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Arizona
Well Owner's Guide To Water Supply

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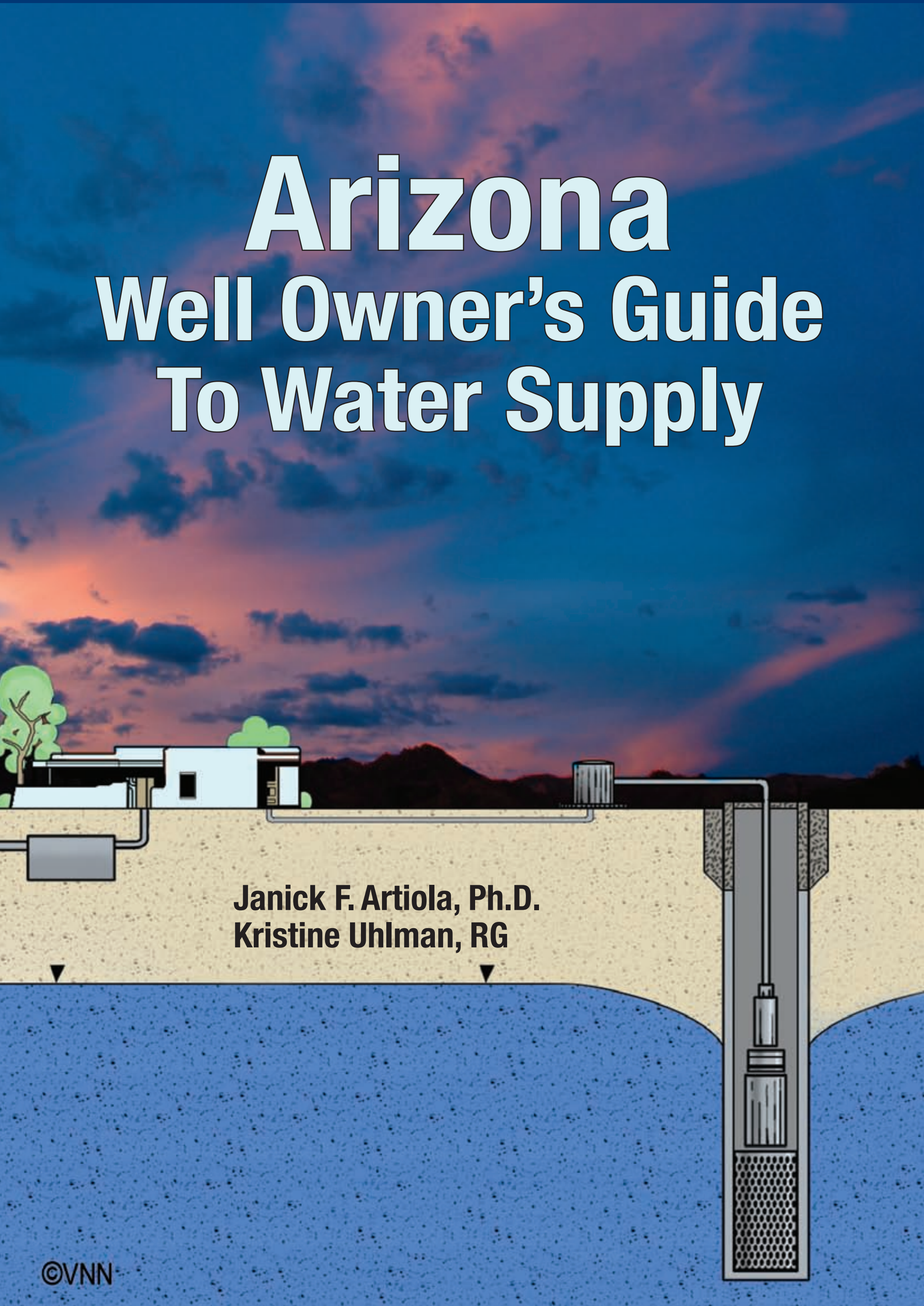

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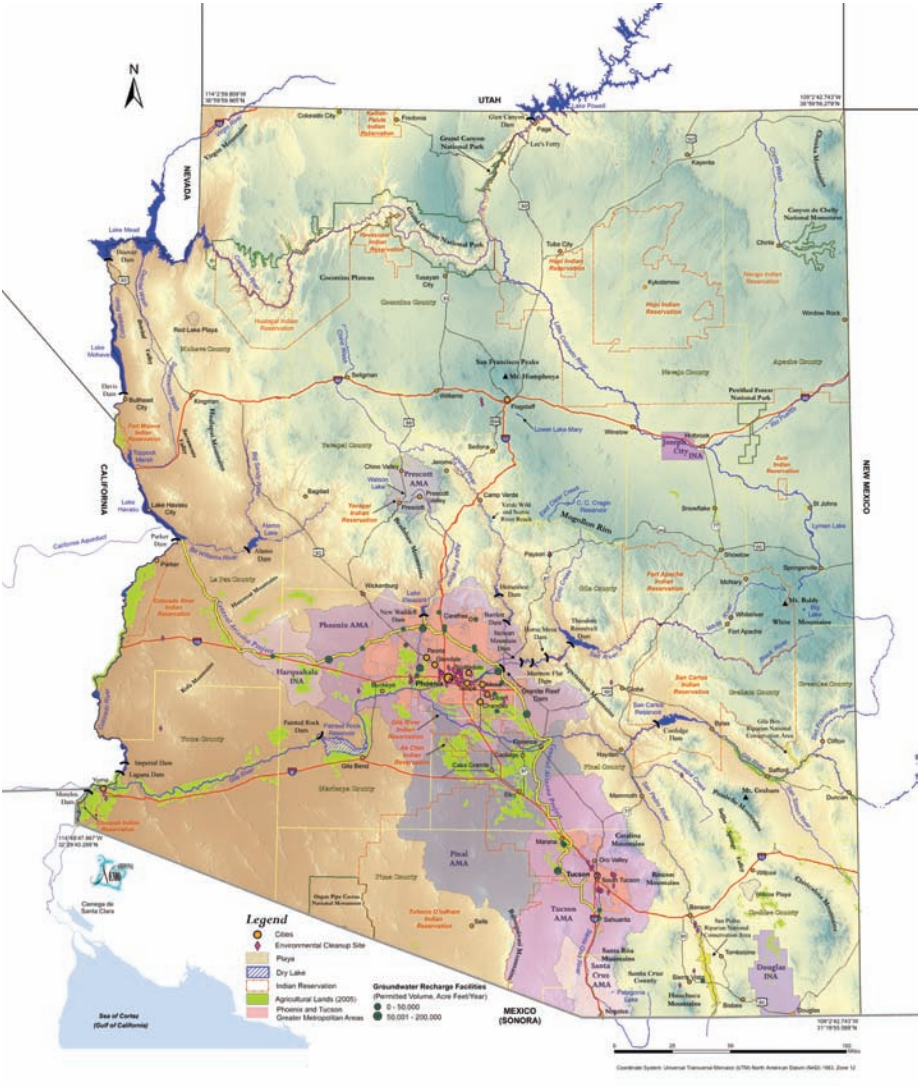

Map of Arizona. Source: Arizona Water Map Poster 2009. Water Resources Research Center, College of Agriculture and Life Sciences, University of Arizona. Contact the WWRC to purchase the full version.

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WELL OWNER'S GUIDE
TO WATER SUPPLY

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Foreword

This booklet is intended for Arizona residents who depend on private wells for their water needs. Well owners who want to become familiar with Arizona's groundwater sources, water quality and water testing options, and well maintenance issues should read this booklet. Topics include:

- An overview of the state's water resources and how Arizona's major cities use these sources.
- A description of Arizona's geology and how location affects the quantity and quality of aquifer water resources in our state.
- Common contaminants found in Arizona's groundwater and guidelines, including national drinking water standards, to test well water to insure safe drinking water in private wells. National drinking water standards and common methods of home water treatments are also presented.
- Detailed descriptions of private wells including regulations, construction, protection, and maintenance guidelines.
- Having read this booklet, the well owners will understand the importance of
  - aquifers as a common water resource;
  - well head protection; and
  - their responsibility in annual testing of the water supply.

Downloadable versions and hard copies for sale of this booklet can be found at The University of Arizona WRRC, SAHRA, and Cooperative Extension websites.

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2. Aquifers in Arizona

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5. Domestic Private Wells – Well Operation and Maintenance

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1. Introduction

Water Use Facts: Water covers about 70% of the world's surface, and all life forms, including humans, depend on it for their basic survival. However, about 97% of the world's water is in the oceans and is considered highly saline and not fit to drink without desalinization. Ice located near the earth's poles accounts for about 2% of the earth's water. About 0.6% of the world's water is fresh water stored below ground (groundwater), often for hundreds to thousands of years. The atmosphere and the soil environment account for about 0.06% of the world's water. About 0.01% of the world's water is found in lakes, rivers, and streams.

There are more than 100,000 domestic use wells in Arizona. These private wells provide water to an estimated 120,000 households, with some 300,000 persons, or about 5% of the state's population. About 10-30% of the U.S. population depends on domestic wells for their water (Bartholomay et al., 2007). Information about the total number of domestic wells in the U.S. is difficult to obtain, but according to the Center for Disease Control more than 90,000 new wells were installed in the U.S. in 1998 (CDC, 1998). In Arizona, the number of new domestic wells now exceeds 3,000 each year (**ADWR**, 2008a). The U.S. Environmental Protection Agency (US-**EPA**, 2008) reports that "approximately 15% of Americans rely on their own well..." for water. Water from domestic wells that service less than 15 connections or 25 people is not subject to EPA drinking water regulations, and undergoes no governmental quality tests for potability in Arizona (note: New Jersey is one of the few states requiring domestic wells be tested with any real estate property transaction).

Most well owners are not trained as well operators and are often unfamiliar with water quality standards and testing, and rarely know much about their systems or the local aquifer. A recent nationwide survey of well water quality conducted by the U.S. Geological Survey (USGS) indicates that about 79% of the wells (12,318 of 15,495 tested) contained one or more contaminants that may be harmful to human health. Of those wells sampled, 9-11% had arsenic and nitrate levels exceeding the U.S. EPA maximum contaminant levels (**MCL**s) established for drinking water standards. In addition, less than 1% of the wells had organic contaminants like the herbicide **atrazine** above drinking water standards (Focazio et al., 2006). **Radon**-222 gas, presently not regulated by the EPA, was detected in 98% of the wells sampled.

A recent well water quality study of a small number of wells from seven Arizona counties found that about 90% of the wells exceeded at least one contaminant standard (such as nitrates, arsenic, and/or coliforms) (Karpiscak et al., 2006). For example, 43% of domestic well waters sampled were contaminated with waterborne **pathogens**, and 33% of the wells had nitrate or arsenic levels exceeding the EPA standards. The data from these recent surveys suggest that domestic well owners should regularly monitor their well water quality. They should also consider home water treatment systems to bring their well water quality to national drinking water standards.

This Well Owner's Guide presents detailed sections that assist the reader to become familiar with water quality concepts, drinking water guidelines, well system operation and maintenance, and water testing. The reader is also introduced to Arizona's **aquifers,** as well as conditions and activities that effect groundwater quality. Well owners can also learn about well construction, well components, and well maintenance needed for the safe and proper function of their wells. This guide also includes a section on water treatment technologies based on water quality conditions.

Arizona Water Sources

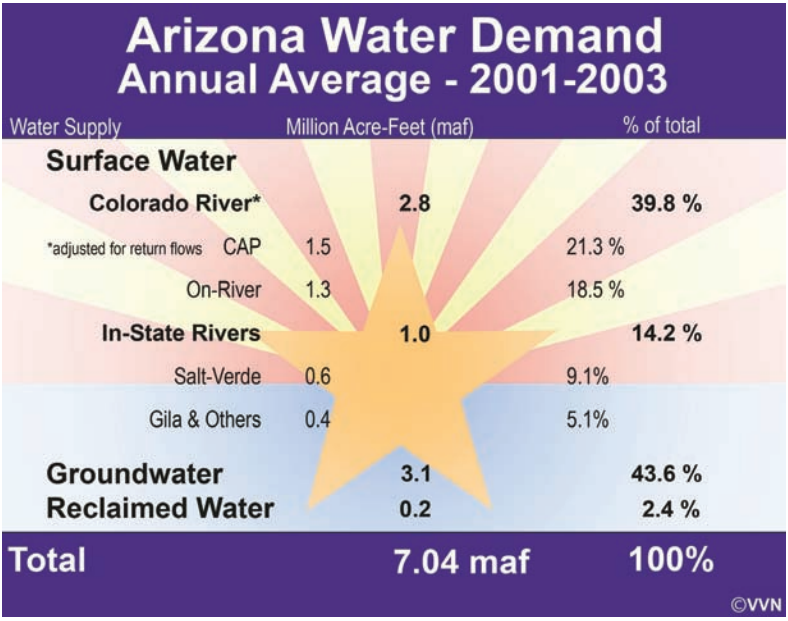
Water Use Facts: A natural resource qualifies as a renewable resource if it is replenished by natural processes at a rate comparable to or faster than its rate of consumption.
A non-renewable resource is a natural resource that cannot be re-made, re-grown, or regenerated on a scale comparable to its consumption.

The total amount of water that circulates annually from the earth's surface to the atmosphere and back down to the earth has remained constant. On average, rivers and lakes produce the same amount of fresh water now as they did 100 years ago. However, the population of the world has increased more than six-fold in the last 100 years, increasing demands on fresh water resources.

Although groundwater is considered a renewable resource in regions with plentiful rain and snow, it is considered a non-renewable resource in the arid West and many other parts of the U.S. and the world where pumping exceeds **recharge** in many aquifers. There is insufficient rainfall in Arizona's dry climate to recharge the aquifers and to keep pace with increased pumping. This will continue to produce significant **overdraft** in many aquifers in the state. Age-dating estimates the time elapsed since the water fell as rain or snow before it percolated to the groundwater. For example, groundwater in the Tucson basin has been age-dated to be between 300 and 8,000 years old. In the San Pedro River basin, the groundwater has been age-dated to over 12,000 years old.

Perennial rivers occur where groundwater is near the land surface and discharges continually to a river bed. During rainfall events, this groundwater '**base flow**' is mixed with rainfall runoff. For example, after the summer monsoons, water flowing in the San Pedro River has been age-dated and found to consist of a combination of groundwater base flow and recent rainfall.

Growth in the arid southwest United States is sustained by the use of mostly groundwater and river-fed reservoirs. Presently, about 44% of Arizona's water supply comes from in-state groundwater sources, as shown on Figure 1. The water supply reservoirs contain a mixture of water derived from seasonal snow melt, rainwater, and groundwater base flow. Surface water from in-state rivers and reservoirs meets about 14% of Arizona's water needs. In addition, **reclaimed water** meets about 2% of Arizona's water demand.



Arizona Water Demand
Annual Average - 2001-2003

Water Supply	Million Acre-Feet (maf)	% of total
Surface Water		
Colorado River*	**2.8**	**39.8 %**
*adjusted for return flows CAP	1.5	21.3 %
On-River	1.3	18.5 %
In-State Rivers	**1.0**	**14.2 %**
Salt-Verde	0.6	9.1%
Gila & Others	0.4	5.1%
Groundwater	**3.1**	**43.6 %**
Reclaimed Water	**0.2**	**2.4 %**
Total	**7.04 maf**	**100%**

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Figure 1. *Arizona Water Supplies (ADWR, 2008b).*

Arizona also has an annual allocation of 2.8 million acre-feet of Colorado River water, established by a Federal Supreme Court decision in 1964, which accounts for nearly 40% of Arizona's total water supply. Following a 1973 Supreme Count Decision, the Central Arizona Project (CAP) began construction of a canal to deliver

Colorado River water across the state, primarily to Maricopa, Pinal, and Pima Counties. Today, CAP water accounts for about 21% of the state's water use. Although CAP water is a dependable resource, Arizona's allocation of Colorado River water is limited by Federal law and access to it is constrained by proximity to the canal. Because of our 'junior' water right to the Colorado River, Arizona's allocation of CAP water will be the first to be reduced in a regional drought.

Agriculture remains the primary user of water resources in Arizona, accounting for about 74% of the 7 million acre-feet of water used annually during 2001-2003. (ADWR, 2008b).

The Arizona Groundwater Management Act (Title 45 of the Arizona Revised Statutes) was passed in 1980 to conserve, protect, and allocate groundwater resources and provide a framework for management and regulation. The Act has three primary goals:

- Control the severe groundwater overdraft occurring in many parts of the state;
- Provide a means to allocate the state's limited groundwater resources to most effectively meet the changing needs of the state; and
- Augment Arizona's groundwater through water supply development.

To accomplish these goals, the Act established the Arizona Department of Water Resources (ADWR) to administer the Act's provisions. "Active Management Areas" or "**AMAs**," were established across the state (Figure 2) to manage excessive pumping. Most of the AMAs have established a goal of "safe yield" by the year 2025. "Safe yield" would be achieved when the volume of groundwater extracted does not exceed the volume of groundwater recharging the system. Excessive pumping was found to result in land **subsidence** as the water table drops. Also, water pumping costs and mineral content (total dissolved solids - **TDS**) increase with aquifer depth.

The Arizona Groundwater Management Act of 1980 identifies wells having a pump capacity of not more than 35 gallons per minute (**gpm**) as "**exempt wells**" because within the AMAs owners are not required to report how much water they pump. These well are typically used for domestic or household purposes. As the number of exempt wells increase in the AMAs, the accumulated volume of unregulated extraction is causing concern. It is expected that future regulations may require monitoring of exempt well pumpage to manage safe yield goals.

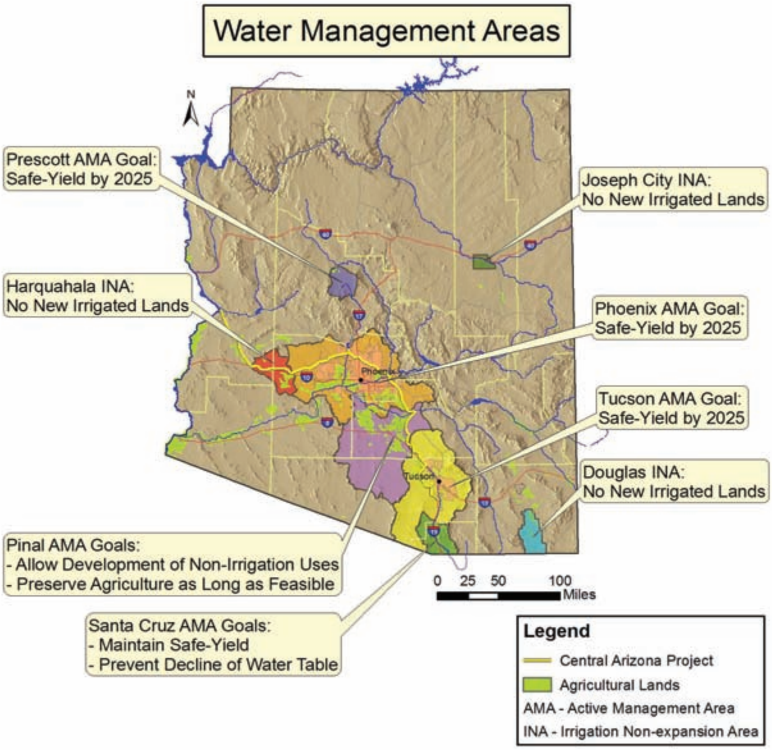


Figure 2. *Arizona Active Management Areas (ADWR 2006).*

Local Water Sources

Phoenix and its surrounding cities – Chandler, Mesa, Tempe, Glendale, Scottsdale, and Peoria – have diverse sources of fresh water. These include several major surface water streams (including the Salt, Gila, Verde, and Agua Fria Rivers), and more recently, the CAP canal. Dams located on these rivers, which flow from the mountains north and east of Phoenix, form reservoirs that provide a steady supply of water. Surface water and CAP water provide about 57% of the Phoenix area water supply. However, if drought persists and the pattern of snow fall and precipitation changes, it is unlikely that these surface water resources will increase in the near future.

Phoenix and its surrounding communities also supplement their water needs by pumping from several large aquifers. However, large portions of the groundwater along the Salt and Gila Rivers are high in **salinity** (> 3000 **mg/L** TDS). Presently, the City of Phoenix, which delivers potable water to 1.3 million people, utilized groundwater for only 8% of its water supply in 2002. Central Arizona Project water and reclaimed wastewater (treated effluent) are used for irrigation or to recharge local groundwater aquifers for future use.

Tucson has no surface water (streams, lakes, or rivers) supplies. These sources were quickly depleted during the first part of the twentieth century, mostly by local groundwater pumping which lowered the water table and depleted river base flow. Although groundwater levels have dropped in the center of the Tucson basin by more than 200 feet over the past fifty years, growth has been sustained by the continued use of groundwater and CAP water. Since 1996, CAP water that is not used directly is discharged into groundwater recharge basins and stored aquifers. This has slowed the lowering of groundwater elevations in the Tucson Aquifer. Tucson also requires the use of treated effluent to irrigate parks and gulf courses and is using 11,000 acre feet of effluent directly; the excess effluent is discharged in to the Santa Cruz river.

Yuma obtains drinking water for its 100,000 residents primarily from the Colorado River and holds the oldest water rights on the river. Groundwater is used locally for irrigation, blended with surface water for municipal supply, and used occasionally for emergency supply. Most of the water diverted from the Colorado River in Yuma is used for agriculture, while drainage wells are used so that the land does not become water-logged from irrigation application.

Flagstaff has diverse but limited sources of water. The primary sources are Lake Mary (located to the southwest), and wells and springs (located to the north). However, both sources are fed by snowmelt, which can vary greatly from year-to-year. Groundwater is also available from the Coconino Sandstone (known as the "C" Aquifer), but it is deep (1,200 to 1,600 feet below land surface) and, consequently, expensive to pump. Presently, about 70% of Flagstaff's water demands are met by groundwater. In 2005, Flagstaff purchased the Red Gap Ranch east of the city as a potential location for new well-field development. This city is also utilizing reclaimed water to irrigate public areas like schools, parks, and golf courses (ADWR 2008b.)

The **Prescott** area and Yavapai County have the unique distinction of having more exempt, private domestic water supply wells than any other area in Arizona. Currently, over 30% of all new wells drilled in Arizona are in Yavapai County, with the greatest concentration of these wells in the Prescott area. The City of Prescott obtains most of its water supply from groundwater wells. Arizona law allows the transportation of groundwater pumped from the Big Chino groundwater sub-basin, located north of the City, into the Prescott AMA. The City of Prescott has purchased the Big Chino Ranch to supplement its water supply. While the law allows pumping of up to 14,000 acre-feet of groundwater a year, the actual permitted volume has not yet been determined (Yavapai County, 2008).

Water Reuse

In urban areas, about 40% of water delivered to homes by community water systems is eventually discharged to the sewer system and then treated in wastewater treatment plants. Once treated, this dependable water source can be reused for agriculture, parks, golf courses, or used to recharge the aquifer. However, reclaimed water is usually about 1.5 times higher in TDS than the original water source. For example, if the water source has 300 mg/L TDS, the reclaimed water will have about 450 mg/L TDS. In addition, wastewater treatments kill or remove most pathogens, but do not remove all residual (trace) organic chemicals. The removal of excess salts and trace amounts of residual **organic chemicals** would increase the cost of wastewater treatment significantly. Reclaimed water is considered safe for irrigation and groundwater recharge, but direct use as a drinking water source requires additional treatment.

Outlook

The earth is a water planet, but only a very small fraction of the world's water is fresh and located where it is needed. Groundwater resources are important to Arizona but are being depleted because pumping exceeds the rate at which natural recharge replenishes the supply. Wise water management is necessary to conserve local water resources, to sustain growth, and to preserve life and the environment.

For the domestic well owner, knowledge of the vulnerability of their well, the importance of water quality monitoring, and appropriate well maintenance is necessary to assure drinking water availability and supply into the future.

Water, water everywhere but only a drop is fresh.

2. Aquifers in Arizona

An aquifer is an underground **geologic formation** capable of producing (yielding or transmitting) usable quantities of water to a well or spring. Depending on the geologic formation, water is typically held in interconnected pores and void spaces between grains of clay, silt, sand, and gravel or in subsurface fractures and cracks of rocks, see Figure 3. Aquifer material types include **consolidated** and **unconsolidated** rock materials, examples of which range from the unconsolidated **alluvial** sands and gravels of river valleys and southern deserts, to the dense consolidated **basalt** of the Mogollon Rim.

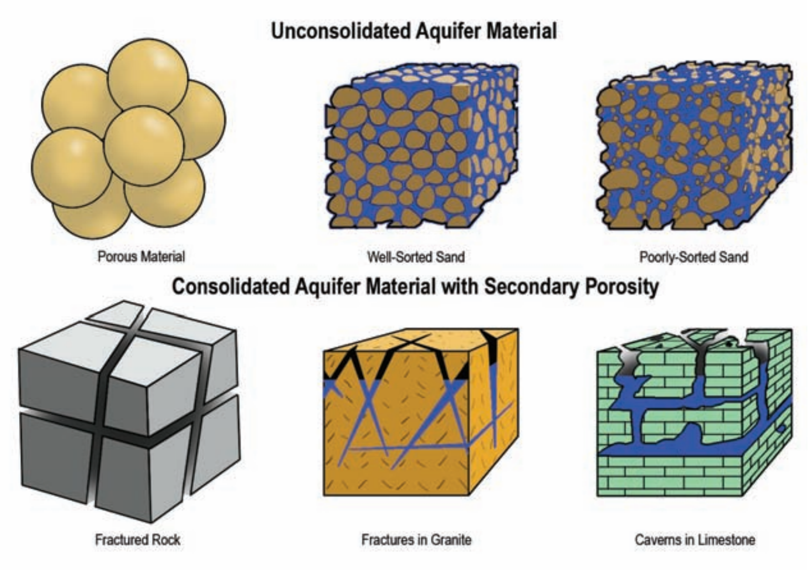


Figure 3. *Aquifer Materials.*

In these two aquifer types, groundwater is filtered through pores (porous flow) or through fractures and cracks (fractured flow) and/or in a combination of these flow types. Water flow through fractures can rapidly transmit contaminants through the subsurface, as there is little opportunity for natural filtration of pollutants. It is important to understand which flow type is prevalent in your aquifer to protect your water supply from contamination.

Arizona's geologic history resulted in the formation of three **physiographic provinces:** the Colorado Plateau; the Central Highlands Region (also known as the Transition Zone between the other two provinces); and, the Basin and Range Province, see Figure 4.

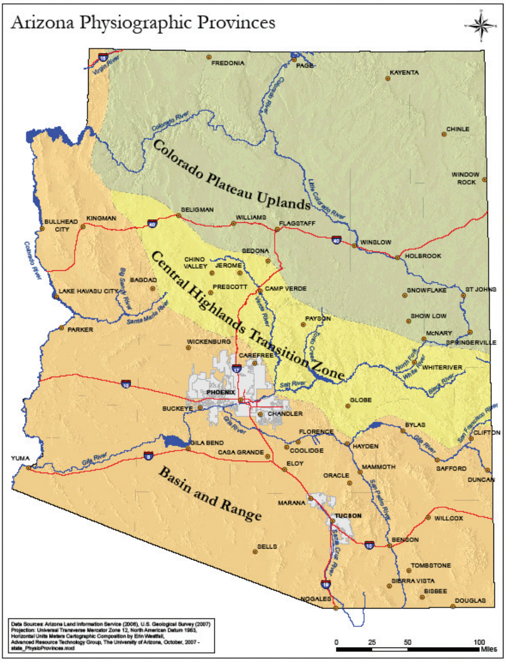


***Figure 4.** : Arizona Physiographic Provinces (Harshbarger et al., 1966).*

Each of these provinces exhibit aquifer types and groundwater flow characteristics unique to that region.

Colorado Plateau Uplands

The Colorado Plateau consists of layers of consolidated sedimentary rock, which form broad plateaus and mesas, separated by deep canyons. The numerous **sedimentary rock** layers are visible in the Grand Canyon walls, and each rock layer has unique aquifer characteristics, dependent on the numbers of sedimentary **bedding planes**, fractures and cracks, and interconnected rock fractures. Some sedimentary rocks maintain their original pore spaces (**porosity**), such as the Coconino Sandstone (see Figure 5) which originated from white-sand dunes. In some places, these layers of sedimentary rock contain caverns and caves, for example in the Redwall Limestone. These caves were produced by large groundwater flows through rock fractures, which then dissolved the rock, forming large caverns. Therefore, a well constructed in the consolidated sedimentary aquifers of the Colorado Plateau may yield little water if the borehole does not intercept sufficient fractures transmitting water, or in the extreme, the well may yield sufficient volumes of groundwater that has had little filtering.

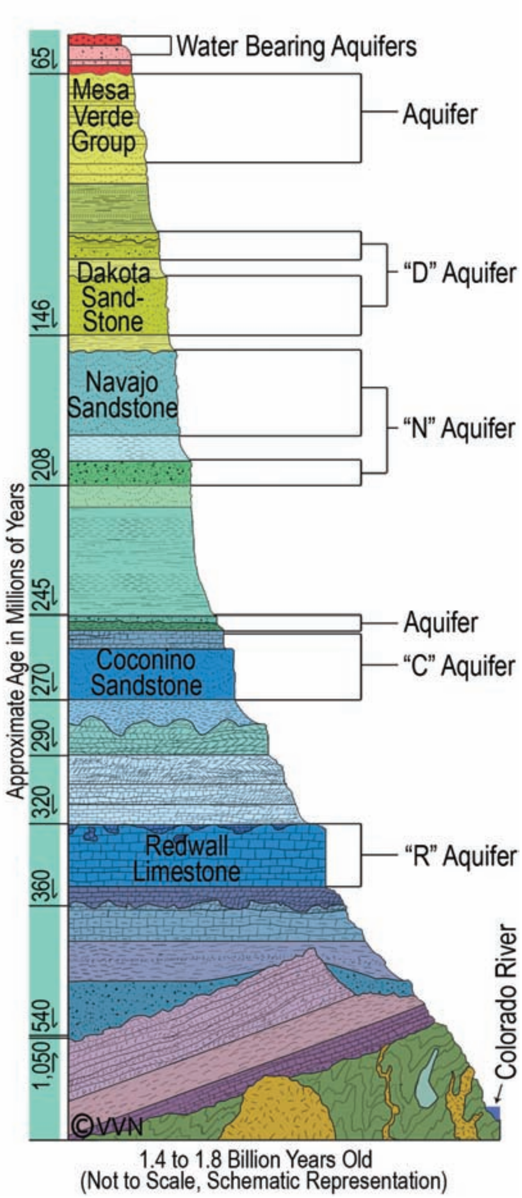


Figure 5. *Colorado Plateau geology showing aquifers available for potential water supply (modified from Harshbarger et al., 1966; and, Kamilli and Richard, 1998).*

Central Highlands Region

The southern boundary of the Colorado Plateau is the Mogollon Rim, a steep ridge formed by erosion after the plateau was uplifted. Large volcanoes, such as the San Francisco Peaks, are present along the Mogollon Rim bordering this Central Highlands Region or Transition Zone. This zone cuts across central Arizona, (see Figure 4) separating the Basin and Range Province from the Colorado Plateau, and exhibits geologic characteristics intermediate between the two. In addition to the volcanoes along the northern margin, it contains mountainous regions (highlands) cut by major canyons and valleys filled by unconsolidated sediments such as in the Verde Valley.

The amount of water produced by wells developed in these valleys will vary depending on the grain-size of the aquifer material – fine-grained silts and clays will yield less water than the more porous coarse-grained sands and gravels. Wells in the dense fractured volcanic basalt rocks will also vary in yield depending on the number of water-bearing fractures intercepted by the well borehole and **permeability** (see Figure 3 and Figure 6).

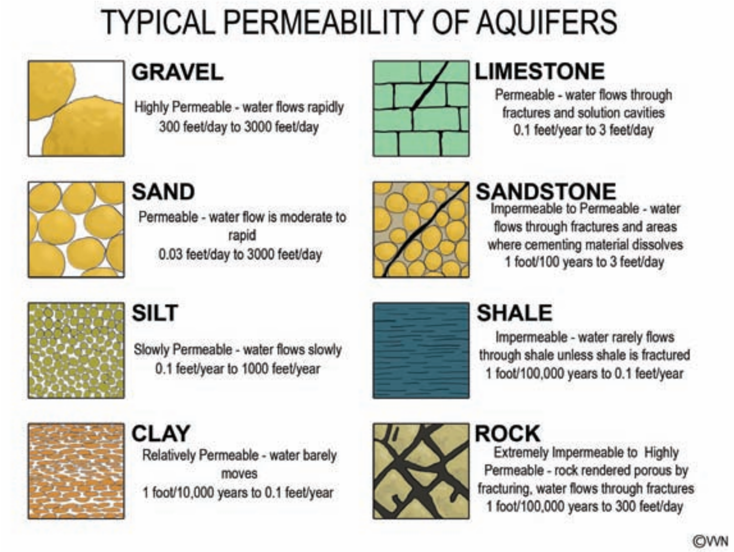


Figure 6. *Permeability ranges for aquifer materials.*

Basin and Range

This province of southern and western Arizona is where the earth's crust was stretched and broken by numerous **faults** so that mountain ranges and basins (broad valleys) were formed by the **vertical displacement** of large consolidated blocks of rock. From mountain top to the valley basement, the average displacement has been estimated at approximately 10,000 feet, with the valleys filled by up to 7,000 feet of gravel, sand, and silt.

The sediments or **alluvial** materials that fill these valley basins originate from the mountains above, and typically consist of sands and gravels produced by the weathering of granite rock. The valleys are filled with materials produced by the action of erosion and transported by rivers and streams (Figure 7). Often, impermeable geologic barriers blocked the basins from forming rivers that would drain the basin and thus created lakes. In these cases, the valley fill may include lake deposits of silt and clay, and occasionally salt. Wells completed in the granites and other rocks of the mountain ranges bordering the alluvial valleys will vary in yield, depending on the number of water-bearing rock fractures intercepted by the well borehole. Note that local geology may vary from the generalizations made above.

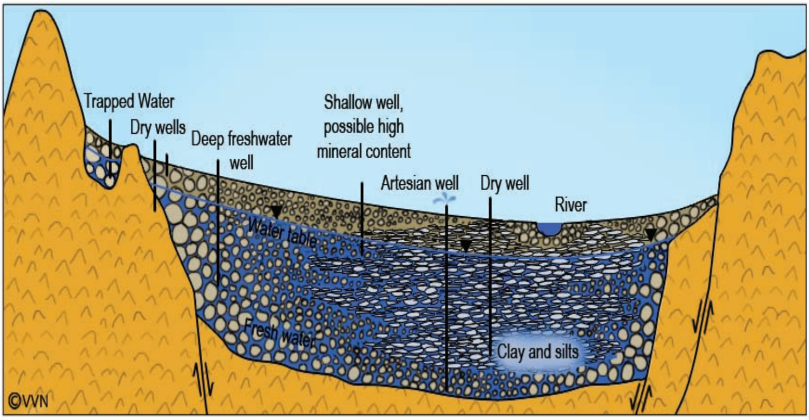


Figure 7. *Profile of a Basin and Range Aquifer.*

Major agricultural areas of the state, as well as the cities of Phoenix and Tucson, are located in the Basin and Range province. Increasing groundwater pumping continues to lower water table elevations, which has resulted in land subsidence in some locations. Because of dropping water tables and local geology, wells in these sediments may require drilling to excessive depths to reach water-bearing zones. For example, in some locations within the San Pedro Valley, domestic water wells must drill through nearly 400 feet of the St. David Clay Formation to find water-bearing sands and gravels.

Across Arizona, pockets of alluvial sands and gravel, and lenses of ancient river gravel channels now buried in clay may result in finding water where none had been expected. In addition, the depth to water and thickness of the water saturated zone of the aquifer, and aquifer permeability, will control the ability of a well to yield sufficient volumes of water.

Aquifer Recharge

Water Use Facts: Age dating is accomplished by looking at carbon, hydrogen, and oxygen isotopes within the groundwater, and calculating when was the last time the water fell as rain or snow prior to recharging the aquifer.

Because of Arizona's arid and semi-arid climate, on average, recharge to groundwater is estimated to be 2% to 3% of the average annual rainfall (Uhlman, 2005). Most aquifer recharge occurs along the mountain fronts because that is where most of the rain falls, and because the fractured rock of the mountains and the coarser grained materials along the margins of the alluvial basins allow water to infiltrate rapidly. Shallow wells near surface water or washes, with a water-table within a few feet of land surface, may exhibit dramatic seasonal variation in water table depth due to rapid infiltration of recharge following precipitation or stream flow. Most Arizona wells, however, are at a distance from their recharge source and are less likely to exhibit seasonal changes. In addition, most regional aquifers across the west, and in Arizona, have not received significant volumes of recharge for hundreds to thousands of years.

Work done by the U.S. Geological Survey has age-dated groundwater (see Figure 8). For most of the west, the last time the climate was wet enough to fill up the aquifers was during the last Ice Age over 10,000 years ago.

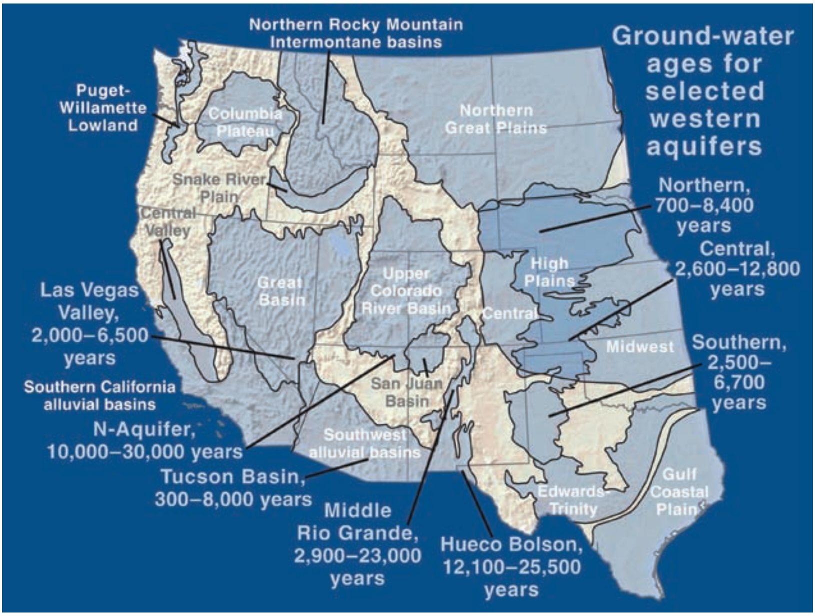


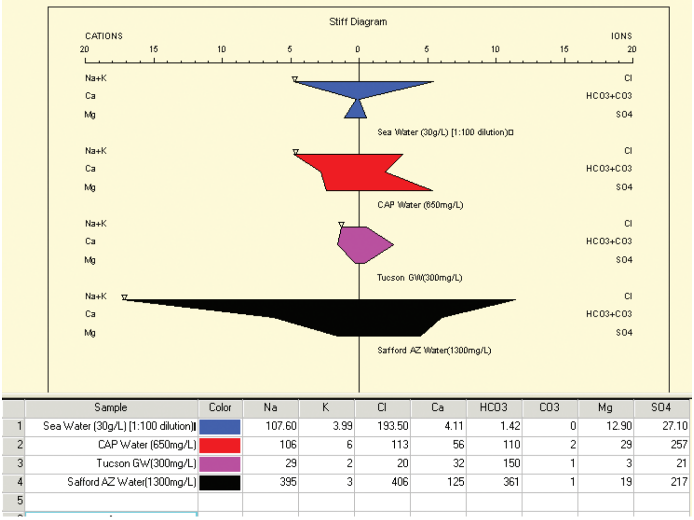
Figure 8. *Map Showing Groundwater Ages in Areas with significant Water supplies in the Western United States (USGS, 2006).*

3. Water Quality

Water has three natural states: solid (ice); liquid; and, gas (vapor), and moves freely between these states. In its liquid form water has the ability to interact with solid matter (minerals, plant residues), dissolve **minerals** (chemicals), and carry particulates and **microorganisms** as it runs off and seeps into the ground. Therefore, water quality often changes when water in its liquid form and interacts with the environment. Water vapor completes the water cycle as it evaporates and condenses to form rain. Rainwater can become contaminated by interacting with atmospheric pollutants. Nonetheless, cycling through this natural distillation process is what makes rain and snowmelt fed "fresh water" rivers and streams an important resource.

Common Minerals found in Water

Fresh water in contact with soils and aquifer material typically contains common minerals including **gypsum, calcite**, and **dolomite** that control the **alkalinity** and **hardness**. Such minerals are the sources of common elements (ions) like calcium, magnesium, carbonates, and sulfate. These ions together with potassium and salt (NaCl) account for about 95% (by mass) of the total dissolved solids (TDS) found in natural fresh water. The amount and proportions of minerals in water affect its taste and can often be used to identify the origin of a water source. (Figure 9).



	Sample	Color	Na	K	Cl	Ca	HCO3	CO3	Mg	SO4
1	Sea Water (30g/L) [1:100 dilution)	🟦	107.60	3.99	193.50	4.11	1.42	0	12.90	27.10
2	CAP Water (650mg/L)	🟥	106	6	113	56	110	2	29	257
3	Tucson GW(300mg/L)	🟪	29	2	20	32	150	1	3	21
4	Safford AZ Water(1300mg/L)	⬛	395	3	406	125	361	1	19	217
5										

Figure 9. *Mineral composition of sea water (diluted 100 times) and three Arizona water sources.*

Numerous other chemicals, found in soil and rocks, are also found in water in trace amounts. These include nutritionally beneficial elements like trace concentrations of copper, zinc, and iron and undesirable elements like arsenic, mercury, and radon gas. Waters that come into contact with minerals rich in these chemicals may contain elevated and potentially toxic concentrations to human health.

Contaminants in Water

Contaminants fall into three categories: those of natural origin, those of natural origin but concentrated by human activities and those human-made and introduced into the environment. Water sources may also have unwanted but naturally occurring toxic elements like arsenic that may naturally concentrate to toxic levels in certain geologic settings. When naturally occurring arsenic is found in a drinking water source at concentrations above National Primary Drinking Water Standards (NPDWS), the water is considered to be "contaminated" with arsenic.

Human activities can also contaminate natural waters with excessive levels of minerals or **pollutants**. These activities include agricultural and industrial release of pollutants; improper disposal of municipal and animal wastes into air, soil, and surface and groundwaters; and transportation and recreation on air, land, and water. The types and concentrations of contaminants that can be tolerated in drinking water without harm to human health are set by the US-EPA.

Human-made contaminants are also commonly referred to as pollutants. These include synthetic organic chemicals such as agricultural pesticides, industrial solvents, fuel additives, petroleum products, plastics, and many other chemicals. Unfortunately, many of these chemicals are ubiquitous (present everywhere) in our environment due to their extensive use in modern society. In addition, microbial pathogens derived from human and animal waste become pollutants when improperly disposed of, and can adversely affect the quality of water resources.

Drinking Water Guidelines and Standards

The EPA sets National Primary and Secondary Drinking Water Standards in collaboration with community water system organizations, scientists, state and local agencies, the public, and others. States and Native American Communities facilitate implementation of these standards by regulating public and private water systems. Standards are published in the Code of Federal

Regulations (Figure 10). Drinking water standards are always evolving as new analytical methods are developed, scientific information becomes available, and new priorities are set in response to the potential health effects of contaminants.

In Arizona, these standards apply to "community water systems," which are systems that serve at least 15 connections used by year-round residents of the area served, or that regularly serves at least 25 year-round residents. Domestic wells that serve water below these limits are not required to comply with the drinking water quality standards. In Arizona, wells equipped with a pump that pumps less than 35 gallons per minute and serve a household (or several households) are private domestic wells and are not required to monitor water quality. For that reason it is important for well owners to be aware of drinking water guidelines and to test their water quality against those standards required for community water systems.

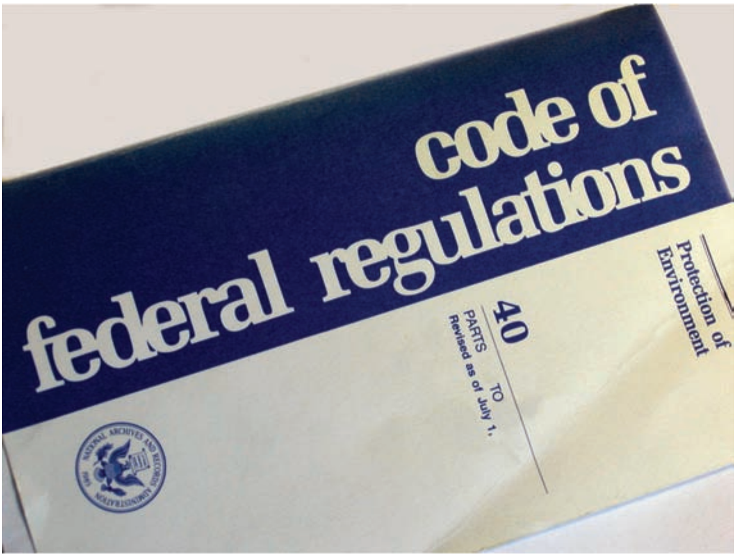


Figure 10. Code of Federal Regulations, Title 40 Protection of the Environment.

Primary Drinking Water Standards

The EPA considers many issues and factors when setting a standard. These include current scientific data, availability of technologies for the detection and removal of contaminants, the occurrence or extent of a chemical in the environment, the level of human exposure, potential health effects (**risk assessment**), and the economic cost of water treatment.

Community water systems must comply with National Primary Drinking Water Standards (NPDWS) by providing water to their customers that does not exceed the MCL of any listed contaminant. Contaminants listed as NPDWS are known to have an unacceptable human health and/or environmental risk, if found in concentrations greater than their MCLs. Additionally, when water sources are treated by community water utilities, they must use EPA-mandated or US-EPA-accepted water treatment methods to treat below the primary MCL.

Primary contaminants (87 individual and categories), regulated under the NPDWS, are divided into six groups, inorganic contaminants (such as arsenic and lead), organic chemical contaminants (such as insecticides, herbicides, and industrial solvents like trichloroethylene or **TCE**), water disinfectants (such as chlorine and chloramines), **disinfection by-products** (such as chloroform), radionuclides (such as uranium) and microorganisms (such as Giardia and intestinal viruses). The complete list of these contaminants, including the MCL allowable in a drinking water supply, can be found in Appendix A and on the EPA website.

If well water exceeds the MCL for any listed contaminant, your water supply may be a health risk. You should treat your water to avoid the health risk or find an alternative supply.

Secondary Drinking Water Standards

EPA has established National Secondary Drinking Water Standards (NSDWS) that set non-mandatory water quality standards for 15 contaminants, as shown on Table 1. EPA does not enforce Secondary Maximum Contaminant Levels (SMCL). They are established only as guidelines to assist community water systems in managing their drinking water for aesthetic considerations, such as taste, color, and odor. These contaminants are not considered to present a risk to human health, and community water systems are not required to reduce these chemicals below the SMCL. However, water utilities control the levels of these chemicals in the water in order to prevent tap water odor and taste-related customer complaints.

If well water exceeds the SMCL for any listed contaminant in Table 1, consider water treatment to bring your water supply within aesthetic considerations. A discussion of commonly found contaminants follows.

Table 1. National Secondary Drinking Water Standards. The Primary Standard, or MCL, is also shown for copper and fluoride.

Contaminant	Secondary Standard	Primary Standard
Aluminum	0.05 to 0.2 mg/L	
Chloride	250 mg/L	
Color	15 (color units)	
Copper	1.0 mg/L	MCL=1.3 mg/L
Corrosivity	noncorrosive	
Fluoride	2.0 mg/L	MCL=4.0 mg/L
Foaming Agents	0.5 mg/L	
Iron	0.3 mg/L	
Manganese	0.05 mg/L	
Odor	3 threshold odor number	
pH	6.5-8.5	
Silver	0.10 mg/L	
Sulfate	250 mg/L	
Total Dissolved Solids	500 mg/L	
Zinc	5 mg/L	

Total Dissolved Solids (TDS)

Water Facts: Most of the minerals found in fresh water are necessary life-sustaining nutrients and many are found in common vitamin supplements. These include calcium, magnesium, potassium, zinc, copper, iron, and selenium. Note, however, that drinking tap water may not provide the recommended levels of most of these nutrients. For example, drinking 64 ounces (~2L) of water a day, containing 50 mg/L calcium, would provide 1/10th of the adult daily requirement of calcium recommended by the National Academy of Sciences.

This measurement combines most dissolved minerals found in water sources into one value. These include sodium, potassium, calcium, magnesium, chloride, sulfate, and carbonates. According to the NSDWS, drinking water should not have more than 500 mg/L of TDS. Still, potable water that has a higher TDS is not necessarily unhealthy. However, high TDS water may cause deposits and/or staining, and may have a salty taste.

pH

This value measures the active **acidity** in water. The **pH** of water is important in controlling pipe corrosion and some taste problems. The recommended pH range is 6.5–8.5.

Taste

Note that TDS and pH values do not determine the proportions of the major minerals found in drinking water sources. However, the mineral composition of water may affect its taste. For example, water with a TDS of 500 mg/L composed of **table salt** would taste slightly salty, have a slippery feel, and be called **soft water**. Whereas, water with the same TDS value but composed of similar proportions of table salt, gypsum, and calcite would have a more acceptable (less salty) taste and feel less slippery due to its greater water hardness. Salty taste can be reduced by limiting the amounts of chloride and sulfate ions in potable water to less than 250 mg/L each.

Organic Matter

Water color, odor, and foaming are affected by the presence of natural organic matter (**NOM**) substances often found in surface water, but much less frequently in groundwater supplies. This organic matter is derived from vegetation, such as leaves, that fall into surface water. Water soluble natural organic constituents impart taste and color to the water, similar to what occurs when tea leaves are brewed in water,

Metals and Fluoride

The NSDWS also include recommended levels for aluminum, zinc, iron, manganese, copper, and fluoride (not a metal). Other metals that are considered more toxic, like lead, chromium, cadmium, and mercury, are regulated under the NPDWS. In general, these elements are found in trace quantities (less than 1 mg/L) in fresh waters. Iron, copper, and zinc, if present above NSDWS, can impart a metallic taste to water and cause staining. Note that copper and fluoride also have NPDWS regulatory levels (MCLs) that must not be exceeded in drinking water (Table1.)

Naturally Occurring Well Water Contaminants

In addition to elevated total dissolved solids, the most common constituents found in Arizona groundwater in concentrations above drinking water standards are arsenic, fluoride, gross alpha radiation, and nitrate. Nitrate contamination, although it can be natural, is usually due to either agricultural practices (excessive fertilizer use and/or poor irrigation practices), or failing septic systems that allow contaminated waters to drain into the aquifer. Ammonium and phosphorus contamination, much less common in Arizona aquifers, are also linked to septic sewage water contamination. Naturally occurring groundwater contaminants are dependent on aquifer geology, and are discussed below.

An important consideration within the Basin and Range Province is how geologic forces have influenced the quality of water held within the aquifers. The Basin and Range could resemble an egg carton filled with sand, with many isolated basins and drainage systems that could not reach the sea, generating large inland seas – such as the Great Salt Lake in Utah – that concentrated the salts leached from the soils as water evaporated. Large **evaporite** deposits of salt are common within valley aquifers within the Basin and Range province, and elevated concentrations of chemical constituents such as boron, sodium chloride (salt) and calcium sulfate (gypsum) are often found in the deeper alluvium zones of the basin these aquifers.

In the Gila River Valley, for example, deep petroleum exploration boreholes have been drilled throughout the region. Although oil was not found, salt brines are now discharging to the land surface through improperly sealed abandoned boreholes, and the local water quality has been impacted. Thick layers of salt are found deep throughout the entire valley.

Today, the Willcox Playa (near Willcox) is an example of the formation of evaporite deposits. Because the basin is not drained, salts are accumulating on the land surface. However, the geologic barrier that stops the flow out of the Willcox Basin is relatively recent in geologic time, and because of this only the shallow groundwater is salty. Water quality in the deep aquifer of the Willcox Basin is excellent.

Figure 11 shows those portions of the state where groundwater has been reported to be **saline**, either due to deep layers of salt originating from the depositional setting, **playa** formation, or in agricultural areas where evaporation of irrigation water concentrates naturally occurring salts.

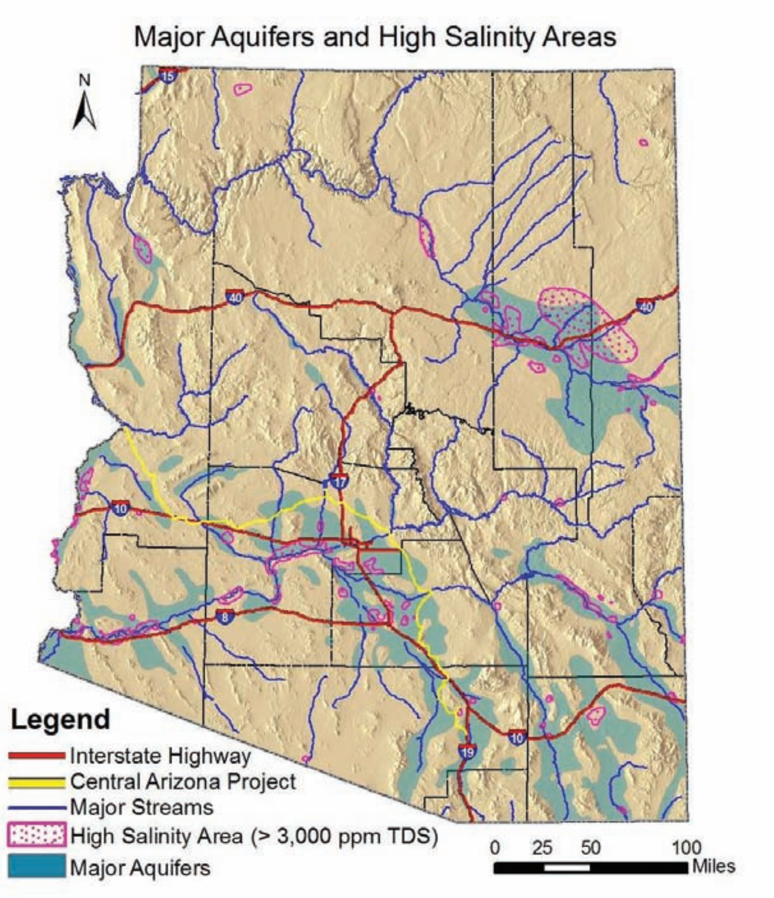


Figure 11. *Major aquifers and regions of saline groundwater (modified from WRRC, 2002).*

Arsenic

Three significant geologic sources of arsenic are found in Arizona, and elevated concentrations of arsenic are found in each of the three geologic provinces. In geologically ancient Arizona, **magma** pushed upward into the host rock and hardened into granitic **plutons** and mineralized veins of ore containing copper, silver, gold, and arsenic. In Arizona, regions of granite bedrock with valuable gold ore often contain elevated concentrations of arsenic. Gold prospectors have found new mine sites by measuring the concentration of arsenic in rivers and streams, using arsenic as a pathfinder as they move upstream following greater and greater concentrations of arsenic until the source is found – and gold is discovered. In addition, Basin and Range aquifers consisting of alluvium eroded from granite bedrock may also contain arsenic.

The geology of northern Arizona and southern Utah consists of layers of ancient sedimentary rock, including the Redwall Limestone and the sandstone formations that can be seen in the exposed cliffs of the Grand Canyon, (see Figure 5). These sedimentary rocks are found layered across the Colorado Plateau province of northeastern Arizona and many water supply wells tap these formations. An extensive cave system was formed over 325 million years ago within the Redwall Limestone, similar to the limestone caves of Kartchner Caverns near Benson. Over geologic time, the weight of overlying rock layers that had accumulated on top of the caves in the Redwall Limestone collapsed, resulting in thousands of feet of vertical collapsed chimneys or drain pipes that filled with rock rubble in the Supai Sandstone and above. These pipes acted as drains, allowing groundwater, which contained dissolved chemicals from the adjacent sedimentary rock to concentrate. Arsenic, various metals, and uranium were deposited and concentrated within these pipes, which are found throughout the Supai Sandstone formation (Kenny, 2003). Wells constructed within the Supai Sandstone in the Colorado Plateau have elevated levels of dissolved arsenic in the groundwater, as well as uranium and other radioactive elements, discussed below.

Arsenic is also found in the Central Highlands Transition Zone of Arizona (see Figure 4). Within the past 2 to 5 million years, the Verde Valley of Yavapai County was formed as earth crust shifts produced faults that separated the Colorado Plateau from the Basin and Range. The arsenic rich Supai Sandstone formation was eroded and re-deposited in the Verde Alluvium Formation, which now forms the aquifer of the Big Chino and Verde Valley. The highest concentration of arsenic in groundwater in Arizona was found near Paulden in the Verde Valley, with a concentration of 2,900 parts per billion in a private, domestic (exempt) well. The EPA drinking water MCL for arsenic is 0.010 mg/L, or 10 parts-per-billion.

Because the **solubility** of arsenic in water is a function of its mineral form, water pH, and oxygen content, any change in the chemistry of an aquifer may increase or decrease arsenic concentrations. An example is the introduction of oxygen as groundwater elevations dropped due to drought in the Verde Valley. The change in geochemistry resulted in arsenic concentrations increasing, and consequently in arsenic poisoning of livestock (Foust et al., 2003)

Radioactive Elements

Radioactivity is the release of energy from within atoms. Certain atom structures are inherently unstable and spontaneously break down (decay) to form more stable atoms. For example, the potassium-40 isotope decays very slowly (**half-life** of 1.25

billion years) but eventually becomes the element argon. Because potassium is a significant component of clay minerals, it is generally true that all clay, including clay soils, bricks and pottery made from clay soils, and living organisms (animals and plants) that contain potassium, are all slightly radioactive.

In Arizona, the most common source of radioactivity is dissolved uranium and dissolved radon gas. As mentioned previously, uranium was deposited and concentrated within collapsed breccia pipes above the Redwall Limestone formation. Uranium mines are found throughout the Supai Sandstone Formation (Kenny, 2003). The water from wells within the Supai Sandstone in the Colorado Plateau show elevated concentrations of uranium, sometimes exceeding the MCL of 0.030 mg/L or 30 parts-per-billion.

Radioactive minerals containing the elements uranium and thorium (760 million and 4.46 billion years half-life, respectively) are also found in some Arizona granites. These elements are unstable and decay, eventually becoming a new element called radium (half-life of 1,620 years), which then decays to the element radon (half-life of 3.8 days). Radon is strongly radioactive as it emits high energy alpha particles. Unfortunately, the radon element is an odorless, colorless, tasteless gas that dissolves in groundwater and may migrate upward though the soil, eventually dissipating into the atmosphere. If radon gas is trapped within a structure, such as a basement, the concentration of radon gas within the closed structure may exceed health standards. The EPA estimates that 1 in 15 U.S. homes contains a high level of the gas and is considered to be the second leading cause of lung cancer in the country (epa.gov/rado/radontest.html). The MCL for radon is 300 **pCi/L.**

'Gross alpha' is a measurement of the amount of radioactivity in water whether it is due to the decay of uranium, radium, or radon, and is a gross measurement of overall radioactivity. 'Gross alpha' is a common naturally occurring "contaminant" in Arizona bedrock aquifers (such as the Supai Sandstone or granite) or in alluvial aquifers composed of eroded granite. The MCL for 'Gross alpha' is 15 pCi/L

Fluoride

Fluoride is a common mineral that is concentrated in volcanic materials, and mineral particles that contain fluoride are common in some sedimentary rocks. In Arizona, the highest fluoride concentrations are found in Cochise County (Hem, 1985); Mohave, Graham, and Greenlee Counties (ADEQ, 2005): and along the lower Gila River in Yuma County. Most of the elevated concentrations are associated with **confined aquifers.** Groundwater from confined aquifers usually has not had the opportunity to mix with recently recharged water high in dissolved oxygen. Therefore, the low oxygen environment and long resident time in confined aquifers allows for fluoride naturally present in the aquifer geology to dissolve into the groundwater. Although fluoride at high concentrations may be harmful, it is essential for strong teeth and bones; many municipal water supply systems add fluoride to the water in a process called fluoridation. Excessive concentrations in drinking water results in tooth mottling and discoloration. The MCL for fluoride is 4.0 mg/L.

Elevated levels of other naturally occurring constituents have been found in wells across Arizona. For example, naturally occurring hexavalent chromium (CrVI), known to cause cancer, has been found in Paradise Valley north of Phoenix and in the Detrital Valley near Kingman (Robertson, 1975). Lithium is found in the brine groundwater of the Gila Valley near Safford. Selenium and boron are also found in geologic settings with evaporite deposits, and these elements have been detected in groundwaters near Kingman. Each of these constituents has known health impacts and should be avoided in high concentrations. The mineral-rich geology of our state results in elevated levels of elements such a copper, silver, zinc, manganese, and sulfate minerals, occasionally being encountered in groundwater near mining districts. Iron is found in nearly all groundwater and is responsible for iron-bacterial fouling of some wells.

Examples of Anthropogenic Contaminants

Anthropogenic contaminants are those chemicals that have been introduced to the environment by the activity of man. These contaminants include industrial chemicals inadvertently released into the environment, those derived from land use activities such as oils and grease flushed off roadways and agricultural chemicals applied to crops. In early June of 2003, the cause of the death of aquarium fish in a home in Tucson was traced to mercury in the water supply. The single source of mercury was a broken water-level indicator, a mercury switch, within one of the wells of the water provider for the neighborhood. This isolated incident points to the fact that water contaminants can be found very close to home.

A neighborhood of recently installed private domestic wells in a new subdivision in New York was tested for contaminants after concern was expressed about the proximity of a nearby landfill. All wells failed water quality testing because a dissolved industrial solvent was found. Since the solvent is also a common contaminant associated with landfills, an extensive investigation was conducted to tie the pollution to the landfill, but no link could be found. The source of water contamination was discovered to be the solvent used to glue the plastic polyvinyl chloride (PVC) pipe used to construct the wells and plumbing.

Chemical plants, manufacturing facilities, gas stations, repair shops, landfills, and mining activities all have the potential to release contaminants into the environment. Many **Superfund** Sites (EPA mandated environmental clean-up sites) were first discovered because domestic well owners noticed an unusual odor as they showered or an odd taste to their well water. In some cases, **plumes** of groundwater contamination have extended miles beyond their original source. The contaminant concentration decreases with distance as the contaminant plume dissipates and mixes with uncontaminated water, and as it moves **down gradient**. Superfund Sites can be found at http://www.epa.gov/superfund/sites/index.htm. If there a site in your neighborhood, you may want to follow up with the Arizona Department of Environmental Quality (**ADEQ**) to obtain information to determine if your water supply is at risk of contamination.

The gasoline additive MTBE (Methyl tertiary-butyl ether) was added to gasoline in the late 1970's to boost octane, to replace the toxic metal lead, and to reduce air pollution. Unfortunately, the fate of this chemical in the water environment was not fully tested before it was approved as a gasoline additive, and has since been tied to respiratory problems. Since then, this chemical has been found to be very soluble and stable (degrades slowly) and has resulted in the contamination of numerous groundwater supplies from leaky underground gasoline tanks. Today, the fate of MTBE is the subject of numerous research studies. It is now banned in California, and EPA is taking actions to reduce and eventually eliminate MTBE use (http://www.epa.gov/mtbe/faq.htm#actions).

Often, the most likely source of groundwater pollution in a domestic well is found near the well-head (Figure 12). Stored pesticides, lawn amendments, oil and grease, and failing septic systems are the most likely sources of domestic water supply pollution. Septic tank de-greasers are banned in many states because the chemicals, industrial solvents, rapidly percolate through the soils and contaminate the aquifer

It is worthwhile to note that the odor threshold (the concentration at which the human nose can detect an odor) of some natural and industrial chemicals is lower than the detection capacity of a testing laboratory. What this means is that sometimes we can be alerted to the presence of contaminants in water by their smell. However, one should not rely on the sense of smell only to determine the possible presence of contaminants in well water. See the following section for more details on well water testing.

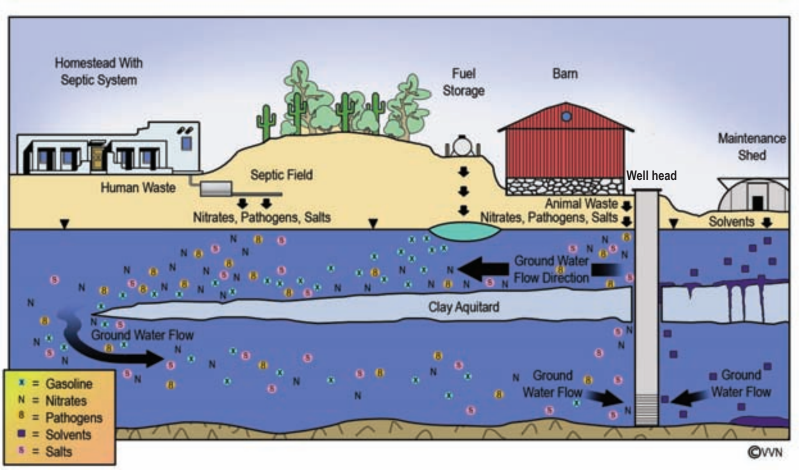


Figure 11. *Major aquifers and regions of saline groundwater (modified from Ontario 2003).*

Pathogens

Drinking water supplies that depend on groundwater are subject to contamination by **enteric** waterborne pathogens. The detection of these pathogens (and other indicator organisms) may indicate fecal contamination of the groundwater. These pathogens can originate from leaking sewer lines, septic systems, or improperly protected well heads that allow contaminated surface water to drain into the aquifer along the outer well casing. Contaminated groundwater represents approximately half of the waterborne disease outbreaks documented in the United States every year.

Organisms of particular concern with respect to groundwater contamination include waterborne pathogenic human enteric viruses such as Adenovirus, Rotavirus, Hepatitis A, and Norovirus; enteric bacteria such as the pathogenic strain of Escherichia coli 0157:H7, *Salmonella, Campylobacter, Pseudomonas, Helicobacter, Aeromonas, Vibrio cholerae*, and *Shigella* spp.; protozoan pathogens such as *Cryptosporidium* and *Giardia*; and, the recently reported amoeba *Naegleria fowleri*. These organisms present a human health risk to those who ingest the water. Typical symptoms associated with an infection include acute gastroenteritis, severe cramping, abdominal pain, dehydration, and diarrhea.

In a recent study in Arizona of 188 drinking water systems and individual household wells, the waterborne amoeba *Naegleria fowleri* was reported in 29 cases (Payal, 2008). According to the Centers for Disease Control (CDC), *Naegleria* infects people by entering the body through the nose. This can occur when people use warm freshwater or untreated groundwater for activities like swimming or diving. The amoeba travels up the nose to the brain and spinal cord where it destroys the brain tissue. Because *Naegleria* is commonly found in warmer temperatures, states within the southwest are particularly prone to its presence. Although it is alarming that this waterborne pathogen is currently being found in wells across Arizona, infections occur only by immersion in the water and do not occur as a result of drinking contaminated water.

Certain bacteria are liable to form **biofilms** within wells if enough nutrients are available for their survival. Occurrence could be due to the use of biodegradable oils used to lubricate pumps in addition to the high temperatures of groundwater in Arizona. The oils may act as a food source for bacteria, and other organisms, such as the amoeba *N. fowleri*, may feed upon bacteria growing on the oils within these wells.

Iron bacteria thrive in groundwater with high concentrations of naturally occurring dissolved iron and are non-injurious to health. Iron bacteria are nuisance organisms that cause plugging of the pores in the aquifer and the openings of the well screen. The bacteria produce accumulations of slime within the well, and precipitate iron and manganese. The combined effect of the growth of the organisms and precipitated mineral has been reported to reduce **well yield** by 75% within a year in some locations (Johnson Division, 1972).

Although all of the above mentioned organisms pose a risk to human health, viral contaminants are typically considered more of a threat to groundwater than bacterial or protozoan contaminants for two reasons. First, because of the small size of viruses, they typically can be transported further into the aquifer than bacteria and can eventually reach the groundwater. Second, viruses are thought to be more persistent in the environment than their bacterial counterparts and require greater disinfection procedures to render them inactive.

Approximately one-third of the groundwater drinking wells used by utilities across the United States contained human pathogenic enteric viruses (Abbaszadegan et al., 2003). However, in another study focused specifically on groundwater supplies in Arizona, none of the 49 groundwater samples tested in seven counties across Arizona reported detection of human pathogenic enteric viruses (Karpisack et al., 2006). Although viruses were not detected, 74% of the Arizona samples exceeded at least one of the NPDWS, 80% exceeded at least one NSDWS, and 95% exceeded one parameter of either of the two standards (Marrero-Ortiz, 2007).

New Contaminants

The EPA is always evaluating so-called “emerging” contaminants that may need to be regulated in our community water systems. **Emerging contaminants** include those chemical constituents, for which new analytical methods allow us to measure very small concentrations, revealing the presence of common household chemicals that were not expected to end up in our water supply. Very small concentrations of chemical fire retardants, antibiotics used in household soaps, and chemicals originating in well-known products such as Teflon®, Scotchgard™, and Gore-Tex® are being found. Of increasing concern are pharmaceuticals and personal care products (PPCPs), and many may affect the endocrine system of living organisms (also called **endocrine disruptors**). Pharmaceuticals in general may be flushed through our bodies and end up in the sewer systems. A recent national survey showed that several of these chemicals are not completely removed during the treatment of wastewaters. Thus, reclaimed waters, when discharged into the environment, may affect the quality of water sources. According to EPA, PPCPs include: therapeutic and veterinary drugs, fragrances, cosmetics, sun-screens, diagnostic agents, and vitamins. See: www.epa.gov/ppcp/basic2.html

In addition, the EPA is evaluating other environmental contaminants for potential regulation. These include the **perchlorate** ion, found in rocket fuel and explosives but also naturally occurring, which has been detected in both the groundwater and surface water of several states (including Colorado River water). Although the EPA has not yet set or passed any national standards on these newly recognized contaminants, individual states may choose to have additional or stricter drinking water quality guidelines.

4. Well Water Quality

To determine the water quality of your well, first obtain all available water quality information from the previous owner, neighbors, and local water utilities, and then consider further testing. Several agencies collect well water information in Arizona, including the ADWR, USGS, ADEQ, and the EPA (see websites of Interest section). In addition, a user-friendly website is now available in Arizona that combines several databases on well water information. The ARIZONAWELLS web tool, created by the Sustainability of Semi-arid Hydrology and Riparian Areas (SAHRA) of the University of Arizona provides this well water information search tool free to the public (www.wellownerhelp.org). The website provides information on well locations and in some instances the depth to water. Although water quality information is not included, neighboring wells can be located and this may be of assistance in the search for local information. Water quality information for domestic wells is not recorded or made available through any public agency.

If your water source is cloudy, smelly, or has an unacceptable taste, it likely does not conform to NSDWS. Consider testing for all NSDW parameters and review Water Problems: Symptoms, Tests, and Possible Sources (Appendix B) to determine water problems and possible sources of contamination. Finally, contact the ADEQ for information on possible or known sources of groundwater contamination in your area.

Testing Schedule

When a well produces water of poor quality, it is important to determine the possible causes or sources of the contamination. Table 2 provides a list of recommended tests and frequency of testing. Initial tests should be conducted with the installation of a new well, as well as prior to your taking ownership (and responsibility) for the well.

More frequent testing is suggested if visual changes in the water quality are noticed, if you smell an unusual odor from the water, if there has been recent maintenance of your well or pump, if you observe spotting on laundry, or if unexplained health changes occur. Unusual smells or tastes, not readily identified by the tests suggested in Table 2, may require testing for **volatile** organics (including solvents and gasoline products.) These tests are also recommended for wells located in or near industrial sites and/or agricultural areas with shallow (less than 100 feet below land surface) groundwater sources.

Water quality tests should be done at the well head (if possible), after water passes through a water softener unit, and/or at the tap. Note that some water softeners change the composition and concentration of salts and may also reduce the levels of arsenic and other trace inorganic chemicals.

Homeowners should not attempt to treat or use any water sources contaminated with industrial chemicals such as solvents, pesticides, and gasoline products at concentrations above National Primary Drinking Water Standards.

Table 2. *Suggested Water Testing* Schedule.*

- **Initial Tests****
  Hardness, sodium, chloride, fluoride, nitrate, sulfate, radionuclides, iron, manganese, arsenic, mercury, and lead. In some locations in Arizona, test for selenium (near both the San Simon and Colorado River, as well as the Gila River in Yuma County) and hexavalent chromium (near Kingman), plus all tests listed below.
- **Annual Tests (at a minimum):**
  Total **coliform bacteria**, TDS, pH, nitrate.
- **Monthly Visual Inspection:**
  Look for and note changes in:
    Turbidity (cloudiness, particulates)
    Color, taste, and odor***
    Health changes (reoccurring gastrointestinal problems in children and/or guests) ****

**See Appendix B for a comprehensive list of poor water quality symptoms, tests, and possible causes.*
***Annual testing may not be needed, as these chemicals usually are naturally occurring and their concentrations do not change over time.*
****Consider one or more of the initial tests listed above.*
*****Tests should be performed right away.*

Well Water Sampling

A good water testing laboratory should provide clean containers and clear instructions on how to collect your water sample. Some laboratories will package and ship the sample collection bottles. After sample collection, return the samples in the same shipping container. In order to prevent biased test results, it is essential that you follow the water sample collection, preservation, and shipment instructions provided by the laboratory carefully. The sample should be taken at the tap, if there is a water softener or pressure tank, a more representative sample should be collected before your well water enters the storage tank.

To locate an Arizona state certified laboratory, contact the Arizona Department of Health Services (ADHS) Bureau of State Laboratory Services for a list of certified water testing laboratories in Arizona (602-364-0720). See also the Cooperative Extension publication AZ1111 (Schalau, 2004). Water testing laboratories must comply with state and federal guidelines by using EPA approved methods of analysis. Guidelines for water testing are regularly published and updated by the EPA and are listed in the Code of Federal Regulations, Title 40. Part 136 (see, http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&tpl=%2Findex.tpl)

Water Testing Costs

Be aware that water testing is not an easy or inexpensive task. Laboratory fees for water quality analysis vary greatly from one parameter to another. For example, testing for hardness, TDS, and pH may cost about $50. Testing for lead or nitrate may cost about $30. Testing for all possible individual pollutants can cost more than $2,500 per sample.

Laboratory Test Results

After you receive the analytical results the laboratory will likely respond to your telephoned questions. Most laboratories include an explanation of their acronyms included with the final report, for example, 'BDL' means that if a constituent was present in your sample, it was below the laboratory analytical detection limit. Most reports list the analytical detection limit, the MCL, and the result of your water analysis. Results should always be lower than the drinking water standards (primary or secondary MCLs). If your results are not at or below the MCL, your water quality may not be suitable to drink. For example, if secondary MCLs are exceeded (example: sulfate above 250 mg/L), one may experience some diarrhea. However, if primary MCLs are exceeded (example: arsenic above 10 ug/L), the water may be a health hazard.

You may wish to contact a water quality expert and/or water treatment vender to assess which water quality parameters can be addressed with treatment options.

Doing Your Own Testing: Water Testing kits

There are numerous types of disposable water testing kits that can be readily purchased from companies that market on the internet. Most of these kits rely on color changes in either paper strips or liquid solutions to determine an approximate range of concentrations in the water sample. These test-strip methods rely on a characteristic color change when a water contaminant is exposed to a specific chemical reagent. Most testing kits provide a color scale, which is used to estimate the level of a contaminant based on the color intensity. These kits provide complete instructions and easy to follow steps. Deviating from them usually results in erroneous data. Other kits may only provide a “negative“ or “positive result” which is of limited use since you still won’t know if the concentration is above the MCL. Testing kits have several limitations when compared to many US-EPA approved methods used in certified laboratories, these include:

- High contaminant detection limits (may only detect contaminants that exceed drinking water standards).
- Limited or narrow contaminant detection range.
- Testing method and/or shortcuts used may not be US-EPA approved.
- Poor or insufficient precision and accuracy.
- Results may be influenced by the presence of other water constituents, such as dissolved iron.

On the other hand, these kits can serve the consumer well when:

- Only kits from reputable companies that offer a certification or approval for use from the US-EPA are used.
- Used for routine verification of water quality in conjunction with less frequent tests done by a certified laboratory to verify these “home” tests.
- Needed to save money and time and provide peace of mind, but only when used properly and when regularly verified by certified laboratories.
- Used as a means by which to routinely monitor your well and to notify you when more accurate testing may be required.

The price of home testing water analysis kits ranges from a few dollars to thousands of dollars, depending on the degree of precision and accuracy, numbers of tests, and automation that the consumer wants. Since most tests are based on color, results may be read directly using color strips, or sophisticated portable **colorimeters** that can cost over a thousand dollars. This costly investment may be worthwhile, depending on the number or samples, types of tests and data quality desired by the consumer.

The informed consumer should use kits that are EPA certified for water testing with a level of complexity that they are comfortable operating. Examples of independent companies that sell water testing kits include Hach®, Lamotte®, EM Quant®, WaterWorks®, and resellers like Benmeadows® (no endorsements implied).

Water Treatment Alternatives

Today, well owners have access to several water treatment systems to help control minerals and contaminants and to disinfect their well water. However, choosing a water treatment system is no easy task. Depending of the volume of water and degree of contamination, the well owner should consider professional assistance in selecting and installing well water treatment systems.   The process of selection is often confounded by incomplete or misleading information about water quality, treatment options, and costs. The following paragraphs outline the major well water treatment options. Further details on types, uses (point of use) and costs of these home water treatment systems are provided in the *Arizona Know Your Water* companion booklet, published by the University of Arizona, College of Agriculture and Life Sciences (CALS).

Each of the following water treatment options should be carefully evaluated when considering water treatment alternatives to reduce the levels of mineral (inorganic) and carbon-based (organic) contaminants, and disinfect water. These methods are well proven and widely accepted by experts and regulatory agencies as being efficient for the reduction of contaminants in water. Use the Filter Application Guide (Figure 13) to help determine which system is right.

Particle and Microfiltration

Particle filtration is a process that removes small amounts of suspended particles, ranging in size from sand to clay, from water. It can be used alone or prior to other water treatment devices installed in homes. Home filters are not intended to filter large amounts of particles. However, larger filtration systems (usually located near the well head or at the home point of entry) are available to remove well sediments and particulates, depending on the well water quality. Microfiltration may also be used to remove some bacteria and large pathogens, like cysts (Giardia and Cryptosporidium). Note that microfiltration should not be relied on to disinfect water with high concentrations of bacteria and viruses, instead chemical disinfection should be used. Other forms of filtration include ultrafiltration and reverse osmosis. See Figure 13.

Activated Carbon Filter

Activated carbon filtration, a form of ultrafiltration, often used as a point of use treatment, may be selected to reduce unwanted taste, odor, and low concentrations of organic chemicals (such as pesticides and solvents) from drinking water. Activated carbon will also reduce radon gas and residual chlorine. Larger filters are

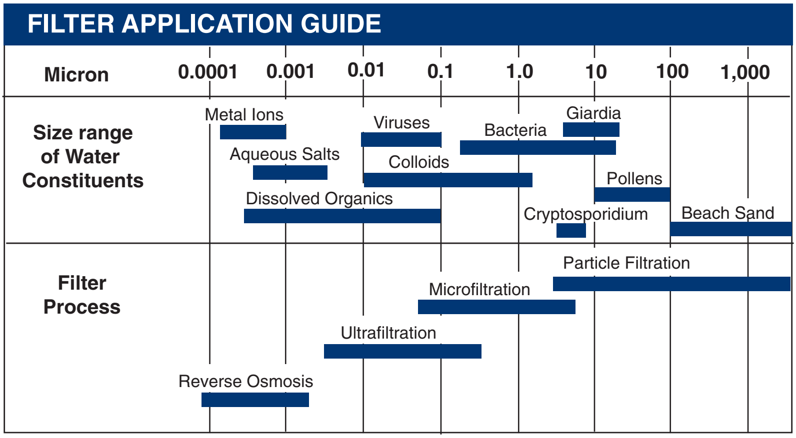


Figure 13. *Filtration Guide (modified from Filtration Application Guide, Water Quality Improvement Center).*

Figure 14. *Point of Use carbon filter. Insert shows carbon filter material.*

available to treat high volumes of water but these usually require professional installation and maintenance. Carbon filters will not remove or reduce major inorganic ions (e.g., sodium, calcium, chloride, nitrate, and fluoride or metals). However, some carbon filters can reduce lead, copper, and mercury. Activated carbon filters will not soften the water or disinfect it. If the source water is cloudy, a particle filter should be used before the activated carbon filter in order to remove particles that may plug or reduce its efficiency.

Reverse Osmosis

Reverse osmosis (RO) is becoming a common home treatment method to reduce total dissolved solids (TDS) in drinking water. RO, probably best known for its use in water desalinization projects, can also reduce chemicals associated with unwanted color and taste. It also may reduce pollutants like arsenic, lead, and many types of organic chemicals.

RO treatment is not effective for the removal of dissolved gases such as radon, or for some pesticides and volatile organic chemicals such as solvents. Consumers should check with the manufacturer to determine which contaminants are targeted and what percent of the contaminant is removed.

RO is not recommended for sediment (particle) and pathogens. Pretreatments such as particle filtration (to remove sediments), carbon filtration (to remove volatile organic chemicals), chlorination (to disinfect and prevent microbial growth), pH adjustment or even water softening (to prevent excessive fouling produced by water with excessive hardness) may be necessary for optimum RO functioning.

Distillation

Distillation effectively removes inorganic contaminants (suspended matter including minerals and metals) from water. Since distilled water has no minerals, some people claim distilled water tastes flat or slightly sweet. Distillation kills or removes microorganisms, including most pathogens. Distillation can also remove organic contaminants, but its efficacy depends on the chemical characteristics of the contaminant. Volatile organic chemicals (**VOCs**) like **benzene** and TCE vaporize along with the water and re-contaminate the distilled water if not removed prior to distillation. Some distillation units may initially purge some steam and volatile chemicals. These units should be properly vented to prevent indoor air contamination. Some home distillation units have activated carbon filters to remove VOCs during distillation.

Ion Exchange - Water Softening

Ion exchange units that replace calcium and magnesium ions from water are known as water softeners. They may also remove varying amounts of other inorganic pollutants such as metals, but they will not remove organic chemicals, pathogens, particles, or radon gas. Water softener units work most efficiently with particulate-free water. Note that soft water, in particular with elevated sodium levels, should not be used to water houseplants, garden vegetables or yard plants with low salinity tolerance. Soft water may not be suitable for drinking due to its salty taste and elevated levels of sodium or potassium.

Pathogens-Disinfection

Waterborne contaminants must be either filtered out of the water or killed (inactivated) to make the water safe to drink. The methods discussed above are not suitable (except for distillation) for this purpose. As a rule, water must be disinfected using chemicals (oxidizing agents such sodium or calcium hypochlorite, chloramines, chlorine and ozone) or UV radiation. Water disinfection will not remove inorganic contaminants from water but it may change the chemical species of some of them and is likely to form disinfection byproducts that may be of concern (see note of caution below). Chlorination guidelines for domestic wells are also discussed below. See also the *Arizona Know your Water* booklet for a more detailed discussion on water chemical and UV-radiation disinfection methods and guidelines.

Equipment for Continuous Chlorination of Domestic Wells

Continuous chlorination of a domestic water supply can be done by various methods: chlorine pump, suction device, aspirator, solid feed unit, and batch disinfection. The injection device should operate only when water is being pumped, and the water pump should shut off if the chlorinator fails or if the chlorine supply is depleted. Consult with a professional for equipment selection and tank requirements. For example, in a domestic well system, the minimum-size holding tank is determined by multiplying the capacity of the pump by a factor of 10. Thus, a 5 gallon-per-minute (gpm) pump requires a 50 gallon holding tank. Other methods to control **contact time** include the use of pressure tanks and coils.

Note of caution: Chlorinated well water may contain disinfection by-products at levels above the NPDWS that are considered unsafe to drink. Well owners that chlorinate the well water should test for the presence of excessive levels of these chemicals in their treated water.

Boiling

Two minutes of vigorous boiling ensures biological safety. Boiling kills all organisms in water (whereas chlorination reduces them to safe levels). But boiling is costly and practical only as an emergency measure. Remember that once boiled, cooled water must be protected from re-contamination.

Emergency Disinfection

The use of household chemicals (such as bleach or iodine) to disinfect water without the appropriate equipment or technical supervision should only be considered under emergency situations. For a list of these chemicals and their safe use, see the EPA website: www.epa.gov/OGWDW/faq/emerg.html

5. Domestic Private Wells—Well Operation and Maintenance

Arizona has stringent permit requirements for the installation of new wells, and the construction diagram and geologic log of all modern wells in the state are recorded with the Arizona Department of Water Resources (ADWR). The ADWR website—www.azwater.gov/dwr/—provides a wealth of information for the private domestic well owner. Domestic well owners must also repair and maintain their own wells to assure a reliable water supply of consistent quality.

Well Construction

For the proper maintenance of domestic wells, it is important to have a basic understanding about the different materials that comprise a home water supply system based on a domestic well. The following sections present some information about well casings, well caps, well screens, and pitless adapters; basic materials that combine with a pump to provide water for a household. Please refer to Figure 15 for the location of these well components.

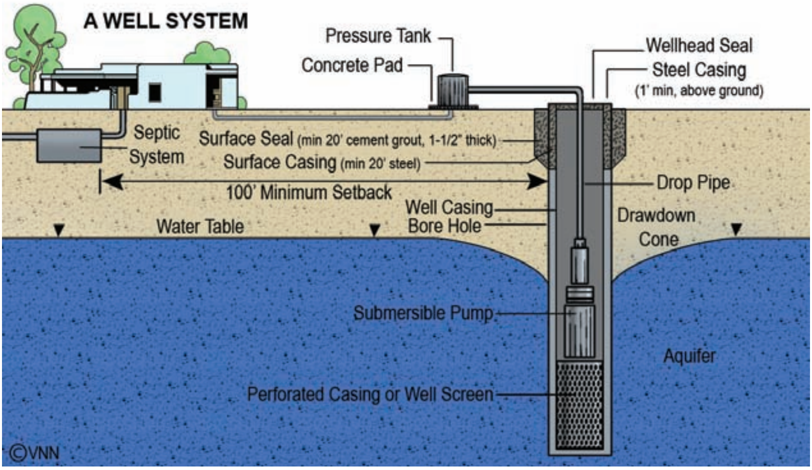


Figure 15. Domestic Well Diagram (adapted from ADWR Well Owners Guide 2007).

Well Casing

A modern domestic well has two well casings – the outer casing is a tubular structure or large diameter steel pipe that encircles the actual well casing, and is used as a surface seal. The length of this surface seal well casing is specified by Arizona Statutes and Rules, as regulated by the Arizona Department of Water Resources (http://www.azwater.gov/dwr/). The surface seal casing must be a minimum of 20 feet, one foot of which must extend above land surface. The final length of the surface seal casing is dependent on the local geology and may extend to a greater depth to seal the well from contact with a shallow aquifer. The intent of the surface seal casing is to prevent surface contaminants from entering the well.

An example of a well head surface seal is a concrete apron, sloped away from the well casing pipe, to reduce the potential for standing water to pool at the well head. At a minimum, the land surface or soils near the well head should slope away from the surface seal casing if a concrete apron is not present.

The well casing is placed in a drilled borehole to maintain the well opening and contain the drop pipe and electrical wiring to the pump. Along with cement grout that seals the upper portion of the well to the surface casing, the well casing prevents mixing of multiple aquifer zones and may extend to the full depth of the well. In rock aquifers, the well casing may only extend a hundred feet or more through broken rock, leaving an open rock borehole as the well.

The most common materials for well casings are carbon steel, plastic (PVC is commonly used), and stainless steel. PVC is lightweight, resistant to **corrosion**, and relatively easy for contractors to install. (Note: To minimize exposure to residual solvents, PVC casing sections should be joined without glues that contain solvents.) Although more expensive, when possible, mechanical couplings or threaded pipe fittings are recommended. Steel, although stronger, is susceptible to corrosion, can develop scale in hard waters, and is more costly. Some well casings may also be constructed of concrete, fiberglass, and asbestos cement. Older wells may be hand-dug and cased with hand-placed bricks or stone.

Caps

On the top of the surface seal casing, and sometimes on the well casing itself, should be a wellhead seal or cap. Well caps are usually aluminum or a **thermoplastic**, and include a vented screen so that the pressure difference between the inside of the well and the outside atmospheric pressure may equalize when water is pumped from the well. The cap should fit snugly so debris, insects, or small animals cannot find their way into the well system.

Well Screens and Gravel Packs

Well screens are filtering devices used to prevent excess sediment from entering the well. Attached to the bottom of the well casing, the screens allow water to move though the well while keeping out most sand and gravel. The most common screens are slotted or perforated pipe.

Perforated pipe is a length of casing with holes or slots drilled into the pipe. It is not efficient for aquifers that contain fine-grained materials because it has wide openings that allow sand to fall into the well. A continuous slot screen is made of wire or plastic wrapped around a series of vertical rods, whereas slotted pipe features machine-cut slots into steel or plastic at set distances.

Well screens are manufactured with specified openings and hole diameters to match their screen filtering capabilities to the geologic conditions. Well screens are designed to be placed only within the saturated portion of the aquifer. If the groundwater elevation drops and air is allowed to enter the well screen, the well may be damaged.

During well design and installation, a gravel pack is typically placed in the **annular space** outside the screen casing yet within the drilled borehole. The gravel pack consists of sand or gravel that has been designed with a grain size finer than the adjacent soils or unconsolidated aquifer material, yet larger than the screen slot size. The gravel pack acts as a filter to prevent sediment from entering the well, and also to manage the velocity of the water passing through the aquifer and into the well. High-speed water velocity, due to excessive pumping or improperly sized gravel pack, results in erosion of the aquifer as sediment is pulled into the well. Above the gravel pack and the well screen, the annular space between the well casing and borehole wall is backfilled with grout and/or concrete to prevent surface water from draining into the aquifer.

It is common for wells constructed in hard, stable bedrock to remain as an open borehole. In these cases, a screen or gravel pack is not necessary. Since groundwater entering an open borehole in a bedrock well typically travels through narrow cracks and fissures, no sand pack to filter sediments may be necessary.

Pitless Adapters

In higher elevations where frost may penetrate the ground, pitless adapters provide wells with a sanitary – and frost proof – seal between the well casing and the water line running to the well system owner's house.

After a frost depth is determined for the area where the well is being installed, the adapter is connected to the well casing below the frost line. Water from the well is then diverted horizontally at the adapter to prevent it from freezing, and the plumbing continues beneath land surface to the well system owner's house.

Storage Tank

Most home-owner water well systems include a pressurized storage tank to store water for use during periods of heavy usage. The pressure tank is designed to have extra water on reserve so that small demands do not require the pump to switch on. However, a tank cannot compensate for demand greater than your pump or well capacity.

Well Log / Report

Every modern well in Arizona is required to be registered with the Arizona Department of Water Resources (ADWR) and a well log must be submitted by the well driller. This log is available to the well owner through the ADWR. The well log identifies the type of geology of the aquifer, the construction materials used to construct the well, the well depth, casing length, screen length, the presence (or absence) of a gravel pack, depth to groundwater at the time of installation, and the capacity of the well at the time of well installation. Every well owner should have a copy of his or her well log.

At the time of construction and pump installation, the licensed well driller pumps the well to test the capacity of the well to yield water and to remove any fluids (such as chemical drilling muds to facilitate drilling) from the aquifer. This pumping also develops the gravel pack around the well, flushing out fine-grain silts and sands from the pack to allow water to flow freely into the well. For an exempt domestic well, well pump capacity is restricted to 35 gallons per minute (gpm), but some aquifers are not able to yield water at that rate. It is not uncommon for wells constructed in consolidated bedrock or finer-grained alluvium to yield 3 to 5 gpm.

How a Well Affects an Aquifer: Cone of Depression

As the well pumps, the groundwater elevation around the well drops, typically in the shape of an inverted cone. This **drawdown** cone is also referred to as the cone of depression and it is the area where the groundwater elevation or water table is depressed due to pumping, see Figure 15. In an unconsolidated, porous aquifer setting, the cone of depression forms around the well head in an ever expanding circle as more water is pumped from the aquifer. In a consolidated aquifer setting, the cone of depression will follow the subterranean fracture systems and may take an unpredictable shape as the cone expands outwards to pull more water into the well. In an **artesian** system, the cone may extend for hundreds of feet.

Any water and contaminants (if present) within the cone of depression around the well are eventually captured and drawn into the well and the water supply system. If the cone extends out and beneath a river or stream, the well will begin pumping river water that has been pulled through the riverbed, through the aquifer, and into the well. If the cone extends out and beneath a contaminant source, such as a leaky gas station storage tank or a land fill, the well will begin to draw the contaminants into the well. If the cone intercepts a neighboring cone of depression from a nearby well, the rate at which the groundwater elevation drops may rapidly increase, and both wells may run dry faster.

The rate at which the groundwater elevation rebounds to its original or near original level after the pumping stops is important to the overall operation of the well. If water level recovery is slow, excessive use over a weekend, for example – may temporarily cause the well to go dry. Pumping from the well should be managed to reduce this type of cyclic dewatering, which can cause pump overheating and permanent damage.

Water Supply Well System Failure

All well systems are vulnerable to mechanical failure, and that failure may contribute to water supply contamination. Broken surface seals, corroded pipe, and standing water that is allowed to seep and drain back into the aquifer along the outside of the well casing can introduce contaminants into the system.

Pump or plumbing failure should always be addressed by a licensed well professional.

The most common water supply well system failure in Arizona is due to dropping groundwater elevations. If the water table drops below the well casing, flow of water becomes turbulent as the water mixes with air. In an uncased, bedrock well, as the water table drops and air is introduced into formerly saturated cracks and fractures, turbulent flow begins to erode the aquifer. The first sign of system failure (and dropping groundwater elevations) is the build-up of sediment in tanks, pipes, and plumbing fixtures. If the well continues to pump gritty sands, the pump itself will grind to a stop and will need to be replaced.

Maintenance Guidelines

Always use an Arizona licensed well driller and pump installer when a well is constructed, a pump is installed, or the system is serviced. A properly constructed water supply system should require little routine maintenance, and these simple steps will help protect your system and water quality:

- Be aware of the geology of your aquifer. Know that a well installed in consolidated (fractured) rock is more vulnerable to contaminant transport, whereas an unconsolidated aquifer retains more water filtering capacity. In other words, if a known contaminant release occurs in your neighborhood, the geology of your aquifer may protect your water supply, or may make your supply more vulnerable to contamination.
- Keep hazardous chemicals, such as paint, degreasers, fertilizer, pesticides, kerosene, and motor oil away from your well head. Do not spill or discard any liquids in your yard. Instead, reuse them or take them to a recycling center.
- Periodically check the well cover or well cap to ensure it is in good repair. Do not allow surface water to puddle near your well; if necessary construct berms around the well to divert surface runoff away from the well head.
- Always maintain separation between your well and buildings, septic systems, chemical storage facilities, garages, or car maintenance areas. Your professional contractor will know the rules on appropriate distances for new construction.
- Do not dispose of chemicals in your septic system, and read the label of any cleaners or additives advertised for septic systems. De-greasers contain industrial solvents that persist in the environment and may seep into the aquifer.
- Do not allow water to siphon back into your well. Install a back-flow preventer on outdoor hoses. When mixing pesticides, fertilizers, or other chemicals do not put the hose inside the tank or container. The best way to prevent backflow is to leave an air space between the hose and the contents of the container.
- When landscaping, keep the top of the well at least one foot above the ground. Slope the ground away from your well for proper drainage.
- Be careful when working or mowing around your well. A damaged casing could jeopardize the sanitary protection of your well. Do not pile landscaping or construction materials near your well.

- Be aware of changes in your well, the area around your well, or the smell, taste, or color of your water.
- Monitor the sediment accumulation in your toilet tank. If the sediment is soft and does not feel gritty if rubbed between your fingers, this is not of concern unless you notice a significant increase in volume. If the sediment is gritty, or if you notice sand in the tank, contact a licensed well pump installer.
- If the flow rate slows and you have not observed any sediment, **scale** build-up may be sealing the well screen or blocking the sand pack. A common iron bacteria or slime may also be growing on your well screen, causing a biofilm to build up (biofouling) that clogs the screen. A licensed well driller will be able to inspect your well with a down-hole video camera to diagnose the problem and rehabilitate your well. Typical methods to rehabilitate a well include using chemicals to dissolve incrusting materials, cleaning the well with a brush attached to a drilling rig, high pressure jetting and surging to dislodge fine materials and open the gravel pack. In a bedrock aquifer exhibiting reduced flow, the contractor may inject water at extreme pressures to induce more fracturing of the rock.
- An annual well maintenance check, including water quality testing, is recommended. The water quality should be checked any time there is a change in taste, odor, or appearance, or anytime a water supply system (such as pump replacement) is serviced.
- Keep your well records in a safe place: These records include the construction report (well log), as well as any water well system maintenance and water testing results.

When your well has come to the end of its serviceable life (usually 20 to 30 years), have a licensed water well contractor assess your system. You may need to have your well properly decommissioned and a new well installed. If your well is to be abandoned your licensed water well contractor will be required to follow specific well abandonment procedures and report the change of well status to the ADWR. If groundwater elevations have dropped and air is entering your system, you may need to have your pump lowered, or the existing well deepened.

Shock Chlorination: Proceed with Caution

Shock chlorination is used to disinfect wells during, or right after construction and thereafter as needed to remove microbial contaminants from the well casing, holding tanks, and even delivery pipes. It is recommended that this procedure be done by qualified personnel since strong bleaching chemicals must be handled during the process. For guidelines on how to proceed, see the Arizona Cooperative Extension Water Facts Number 5 by Hassinger et al., (1994) “Shock Chlorination of Domestic Wells,“ available online at http://ag.arizona.edu/publications. See also a more detailed guide on shock chlorination background and principles (Fact Sheet—06-68).

Note of Caution: Recent preliminary research done outside Arizona suggests that in some instances shock chlorination may result in the release of arsenic from aquifer minerals near the well screen. Arsenic trapped in pipe scale deposits may also re-dissolve when exposed to strong chlorine solutions. As previously mentioned, changes in the water chemistry (for example, raising or lowering the water pH) may result in the release of arsenic in the water. The effect has been observed in some aquifers with minerals high in arsenic and has prompted the Wisconsin Department of Natural Resources to publish a bulletin titled “Well Chlorination in Arsenic Sensitive Areas” which cautions about using chlorine solutions (WDNR, 2008).

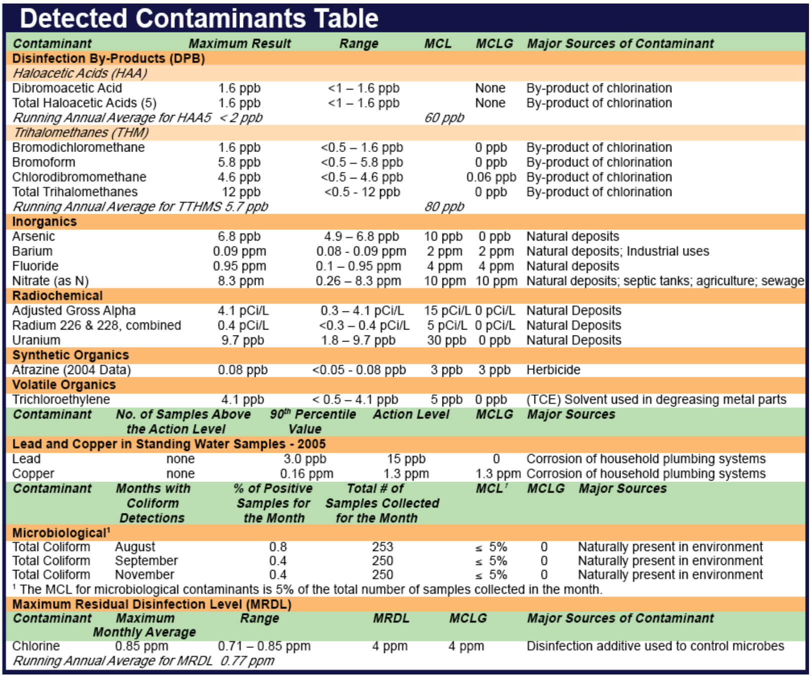
Well owners that shock chlorinate their wells in regions of Arizona known to have arsenic, should follow shock chlorination steps carefully. Avoid the use of either acid or alkaline bleach solutions (pH 6-7 is best), and do not leave chlorine solutions inside well casings for longer times than those prescribed. Well casings, tanks, and pipes should be flushed thoroughly until no residual levels of chorine are found. Well water used for drinking should also be tested for arsenic after shock chlorination.

Alternate Sources of Potable Water

Water Providers

Well owners or potential well owners that can opt to connect to a water utility should do so. Water utilities are highly regulated providers of water and must meet National Drinking Water Standards. For this reason they routinely monitor water quality, must provide annual water quality reports, and report any water quality problems to their customers, as shown on Figure 16 of the City of Tucson’s 2006 Annual Water Quality Report.

Community water utilities charge a monthly water delivery fee, which primarily covers the costs of pumping, treatment, and delivery – with additional fees charged for CAP water in certain parts of Arizona. Presently, water is being delivered at bargain prices by many water utilities in Arizona. In Tucson, for example, 8,000 gallons of water cost about $30 (including sewage treatment costs) or about 0.4 cents/gallon. However, connection fees for water and sewage are significant. For example, in Pima County, new home owners must pay water equity fees and sewage connection fees around $7,000 per hook-up.



Detected Contaminants Table

Contaminant	Maximum Result	Range	MCL	MCLG	Major Sources of Contaminant
Disinfection By-Products (DPB)					
Haloacetic Acids (HAA)					
Dibromoacetic Acid	1.6 ppb	<1 – 1.6 ppb		None	By-product of chlorination
Total Haloacetic Acids (5)	1.6 ppb	<1 – 1.6 ppb		None	By-product of chlorination
Running Annual Average for HAA5	*< 2 ppb*		*60 ppb*		
Trihalomethanes (THM)					
Bromodichloromethane	1.6 ppb	<0.5 – 1.6 ppb		0 ppb	By-product of chlorination
Bromoform	5.8 ppb	<0.5 – 5.8 ppb		0 ppb	By-product of chlorination
Chlorodibromomethane	4.6 ppb	<0.5 – 4.6 ppb		0.06 ppb	By-product of chlorination
Total Trihalomethanes	12 ppb	<0.5 - 12 ppb		0 ppb	By-product of chlorination
Running Annual Average for TTHMS	*5.7 ppb*		*80 ppb*		
Inorganics					
Arsenic	6.8 ppb	4.9 – 6.8 ppb	10 ppb	0 ppb	Natural deposits
Barium	0.09 ppm	0.08 - 0.09 ppm	2 ppm	2 ppm	Natural deposits; Industrial uses
Fluoride	0.95 ppm	0.1 – 0.95 ppm	4 ppm	4 ppm	Natural deposits
Nitrate (as N)	8.3 ppm	0.26 – 8.3 ppm	10 ppm	10 ppm	Natural deposits; septic tanks; agriculture; sewage
Radiochemical					
Adjusted Gross Alpha	4.1 pCi/L	0.3 – 4.1 pCi/L	15 pCi/L	0 pCi/L	Natural Deposits
Radium 226 & 228, combined	0.4 pCi/L	<0.3 – 0.4 pCi/L	5 pCi/L	0 pCi/L	Natural Deposits
Uranium	9.7 ppb	1.8 – 9.7 ppb	30 ppb	0 ppb	Natural Deposits
Synthetic Organics					
Atrazine (2004 Data)	0.08 ppb	<0.05 - 0.08 ppb	3 ppb	3 ppb	Herbicide
Volatile Organics					
Trichloroethylene	4.1 ppb	< 0.5 – 4.1 ppb	5 ppb	0 ppb	(TCE) Solvent used in degreasing metal parts

Contaminant	No. of Samples Above the Action Level	90th Percentile Value	Action Level	MCLG	Major Sources
Lead and Copper in Standing Water Samples - 2005					
Lead	none	3.0 ppb	15 ppb	0	Corrosion of household plumbing systems
Copper	none	0.16 ppm	1.3 ppm	1.3 ppm	Corrosion of household plumbing systems

Contaminant	Months with Coliform Detections	% of Positive Samples for the Month	Total # of Samples Collected for the Month	MCL[1]	MCLG	Major Sources
Microbiological[1]						
Total Coliform	August	0.8	253	≤ 5%	0	Naturally present in environment
Total Coliform	September	0.4	250	≤ 5%	0	Naturally present in environment
Total Coliform	November	0.4	250	≤ 5%	0	Naturally present in environment

[1] The MCL for microbiological contaminants is 5% of the total number of samples collected in the month.

Maximum Residual Disinfection Level (MRDL)

Contaminant	Maximum Monthly Average	Range	MRDL	MCLG	Major Sources of Contaminant
Chlorine	0.85 ppm	0.71 – 0.85 ppm	4 ppm	4 ppm	Disinfection additive used to control microbes
Running Annual Average for MRDL	*0.77 ppm*				

Figure 16. *City of Tucson Water 2006 Water Quality Report. Table of Detected Contaminants (http://www.ci.tucson.az.us/water)*

Bottled Water

There are numerous types and sources of bottled water. Common bottled waters include mineral water (with more than 250 mg/L TDS), **purified water** (which has been treated to reduce TDS levels and other contaminants), and sparkling water (which is naturally or artificially carbonated), among others. For a more complete list, see the National Sanitation Foundation (NSF) website (www.nsf.org)

Bottled water is regulated as a packaged food product by the Food and Drug Administration (FDA) and state governments. Self-imposed standards on bottled water are also required by members of the International Bottled Water Association (IBWA). The US-EPA is not directly involved in the regulation of bottled water. However, if the bottled water suppliers use water from community water systems, the water utility must meet EPA standards. If other water sources are used, such as springs and wells, bottled water may be filtered, but the levels of minerals and contaminants may vary. Also, water disinfection is usually necessary, and packaging is done according to FDA food guidelines, as shown in Figure 17.

SODIUM FREE

Nutrition Facts

Serv. Size 8 fl oz (240 mL)

Servings Per Container 4

Amount Per Serving

Calories 0

% Daily Value*

Total Fat 0g **0%**

Sodium 0mg **0%**

Total Carb 0g **0%**

Protein 0

*Percent Daily Va

based on a 2,000

Typical Analysis in mg/litre:	
Calcium	17
Magnesium	13
Silica	85
pH	7.5
Bicarbonates	140
Total Dissolved Solids :	210

Figure 17. *Bottled water label conforming to USDA requirements and non-US bottled water (insert) showing mineral contents.*

Large surveys conducted both in the U.S. and worldwide have shown that, in general, bottled water is no safer than tap water. Concerns about the safety of mineral bottled water has prompted the World Health Organization (**WHO**) to work on the development of an international code of bottled water quality that would require the disclosure of the source, mineral content, and treatment of all bottled water.

One advantage of drinking bottled water is its portability and the fact that, unlike tap water, it requires no residual disinfection during storage or delivery to the consumer. Therefore, there is no unpleasant chlorine taste or smell. These conveniences come at a price since price of a quart of water at a supermarket usually starts at $0.50 (local brands) and $1 to $2 for imports.   Plastic-bottled water should be consumed quickly, not stored for months, as these containers may degrade over time and contaminate the water with **plastic residues.**

6. Glossary

A

Acidity: The total amount of acid and acid forming substances in water. See also pH.

ADEQ: Arizona Department of Environmental Quality. Administers all of Arizona's EPA programs and regulates community water systems that have at least 15 service connections or serve 25 people.

ADWR: Arizona Department of Water Resources. Established by the Arizona Groundwater Code to administer and enforce the Code provisions. Its primary mission is to ensure a long-term water supply for Arizona.

Alkalinity: Total amount of bicarbonate and carbonate ions present in water reported in mg/L of calcium carbonate. Water alkalinity helps protect (buffers) against abrupt pH changes limiting its range to between 7.5 and 8.5. Alkalinity and hardness also control pipe scale formation. There is no drinking water standard for alkalinity.

Alluvial: A general term for sedimentary deposits made by streams on river beds, flood plains, and alluvial fans, especially a deposit in an arid or semiarid region where a stream issues from a canyon unto a plain or valley floor.

AMA: Active Management Area. Five geographic areas designated by the Arizona Groundwater Code as requiring active management of groundwater. Each AMA has a management goal, management plan, a groundwater rights system, restrictions on agricultural land expansion and other requirements designed to preserve groundwater resources.

Annular Space: Space between well casing and the wall of the drilled bore hole.

Aquifers: A body of geologic material that is sufficiently permeable to conduct groundwater and to yield economically significant quantities of water to wells.

Artesian: Pertaining to groundwater under sufficient hydrostatic pressure to rise above the aquifer containing it.

Atrazine: An s-triazine-ring herbicide that is used globally to stop pre- and post-emergence broadleaf and grassy weeds in major crops.

B

Basalt: A dark-colored consolidated igneous rock, commonly extruded from volcanoes.

Base flow: The level at which the water in a river is sustained by groundwater, not including overland surface water flow contribution.

Bedding plane(s): In sedimentary or stratified rocks, the division plane that separates each successive layer or bed from the one above or below.

Benzene: A volatile organic chemical used as an industrial solvent and a major component of gasoline.

Biofilm: A structured community of microorganisms encapsulated within a self -developed matrix and adherent to a living or inert surface.

Brine: Water with a high content of dissolved salts.

C

Calcite: A very common mineral composed of calcium and carbonate ions.

Chloramine chemicals: Chlorine- and ammonia-based chemicals used for long-term residual disinfection of potable water. Chloramines are very effective at controlling bacterial and algal growth in water; however, they are also very toxic to fish.

Confined Aquifer: An aquifer bounded above and below by impermeable beds, or by beds of distinctly lower permeability (such as clay) than that of the aquifer itself.

Coliform bacteria: Routine water testing for coliform bacteria is used as an indicator of animal or human fecal contamination. Positive results may indicate the presence of pathogens such as bacteria, viruses, and parasites (present in surface water only) in the water.

Colorimeter(s): Instrument that uses characteristic light absorption to measure specific chemicals (concentrations) in water samples.

Consolidated and unconsolidated: Terms to describe geologic material. A consolidated rock has undergone any process whereby loose, soft, or liquid earth materials become firm and coherent, for example the cooling of lava or the cementation of sand. An unconsolidated material typically consists of sediment (sand, gravel, silts and/or clays) that is loosely arranged or whose particles are not cemented together.

Contact time: In chlorination, the period of time between the introduction of chlorine to the water and when the water is safe to drink (the time needed to disinfect the water).

Contaminants: Foreign substances (such as chemical, microbe, or plant and/or mineral particulate matter) found in water. Contaminants may or may not be harmful to human health.

Corrosion: In metal pipelines, corrosion occurs spontaneously by the presence of oxygen in water. Pipe corrosion is accelerated by corrosive water, high TDS, low (acidic) pH, low alkalinity, and high concentrations of chloride and sulfide ions. Iron metal pipes corrode the most, followed by zinc (galvanized ion) and copper metal pipes. Modern plastic pipes used in home construction do not corrode.

D

Disinfection by-products: Organic chemicals such as chloroform that can form during water disinfection using chlorine-based chemicals. Their concentrations are regulated under the NPDWS.

Dolomite: A common mineral composed of calcium, magnesium, and carbonate ions.

Down gradient: Down stream or down hill. Groundwater flows in the aquifer from a hydrostatic high elevation down gradient to a hydrostatic low elevation.

Drawdown: The lowering of the water level in a well as a result of pumping. It is the difference between the height of the water table and that of the water in a pumping well.

E

Emerging contaminants: Newly recognized contaminants requiring EPA evaluation.

Endocrine disruptors: A class of water pollutants that affect the human endocrine system. These include pesticides and emerging contaminants like pharmaceuticals and surfactants.

Enteric: Of or within the intestine.

EPA: The U.S. Environmental Protection Agency.

Evaporite: A sediment deposited from an aqueous solution because of evaporation, such as rock salt and various other combinations of evaporated material typically containing mineral salts.

Exempt well: Within an AMA, a well having a pump with a maximum pumping capacity of 35 gallons per minute or less, used to withdraw groundwater for non-irrigation purposes. This term is also used to describe any well outside an AMA having a pump with a maximum pumping capacity of 35 gallons per minute or less. These wells are "exempt" because their owners are exempt from reporting to authorities how much water they draw.

F

Fault(s): A fracture or fracture zone along which there has been displacement of the sides relative to one another parallel to the facture.

G

GPM: Gallons of water per minute (one gallon = 3.8 liters).

Gypsum: Common mineral composed of calcium and sulfate.

Geologic formation(s): A body of rock strata that consists dominantly of one type of geologic material. For example, the Redwall Limestone Formation is a massive consolidated rock consisting of limestone and is found in the cliffs of the Grand Canyon and as a sedimentary layer in the Colorado Plateau.

H

Half-life: The time period in which half the initial number of atoms of a radioactive element disintegrate into atoms of the daughter element. For example, Carbon 14 has a half-life of 5,730 ± 40 years, and after that period of time half of the original carbon will have disintegrated to nitrogen.

Hardness: The total amount of calcium and magnesium ions found in water. Hard water affects detergents by limiting suds formation. Scale formation in pipes is accelerated by hard water. Some scale formation is desirable to protect pipes from corrosion. Excessive scaling clogs pipes and can short the life of home appliances. There is no drinking water standard for hardness.

Hydrogen sulfide: A toxic, rotten egg smelling gas that occurs naturally in aquifers and sediments.

M

Magma: Natural molten rock materials, generated within the earth and capable of intrusion and extrusion, from which igneous rocks have been derived through solidification.

MCL: The maximum contaminant level or maximum concentration of a contaminant allowed in drinking water.

mg/L: Milligrams per liter or part per million (ppm). Most chemical drinking water standards are reported in mg/L.

Microorganisms: Organic carbon based organisms that are not visible with the naked eye, including bacteria and viruses.

Minerals: Natural crystalline materials found in rocks (such as granite, marble, and sandstone) and soils (such as sand silt and clays). Minerals are composed of chemical elements like oxygen, silicon, aluminum, iron, and many other elements.

N

NOM: Natural organic matter (mostly from plant and animal tissue decay) present most often in surface water sources and contaminated groundwater. Colored water usually has high concentrations of NOM.

O

Organic chemicals or contaminants: Carbon-based compounds, including pesticides and oil-derived products (fuels, plastics, and solvents). This should not be confused with the popular used of the term “organic,” meaning food grown without pesticides.

Overdraft: Groundwater pumping at a rate that exceeds the rate of recharge.

P

Pathogens: Microorganisms that produce diseases. Common pathogens regulated in drinking water include bacteria (such as Salmonella) and protozoan parasites (such as Giardia and Cryptosporidium). Note that water sources are commonly tested for the possible presence of pathogens by measuring total coliform bacteria.

pCi/L: PicoCurie, a measurement of radioactivity. One picoCurie is 3.7x 10-2decays per second.

Perchlorate: Found in rocket fuel and explosives, and has been found in both the groundwater and surface water of several states.

Perennial: A stream that flows throughout the year, a permanent stream.

Permeability: The capacity of a porous rock, sediment, or soil for transmitting a fluid, it is a measure of the relative ease of fluid flow.

pH: Values range from 1-14 units. Water with a pH of 7 is neutral, below 7 is acidic, and above is basic (usually alkaline). Most water sources in AZ have a basic pH (7-8.5) due to their natural alkalinity.

Physiographic province: A region of which all parts are similar in geologic structure and climate and which has had a unified geomorphic history; its physical features differ significantly from those of adjacent regions.

Plastic Residues: These include plasticizers commonly found in plastics to make them more flexible. Widely use plasticizers like phthalates can now be detected in most surface waters for the world. Breakdown products of these chemicals are commonly detected in humans and are a cause of concern in children.

Playa: A term used in the southwestern U.S. for a dry, barren area in the lowest part of an undrained desert basin, underlain by clay, silt, or sand, and commonly by soluble salts.

Plume(s): A volume of contaminated water that extends down gradient from a source of contamination.

Plutons: A large body of granitic rock originating from deep within the earth.

POE: Point of entry. A device that treats all or most of the water entering the home.

Pollutants: Unwanted contaminants and pathogens of anthropogenic origin that can be found in water, soil, and air. Pollutants are chemicals and organisms that have been associated with adverse environmental and health effects.

Porosity: Porous geologic material containing voids, pores, fractures, or interstices, which may or may not be interconnected.

The ratio between the void space and the total volume is the porosity (typically stated as a percentage).

POU: Point of use. Device that treats water at a particular tap source.

Precipitation of a mineral: Opposite of dissolution. The mineral crystallizes and forms a solid again.

Purified water: A vague and misused term. In general, a type of water produced by distillation, deionization, reverse osmosis, or other suitable processes.

R

Radon: A radioactive gas that may be present in groundwater sources that come into contact with uranium-rich minerals.

Recharge: The processes involved in the addition of water to the saturated zone of the aquifer, also the amount of water added.

Reclaimed water: Comes from sewage that is processed using physical, biological, and chemical treatments at a sewage treatment plant.

Risk assessment: A scientific process that estimates the chances of getting a disease from drinking water with a contaminant at a given concentration.

S

Salinity: A measure of the quantity of dissolved salts (minerals) in water.

Saline water: Exceeds 1000mb/L TDS or salts. Moderately saline water is referred to as brackish or briny.

Scale: Hard residues that coat the inside of water pipes and appliances and is the result of the precipitation of minerals composed of calcium and magnesium carbonates. Hot water helps form scale.

Sedimentary rock: A layered rock resulting from the consolidation of sediment, such as sandstone or limestone.

Shock-chlorination: The circulation of strong chlorine-based (bleach) solution through the well casing and house plumbing.

Soft water: Contains mostly sodium or potassium ions. Hard water can be “softened” by replacing calcium and magnesium for sodium or potassium ions using a water softener system. Water naturally low in TDS is also called soft water.

Solubility: Describes the amount of a chemical or mineral that can be dissolved in water.

Subsidence: The sinking or downward settling of the land surface that can be associated with groundwater pumping. It causes damage to roads, buildings, utility infrastructure, and other underground infrastructure.

Superfund: Superfund is the common name for the federal environmental law officially known as the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, 42 U.S.C. § 9601-9675), enacted on December 11, 1980. The Superfund law paid for toxic waste cleanups at sites where no other responsible parties could pay for a cleanup by assessing a tax on petroleum and chemical industries.

T

Table salt: A mineral composed of sodium and chloride ions.

TCE: The abbreviation for the volatile industrial solvent trichloroethylene notorious for industrial groundwater contamination.

TDS: Total dissolved solids (minerals, chemicals…) in milligrams per liter.

Thermoplastic: plastic (polymer) material that can be remolded with heat such as vinyl, polyethylene, and polypropylene.

Turbidity: A measure of the amount of suspended solids (particles) in water.

V

Vertical Displacement: In faulting, the vertical component of the net movement.

VOCs: Volatile organic chemicals such as chloroform, TEC, and benzene.

Volatile: A characteristic of organic chemicals that have boiling points lower than water. These include gasoline products, industrial solvents, and water disinfection by-products. Volatile organic chemicals are commonly abbreviated as VOCs.

W

Well yield: The maximum pumping rate that can be supplied by a well without lowering the water level in the well below the pump intake or causing the well to go dry.

WHO: The World Health Organization.

7. Appendix

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Various Agencies

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ADHS: Arizona Department of Health Services. http://www.hs.state.az.us/

ADHS Lab Services: Arizona Department of Health Services, Bureau of State Laboratory Services. http://www.azdhs.gov/lab/license/env.htm

ADWR: Arizona Department of Water Resources.
http://www.azwater.gov/dwr/default.htm
http://www.azwater.gov/dwr

ADWR Well Owner's Guide: http://www.water.az.gov/adwr/Content/Publications/files/well_owners-guide.pdf

University of Arizona Cooperative Extension publications. http://ag.arizona.edu/publications.

USGS: US Geologic Survey, Arizona water resources. http://az.water.usgs.gov

U.S. EPA Water

EPA: Environmental Protection Agency main website. http://www.epa.gov

EPA: EPA Groundwater and Drinking Water Website. http://www.epa.gov/safewater

EPA: Private Wells. http://www.epa.gov/safewater/privatewells

EPA: State Certification Offices for Drinking Water Laboratories (see Arizona addresses). http://www.epa.gov/safewater/labs/index.html

EPA: List of Household Chemicals and their Safe Use to Disinfect Water. http://www.epa.gov/OGWDW/faq/emerg.html

EPA: Frequently Asked Questions. http://www.epa.gov/safewater/faq/faq.html

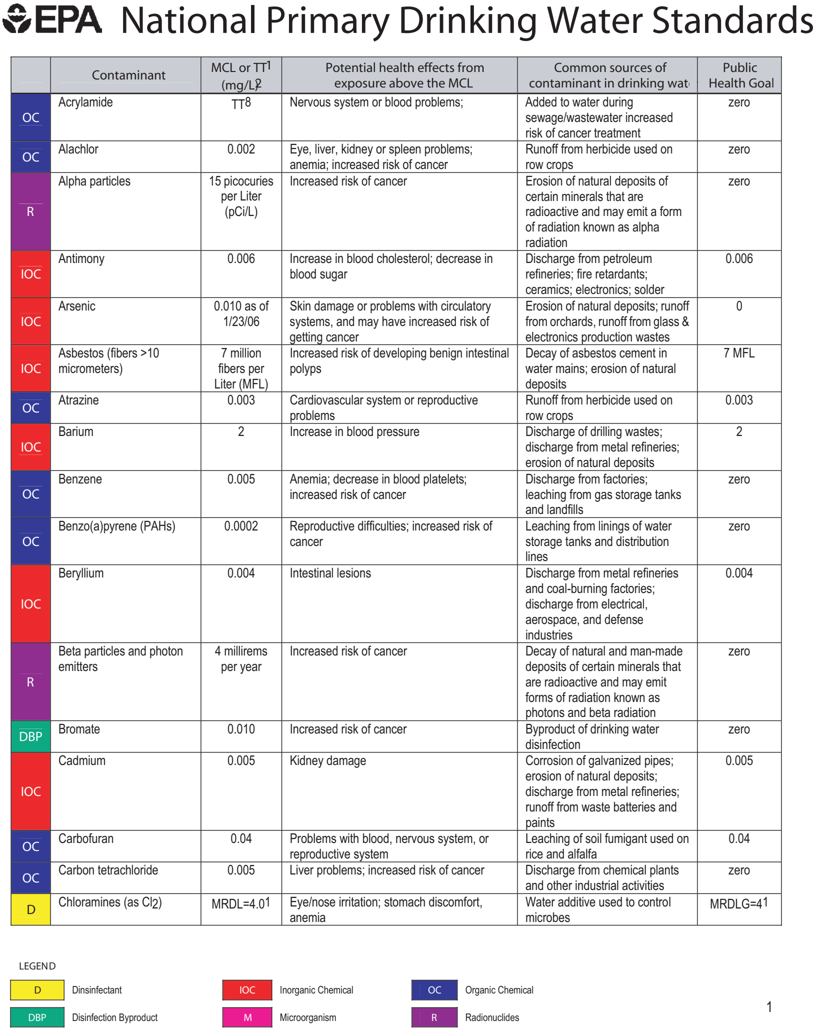
Private and Non-Profit Organizations

Home Water Purifiers and Filters: Very good website of a company that sells water purification systems. The website has detailed information on contaminants, water quality, and treatment options, and the information appears to be fairly objective. http://www.home-water-purifiers-and-filters.com/

NSF: The National Sanitation Foundation, a “not-for-profit, non-governmental organization” that tests and certifies consumer products (including water treatment devices) and lists common water treatment methods (standards). http://www.nsf.org

WQA: Water Quality Association. A “not-for profit international trade association representing the household, commercial, industrial, and small community water treatment industry.” http://www.wqa.org

Appendix A: National Primary Drinking Water Standards.



EPA National Primary Drinking Water Standards

	Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking wat	Public Health Goal
OC	Acrylamide	TT[8]	Nervous system or blood problems;	Added to water during sewage/wastewater increased risk of cancer treatment	zero
OC	Alachlor	0.002	Eye, liver, kidney or spleen problems; anemia; increased risk of cancer	Runoff from herbicide used on row crops	zero
R	Alpha particles	15 picocuries per Liter (pCi/L)	Increased risk of cancer	Erosion of natural deposits of certain minerals that are radioactive and may emit a form of radiation known as alpha radiation	zero
IOC	Antimony	0.006	Increase in blood cholesterol; decrease in blood sugar	Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder	0.006
IOC	Arsenic	0.010 as of 1/23/06	Skin damage or problems with circulatory systems, and may have increased risk of getting cancer	Erosion of natural deposits; runoff from orchards, runoff from glass & electronics production wastes	0
IOC	Asbestos (fibers >10 micrometers)	7 million fibers per Liter (MFL)	Increased risk of developing benign intestinal polyps	Decay of asbestos cement in water mains; erosion of natural deposits	7 MFL
OC	Atrazine	0.003	Cardiovascular system or reproductive problems	Runoff from herbicide used on row crops	0.003
IOC	Barium	2	Increase in blood pressure	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits	2
OC	Benzene	0.005	Anemia; decrease in blood platelets; increased risk of cancer	Discharge from factories; leaching from gas storage tanks and landfills	zero
OC	Benzo(a)pyrene (PAHs)	0.0002	Reproductive difficulties; increased risk of cancer	Leaching from linings of water storage tanks and distribution lines	zero
IOC	Beryllium	0.004	Intestinal lesions	Discharge from metal refineries and coal-burning factories; discharge from electrical, aerospace, and defense industries	0.004
R	Beta particles and photon emitters	4 millirems per year	Increased risk of cancer	Decay of natural and man-made deposits of certain minerals that are radioactive and may emit forms of radiation known as photons and beta radiation	zero
DBP	Bromate	0.010	Increased risk of cancer	Byproduct of drinking water disinfection	zero
IOC	Cadmium	0.005	Kidney damage	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints	0.005
OC	Carbofuran	0.04	Problems with blood, nervous system, or reproductive system	Leaching of soil fumigant used on rice and alfalfa	0.04
OC	Carbon tetrachloride	0.005	Liver problems; increased risk of cancer	Discharge from chemical plants and other industrial activities	zero
D	Chloramines (as Cl_2)	MRDL=4.0[1]	Eye/nose irritation; stomach discomfort, anemia	Water additive used to control microbes	MRDLG=4[1]

LEGEND

D	Dinsinfectant	IOC	Inorganic Chemical	OC	Organic Chemical
DBP	Disinfection Byproduct	M	Microorganism	R	Radionuclides

1

	Contaminant	MCL or TT^1 (mg/L)^2	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking wat	Public Health Goal
OC	Chlordane	0.002	Liver or nervous system problems; increased risk of cancer	Residue of banned termiticide	zero
D	Chlorine (as Cl_2)	MRDL=4.0^1	Eye/nose irritation; stomach discomfort	Water additive used to control microbes	MRDLG=4^1
D	Chlorine dioxide (as ClO_2)	MRDL=0.8^1	Anemia; infants & young children: nervous system effects	Water additive used to control microbes	MRDLG=0.8^1
DBP	Chlorite	1.0	Anemia; infants & young children: nervous system effects	Byproduct of drinking water disinfection	0.8
OC	Chlorobenzene	0.1	Liver or kidney problems	Discharge from chemical and agricultural chemical factories	0.1
IOC	Chromium (total)	0.1	Allergic dermatitis	Discharge from steel and pulp mills; erosion of natural deposits	0.1
IOC	Copper	TT^7; Action Level = 1.3	Short term exposure: Gastrointestinal distress. Long term exposure: Liver or kidney damage. People with Wilson's Disease should consult their personal doctor if the amount of copper in their water exceeds the action level	Corrosion of household plumbing systems; erosion of natural deposits	1.3
M	Cryptosporidium	TT^3	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste	zero
IOC	Cyanide (as free cyanide)	0.2	Nerve damage or thyroid problems	Discharge from steel/metal factories; discharge from plastic and fertilizer factories	0.2
OC	2,4-D	0.07	Kidney, liver, or adrenal gland problems	Runoff from herbicide used on row crops	0.07
OC	Dalapon	0.2	Minor kidney changes	Runoff from herbicide used on rights of way	0.2
OC	1,2-Dibromo-3-chloropropane (DBCP)	0.0002	Reproductive difficulties; increased risk of cancer	Runoff/leaching from soil fumigant used on soybeans, cotton, pineapples, and orchards	zero
OC	o-Dichlorobenzene	0.6	Liver, kidney, or circulatory system problems	Discharge from industrial chemical factories	0.6
OC	p-Dichlorobenzene	0.075	Anemia; liver, kidney or spleen damage; changes in blood	Discharge from industrial chemical factories	0.075
OC	1,2-Dichloroethane	0.005	Increased risk of cancer	Discharge from industrial chemical factories	zero
OC	1,1-Dichloroethylene	0.007	Liver problems	Discharge from industrial chemical factories	0.007
OC	cis-1,2-Dichloroethylene	0.07	Liver problems	Discharge from industrial chemical factories	0.07
OC	trans-1,2-Dichloroethylene	0.1	Liver problems	Discharge from industrial chemical factories	0.1
OC	Dichloromethane	0.005	Liver problems; increased risk of cancer	Discharge from drug and chemical factories	zero
OC	1,2-Dichloropropane	0.005	Increased risk of cancer	Discharge from industrial chemical factories	zero
OC	Di(2-ethylhexyl) adipate	0.4	Weight loss, live problems, or possible reproductive difficulties	Discharge from chemical factories	0.4
OC	Di(2-ethylhexyl) phthalate	0.006	Reproductive difficulties; liver problems; increased risk of cancer	Discharge from rubber and chemical factories	zero
OC	Dinoseb	0.007	Reproductive difficulties	Runoff from herbicide used on soybeans and vegetables	0.007
OC	Dioxin (2,3,7,8-TCDD)	0.00000003	Reproductive difficulties; increased risk of cancer	Emissions from waste incineration and other combustion; discharge from chemical factories	zero
OC	Diquat	0.02	Cataracts	Runoff from herbicide use	0.02
OC	Endothall	0.1	Stomach and intestinal problems	Runoff from herbicide use	0.1

LEGEND

D	Dinsinfectant	IOC	Inorganic Chemical	OC	Organic Chemical
DBP	Disinfection Byproduct	M	Microorganism	R	Radionuclides

2

	Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking wat	Public Health Goal
OC	Endrin	0.002	Liver problems	Residue of banned insecticide	0.002
OC	Epichlorohydrin	TT[8]	Increased cancer risk, and over a long period of time, stomach problems	Discharge from industrial chemical factories; an impurity of some water treatment chemicals	zero
OC	Ethylbenzene	0.7	Liver or kidneys problems	Discharge from petroleum refineries	0.7
OC	Ethylene dibromide	0.00005	Problems with liver, stomach, reproductive system, or kidneys; increased risk of cancer	Discharge from petroleum refineries	zero
IOC	Fluoride	4.0	Bone disease (pain and tenderness of the bones); Children may get mottled teeth	Water additive which promotes strong teeth; erosion of natural deposits; discharge from fertilizer and aluminum factories	4.0
M	Giardia lamblia	TT[3]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste	zero
OC	Glyphosate	0.7	Kidney problems; reproductive difficulties	Runoff from herbicide use	0.7
DBP	Haloacetic acids (HAA5)	0.060	Increased risk of cancer	Byproduct of drinking water disinfection	n/a[6]
OC	Heptachlor	0.0004	Liver damage; increased risk of cancer	Residue of banned termiticide	zero
OC	Heptachlor epoxide	0.0002	Liver damage; increased risk of cancer	Breakdown of heptachlor	zero
M	Heterotrophic plate count (HPC)	TT[3]	HPC has no health effects; it is an analytic method used to measure the variety of bacteria that are common in water. The lower the concentration of bacteria in drinking water, the better maintained the water system is.	HPC measures a range of bacteria that are naturally present in the environment	n/a
OC	Hexachlorobenzene	0.001	Liver or kidney problems; reproductive difficulties; increased risk of cancer	Discharge from metal refineries and agricultural chemical factories	zero
OC	Hexachlorocyclopentadiene	0.05	Kidney or stomach problems	Discharge from chemical factories	0.05
IOC	Lead	TT[7]; Action Level = 0.015	Infants and children: Delays in physical or mental development; children could show slight deficits in attention span and learning abilities; Adults: Kidney problems; high blood pressure	Corrosion of household plumbing systems; erosion of natural deposits	zero
M	Legionella	TT[3]	Legionnaire's Disease, a type of pneumonia	Found naturally in water; multiplies in heating systems	zero
OC	Lindane	0.0002	Liver or kidney problems	Runoff/leaching from insecticide used on cattle, lumber, gardens	0.0002
IOC	Mercury (inorganic)	0.002	Kidney damage	Erosion of natural deposits; discharge from refineries and factories; runoff from landfills and croplands	0.002
OC	Methoxychlor	0.04	Reproductive difficulties	Runoff/leaching from insecticide used on fruits, vegetables, alfalfa, livestock	0.04
IOC	Nitrate (measured as Nitrogen)	10	Infants below the age of six months who drink water containing nitrate in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits	10
IOC	Nitrite (measured as Nitrogen)	1	Infants below the age of six months who drink water containing nitrite in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits	1

LEGEND

D	Dinsinfectant	IOC	Inorganic Chemical	OC	Organic Chemical
DBP	Disinfection Byproduct	M	Microorganism	R	Radionuclides

3

	Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking wat	Public Health Goal
OC	Oxamyl (Vydate)	0.2	Slight nervous system effects	Runoff/leaching from insecticide used on apples, potatoes, and tomatoes	0.2
OC	Pentachlorophenol	0.001	Liver or kidney problems; increased cancer risk	Discharge from wood preserving factories	zero
OC	Picloram	0.5	Liver problems	Herbicide runoff	0.5
OC	Polychlorinated biphenyls (PCBs)	0.0005	Skin changes; thymus gland problems; immune deficiencies; reproductive or nervous system difficulties; increased risk of cancer	Runoff from landfills; discharge of waste chemicals	zero
R	Radium 226 and Radium 228 (combined)	5 pCi/L	Increased risk of cancer	Erosion of natural deposits	zero
IOC	Selenium	0.05	Hair or fingernail loss; numbness in fingers or toes; circulatory problems	Discharge from petroleum refineries; erosion of natural deposits; discharge from mines	0.05
OC	Simazine	0.004	Problems with blood	Herbicide runoff	0.004
OC	Styrene	0.1	Liver, kidney, or circulatory system problems	Discharge from rubber and plastic factories; leaching from landfills	0.1
OC	Tetrachloroethylene	0.005	Liver problems; increased risk of cancer	Discharge from factories and dry cleaners	zero
IOC	Thallium	0.002	Hair loss; changes in blood; kidney, intestine, or liver problems	Leaching from ore-processing sites; discharge from electronics, glass, and drug factories	0.0005
OC	Toluene	1	Nervous system, kidney, or liver problems	Discharge from petroleum factories	1
M	Total Coliforms (including fecal coliform and *E. coli*)	5.0%[4]	Not a health threat in itself; it is used to indicate whether other potentially harmful bacteria may be present[5]	Coliforms are naturally present in the environment as well as feces; fecal coliforms and *E. coli* only come from human and animal fecal waste.	zero
DBP	Total Trihalomethanes (TTHMs)	0.10 0.080 after 12/31/03	Liver, kidney or central nervous system problems; increased risk of cancer	Byproduct of drinking water disinfection	n/a[6]
OC	Toxaphene	0.003	Kidney, liver, or thyroid problems; increased risk of cancer	Runoff/leaching from insecticide used on cotton and cattle	zero
OC	2,4,5-TP (Silvex)	0.05	Liver problems	Residue of banned herbicide	0.05
OC	1,2,4-Trichlorobenzene	0.07	Changes in adrenal glands	Discharge from textile finishing factories	0.07
OC	1,1,1-Trichloroethane	0.2	Liver, nervous system, or circulatory problems	Discharge from metal degreasing sites and other factories	0.20
OC	1,1,2-Trichloroethane	0.005	Liver, kidney, or immune system problems	Discharge from industrial chemical factories	0.003
OC	Trichloroethylene	0.005	Liver problems; increased risk of cancer	Discharge from metal degreasing sites and other factories	zero
M	Turbidity	TT[3]	Turbidity is a measure of the cloudiness of water. It is used to indicate water quality and filtration effectiveness (e.g., whether disease-causing organisms are present). Higher turbidity levels are often associated with higher levels of disease-causing micro-organisms such as viruses, parasites and some bacteria. These organisms can cause symptoms such as nausea, cramps, diarrhea, and associated headaches.	Soil runoff	n/a
R	Uranium	30 ug/L as of 12/08/03	Increased risk of cancer, kidney toxicity	Erosion of natural deposits	zero

LEGEND

D	Dinsinfectant	IOC	Inorganic Chemical	OC	Organic Chemical
DBP	Disinfection Byproduct	M	Microorganism	R	Radionuclides

4

	Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking wat	Public Health Goal
OC	Vinyl chloride	0.002	Increased risk of cancer	Leaching from PVC pipes; discharge from plastic factories	zero
M	Viruses (enteric)	TT[3]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste	zero
OC	Xylenes (total)	10	Nervous system damage	Discharge from petroleum factories; discharge from chemical factories	10

NOTES

1 Definitions

- Maximum Contaminant Level Goal (MCLG)—The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.
- Maximum Contaminant Level (MCL)—The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.
- Maximum Residual Disinfectant Level Goal (MRDLG)—The level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contaminants.
- Maximum Residual Disinfectant Level (MRDL)—The highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.
- Treatment Technique (TT)—A required process intended to reduce the level of a contaminant in drinking water.

2 Units are in milligrams per liter (mg/L) unless otherwise noted. Milligrams per liter are equivalent to parts per million (ppm).

3 EPA's surface water treatment rules require systems using surface water or ground water under the direct influence of surface water to (1) disinfect their water, and (2) filter their water or meet criteria for avoiding filtration so that the following contaminants are controlled at the following levels:

- *Cryptosporidium* (as of 1/1/02 for systems serving >10,000 and 1/14/05 for systems serving <10,000) 99% removal.
- *Giardia lamblia*: 99.9% removal/inactivation
- Viruses: 99.99% removal/inactivation
- *Legionella*: No limit, but EPA believes that if *Giardia* and viruses are removed/inactivated, *Legionella* will also be controlled.
- Turbidity: At no time can turbidity (cloudiness of water) go above 5 nephelolometric turbidity units (NTU); systems that filter must ensure that the turbidity go no higher than 1 NTU (0.5 NTU for conventional or direct filtration) in at least 95% of the daily samples in any month. As of January 1, 2002, for systems servicing >10,000, and January 14, 2005, for systems servicing <10,000, turbidity may never exceed 1 NTU, and must not exceed 0.3 NTU in 95% of daily samples in any month.
- HPC: No more than 500 bacterial colonies per milliliter
- Long Term 1 Enhanced Surface Water Treatment (Effective Date: January 14, 2005); Surface water systems or (GWUDI) systems serving fewer than 10,000 people must comply with the applicable Long Term 1 Enhanced Surface Water Treatment Rule provisions (e.g. turbidity standards, individual filter monitoring, *Cryptosporidium* removal requirements, updated watershed control requirements for unfiltered systems).
- Filter Backwash Recycling: The Filter Backwash Recycling Rule requires systems that recycle to return specific recycle flows through all processes of the system's existing conventional or direct filtration system or at an alternate location approved by the state.

4 No more than 5.0% samples total coliform-positive in a month. (For water systems that collect fewer than 40 routine samples per month, no more than one sample can be total coliform-positive per month.) Every sample that has total coliform must be analyzed for either fecal coliforms or *E. coli* if two consecutive TC-positive samples, and one is also positive for *E. coli* fecal coliforms, system has an acute MCL violation.

5 Fecal coliform and *E. coli* are bacteria whose presence indicates that the water may be contaminated with human or animal wastes. Disease-causing microbes (pathogens) in these wastes can cause diarrhea, cramps, nausea, headaches, or other symptoms. These pathogens may pose a special health risk for infants, young children, and people with severely compromised immune systems.

6 Although there is no collective MCLG for this contaminant group, there are individual MCLGs for some of the individual contaminants:

- Haloacetic acids: dichloroacetic acid (zero); trichloroacetic acid (0.3 mg/L)
- Trihalomethanes: bromodichloromethane (zero); bromoform (zero); dibromochloromethane (0.06 mg/L)

7 Lead and copper are regulated by a Treatment Technique that requires systems to control the corrosiveness of their water. If more than 10% of tap water samples exceed the action level, water systems must take additional steps. For copper, the action level is 1.3 mg/L, and for lead is 0.015 mg/L.

8 Each water system must certify, in writing, to the state (using third-party or manufacturers certification) that when it uses acrylamide and/or epichlorohydrin to treat water, the combination (or product) of dose and monomer level does not exceed the levels specified, as follows: Acrylamide = 0.05% dosed at 1 mg/L (or equivalent); Epichlorohydrin = 0.01% dosed at 20 mg/L (or equivalent).

LEGEND

D	Dinsinfectant	IOC	Inorganic Chemical	OC	Organic Chemical
DBP	Disinfection Byproduct	M	Microorganism	R	Radionuclides

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Appendix B: Water Problems: Symptoms, Tests, and Possible Sources

(* indicates a common Arizona water quality issue)

	Symptom	Cause	Treatment devices
Visual (Water appearance)	Cloudiness of water with a yellow, brown or black cast that clears after standing 24 hours	*Turbidity	Flocculation and sedimentation or particle and microfiltration (POE)
	Transparent yellow-brown tint to water that doesn't clear after standing 24 hours	*High levels of natural organic matter (NOM), usually in surface water	Activated carbon filtration or chlorination followed by activated carbon filtration Water utilities use flocculation to remove NOM.
	Brown-orange stains or reddish slime or tint to water	Presence of dissolved iron and iron bacteria	Low amounts: reduce with particle filter or during reverse osmosis or distillation treatments (POE or POU) High amounts: remove by potassium permanganate-regenerated oxidizing filter and particle filter (POE) Very high amounts: remove by chlorination followed by particle filter (POE) Consider well and distribution/storage shock chlorination to kill iron bacteria.
	Brownish color or rusty sediment	Suspended iron and manganese particles	Particle filter (POE)

Visual (Staining and deposits)	Blackened or tarnished metal utensils and pipes	High chloride and sulfate levels	Reverse osmosis unit (POE) or distillation unit (POU)
	Blackened or tarnished metal utensils and pipes	High water acidity and high hydrogen sulfide	Acid-neutralizing filters (calcite or calcite/ magnesium oxide) (POE) or addition of alkaline chemicals such as lime
	Stains in showers, toilet bowls, and faucet ends	*Hardness	Water softener (POE or POU)
	Excessive staining in showers and aluminum cookware	*Salinity	Reverse osmosis unit or distillation unit (POU)
	Green water stains	Acidity	Acid neutralizing filters (POE) or addition of alkaline chemicals such as lime
	Soap deposits or excessive scaly deposits in plumbing and appliances	*Hardness	Water softener or reverse osmosis or distillation (POE or POU)
	Excessive salt deposits	Alkalinity (high pH and sodium)	Reverse osmosis or distillation systems (POE) Consider acid neutralization of excessive alkalinity
Other visual	Houseplants stunted or with burned leaf tips	*Salinity	Reverse osmosis unit or distillation unit (POU)
Taste	Taste of chlorine, gasoline, or oil	VOCs, including residual chlorine, disinfection byproducts, pesticides, or fuel (gasoline, diesel, oil products)	Activated charcoal filter or aeration (POE)

	Metallic taste	Acidity	Acid neutralizing filters (POE) or addition of alkaline chemicals such as lime
	Salty or bitter taste	*High total dissolved solids, sodium, sulfates, or nitrates (salinity)	Reverse osmosis or distillation (POU)
Smell	Chlorine-like smell	*VOCs, including residual chlorine, disinfection byproducts, pesticides, gasoline products	Activated charcoal filter or aeration (POU)
	Gasoline-like smell	Gasoline, diesel, oil products	Activated charcoal filter or aeration (POU)
	Earthy, musty, or chemical smell	Algae products (geos-min and MIB)	Activated charcoal filter (POU)
	Rotten egg odor	Excessive acidity, lack of oxygen in water source, or contamination by hydrogen sulfide gas (occurs naturally in aquifers and sediments)	Oxidation of water during aeration (POE) or chlorination and a particle filter (POE) or oxidizing filter (POE) followed by an activated carbon filter Acidity control may also be needed.
Illness	Gastrointestinal problems such as diarrhea and vomiting	Pathogens	Remove source of contamination. Reduce pathogens through chlorination, UV radiation, or ozonation (POE). Chloramine chemicals may be used after chlorination is completed in order to maintain acceptable chlorine residual levels.

Appliance/hardware problems	Early appliance failure	*Hardness	Water softener (POE or POU)
	Poor evaporative cooler performance	Build-up of scale on pads (high hardness, high salinity)	Use bleed-off mechanism to prevent build-up of salts and minerals (more information on Water Conservation website
	Blackened/tarnished metal utensils and pipes	High chloride levels	Reverse osmosis unit or distillation unit (POU)
	Blackened/tarnished metal utensils and pipes	High water acidity and high hydrogen sulfide	Acid-neutralizing filters (POE) or addition of alkaline chemicals such as lime

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