Member of the World Water Council (WWC) by IAH

HIDROGEOLOGIA

AQUÍFEROS

Formação hidrogeológica permeável que permite o escoamento da água subterrânea. Trata-se de um sistema hidrológico, hidrodinâmico. É identificado por cinco conjuntos de características quantificáveis:

- ✓Um reservatório, caracterizado pela sua configuração, dimensões e limites
- ✓Processos internos ou mecanismos hidrodinâmicos, hidroquímicos e hidrobiológicos
- ✓Sequência do ciclo da água, com interações com o ambiente
- ✓Variabilidade no espaço destas características
- ✓Condições de tempo, pois as medidas das caraterísticas variam com o tempo (quanto mais tempo um aquífero estiver sob observação, melhor se poderá conhecer e melhores poderão ser as previsões acerca do seu futuro)

Estas características podem ser representadas a três dimensões por blocos-diagrama ou a duas, através de perfis hidrogeológicos ou cartas hidrogeológicas.

António Chambel

António Chambel

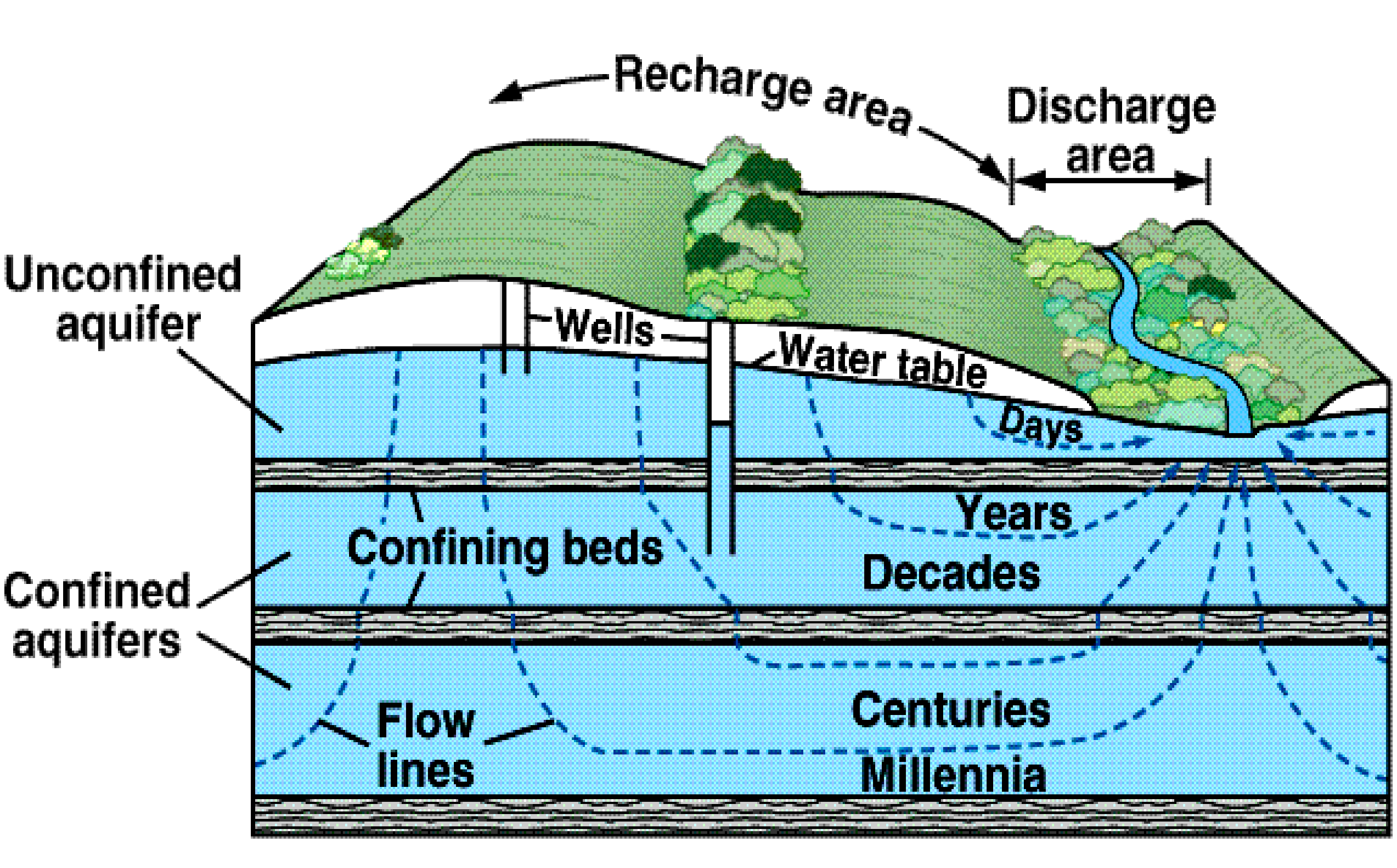
Que tipo de aquíferos existem e como circula a água em cada um desses tipos?

Depósitos de raña, Cabo, África do Sul
Novembro 2000, Foto: J. Duque

Xistos, Mértola, Portugal
Março 2004, Foto: A. Chambel

Labské pískovce, Rep. Checa
Outubro 2005, Foto: A. Chambel

AQUÍFEROS LIVRES E CONFINADOS



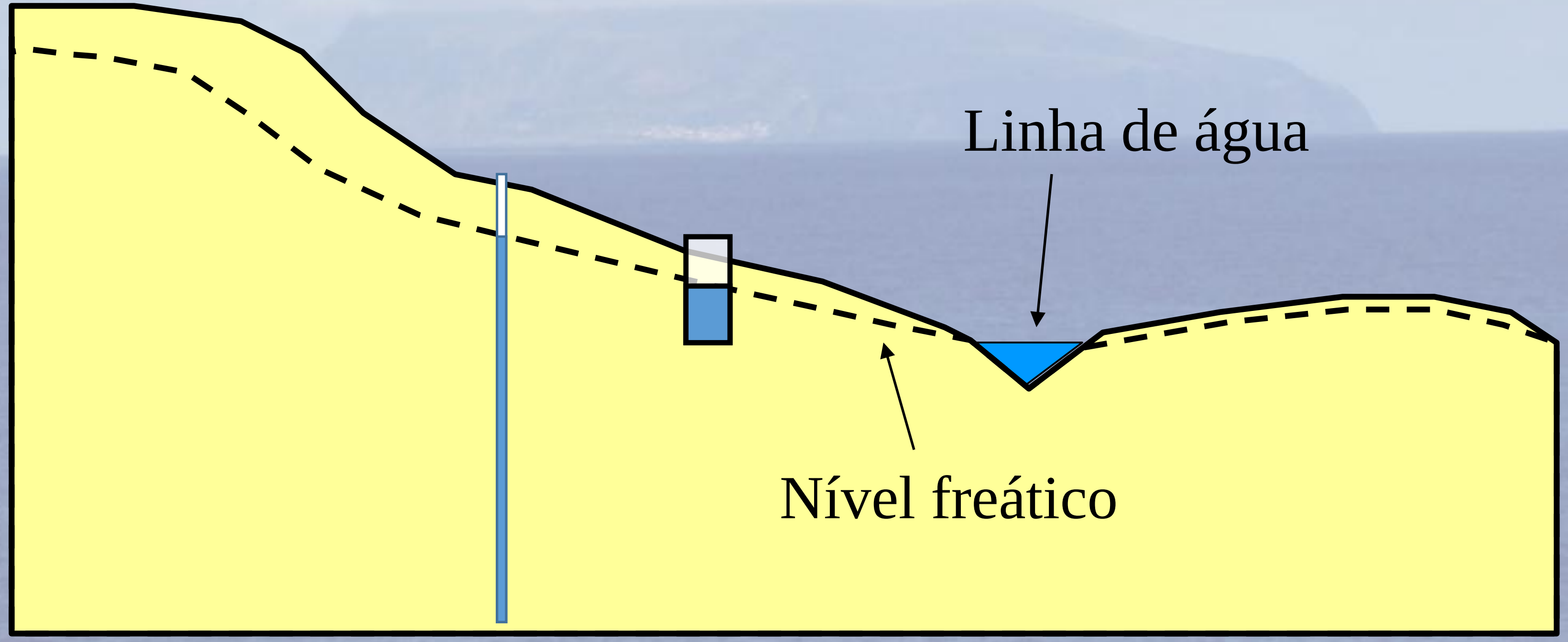
António Chambel

António Chambel

Relação água subterrânea/água superficial

Nível freático

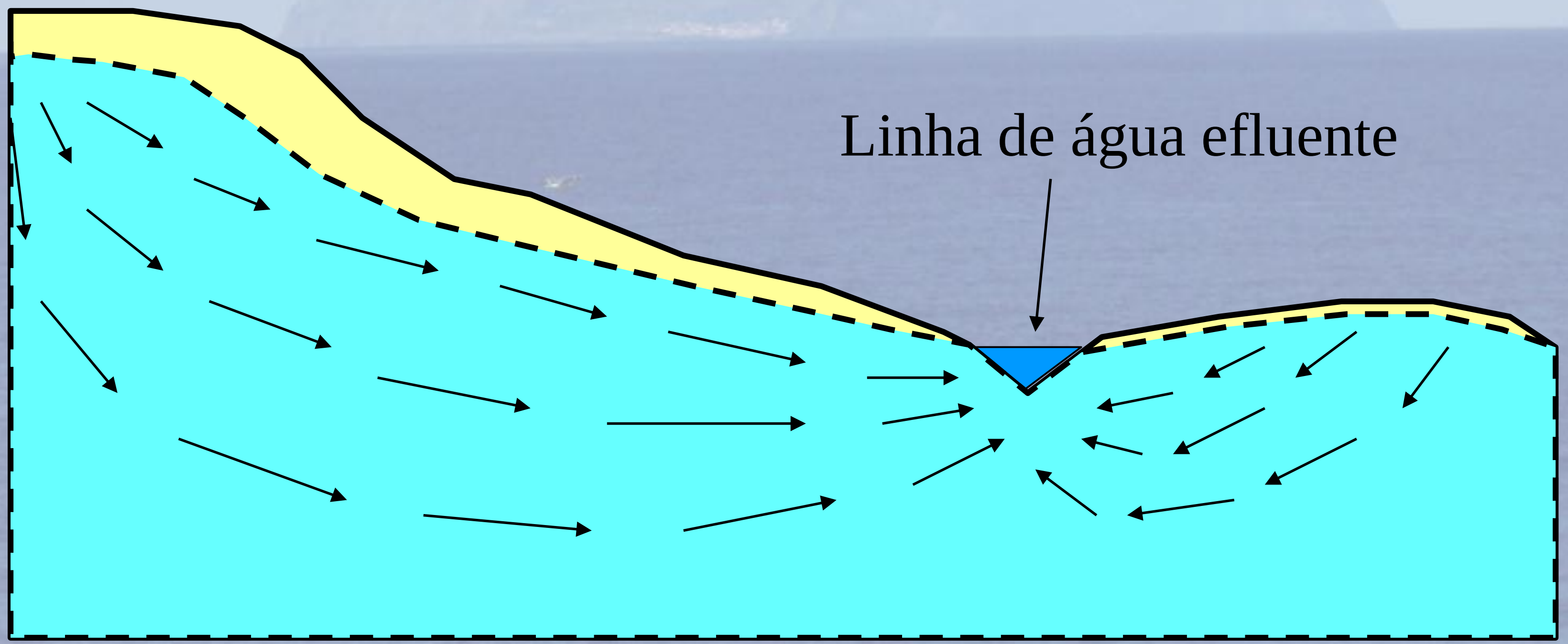
- Segue a inclinação topográfica
- Encontra a superfície nas zonas baixas



António Chambel

Fluxo de água subterrânea

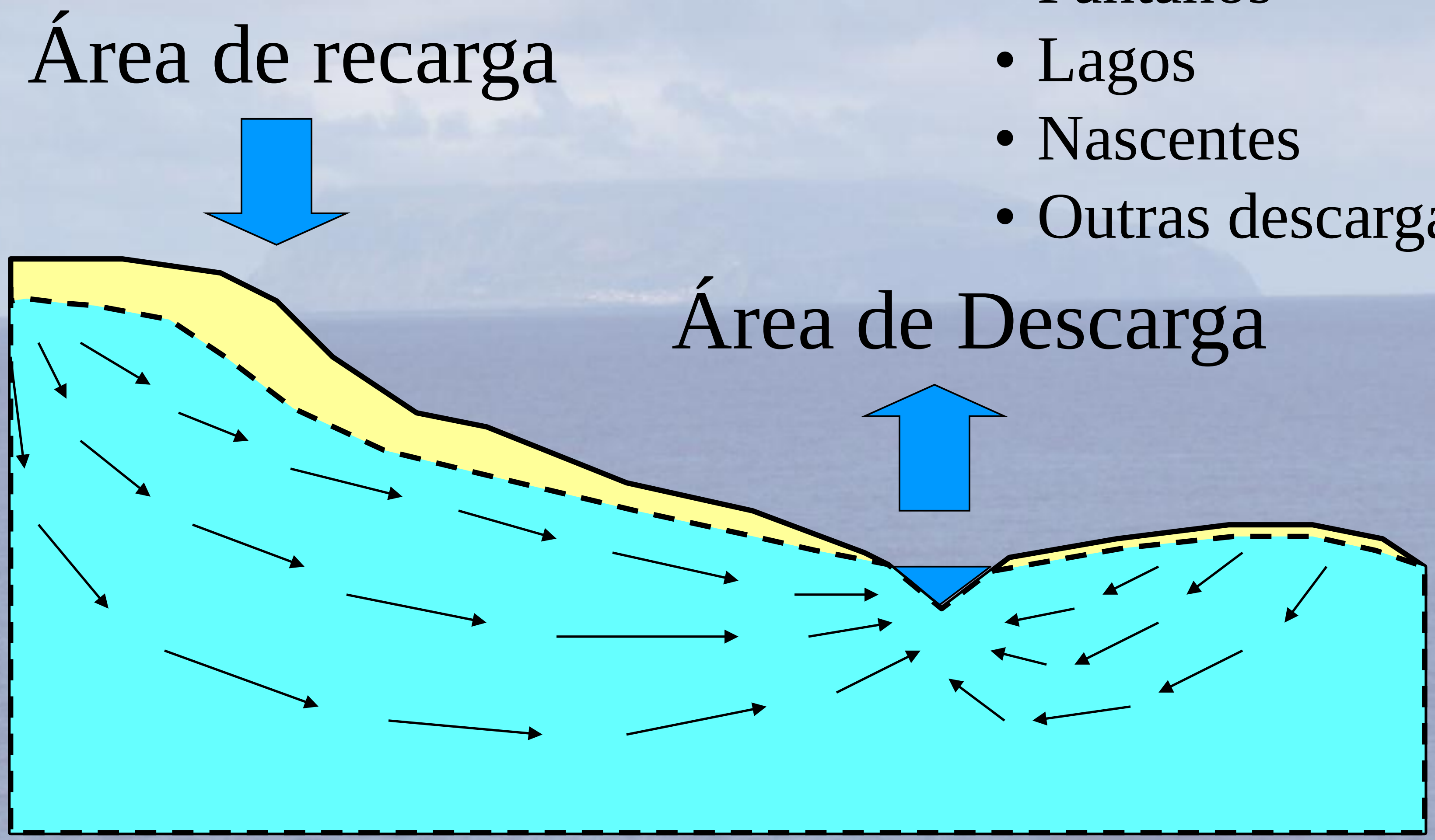
- Fluxo das zonas mais elevadas para as mais baixas
- Fluxo subterrâneo atinge a superfície em linhas de água = descarga
- Fluxo de base = água subterrânea abastece as linhas de água
- Linha de água efluente = alimentada por água subterrânea



António Chambel

Fluxo de água subterrânea

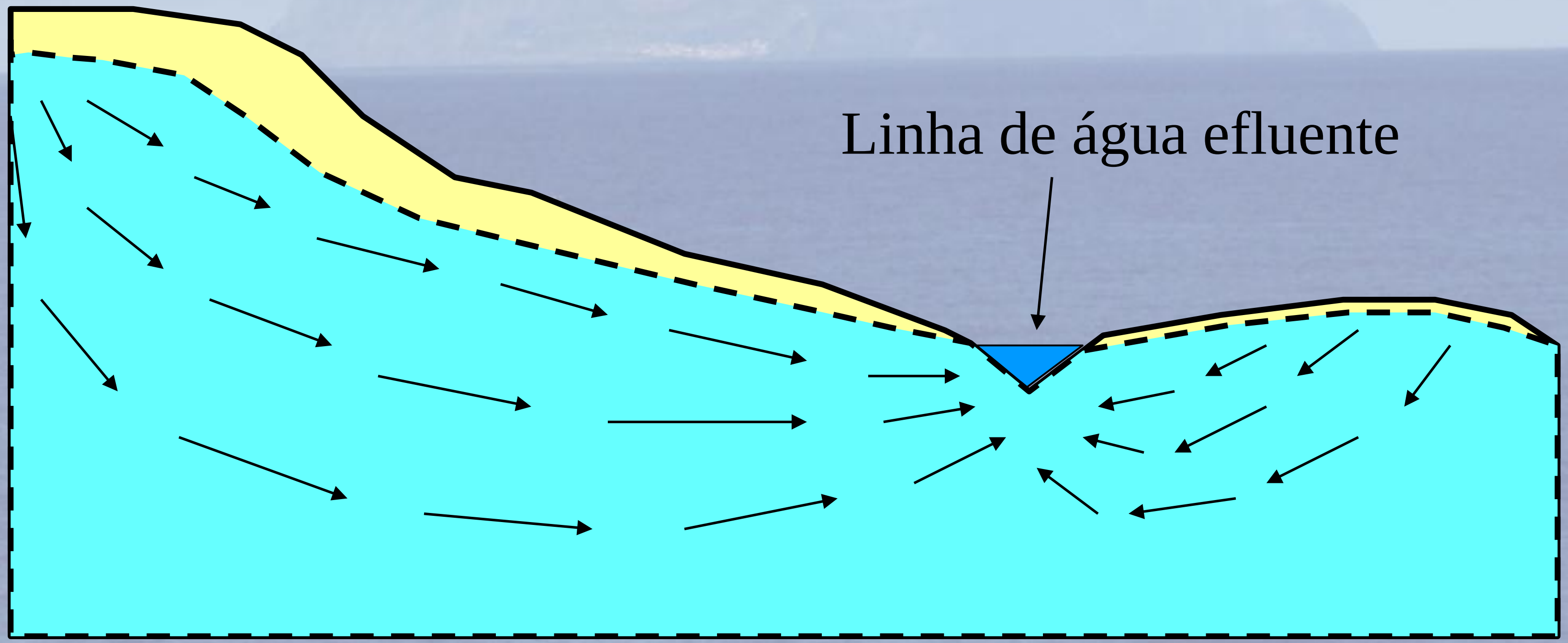
- Linhas de água
- Pântanos
- Lagos
- Nascentes
- Outras descargas



António Chambel

Secas

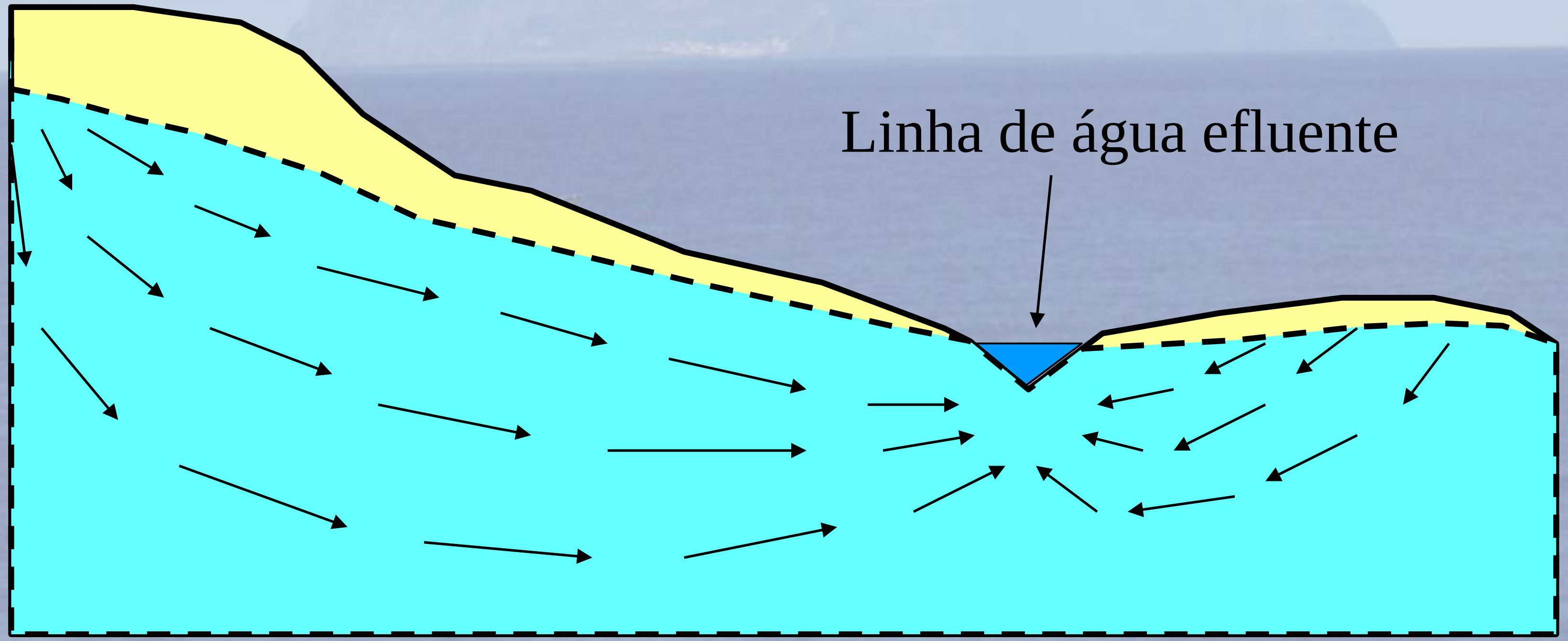
- A água já não se infiltra a partir da superfície
- O fluxo subterrâneo continua
- O nível da água subterrânea decresce



António Chambel

Secas

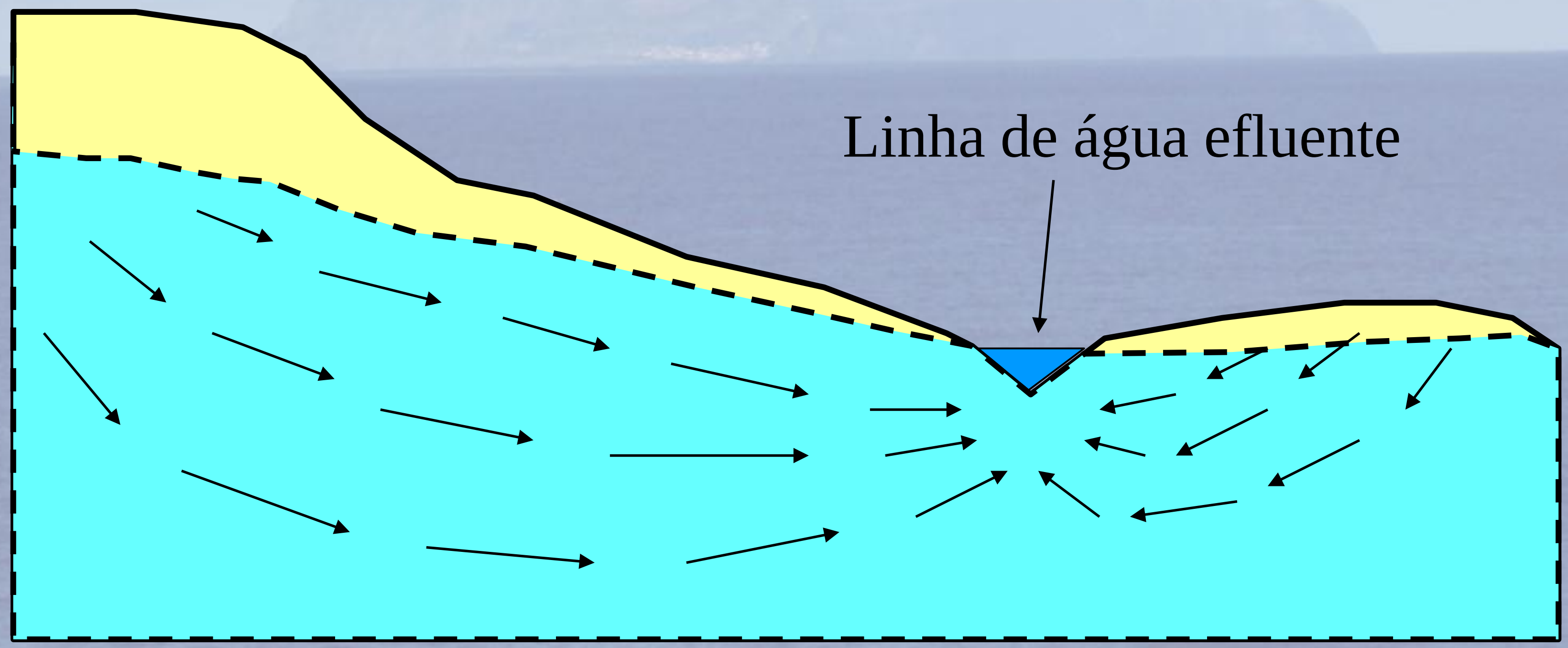
- A água já não se infiltra a partir da superfície
- O fluxo subterrâneo continua
- O nível da água subterrânea decresce



António Chambel

Secas

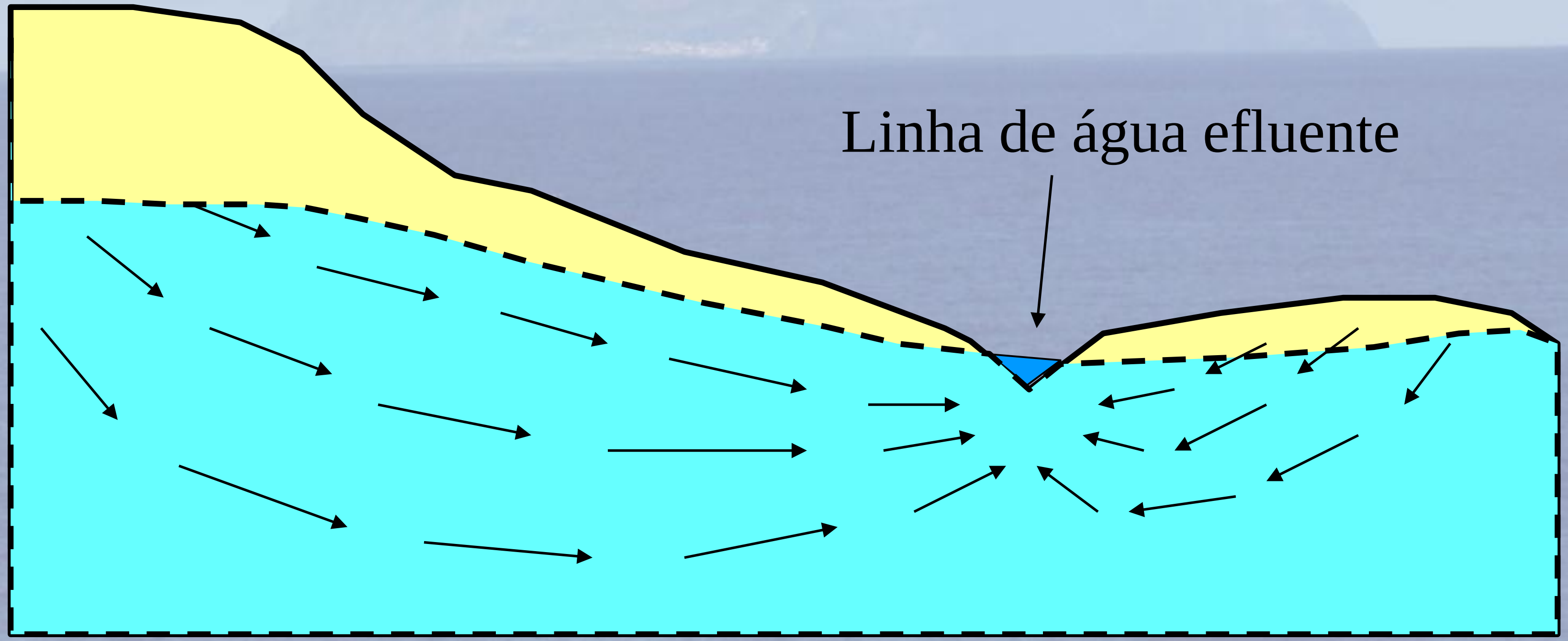
- A água já não se infiltra a partir da superfície
- O fluxo subterrâneo continua
- O nível da água subterrânea decresce



António Chambel

Secas

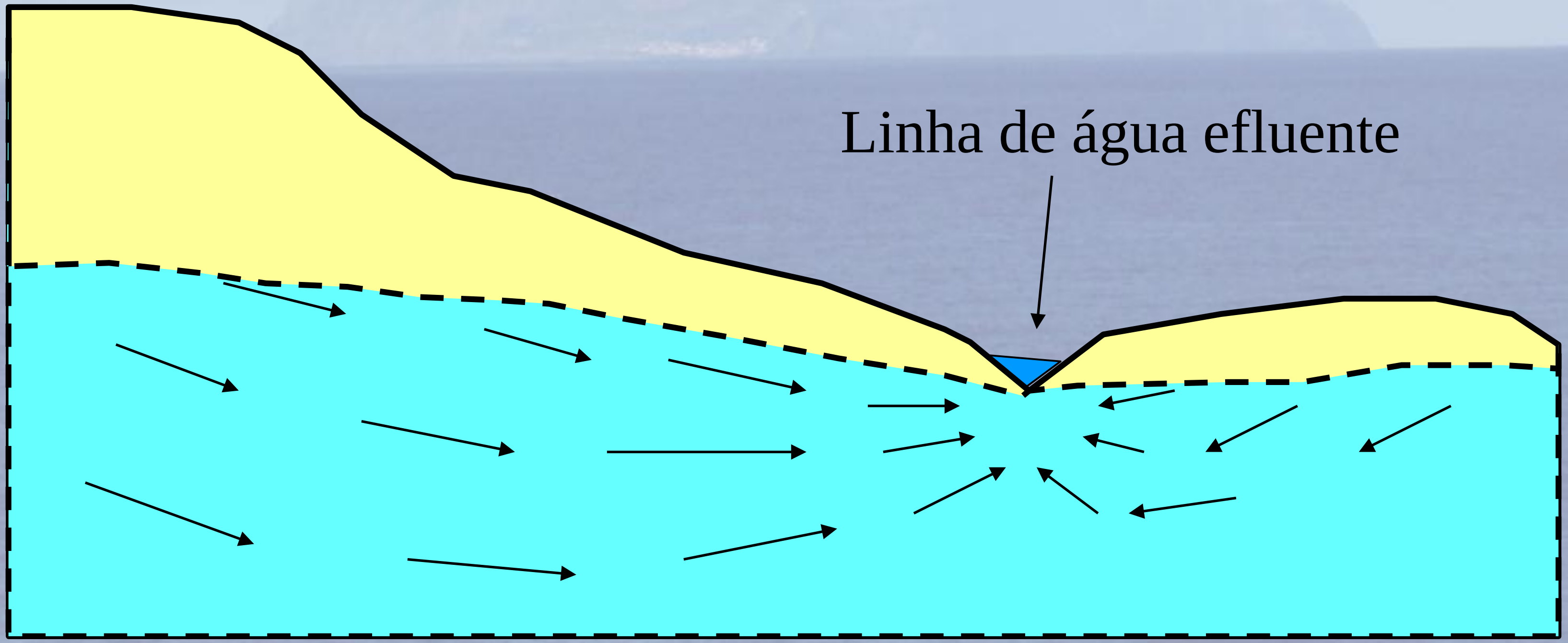
- A água já não se infiltra a partir da superfície
- O fluxo subterrâneo continua
- O nível da água subterrânea decresce



António Chambel

Secas

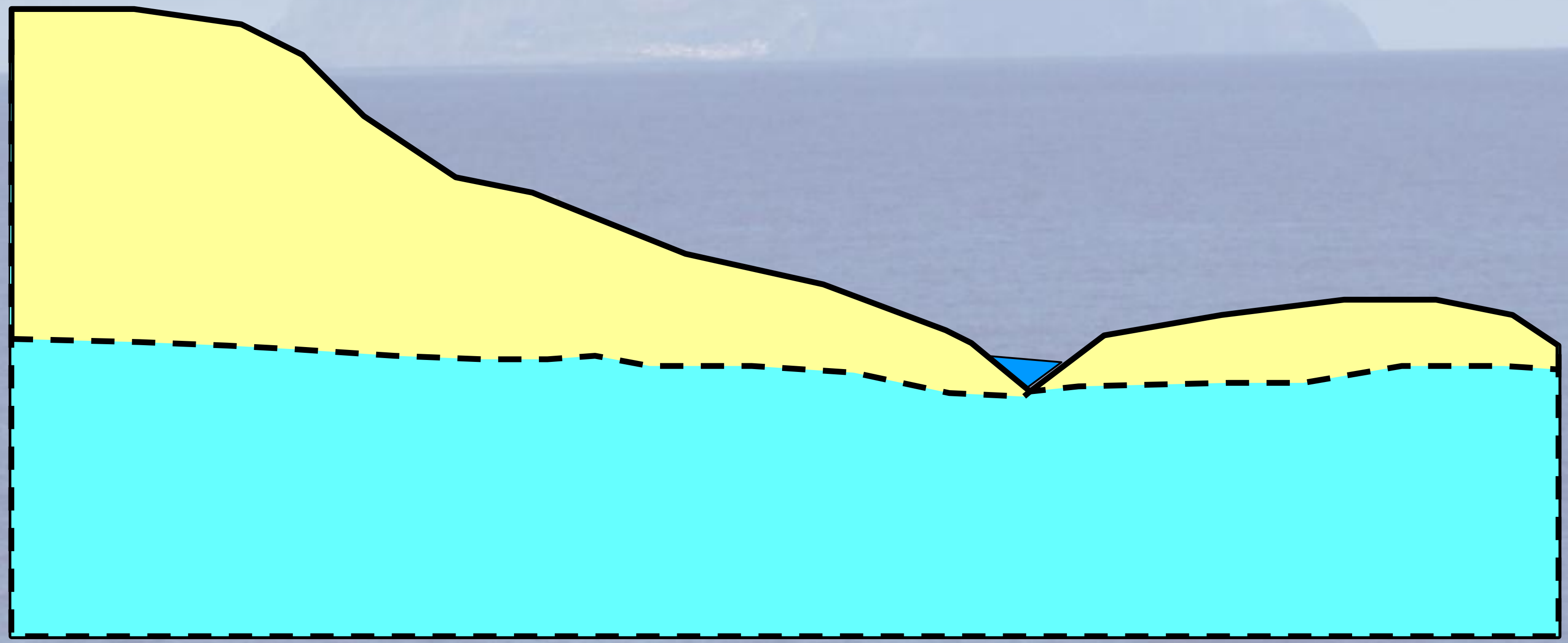
- A água já não se infiltra a partir da superfície
- O fluxo subterrâneo continua
- O nível da água subterrânea decresce



António Chambel

Secas

- A água já não se infiltra a partir da superfície
- O fluxo subterrâneo pára
- O nível freático estabiliza

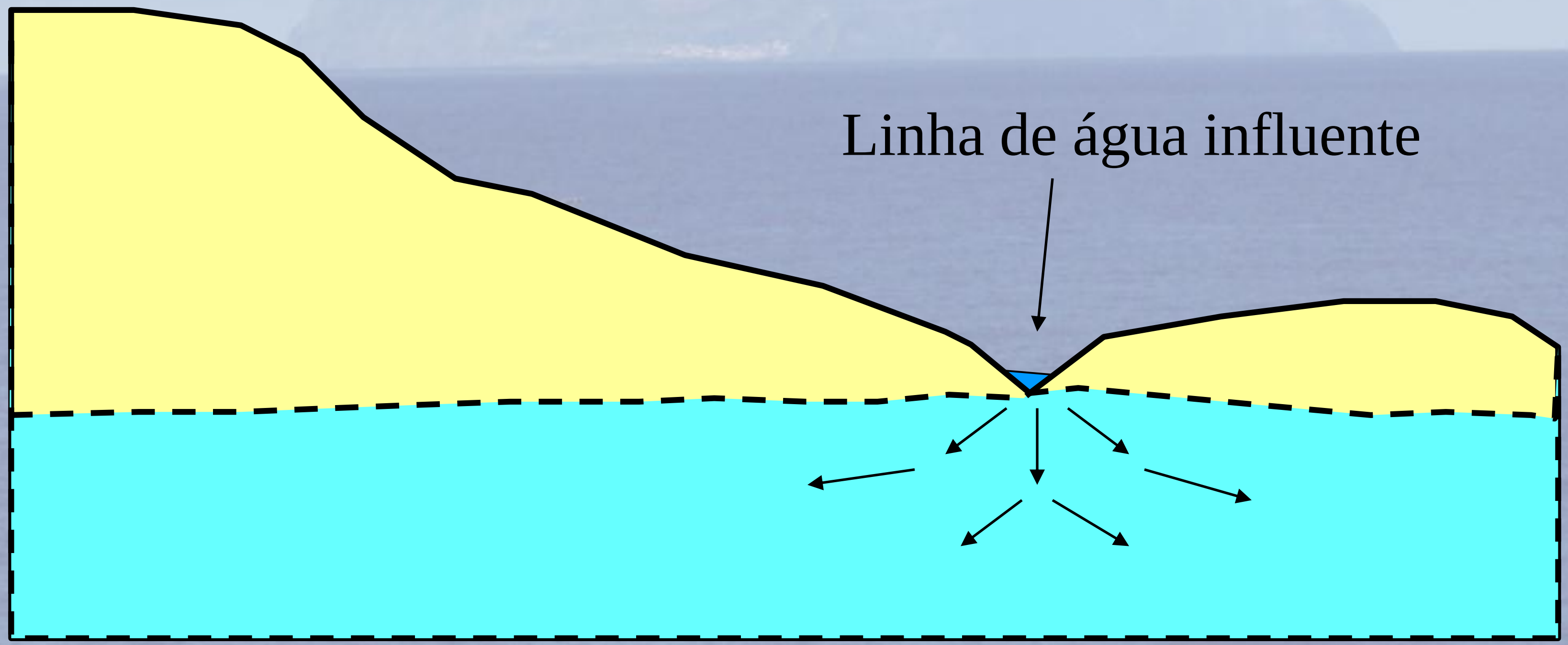


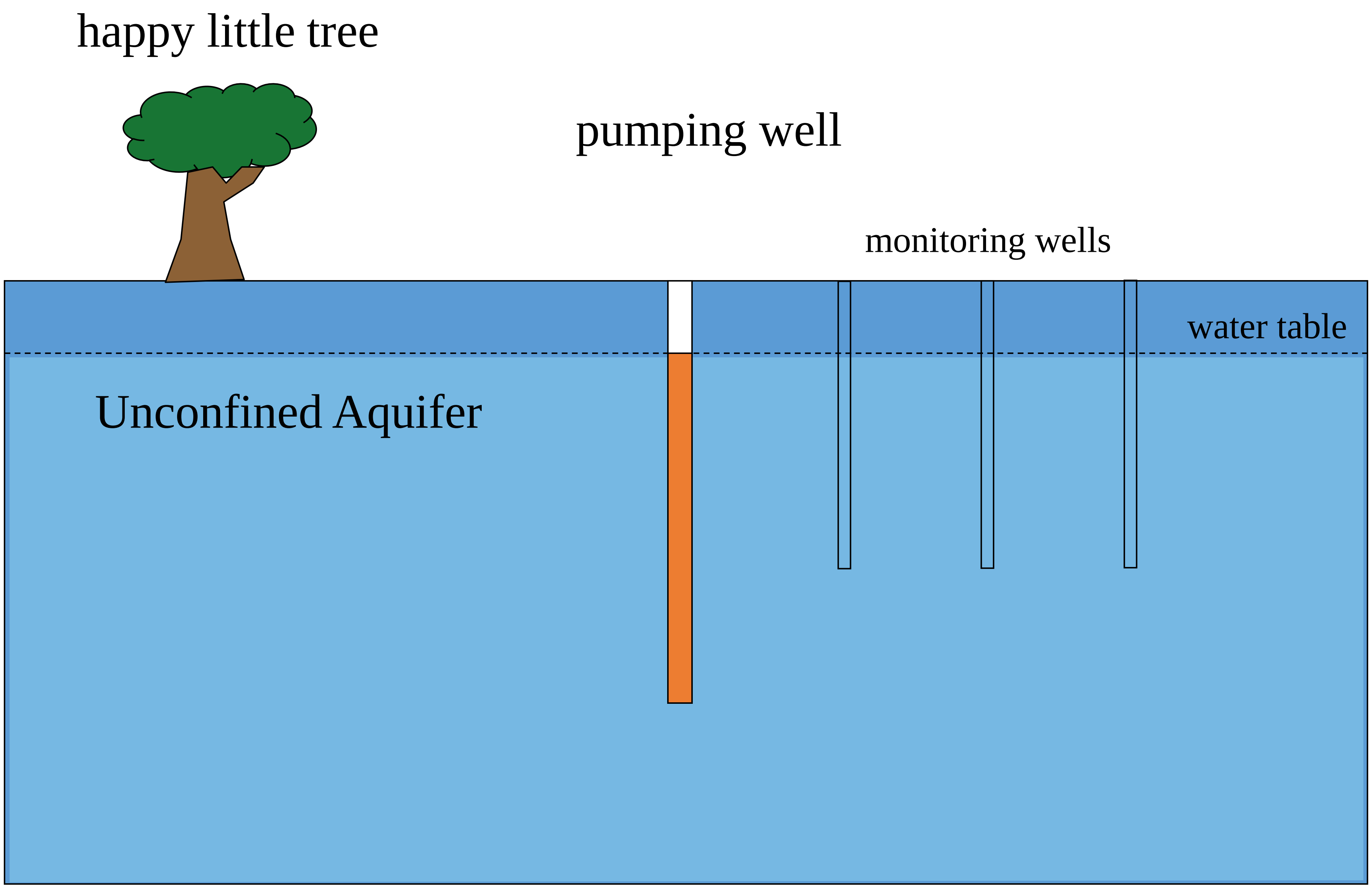
António Chambel

António Chambel

Secas

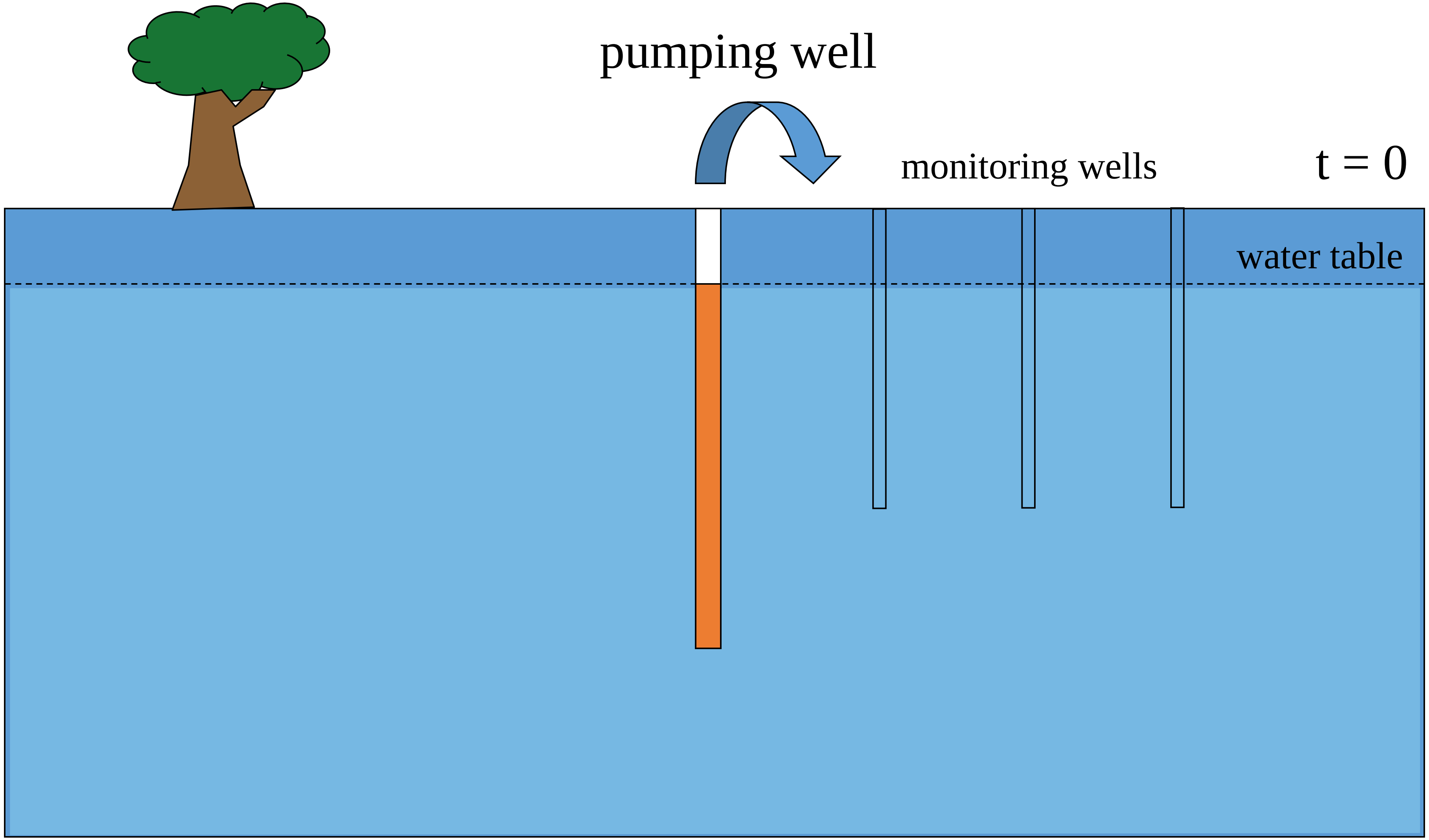
- A água já não se infiltra a partir da superfície
- O fluxo subterrâneo reverte-se
- A linha de água torna-se influente e seca

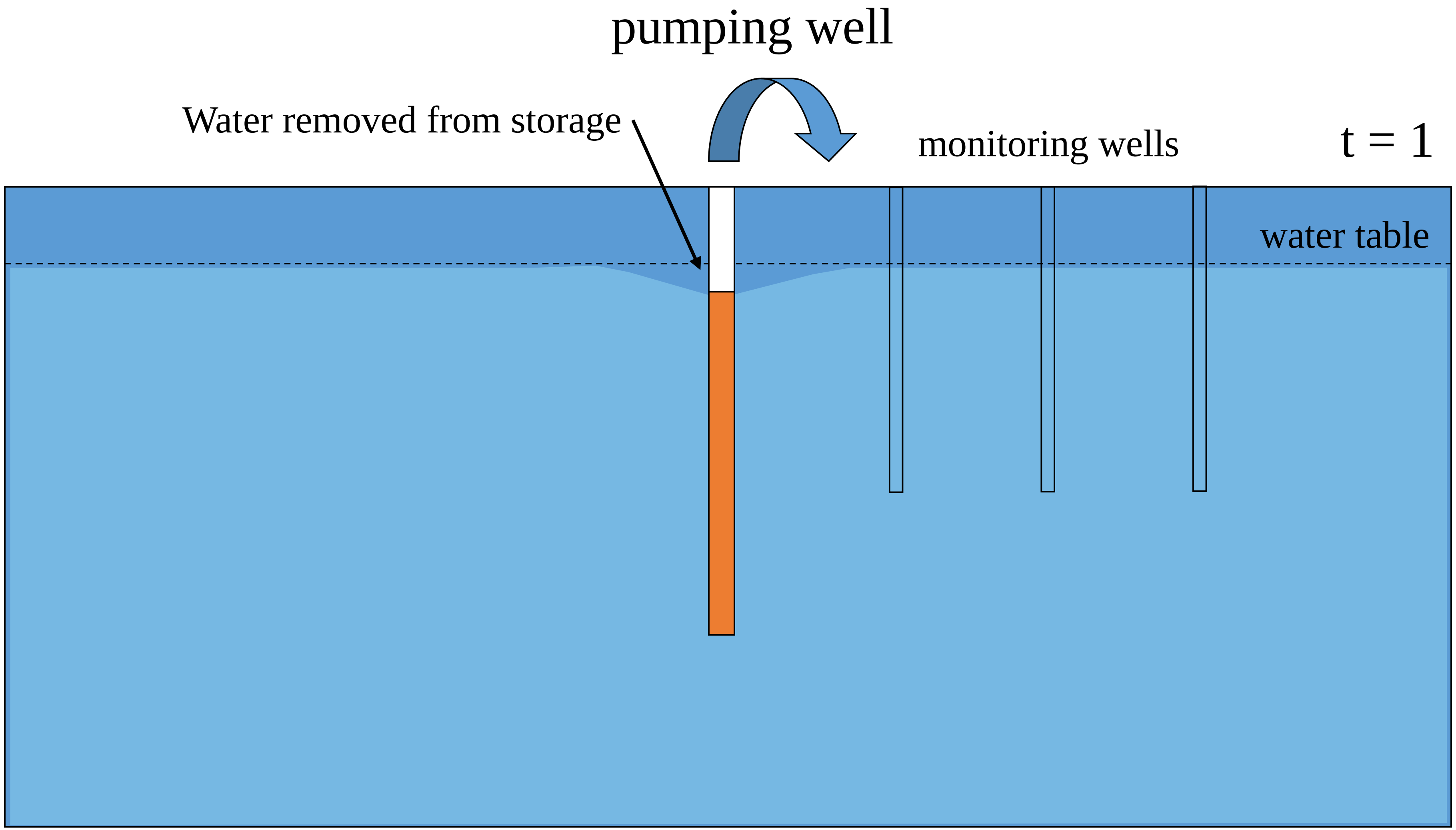


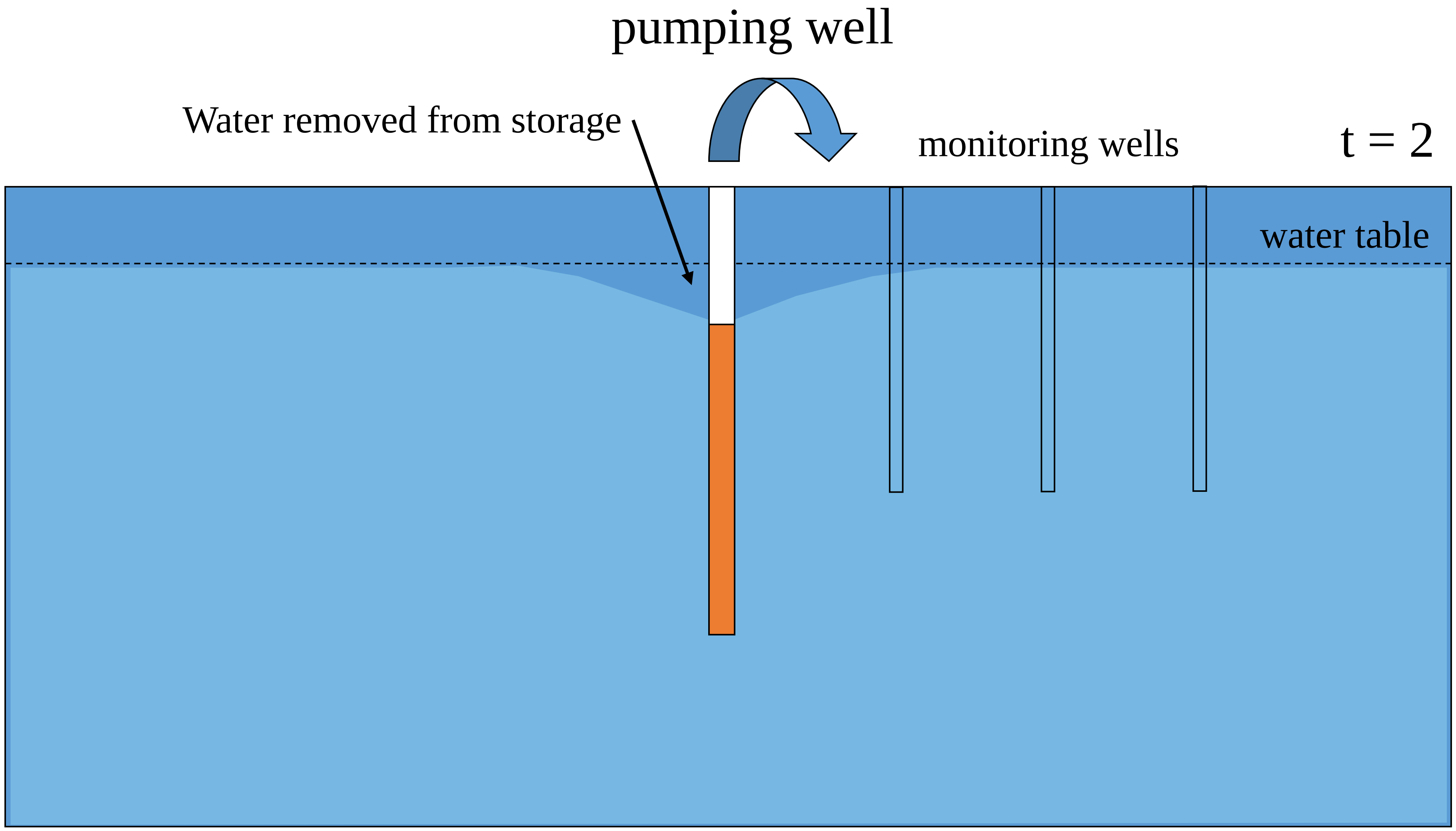


António Chambel

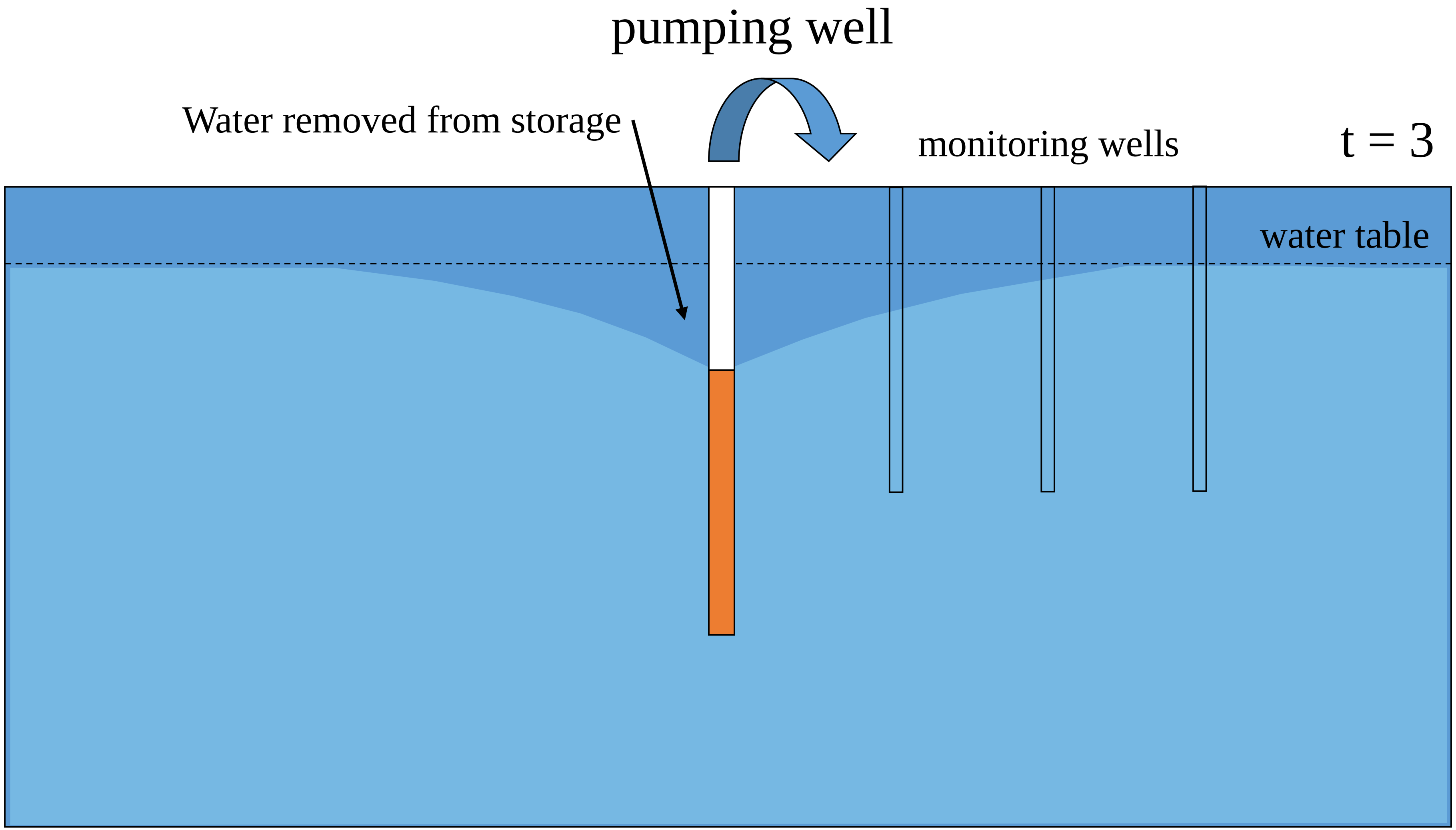
António Chambel



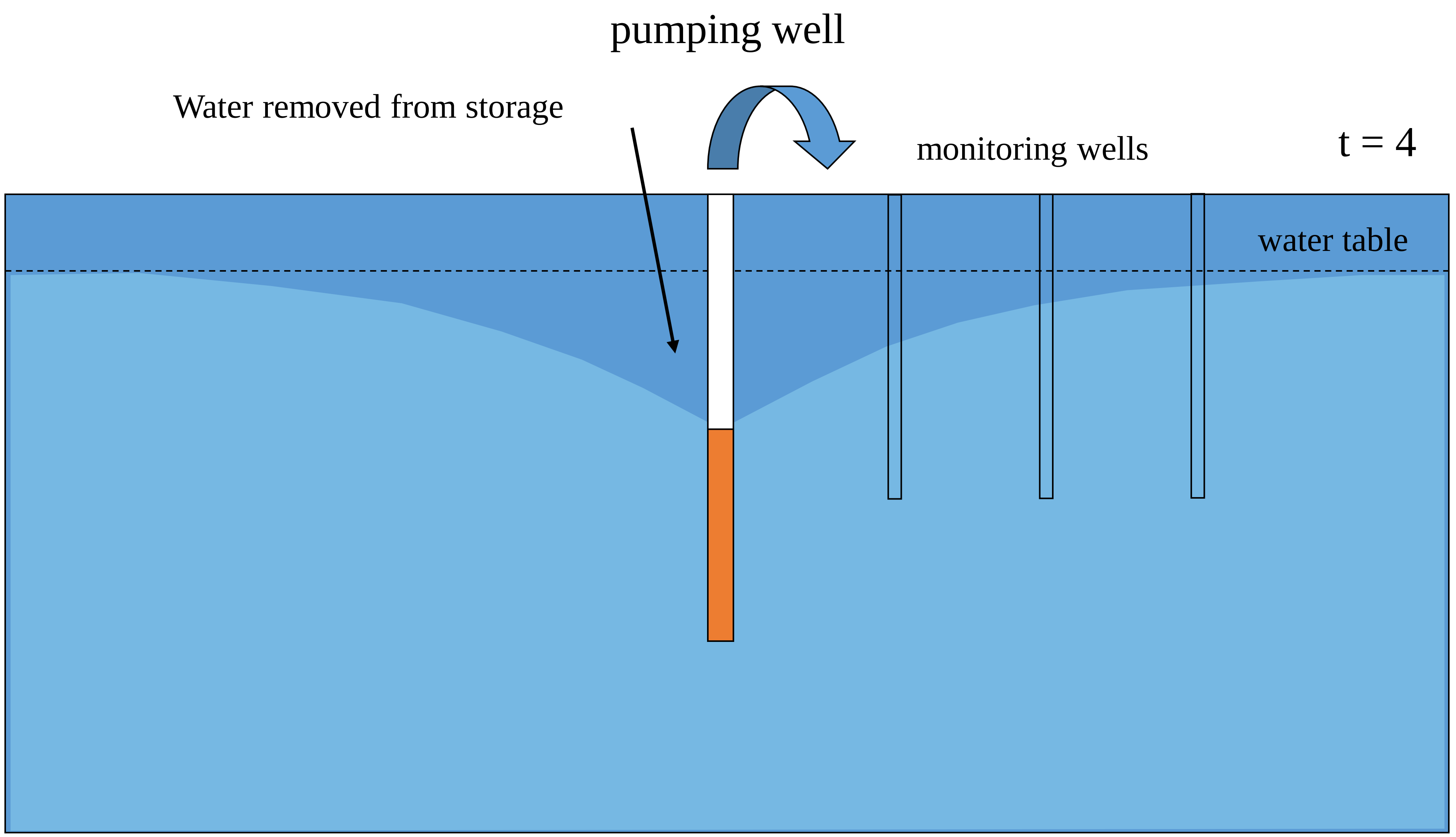

pumping well
Water removed from storage
monitoring wells
t = 1
water table

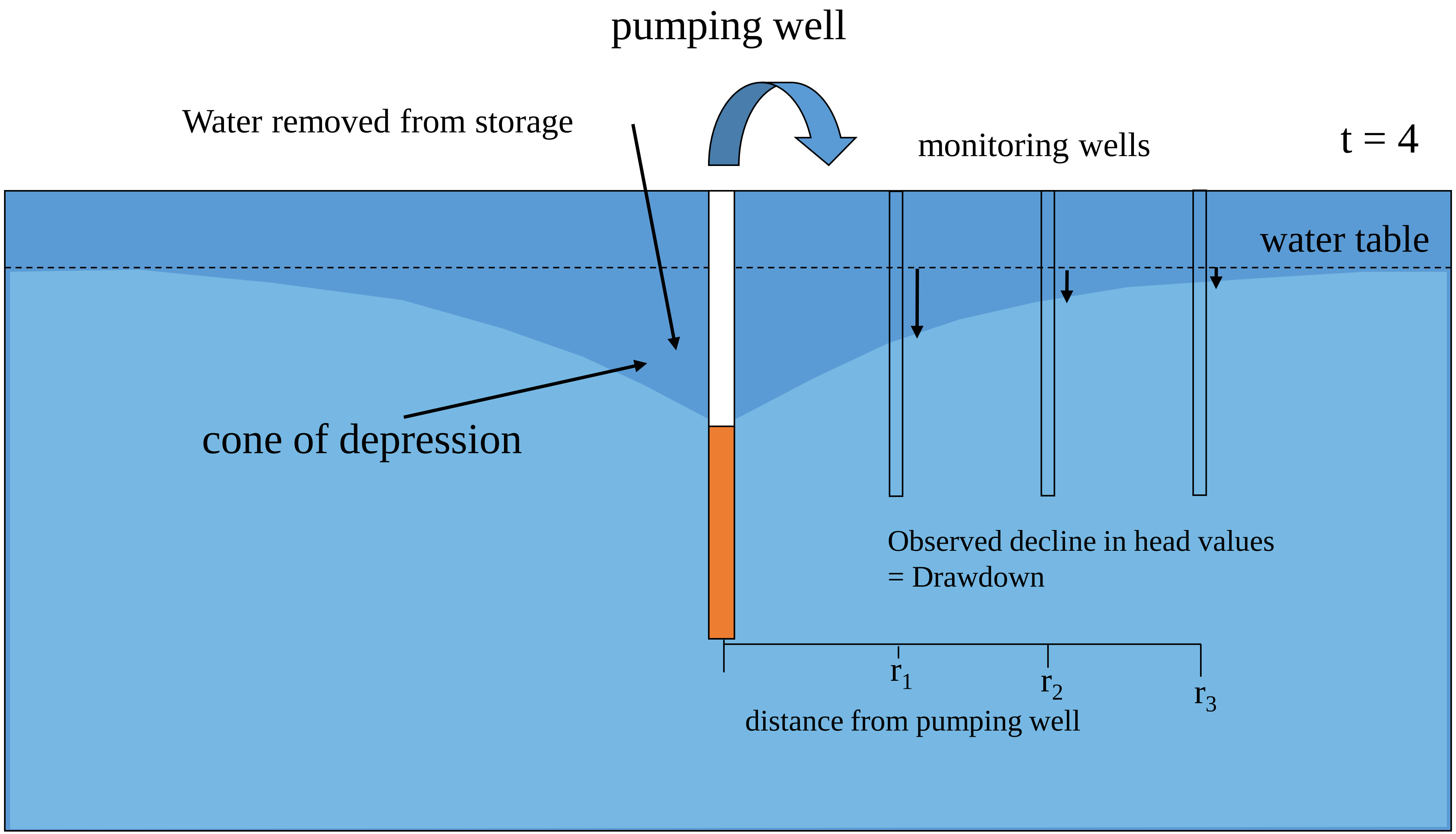


António Chambel



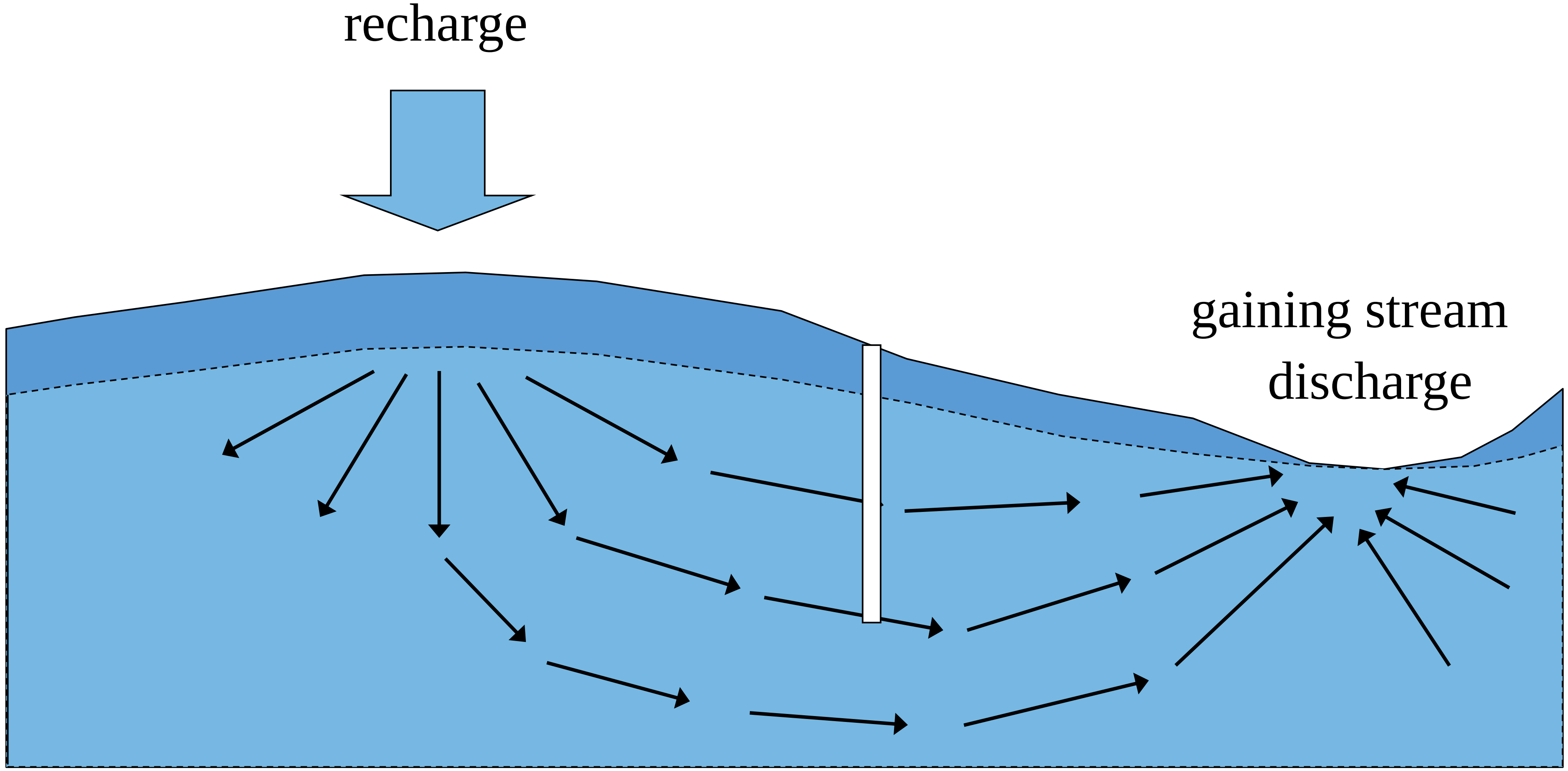
António Chambel


pumping well
Water removed from storage
monitoring wells
t = 4
water table



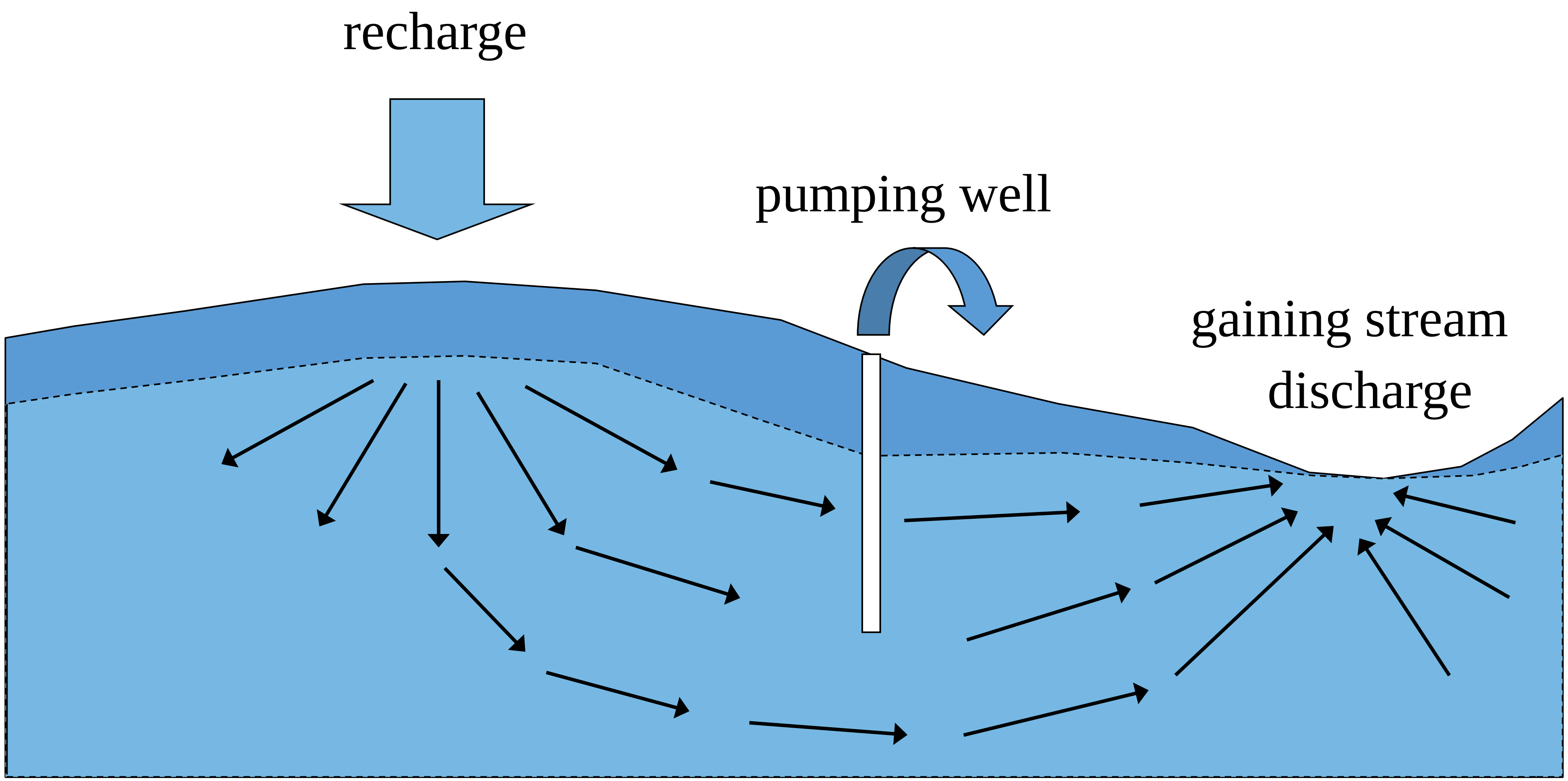
António Chambel

prior to pumping



António Chambel

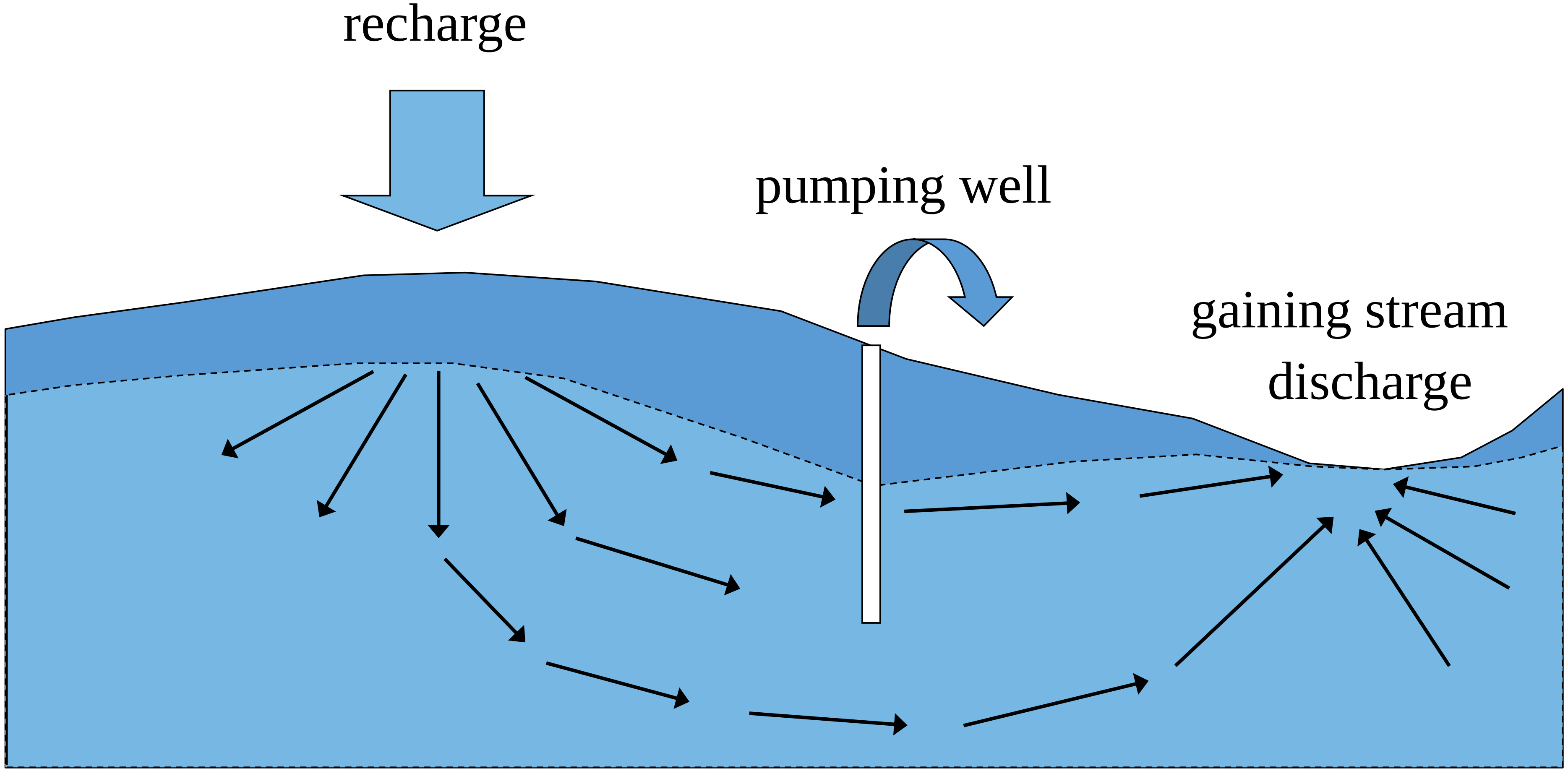
Pumping and growth of cone of depression



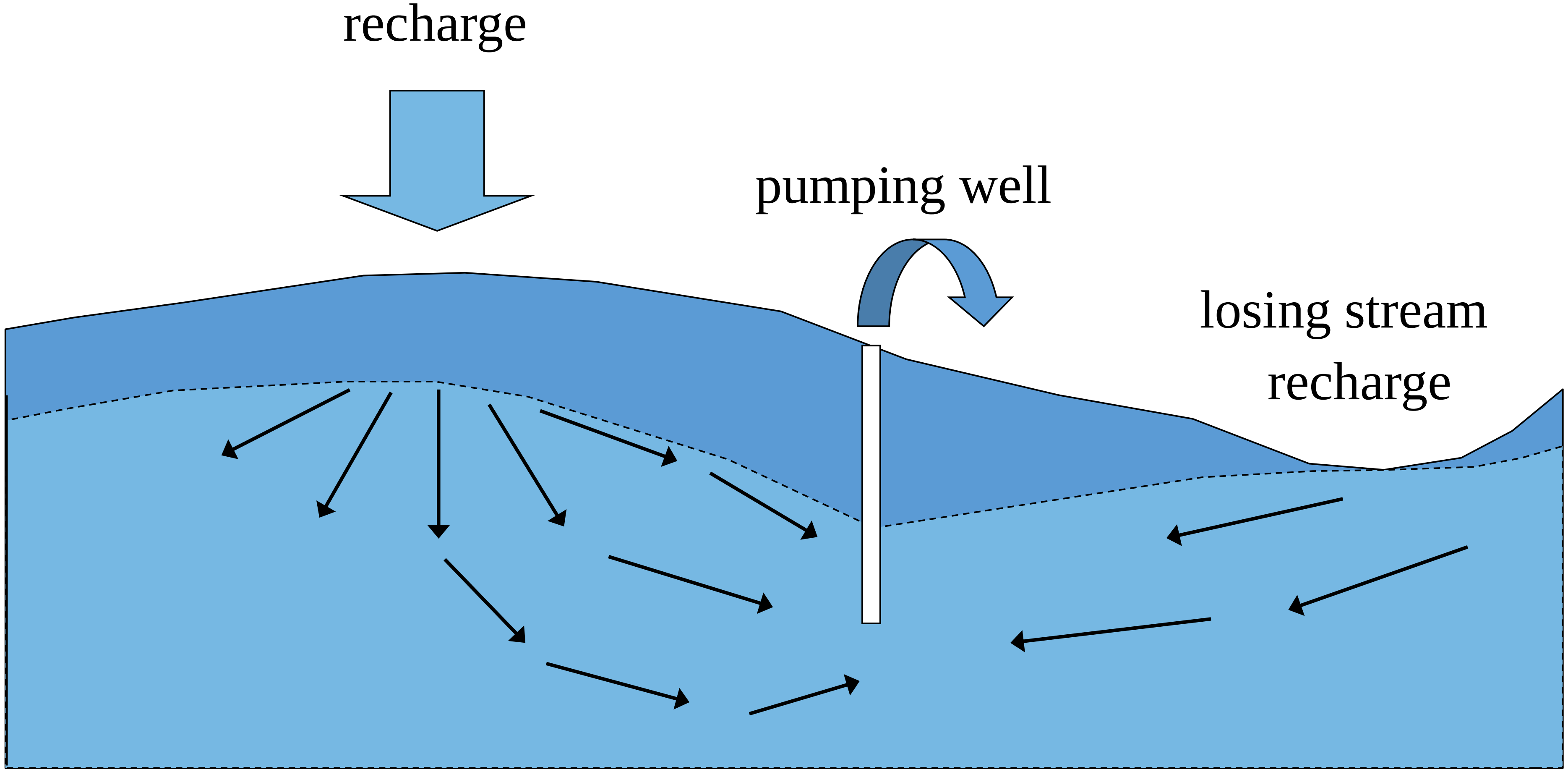
António Chambel

António Chambel

Pumping and growth of cone of depression



Cone of depression stabilizes: flow to well derived from additional recharge, not storage.

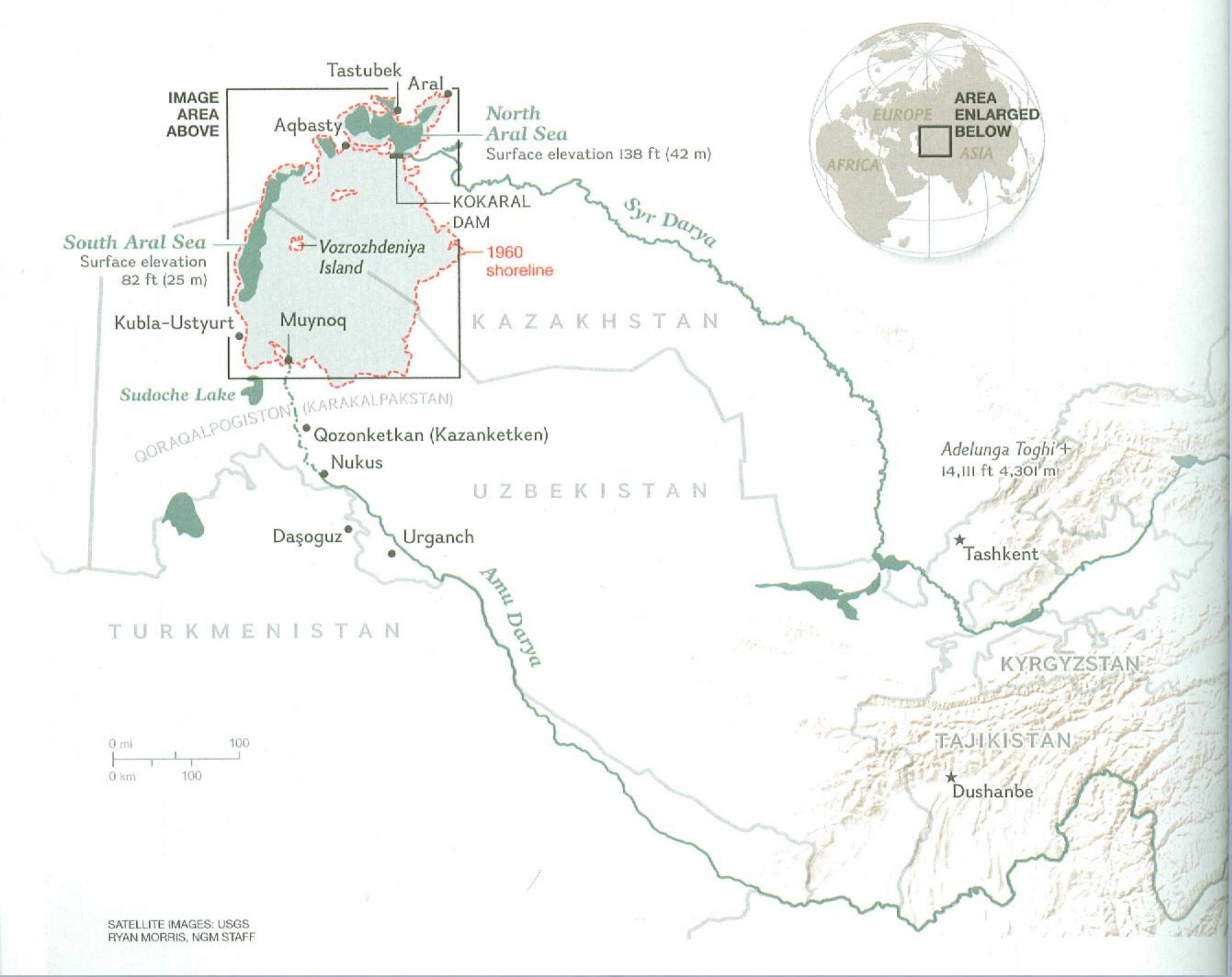


António Chambel

ALGUNS PROBLEMAS RELACIONADOS COM ÁGUAS SUBTERRÂNEAS NO MUNDO

António Chambel

Lago (ou Mar) Aral

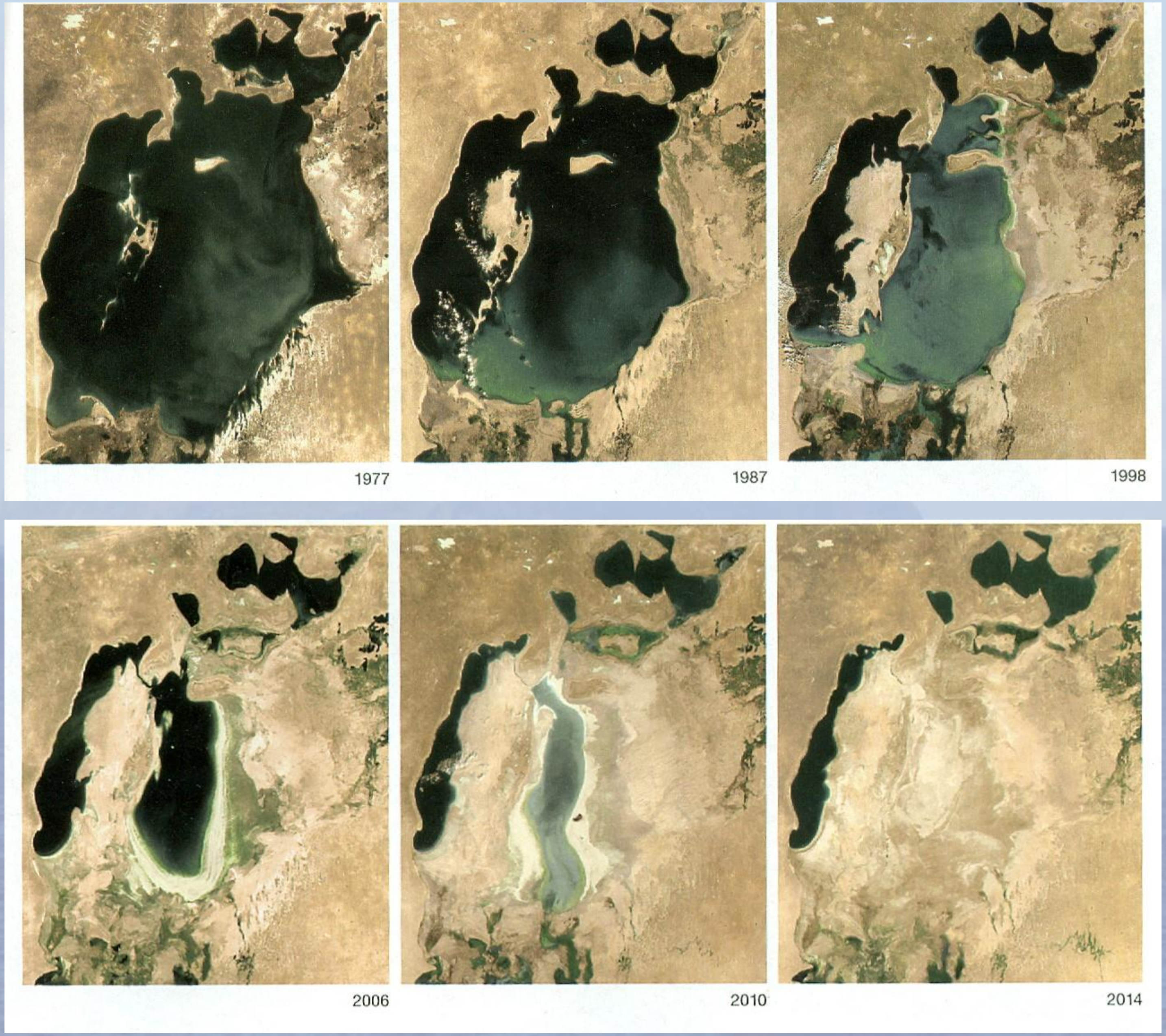


National Geographic June 2015

António Chambel

António Chambel

Lago (ou Mar) Aral



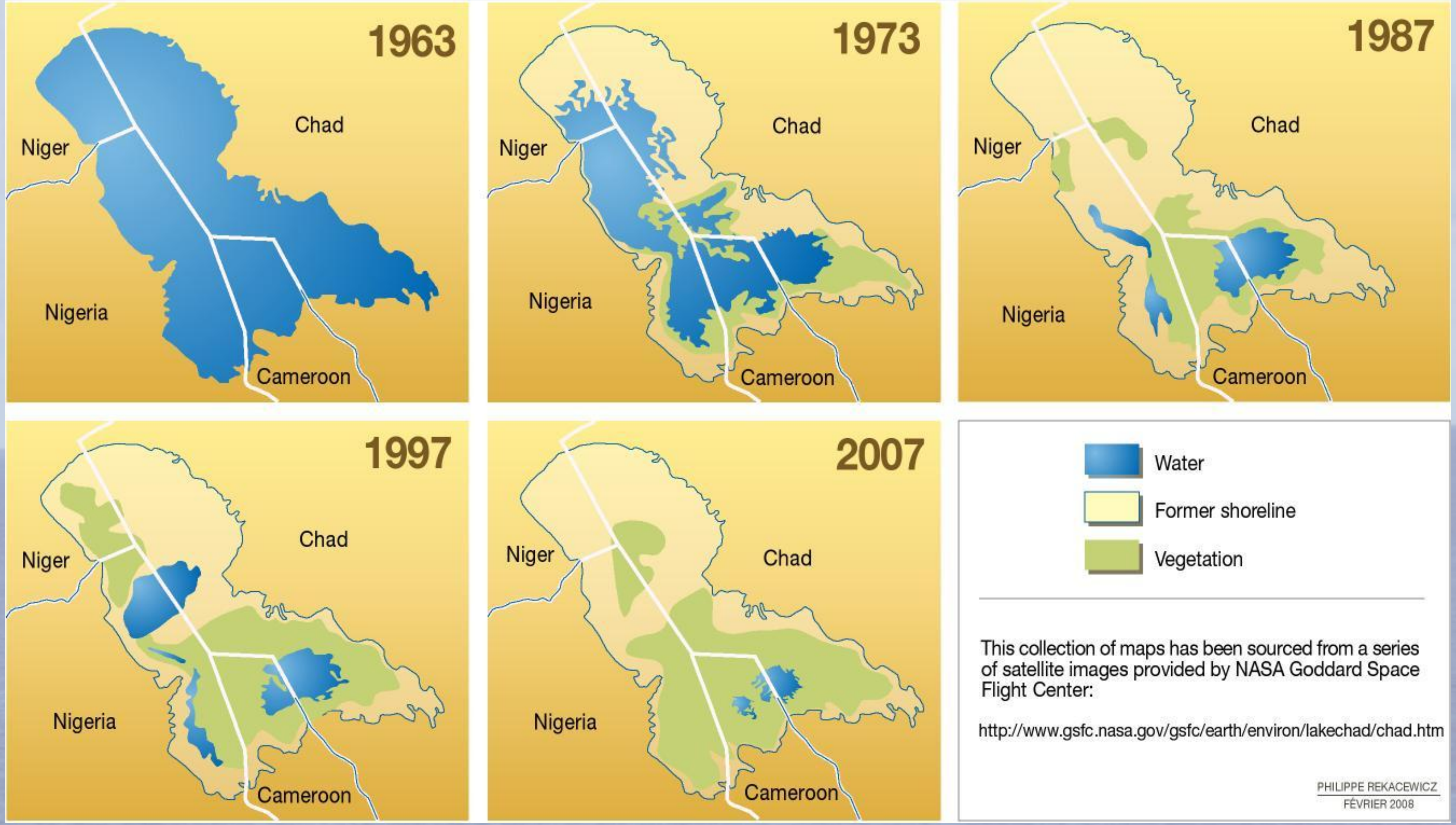
National Geographic June 2015

Lago (ou Mar) Aral

National Geographic June 2015

António Chambel

Lago Chade



http://www.unep.org/dewa/vitalwater/article116.html

António Chambel

António Chambel

Lago Chade

Since 1963, the lake has shrunk to nearly a twentieth of its original size, due both to climatic changes and to high demands for agricultural water. Since 1963, the surface area of Lake Chad has decreased from approximately 25,000 km^2 to 1,350 km^2 (Scientific American, 2001).

The changes in the lake have contributed to local lack of water, crop failures, livestock deaths, collapsed fisheries, soil salinity, and increasing poverty throughout the region:

- **Between June 1966 and January 1973, the surface area of Lake Chad shrunk from 22,772 km^2 to 15,400 km^2.**
- **In 1982, the lake's surface area was estimated to be about 2,276 km^2. In February 1994, Meteosat images measured it at just 1,756 km^2.**
- Between 1953 and 1979, irrigation had only a modest impact on the Lake Chad ecosystem. But between 1983 and 1994 irrigation had increased four-fold.
- **About 50% of the decrease in the lake's size since the 1960s is attributed to human water use, with the remainder attributed to shifting climate patterns.**

Invasive plant species currently cover about 50% of the remaining surface of Lake Chad. Research carried out over the past 40 years indicates that the main factors in the shrinking of the lake have been:

- **Major overgrazing** in the region (Coe and Foley, 2001), resulting in a loss of vegetation and serious deforestation, contributing to a drier climate.
- **Large and unsustainable irrigation projects built by Niger, Nigeria, Cameroon and Chad**, which have diverted water from both the lake and the Chari and Logone rivers.

http://www.unep.org/dewa/vitalwater/article116.html

António Chambel

Bacia de Murray-Darling, SE da Austrália

http://www.abc.net.au/news/rural/specials/murray-darling-basin-plan/

154_Decades-of-drought-and-irrigation-excesses-starving-the-Murray-Darling-Photo-by-Anna-Maria

http://annamariacom.blogspot.com/2010/10/murray-darling-basin.html

Bacia de Murray-Darling, SE da Austrália

Blue Green Algae Swamp, Forbes NSW. Photo by Arthur Mostead.

A dying wetland, Coorong area SA, as the wetlands dries out salinity and sulfidic soils have become major issues. Photo by Arthur Mostead.

http://www.mdba.gov.au/about-basin/basin-environment/challenges-issues

Bacia de Murray-Darling, SE da Austrália

Threats to water quality in the Basin include:

Toxins: Blue-green algal blooms can generate algal toxins which can be a serious health risk to humans and livestock;

Salinity: In high concentrations, salt can affect ecosystem health, reduce drinking water quality and cause economic loss in irrigated agriculture;

Nutrients: High levels of nutrients can stimulate algal growth. Nutrients include phosphorus and nitrogen from agricultural activity, stormwater and erosion;

Turbidity: Matter suspended in water carries nutrients and reduces light penetration, which can affect aquatic plants and animals;

Temperature: Lower water temperatures due to the release of water from deeper layers held in dams during summer can damage downstream ecological communities. Higher temperatures resulting from lack of flow and/or from clearing of vegetation at the edges of rivers, creeks and lakes, may worsen an algal bloom;

Dissolved oxygen (Blackwater): Low levels of dissolved oxygen can occur when floodplains are inundated. Floodwaters flush organic matter such as leaves from floodplains to the river system. As they are flushed down the river they rapidly break down and release tannins and other compounds. The tannins and other compounds released during the breakdown of this organic material discolour the river water, making it appear blackish. This blackwater can sometimes become very low in dissolved oxygen, which can harm aquatic plants and animals.

http://www.mdba.gov.au/about-basin/basin-environment/challenges-issues

Bacia de Murray-Darling, SE da Austrália
O velório do Lago Menindee e do Rio Darling

Protesters mourn 'death' of Menindee Lakes and Darling River

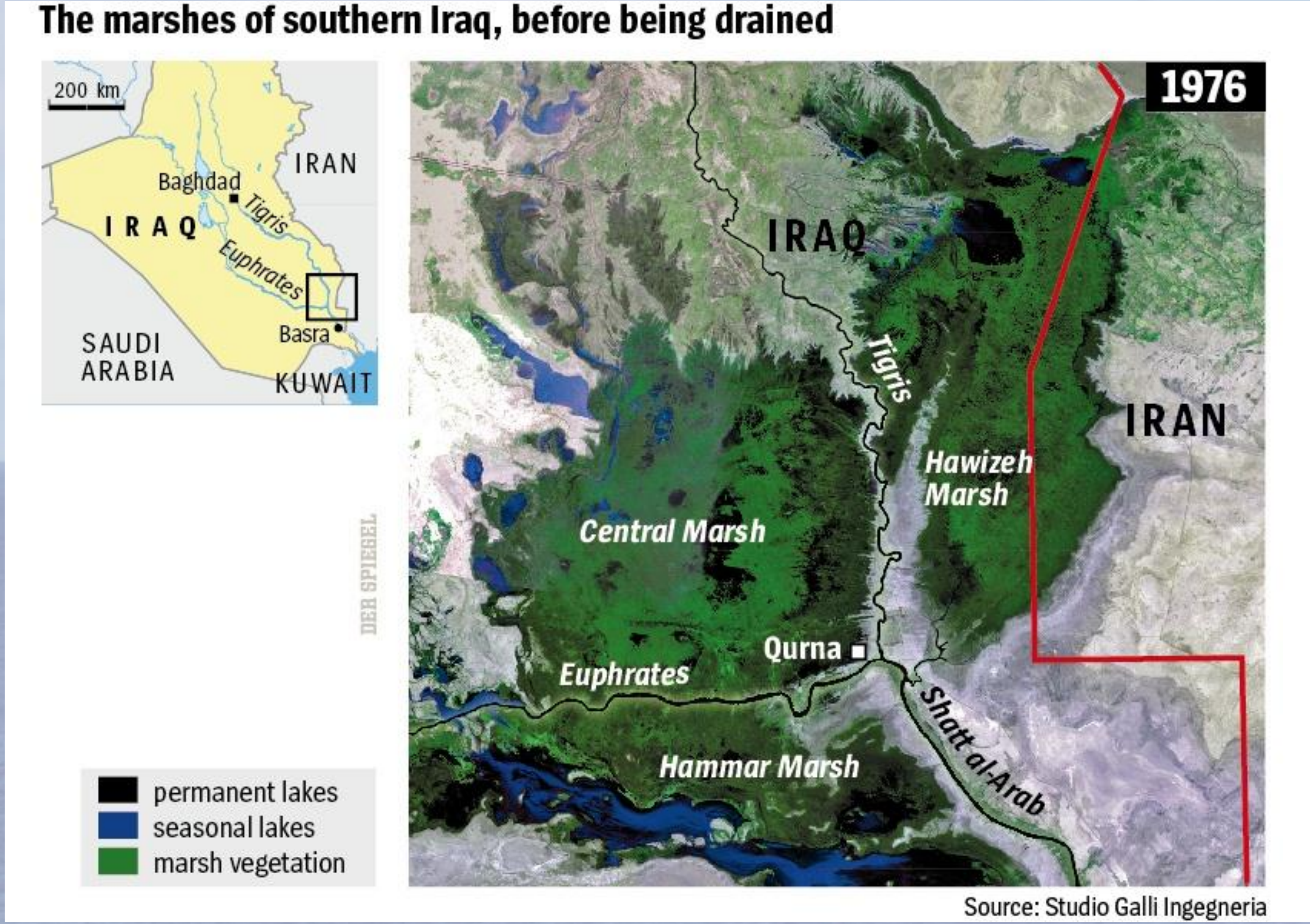
More than 100 people turned out on the bone-dry bed of Lake Menindee over the weekend to protest 'mismanagement' of the water system.

http://www.abc.net.au/news/rural/specials/murray-darling-basin-plan/

IRAQUE
Shatt al-Arab

António Chambel

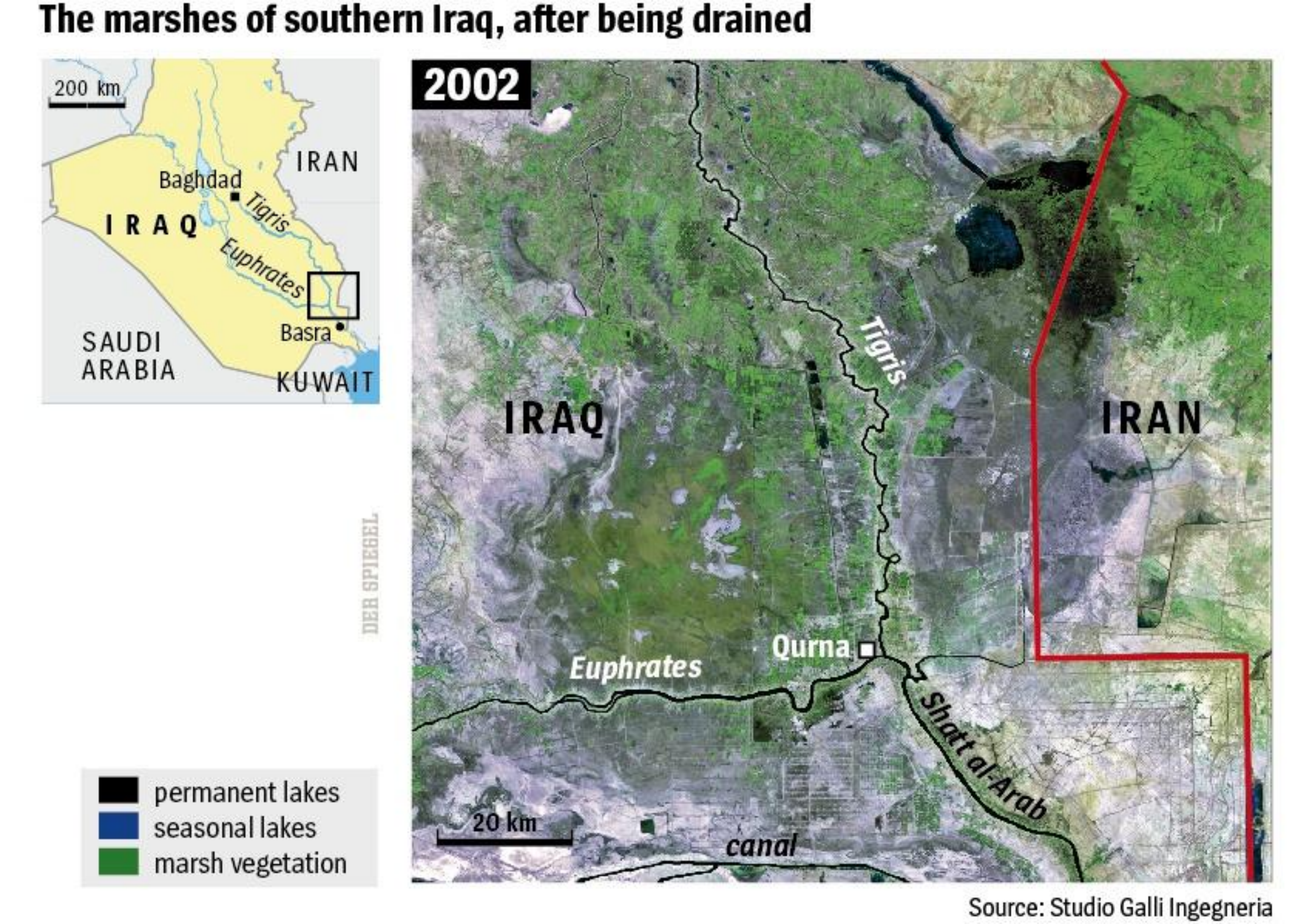
IRAQUE



António Chambel

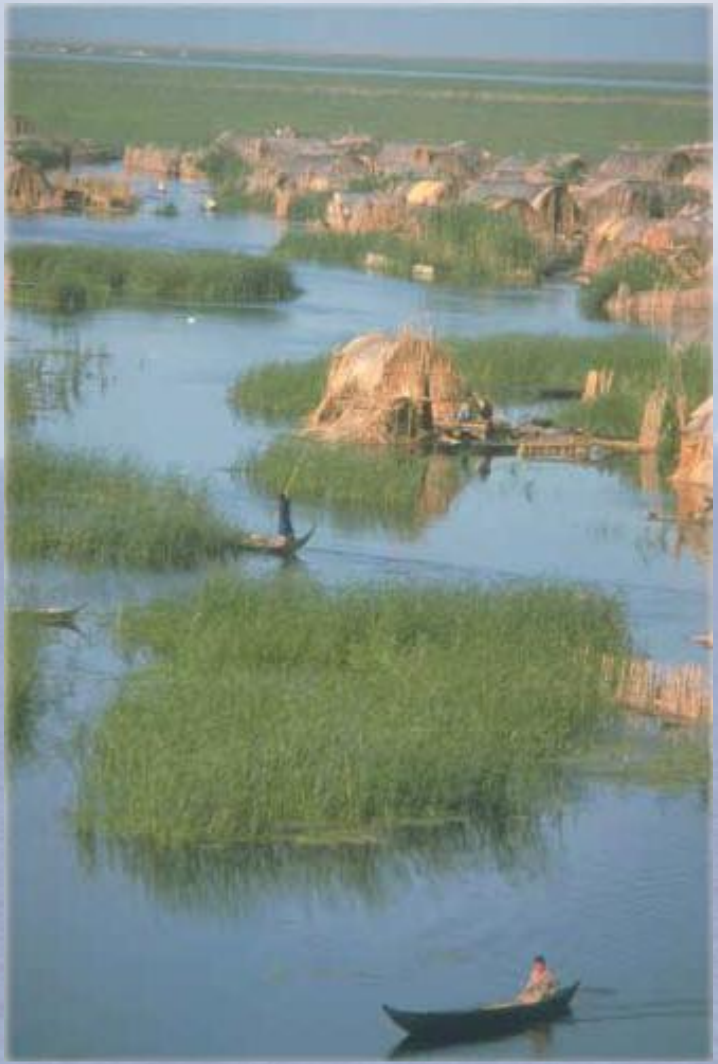
António Chambel

IRAQUE



António Chambel

IRAQUE



IRAQUE

António Chambel

IRAQUE

António Chambel

IRAQUE

António Chambel

IRAQUE

António Chambel

Jordania

António Chambel

Jordania

António Chambel

António Chambel

Jordania

Jordania

António Chambel

Jordania

António Chambel

António Chambel

Jordania

António Chambel

Jordania

Desert of Wadi Rum
Water Wells

Photo: A. Chambel
Jordania, 09/2010

Jordania

António Chambel

António Chambel

Jordania

Luanda

Depósitos de lixo

António Chambel

Luanda, Angola
Fotos: A. Chambel,
Dez 2009

Photos: A. Chambel

Índia

Contaminação orgânica

Khajuraho, Índia
Fotos: A. Chambel,
Set 2009

António Chambel

-Conflitos:

- Intervenções humanas no ciclo hidrológico:
  - Derrames de petróleo – Baku, Azerbeijão

António Chambel

Subsidência
Califórnia
Las Vegas

António Chambel

Subsidência

- México
- Taipé

António Chambel

Subsidência
- México

Photos: A. Chambel

António Chambel

Gestão de sistemas baseados em águas subterrâneas

La sostenibilidad de la gestión de sistemas de uso diverso basados (o parcialmente basados) en agua subterránea tiene que tener en cuenta:

- Factores externos (uso del agua):
  - Que uso tendrá el agua
  - Las necesidades en agua
  - El periodo de uso
  - Necesidades de punta
  - Calidad de agua necesaria

- Factores internos al acuífero:
  - El tipo de acuífero (roca, intemperismo, fracturación, etc.)
  - La capacidad productiva del acuífero
  - La calidad del agua
  - La capacidad de recarga del acuífero

- Otros factores antropogénicos:
  - Contaminación
  - Sobrexplotación
  - Recarga artificial

- Otros factores geológicos y hidrológicos:
  - Pluviometría
  - Calidad de agua de infiltración
  - Ligación con otras fuentes de recarga
  - Ligación a otros acuíferos

Gestión de sistemas basados en aguas subterráneas

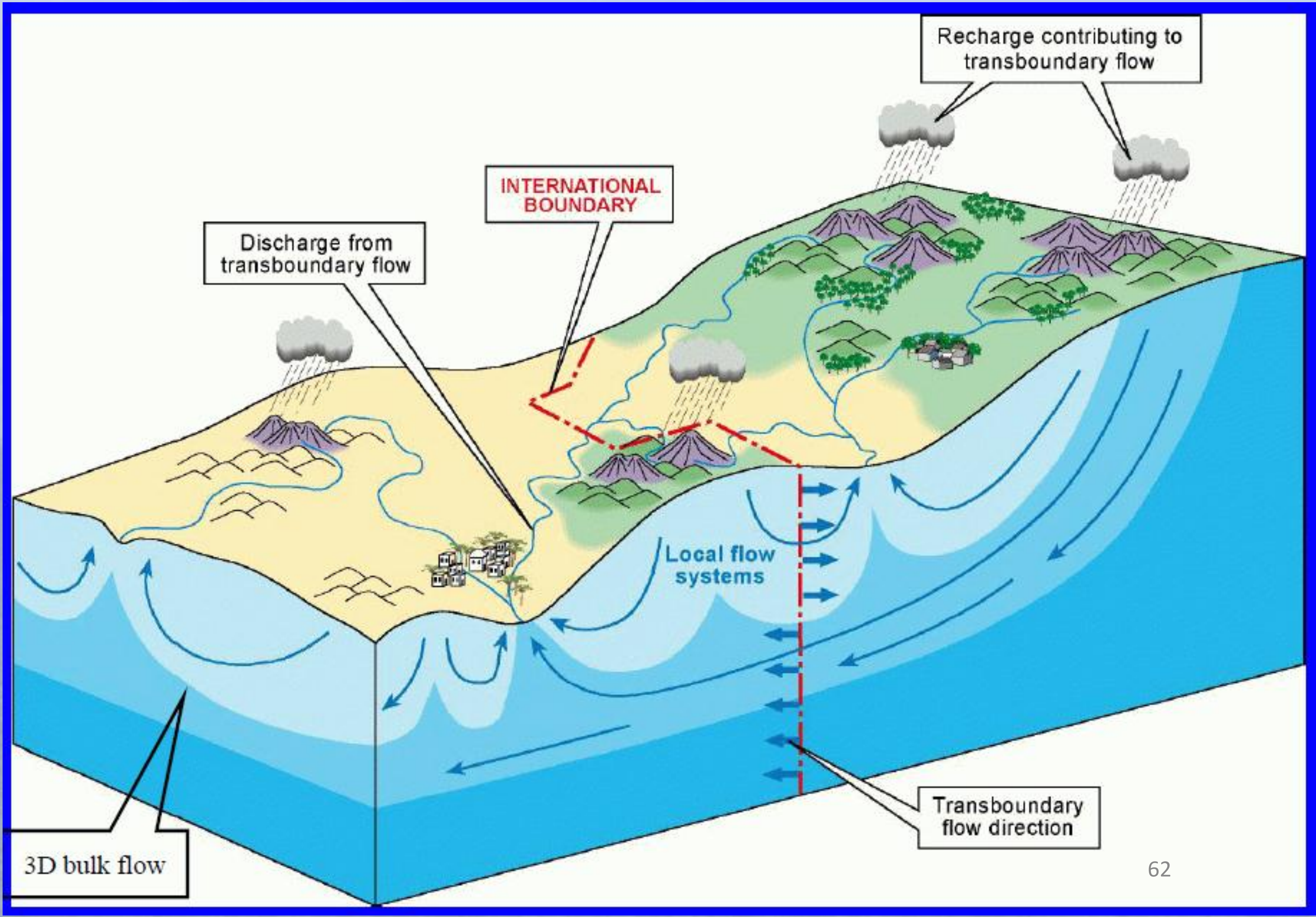
Para que se haga una gestión rigorosa, hay que primero conocer el recurso e saber lo mejor posible la reacción del acuífero a las acciones y presiones que sobre el actúan. Esto se hace:

- Haciendo estudios lo más completos posible del sistema acuífero, incluyendo, siempre que posible, modelación
- Conociendo la hidroquímica natural del acuífero
- Manteniendo un sistema de monitoreo permanente (químico y cuantitativo)
- Conociendo las presiones permanentes que actúan, a cada momento, en el acuífero (agricultura, zonas urbanas, industriales, etc.)
- Conociendo los riegos súbitos a que se sujeta el acuífero (derrame de petróleo, derrame de una ETAR, inundaciones, etc.)
- Conociendo el balance hídrico global en el acuífero (precipitación, infiltración, extracción, salidas naturales, etc.)
- Conociendo los usos y los gastos de agua subterránea en ese acuífero
- Conociendo las ligaciones del acuífero con otros acuíferos y con las aguas superficiales
- Protegiendo las captaciones
- Protegiendo los acuíferos y las zonas de infiltración potencial

António Chambel

António Chambel

Aquíferos transfronteiriços



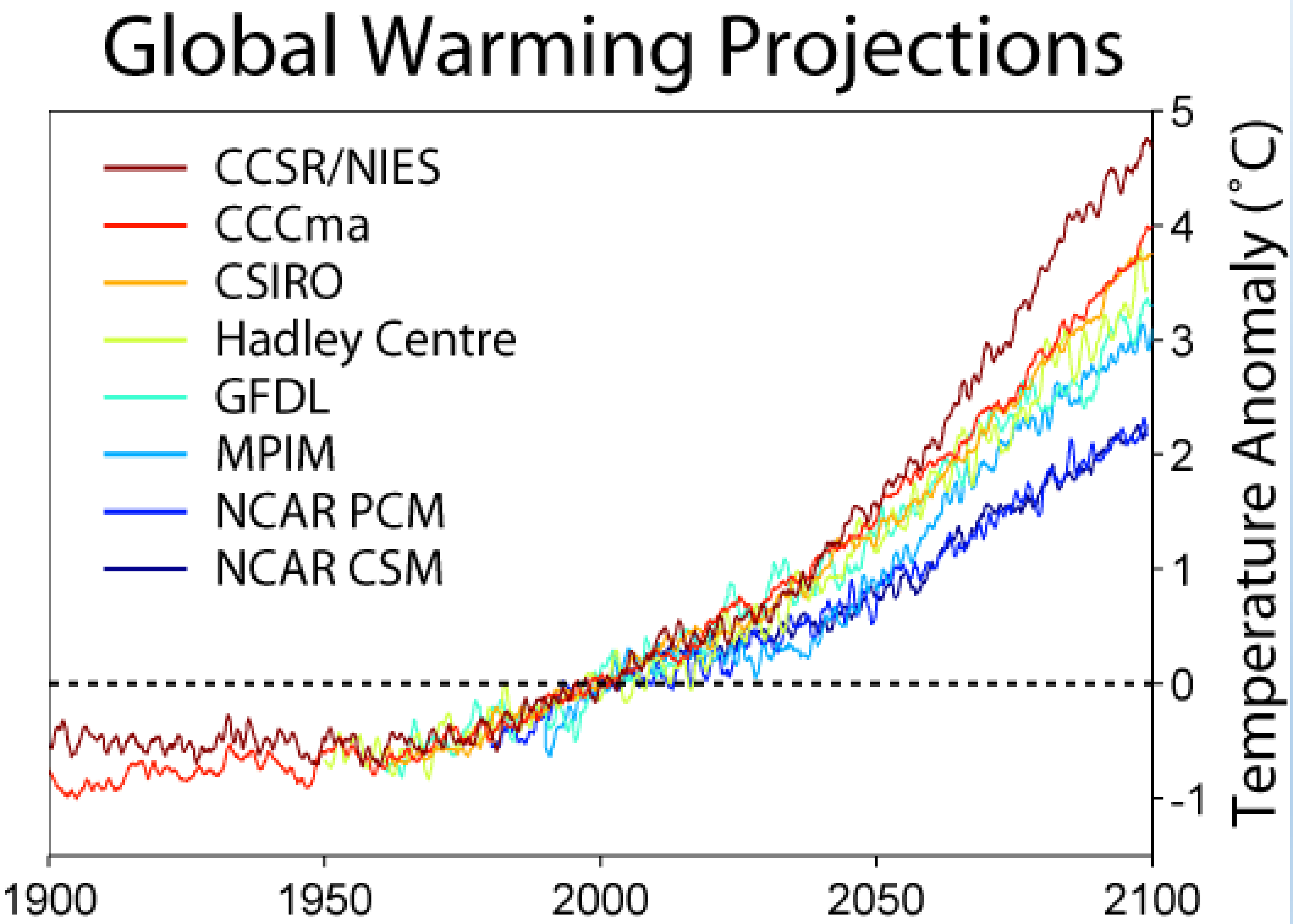
Mapa dos Sistemas Aquíferos Transfronteiriços

Apresentado no 4º Forum Mundial da Água, Cidade do México, México, 2006

António Chambel

Global changes in the Mediterranean region…

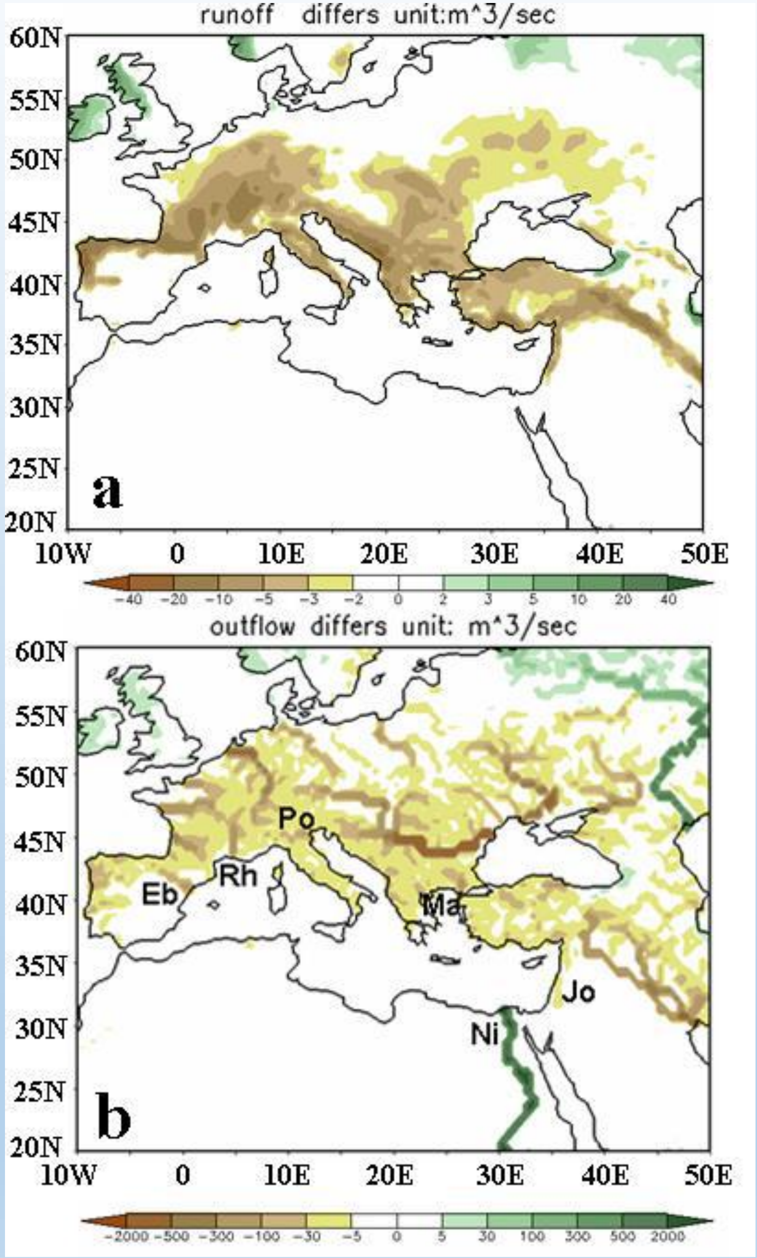
What to expect from the climate changes in the Mediterranean regions?



Source: http://www.agri.gov.il/

Global changes in the Mediterranean region…

What to expect from the climate changes in the Mediterranean regions?



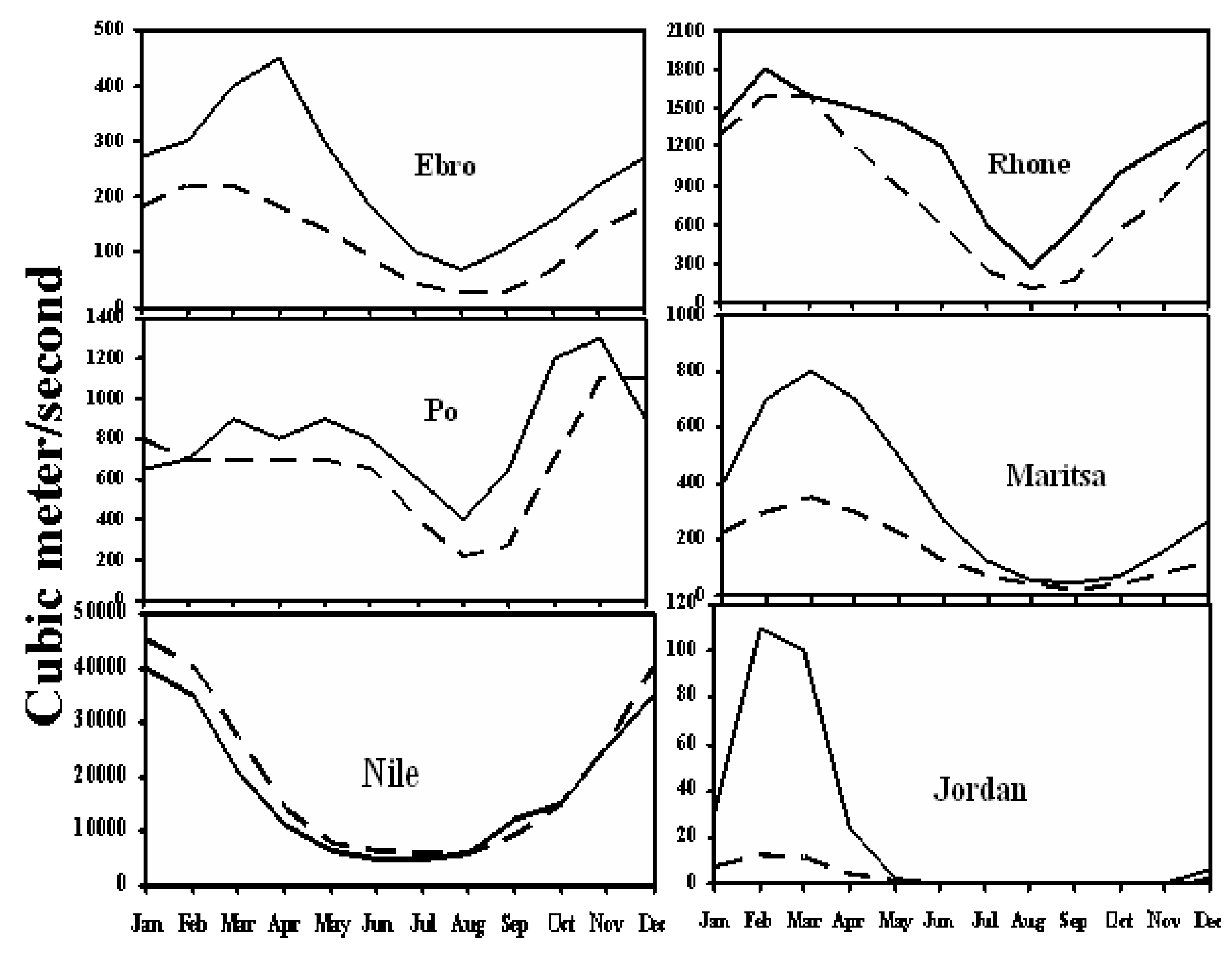
Changes of runoff and river discharge by 1979-2003 compared to (2075-2099)

(a) runoff (b) river discharge. Six rivers are marked as Ebro (Eb), Rhone (Rh), Po (Po), Maritsa (Ma), Jordan (Jo) and Nile (Ni). Unit: (m^3/s).

Source: http://www.agri.gov.il/

Global changes in the Mediterranean region…

What to expect from the climate changes in the Mediterranean regions?



Seasonal changes of monthly mean river discharge of six rivers (1979-2003; bold), compared to (2075-2099; dashed).

Except to the Jordan River, all rivers flow into the Mediterranean (m3/s). Bold lines are for current climate, while dashed for the future.

Source: http://www.agri.gov.il/

Global changes in the Mediterranean region…

What to expect from the climate changes in the Mediterranean regions?

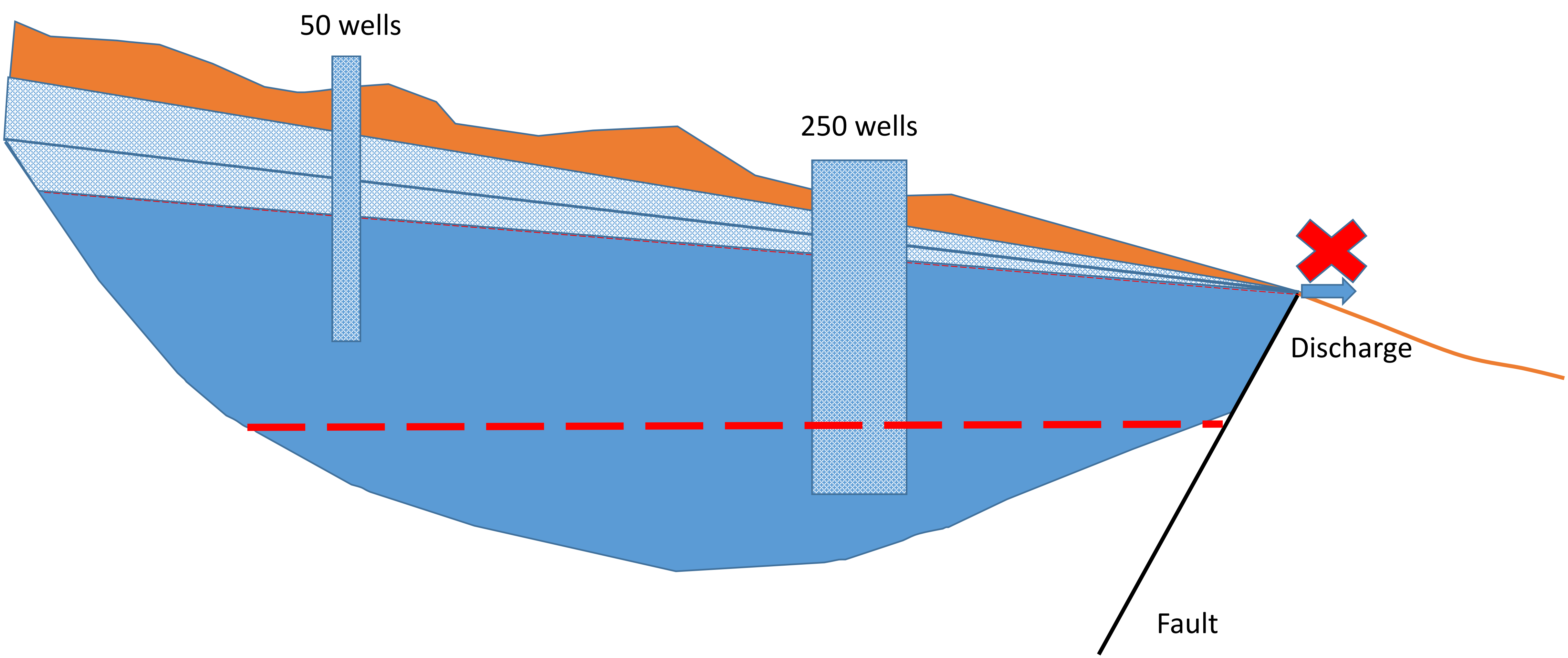
Aquifers:

- Reduced infiltration
- But aquifers are bounded by natural conditions that control water storage
- They will be much more resilient than surface water bodies
- The question will not be a significant loss in groundwater storage, but the increment of pressure to use groundwater

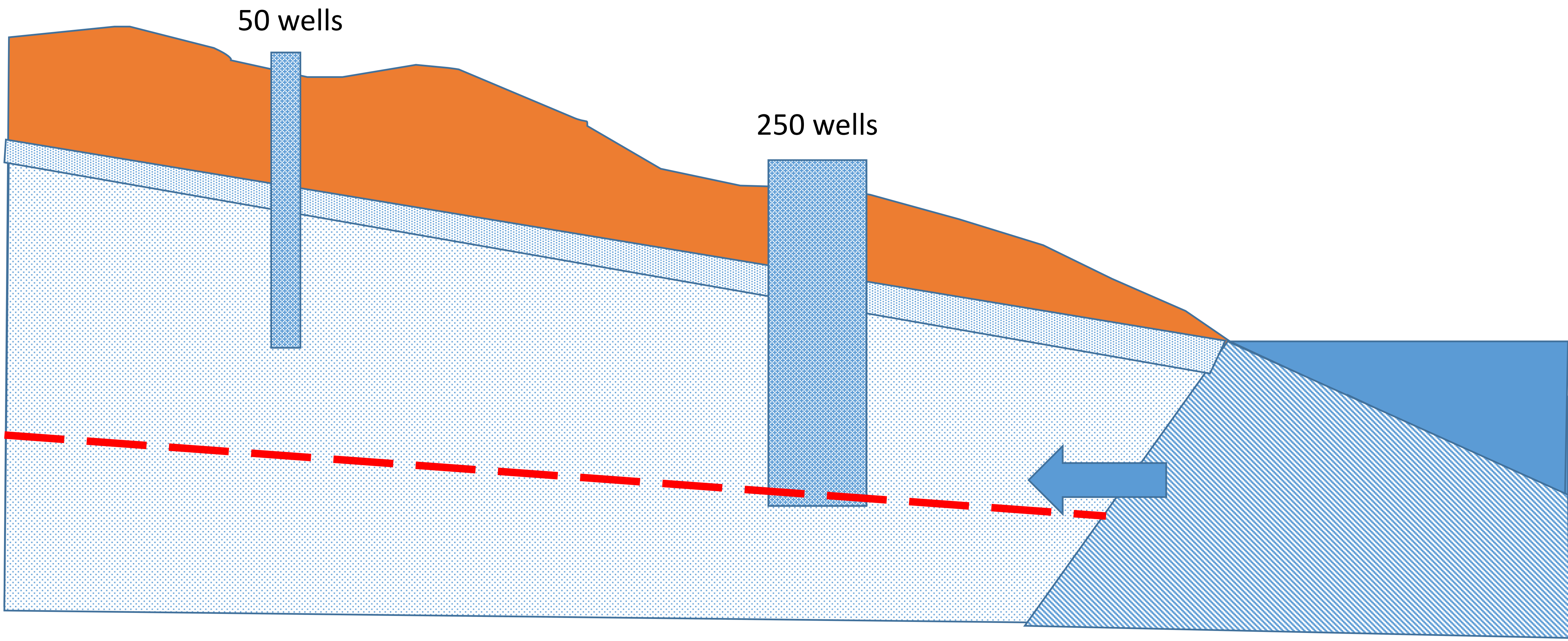
Source: http://www.agri.gov.il/

António Chambel

Climate change **Global change**



Climate change **Global change**



António Chambel

Global changes in the Mediterranean region…

António Chambel

What to expect from the global changes in the Mediterranean regions?

The impacts of climate change on the Mediterranean environment will relate particularly to:

• Water, via a change of its cycle due to a rise in evaporation and a decrease in rainfall. This water problem will be of crucial importance with regard to the issue of sustainable development in the region;

• Soil, via the acceleration of already existing desertification phenomena;

• Land and marine biological diversity (animal and plant), via a displacement northwards (in Europe) and in altitude of certain species, extinction of less mobile or more climate sensitive species, and emergence of new species;

• Forests, via a rise in fire hazards and parasite risks.

Source: Climate Change and Energy in the Mediterranean, FEMIP, 2008

Global changes in the Mediterranean region…

What to expect from the global changes in the Mediterranean regions?

These impacts will exacerbate already existing pressures on the natural environment connected with anthropogenic activities.

Climate change will have impacts particularly on: agriculture and fishery (reduction of yields), tourism attractiveness (heat waves, water scarcity), coastal areas and infrastructures (significant exposure to the action of waves, coastal storms and other extreme weather events, rise in sea level), human health (heat waves), the energy sector (water needs for power plants, hydropower and increased consumption).

Source: Climate Change and Energy in the Mediterranean, FEMIP, 2008

Lets talk about management…

Wet periods and dry periods

Floods cover the streets in Agartala, the capital of Tripura State in India. Agosto 2017

India: The Worst Drought in Living Memory, 300 Million People Affected, 2015, Dr. S. G. Vombatkere (2016)

António Chambel

The planning of water resources must be carried out in order to integrate all water, and the policies and management must take into account this situation.

There is not, on the part of many administrations and politicians, an awareness of the relationships between groundwater and surface water and it is absolutely necessary they have it.

For the success of a good water administration, it is necessary to have a joint planning and management of water, that is, coordinated management of groundwater, surface water and other water sources, in order to reach the final political and management objectives.

This event must be fulfilled through awareness at the individual level and a strategy in the conjunctive use of water by collective users and governments to achieve the objectives, including adequate legislation.

The planning for aquifers (and for water in general) must account on:

- Aquifer management recharge (including artificial recharge)
- Permanent monitoring (quality, quantity) and of the condition of dependent ecosystems
- Joint management with waters of another origin (surface, treated organic wastewater, treated industrial wastewater, precipitation)
- Utilization of water for different purposes before returning it to the environment
- The fight against water waste, mainly in agriculture
- A permanent availability of data, so that science advances without restrictions and users can be aware of what is happening at each moment

Groundwater Governance: a Global Framework for Action

Key deficiencies identified in the ‘Global Diagnostic’:

- Inadequate leadership from government agencies
- Lack of awareness of long-term risks
- Lack of knowledge of the resource and its status
- Non-performing legal systems
- Insufficient stakeholder engagement
- Poor integration with related national policies

UNESCO, FAO, IAH, World Bank, GEF

António Chambel

OBRIGADO

Foto: Meninas em busca de agua em Moçambique
A. Chambel, Missão dos Hidrogeólogos Sem Fronteiras em África, 2011

Para uma melhor gestão, primeiro há que conhecer

António Chambel