Aquifer Compaction in the Virginia and Maryland Coastal Plain Resulting from Groundwater Pumping

USGS Virginia Water Science Center Kurt J. McCoy and Andrew Staley

U.S. Subsidence



Reported subsidence caused by groundwater withdrawal





Rates of Elevation Change in the Chesapeake **Bay Area** (1940 - 1971)mm/year

Holdahl and Morrison, 1974





Groundwater Levels Potomac Aquifer 2008

Groundwater levels below sea level over most of coastal plain

2 industrial pumping centers with large cones of depression





Deep aquifer heads in Maryland's Lower Patapsco aquifer



Maryland and Virginia share the same aquifer system



Vertical scale greatly exaggerated

Virginia Coastal Plain Groundwater Withdrawals by Aquifer



Date

Land Subsidence caused by Aquifer-System Compaction

Land surface



- Concentrated in the finegrained deposits (clays/silts)
- Inelastic (permanent) compaction occurs when the critical head is exceeded
- ► Critical head ≈ previous lowest groundwater level

science for a changing world

Storage capacity is reduced





Monitoring network - location of benchmarks



Before groundwater pumping . . .



... and after groundwater pumping





USGS Measurement of Aquifer System Compaction

Franklin Extensometer Oct. 1979 – Dec. 1995 Depth = 255.1 m

Suffolk Extensometer June 1982 – Dec. 1995 Depth = 484.0 m

 Miles

 0
 25

Aquifer-System Compaction at Franklin and Suffolk, Virginia (1979-1996)



Southeastern Virginia Subsidence Monitoring Network



Pumping Induced Aquifer Compaction







Estimated Cumulative Land Subsidence in Southeastern Virginia

FRANKLIN		SUFFOLK		
Before 1940	< 10 mm	0 mm	Before 1940	
1940-71	81	62	1940-71	
1971-79	~ 21	~ 22	1971-82	
1979-1996	24.2	50.2	1982-1996	
Total	~136.2	~134.2	Total	
1996-2015	?	?	1996-2015	

Simulated Compaction at Franklin, Va.



Rates of Relative Sea-Level Rise at NOAA Tidal Stations

NOAA ID	Site name	Period	Rate of relative sea- level rise, <u>mm/yr</u> / <u>95% CI</u>	
8632200	Kiptopeke, VA	1951–2006	3.5	±0.42
8637624	Gloucester Pt., VA	1950–2006	3.8	± 0.47
8638610	Sewells Point, VA	1927–2006	4.4	±0.27
8638660	Portsmouth, VA	1935–2006	3.8	±0.45
	Average		3.9	±0.40



Subsidence Summary

- More than 50 areas in the United States have been affected by land subsidence due to fluid withdrawal
- Subsidence areas are largest in the Chesapeake Bay area
- Subsidence exacerbates sea level rise in affected coastal basins
- Adversely affecting water conveyances, infrastructure, wetlands
 - Differential subsidence reduces conveyance capacity of gravity-driven canals
 - Flooding frequency, depth of flood, and duration of flooding increase
- Long-term monitoring of water levels and subsidence is needed to detect and track groundwater conditions for decision support

