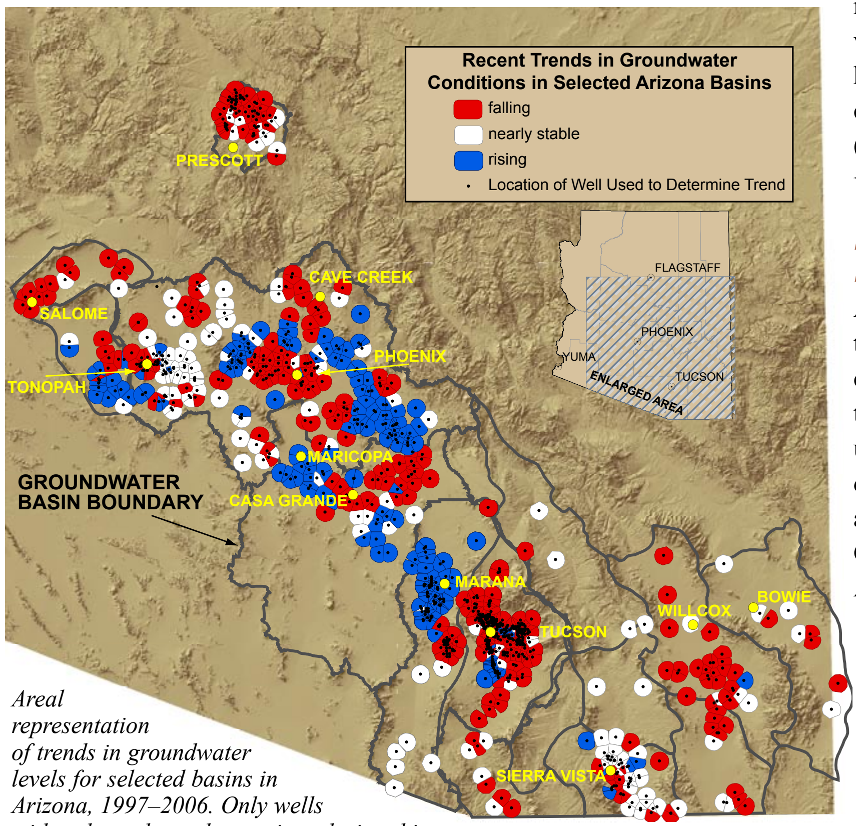
A Visual Representation of Trends in Groundwater Conditions

Fred D. Tillman and Stanley A. Leake –
U.S. Geological Survey

Groundwater databases maintained by the Arizona Department of Water Resources (ADWR) and the U.S. Geological Survey (USGS) are an important component of many studies of water resources in Arizona. In the past few years, the USGS Ground-Water Resources Program has been studying the possibility of using these databases to present basic interpretations of groundwater conditions over large areas, as has been done for surface water in the form of networks of stream gauging stations (for example, see WaterWatch at *water.usgs.gov/waterwatch/*). A web-based system that presents basic interpretations of groundwater conditions would give water managers, politicians, and the general public a way to understand this valuable resource. A prototype system has been developed for a number of alluvial basins in Arizona.



Areal representation of trends in groundwater levels for selected basins in Arizona, 1997–2006. Only wells with at least three observations during this time period and a goodness of linear fit of 0.75 are shown. Trends are represented to a maximum distance of five kilometers (if no other well is closer).

Turning Data into Trend Maps

One indicator of groundwater conditions that can benefit from an expanded-area approach is the trend in recent water levels measured in wells. For surface water, "recent" might encompass periods of days or weeks, but for groundwater in the alluvial basins of Arizona, it could encompass years.

Water-level data from USGS and ADWR databases have been combined and a computer algorithm developed to evaluate trends in the water-level data. The algorithm requires, at a minimum, a unique well identifier with water-level observations and dates, along with location information for the well. Sufficient spatial coverage of water levels is necessary to show trends in groundwater conditions. Sparse data, especially evident in rural areas, present challenges to interpreting trends in poorly monitored regions. Regular and frequent data collection is also required to capture temporal changes in water levels.

The algorithm computes linear trends in water-level observations based on a user-defined date range, minimum required number of observations, and goodness of linear fit. The algorithm seeks the best linear fit of data in the time period, based on the user's choice of any or all of the following: 1) all observations; 2) maximum and minimum amplitude observations of cyclical periodic data; and 3) user-specified months of observation. Water levels recorded during pumping are not used in computing these trends, and all hydrographs are visually inspected to ensure that the computed linear trend qualitatively represents the trend in the data.

Linear trends from individual wells are projected to a regional scale by a second algorithm that constructs modified Thiessen polygons around each well, utilizing a user-defined maximum distance to constrain the representative area for each well. These regional trends are presented in a prototype online interactive map service with linked well hydrographs that highlight data used in computing the trend (*montezuma.wr.usgs.gov/website/azgwconditions/*).

Lower Colorado River Basin Example

An investigation of recent trends in groundwater conditions that employs this approach is currently underway on the most developed of the 72 alluvial basins in the Lower Colorado River Basin in Arizona (see map), with the results to be made available as part of a broader "Arizona Groundwater Conditions" website. For these analyses, trends are computed for the most recent 10-year period (1997 through 2006). Areas are labeled "falling" if the rate of water-level decline exceeds one foot per year. "Rising" areas indicate rates of water-level rise exceeding one foot per year, and "nearly stable" areas indicate rates of change between these two thresholds.

Recent groundwater-level trends in some of the most-developed basins in Arizona reveal areas under stress and those that may be responding positively to water-resources management actions such as reduction in withdrawals and managed recharge. In less-developed areas, trends may be more indicative of climatic variability. Trends from defined

time periods, such as subsequent to the enactment of a groundwater policy, can be evaluated with this method as well. Other trend categories also can be shown, such as regions experiencing declines in water levels greater than some critical threshold.

Groundwater levels are one good measure of the health of an aquifer system. Publicly available tools that are easy to understand are needed to make use of these valuable datasets. This new tool is one such approach. Trend analyses of groundwater observations take into account anthropogenic and climatic impacts on our aquifers and allow insight into systems where lengthy historical records are unavailable. Although estimates of recharge and groundwater extractions and forecasts based on groundwater models are useful, ultimately only "facts under the ground" are proof that groundwater resources are being managed sustainably.

Contact Fred Tillman at ftillman@usgs.gov.

Where Will the Lower Basin's Water Come From?

Mark Lellouch – *Sonoran Institute*

Two powerful forces are affecting the Lower Colorado River Basin's water supplies: rapid urban growth and climate change. As California, Arizona, and Nevada are already using their full allocation of Colorado River water (14.5 million acre-feet per year [afy]), increases in use will have to be offset by transfers from the agricultural sector or from the Upper Basin, or development of new supplies both inside and outside the basin. This article focuses on the last of these sources, augmentation of supplies, including augmentation projects, efficiency projects, and conservation programs. The table below summarizes the supply gains and costs of the major augmentation and efficiency projects.

Augmenting the Resource

Recent research by the U.S. Bureau of Reclamation estimates that cloud seeding could generate an additional 1 million afy in basinwide snowpack during an average precipitation year and approximately half that amount in a drought year, *assuming the process produces a 10 percent increase in precipitation.* However, studies over the past sixty years have not proved that cloud seeding does enhance water supplies on a basin scale. More studies are needed to understand the atmospheric processes that are involved.

Desalination is another option being closely examined. As of spring 2006, 21 desalination plants were proposed along the California coast that, as a whole, could produce 600,000 afy. If implemented, some of these could supplement existing Colorado River supplies. While reverse osmosis is a very energy-intensive and expensive process, costs continue to decrease.

One of the more ambitious alternatives being considered is importing water from other basins. For example, Mississippi River water from southern Missouri could be imported into the Navajo River in southwestern Colorado through a 1,000-mile-long pipeline to provide an estimated 675,000 afy. However, the political and institutional hurdles associated with such a project are tremendous.

Nevada, with a Colorado River allocation of only 300,000 afy, is aggressively pursuing groundwater supplies in Clark, Lincoln, and White Pine counties to provide approximately 160,000 afy to the Las Vegas Valley. Surface water diversions from the Virgin and Muddy rivers, currently on hold, could provide the Southern Nevada Water Authority (SNWA) with another 125,000 afy.

Increasing Efficiency

A number of water efficiency projects have been proposed to reduce leaks in the Lower Basin's water delivery system. The benefits from two of these projects—the lining of the All-American Canal (AAC) and the construction of the Drop 2 reservoir along the AAC—will accrue at the expense of agricultural stakeholders in the Mexicali Valley and riparian and wetland areas in the Colorado River Delta, straining relations between the United States and Mexico. Reclamation is working closely with environmental groups to ensure that the operation of the Yuma Desalting Plant does not threaten the existence of the Ciénega de Santa Clara wetlands, a key stopover for migrating birds on the Pacific Flyway.

A new treatment plant south of Mexicali is designed to capture all of the effluent from the city that was previously draining into the New River and the Salton Sea. There are also significant opportunities to improve water delivery in Mexico. The lining of canals and other efficiency measures in the Mexicali Valley could save 150,000 afy. The water conserved could provide replacement supplies in the face of shortages, reduce dependence of local farmers on groundwater, and restore key riparian areas in the Delta.

Leaf beetles *(Diorhabda elongata)* have been used effectively to destroy water-consuming invasive species such as tamarisk in pilot projects in Nevada. Their large-scale use along the Lower Colorado might yield significant amounts of water at a very low cost per acre-foot. More studies are needed to quantify the savings after replacing tamarisk by native vegetation.

Conservation Options

Municipal water savings are being pursued across the Southwest. In Las Vegas, SNWA imposes drought restrictions on outdoor use and offers incentives to residents who replace their lawns with water-efficient landscaping. In Tucson, a four-tiered pricing system, where residential consumers who use a lot of water pay rates more than three times those in Las Vegas, has reduced per capita water use to only 60 percent that of Las Vegas.

	Supply gains (afy)	Cost ($ million)	Cost per acre-foot[3]
Augmentation projects			
Nevada ground and surface water	285,000	2,600-3,100	9,123-10,877
Desalination–ocean water	20,000-100,000	22-160	1,100-1,600
Desalination–brackish groundwater[1]	152,000	61-289	400-1,900
Mississippi River importation[2]	675,000	925	1,370
Efficiency projects			
Lining of All-American and Coachella canals	200,000	354	1,770
Canal lining in Mexico	150,000	56	373
Drop 2 storage reservoir	40,000	147	3,675
Mexicali II treatment plant	22,500	26	1,156

[1] Includes 108,000 afy from the Yuma Desalting Plant
[2] Costs are speculative
[3] One-time cost for an acre-foot annually in perpetuity

Projected supply gains and cost of various water augmentation and efficiency projects.

Decisions in the agricultural sector, while likely rational at the farm level, are skewed by incentives (water prices and crop subsidies) that ignore the real scarcity of water. The sector, which consumes roughly 85 percent of the water used in the Lower Basin, can reduce its water consumption in three main ways: by investing in irrigation efficiency, by switching to lower water-use crops, and by retiring agricultural land. Studies estimate that the first two methods could generate water savings on the order of 800,000 afy in Arizona alone.

Creativity and resourcefulness have always been key traits of Westerners, especially when it comes to finding water. Barring particularly fierce impacts from climate change, the real threat to unlimited growth in the Southwest may be related to quality-of-life issues rather than water scarcity.

See Chapter 4 of the report "Ecosystem Changes and Water Policy Choices: Four Scenarios for the Lower Colorado River Basin to 2050" at www.sonoran.org. Contact Mark Lellouch at mlellouch@sonoran.org.