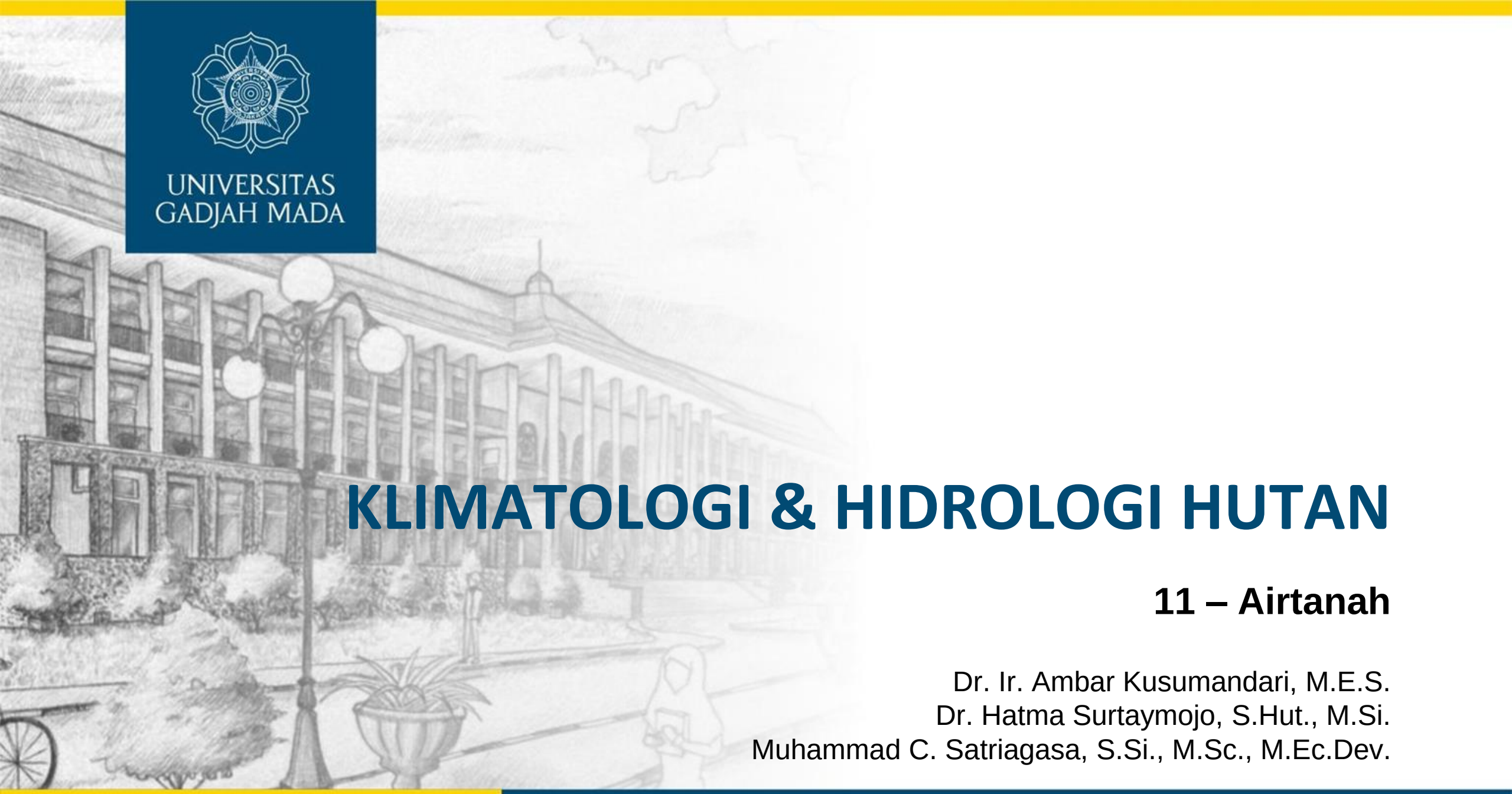

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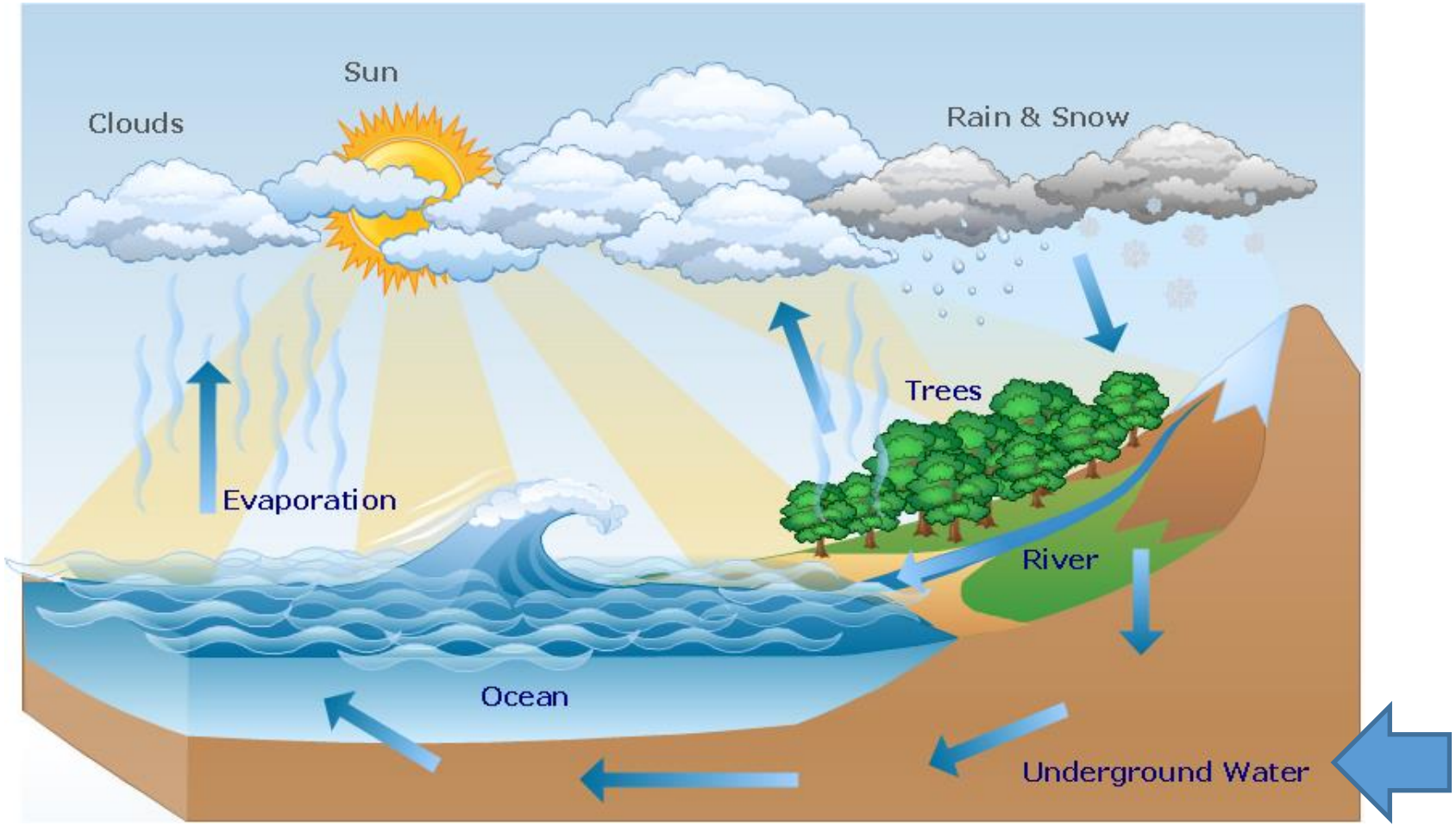
KLIMATOLOGI & HIDROLOGI HUTAN

11 – Airtanah

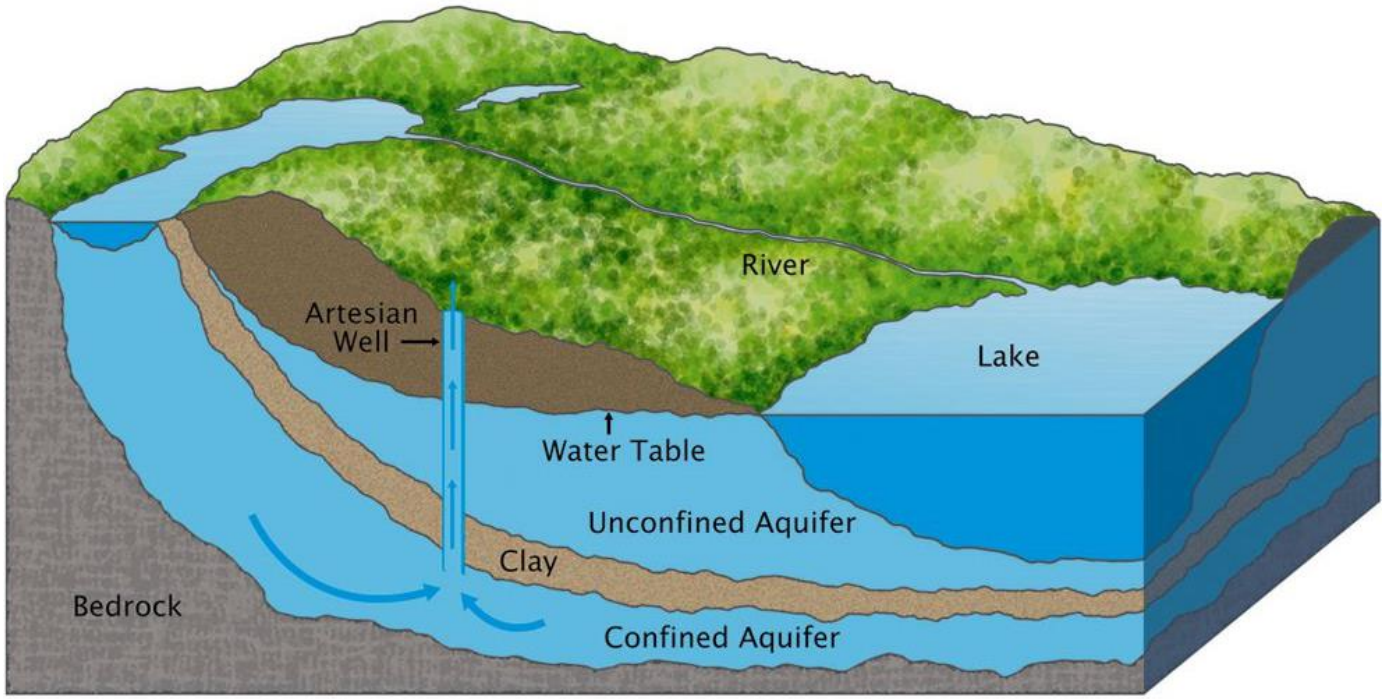
Dr. Ir. Ambar Kusumandari, M.E.S.
Dr. Hatma Surtaymojo, S.Hut., M.Si.
Muhammad C. Satriagasa, S.Si., M.Sc., M.Ec.Dev.

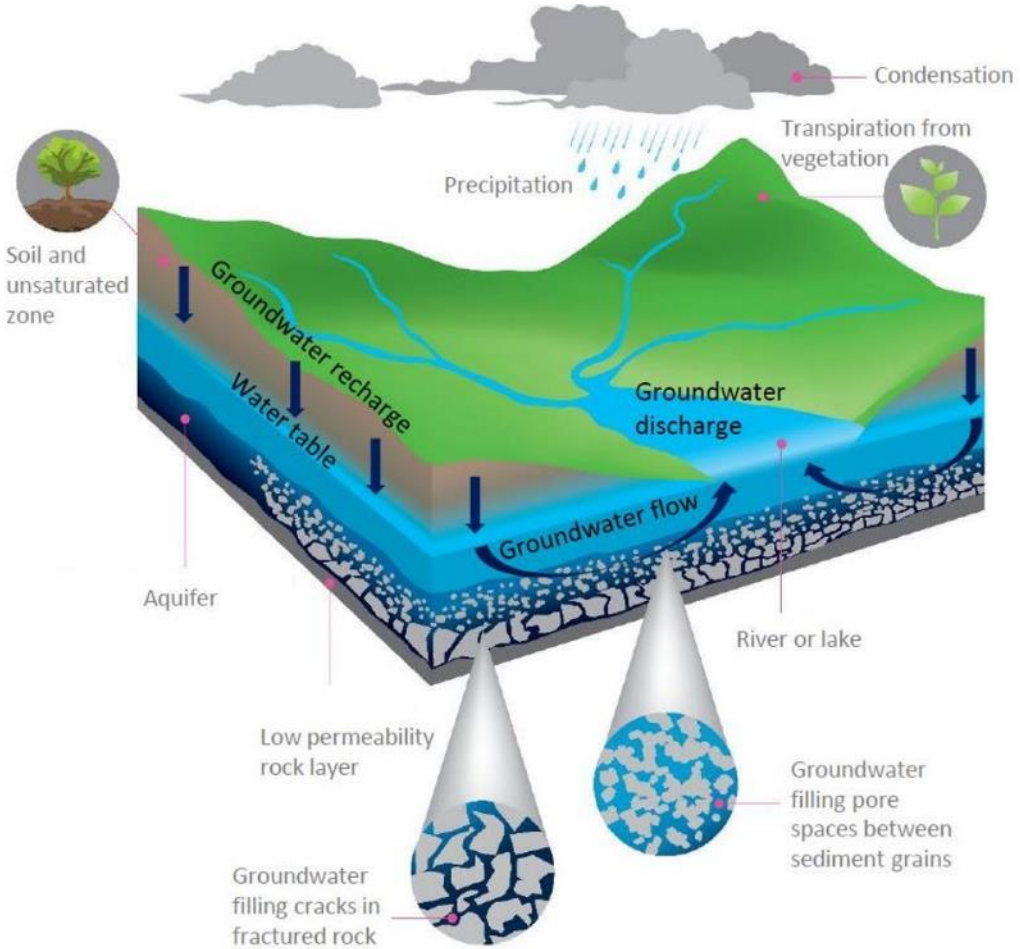
“Jangan sampai mata air berubah menjadi air mata”

Air tanah


Sun
Clouds
Rain & Snow
Trees
Evaporation
River
Ocean
Underground Water

Aquifer


River
Artesian Well
Lake
Water Table
Unconfined Aquifer
Clay
Bedrock
Confined Aquifer


Condensation
Transpiration from vegetation
Precipitation
Soil and unsaturated zone
Groundwater recharge
Water table
Groundwater discharge
Groundwater flow
Aquifer
River or lake
Low permeability rock layer
Groundwater filling pore spaces between sediment grains
Groundwater filling cracks in fractured rock

Material Aquifer

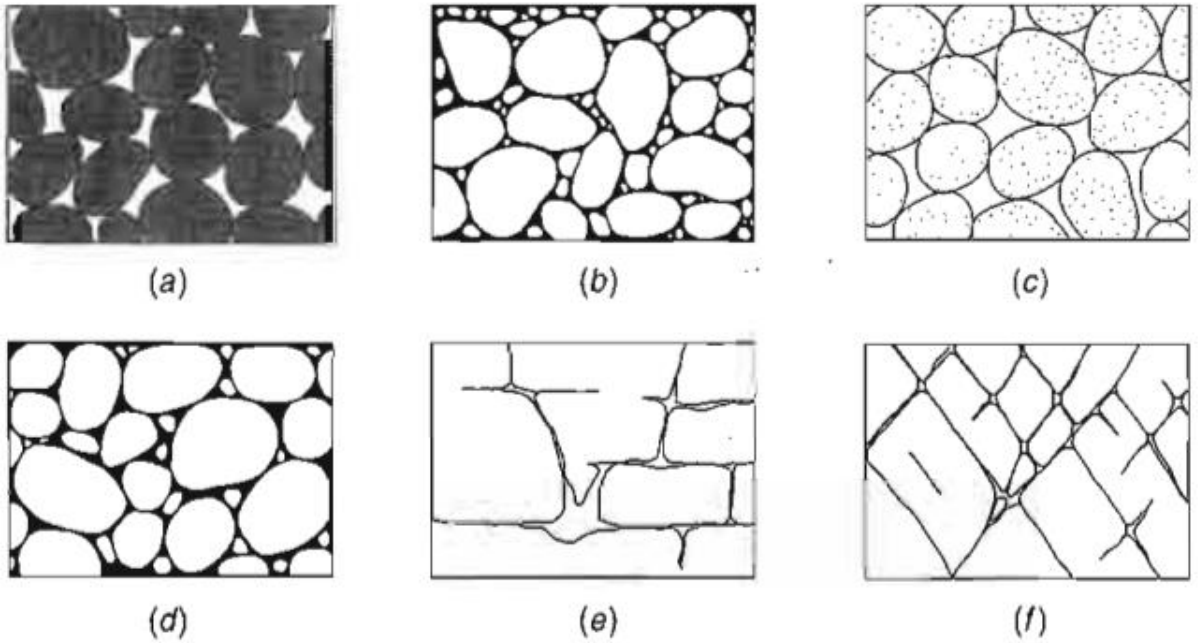
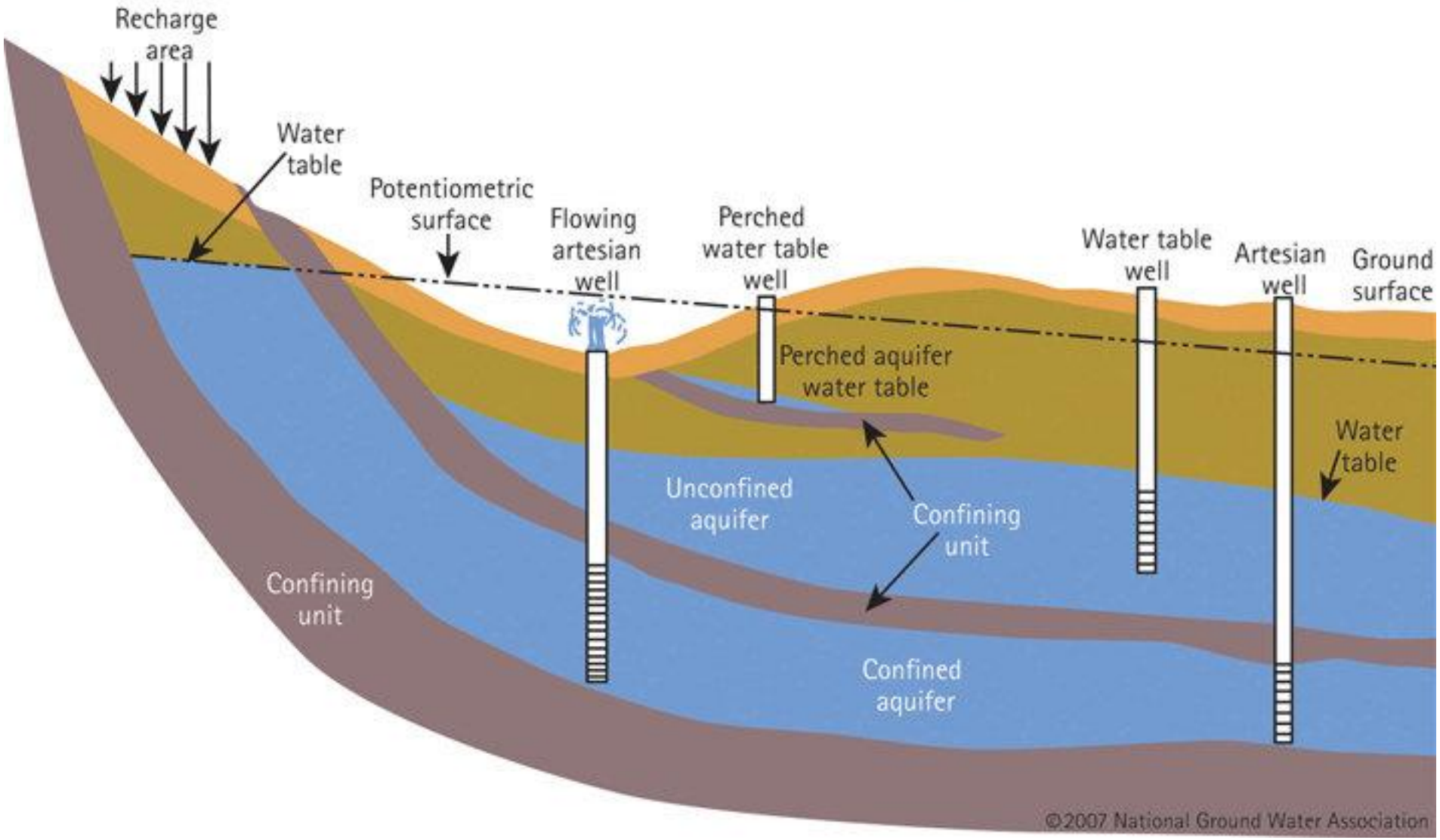
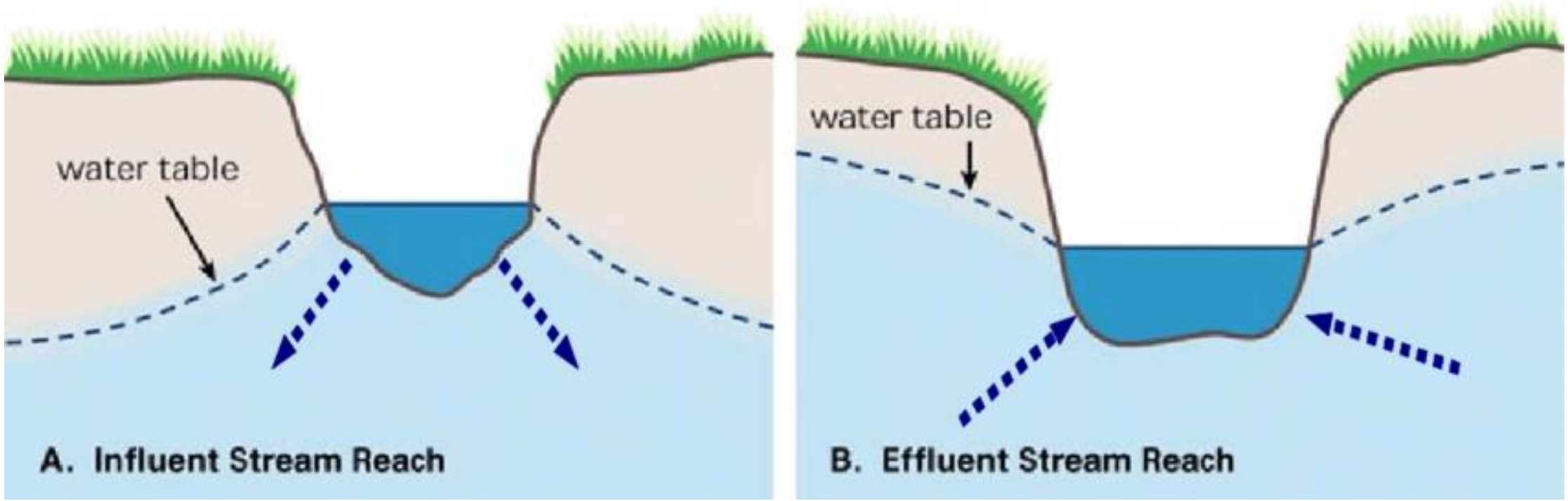


Figure 2.2.1. Examples of rock interstices and the relation of rock texture to porosity. (*a*) Well-sorted sedimentary deposit having high porosity. (*b*) Poorly sorted sedimentary deposit having low porosity. (*c*) Well-sorted sedimentary deposit consisting of pebbles that are themselves porous, so that the deposit as a whole has a very high porosity. (*d*) Well-sorted sedimentary deposit whose porosity has been diminished by the deposition of mineral matter in the interstices. (*e*) Rock rendered porous by solution. (*f*) Rock rendered porous by fracturing.[42]

Confined/Unconfined Aquifers



Hubungan Airtanah dengan Air Permukaan



Hubungan DAS dan CAT

- Sistem sungai → Daerah Aliran Sungai (DAS)
- Sistem airtanah → Cekungan Air Tanah (CAT)
- Batas DAS ≠ Batas CAT

Peta CAT Yogyakarta – Sleman

(Dr. Ir. Heru Hendrayana)

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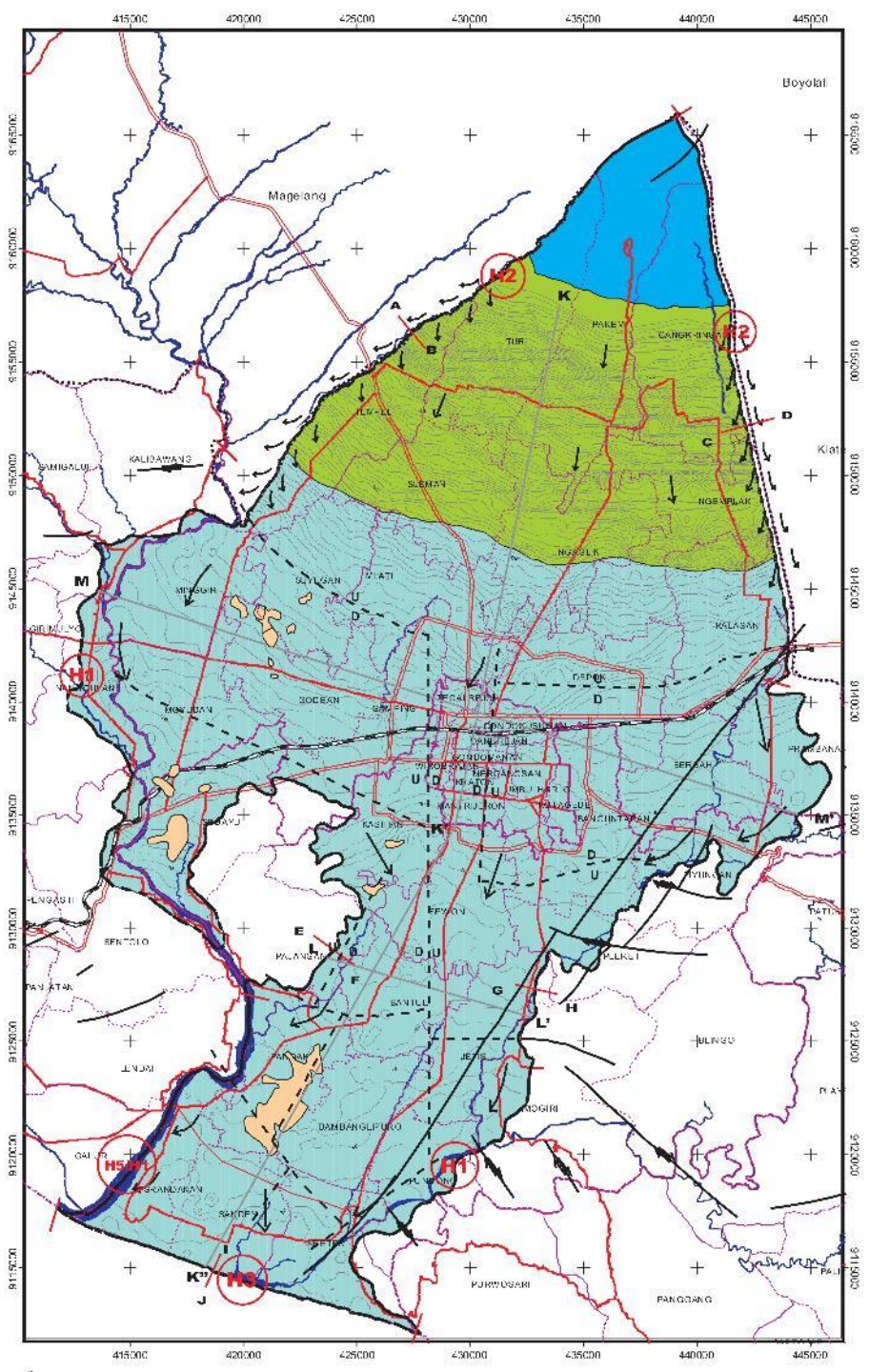
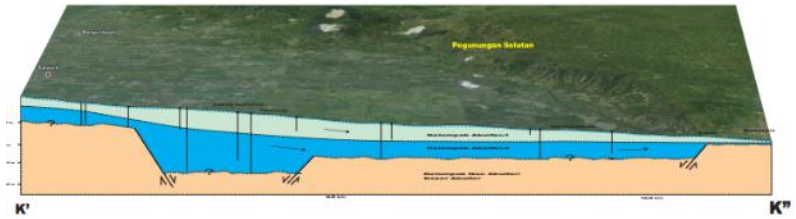
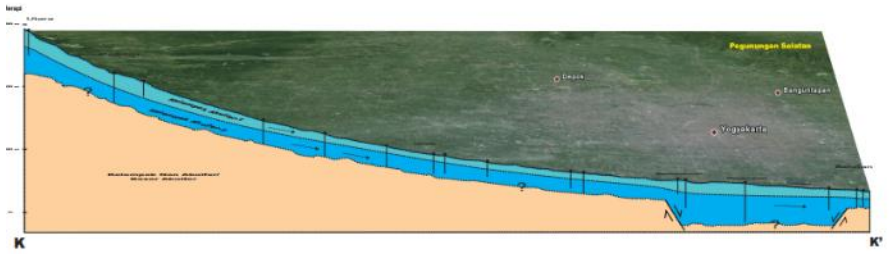


KETERANGAN :

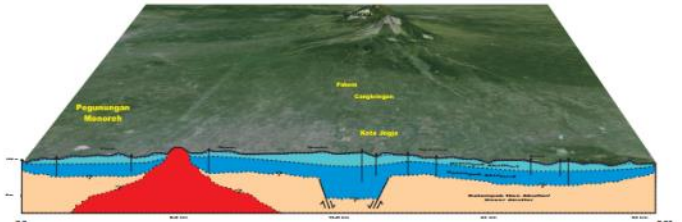
- Daerah Recharge
- Daerah Transisi
- Daerah Discharge
- Kelompok Non Akuifer
- Batas segmen horizontal

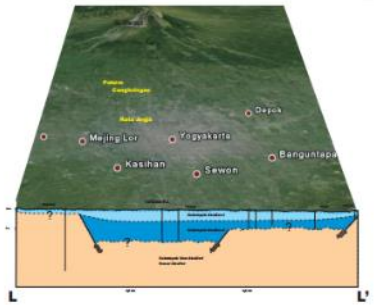
Sayatan 3-Dimensi Utara-Selatan





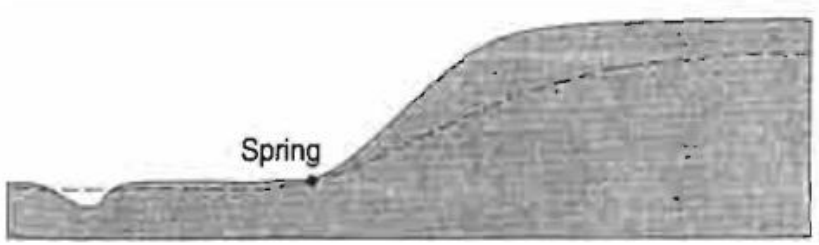
Sayatan 3-Dimensi Barat-Timur



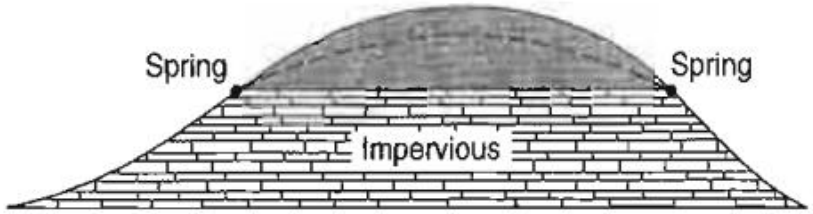


LOCALLY ROOTED, GLOBALLY RESPECTED

Mata Air

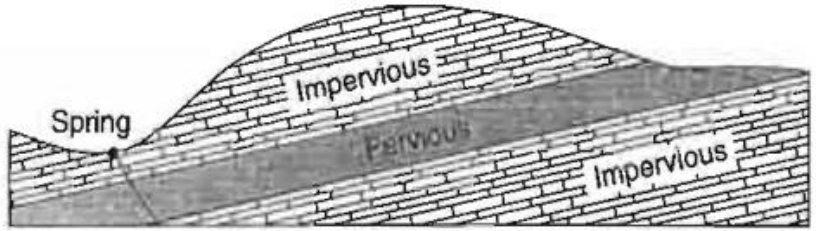


(a)

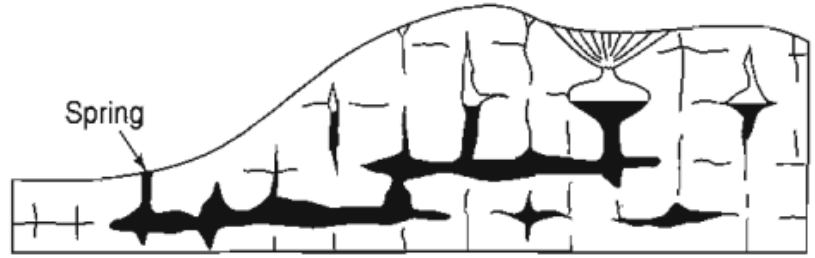


(b)

1. *Depression Springs*—Formed where the ground surface intersects the water table.
2. *Contact Springs*—Created by a permeable water-bearing formation overlying a less permeable formation that intersects the ground surface.
3. *Artesian Springs*—Resulting from releases of water under pressure from confined aquifers either at an outcrop of the aquifer or through an opening in the confining bed.
4. *Impervious Rock Springs*—Occurring in tubular channels or fractures of impervious rock.
5. *Tubular or Fracture Springs*—Issuing from rounded channels, such as lava tubes or solution channels, or fractures in impermeable rock connecting with groundwater.



(c)



(d)

Figure 2.10.1. Diagrams illustrating types of gravity springs. (*a*) Depression spring. (*b*) Contact spring. (*c*) Fracture artesian spring. (*d*) Solution tubular spring (after Bryan,[10] copyright © 1919 by the University of Chicago Press).

Mata Air berdasarkan debitnya

Table 2.10.1 Classification of Springs by Discharge (after Meinzer[41])[a]

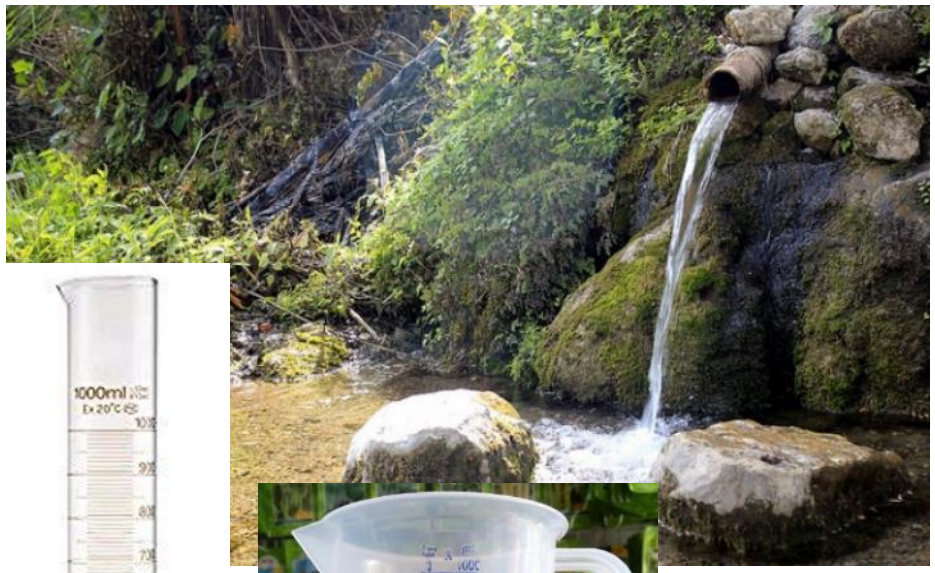
Magnitude	Mean discharge
First	>10 m^3/s
Second	1–10 m^3/s
Third	0.1–1 m^3/s
Fourth	10–100 l/s
Fifth	1–10 l/s
Sixth	0.1–1 l/s
Seventh	10–100 ml/s
Eighth	<10 ml/s

[a]Another discharge classification of springs, also proposed by Meinzer and based on English units, has been in use for many years in the United States.

Volumetric method

$Q = V/t$

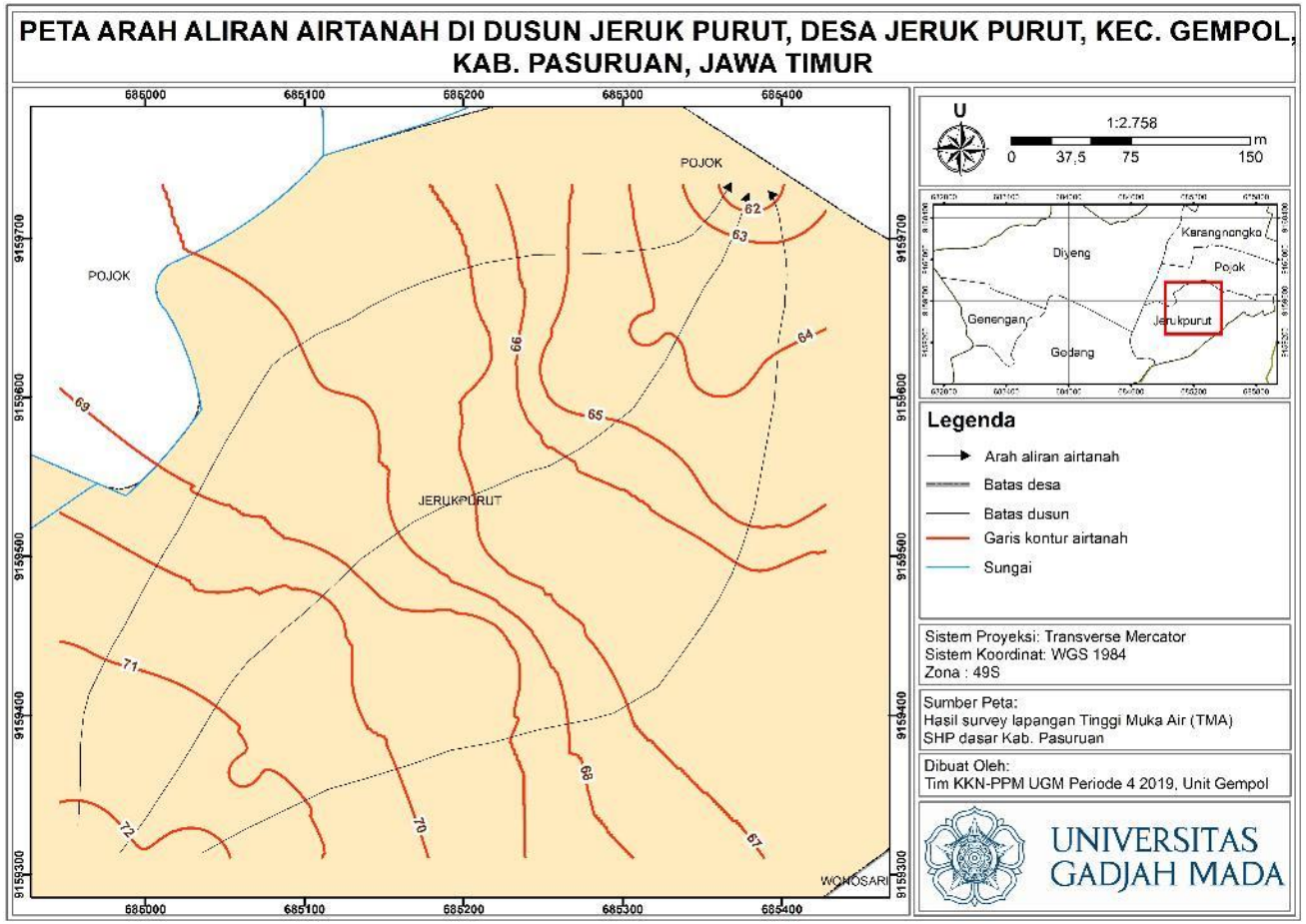
V = volume (m^3)
t = waktu (s)



Pengukuran Potensi Air Tanah

Pengukuran Potensi Air Tanah

Penentuan TMA Aquifer



Pengukuran Potensi Air Tanah

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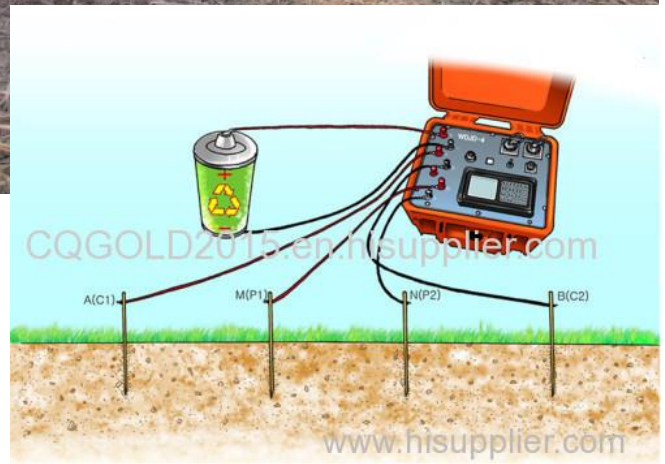
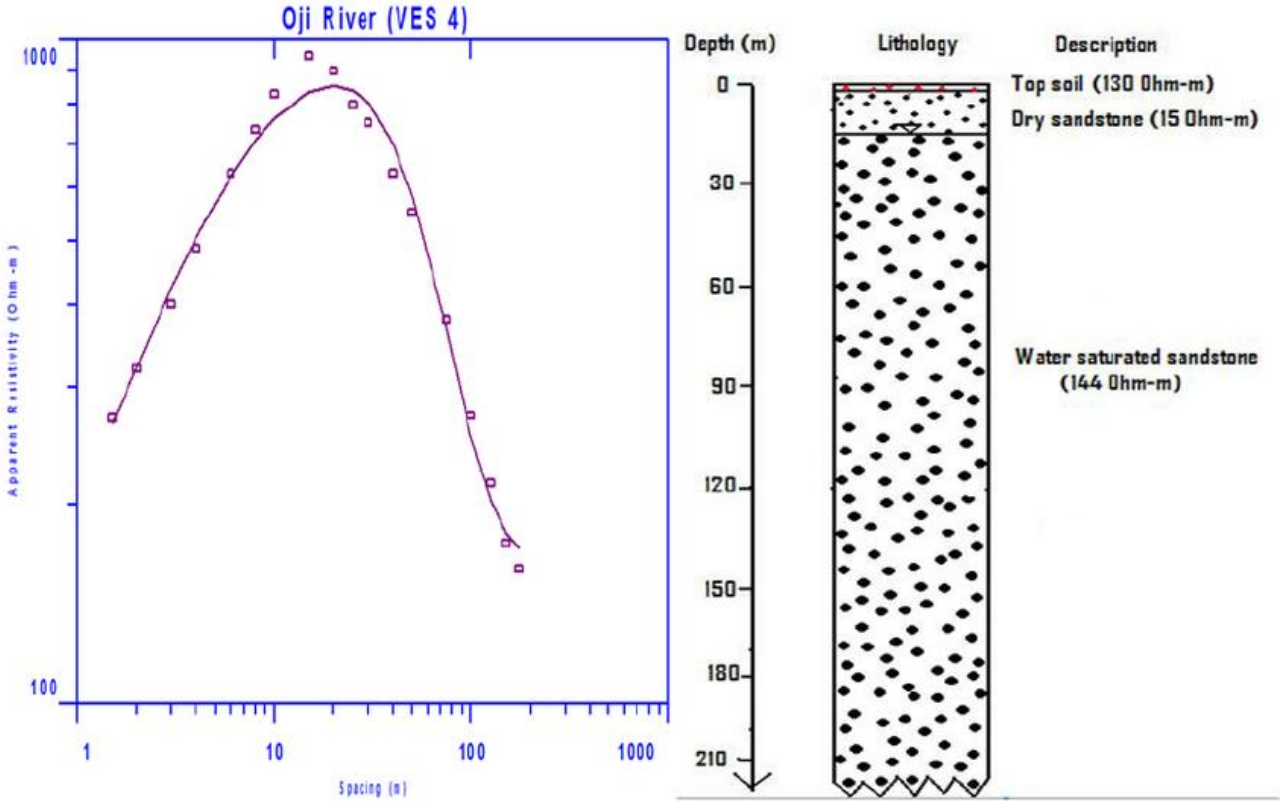
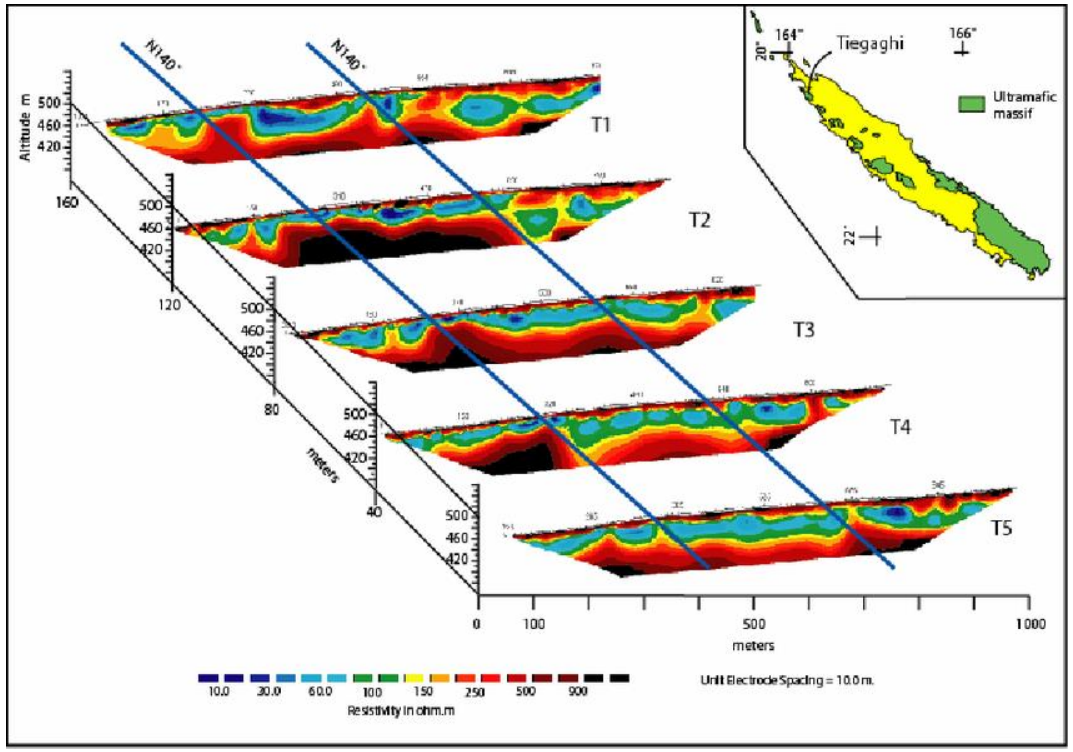
Geolistrik

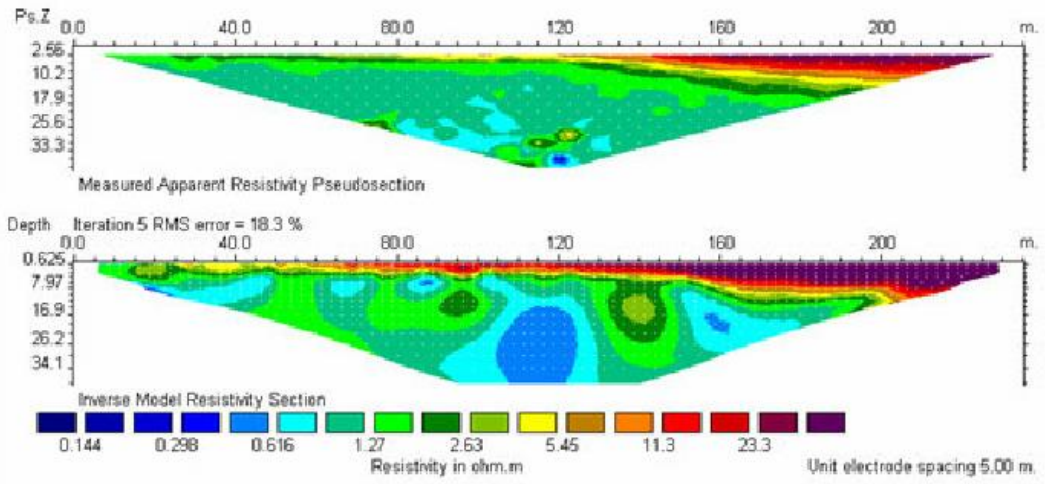


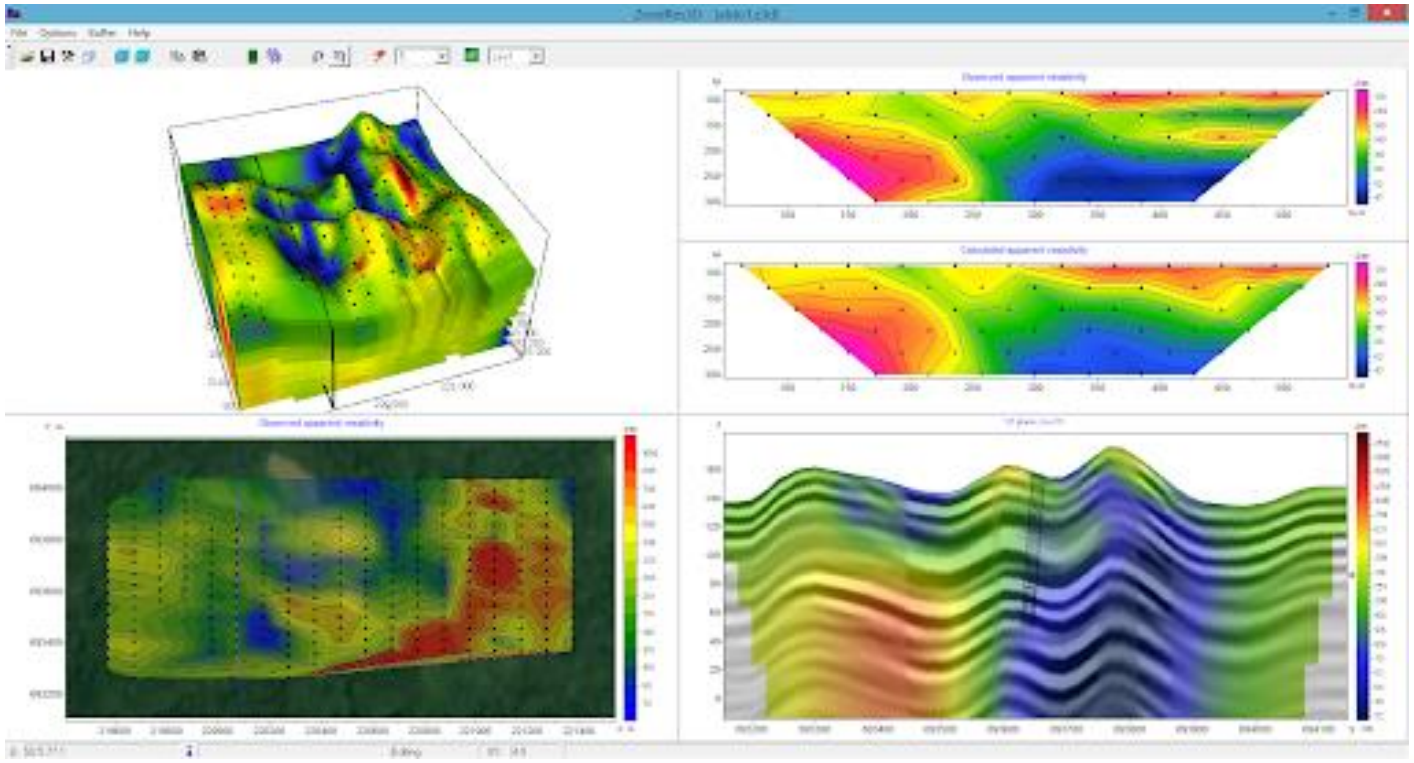
Vertical Electrical Sounding (VES)



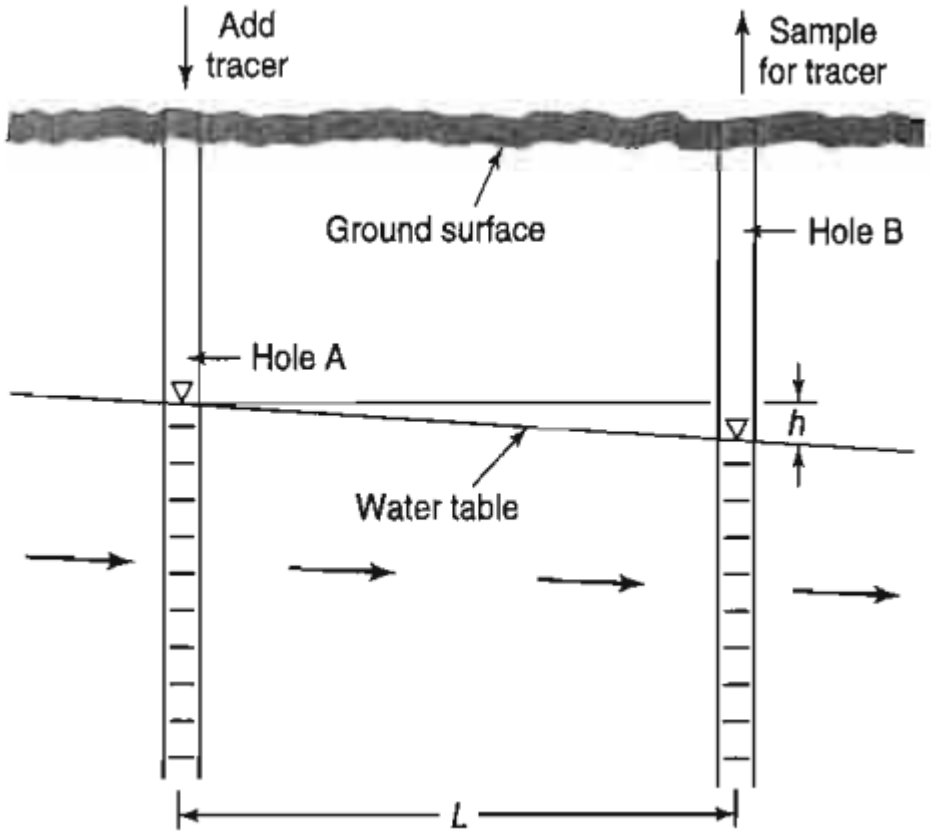
Electric Resistivity Tomography (ERT)



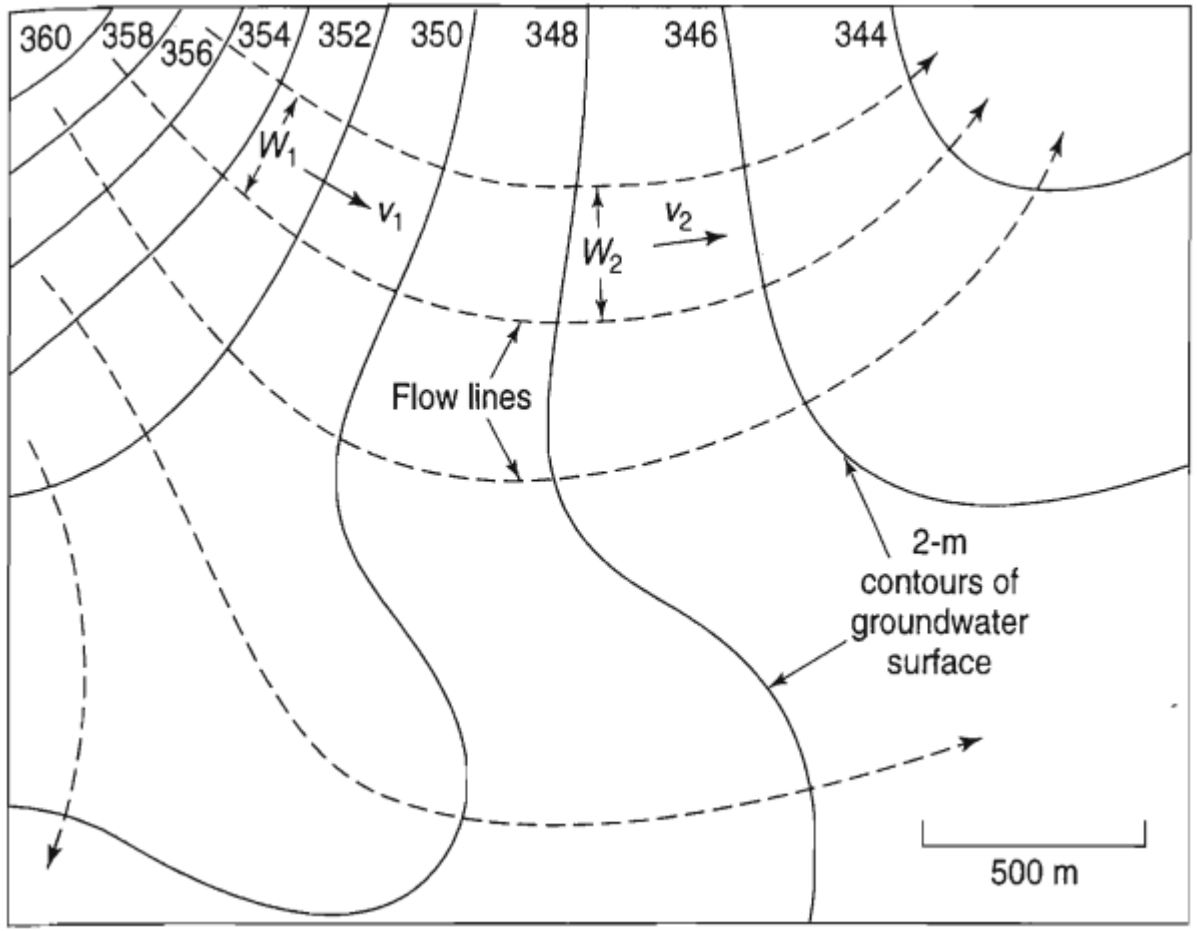




Pergerakan airtanah



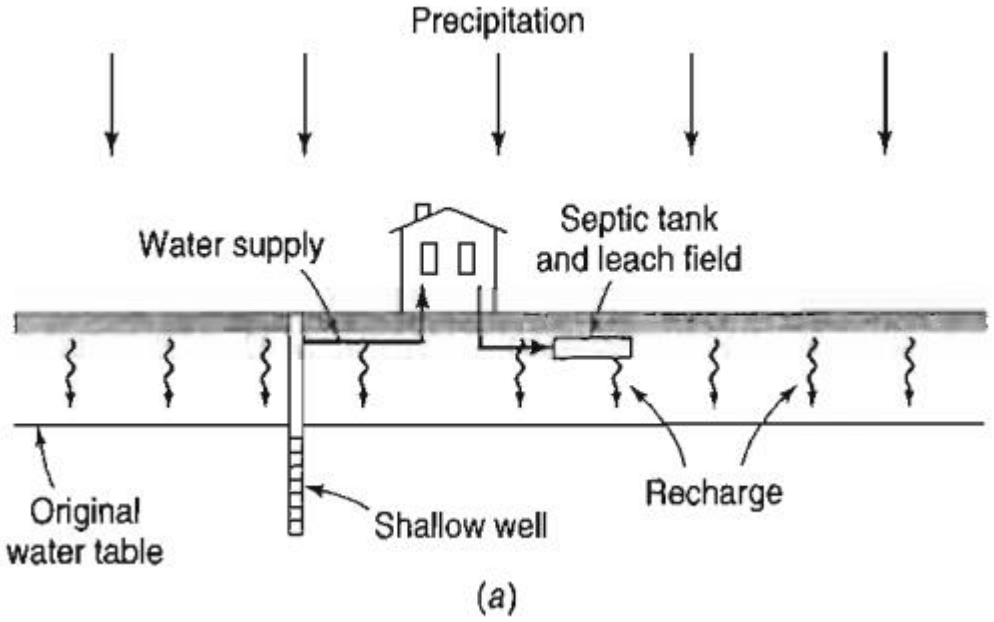
Flow Net

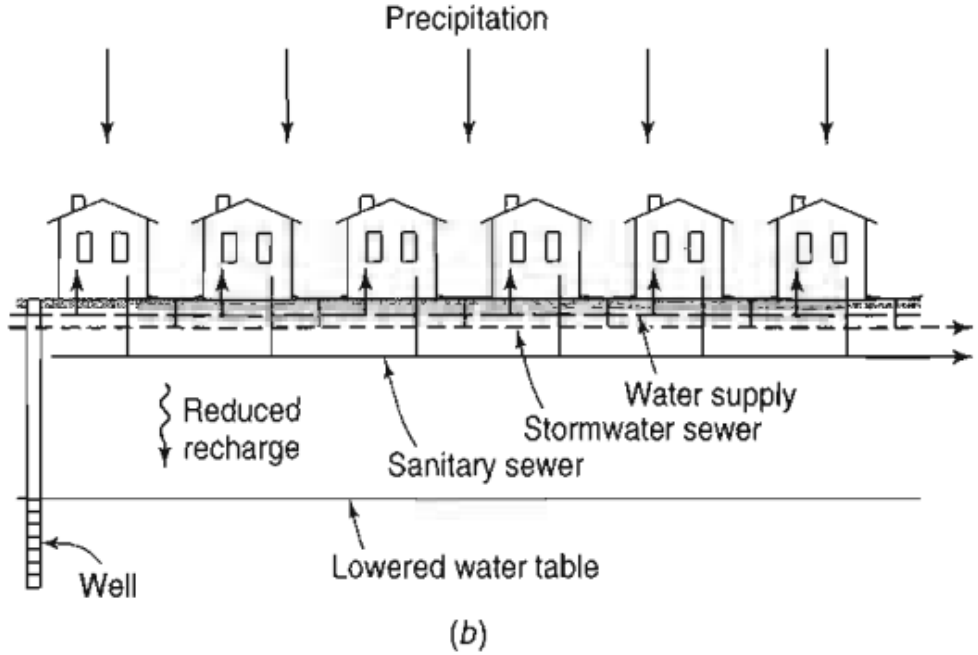


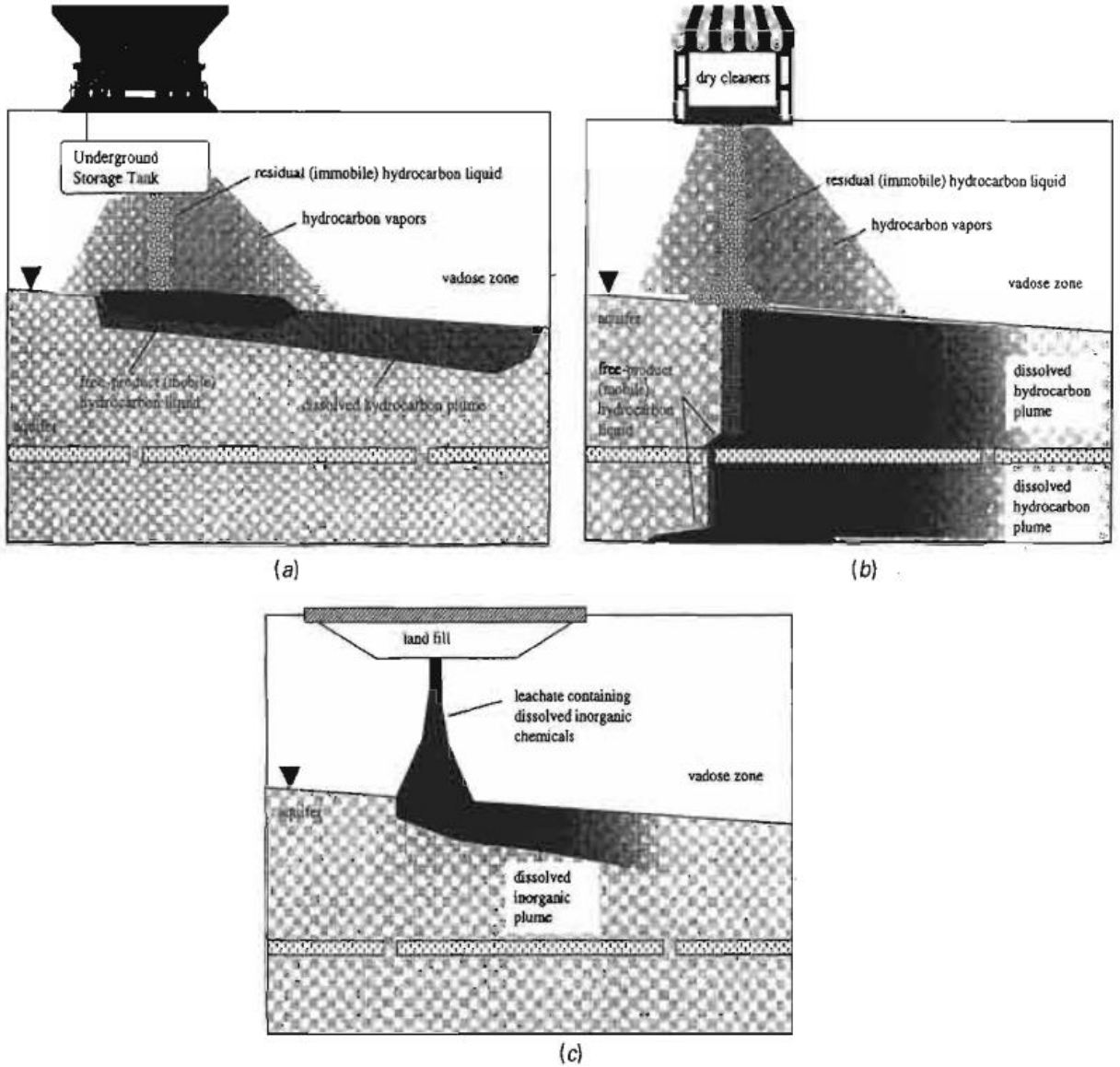
Permasalahan Airtanah

- Akibat urbanisasi

1. Reduced groundwater recharge due to paved surface areas and storm sewers
2. Increased groundwater discharge by pumping wells
3. Decreased groundwater recharge due to export of wastewater collected by sanitary sewers

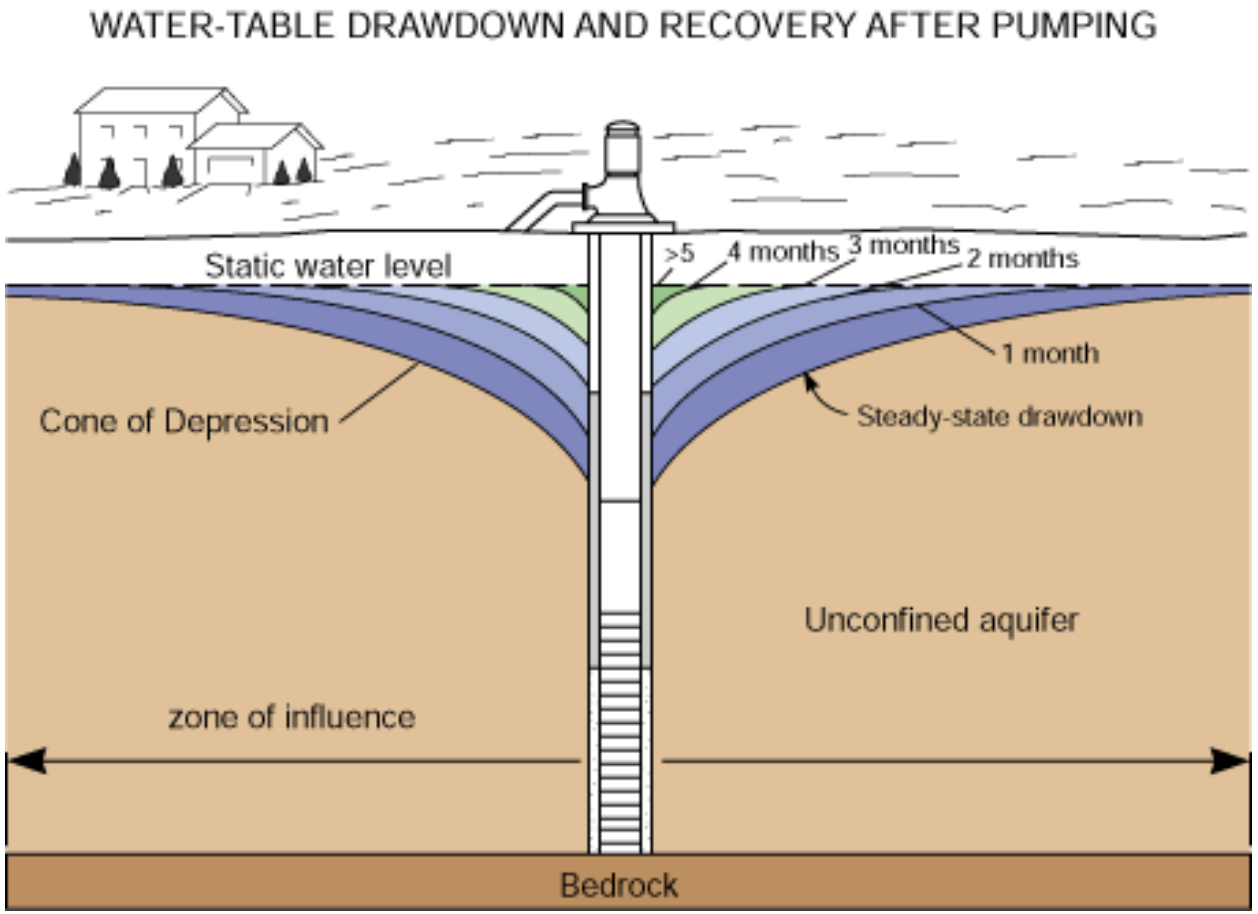




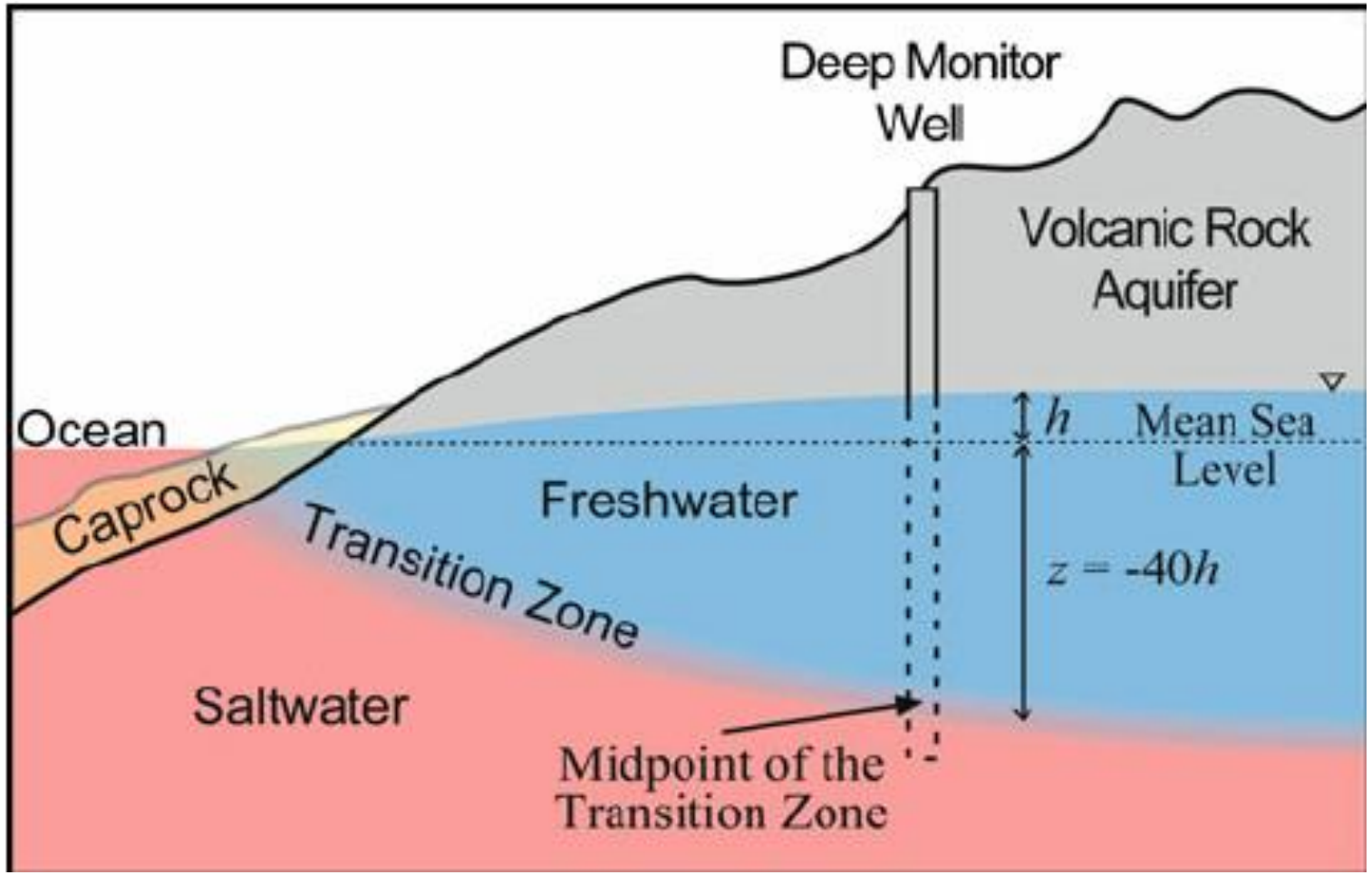


Pencemaran airtanah

Cone of depresion



Intrusi air laut



Land subsidence

GRAPHIC: AAMIR SHAIKH

GRADUALLY GOING DOWN

SUBSIDENCE

Land surface sinking is ground failure ranging from broad regional lowering of the land surface to local collapse. It is a gentle and continuous lowering of the ground surface occurring particularly in densely populated deltaic regions causing damage

- Tectonic motion and sea-level rise
- Heavy withdrawal of ground water, geothermal fluids, oil, and gas, or the extraction of coal, sulphur, gold, and other solids through mining, or underground construction (tunnelling), or from other mixed causes, such as the hydro-compaction of loosely deposited sediments, oxidation and shrinkage of organic deposits

CONCLUSIONS OF THE STUDY IN CHINA

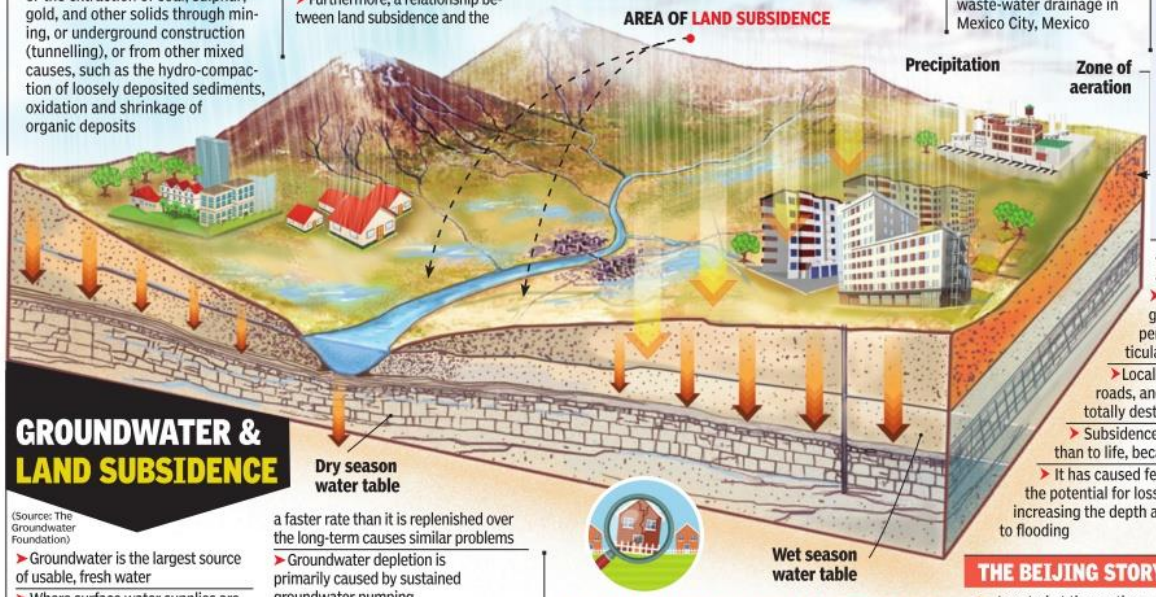
- The Beijing region has experienced significant ground subsidence from 2003 to 2010 with a maximum accumulative displacement of 790 mm
- The spatiotemporal analysis of land subsidence indicates an increasing trend in the rate and extent of land subsidence
- The join spatial and/or temporal analysis of InSAR data and conditioning and triggering factors shows that land subsidence is correlated with groundwater levels, active faults, different soft soil ranges and aquifer types
- Furthermore, a relationship between land subsidence and the distance to the pumping wells has been found.
- The analysis of different stress-strain relationships shows that the aquifer-system exhibits different behaviour, such as quite elastic behaviour and predominantly inelastic behaviour.
- Among the biggest contributors to land subsidence are the clayey layers.
- The InSAR data statistics and the distance to the pumping wells show that land subsidence rates are higher near the pumping wells, as expected according to the shape of a well's cone of depression.

(Source: 'Imaging Land Subsidence Induced by Groundwater Extraction in Beijing (China) Using Satellite Radar Interferometry' published by Mi Chen and other nine researchers in a journal 'Remote Sensing')

The main Cathedral in Mexico City leans to the left after centuries of land subsidence. Rapid land subsidence caused by groundwater withdrawal and associated aquifer-system compaction has damaged colonial-era buildings, buckled highways, and disrupted water supply and waste-water drainage in Mexico City, Mexico

WHERE DOES IT OCCUR

- There are over 150 areas of contemporary subsidence some with as much sinking as 10m in Mexico, Japan, and the United States
- Many more areas of subsidence are likely to develop in the next few decades as a result of accelerated exploitation of natural resources in order to meet the demands of increasing population and industrial development in many developed countries of the world
- As developing countries expand their industry, subsidence is likely to occur in many more areas



GROUNDWATER & LAND SUBSIDENCE

(Source: The Groundwater Foundation)

- Groundwater is the largest source of usable, fresh water
- Where surface water supplies are not available, domestic, agricultural, and industrial water needs can only be met by using the water beneath the ground
- **The US Geological Survey compares ground water stored to money kept in a bank account**
- If the money is withdrawn at a faster rate than new money is deposited, there will eventually be account-supply problems
- Pumping water out of the ground at a faster rate than it is replenished over the long-term causes similar problems
- Groundwater depletion is primarily caused by sustained groundwater pumping
- **Groundwater and surface water are connected. When groundwater is overused, the lakes, streams, and rivers connected to groundwater can also have their supply diminished**
- Land subsidence occurs when there is a loss of support below ground
- This is most often caused by human activities, mainly from the overuse of groundwater, when the soil collapses, compacts, and drops

ITS IMPACT

- Regional lowering may aggravate the flood potential or permanently inundate an area, particularly in coastal or riverine areas
- Local collapse may damage buildings, roads, and utilities and either impair or totally destroy them
- Subsidence is more hazardous to property than to life, because it happens at a slow rate
- It has caused few casualties, but increases the potential for loss of life in flood-prone areas by increasing the depth and size of areas susceptible to flooding

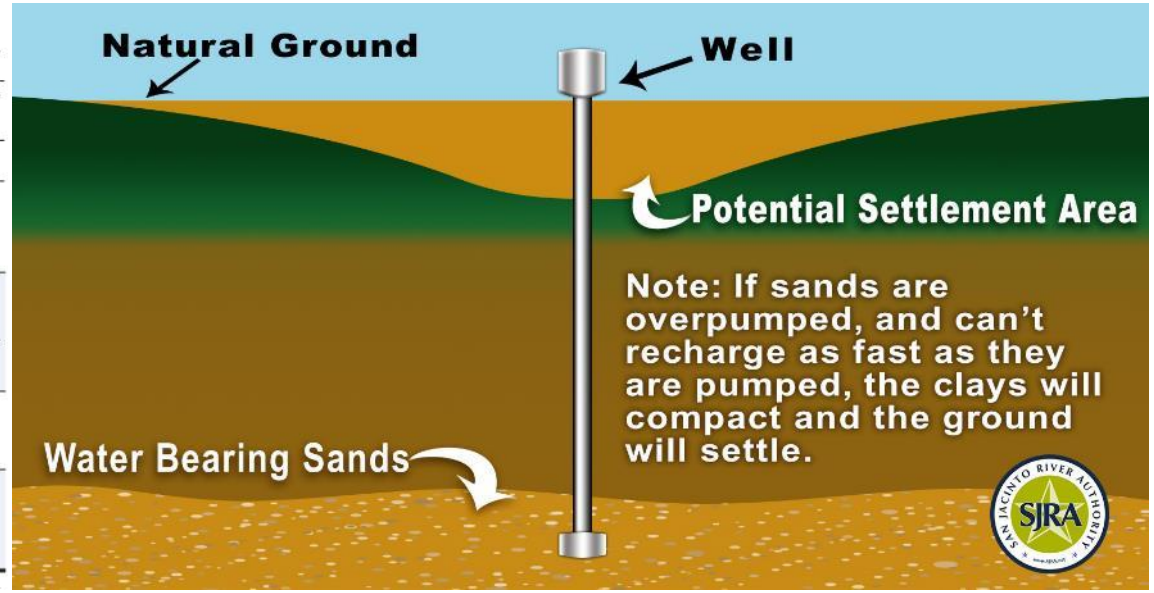
(Source: UNESCO)

MEASURING LAND SUBSIDENCE

- Interferometric Synthetic Aperture Radar (InSAR) is widely used to map land subsidence over wide regions with high spatial-temporal resolutions
- InSAR time series techniques such as Persistent Scatterer Interferometry and the Small Baseline Subset can minimise the limitations of traditional InSAR (e.g., spatial and temporal decorrelation and atmospheric effects)
- In this work, the Small Baseline InSAR technique was employed to investigate land subsidence in the Beijing region and its relationship with different triggering and conditioning factors

THE BEIJING STORY

- Located at the northern end of the North China Plain, Beijing is the 5th most water-stressed city in the world
- Groundwater is the main water source for industrial, agricultural and household activities
- With its rapid urban growth, there has been increasing water demand in Beijing
- Previous studies reveal that the Beijing region has been suffering from land subsidence due to over-exploitation of groundwater since 1935, and more seriously, the rate and extent
- Land subsidence is a severe geohazard threatening the safety of the public and urban infrastructure
- Continuous monitoring of land subsidence is critical for detecting potential hazards and designing compensation strategies



Sumber referensi

- Todd DK, Mays LW. 2005. Groundwater Hydrology. USA : John Willey & Sons

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