Recent ground level changes in the Taipei Basin, Northern Taiwan

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Thirty-year land elevation change from subsidence to uplift following 
the termination of groundwater pumping and its geological 
implications in the Metropolitan Taipei Basin, Northern Taiwan. 

Prehistoric earthquakes along the Shanchiao Fault, Taipei Basin, 
Outline

- Introduction
- Regional setting
- Analyses and results
- Mechanisms of land elevation changes
- Conclusions
Distribution of the 406 benchmarks of levelling routes. Benchmarks in groups (a) and (b) are used to represent the average movements in western Taipei Basin and Central Taipei, respectively.

Leveling data: 1975–2003

Stopped pumping groundwater: early 1970s
The land elevation change of the Taipei Basin could be classified into three main mechanisms by their operation depth.

- **Near surface soil compaction**
  (the shallow component)

- **Deformation of aquifers**
  (the intermediate component)

- **Tectonic subsidence**
  (the deep and crustal-scale component)
A. The Tatun Volcano  
B. Western Foothills  
C. Linkou Tableland  

Red solid line: Shanchiao Fault

The Taipei Basin filled with Quaternary sediments since about 0.4 Ma. The maximum depth of thickness is about 700 m in the western margin.

Regional setting

i. The Sungshan formation
ii. The Jingmei formation
iii. The Wuku formation
iv. The Banchiao formation

<table>
<thead>
<tr>
<th>Top</th>
<th>stratigraphic</th>
<th>depths for central basin (m)</th>
<th>Aquifer</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>ii.</td>
<td>Jingmei</td>
<td>50-100</td>
<td>Aquifer 1</td>
<td>lateritic conglomerates</td>
</tr>
<tr>
<td>iii.</td>
<td>Wuku</td>
<td>100-130</td>
<td>Aquifer 2</td>
<td>sand, conglomerates with mud</td>
</tr>
<tr>
<td>iv.</td>
<td>Banchiao</td>
<td>130-160</td>
<td>Aquifer 3</td>
<td></td>
</tr>
</tbody>
</table>

Legend:
- Lateritic conglomerate
- Pyroclastic breccia
- Gray pebble
- Pebby sand
- Sand
- Interbedded sand/mud
- Massive mud
- Varved/laminated mud
- Unconformity
1955-1970 — The groundwater over-pumping resulted in severe land subsidence, and the groundwater table of Aquifer 1 decreased more than 40 m.

Early 1970s — The government put a stop on the use of groundwater in the Taipei Basin. The groundwater table was gradually recovered and the subsidence rate in the Taipei Basin gradually decreased.

Late 1990s — The groundwater table was gradually recovered and became approximately stable, and the groundwater table had gradually recovered 30-40 m.

Leveling data from 1975-2003, in order to interpret effects of post-pumping.

Piezometric head records of Aquifer 1 at four monitoring wells since 1972 to 2003
Analyses and results

Based on the rates of elevation change for each benchmark, they construct contour map of land change for each period. And we investigated these contour maps to know the ground level change.
## Analyses and results

We divided these data into two phases from 1975-2003. Phase 1 appears subsidence in the Taipei basin from 1975-1989. Phase 2 appears uplift in the Taipei basin from 1989-2003. For the sake of discontinuity of measurements, Phase 1 divided into 3 periods and Phase 2 divided into 4 periods.

<table>
<thead>
<tr>
<th></th>
<th>Entire time span</th>
<th>Periods</th>
<th>Ground level change type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2000-2003</td>
<td></td>
</tr>
</tbody>
</table>
Analyses and results

Phase 1

Phase 2
Analyses and results

- Phase 1 (1975-1989)

Contour maps of observed land surface elevation change in Phase 1 (1975–1989) of post-pumping period. Contour interval is 5 mm/yr. The whole basin still subsided after the stop of groundwater pumping, but with a decreasing trend from 40-70 mm/yr to 0-30 mm/yr.
Analyses and results


The surface subsidence almost ceased and a large portion of the Taipei Basin began to slight uplift, especially in the central of the basin. Nevertheless, slight subsidence still persisted in western margin of the basin.

Contour maps of observed land surface elevation change in Phase 2.
Analyses and results

- **Phase 1 (1975-1989)**
  The whole basin still subsided after the stop of groundwater pumping, but with a decreasing trend from 40–70 mm/yr to 0–30 mm/yr.

- **Phase 2 (1989-2003)**
  Starting from about 1989, uplift began to appear significantly in the Taipei Basin and declined in magnitude in the later half of Phase 2.

- The subsidence continuously occurred along the western margin of the basin in Phase 1 and Phase 2, such as Guandu, Wuku.
Mechanisms of land elevation changes

Near surface soil compaction

We estimated shallow soil compaction to contribute 1–8 mm/yr of subsidence in the basin with most land ranging 2 to 5 mm/yr.

(a) Isopach of the Holocene clayish sediments (topmost 50-m deposits) in Taipei Basin. (b) Estimated compaction rate of clayey layers within the Holocene deposits (soil compaction).
Mechanisms of land elevation changes

- Deformation of aquifers

- **Sand or Conglomerate** — Behave in a seemingly elastic manner and might be a reason for land rebound.

- **Clay** — Irreversible one-way process, and is the major source for severe pumping-induced land subsidence.

General conceptual model of ground elevation change due to artificial groundwater table drawdown and recovery. (a) short-term pumping test and (b) long-term artificial pumping.
Mechanisms of land elevation changes

➢ Tectonic subsidence

The initial deposition of Quaternary strata in the Taipei Basin immediately followed subsidence of the basin, the total offset for the past 400,000 years is approximately 700 m.

The Quaternary averaged tectonic subsidence rate to be 1.75 mm/yr since 0.4 Ma. (it contain contributions from co-seismic slips)

The averaged tectonic subsidence rate is approximately 0.88 mm/yr in the central part.
Mechanisms of land elevation changes

Tectonic load

Net offset and timing of two subsidence events recorded in boreholes SCF05, SCF06, SCF01, and SCF02. Horizontal axis represents radiocarbon ages and vertical axis represents amount of offset.

8.4–8.6 ka (3.7m) 9.1–9.3 ka (4.5m)
9.0–9.3 ka (3.3m) 11 ka (2.3m)

Ka: ky B.P.
Mechanisms of land elevation changes

- Tectonic load

- We consider the Shanchiao fault had three prehistoric earthquakes in Holocene, which produced about 10 m offset.

- As if we removed the offset of Shanchiao fault in Holocene, the averaged tectonic subsidence rate to be 1.72 mm/yr since 0.4 Ma. The averaged tectonic subsidence rate is approximately 0.85 mm/yr in the central part.
Mechanisms of land elevation changes

- **Tectonic load**

The correlation profile of boreholes SCF15, SCF16, SCF14, and SCF17. The boreholes did not show displacement between Quaternary strata.
Conclusions

This figure is a model of mechanisms for the cumulative ground level changes of Western and Central Taipei during Phase 2 from 1989 to 2003.
This is the mechanisms of land elevation change in the Taipei Basin during the past 30-year post-pumping period. It shows the effect from three major mechanisms in the western and central basin.
Near surface soil compaction

The rate of shallow soil compaction is estimated about 1–8 mm/yr throughout the basin according primarily to the shallow clay thickness.

Deformation of aquifers

The rebound of aquifer strata was estimated to be about 6.7 cm in western margin and 16 cm in Central Taipei.

Tectonic subsidence

The tectonic subsidence related to the Shanchiao Fault was estimated to be 1.72 mm/yr in the western part of Taipei Basin and 0.85 mm/yr in the central part of the Taipei Basin.
Thank you