Assessment of seawater intrusion potential from sea level rise

in coastal aquifers of California

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Introduction

One of the likely impacts of modern-age climate change in California identified by the California Department of Water Resources (DWR) was the "increased potential for salinity intrusion into coastal aquifers" (DWR, 2006). The United Nations Intergovernmental Panel on Climate Change (IPCC) estimated an average worldwide mean sea-level rise between 0.10 and 0.20 meters during the 20th century (IPCC, 2001). DWR (2006) postulated a plausible additional increase ranging from 0.10 to 0.90 meters along California's coast by 2100.

One effect of such an increase in sea-level rise is to induce seawater intrusion into the coastal aquifer (Zektser and Loáiciga, 1993). Given the prominent role that groundwater has on water supply in California – amounting to about 30% of its urban and agricultural use – it is timely to address the threat posed by future sea level rise to California's groundwater. This project examines quantitatively the threat of sea-level rise in two of California's most productive coastal aquifers: the Oxnard Plain aquifer in Ventura County and the Salinas Valley coastal aquifer (Seaside Area) in Monterey County (DWR, 2003). The project was begun in September 2007 and is scheduled for completion in July 2009.

Objectives

•**Rapid assessment of seawater intrusion** – Develop an approach utilizing the flow-net geometry of coastal groundwater flow and on a variant of the Dupuit-Ghyben-Herzberg equation to calculate the freshwater head corresponding to a landward-displaced seawater-freshwater interface.
•**Numerical simulation of seawater intrusion in coastal aquifers** – Utilize finite element subsurface flow and transportation simulation system (FEFLOW) to model fluid flow and mass transport (Diersch, 2006).
•**Management recommendations** – Research results will be used to make recommendations concerning the need for and the nature of mitigating measures to counter the probable impacts of sea-level rise in coastal aquifers.

Seaside Study Area

In addition to FEFLOW, the Matlab computing environment and ArcGIS 9.2 were used for spatial and analytical operations.

The numerical model for the Seaside, CA area is currently being calibrated to approximate observed flow conditions. Figure 1 below shows the study area and the distribution of production wells in the area. Current groundwater extraction from the basin is concentrated in the northeast near the ocean boundary. Water levels in the coastal area are declining at a rate of approximately 1 ft/yr since pumping over the entire basin exceeds recharge by an estimated 1,540 acre-ft/year (Yates et al., 2005).

The Chupines Fault forms the southern boundary of the basin, where relatively impermeable Monterey Shale has been uplifted and prevents southerly flow. The remainder of the boundary of the Seaside Area sub-basin is largely administrative, and is hydraulically connected to the larger Salinas Valley Aquifer.
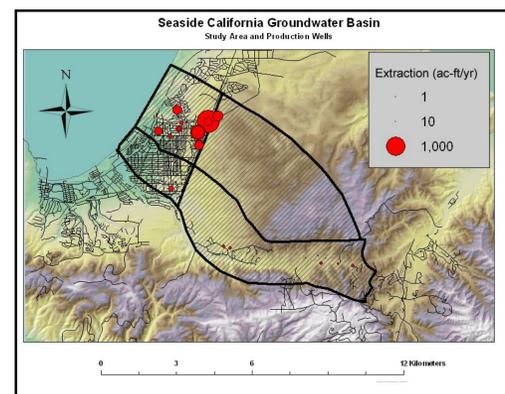

Figure 1. The Seaside Area Sub-basin of the Salinas Valley Groundwater Basin (3-4.08). Surface area: 14,900 acres. Most groundwater extraction occurs within 3 kilometers of the ocean boundary, contributing to the risk of seawater intrusion.

Model Construction

Flow patterns in the finite element model are largely governed by values of hydraulic conductivity, groundwater recharge estimates, and the shape and distribution of material in the aquifer. The Santa Margarita and Paso Robles/Aromas formations (weakly consolidated sandstone) form the base and middle sections of the aquifer, with small alluvial deposits overlying these in some areas (DWR, 2006).
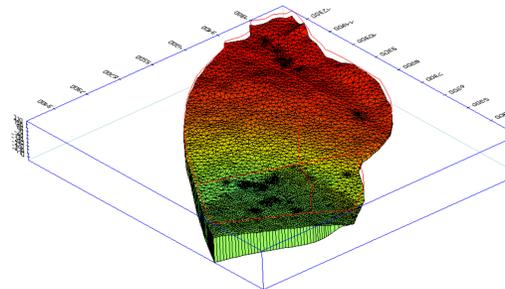
Figures 2 (above) and 3 (below). Above, Seaside Area sub-basin as viewed looking southeast, with color mapped to hydraulic head before final calibration. The finite element mesh has been refined around extraction wells and near the ocean boundary to enhance local precision. The current model has 8864 nodes per surface.
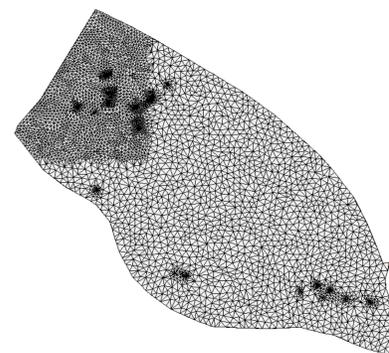
Model Calibration

The current round of model calibration incorporates both historical measurements from well records and previous numerical models to closely approximate current flow patterns, groundwater heights, and coastal salinity levels. Relatively little sampling has been done in the upland portion of the basin, and no records exist for the Fort Ord Reservation area (the upper right sub-division on Figure 1). As a result, material conductivities and spatial extents must be interpolated from surrounding formations. These values are run in FEFLOW and compared to overall groundwater levels and trends.
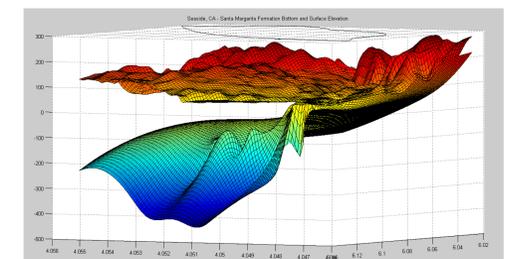

Figure 4. Three dimensional rendering (looking southeast) in Matlab of ground surface (National Elevation Dataset) and bottom layer of Seaside Area aquifer (interpolated from Yates et al., 2005; Muir, 1982).
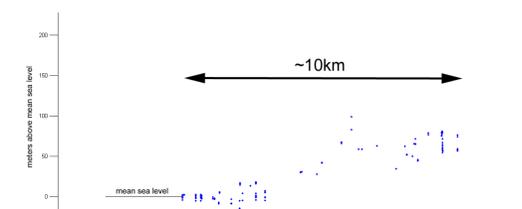

Figure 5. Overall groundwater elevation trend from northwest to southeast compressed to a transect orthogonal to the shoreline.

Literature cited

California Department of Water Resources (DWR). (2003). California's Groundwater. Bulletin 118. Sacramento, California.

Diersch, H. J. G. (2006). FEFLOW 5.3: Finite element subsurface flow and transport simulation system user manual version 5.3. Berlin: WASY GmbH Institute for Water Resources Planning and Systems Research.

IPCC. (2001). Climate Change 2001: The Scientific Basis. Houghton, J.T. et al., eds., Cambridge University Press, Cambridge, UK.

Muir, K. S. (1982). Ground water in the seaside area, Monterey county, California. U.S. Geological Survey Water-Resources Investigation 82-10. Washington, D.C.: United States Geological Survey.

Yates, E. B., Feeney, M. B., & Rosenberg, L. I. (2005). Seaside groundwater basin: Update on water resource conditions. Monterey, CA: Monterey Peninsula Water Management District.

Zekster, I.S., Loáiciga, H.A. (1993). Groundwater fluxes in the hydrologic cycle: past, present, and future. *Journal of Hydrology*, 144, 405-407.

Acknowledgments

For further information

Please contact *thomas.pingel@gmail.com*. More information on this and related projects can be obtained at *www.geog.ucsb.edu/~hugo*.