Affordable Water Quality Protection Methods for Municipal Supply Wells

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Background

In the mid to late 1980s, as an alternative to more expensive ground water contamination clean up projects, federal and state regulatory agencies began to promote the use of voluntary ground water protection programs by owners of drinking water supply wells. Prevention was found to be more advantageous based on accumulated evidence that the total cost of ground water remediation was more expensive and took decades longer to remove contaminants than originally predicted by science. Voluntary pollution prevention programs for ground water are commonly referred to as wellhead protection programs (WHPs).

Many WHPs eliminate the potential introduction of pollutants into a well's capture zone by enacting land use restrictions (buffer zones around a well). Unfortunately, small to medium water providers often do not have the authority to make land use zoning decisions. This paper provides two groundwater quality protection options for water providers under those circumstances.

Metro Water District

The Metropolitan Domestic Water Improvement District (Metro Water), a medium-sized public water utility located northwest of Tucson, Arizona, began implementing a wellhead protection program in 1995. It is the second largest municipal water provider using ground water from the Tucson basin aquifer. In 1984, the Tucson basin aquifer was federally designated as a sole source drinking water aquifer. Metro Water has a service area of 23 square miles and provides on average 9,200 acre-feet of ground water annually to about 45,000 people from 27 production wells. Depth-to-water ranges from 133 to 352 feet. Well production varies from 110 gallons per minute to 1,100 gallons per minute with an average flow rate of 500 gallons per minute.

Metro Water's interest in a WHP Program first developed as a result of a volatile organic compound (VOC) detected in its ground water, which later impacted one of its production wells. In late 1993, a Pima County environmental regulatory agency sampled for VOCs at one of the District's production wells. The VOC sampling was performed in conjunction with State and local efforts to delineate the VOC contamination from a known State Superfund site. Laboratory results from the one Metro Water well located far outside the State Superfund site had trace levels at 0.6 micrograms per liter of perchloroethylene (PCE), an industrial solvent. Resampling of the well water did not detect VOCs and the presence of PCE was not confirmed until March 1994 after two consecutive sampling rounds. A wellhead treatment system was later installed by Metro Water in July 1997 before PCE levels exceeded the drinking water standard of 5 micrograms per liter at the wellhead. The VOC contamination prompted Metro Water to begin an inventory of pollution sources within a one-half mile radius of its wells and developing a wellhead protection program.

Statement of Problem

Increasing population and declining ground water levels in both urban and developing rural areas of Arizona have made it necessary for many ground water users to deepen or protect their wells from improperly closed wells and contaminants. Similar conditions occur in other western arid states.

A water well cannot be deepened in Arizona, however, without first obtaining a permit from the Arizona Department of Water Resources (ADWR). Not only does the permit require that the work be performed by a licensed driller, the deepened well must be modified to meet all current state well construction standards, including those for grout seals. Arizona's well construction regulations require a cement grout seal, at least 1-1/2 inches thick, be installed on the outside of the well casing from the surface to a minimum depth of 20 feet. Thicker, and deeper, grout seals are allowed, but this is the regulatory minimum. The challenge for water providers is how to get a seal installed around an older well that is being deepened or modified in a cost-effective and efficient way.

Additionally, during the WHP scope of work development, Metro Water observed rapid conversion of undeveloped or underdeveloped land to high-density urbanization within its service area. Staff inspection of these development projects often found incidences of non-compliance with State of Arizona well closure and well capping laws. The well pad and upper casing of unused wells at several construction sites were often sheared or destroyed by earth moving equipment. The well damage was caused by the contractor not flagging the well location and/or lack of knowledge of State well closure rules. An open well or improperly closed well can serve as a conduit that allows surface water runoff, containing many unwanted toxins and pollutants, to directly enter the ground water supply.

WHP Management Tools

Metro Water has developed an innovative method for installing grout seals around older existing wells in order to comply with the Arizona regulation. Metro's utility superintendent (now deputy manager) Christopher Hill and assistant utility superintendent Steve Shepard devised the method using presently available technology, and some good old American ingenuity. Basically, it's done by using a high-powered vacuum cleaner to clear an annular space around the existing well casing. All 27 of Metro Water's active supply wells were constructed prior to 1980 using cable tool methods; therefore, many of them were constructed without cement grout seals to 20 feet deep as required by current state well construction standards.

Customer concern for protection of ground water quality also inspired Metro Water staff to develop a closure (abandonment) policy for unused wells and educational measures to ensure that well owners comply with existing State rules. This protection measure is especially critical in areas of new residential, commercial, and industrial developments near public supply wells.

These innovative solutions were recognized by the National Ground Water Association (NGWA) at the 50th National Convention and Exposition with the award for an outstanding solution in ground water protection category. Additionally, this program received in 2000 the best wellhead protection award from the Arizona Water and Pollution Control Association. In 2002, the two WHPs also were given a Clean Water Partners Award by the U.S. Environmental Protection Agency (EPA).

Conventional Grout Installation Methods

Conventional methods used for grout seals of new water wells include installation of 20 to 40 feet of steel surface casing set in oversized boreholes that are either augered or rotary drilled. Retrofitting existing wells that are without vertical grout seals has typically involved removing the soil over a large aerial extent around the well with a backhoe. Grout rings were cast around the steel casing, and the soil was replaced. This method is largely ineffective because the re-compaction of soil around the well did not provide much of a vertical barrier. Other methods that have been tried include over-drilling the original well casing with a larger-diameter casing, and pressure grouting via many small boreholes in a ring adjacent to the well casing. None of these methods have proven practical or dependable for meeting the intent of the grout seal regulation.

A Better Method Is Devised

Christopher Hill, who was at the time Metro Water's utility superintendent, devised the vacuum excavation method based on his water utility experience in Dixon, Illinois. His technique involved the use of large truck-mounted vacuum equipment, something that is commonly found around municipalities and industrial areas. Hydro-vac truck services can typically be hired on an hourly basis and they are often used for cleaning out storm drains, dry wells, and excavating and cleaning out underground utility vaults. Gary Hix with Saguaro Well & Pump Co. in Tucson, Arizona has used them to remove drill cuttings from portable mud pits for transportation to another area and disposal. Hix reported that Hydro-vac trucks have also been used by ground water scientists to vacuum purge monitoring wells (Water Well Journal, June 1993).

Front view of vacuum truck and operator pre-wetting soil with pressurized water hose for soil removal by vacuum hose on right side of operator.

Hill and Shepard have demonstrated that vacuum trucks can be readily adapted for excavating 20-foot-deep annular space around an existing well casing. The vacuum truck operator uses a pressurized water hose mounted on the truck to pre-wet and loosen the area around the well casing in need of soil removal (minimum of 1½ inches away from the well casing). As the water is injected or jetted into the soil, the large-diameter vacuum hose is lowered into one place to remove the liquefied material by the operator washing the cuttings towards the vacuum hose. This model hydro-vac truck used a boom to support the heavy vacuum hose where it protrudes from the front of the vehicle (see photo on previous page). The soil and water slurry, along with cobbles, is vacuumed directly into the truck. The diameter of the hose on the hydro-vac truck that Metro uses ranges from 4 to 12 inches. The hose size depends on the power needed to lift large cobbles if encountered (10 inch). All the water, soil, and rocks go into a large container mounted on the back of the truck so there is no mess to clean up. The cuttings can be disposed and spread on-site if the subsurface soils have not been contaminated by any hazardous chemicals.

The first job this innovation was performed on was a Metro Water well that was being deepened; hence, it had to comply with current well construction regulations. This well was a little unusual in that it had a partial grout seal around the primary well casing. The grout seal extended only to a depth of 10 feet and was surrounded in a piece of galvanized culvert. This construction did not meet the state requirement for a sanitary well seal because the seal did not extend deep enough (20 feet) and the grout was not in contact with the surrounding soil.

In order to expose the casing below the upper grout ring, and remove all the soil adjacent to the well casing to a depth of 20 feet, the water jetting hose was adapted with a 90-degree elbow and a 12 inch vacuum hose was moved around the well casing. The annular space created in this manner was approximately 1 foot wide from the surface to a depth of 10 feet, and nearly 2 feet wide from 10 to 20 feet. Even with this unusual construction, soil was removed in a 20-foot deep by a little more than 1-foot-wide annulus around the well casing in about three hours. The excavation made using this hydro-vacuum method was stable and resembled a drilled borehole (see photo). It was allowed to remain open for only 30 minutes or so until the cement grout was placed in the opening. When the annular space was filled full of cement grout, it more than met the requirements for a grout seal around this well. The soil removed during the excavating process was later emptied from the back of the truck near the well site.

Excavation was completed in less than three hours plus three hours travel time at a total cost of $960 for the hydro-vac services. The 12 yards of grout for the sanitary seal was an additional $900. Normal excavations that did not require under-cutting (as this one did), would require less time and less grout. To save costs on later retrofits, Metro Water reduced the annular space in thickness by using a smaller diameter vacuum hose and keeping the vacuum hose stationary while the cuttings are washed to it. Additionally, Metro Water does not use this technique on older wells that have bar holes at shallow depths within the well casing. Bar holes or casing breaks can act as a conduit for the grout to enter the inside of the well and potentially plug the well's perforations.

Unused Well Tracking and Closure Program

An unused well tracking and closure program was developed

in late 1997 by Metro Water, with the support of the Tucson Active Management Area Office of the ADWR. Metro Water became the first known entity in Arizona to track unused wells and use the state's well abandonment rules for closure of unused wells. Administratively, Metro Water's policy requires that an educational brochure be given to each land developer detailing the well closure and capping program and State well rules. The program is summarized in the following outlined steps.

Close up of cement grout being added to annular space. Fine and coarse grain texture of alluvial deposits can be seen in hole profile.

Steps of Metro Water's Unused Well Closure and Capping Program

Step	Description
1	Subsequent to the submittal of development plans, the property location is reviewed for any wells registered by the State of Arizona. A quick visual review is made easy by using existing aerial photographs with a scale of 1″ = 400' on which the wells have been previously plotted. As a precautionary measure, a field inspection is made by Metro Water's hydrology staff with the property owner's permission to locate any unregistered wells.
2	The results of this review and inspection are provided to the Metro Water's Development Supervisor who notifies the Developer if there is a need to include the well on the Development's water improvement plans. Copies of the well closure program and State Abandonment Rules are also mailed or given directly to the Developer.
3	The Developer has the well location surveyed and drafted onto the plans citing the applicable state regulations (for either well capping or closure), the state well registration number (if registered) as well as identifying the legal location.
4	Metro Water informs the ADWR of the planned well capping or closure.
5	Metro Water's Inspection staff is notified of the capping/closure date by the Developer or Licensed Driller and he/she observes the work. When the well has been properly capped or closed it is reported by the Developer to the ADWR and a copy of the completed State form is provided to Metro Water. Upon completion of these requirements and any others, Metro Water releases the Developer of assurances and accepts the water system improvements.

Staff Requirements for Maintaining the Tracking Program

Initial staff requirements involved a University of Arizona undergraduate civil engineering student intern, Scott Schladweiler (now with Brown and Caldwell), who worked during the summer of 1997 to field check a total of 175 well locations in the state well registry. In 1999, Metro Water purchased a small water company outside of its main service area and a U of A graduate hydrology student, Brian Walsh (formerly with the ADWR), completed locating an additional 250 registered wells (see photo). The program requires about 30 hours per year of staff time to update the well maps and complete field assessments for a total annual cost of $1,000.

Annually, three to six wells are found to be impacted by new developments. A total of 13 wells have been closed since the pilot and full-scale programs began. Additionally, Metro Water conducts closure of its own supply wells that become dry or fail. Closure of three Metro Water wells have been completed since 2000 and a two more closures are scheduled for in 2003.

Assuring Safe Water in the Future

Since 1993, undeveloped or underdeveloped land within Metro's district has been rapidly converting to high-density urbanization. Similar phenomena are taking place in other parts of the country. Providing sufficient water to these growing communities is a challenge for both water suppliers and water well contractors. Making the most of existing resources can mean converting former irrigation wells into municipal supply wells. Aging and neglect of these wells has left situations where these older wells can serve as a conduit allowing surface water runoff containing pollutants to directly enter the ground water supply. Metro Water's concern for protecting its supply wells inspired staff to develop an unused well tracking program to ensure compliance with existing state well abandonment rules. Tucson Water adopted the program with a modification. If the well remains on-site, they require the developer (well owner) to sign a waiver from objecting to any new City of Tucson wells that would occur at or adjacent to the well. Metro Water has included this provision within its water service agreements to help meet future water supply needs.

The upcoming Ground Water Rule from the U.S. EPA will require many best management practices (BMPs) prior to mandatory disinfection by water utilities. One of the required BMPs will be for all wells to have an effective sanitary well seal. These protection measures are especially critical in areas of new residential, commercial, and industrial developments near public supply wells. Metro Water feels that this retrofit grout seal will provide just as effective a barrier to microbial contamination from surface runoff as would the grout seal cast in place around a brand new well.

The hydro-vacuum method described above was developed as a low-cost, quick, and efficient means to bring cable tool drilled wells lacking a 20-foot grout seal up to present and future well construction codes. Metro Water is happy to share this method and hopes it will benefit other well owners with similar problems.

Conclusions

Metro Water's two innovative wellhead protection tools are protective of public health, cost less and require minimal staff to implement, and have been accepted by the State water management agency and the development community. More importantly, Metro Water's customers and the Tucson area media have supported the program as acceptable groundwater protection tools. The program was recognized in 1998 at the National Ground Water Association's Annual Conference as the best groundwater protection project. The Arizona Water and Pollution Control Association recognized the program in 2000 as the State's best wellhead protection program. Additionally, the U.S. EPA awarded the Program one of its first annual Clean Water Partners Awards in Arizona.

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Block, Michael 1999. Well Closure in Arizona: Opportunities to protect ground water. Water Well Journal, Vol. 53, No. 11., pg. 74 to 76.

Block, M. W. and Hix, G. L. 1999. Innovative Low-Cost Method for Installing Grout Seals Around Older Wells. Water Well Journal, Vol. 53, No. 3., pg. 64 to 67.

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