Crisis Management: Ground-Water Supplies in the 21st Century*

Continued population growth in both urban and rural USA has brought about a major change in the way water supplies are managed. Past practices are depleting low-cost, high-quality ground-water resources and water costs are increasing as high-cost, low quality surface-water resources are brought on-line. New technologies are the only solution.

Figure 1: High-Capacity Water Well, Houston, Texas
Capacity greater than 1 million gallons/day.

Developing, maintaining and protecting ground-water supplies over the past century began by drilling a hole in the ground and pumping water to the surface via an engineered system. New technology was neither available nor needed. Water well technology consisted of time-tested methods, procedures and devices used for years in the water well and oil industries by companies and consultants in constructing both high-capacity municipal and low-capacity rural water systems (Campbell and Lehr, 1973a). The technology developed slowly during the early years because of technical isolation in both the water well and oil well industries. Technical developments in one field did not find their way into the other field (Campbell and Lehr, 1973b).

Over the past 30 years, however, significant population growth has occurred in both urban and rural U.S. The relatively shallow, cheap ground-water resources have been seriously depleted in areas of high-population growth. This depletion of ground-water resources often involves other consequences beyond increased pumping costs. For one example, land subsidence is caused when the aquifer's artesian pressure is lowered over years of pumping in aquifers consisting of compressible, unconsolidated sediments.

A paradigm shift is now required if the rate of population growth is to be maintained without major disruptions in our system. This not only applies to the U.S. but also to other parts of the world. The transition of old ways giving way to new methods involves the need for new attitudes about the value of drinking water. The need to maintain the production and, in some areas, upgrade drinking water quality outweighs the pressure to continue as in the past. It is clear that these programs will cost more to operate because new types of managerial systems and technology are required to implement and optimize the new programs.

Technical isolation in the ground-water supply industry is decreasing because of the Internet. Case histories and related issues can now be made available throughout the world, and U.S. federal and state regulatory agencies are providing important technical and financial assistance online. This rapid acquisition of information is one of the major reasons we may be able to respond to and meet the pressing need to change our old ways of using water, especially ground water. It is no longer "well" water but ground water obtained from a common aquifer of great aerial extent deep underground away from surface contaminants.

With the growing difficulties in over dependence on ground water, many state, county, and city agencies in the U.S. often resort to old engineering thinking such as building dams to supply surface water. In the U.S., we have come to realize that ground water is characteristically a high-quality, low-cost resource, while surface water is a low-quality, high-cost resource requiring considerable treatment and protection.

This is why ground water has been so aggressively developed over the past 30 years and more in many parts of the U.S. as well as overseas (see Figure 1). However, the old thinking has resurfaced as cities and counties attempt to meet the water demands of the approaching 30 years.

The cost-benefit analysis of ground water vs. surface water strongly favors the former over the latter in most cases. Ground-water supplies are less costly to develop than surface water and are less susceptible to contamination than surface water. In large cities, water is usually supplied by a network of underground pipes from either a surface reservoir or from a system of high-capacity water wells. As suburbs have expanded into rural areas, water wells often coexist with nearby oil and gas wells as well as with other projects such as landfills, mines, and similar industrial operations. Cooperation and coexistence are a necessity in today's society and can be resolved without resorting to litigation, often perceived in the U.S. as an answer to diverging opinions.

The selection process of deciding between a surface-water or ground-water source depends on many factors. Some of these are:

Geographic Factors

In regions where the land surface is hilly or has some relief, a surface source of water can be developed by damming a river or large stream, or by sculpturing a reservoir out of lowlands that receive regular runoff. The political issues are often major but usually surmountable if the project makes sense to the majority of those interest groups involved. The projects are promoted on the basis of the potential multiple use of the land involved. A reservoir would not only hold a supply of water but also would be used for fishing, boating, and swimming, as well as serve as a focal point for development of surrounding residential subdivisions. A concentrated effort by the developers of such projects is required.

Hydrogeologic Factors

Ground-water supplies are usually available everywhere. Regional variation in water quality depends on the local makeup of the subsurface rocks and sediments within the aquifer produced as a water supply. In high rainfall areas, the depth to water will be minimal, usually less than 20 feet below surface, depending upon the time of the year. The top of the ground-water reservoir is known as the water table. It varies in elevation over the year and adjusts to infiltrating local rainfall. During droughts, the water table declines. During years when rainfall is above normal, the water table will rise, sometimes high enough to create a temporary bog or swampy area. If this happens on a regular basis over the years, a wetland may develop. For all practical matters, the water table is a dynamic surface, in constant change. Even in so-called “hard rock” desert areas of the western U.S. and in northern Africa, where ground water is present in joints, cracks, and permeable fault zones, substantial volumes of potable ground water are available for use by local towns and villages if the well is maintained and the area sounding the well is protected from sources of pollution (UNESCO, 1984). However, well depths of 100 feet or more are advisable to avoid contamination often present in shallow ground water in urban and agricultural areas.

Ground-water taste also varies regionally because of the nature of the rocks though which the ground water passes. The taste of tea and coffee depend more on the water used to make the drink than to the quality of the tea leaves and coffee beans used. Many water supplies that use ground water often involve minimal engineering and usually involve a relatively small population base. This source provides water for small groups of residents, which range from a few residents in small subdivisions to thousands of residents in the larger suburbs surrounding major cities and towns. Some large municipalities also utilize ground water as opposed to surface water. These projects involve only minimal real estate, few permits, and generally little interference from state and federal agencies and polarized interest groups.

Engineering Control Factors

The difference in cost between surface-water and ground-water resources is substantial, for obvious reasons. Surface-water sources require large expenditures; ground-water sources require small expenditures. Although regionally variable, surface water is usually soft water that makes good suds for washing and showering, while ground water tends to be hard water and may not provide good suds without additional treatment, which would add a few more cents per thousand gallons to its cost.

Contamination Factors

Surface water is vulnerable to widespread contamination from industrial processes, by accidents involving railroad chemical tank cars or trucks and intentional contamination by a disturbed individual or radical group, although building in access to alternate systems has offset the latter impact. Surface water is also subject to bacterial contamination from leaking drain fields of septic tanks provided with homes built in areas surrounding the reservoir.

Ground water is not as vulnerable to widespread, rapid contamination from surface spills or other contamination as surface water, but ground water is subject to subsurface contamination from oil and gas wells (both abandoned fields as well as operating fields), from mining activities (old and new), from road-salting activities (by state and county agencies), and from leaking underground storage tanks from nearby gasoline stations, among many other possible sources of contamination. In rural areas, sources of contamination also involve septic tanks, proximity of farm animals, and other sources. Large municipal water wells are usually unaffected by these issues because their depths and quality of construction are designed to minimize problems common with shallow water wells.

Many wells, both urban and rural, develop nonpathogenic iron and manganese bacteria that can affect the water by creating taste and odor anomalies. The iron-stained toilet bowl is an indication of the high-iron content of the supply, often common when using ground-water supplies. These problems will tend to give the water a yellow-brown to light-orange appearance. Regular monitoring of the water's inorganic chemistry, combined with appropriate water treatment, can control such problems. If wells are located too close to farm animals, or are not appropriately constructed, especially the upper seal with the surface, more dangerous bacteria, e.g., **E-*coli*** (of the new strain: **O157:H7**) can cause illness in young and elderly individuals because of their undeveloped or compromised immune systems.

New Ground-Water Treatment Programs

In the water chemistry area, the typical chlorination treatment process naturally creates unwanted by-products called THMs (of the trihalomethanes group) and other constituents. New treatment methods are under development and some are in use today. The U.S. EPA is providing substantial information about these new developments. Methods such as ozonation, radiation from various sources, UV treatments and other approaches will come into use as they prove their way in the water-supply field. With the rapid communication offered by the Internet, case histories reporting the successes and the failures will guide their development according to the merits of the method, not solely in response to advertising claims as in the past. In any event, rural water supplies, in areas of definable high risk, should be treated to eliminate bacterial contamination of the drinking water supply.

The New Road

Technology is now changing very quickly in the water-supply industry where change has been slow over the past 50 years. As the value of drinking water resources increases, and with continuing assistance in technology development and in water-resource monitoring from federal, state, county, and city agencies, the water-supply industry is bringing a new level of efficiency to create a healthy water supply for the American public. This transition will involve resources from ground water, surface water, or an optimized combination of both, including re-use and recycling. In any case, the cost to the consumer can be expected to increase if progress is to be made in this vital area of human health and development.

Probably the most important aspect in the recent improvement in the water-supply industry is the communication now available via the Internet. Change will now be even faster than ever before, both in terms of available technical resources and in the associated communication. Communication allows the local water-supply utility to have access to the latest technical information to run their systems and to publish all water analyses and other data concerning the water supply on the utility's Web site. This will help to allay concerns by utility customers that the water supply may be unfit to drink.

The information is there for all to see, and in democracies in the U.S. and all over the world, isn't that what it's all about, serving people.

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