TRADITIONAL WELLS AS PHREATIC BAROMETERS: A VIEW FROM QANATS AND TUBE WELLS IN DEVELOPING ARID LANDS

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Groundwater levels are falling throughout settled areas of the world, though we often don't know where they are falling a little and where the problem is severe. Monitoring wells may be installed to keep track of these changes but, because of cost and scale, cannot always be installed where needed to examine regional groundwater trends. Groundwater data reported in published sources are usually tabulated by country and do not reveal the intra-state variation needed by decision makers to practically address groundwater problems. Local farmers and decision makers may be generally aware that a problem exists but may not understand the spatial or temporal pattern of change and are therefore not prepared to mitigate problems.

Research reported here was designed to address this lack of information; to combine surveys of traditional water systems and computer trend-surface mapping with information derived from users of traditional wells to depict change in groundwater over time. Many users of old wells depend for their livelihoods on the availability of groundwater, and are aware of the depth to the water table in their wells, and any changes in access to this resource. This information offers a source of proxy data which, when collected across a broad area, can be mapped to show regional variations in the depth to groundwater. Results offer a graphic portrayal of groundwater trends where, heretofore, there has been only anecdotal evidence of groundwater fluctuation.

This interview-based approach to groundwater assessment has evolved through field research conducted by the author on the history and ecology of qanat irrigation and tube wells in North Africa, the Middle East, and Central Asia. The title—traditional wells as phreatic barometers—suggests a special use for qanats and tube wells that has become obvious during the course of these field studies; *phreatic*: of or pertaining to groundwater; *barometer*: anything that gives notice of fluctuations, an indicator. In other words, the health or condition of qanats and tube wells will indicate the condition of the aquifers from which these systems draw water. Qanats, a form of subterranean aqueduct, along with traditional tube wells that have remained in use for a long period of time, offer a unique source of data regarding the depth to water for any decade retained in the collective memory. Old wells have been excavated and used throughout history, offering a ready supply of data points scattered across settled regions of the earth. When the depth to water is gleaned from users of these wells, and these data are geographically referenced and stitched together via trend surface maps, regional changes in depth to the water table may be depicted.

This paper summarizes results of this approach to groundwater assessment from research conducted over the past decade. Case studies drawn from Morocco, Syria, Yemen, and Uzbekistan examine the impact of modern irrigation systems on traditional water management and changes through time in the depth of associated water tables.

MOROCCO: UPSTREAM DAM AND DOWNSTREAM DAMNING OF A MORIBUND OASIS

In southern Morocco, beyond the valley oases of the Atlas Mountains, out into the margins of the Sahara Desert, lies the isolated Moroccan oasis known as the Tafilalt. Irrigation in the Tafilalt mostly depends on a dense and intricate network of canals distributed across the oasis. In the northern part of the Tafilalt oasis, water for irrigation canals has, since the late-14th century, also been provided by *khettara* (qanats). In all, 80 qanats once provided life-sustaining water for 28 villages and irrigated about 3000 hectares (about 20% of the cultivable land of the Tafilalt oasis). Beginning in the early 1970s, the 44 remaining active qanats began to experience reduced flow, and over the next two decades many more qanats dried up and were abandoned (Lightfoot 1996a).

The diminishing and abandonment of qanats since the early 1970s is attributed to the Hassan Adahkil dam and its new reservoir upstream from the Tafilalt oasis. This reservoir impounds surface water that used to flow unimpeded to the Tafilalt. Now this water is carried to the Tafilalt in concrete-lined canals, which inhibit groundwater recharge to the aquifers underlying the Tafilalt. Furthermore, this water is released only three or four times per year (depending on lake levels), which is insufficient for irrigation in the oasis, and is viewed by agricultural officials and farmers as "supplementary irrigation water."

To make up for this dam-induced deficit of surface water, diesel-pumped wells have become very popular. Today, these private or cooperatively owned pumped wells are the preferred method of irrigation, and their number has grown from zero in 1964 to more than 1000 in the late 1990s (Lightfoot 1996a). While the initial installation of pumps is nominally regulated, the combined and cumulative impact of hundreds of pumps removing groundwater that is no longer adequately recharged is not monitored.

This combination of a lack of recharge to the aquifer (because of the dam) and the unregulated withdrawal of the groundwater which remains (because of diesel-pumped wells) has resulted in a rapid drop in the Tafilalt's water table since 1970. This loss of groundwater, mapped for the entire oasis using interview-derived data, has most severely affected the southern Tafilalt, where the water table has always been deepest and most difficult to access. But the greatest percent drop—the most rapid change in groundwater availability since completion of the dam—has been in the northern Tafilalt, where all of the qanats are concentrated. The result has been widespread abandonment of qanat irrigation as the mother well and water-collecting galleries become dry (Lightfoot 1996a).

SYRIA: THE REGIONAL IMPACT OF DIESEL-PUMPED WELLS

Qanats are found over much of Syria because this was a "breadbasket" of the Roman, Byzantine, and the later Islamic empires that built many qanats throughout the region, so many sample sites exist for collecting groundwater data from users of these historic systems. Much irrigation water in Syria today is derived from surface water, especially from Lake Assad. Many tube wells have also been installed since the 1950s to extract groundwater for irrigation. After the world price for cotton increased in the 1950s, the Syrian government encouraged farmers to produce more cotton to increase foreign exchange earnings, leading to a great increase in cotton production throughout Syria, and increasing the need for irrigation water. This modern groundwater equipment has successfully antiquated the old qanat technology across most of the country. But where, and to what extent, have these changes taken place?

A map showing the distribution of Syrian qanats, and the status of qanats at those sites, presents a picture of widespread abandonment, except in (1) those areas where commercial irrigation with diesel pumps has only recently been introduced, or was soon abandoned because of salinization problems, or (2) where rainfall is more plentiful and groundwater recharge is adequate (Lightfoot 1996b). When qanats go dry across a wide region, within a span of only 20 years, it indicates a regional problem with groundwater stewardship, as in central Syria (e.g. Selemiya Plain region) where cotton production and associated groundwater pumping has most noticeably desiccated qanats.

YEMEN: ABANDONMENT OF QANATS IN ARABIA FELIX

Ghayl and *miyan*, vernacular terms for qanats in Yemen, are found at 23 sites in the Hadramaut coastal region of eastern Yemen (where they are called *miyan*), and 17 sites in the montane plains of highland western Yemen (where they are called *ghayl*) (Lightfoot 2000). In many areas of the world where qanats are found, they have continued to provide water to farms and towns well into the 20th century. But in each of these cases qanats have been challenged by new hydraulic technology—especially the mechanically-pumped tube well—which has led to extensive abandonment of qanats as water tables have fallen. This story is repeated in Yemen, too, but many qanats here were abandoned before tube wells were introduced (especially in the Hadramaut). Some of the qanats of Yemen were abandoned centuries ago.

Within the Hadramaut, 77 qanats lie scattered around 23 villages and towns. Of this number, 54 have dried up and fallen out of use. Twenty-three still function, though many of these have a flow much diminished from previous years. Of the 17 qanats in the montane plains, 11 were functioning in the 1960s, mostly on the Sana’a plain. Nine were still operative in the 1970s, and now there are only two still working (at Thilla and Hababa). The qanats of western Yemen (unlike the Hadramaut) have mostly gone out of use as water tables have fallen after the introduction and proliferation of mechanically-pumped wells (Lightfoot 2000).

UZBEKISTAN: ASSESSING GROUNDWATER CHANGE IN SAMARKAND OBLAST

The Samarkand oblast lies in the east of Uzbekistan. The riverine central portion of the oblast—the most densely settled of the province—has abundant surface water. Few areas north or south of this valley possess reliable surface supplies so these sparsely populated regions more typically rely on groundwater.

Within this settled and irrigated milieu, long exposed to mechanized agriculture through decades of Soviet management of a mostly cotton monoculture, we expected to find over-appropriated aquifers; an irrigation culture at risk (Lightfoot, in review). More than half of the irrigated land in Uzbekistan is in cotton (Lubin 1995, 296). It was assumed that the unsustainable—some might say “reckless”—abandon with which the Soviets pursued the canalization and over-appropriation of the region's two major rivers—the Amu-darya and the Syr-darya—to irrigate and support their demand for more cotton would also manifest itself as too many mechanized tube wells in desiccated aquifers. What was found, instead, was a historic dependence on surface water in the oblast. Groundwater development here is in its infancy. Groundwater in Uzbekistan contributes little to the supply of irrigation water and accounts for less than 40% of surface water withdrawals (Smith 1995). Few areas of the oblast use groundwater for more than drinking or livestock, and those that do have not long relied on aquifers for irrigation. Seasonal and periodic drought has had a greater impact on fluctuations in groundwater than have the relatively few tube wells in the oblast.

The Samarkand oblast maintains quite healthy aquifers that, with few exceptions, might withstand even greater withdrawal without adversely affecting the long-term balance of the water table. Throughout the riverine central oblast, groundwater depths remain shallow and recharge in this area with abundant surface flow is healthy. In this most heavily settled and farmed region, few wells experienced notable change in depth to water over the past 20 years, and several have seen rising water tables due to seepage and recharge from recently completed canals (Lightfoot, in review). In spite of the more visible surface water problems that exist in this region, and the doom they portend for the Aral Sea, a healthy condition of stasis characterizes the underutilized aquifers in this province.

SUMMARY

Future efforts will work to generate the type of data produced for the Morocco and Uzbekistan studies—specifically, information collected from systematically selected and more closely spaced data points. These data points are qanat and tube wells that have been in use for a long period of time, where farmers and village cooperatives can report an uninterrupted oral record concerning how far down they have had to go to find water over a multi-decade period. When details from these localized point data are collected across a broad region, we can produce trend surface maps showing changes in groundwater across space and through time.

In response to this research, groundwater hydrologists have sometimes raised objections over the use of "touchy-feely" oral reporting from farmers and resource managers, rather than relying on "hard" data from well logs. But monitoring wells won't always exist where they are needed. We need to add a spatial face to general proclamations of "falling water tables," to examine where and to what extent water tables have fallen. It is impractical and imprudent to wait until monitoring wells are installed, since they are not likely to ever be installed across all developing world regions now believed to be experiencing changes in groundwater supply. And, even if installed today, monitoring wells can only begin recording changes from this day forward. New monitoring wells do nothing to reveal past changes in groundwater that would be useful to water planners today.

While farmers in affected regions may not understand monitoring well mechanics or the science of hydrology, they know a lot about their water. Their lives depend on it. It is the intent of this research to glean this local knowledge from the people who are closest to the water, who use it every day, and the ones who could most benefit if the changes to their groundwater had a geographically-referenced face. Such maps and data will provide policy analysts with a clearer picture of where agricultural development or population growth has had either deleterious or acceptable impacts on groundwater resources, and where planned developments might, or might not be, sustainable.

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