Delineating Zones of Seawater Intrusion in a Coastal Southern California Aquifer

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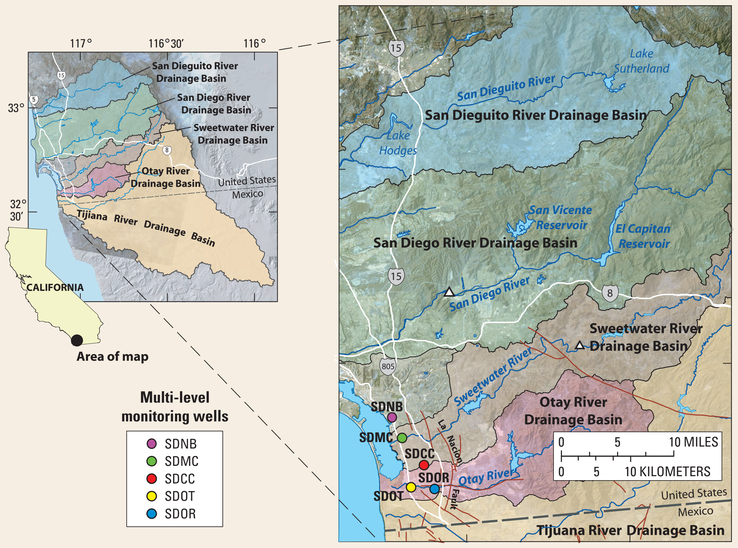
Abstract

A comprehensive investigation is being conducted by the U.S. Geological Survey in the San Diego, California area to evaluate the suitability of the San Diego Formation and overlying alluvial deposits for use as a drinking water supply. *As many as 6 monitoring wells were installed at 10 sites to depths of as much as 2,000 feet for this investigation. Lithologic information was compiled from descriptions of drill cuttings collected at each borehole site and from observations recorded during drilling. Electromagnetic induction (EM) logs were obtained prior to the installation of the monitoring wells, and during subsequent site visits. EM logs are sensitive to changes in lithology and water quality; because the lithology remains constant repeated EM logs can be used to show changes in water-quality due to natural recharge processes, seawater intrusion, or other processes. Monitoring wells were sampled for major-ions, selected minor-ions and trace elements, the stable isotopes of oxygen and hydrogen, and age-dating constituents, including tritium and carbon-14, to identify sources of high-chloride groundwater to the monitoring wells in the San Diego area.*

This paper presents lithologic, geophysical, and water-quality data collected from three of the multiple-well monitoring sites located along the San Diego Bay and from two multiple-well monitoring sites located on a plateau away from the coastal area. *These monitoring sites were chosen based on their location near the coast and on their close proximity to each other. Lithologic data indicate the hydrogeology of the San Diego area is characterized by alternating layers of marine and non-marine sediment lacking continuity over long distances. Chloride concentrations in sampled wells ranged from 136 milligrams per liter (mg/L) to 40,000 mg/L, the high chloride concentrations suggest the presence of seawater intrusion in several near-coastal monitoring wells. Bromide-to-chloride ratios indicate that chloride concentrations greater than seawater likely result from seawater altered by evaporation. A relation established between EM logs, lithology, and water quality allowed for an estimate of the quality of water in intervals not sampled by wells. Finally, the EM logs, in combination with the water-quality data, is used to distinguish between high-salinity zones that are caused by seawater intrusion from those that are caused by "freshening" of a previously-saline aquifer by recently recharged water.*

Background

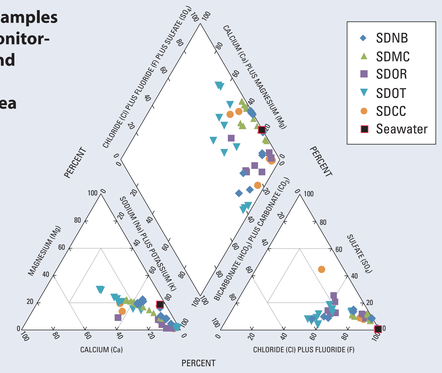
The regional assessment of groundwater resources in the San Diego area was designed as an integrated set of five drainage-basin investigations, to evaluate the suitability of the San Diego Formation and overlying unconsolidated Quaternary alluvium for use as a drinking water supply. The San Diego Formation is composed of thinly bedded sandstone and conglomerate, which originated as marine and non-marine sediment during the late Pliocene and early Pleistocene, ranges in thickness from about 100 feet to more than 800 feet, and is overlain by about 100 feet of unconsolidated Quaternary alluvium from the Linda Vista and Bay Point Formations. An integral part of the investigation is the installation of as many as 6 monitoring wells at 10 sites to depths depths of as much as 2,000 feet. Data includes lithologic information, geophysical logs, and water-quality samples analyzed for a broad range of constituents including major and minor dissolved ions, trace metals, volatile organics, pesticides, wastewater indicators, and stable and radiogenic isotopes. In addition, the multiple-well monitoring sites are equipped with real-time, water-level recording equipment and the data is available via the project website shown below.



For more information see—http://ca.water.usgs.gov/sandiego

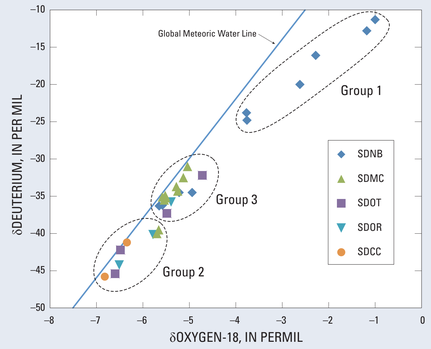
Major-ion Chemistry

Major-ion composition of 55 groundwater samples collected from three of the multiple-well monitoring sites located along the San Diego Bay and from two multiple-well monitoring sites located on a plateau away from the coastal area is presented using a trilinear diagram. Percentages of major ions on a charge-equivalent basis indicate the chemical composition of the groundwater in the Sweetwater and Otay River drainage basins can be characterized as mixed cation-Cl to Na-Cl type. The percentages of major ions indicate also that the chemical composition of several groundwater samples collected along the San Diego Bay resemble the major-ion composition of seawater.



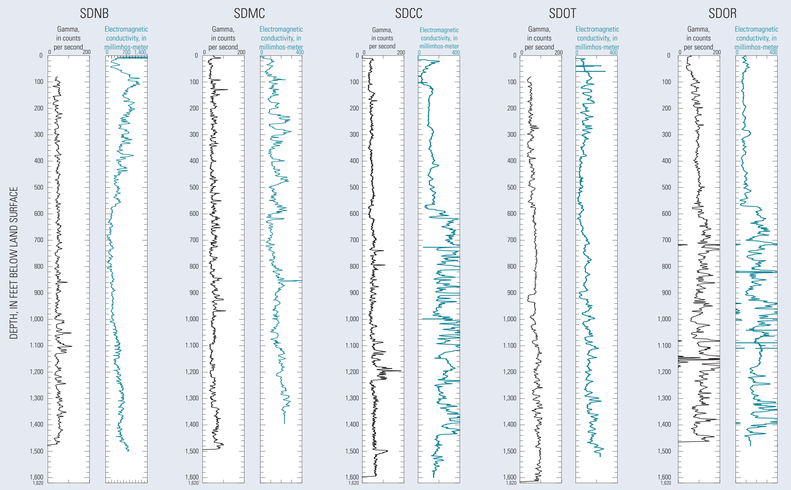
Stable Isotopes of H and O

The stable isotopes of hydrogen and oxygen can be used to identify the different sources of recharge in the Sweetwater and Otay River drainage basins. These different groups are distinguishable by: (1) isotopic values comprised of a mixture of groundwater and seawater; (2) lighter (more negative) ground-water isotopic values that are characteristic of recharge which originates in the mountains to the east of the Sweetwater and Otay River drainage basins; and (3) intermediate isotopic values which are characteristic of local precipitation as the source of recharge to the multiple-well monitoring sites.



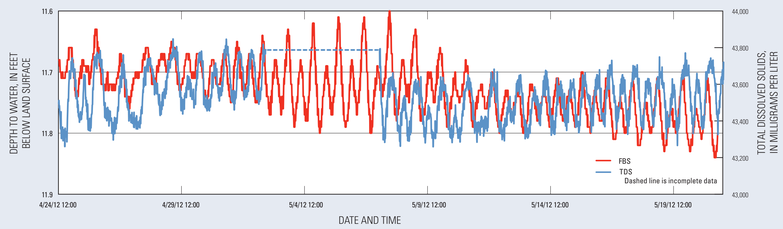
Geophysical Logs

Gamma and electromagnetic induction (EM) logs were obtained prior to the installation of the monitoring wells, and during subsequent site visits. A natural gamma tool is designed to measure the total intensity of gamma-ray emissions from the formation. EM logs are sensitive to changes in lithology and water quality; because the lithology remains constant repeated EM logs can be used to show changes in water-quality due to natural recharge processes, seawater intrusion, or other processes.



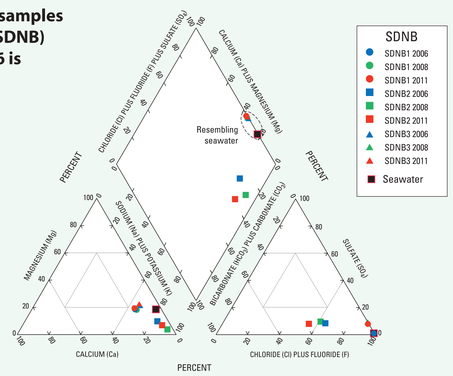
Tidal Effects on Salinity

From the April 24, 2012, through May 21, 2012, an in situ salinity transducer was installed at a depth of 200 feet below land surface to measure total dissolved solids (TDS) concentrations values every 15 minutes. This data was compared against the mixed semi-diurnal tidal influenced water levels of SDNB3. The TDS concentrations reached a maximum of 43,844 mg/L on May 1st at 0745 and reached its minimum value of 43,259 mg/L on May 9 at 1730.



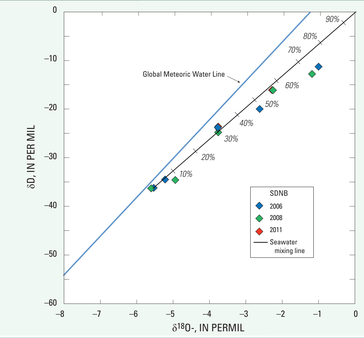
Major-ion Chemistry in SDNB

Major-ion composition of 9 groundwater samples collected from the San Diego Navy Base (SDNB) multiple-depth monitoring site since 2006 is presented using a trilinear diagram. The chemical composition of groundwater samples collected from SDNB1 and SDNB3 resemble the major-ion composition of seawater. There chemistry has remained relatively unchanged since 2006. While SDNB2 major-ion samples plot as more bicarbonate and carbonate rich water that has changed since 2006. These differences imply SDNB has multiple zones of water recharge some of which are seawater intrusion.



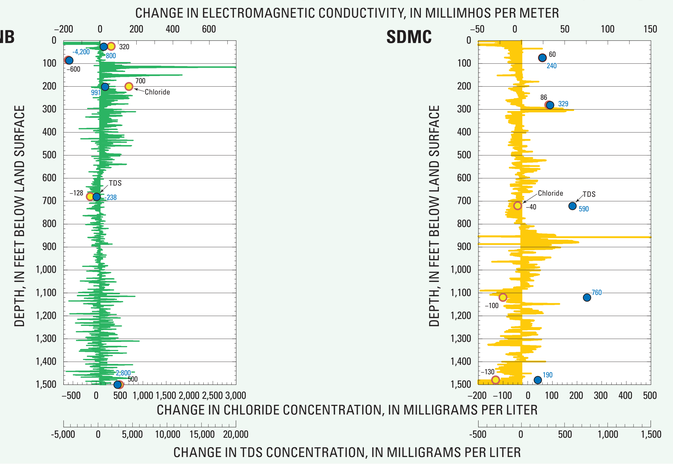
Stable Isotopes of H and O in SDNB

The stable isotopes of hydrogen and oxygen of 12 groundwater samples collected from the SDNB multiple-depth monitoring site since 2006 indicate the groundwater is comprised of a mixture of groundwater and seawater. Also shown is a simple two-member mixing line between native freshwater and seawater. The stable isotopic values from the coastal monitoring wells plot along the mixing line and suggest that water from these wells are as much as 70-percent seawater, and the percentage of seawater in groundwater samples collected from SDNB has changed since 2006.



Changes in EM and Chloride Concentration

Changes in chloride concentrations and electromagnetic conductivity logs for SDNB and SDMC are presented below. Conductivity has increased to a depth of about 580 feet below land surface (fbls), with a corresponding increase in chloride concentrations. The presence of the high-salinity groundwater indicates seawater intrusion is occurring within this zone. Conductivity has increased below a depth of 820 fbls and suggests that seawater intrusion is occurring in this zone as well, although to a much lesser extent. In contrast, chloride concentrations and electrical conductivity have decreased from 560 fbls to 820 fbls and at 1,460 fbls. The absence of high-salinity groundwater with in this zone indicates "freshening" of a previously-saline aquifer by recently recharged water.



Significant Findings

1. Groundwater in the Sweetwater and Otay River drainage basins is characterized as mixed cation-Cl to Na-Cl type. The percentages of major ions indicate also that the chemical composition of several groundwater water samples collected along the San Diego Bay resemble the major-ion composition of seawater.

2. Chloride concentrations greater than seawater likely result from seawater altered by evaporation.

3. The stable isotopes of hydrogen and oxygen indicate the groundwater in the Sweetwater and Otay River drainage basins can be separated into at least three distinct sources of recharge.

4. The major-ion chemistry and stable isotopic values for groundwater samples collected from SDNB2 has changed since 2006.

5. EM logs, in combination with the water-quality data, can be used to distinguish between high-salinity zones that are caused by seawater intrusion from those that are caused by "freshening" of a previously-saline aquifer by recently recharged water.