A1 Anisotropy
K1 Horizontal hydraulic conductivity of the Kayenta aquifer
V1 Vertical hydraulic conductivity of the Kayenta aquifer
S1 Streambed hydraulic conductivity
K2 Hydraulic conductivity near the Gunlock Fault
R1 Recharge from Gunlock Reservoir
I1 Infiltration of precipitation

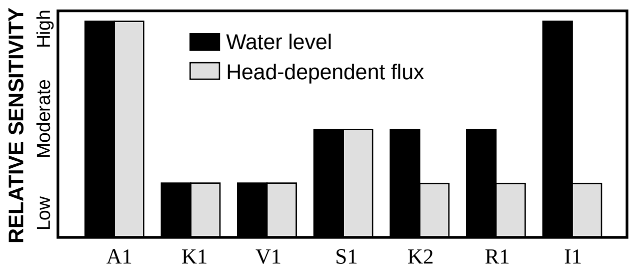

Figure 65. Relative sensitivity of the baseline model of the Gunlock part of the Navajo and Kayenta aquifers to uncertainty in selected properties and flows.

would help identify temporal variations in the potentiometric surface of the aquifers. Long-term water-level trends would help determine whether natural recharge to the aquifers is in balance with well discharge and seepage to the Santa Clara River.

Water-resource management

For the Gunlock part of the Navajo and Kayenta aquifers, the most important hydrologic parameter is the ground-water/surface-water interaction between the Santa Clara River and Navajo aquifer. Interaction is a function of aquifer boundaries and the hydraulic properties of the Navajo aquifer and streambed materials. Effective water-resource management must consider the effects of pumping at the St. George municipal well field on ground-water/surface-water interaction. The baseline model is a tool that can be used to better illustrate the role of pumping on streamflows.

Model Limitations

The ground-water flow model of the Gunlock part of the Navajo and Kayenta aquifers required simplification and, thus, could not accurately represent the actual heterogeneity of the system. Rarely are model simulations in perfect agreement with observations and field measurements. These factors are even more relevant for the baseline model, which, because of limited data, is not calibrated to reproduce a specific set of hydrologic conditions. Also, the model simulates steady-state conditions and does not account for the effects associated with any changes in the amount of water stored in the aquifers. Although this model simulates the Gunlock aquifers reasonably well, the solution is not unique. Other numerical simulations could yield similar results. Model results should only be used for verifying concepts and indicating generalized effects associated with the hydrologic stresses that are simulated. Results should not be used to evaluate absolute water levels and flows at specific locations. The ability of this model to represent actual ground-water conditions could be better evaluated when additional data are collected and the system is observed under other stress conditions.

A specific limitation of the baseline model concerns flow at specified-flux boundaries. Because the model contains only one head-dependent flux boundary (the Santa Clara River), any change in specified flux will be exactly compensated for at the head-dependent flux boundary. For example, an increase in simulated pumping rates will be compensated for by a net increase in seepage from the Santa Clara River. Pumping cannot be increased beyond the point where seepage from the stream exceeds total streamflow, which is specified at 6.0 ft^3/s. Therefore, any increase in pumping rates beyond that will result in the complete dewatering of the model area. Although this is consistent with the conceptual model, it represents a simplification that may not accurately reflect the natural system.

SUMMARY

This study focused on the two main ground-water reservoirs within the central Virgin River basin: the upper Ash Creek basin ground-water system and the Navajo and Kayenta aquifer system. On the basis of measurements, estimates, and numerical simulations of reasonable values for all inflow and outflow components, total water moving through the upper Ash Creek drainage basin ground-water system is estimated to be about 14,000 acre-ft/yr. Recharge to the upper Ash Creek drainage basin ground-water system primarily enters the system as infiltration of precipitation and seepage from ephemeral and perennial streams. The main source of discharge is assumed to be evapotranspiration; however, subsurface discharge near Ash Creek Reservoir also maybe important. The character of two of the hydrologic boundaries of the upper Ash Creek drainage basin ground-water system is speculative. The eastern boundary represented by the Hurricane Fault is assumed to be a no-flow boundary. Likewise, it is assumed that the principal drain for the system is subsurface outflow beneath Ash Creek Reservoir along the southern boundary. However, these conceptualizations could be incorrect because alternative numerical simulations using different boundary conditions proved to be feasible. Major ion chemistry data from ground- and surface-water along the Ash Creek drainage were analyzed to determine possible sources for Toquerville and Ash Creek Springs. Although additional data are needed, the preliminary analysis indicates that the sources may be Ash Creek Reservoir surface water seeping in and mixing with ground water from the Pine Valley monzonite aquifer, the Navajo aquifer, or upper Ash Creek drainage.

Because of large outcrop exposures, uniform grain size, and large stratigraphic thickness, the Navajo Sandstone and Kayenta Formation receive and store large amounts of water and provide most of the potable water to the municipalities of Washington County. Aquifer tests of the Navajo aquifer indicate that horizontal hydraulic-conductivity values range from 0.2 to 32 ft/d at different locations and may be primarily dependent on the extent of fracturing. The Navajo and Kayenta aquifers are bounded to the south and west by the erosional extent of the formations and to the east by the Hurricane Fault, which completely offsets these formations and is assumed to be a lateral no-flow boundary. Like the Hurricane Fault, the Gunlock Fault is assumed to be a lateral no-flow boundary, dividing the Navajo and Kayenta aquifers within the study area into two parts: the main part, located between the Hurricane and Gunlock Faults; and the Gunlock part, located west of the Gunlock Fault.

Generally, water quality within the Navajo and Kayenta aquifers is very good with respect to dissolved-solids concentration. However, two distinct areas contain water with a dissolved-solids concentration greater than 500 mg/L and water temperatures greater than 20^{o}C: a larger area north of St. George and a smaller area a few miles west of Hurricane. Mass-balance calculations indicate that in the higher dissolved-solids and higher water-temperature area north of St. George, as much as 2.7 ft^3/s of hydrothermal water may be entering the aquifer from underlying formations. For the area west of Hurricane, as much as 1.5 ft^3/s of hydrothermal water may be entering the aquifer from underlying formations. A relation between higher dissolved-solids concentrations and lighter stable isotopic ratios in these two areas indicates that mixing may be occurring between the upward seepage of hydrothermal water and recharge along the outcrop carrying isotopically light precipitation from the higher-elevation Pine Valley Mountains.

A preliminary investigation of aquifer residence times, based on CFC and radio-isotope techniques, indicates that the time it takes for water to move through the main part of the Navajo and Kayenta aquifers from points of recharge to points of discharge varies from less than 20 years to more than 50 years. However, additional sampling sites, age-dating techniques, and computer particle-tracking analysis are needed to more thoroughly define regional aquifer residence times. Also, CFC data, in combination with major-ion geochemical data, show that the Santa Clara River is likely the main source of recharge to the Gunlock part of the Navajo aquifer in the vicinity of the St.George municipal well field.

On the basis of measurements, estimates, and numerical simulations, total water moving through the Navajo and Kayenta aquifers is estimated to be about 25,000 acre-ft/yr for the main part and 5,000 acre-ft/yr for the Gunlock part. The primary source of recharge is assumed to be infiltration of precipitation in the main part and seepage from the Santa Clara River in the Gunlock part. The primary source of discharge is assumed to be well discharge for both the main and Gunlock parts of the aquifers. Numerical simulations indicate that faults with major offset may impede horizontal ground-water flow. Also, increased horizontal hydraulic conductivity along the orientation of predominant surface fracturing appears to be an important factor in regional ground-water flow. Computer simulations with increased north-south hydraulic conductivity substantially improved the match to measured water levels in the central area of the model between Snow Canyon and Mill Creek.

Numerical simulation of the Gunlock part of the Navajo and Kayenta aquifers, using aquifer properties determined for the St. George municipal well field, resulted in a reasonable representation of regional water levels and estimated seepage to and from the Santa Clara River. Analysis of hydrologic properties and flows indicates that horizontal hydrologic conductivity along the direction of regional fracturing and streambed aquifer properties are important to ground-water flow. Additional data needed to improve the conceptual model of ground-water flow within the Gunlock aquifers include better understanding of flow properties of the Gunlock Fault and better water-level information for areas away from the St. George municipal well field.