Ground Water in the Anchorage Area, Alaska

Meeting the Challenges of Ground-Water Sustainability

Ground water is an important component of Anchorage's water supply. During the 1970s and early 80s when ground water extracted from aquifers near Ship Creek was the principal source of supply, area-wide declines in ground-water levels resulted in near record low streamflows in Ship Creek. Since the importation of Eklutna Lake water in the late 1980s, ground-water use has been reduced and ground water has contributed 14–30 percent of the annual supply. As Anchorage grows, given the current constraints on the Eklutna Lake water availability, the increasing demand for water could place an increasing reliance on local ground-water resources. The sustainability of Anchorage's ground-water resources challenges stakeholders to develop a comprehensive water-resources management strategy.

Throughout the city of Anchorage, ground water is pumped from hydrologic units consisting of unconsolidated surficial deposits and metamorphic bedrock underlying hillside areas. The surficial deposits of gravel, sand, silt, and clay range in thickness from several feet to more than 1,500 feet below land surface (Barnwell and others, 1972). These water-bearing materials constitute two surficial aquifers overlying a bedrock aquifer and extend from the foothills of the Chugach Mountains to Cook Inlet and from the Elmendorf and Fort Richardson military bases to Potters Marsh.

A growing municipality

The city of Anchorage, part of the municipality of Anchorage, covers about 200 square miles and extends from Ship Creek south of Eagle River, AK, to Potters Marsh just west of Girdwood, AK. About 280,000 people, more than 42 percent of Alaska's population, live within the city of Anchorage, which accounted for about 44 percent of the State's population growth in the 1990s (State of Alaska, 2004). Forecasts predict that Anchorage's population will grow about 35 percent by 2020 (MOA, 2001; Williams, 2004).

Present and projected water use

Anchorage Water and Wastewater Utility (AWWU) provides locally obtained surface water and ground water to satisfy most of the city's public water demand. The remaining water is supplied primarily from private domestic wells. In 2002, AWWU delivered on average 27.6 million gallons per day (Mgal/d) of water to more than 52,600 customers, equating to nearly 127 gallons per person per day (AWWU, 2005a). About 83 percent of the water supplied by AWWU in 2002 was surface water obtained from Eklutna Lake (79 percent) and Ship Creek (4 percent). The remaining 17 percent (4.7 Mgal/d) was obtained from ground water pumped from local aquifers (AWWU, 2005b). An additional estimated[1] non-AWWU production (4 Mgal/d) pumped from private domestic wells contributed to a total of about 8.7 Mgal/d of ground water pumped from local aquifers in 2002.

As the demand for water increases in proportion to the expected 35-percent

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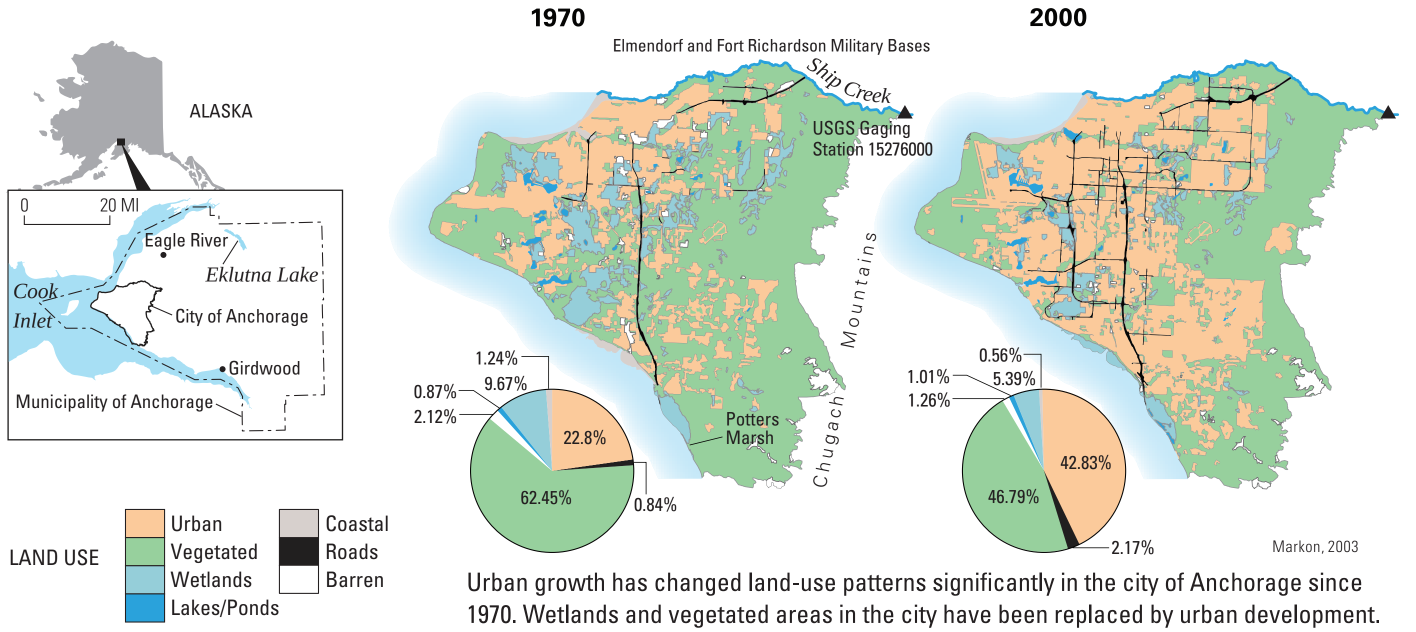
[1] Based on 1972 estimate (USCOE, 1979) adjusted for growth.



Urban growth has changed land-use patterns significantly in the city of Anchorage since 1970. Wetlands and vegetated areas in the city have been replaced by urban development.

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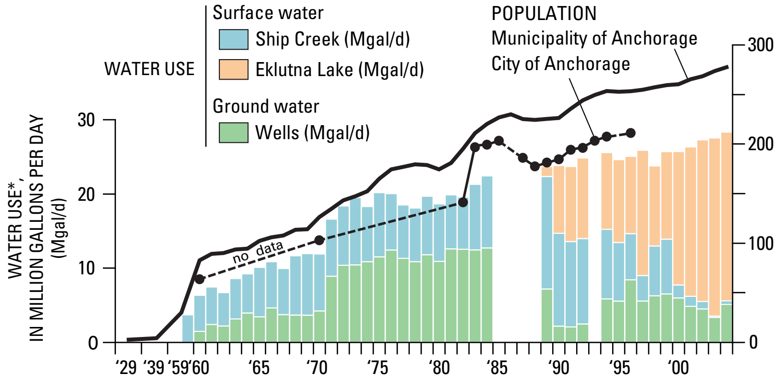


*AWWU, 2005a and 2005b and USGS, 1987

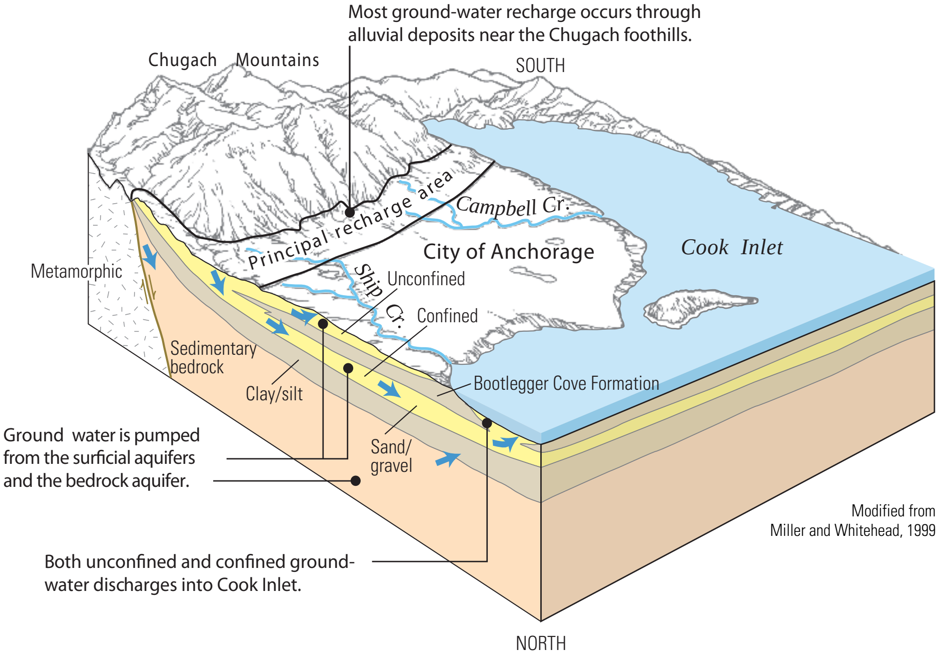
Water use in Anchorage keeps pace with a growing population.

growth in population, by 2020, AWWU will need to supply an estimated 37 Mgal/d of water. If ground-water use increased at the same rate as population, ground water would constitute about 6.3 Mgal/d of AWWU water deliveries, and domestic pumpage would contribute to a total of about 11.7 Mgal/d of ground water pumped from local aquifers.

Surface-water availability

Anchorage has several good-quality sources of water. Eklutna Lake alone is capable of providing more than 100 Mgal/d, but is currently limited by the 35 Mgal/d capacity of the Eklutna Water Treatment Facility (AWWU, 2005a). Average flows in Ship Creek (USGS gaging station 15276000) as measured at the foothills of the Chugach Mountains below the Fort Richardson military base diversion dam were about 93 Mgal/d from 1947–2003 (USGS, 2005). As potential sources these quantities far exceed the projected 2020 demand for water.

Increasing the supply from Eklutna's Water Treatment Facility would require substantial capital investment and would consume water currently used for electricity production. The water treatment facility could meet the expected 2020 demand; however, by 2030–40, the expected demand likely would exceed its capacity. AWWU's Ship Creek supply primarily is limited by the 10.5 Mgal/d annual water right and limits on withdrawals of 3 Mgal/d or less during low-flow winter periods. Because of variable flows and water quality of Ship Creek, its use has been minimized to maintain flows for aquatic and riparian habitat and to mitigate fecal coliform contamination (ADEC, 2004).



Most ground-water recharge occurs through alluvial deposits near the Chugach foothills.

Ground water is pumped from the surficial aquifers and the bedrock aquifer.

Both unconfined and confined ground-water discharges into Cook Inlet.

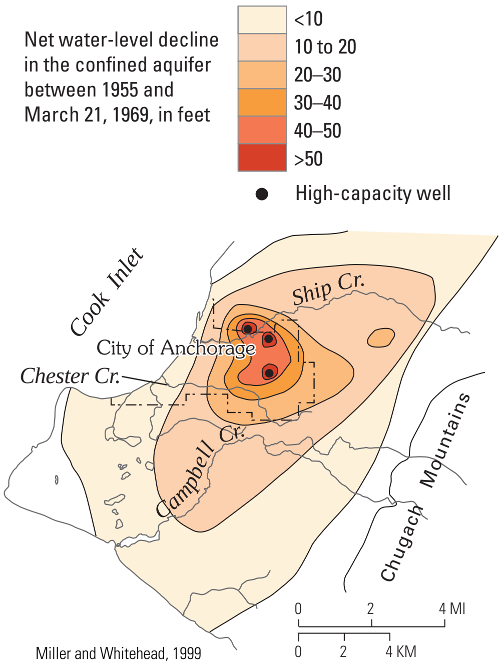
Modified from Miller and Whitehead, 1999

Ground-water availability

An estimated 75 Mgal/d of water on average recharges Anchorage-area aquifers (Barnwell and others, 1972). Ground water flows toward Cook Inlet from recharge areas in the Chugach Mountains and upland areas of the coastal plain deposits. Much of the flow discharges directly into Cook Inlet. Along the way, ground water is recharged by infiltration of streamflow in the upper reaches of the major watersheds, such as Ship Creek, and to a lesser degree throughout Anchorage by infiltration of precipitation through the surficial deposits. In the lowland areas of the coastal plain, ground water discharges into streams, springs, seeps, and wetlands, where it runs off, evaporates, or is transpired by plants (Barnwell and others, 1972; Patrick and others, 1989).

Under natural conditions, over the long term, a flow system is in a dynamic equilibrium, or steady state—the average discharge approximates the average recharge. The equilibrium is dynamic because recharge fluctuates seasonally and annually. Major climate shifts, changes in landscape owing to natural events, such as earthquakes or human alteration, and varying ground-water pumping rates can disrupt the equilibrium for years until a new equilibrium is established. By 1969, pumping from high-capacity wells lowered water levels more than 50 feet in the lower part of Ship Creek basin, resulting in reduced Ship Creek streamflow, and by 10 feet or more over an area of 40 square miles (Miller and Whitehead, 1999). However, ground-water levels in some areas of Anchorage have recovered to predevelopment levels owing to reduced extraction.

Poor water quality can render ground water unusable for drinking. Human activities can introduce undesirable chemicals into aquifers and increase concentrations of the nutrients nitrogen and phosphorous. Regionally, the quality of Anchorage-area ground water generally is good (Glass, 2001). In isolated areas in Anchorage, however, oil and fuel spills and waste-disposal sites have released benzene, xylenes, arsenic, chromium, fluorescein, and sulfate into the ground water (ADEC, 2005). Leachate from septic systems, a landfill, and other disposal sites have introduced coliform bacteria and higher concentrations of iron, manganese, dissolved organic carbon, and chloride in local ground water (Munter, 1987; Munter, and Maynard, 1987).



Miller and Whitehead, 1999

Ground-water sustainability

A sustainable ground-water supply largely is a subjective quantity that depends on the "acceptable" consequences and knowledge of the realized or expected outcomes of ground-water management practices. Whether the consequences and outcomes are "acceptable" is best determined by stakeholders. But choosing the best or most desirable outcomes requires knowledge of the hydrogeologic system and its responses to imposed stresses, such as ground-water pumping.

The development of water resources imposes stresses on flow systems. Poorly planned, ground-water pumping can reduce streamflow that sustains riparian ecosystems, which occurred along Ship Creek in the 1970s and 1980s. Additionally, high rates of ground-water extraction can reduce outflow to coastal areas causing landward migration of saline ground water—saltwater intrusion.

Overuse can deplete a ground-water resource and potentially cause adverse consequences. Maximizing the sustainable use of the ground-water resource in the context of conjunctive-use management can be beneficial. In Anchorage, for example, it may be more economical to substitute local ground water for some Eklutna Lake water. But, depending on the location, timing, and amount of ground-water pumping, increased extractions may be environmentally and economically unacceptable owing to:

1. Consequences associated with reduced flows to streams, wetlands, and Cook Inlet;
2. Costs associated with constructing new wells, rehabilitating old ones, and extracting deeper ground water; and
3. Costs incurred for purifying poor-quality ground water.

Optimal use of a ground-water resource refers to sets of choices or management alternatives that achieve sustainability of the resource while maximizing the overall acceptability of any environmental, economic, or social consequences. For Anchorage, the choices involve the conjunctive use of ground water and surface water—how much of each to use, when, and subject to what constraints. What constitutes "maximizing acceptability of consequences"? These are subjective decisions made by stakeholders, but, ideally, these decisions are based on objective scientific evaluation of alternative outcomes.

Meeting the challenges of ground-water sustainability

The ability to address issues concerning future water-resources management in Anchorage depends on many factors including an understanding of the hydrologic systems. The ability to simulate or predict the short- and long-term responses of the system to imposed stresses, hypothetical or real, is improved by monitoring natural and anthropogenic induced variations in the flow system. As Anchorage grows and the demand for water reaches the capacity of the surface-water resources, good-quality ground water again will become an important source of water. Effective management of these water resources will require:

1. Further knowledge of the hydrogeology, sustainability, and interconnectivity of Anchorage's ground-water and surface-water systems;
2. Understanding the consequences of ground-water depletion; and
3. A set of effective water-resources management objectives and constraints and optimal conjunctive-use alternatives.

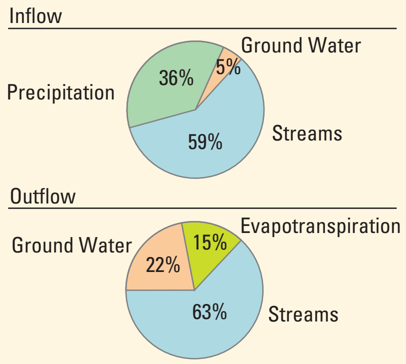
Hydrologic data collection and analysis can lead to improved understanding of the ground-water flow system. The development of a comprehensive hydrogeologic database that reflects long-term natural and anthropogenic stresses can be used to assess future sustainable management strategies (Alley and others, 1999). These data would include lithologic, geophysical, and hydraulic properties of hydrogeologic units, ground-water levels, and water-level maps for the principal aquifers, ground-water quality, and streamflow characteristics indicative of ground- and surface-water interaction.

Numerical ground-water flow models, such as MODLFOW (Harbaugh, 2005), are important tools that increase an understanding of ground- and surface-water systems. Models constrained by available hydrologic data can simulate periods of historical ground-water development and a means to forecast the consequences associated with future water-use requirements (Reilly and Harbaugh, 2004).

Water budget

A water budget defines the amount of inflow and outflow in a hydrologic unit. Prior to urban development, about an average 275 Mgal/d of water moved through the surface- and ground-water systems in the city of Anchorage. Streamflow and precipitation accounted for 95 percent and ground-water inflow from adjacent bedrock and other outlying areas contributed 5 percent. Stream discharge and ground-water flow to Cook Inlet accounted for 85 percent of the outflow and evapotranspiration accounted for the remaining 15 percent. Of the estimated 75 Mgal/d of pre-development recharge to local aquifers, 15 Mgal/d discharged to local streams flowing to Cook Inlet (Patrick and others, 1989).

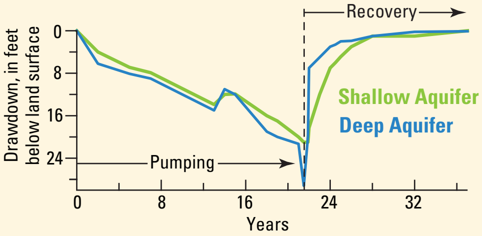
PRE-DEVELOPMENT WATER BUDGET



Simulated effects of ground-water withdrawals on the Anchorage ground-water flow system

Some of the potential effects of sustained pumping on the predevelopment ground-water system were simulated using a numerical ground-water flow model (MODFLOW) calibrated to pre-1955 conditions (Patrick and others, 1989). The model simulated about 21 years of pumping at a rate of about 19 Mgal/d from wells distributed throughout the basin, which was based on pumping distributions estimated during the 1970s-80s. Although the simulated effects of pumping are hypothetical and uncalibrated, the model demonstrated decreased ground-water discharge to streams and Cook Inlet, increased recharge from streams to the shallow aquifer, increased leakage of water from the shallow aquifer to the deep aquifer, and 20-30 ft drawdowns of pre-pumping ground-water levels. Simulated ground-water levels recovered to near pre-pumping conditions in 7 years following the cessation of simulated pumping. The ability to calibrate the historical response of the flow system to ground-water development during the period 1955-84 was limited by the available hydrogeologic data.

Simulated drawdown and recovery in the aquifer system at a location between Ship Creek and Chester Creek, southeast of the city of Anchorage



Implementing a strategy or policy for sustainable use of ground-water resources is a complex task. Stakeholders in developed ground-water basins have used simulation-optimization modeling techniques to determine optimal alternatives related to conjunctive-use management problems (Ahlfeld and Mulligan, 2000; Ahlfeld and others, 2005) by coupling stakeholder-defined water-resources objectives and constraints with a physically-based model of the ground-water flow system. Simulation-optimization modeling could facilitate the sustainable use of the combined ground- and surface-water resources in the Anchorage area.

Edward H. Moran,
USGS, Anchorage, Alaska

Devin L. Galloway
USGS, Sacramento, California

Eklutna Lake lies in the Chugach Mountain Range and receives much of its recharge from Eklutna Glacier.

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For more information, please contact:
U.S. Geological Survey
4230 University Drive, Suite 201
Anchorage, AK 99508-4664
Telephone 907-786-7000
or visit website URL: *http://ak.water.usgs.gov*

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