Land Subsidence Monitoring, San Joaquin Valley

Michelle Sneed
California Water Science Center
U.S. Geological Survey
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Land Subsidence in the San Joaquin Valley Aquifer-System Compaction

- Concentrated in the fine-grained deposits (clays/silts)
- Inelastic (permanent) compaction occurs when the critical head is exceeded
- Critical head ≈ previous lowest groundwater level
- Storage capacity is reduced

Galloway and others (1999); USGS Circular 1182
Groundwater Level Declines

Water level data from USGS and Luhdorff and Scalmanini Consulting Engineers; Preliminary and subject to revision

Historically low levels
Clay-Rich Aquifer Systems

clay
silt
sand
gravel
soils
Subsidence Monitoring

- Can result in early detection
- Provides a measure of water-resources sustainability within relevant planning horizons
- Produces data needed for subsidence management
Subsidence Measurements: 
Space and Time

- One to Several Points
  - Borehole Extensometer*
- 10’s of Points
  - Spirit Leveling
  - GPS (RTK/static/continuous)
- 1000’s-1,000,000’s of Points
  - InSAR (space and airborne)
  - LiDAR
  - Radar Altimetry

- <Several measurements/year
  - Spirit Leveling
  - GPS (RTK, Static)
- Several measurements/year
  - InSAR (space and airborne)
  - LiDAR
  - Radar Altimetry
- 1000’s measurements/year
  - Borehole Extensometer*
  - GPS (continuous)

* Measures aquifer-system compaction
InSAR: High Spatial Resolution

GUIDE DESIGN OF MONITORING NETWORKS (LIKE GPS)

CGPS: High Temporal Resolution

CGPS data from UNAVCO; survey data from DWR
Extensive withdrawal of groundwater caused widespread subsidence (1920s-1970)

Surface-water deliveries caused widespread recovery and slowing or cessation of subsidence, except when deliveries were curtailed and groundwater pumping increased to meet demand.
Recent Subsidence

- Renewed subsidence concern during the 2007-09 drought initiated investigations
  - Reduced surface water importation
  - More reliance on the groundwater resources
  - As it turns out...this is not just a problem during droughts for some areas with limited surface-water access

CGPS data from UNAVCO; water level data from DWR, USGS, and Luhdorff and Scalmanini Consulting Engineers
Water Conveyance Infrastructure

EXPLANATION

- Selected water conveyance features

Land Subsidence (2008-10)

- Inches
- Estimated

- 1 - 2
- 2 - 4
- 4 - 6
- 6 - 11
- 11 - 16
- 16 - 21
- > 21
Periodic Leveling/GPS Surveys

Survey data from Bureau of Reclamation
Periodic Leveling/GPS Surveys

Survey data from Caltrans, Bureau of Reclamation, and DWR
Continuous GPS Stations in CA

http://www.unavco.org/instrumentation/networks/status/pbo

http://sopac.ucsd.edu/map.shtml
Continuous GPS Time Series

CGPS data from UNAVCO

Rate increases during droughts

Subsidence only during droughts

P303

P307

P304
Continuous GPS Time Series

CGPS data from UNAVCO
Continuous Compaction: Extensometers

Extensometer and water-level data from USGS and Luhdorff and Scalmanini Consulting Engineers
Compaction Depths (Mendota)

- Extensometer is anchored in the top of Corcoran Clay
- GPS reflects subsidence relative to the center of the Earth
- GPS measured much more deformation than the extensometer

**Conclusion:** Most of deformation is occurring below the top of the Corcoran Clay
Subsidence Monitoring Summary

- Measuring subsidence/compaction AND groundwater levels is essential to understanding aquifer-system behavior
  - Estimate critical head and aquifer-system storage properties (model input)
- High spatial resolution of subsidence provided by InSAR data can help focus monitoring resources
  - Design ground-based networks to improve temporal resolution
- High temporal resolution of subsidence provided by continuous GPS or extensometers can help managers determine how various management strategies affect subsidence (decision support)
- Extensometers are the only measurement technique that will indicate depth intervals of compaction
  - Understanding compacting intervals is critical in subsidence management
Thanks!

For more information:

http://ca.water.usgs.gov/land_subsidence/