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Regulatory Challenges to Shifting from Groundwater to Surface Water as a Source of Drinking Water Supply

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BACKGROUND

The drinking water systems of the State of New Mexico have historically relied primarily on groundwater, which is to be expected in an arid state with a relatively small number of perennial surface water bodies. Of the 1254 Public Water Systems (PWS) in the state, 1194, or 95%, rely entirely on groundwater for their water supply. From a population perspective, it looks somewhat different. At this point in time with Albuquerque still a groundwater system, we have 84% of the population connected to a PWS relying solely on groundwater. When Albuquerque switches to surface water, we will have 41% of the population connected to a PWS relying at least in part, on surface water (curiously, Albuquerque will be the first water system to use the main stem of the Rio Grande as a water supply). This is shown graphically in Figure 1. The current distribution of surface water systems, including surface water purchase systems that purchase some or all of their water from surface water systems, is shown in Figure 2.

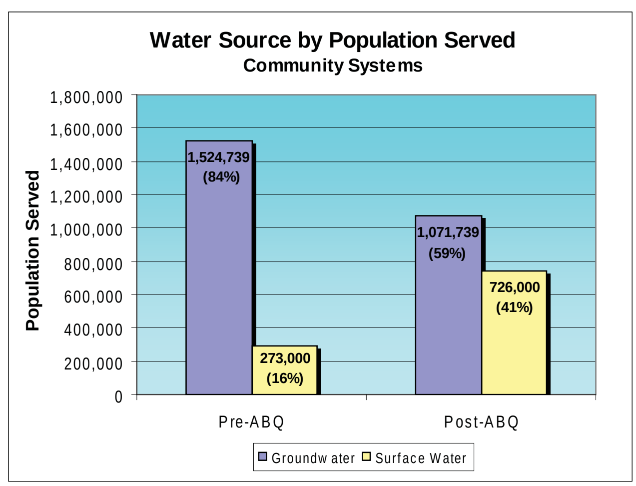

Figure 1. Distribution of population served by Public Water S by water source type before and after the Albuquerque-Bernalillo County WUA converted to surface water.

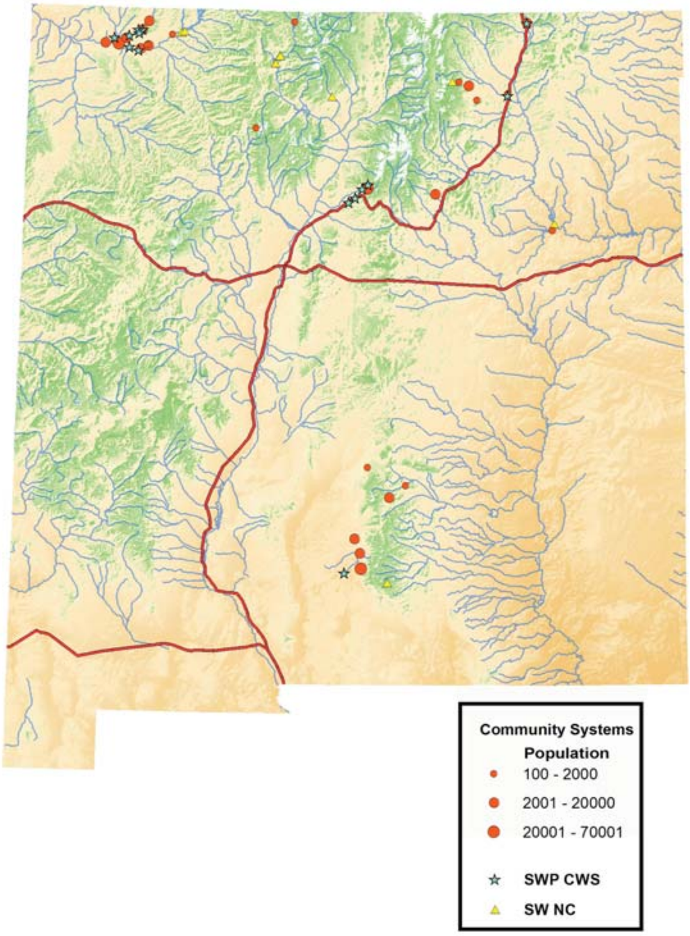

Figure 2. Surface water systems in New Mexico (SWP = Surface Water Purchase System, CWS = Community Water System, NC = Non-Community Water System)

Other groundwater systems in the state are in the process of converting to or increasing their usage of surface water or are considering such a conversion. This would include Santa Fe, Gallup (via Navajo-Gallup Water Supply Project), Flora Vista MDWCA, Doña Ana MDWCA, and several eastern communities via the planned Eastern New Mexico Water System (i.e., the Ute Pipeline), to mention a few. There are many reasons drinking water systems may consider developing a surface water source including concerns for the long-term sustainability of a groundwater source, inadequate groundwater quality or quantity, or to increase the diversity of the water supply. However, there are many factors to be considered that make the development and operation of a surface water system much more complex and costly. These factors are the topic of this paper.

Before discussing these factors, it is worth reviewing the basic elements of surface water quality and treatment.

SURFACE WATER AND TREATMENT

All surface water contains microorganisms, though most are not pathogenic (i.e., causing disease). The three types of microorganisms commonly found in surface waters that may be pathogenic are bacteria, protozoa, and viruses. Some of the most common waterborne pathogens are listed in Table 1. From a regulatory standpoint, the primary goal of surface water treatment is the removal or inactivation of pathogens (secondary goals include improving taste, odor, and clarity). Removal of pathogens is accomplished through filtration while inactivation of pathogens is accomplished through the addition of a disinfectant (e.g., chlorine or ozone) or UV radiation. Table 1 indicates that protozoa are not effectively inactivated by chlorine so treatment only by disinfection is not sufficient.

Table 1. Pathogenic waterborne microorganisms and their response to conventional disinfectants

Microorganism Type	Examples	Disinfection Effectiveness
Bacteria	E. Coli, Cholera, Shigella	Excellent
Viruses	Hepatitis A, Enterovirus	Excellent
Protozoa	Giardia, Cryptosporidium	Limited

Under the federal Safe Drinking Water Act (SDWA), all surface water supply systems are required to treat the raw water with both filtration to remove pathogens (except under certain limited circumstances) and disinfection to inactivate pathogens. Filtration must be sufficiently effective to remove specific percentages of the various organisms. Disinfection (other than UV) must meet requirements for inactivation of Giardia (which will also satisfy disinfection requirements for bacteria and viruses).

The two factors that determine the effectiveness of inactivation of Giardia by chemical disinfectant are disinfectant residual concentration (denoted by C) and contact time of the water with the disinfectant (denoted by T). Since either a higher C or a higher T will result in greater inactivation, the product of the two, CT, is the measure of satisfactory inactivation and has been tabulated by EPA. The required amount of CT is dependent on pH, temperature and, the particular chemical disinfectant.

It is fairly expensive to quantify a specific pathogen in water and impossible to do so in real time. So a surrogate for pathogen content that was easily measured continuously was needed. The surrogate that has been used traditionally and is used as the regulatory standard in SDWA is turbidity (as measured in Nephelometric Turbidity Units or NTU). By decreasing turbidity, there is a reduction of all particles including suspended sediment and pathogens.

Conventional treatment of surface water utilizes a series of processes to reduce turbidity. The first step may consist of a settling process in a reservoir to remove sand and some silt-size particles (often considered pre-treatment). Next, flocculation chemicals are injected followed by a flocculation and settling process that will remove a significant amount of the remaining silt and smaller sized particles, including a significant amount of the organic carbon that is a precursor to Disinfection Byproduct production (as described below). The settled water is then filtered through a sand filter to remove the majority of remaining particles. Disinfectant is added at this point. There are many factors that can affect the quality of the finished water including raw water chemistry (temperature, pH, turbidity, organic carbon content, etc.), choice of flocculation chemicals, chemical dosage, loading, and mixing rates. To meet regulatory compliance requirements for surface water requires frequent attention to the treatment process. To get optimal treatment (i.e., to produce the best finished water quality water that a given plant is capable of for a given raw water quality) requires even more attention to the treatment process and water chemistry.

There are many variations on the conventional treatment theme as well as alternative treatment approaches such as membrane technologies (nano filtration and reverse osmosis). Membrane technologies can be very effective at removing particles and chemicals from water, but create a significant waste stream (which must be disposed of and can put a dent in a systems water rights) and are expensive.

CHALLENGES IN THE UTILIZATION OF SURFACE WATER

There are several areas of concern that should be carefully considered when a water system is planning to utilize surface water as a source of drinking water supply. Capital costs and water rights will not be considered in this paper, but are very significant practical matters.

1. Availability of Qualified Operators

The New Mexico Utility Operator Certification Act requires that all public water supplies employ a certified operator to operate and maintain their water system. As the size or the complexity of the water system increases, so does the required level of operator certification. Systems that treat surface water require operators to have the highest level of certification (Level 3 or Level 4 for systems serving over 500 customers) as result of the significantly greater complexity of a surface water treatment system in contrast to a typical groundwater system. Larger groundwater systems may also require high level certification, but these Level 3 and Level 4 operators aren't likely to have the knowledge and experience to operate surface water treatment systems (note that there is no certification distinction between surface water and groundwater). Thus, systems converting from groundwater to surface water will be required to retrain their operators and/or hire additional operators with the necessary skills.

Hiring an operator with sufficient certification and appropriate surface water treatment experience could prove to be a challenge. Approximately 1/3 of the certified operators in New Mexico are certified level 3 or level 4 (see Figure 3). Only a small percentage of these operators have any experience with surface water treatment. The majority of these operators are currently employed by water systems so hiring a Level 3 (W3) or Level 4 (W4) operator with sufficient knowledge and experience in surface water treatment would likely require hiring them away from another water system or hiring from out-of-state where salaries are often higher. This puts an upward pressure on salaries for skilled surface water operators in New Mexico. Smaller surface water systems in New Mexico are thus having a difficult time finding qualified operators (larger systems can generally pay higher salaries). Some systems have reported hiring lower level operators and training them so they can obtain their higher level certification at which point they are hired away by larger or out-of-state systems that pay higher salaries. Thus the problem is not just one of finding skilled operators, but also one of employee retention.

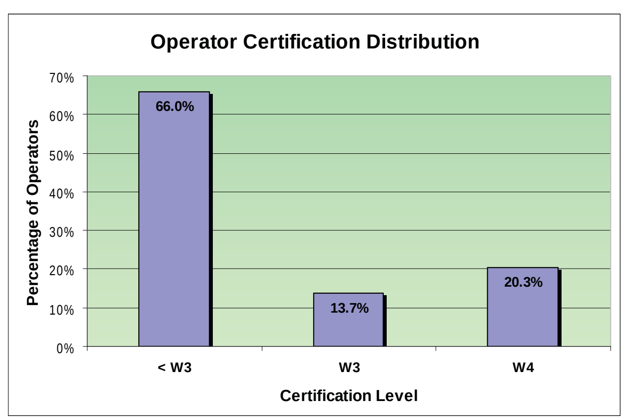

Figure 3. Distribution of operator certification levels in New Mexico. W3 and W4 operators are the levels generally required for surface water treatment.

To further complicate this shortage of skilled surface water operators, the certified operator workforce nationwide is aging because not enough young people are looking at water system operation as a desirable career. The primary reason for this is the relatively low salaries being paid by water systems. In addition, the work can often involve long hours and work on the weekend. The American Water Works Association has estimated that 30 – 50% of the currently certified operators will retire in the next 5 – 10 years. In New Mexico, the average age of Level 3 operators is 48.6 years old and the average age of Level 4 operators is 49.6 years old. Figure 4 shows the age distribution of Level 3 and Level 4 operators in New Mexico. Clearly, the situation that AWWA has identified nationwide is also a problem in New Mexico. The number of Level 3 and 4 operators certified in the past three years is shown in Figure 5. Although the loss of Level 3 and 4 operators will be partially offset by newly certified operators each year, there will be a wealth of knowledge and experience retiring along with the operators that may not get transferred and will take many years to replace.

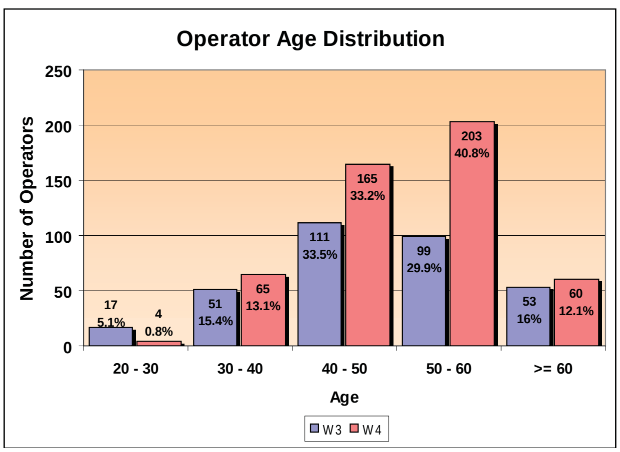

Figure 4. Age distribution of Level 3 and 4 operators in New Mexico as of September 2008. The number of operators and the percentage within each certification level is given.

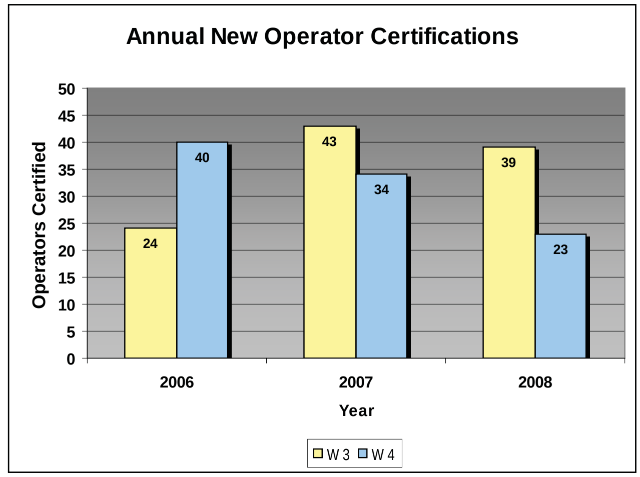

Figure 5. Number of New Level 3 and 4 operators certified from 2006 - 2008

For all the reasons mentioned, small to moderately sized surface water systems will find it difficult to find qualified operators in the future. Those surface water systems that are geographically more isolated will have an additional challenge to attracting surface water operators. Water systems will need to pay competitive wages in order to retain their operators. It will also be necessary to have a concerted effort in New Mexico to increase the number of new water operators by attracting more young people to the profession so there can be a transfer of knowledge from the experienced operators that are within a few years of retirement.

2. Regulatory Burden

The SDWA regulations are quite comprehensive currently consisting of 270 pages. The portion specific to surface water systems is approximately 56 pages (though portions may or may not apply depending on the population size served by the water system). In addition, there are 26 pages of regulations regarding disinfection byproducts that apply to systems that disinfect, but have the greatest impact on surface water systems (this will be discussed in more detail below). The surface water regulations are the most complex of all the SDWA regulations.

It takes a considerable amount of effort for surface water systems to remain in compliance with the monitoring, reporting, sampling and treatment requirements of SDWA. Larger systems frequently employ part or full time compliance manager to ensure compliance requirements are being met. Periodic training on the regulatory requirements is strongly recommended for operators and compliance managers.

There is always the potential for new and revised federal and state rules that will add to the regulatory burden. In the last year, the Long Term 2 Enhanced Surface Water Treatment Rule and the Stage 2 Disinfection Byproducts Rule became effective, both of which have a significant impact on surface water systems. It is a reasonable assumption that there will be new rules or revisions to existing rules that impact surface water systems in the future.

3. Disinfection Byproducts

SDWA requires that a disinfectant be used by all surface water treatment systems, not only to try to inactivate those pathogens that managed to survive the filtration process, but to also to create and maintain a residual disinfectant concentration within the distribution system in the event of contamination downstream of the treatment process. By far, the most common disinfectant used by surface water systems in New Mexico and nationwide is chlorine due to its relative low cost, ready availability and ease of use. Chlorine has been the single biggest factor in reducing waterborne disease worldwide since it was first used as a disinfectant in the early 1900s and has saved millions of lives over that time period.

However, chlorine's evil twin is the creation of disinfection byproducts (DBPs) that are formed when chlorine reacts with certain forms of organic carbon nearly always found in surface water. Many of the DPBs are known carcinogens and so are regulated under SDWA. The two classes of regulated DBPs are Trihalomethanes (THM) and Haloacidic acids (HAA).

The formation of DBPs is dependent on the type and concentration of organic carbon, chlorine concentration, water temperature, pH and contact time. These relationships are sufficiently complicated that it is nearly impossible to predict the forms and concentrations of DBPs that will result when a dose of chlorine is added to a water sample. However, one can make the following generalizations:

- DBP formation increases with increasing water temperature (DBP concentrations are often higher in the summer months)
- DBP formation requires time so that DBP concentrations correlate to water age (DBP concentrations are frequently higher at the farther reaches of the distribution system)

The best way to prevent DBPs is to remove DBP precursors, i.e., organic carbon, prior to chlorination. Although conventional treatment systems may be in compliance with SDWA turbidity requirements, they never remove all organic carbon and frequently enough passes through the treatment system so that DBP production is a compliance issue for the system. Frequently, a combination of chemical modification (change of flocculent and/or adjustment of flocculent and chlorine dosage), control of loading rates or other operational changes can improve precursor removal, but this takes increased skill and attention on the part of operators and is often beyond the capabilities of many operators with their existing level of training.

Membrane technologies are more effective at removing DBP precursors, but generally have higher capital, operation and maintenance costs than conventional treatment and result in a significant waste stream.

4. Source Water Protection and Alternative Sources

Protecting a water system's source of supply from contamination is never easy, but can be extremely difficult with surface water sources. The watershed for most surface water intakes is quite large and generally not within the control of the water system (Santa Fe being a notable exception). Nevertheless, it is worthwhile for water systems to work with state and federal agencies to identify potential point and non-point sources of contamination and to participate in collaborative efforts to maximize routine water quality and minimize the likelihood of a catastrophic event that could result in shutting down water intake to the system (e.g. forest fire or contaminant release).

Spring runoff and large precipitation events can cause turbidities to spike dramatically. Systems that have intakes off a river may be required to shut down intake until turbidities fall, depending on pretreatment storage capacity of the system and the capabilities of the treatment system. Drought conditions can also cause water quality and/or quantity to be reduced to the point that the surface water source is no longer adequate to meet the systems needs for extended periods of time. If the water storage capacity of the system is insufficient to outlast the high turbidity or drought event, an alternative source would be needed. This can be accomplished through a groundwater supply or through an emergency connection to a nearby system that does not share the same risk of loss of supply, if such a system exists. Such an alternative or emergency source should always be a part of a surface water system's water supply.

5. Administrative Support

It is not uncommon for operators of smaller drinking water systems to do a variety of tasks including some that do not qualify as operating a drinking water system. Such tasks could include operating a wastewater system, reading meters, mowing the lawn, driving the garbage truck, and so on. If the system is a relatively simple groundwater system, it may be feasible for the operator to include several such tasks. But as discussed above, the operation of a surface water system requires significant time on the part of the operators just to meet compliance requirements, let alone getting optimal performance from the treatment plant.

It is essential that system administrators understand the time commitment required for the operation of a surface water system in order to meet the SDWA requirements. The priority for surface water system operators must be the operation of the water system. It must be understood that even with automated treatment systems, there is still an important role for the operators and that a certain amount of daily plant time is essential, especially during times of changing raw water quality.

6. Emerging Contaminants

Currently, a relatively small number of the universe of potential contaminants are regulated under SDWA. EPA has a process it goes through on a periodic basis to review unregulated contaminants for possible inclusion in SDWA. Every five years it publishes a Contaminant Candidate List which contains all the contaminants it will review for SDWA inclusion.

One class of contaminants that has received considerable attention in the press recently is pharmaceuticals, which are often grouped with hormones and personal care products. Many of these organic compounds, if present in source water, are only partially removed or degraded by conventional water treatment systems. Thus far, EPA's process to review unregulated contaminants has not addressed the large number of these chemicals, but it is almost certain that in the next round of review of potential contaminants, EPA will include some pharmaceuticals, hormones and other household chemicals. If such a review results in any of these chemicals being regulated under SDWA, surface water systems will likely have to augment their monitoring regimes and possibly modify their treatment systems to meet SDWA requirements.

On EPA's most recent Contaminant Candidate List, nine microorganisms were included. It is not yet known if any of these "emerging" pathogens will become regulated under SDWA or what the implications are if any are included.

SUMMARY

Public water systems are regulated under a variety of federal and state laws, all to ensure that the public is protected from waterborne illness. Being a public water system is a challenge for all water systems, regardless of size or water source. Due to the complexity of surface water treatment and the numerous SDWA requirements for surface water systems, there are many issues that a surface water system must consider that are lesser or nonexistent issues for groundwater systems. All of these considerations can probably be addressed by a surface water system, but at a significant cost. To ensure a successful transition, all of these issues should be taken into account starting at the earliest planning stages when a water system is considering utilizing surface water as part of its water supply.