# Land Subsidence Management in Japanese Deltas

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- 1. Land subsidence problems in deltas
- 2. Mechanism of land subsidence
- 3. Groundwater monitoring
- 4. Measures to prevent land subsidence
- 5. Conclusion

### Tokyo "Zero-meter" Area below Sea Level

Tokyo metropolitan has a large storm surge hazard area including areas below high tide and low tide.





Contour lines show elevation (m) from Arakawa River Peil, which is 1.13m below Tokyo Peil (Average Tokyo Bay Sea Level). Source: Tokyo Metropolitan Government Construction Bureau

#### **Evidence of Land Subsidence**



Land subsidence caused by the contraction of confining clay layer

Ground level in 1970 \_

Source: Tokyo Metropolitan Government Environment Bureau

### Groundwater Level and Land Subsidence Rate Selection Se

Groundwater levels and land subsidence rate change in parallel.



Kujo Reference Point in Western Osaka

Ground water levels of each deep well were based on the average sea level of Osaka Bay. (Source: Kiyoo WADACHI in 1940)

# Mechanism of Land Subsidence in Alluvial Lowland<sup>QQ</sup>国土交通省

Pressures of the water of confined aquifer and the confining clay layer are balanced.

When the water pressure of confined aquifer falls, the water in the clay layer is squeezed out.



Source: Masaru MORITA, 2012

## **Groundwater Flow in Musashino Plateau**

- A spring depletes when an unconfined groundwater level falls below a spring discharge level.
- Rainfall infiltration can't catch up with unconfined water leakage into lower confined aquifer.



- 3) Run off, Spring water form cliff surface
- 4) Pumping up from shallow wells
- 5) Leakage into a lower confined aquifer

#### **Obstructed Groundwater Flow by Structure**

A linear underground structure blocks an unconfined groundwater flow and causes negative impact.



A long and successive underground structure (from front to back in this figure) blocks groundwater flow (white arrow from left to right).

Source: Masaru MORITA, 2012

### **Trend of Groundwater Level in Tokyo**

- The line shows a record of groundwater level at Tokyo University from 1900 to 2000.
- The groundwater level dropped sharply during the era of post-war economic growth.
- After the effective pumping regulation, the groundwater level has recovered.



(The ground water level is converted based on the average Tokyo Bay Sea Level) Source: Masaru MORITA, 2012

### Land Subsidence and Groundwater Level



- Land subsidence in Tokyo lowland started in the 1920s.
- In the 1960s, the groundwater level dropped 2.5 m/year, and land subsidence advanced 10 cm/year.
- The pumping regulation of 1970s restored the groundwater level, but the subsided land is not recovered.



The ground water levels are converted based on the average Tokyo Bay Sea Level. Source: Tokyo Metropolitan Government Civil Engineering Laboratory



#### **River water in Japan**

**River Act** 

<u>Article 2</u>

"A river is public property."

• Article 23

"Any person who intends to use the water of a river shall obtain permission of the river administrator."

#### **Groundwater in Japan**

Civil Code

• <u>Article 207</u> "Ownership in land shall extend to above and below the surface of the land, subject to the restrictions prescribed by laws and regulations."



Industrial Water Act (1956)

Objectives

- 1) Ensure the rational supply of industrial water
- 2) Conserve sources of groundwater in designated districts and prevent land subsidence
- 1. Industrial zones where land subsidence and other groundwater damage occurred shall be designated.
- 2. Wells with pump outlet of 21 cm<sup>2</sup> (currently 6 cm<sup>2</sup>) and over shall get governor's permission.
- 3. Boring new wells that do not meet the standard is prohibited.
- 4. Where the construction of unqualified well is prohibited, a substitute water source is provided.

### **Code of Preventing Land Subsidence**

The Code of Preventing Land Subsidence (1985-) aims to prevent land subsidence caused by groundwater pumping and to preserve groundwater.

#### **Outline of the Code**

- Objective
- Current situation
- Target area
- Limit of groundwater pumping
- Prevention measures of land subsidence
- Monitoring and survey
- Prevention of damages and recovery
- Promotion of the Code



#### Three Target Delta Areas



#### Conclusion



- Restoration of healthy hydrological cycle
  - Expand the recharge (permeable) area
  - Prevent groundwater flow obstruction
  - Prevent unconfined ground water leakage into the lower confined aquifer
- Groundwater as a future water resource
  - First priority of water resource is river water.
  - Groundwater supplements river water.
- Groundwater level is an indicator to measure the amount of water pumping.





Reference:

Groundwater Tells – Crisis in Hidden Resources (in Japanese) Dr. Masaru MORITA, June 2012