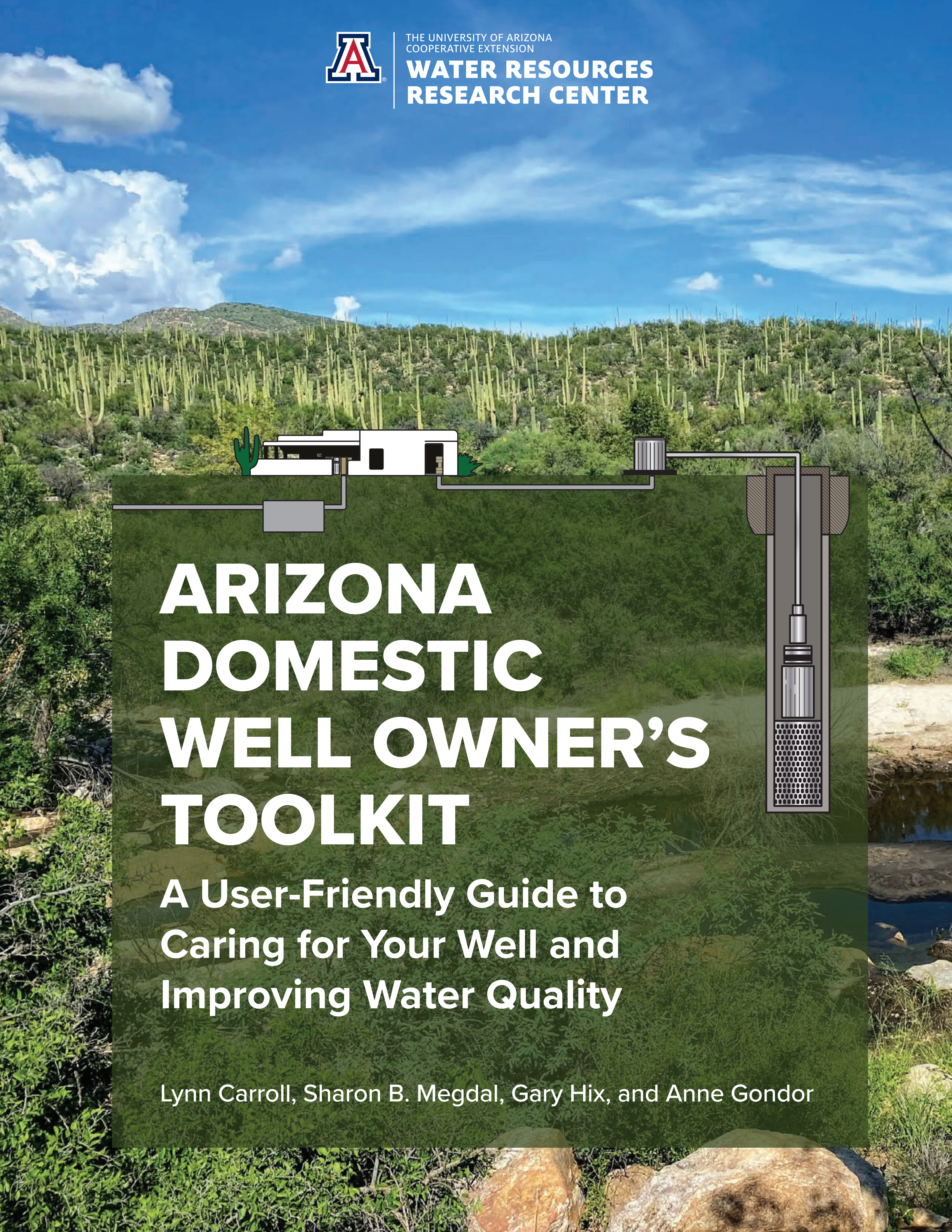


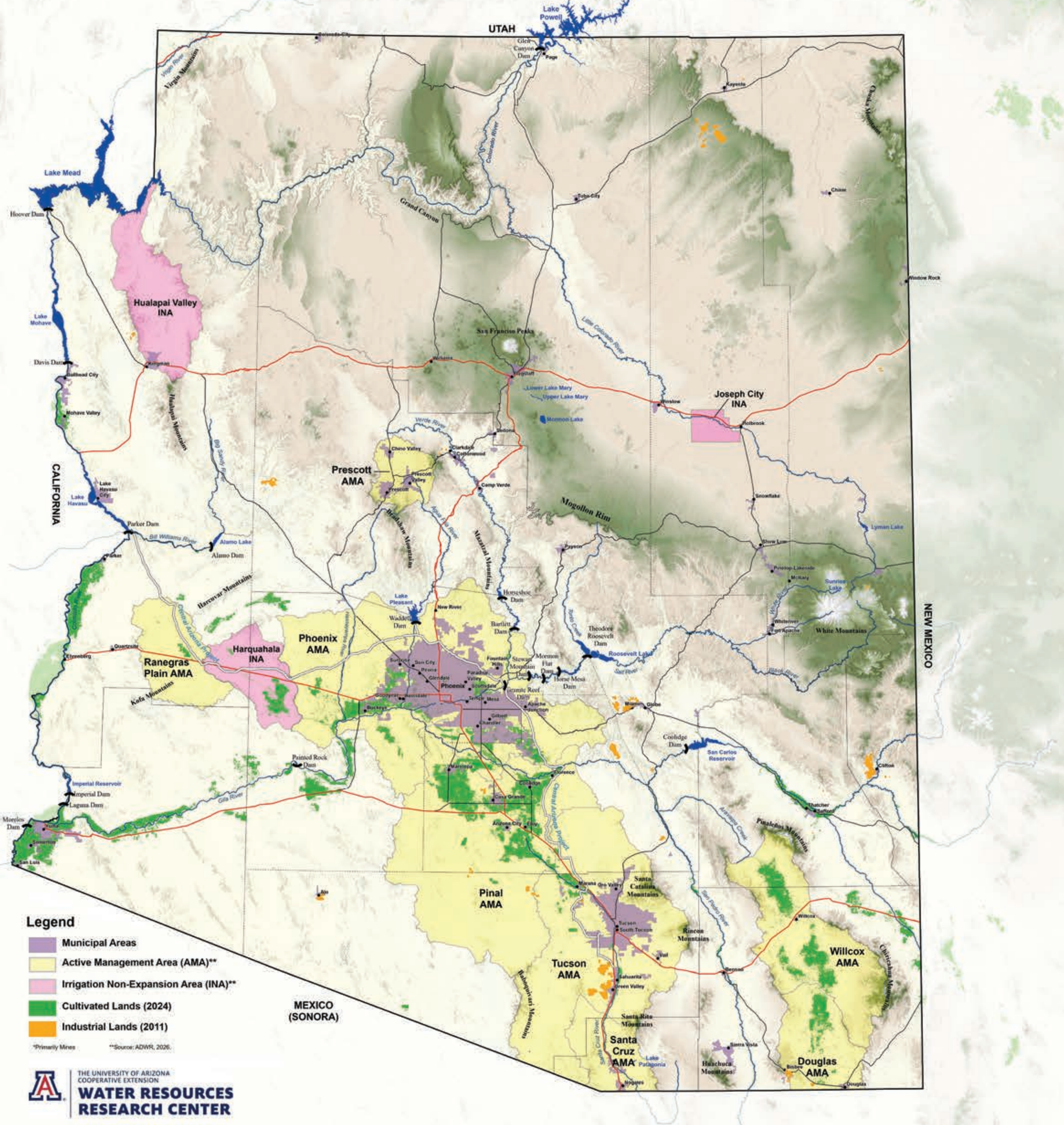
THE UNIVERSITY OF ARIZONA
COOPERATIVE EXTENSION
WATER RESOURCES
RESEARCH CENTER

ARIZONA DOMESTIC WELL OWNER'S TOOLKIT

A User-Friendly Guide to Caring for Your Well and Improving Water Quality

Lynn Carroll, Sharon B. Megdal, Gary Hix, and Anne Gondor

ARIZONA



Lake Powell
UTAH
Glen Canyon Dam
Page
Kayenta
Chinle
Tuba City
Grand Canyon
Colorado River
Little Colorado River
Window Rock
Lake Mead
Hoover Dam
Hualapai Valley INA
Lake Mohave
Davis Dam
Bullhead City
Mohave Valley
Kingman
Hualapai Mountains
Williams
San Francisco Peaks
Flagstaff
Lower Lake Mary
Upper Lake Mary
Mormon Lake
Winslow
Joseph City INA
Holbrook
Sedona
Verde River
Chino Valley
Clarkdale
Cottonwood
Prescott AMA
Prescott
Prescott Valley
Camp Verde
Snowflake
Mogollon Rim
CALIFORNIA
Lake Havasu
Lake Havasu City
Parker Dam
Bill Williams River
Alamo Lake
Alamo Dam
Parker
Show Low
Lyman Lake
Payson
Pinetop-Lakeside
McNary
Sunrise Lake
White Mountains
Whiteriver
Fort Apache
NEW MEXICO
Harcuvar Mountains
Lake Pleasant
New River
Waddell Dam
Horseshoe Dam
Bartlett Dam
Phoenix AMA
Harquahala INA
Ranegras Plain AMA
Quartzsite
Ehrenberg
Kofa Mountains
Central Arizona Project
Theodore Roosevelt Dam
Roosevelt Lake
Salt River
Stewart Mountain Dam
Mormon Flat Dam
Horse Mesa Dam
Granite Reef Dam
Surprise
Sun City
Peoria
Glendale
Phoenix
Scottsdale
Fountain Hills
Tempe
Mesa
Goodyear
Avondale
Buckeye
Chandler
Gilbert
Apache Junction
Miami
Globe
Coolidge Dam
San Carlos Reservoir
Clifton
Painted Rock Dam
Gila River
Imperial Reservoir
Imperial Dam
Laguna Dam
Morelos Dam
Yuma
San Luis
Maricopa
Casa Grande
Coolidge
Florence
Eloy
Arizona City
Thatcher
Safford
Pinaleño Mountains
Marana
Oro Valley
Santa Catalina Mountains
Pinal AMA
Tucson
South Tucson
Rincon Mountains
Vail
Willcox
Willcox AMA
Chiricahua Mountains
Benson
San Pedro River
Tucson AMA
Sahuarita
Green Valley
Baboquivari Mountains
Santa Rita Mountains
Santa Cruz AMA
Santa Cruz River
Lake Patagonia
Nogales
Sierra Vista
Huachuca Mountains
Douglas AMA
Bisbee
Douglas
Ajo
MEXICO (SONORA)
Legend
Municipal Areas
Active Management Area (AMA)**
Irrigation Non-Expansion Area (INA)**
Cultivated Lands (2024)
Industrial Lands (2011)
*Primarily Mines
**Source: ADWR, 2026.
THE UNIVERSITY OF ARIZONA COOPERATIVE EXTENSION
WATER RESOURCES RESEARCH CENTER

ARIZONA DOMESTIC WELL OWNER'S TOOLKIT

A User-Friendly Guide to Caring for Your Well and Improving Water Quality

This guide was written to help domestic well owners learn more about a topic of the utmost importance—your drinking water. As a well owner, you are responsible for the maintenance of your well and the quality of the water you use from it. Gaining a better understanding about your well, its upkeep, geology, water quality, and water treatment options will ultimately empower you, the well owner, to better monitor and maintain your well and your water supply. This guide covers these topics and more!

The information in this publication is for educational purposes only.

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Cover Image: Casey Harkleroad, Cactus Creek Oasis, Sabino Canyon AZ 2021

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SECTION 1
INTRODUCTION

This guide was written to assist domestic well owners in learning more about a topic of the utmost importance—your drinking water. It is estimated that 13% of the US population gets their **domestic** water from self-supplied sources (Dieter, 2017). In Arizona, it is estimated that 330,000 residents get their domestic water from a self-supplied water source. This is primarily from thousands of domestic wells across the state that are registered with the Arizona Department of Water Resources (ADWR). 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 sustainable supply into the future.

As a private well owner, you are responsible for the upkeep of your well and the quality of water it produces. While a loan provider or real estate company may require a water quality test, there are no federal or state laws within Arizona that require a well owner to have their well tested. This means that while **public water systems** must meet certain water quality standards in order to provide safe, potable drinking water for their customers, well owners are solely responsible for testing their water, in order to protect the health of anyone who drinks it.

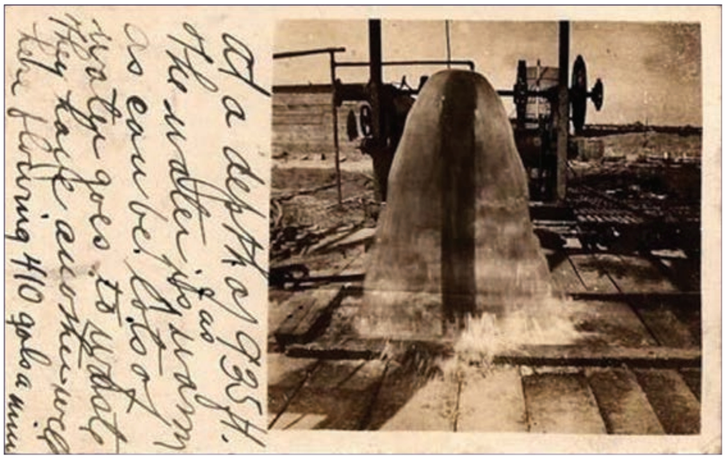


Figure 1.1 Year and location unknown, postcard of **artesian** well in southeastern Arizona. Source: Artiola, Uhlman, Hix, 2017. *Arizona Well Owner's Guide to Water Supply 2nd Edition*

Gaining a better understanding about your well, its components and maintenance, geology, water quality, and water treatment will ultimately empower you, the well owner, to better maintain and monitor your well and your water supply. This guide covers these topics and more!

1.1 A Brief Note on Content

This guide was written to provide information for new well owners and experienced well owners alike. Explore the sections of interest to you.

Information from geology to well installation is covered in the beginning of the guide. We start with an overview of how the geologic and hydraulic conditions throughout the state can impact the characteristics of wells in Section 2 – Aquifers. Following this, Section 3 – Well Installation and Permitting, includes information about the physical well installation and permitting processes for installing a new well or updating an existing well. Tips on maintaining your well and improving your well yield are included in Section 4 – Well Operation and Maintenance.

Next, the guide explores the critical topic of water quality. Common well water constituents and contaminants are explored in Section 5 – What is in Groundwater. Following this is Section 6 – State and Federal Law and Regulation that includes information regarding water quality and reporting information recommended and required for domestic well owners. Water quality testing and interpretation guidance are included in Section 7 – Testing Well Water Quality. Methods of improving well water quality with water treatment and protecting water quality are included in Section 8 – Water Treatment Options and Section 9 – Protecting Your Well Water

Quality, respectively. Lastly, Section 10 – Looking Towards the Future, briefly explores tips for domestic well owners to stay proactive to keep water systems resilient and ready for long-term use.

1.2 How to Use the Guide

While exploring the guide, keep in mind the following:

- The guide includes many terms that may be new to you.
- Terms in **bold** are defined in the Glossary at the end of the guide.
- Boxes throughout the guide include additional information about select topics that may be of interest to you.
- At the end of each section are "What does this mean for well owners?" and "Resources". These include key takeaways for domestic well owners and include additional resources with more information about the topic.
- There are also a number of Appendices included at the end of the guide, which include detailed information about different topics including drinking water standards, common water quality issues and symptoms, certified drinking water labs, water treatment technology maintenance requirements, and resources with common groundwater quality information.

Resources

Dieter, C. & Maupin, M. *Public Supply and Domestic Water Use in the United States*, 2015. **https://doi.org/10.3133/ofr20171131** (2017).

SECTION 2
AQUIFERS

Rainfall and snowmelt seep into the ground and are stored in geologic formations. An **aquifer** is an underground geologic formation capable of producing (yielding or transmitting) usable quantities of groundwater to a well or spring. In some locations around the state, there may be multiple aquifers of different depths present in a single location.

If the formation is porous enough to hold water, the saturated portion is the aquifer. The upper portion of the aquifer, the line between the saturated and the unsaturated part, is called **the water level or water table**, depending on the geology (Figure 2.1). As groundwater is pumped and/or rainfall infiltrates into the ground across the seasons, the water level moves up and down. Above the water level, which is termed the **vadose zone**, the geologic formation and **soils** are not saturated but will contain some moisture. In some cases, well drillers and engineers may also refer to this layer above the water level as **overburden**.

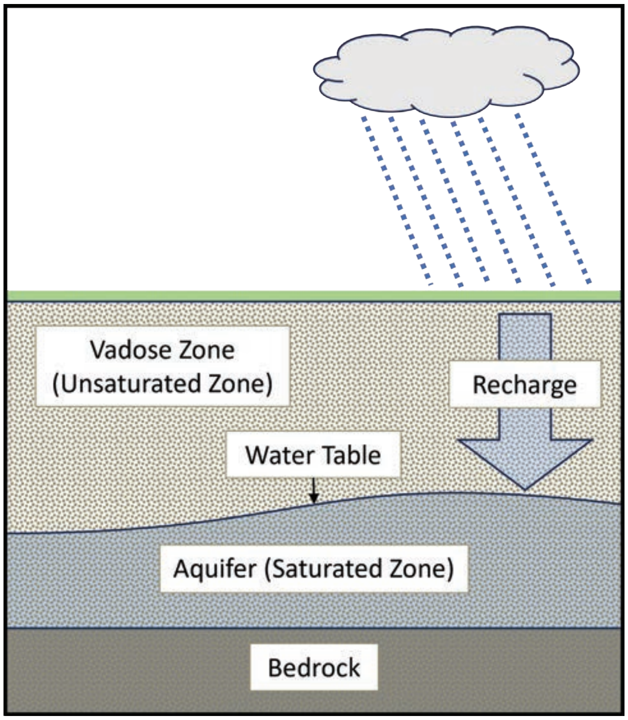


Figure 2.1 An unconfined aquifer (defined in section 2.2) that is being recharged by rainfall. As the rain flows through the vadose zone and into the aquifer, the water table rises.

Knowing the local geology helps us understand how much water a well can **yield**, how the aquifer can **recharge**, what the naturally occurring chemistry of groundwater may be, and how vulnerable the aquifer may be to contamination. Climate conditions control how much water recharges the aquifer and how sustainable the aquifer may be during drought conditions. Under present climate conditions, little to no recharge is taking place in many Arizona aquifers, which may lead to dropping groundwater levels and even **land subsidence** in some locations. The following sections explore these topics in more detail.

2.1 What is an aquifer?

Aquifers may be composed of one or a combination of materials that allow for water to be held in the formation. Each material has different **porosity** and **permeability** characteristics, as shown in Figure 2.2, which impacts the speed that water moves below ground.

The interconnected space within the rock is termed porosity. When porosity is developed after the rock is formed—for example, by fracturing the rock—it is termed secondary porosity. The primary, or initial, porosity of the rock may be very low, but after fracturing, the secondary porosity may allow water to flow rapidly through the aquifer, such as with fractured sandstone.

The permeability is the ability of the rock to allow liquid to pass through. The high porosity in sandy soils allows for high permeability, rapid movement of groundwater; however, they contain less water per unit volume than clay soils. For example, an aquifer made of sandy-gravely sediments and soils may contain about 30 percent water by volume, whereas a saturated clay soil or aquifer can have approximately 45 percent water by volume.

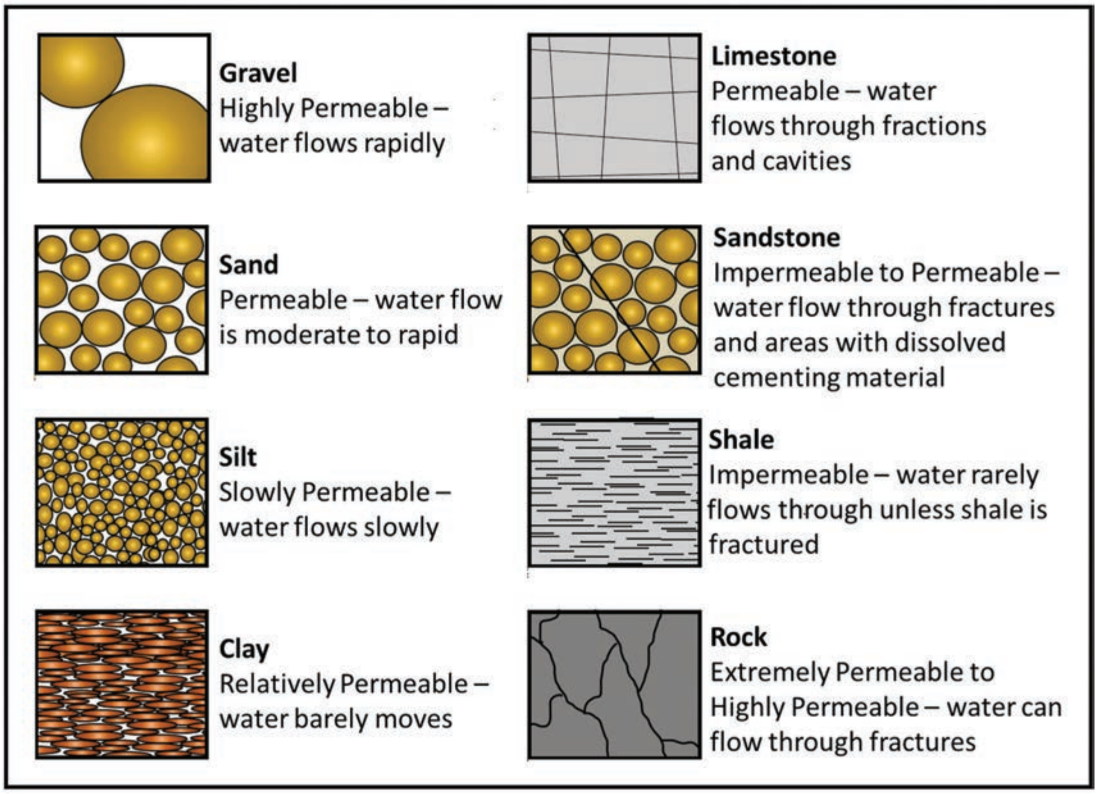


Figure 2.2 Typical permeability of different aquifers materials. Porosity is given in ranges since porosity of a material is impacted by differing levels of sorting and compaction. Source: Adapted from the Artiola, Uhlman, Hix, 2017. *Arizona Well Owner's Guide to Water Supply 2nd Edition*

Aquifers are classified as **unconsolidated** or **consolidated** aquifers depending on their composition:

- Unconsolidated (loose) rock materials include the sands and gravels of river valleys, sand dunes, and the desert basins of Phoenix, Tucson, and Benson. In unconsolidated aquifers, water is held in the empty spaces (pores) between grains of clay, silt, sand, and gravel.
- Consolidated (bound or cemented) rock materials include the granite formations near Globe, Prescott, the volcanic basalts near Flagstaff, and several of the isolated mountain ranges referred to as Sky Islands. In consolidated aquifers, the water is held in the fractures and cracks in the rock. Therefore, a well constructed in the consolidated sedimentary aquifers may yield little water if the borehole does not intercept sufficient fractures capable of yielding water, or in the extreme, the well may yield significant volumes of groundwater.

The composition of aquifers helps us to understand the potential yield and recharge characteristics of the aquifer.

2.2 Types of Aquifers

In addition to the composition of the aquifer, local geology also helps us to better understand the type of well and water movement within the aquifer. In Figure 2.3, we can observe three different types of wells: unconfined, confined, and artesian.

An **unconfined aquifers** occur near the ground surface. In an unconfined aquifer, the water level is the upper boundary of the aquifer with **permeable** material above it. A **confined aquifer** is confined between two **aquitards** or confining layers. The aquitard is a low-permeability layer. In some cases, especially at higher elevations, recharge water must flow around the aquitard to reach the aquifer. Lastly, an **artesian aquifer** is formed when the rocks above the aquifer and/or the elevation of the recharge puts the aquifer under pressure. If the pressure is such that water rises above the land surface when a well is installed, the artesian well is referred to as a flowing well, which is depicted in Figure 2.3.

Information about pumping water from these different types of wells is outlined in the next section.

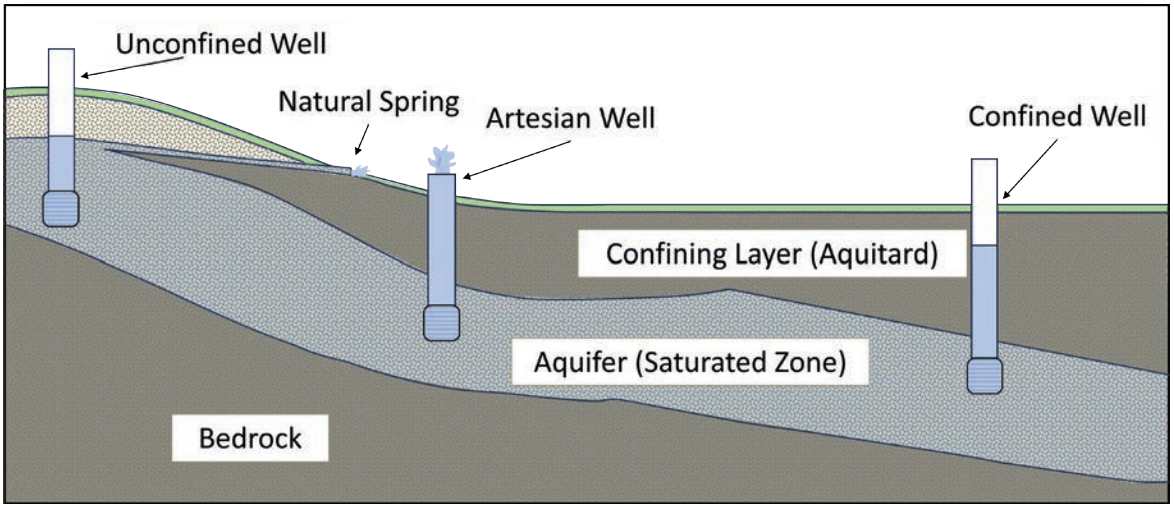


Figure 2.3 Underground geologic characteristics define the type of well: unconfined, confined, or artesian. The well type can influence recharge and withdrawal characteristics of the aquifer.

2.3 Pumping Water from Aquifers

There are local changes to groundwater levels around a well. In an unconfined aquifer, the elevation of the water level drops, typically in the shape of an inverted cone. The cone is known as a **drawdown cone or a cone of depression**, as shown in Figure 2.4. The water level is drawn down, and the gradient increases, allowing water to flow to the well.

In a confined system, the water pressure near the well is decreased as groundwater is pumped out, forming a pressure gradient. This pressure gradient allows groundwater to flow into the well. The steeper the gradient, the more rapid the groundwater flows. Unfortunately, not all aquifers have the capacity to sustain this flow. If the gradient is so steep that the cone of depression rapidly draws the water level down, the well may go dry within moments of the pump being turned on; however, if the pump is sized correctly and well placed, this is not likely. The shape and size of the cone depend on the pumping rate, type of aquifer, and direction of groundwater flow.

- In an unconsolidated, porous aquifer, the cone of depression forms around the wellhead in an ever-expanding circle or oval shape due to groundwater flow, as more water is pumped from the aquifer. The depth of the cone is dependent on the aquifer's storage capacity and its ability to sustain the flow.
- In a consolidated, fractured-rock aquifer, the cone of depression follows the underground fracture system and may take an unpredictable shape as the cone expands outward to pull more water into the well.
- In an **artesian**, confined system, the cone may extend for hundreds of feet but be only a few inches deep.

Several problems can arise from cones of depression:

- As depicted in Figure 2.4, if the cone extends beneath a river or stream, the well will begin pumping river water from the riverbed, through the aquifer, and into the well. Groundwater pumping in the Tucson basin since the mid-20th century has resulted in the Santa Cruz River going dry.
- As regional water-table elevations drop in the unconfined aquifers, the land surface can drop, resulting in large cracks in the earth. This land **subsidence** has resulted in the near-reversal flow of some sewage lines across the city of Tucson after excessive groundwater pumping.
- If the cone extends out and beneath a source of pollution, such as a landfill, an agricultural field receiving excessive fertilizers or pesticides, or a leaky gas station storage tank, groundwater pumping may draw the contaminants into the well.
- If a cone intercepts a neighboring cone of depression from a nearby well, both wells may run dry faster.
- If the water level in the well recovers slowly after pumping, the well may temporarily run dry when too much water is used rapidly, such as over a weekend. The residents can use the water more uniformly throughout the week or month to prevent this problem.

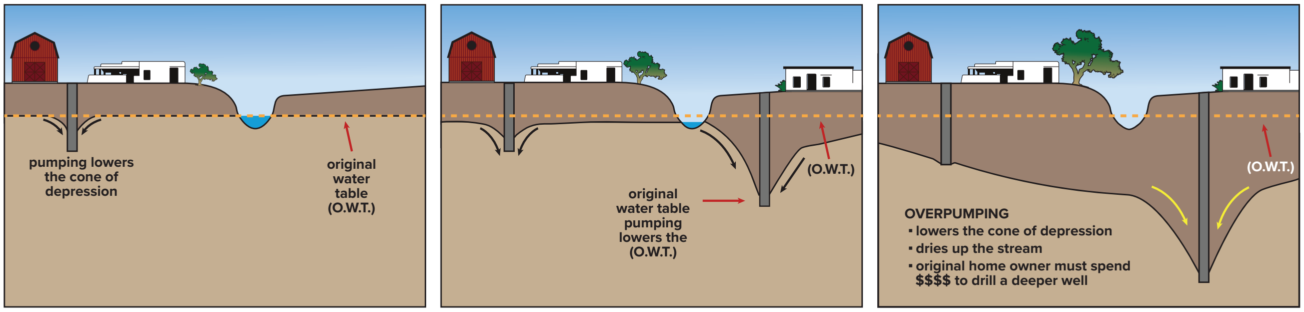


Figure 2.4 Overlapping drawdown cones can lower the water level to the point where neighboring homeowner wells and streams can go dry. Source: U of A WRRC. Adapted from the Artiola, Uhlman, Hix, 2017. *Arizona Well Owner's Guide to Water Supply 2nd Edition*

2.4 Aquifer Recharge

A natural resource, such as water, qualifies as a renewable resource if it is replenished by natural processes at a rate equal to or faster than its rate of consumption. A nonrenewable resource cannot be remade, regrown, or regenerated on a scale comparable to its consumption.

Although both surface water and groundwater are considered renewable resources in regions with plentiful rain and snow, groundwater is considered a nonrenewable resource in the arid west and across Arizona. According to data compiled by the Arizona Department of Water Resources (ADWR), there is insufficient rainfall in Arizona's dry climate to sustain river flow and reservoir storage to meet the growing population demands. Groundwater pumping exceeds the rate of aquifer recharge, causing **overdraft** in aquifers, especially those serving large population centers or having extensive areas of irrigated farmland. This can lead to dropping groundwater levels and land subsidence.

Recharge is the means by which the aquifer is filled with water, usually by rainfall or snowmelt infiltrating into the ground. Several factors impact infiltration and percolation through the vadose zone (unsaturated soils and rocks), including soil type and precedent moisture, climate and land use, topography, precipitation rate and type, available pore space, and aquifer type.

Most aquifer recharge occurs along the mountain fronts when runoff rainfall from the mountains makes its way to fractured rock and coarser-grained materials in the mountain front that allow the water to infiltrate rapidly. If all the pore spaces and fractures are filled with water, no more recharge can occur, and the excess water flows over the land surface to washes and streams. Shallow wells near surface water or washes, with a water table with 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 and evapotranspiration of water within the root zone. Most Arizona wells, however, are at a distance from their recharge source and are less likely to exhibit seasonal changes. Most regional aquifers across the west, and in Arizona, have not received significant volumes of recharge for hundreds to thousands of years.

2.5 What does this mean for well owners?

- Groundwater is stored in aquifers.
- Geologic characteristics of the aquifer impacts the movement of water to and from a well.
- Understanding geologic characteristics can provide us with insights into how quickly the aquifers recharge, achievable well yield, and how susceptible wells may be to contamination.

Aquifer Recharge and Contamination

Higher rates of **recharge** also mean higher risk of contamination, as water contaminants can make it into the groundwater quicker. Thus, wells that are located in areas with high rates of recharge, such as mountain fronts or **alluvial** wells near stream beds may be more susceptible to contamination from human derived contaminants, especially from contaminant sources in close proximity. For example, agricultural runoff can introduce pesticides or nitrate contamination into the aquifer and well. More information about the types of water contaminants, testing water quality, and ways to protect your water quality are included in the following sections.

Resources

Videos:

- *Arizona Aquifers*. 2013. UofAZCALS YouTube. https://www.youtube.com/watch?v=jZHeO46SQtk&list=PLk4rXk_uk7PkbZivdzVaZRbOM0lwhVd5Q
- *Arizona Groundwater Episode 2 – Groundwater Basics*, 2022. Project Wet YouTube. https://www.youtube.com/watch?v=TQNawfSkBM4&list=PLI7_I38IJ9TKgnT2QgRQDIQGaAfU4bQ_o&index=2
- *Well Components. 2013*. UofAZCALS YouTube https://www.youtube.com/watch?v=BLw2TO140J4&list=PLk4rXk_uk7PkbZivdzVaZRbOM0lwhVd5Q

Publications:

- *Arizona Well Owner's Guide to Water Supply, 2nd Edition*. 2017. Extension Publication #AZ1485
- *ADWR Land Subsidence Monitoring Report No. 4*. 2019. https://www.azwater.gov/sites/default/files/ADWR%20Land%20Subsidence%20Monitoring%20Report_Number4_Final.pdf

SECTION 3

WELL INSTALLATION AND PERMITTING

Installing or gaining ownership of a water well requires (1) knowledge of well permitting regulations in the state of Arizona and/or on Tribal Lands and (2) responsibilities of the well owner, drilling contractor, and pump installer. Well ownership requires a basic knowledge about the aquifer, well components, and if applicable, an understanding of the legal contract associated with your shared well. In Arizona, all wells, including domestic wells, are permitted and regulated by the **Arizona Department of Water Resources (ADWR)**. This section provides an overview of this information and resources to access updated information. Since state permitting requirements may change, it is recommended that well owners check the ADWR website for the most up to date information.

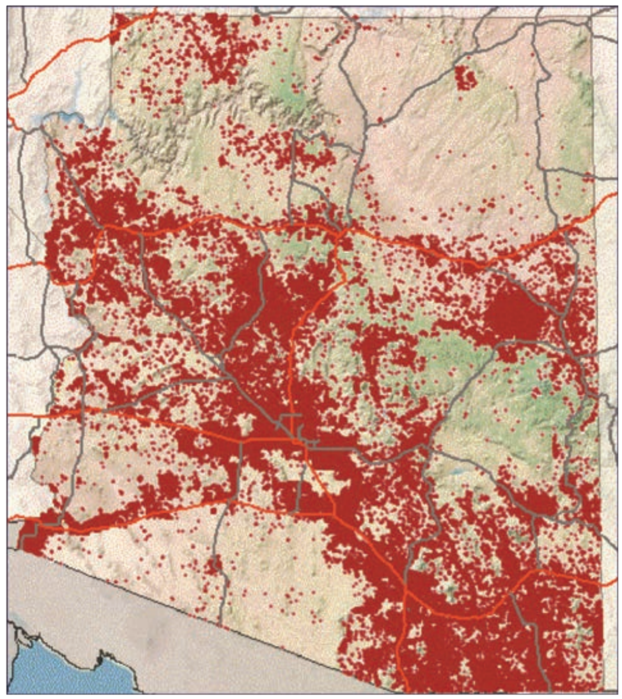


Figure 3.1. Domestic wells in the ADWR database. (2014) An updated map can be found on the ADWR website, https://azwatermaps.azwater.gov/wellreg/.

3.1 Registered Domestic Well

All wells in Arizona must be approved or permitted by ADWR. Most **domestic purpose** water wells are classified as “exempt” wells, allowed to pump up to 35 gallons per minute (GPM) and irrigate less than two acres. They are exempt from having to report their pumpage to the state, hence the classification as an “exempt well.” A well that is permitted to pump more than 35 GPM is classified as a “non-exempt” well and may have other uses, such as irrigation, public water supply, or mining. This classification, and the fact that some older wells may not be registered, makes it difficult to determine precisely just how many private domestic water wells are in Arizona, but as of October 2025, there were 118,955 wells registered with ADWR. Wells registered in the ADWR database are denoted by a red dot in Figure 3.1. Five to seven percent of Arizona residents have private, shared, or community exempt water wells, so the total number of people who rely on groundwater from a given well for their household and drinking water is not known.

Well record information is available on the ADWR Well Record Search found at **https://app.azwater.gov/WellRegistry/SearchWellReg.aspx** and on the interactive mapping tool found at **https://azwatermaps.azwater.gov/wellreg/**. Private well owners are encouraged to verify the information the ADWR has on file for their well. It is especially important that private well owners keep their own records of their well permits and logs, pump, controls, tanks, and treatment system operating manuals, and water testing results. No state agency oversees exempt water well withdrawals or monitors their water quality. It is the well owner’s responsibility to test the well water quality.

3.2 Domestic Well Permitting

Water wells drilled in Arizona must be approved or permitted using one of several Notice of Intention (NOI) forms that can be submitted on the ADWR Constituent Portal at: **https://www.azwater.gov/adwr-**

customer-portals. Updated procedures and forms can be found on the ADWR website. Only Tribal Lands and some federal lands are exempt from this requirement.

Obtaining authority to drill a water well requires approval of the well's location for parcels with an area of 5 acres or less by the county where the land is located. Some counties have fees for their review and approval. Their approval must be obtained prior to submitting the NOI to the ADWR. At the county level, the approval process is also linked to new septic system installment or revision, and is an effort to reduce the incidence of septic overload impacts to domestic wells.

In addition to permitting water wells, ADWR also licenses well drilling contractors, who must also hold licenses from the Registrar of Contractors (ROC). Water well drillers licensed by the ADWR are required by Arizona Statute ARS §45-600A to submit a well driller report and **well log** (Form 55-55) within 30 days of completing a well. This form includes important well construction information such as aquifer geology, total well depth, screen length, pump setting, and measured pumping capacity of the well when installed. This form provides important details about your well and should be kept for future reference.

Some water well drillers do not install pumping equipment. The equipping of the well for domestic use is usually completed by water well pump installers. They do not drill wells and therefore are not required to be licensed by the ADWR, but they are required to have a contractor's license from the Arizona Registrar of Contractors (AZ ROC). ARS §45-600B requires the well's registered owner to report to ADWR the static and pumping water levels, pump size, and motor installed in the well, and the resulting gallons-per-minute discharge during a four-hour pump test by filing a Pump Installation and Well Completion Form (55-56). All subsequent pump replacements in the well must be reported to ADWR using this form.

The Groundwater Management Act of 1980 (GWMA 1980) also calls for private well owners to keep the ADWR informed of changes of well ownership or registration (Form 55-71A), inform them of the pumping equipment in the well (Form 55-56), and the operational status of the well, whether it's active, capped (Form 55-39), or abandoned (Form 55-36). Details about these forms and other forms are available on the ADWR website.

In addition, if you are within the service area of an existing water utility, you may be prohibited from installing a new well. Since January 1, 2006, ARS §45-454C prohibits the drilling of an exempt well on any parcel of the land if within 100 feet of an operating water distribution system of a municipal provider that has an assured water supply designation within an Active Management Area (AMA) (see Section 6 for information on AMAs).

Each Active Management Area (discussed in Section 6) may have different groundwater management goals and reporting requirements.

In all instances, your contractor should be aware of the local issues and constraints on the installation of a new domestic water supply, and your contractor will submit the documentation to the appropriate jurisdictions. However, you are responsible to assure the information they provide is correct because you must sign the NOI.

3.3 Domestic Well Permitting on Tribal Land

ADWR specifically, and the state of Arizona in general, has no regulatory authority on Tribal lands. Water well drilling approval and permitting procedures in Tribal Nations are dependent on the Tribal water management entity, which may be a Department of Water Resources, Division of Water, or Department of Community Operations, depending on the government structure. For some Nations, many of the steps are similar to ADWR's procedures, such as submitting a NOI before drilling, working with an approved well driller, and/or submitting a well log. However, there may be important differences, including a requirement to obtain an archeological clearance and/or receive written approval from a leaseholder or farm plot holder. Specific details about well permitting and records should be obtained from the appropriate water management entity.

Appendix VI provides a list of relevant Tribal departments and contacts that may be able to provide more information about well permitting and record keeping requirements.

3.4 Initial Well Disinfection

ADWR regulations state that all wells destined to be used as a source of drinking water shall have the well-

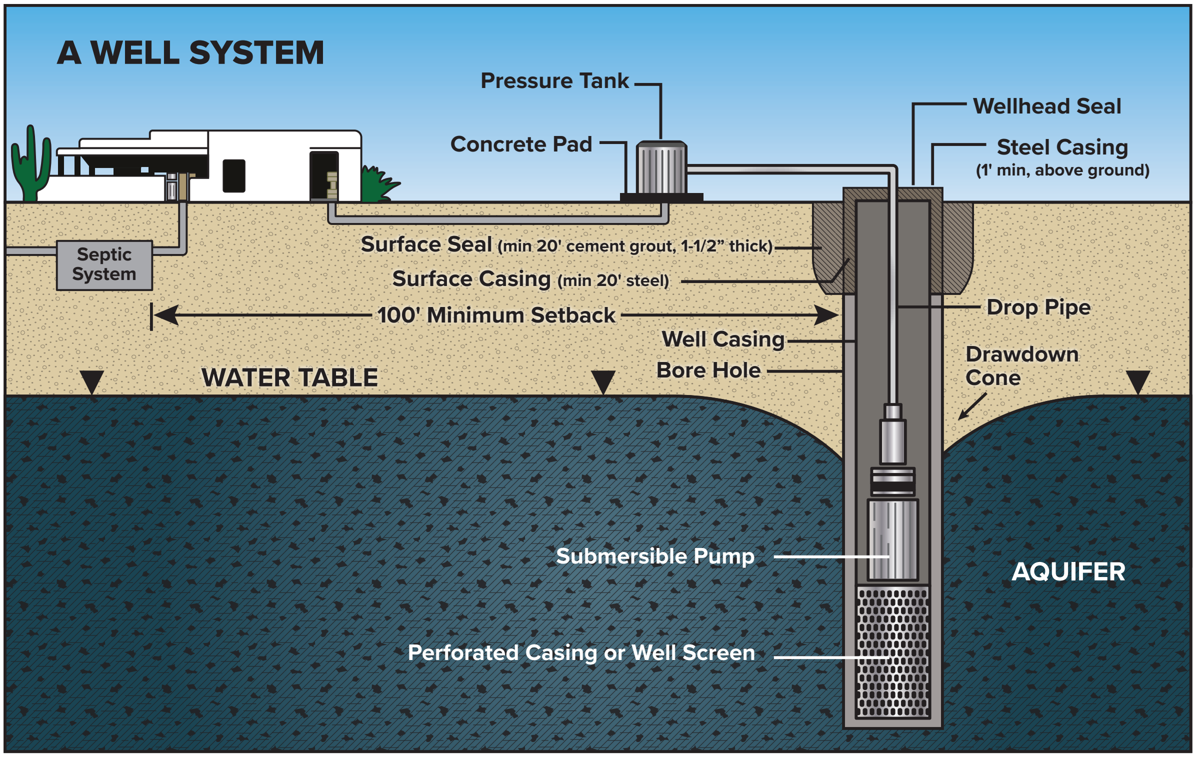


Figure 3.2 An Arizona Domestic Well System. Source: U of A WRRC. Adapted from the Artiola, Uhlman, Hix, 2017. *Arizona Well Owner's Guide to Water Supply 2nd Edition*

drilling contractor "disinfect" and, subsequently, sample the well for total and fecal coliforms before removing the rig from the completed well. This bacteria sampling is the only occasion that water quality testing and disinfection of the well is routinely done by the well driller, and it is strongly encouraged by ADWR. Disinfection should also be conducted after any well maintenance or new pump installation. The well owner should request this procedure. More information about well disinfection is provided in sections 4.2 and 9.4.

3.5 Well Components

ADWR guidelines identify basic well components and required minimum dimensions, as shown in Figure 3.2. In addition to pumps, these include well casings, sanitary seals, well caps, well screens, and storage tanks.

Well Casing

The well casing is a pipe placed in the borehole. The casing keeps the well open and helps prevent the mixing of materials from different zones of the aquifer. Within the casing is the drop pipe, which carries the water to the surface and the electrical wiring to the submersible pump.

A typical domestic water well will have two well casings – an outer or surface sanitary seal casing and an inner well casing that may be constructed of either steel or PVC. Current regulations require the outer casing to be constructed of steel and extend at least 1-foot minimum above the land surface. This outer casing extends to a minimum depth of 20 feet below land and is cemented around the annular space between the casing and borehole with a minimum of 20 feet of cement grout, at least 1-1/2 inches thick, between the casings and borehole. This serves as a sanitary surface seal, reducing the likelihood of ponded surface water around the wellhead seeping down into the aquifer. Outer well casing for domestic wells can vary from 4 to 8 inches in diameter, depending on aquifer conditions, final depth of the well, and the type of pump to be installed. The inner casing and/or the casing that extends below the 20-foot seal may be constructed of carbon steel, plastic (usually ASTM Schedule 80 PVC), or stainless steel. Older wells, drilled before 1980, may be constructed of concrete, fiberglass, and asbestos cement. Hand-dug wells may be lined with brick or stone. Hand-dug wells do not meet current well construction standards for sanitary surface seals and well head covers to prevent bacterial contaminants from entering the well.

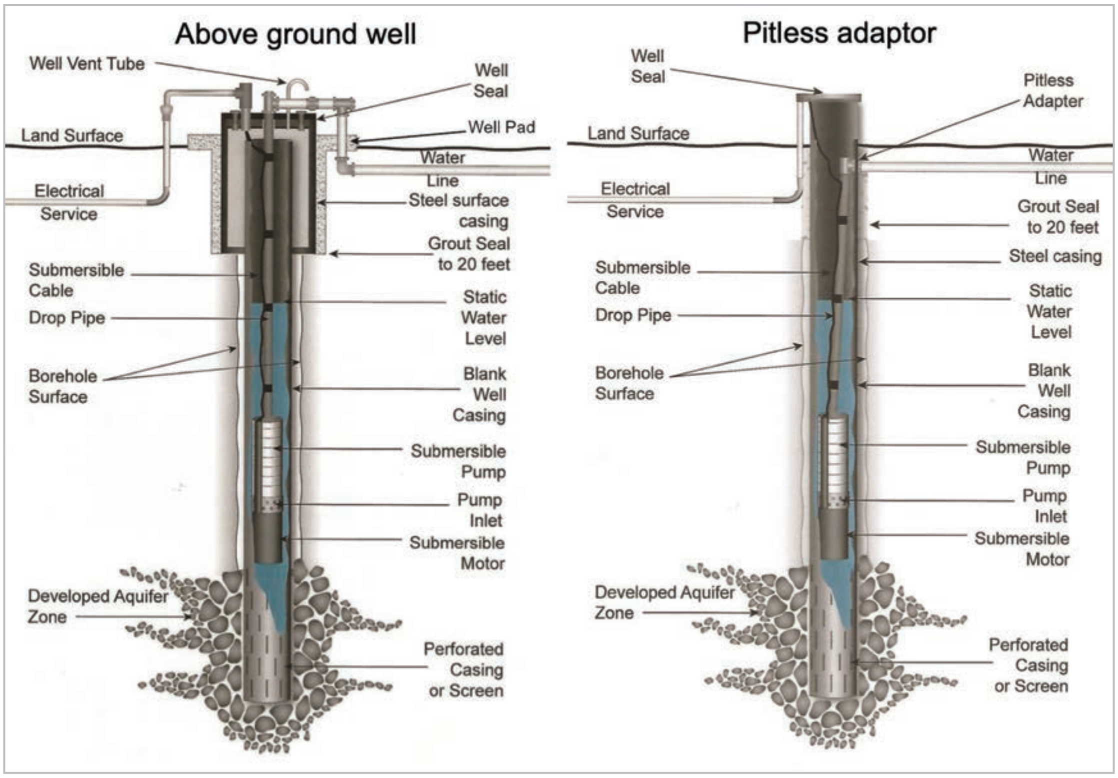


Figure 3.3 Examples of an above ground well (left) and a well with a pitless adaptor connection (right). Source: Gary Hix

To minimize the risk of contaminating the well water with solvents, PVC casing sections should be joined without glue. If PVC primer and solvent cement have been used, water tests in newer wells may indicate low levels of solvents in the water. However, over time, the solvent will flush out of the system. Many of the domestic water well drillers today are using a PVC well casing with couplings that do not require glue. The definite advantage is that the well casing can be removed quickly and reinstalled if it does not all go down the borehole on the first try.

Single casing wells, where the sanitary seal casing is built into a pitless adapter completion, are far more common in the northern portions of the state to avoid frost damage. In the southern desert portions of the state, wells are more typically completed with above-ground plumbing and electrical connections. Illustrations of both styles of well completions are depicted in Figure 3.3.

The pitless adapter completion has the electrical wiring entering and the plumbing exiting the well casing in the ground below the soil frost line. This form of well completion is most common in the mountainous northern regions of Arizona. One advantage of the pitless adapter installation is that the well head does not require freeze protection. Other components of the water system, like tanks and pressure switches, can be located some distance from a pitless well. The above-ground completion has both the electrical and plumbing exiting out the top of a well. The plumbing can be wrapped with insulating materials and/or housed within a well house for freeze protection, where dictated by winter weather temperatures.

Sanitary Seal

Coupled with the 20 feet of grout, the sanitary seals prevent the infiltration of surface water into the annulus of the borehole and to the water level. Wellhead sanitary seals feature a concrete apron, sloped away from the well casing pipe. This keeps rodents from burrowing alongside the well casing and keeps rain and flood waters away from the wellhead. If a concrete apron is not present, the land surface near the wellhead should slope away from the surface casing.

Domestic wells drilled before 1980 were not required to have this sanitary surface seal; they were "grandfathered in" as constructed until they are deepened or modified in any way. Most domestic water wells drilled before 1980 were drilled using the earlier cable tool method and were made of 8-inch diameter steel casings driven into place and perforated after installed. These wells can be deepened if the groundwater level drops significantly.

More recently constructed domestic water wells are constructed of four-to-five-inch diameter PVC well casings. Common rotary drill pipe today measures 4.5-inches in diameter, preventing drilling deeper inside the PVC well casing.

Figure 3.4 is a photo of the sanitary grout placed around the surface casing during well construction.

Caps

Arizona rule states that "Every well with casing four inches in diameter or larger shall be equipped with a functional water tight access port." The vent/access port in the well seal or pitless cap is desired to easily access the well for maintenance/water level measurements and because water wells breathe air in and out many times a day. Wells take in air as the water level is drawn down during pumping, and they push air out when the pump shuts off, and the water level recovers back to static. Wells also breathe as atmospheric pressure changes take place due to passing weather fronts. Water well caps should be vented through holes smaller than what insects, reptiles, or rodents can enter, as seen in Figure 3.5.

Well Screens

Well screens allow groundwater to enter the well and help prevent sediment from entering the well, keeping out most of the sand and gravel. The most common screens used in domestic water wells are made of slotted or perforated pipe and are made of mild steel or PVC.

Figure 3.4 Photo of the sanitary seal grout around the surface casing of a well in construction. Source: Artiola, Uhlman, Hix, 2017. Arizona *Well Owner's Guide to Water Supply 2nd Edition*

Figure 3.5 Example of a well cap made of aluminum. Source: Artiola, Uhlman, Hix, 2017. *Arizona Well Owner's Guide to Water Supply 2nd Edition*

Well screens are manufactured with specified openings and slot diameters to accommodate local geologic conditions. They are placed in the saturated part of the aquifer and may be damaged if the groundwater elevation drops.

Storage Tanks

The domestic well system may be configured to pump water into a storage tank at atmospheric pressure or into a pressure tank. There are advantages and disadvantages for both. Low **yielding** water wells (2 to 5 GPM) are most commonly pumped to water storage tanks and later boosted to pressure tanks at greater flow rates.

Above-ground storage tanks are exposed to both hot sun and cold winter weather, storing the water at atmospheric temperature and pressure until it is needed. They can be constructed of galvanized steel, mild steel, fiberglass, or polymer plastics, as shown in Figure 3.6. In the Arizona summer, the water in storage is warmed to a temperature that can encourage microbial and algal growth. Because of this, the tank should be periodically cleaned and chlorinated. Well owners who have groundwater storage tanks are referred to the Cooperative Extension Bulletin AZ1586 "Water Storage Tank Disinfection, Testing and Maintenance."

In most Arizona domestic wells, the pumping capacity of the submersible pump and the yield of the well are such that groundwater is pumped directly into captive air bladder tank(s). This water system design, as shown in Figure 3.7, reduces the concern for bacterial contamination since the water comes directly out of the ground and goes directly into a pressure system without coming into contact with air. The captive air bladder tank sustains pressure throughout the household plumbing, including water treatment systems, and stores water for periods of heavy water usage.

Figure 3.6 Above ground storage tank and well house, in northern Arizona. Source: Artiola, Uhlman, Hix, 2017. *Arizona Well Owner's Guide to Water Supply 2nd Edition*

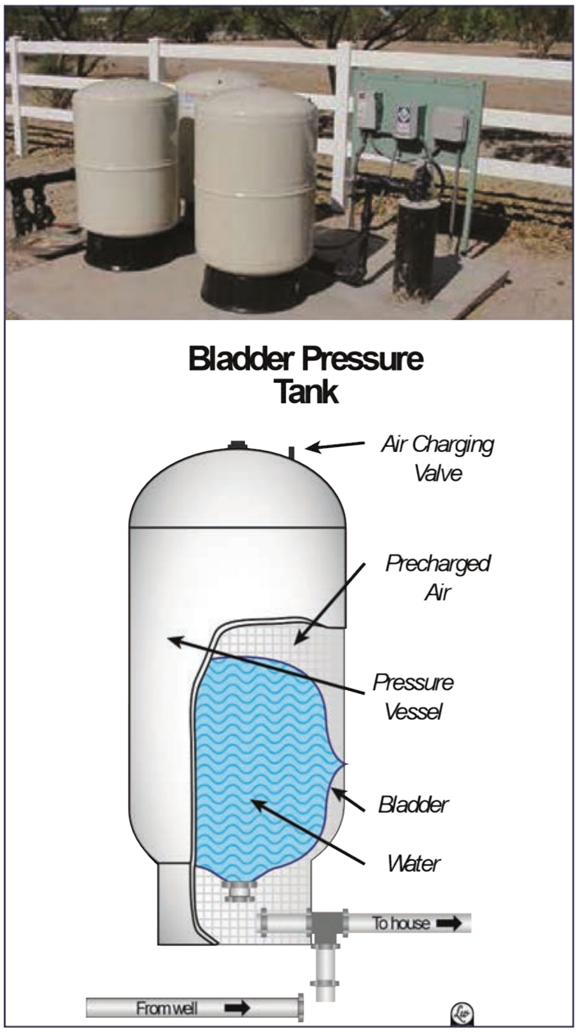


Figure 3.7 Captive air bladder tank for a private well system. Source: Artiola, Uhlman, Hix, 2017. *Arizona Well Owner's Guide to Water Supply 2nd Edition*

The pressure switch, (see Figure 3.8), is possibly the most important piece of the water delivery system that homeowners can readily observe, maintain, and, to some extent, adjust. Well owners should observe this component to assure that the small pipe stem that connects it to the system is insulated and protected from freezing. A pressure switch must sense and respond to changes of water pressure. Note that changing the pressure switch settings will also require adjusting the air pressure inside the bladder tank.

Figure 3.8 Captive air bladder tank pressure switch. Source: Artiola, Uhlman, Hix, 2017. *Arizona Well Owner's Guide to Water Supply 2nd Edition*

Additional above-ground equipment found in domestic water systems might include a valve that can shut off the water from the well and pressure tank whenever there is a need, such as a water leak. Well and pump contractors will typically install a pressure relief valve somewhere in the system so that if the pump producing the water pressure does not shut off, a 75 PSI relief valve will vent the water to keep from overpressurizing the system, which could explode the pressure tank.

Low yield wells may need storage tanks that can hold 2,000 gallons of water, usually adequate for a single-family residence. If a number of homes share a single exempt well, then a storage tank of 5,000 gallons, two booster pumps, and a number of pressure tanks would be a more typical design, shown in Figure 3.9.

3.6 Shared Wells

Wells that provide drinking water for community systems are regulated by state and federal law. These water systems, termed **public water systems**, serve at least 15 residential service connections year-round or at least 25 residents year-round who use the water for drinking, cooking, bathing, and cleaning. Water supply systems that serve fewer than 15 service connections are non-

Figure 3.9 A shared well system with above ground storage and two pressure tanks, delivering water to two households. Source: Artiola, Uhlman, Hix, 2017. *Arizona Well Owner's Guide to Water Supply 2nd Edition*

regulated and are considered merely shared private wells. Shared wells are a civil matter between the private parties that agree to share the well. If you are on a shared well system, you should consider entering into a legal contract agreement to:

- Acquire and protect access to your water supply if the well is not on your parcel;
- Stipulate costs and responsibilities for well maintenance;
- Address the operation of the well and water distribution system. If the well is on another property, you may be limited to access to the well unless stipulated in the contract. If the well is on your property, you may be held responsible for operation and maintenance by default;
- Set an annual fee and shared expenses; and,
- Require that the well water be tested annually to make sure it is safe to drink.

For an example of a shared well agreement recommended by the U.S. Department of Housing and Urban Development, visit the agency's website at **www.hud.gov**. Well owners can record their shared well agreement with the County Recorder's Office. Additional information can also be found in Extension Publication AZ1810 and in the resources listed at the end of the section.

3.7 What does this mean for well owners?

- Domestic wells require permits for well drilling, modification, or deepening that should be submitted to ADWR and in some cases Tribal departments. After filing documents like the drill log, a pump report and changes of ownership. or information must also be submitted.
- Submitting the drill log is the responsibility of the well driller. Other permits and forms, including the pump report, are the responsibility of the well owner.
- Well owners should always keep records of well logs for future reference (e.g. permitting and maintenance).
- Wells include many standards component include well casings, sanitary seals, well caps, well screens, and storage tanks. Understanding the function of these components can help well owners to maintain their system and identify failures.
- If you use a shared well, you should have a properly worded, legally and properly prepared, signed and notarized shared well agreement recorded in the county where the shared well is located.

Resources

Websites:

- ADWR Well Record Search, **https://app.azwater.gov/WellRegistry/SearchWellReg.aspx**
- ADWR interactive mapping tool, **https://azwatermaps.azwater.gov/wellreg/**
- HUD Shared Well Guide, **https://archives.hud.gov/offices/hsg/sfh/ref/sfh1-21c.cfm**

Videos:

- *Well Components*. 2013. UofAZCALS YouTube, **https://www.youtube.com/watch?v=BLw2TO140J4&list=PLk4rXk_uk7PkbZivdzVaZRbOM0lwhVd5Q**

Publications:

- *A Guide for Operating Shared Water Wells In Arizona*, 2020. Extension Publication #AZ1810
- *Private Well Components*. 2011. Extension Publication #AZ1486
- *Guideline for the Construction of Water Systems*. 1978. ADEQ Engineering Bulletin No. 10, **https://static.azdeq.gov/er/eb10.pdf**
- *A Practical Guide to Drilling a Domestic Water Well in Arizona*, 2019. ADWR, **https://www.tucsonaz.gov/files/sharedassets/public/v/1/pdsd/documents/boards-committees-commissions/planning-commission/02.15.23/attachment_e_-_a_practical_guide_to_drilling_a_domestic_water_well_in_arizona.pdf**
- Hix, G. (2026). *Groundwater Sharing Contracts: Formerly Called Well Sharing Agreements*. Writer's Publishing House

SECTION 4

WELL OPERATION AND MAINTENANCE

Maintaining the amount of water produced by a well, termed **yield**, and water quality are of the utmost importance for any well owner. Microbial growth and chemical precipitation may occur and can cause low well yield and water quality issues.

The prevention of microbial growth and well screen blockage requires a carefully planned program of well rehabilitation from time to time. Any decline in the performance of the well may indicate the need for rehabilitation. If the cost for operating the well has been slowly increasing, it may be time to investigate it for biofouling, sediment buildup, or a sustained drop in the water level. It takes a trained professional with the proper equipment to remove and install pumps in wells and to safely handle the chemicals used to rehabilitate wells.

This section provides an overview of causes of low well yield, troubleshooting strategies, and overall best practices for well maintenance. Additional resources, including resources for measuring depth to groundwater for your well, are provided at the end of the section.

4.1 Well Yield

All water wells begin a gradual decline in performance from the first day they are drilled and constructed. There are three primary factors causing this slow decline in performance: biological slime buildup (microbial growth) in the aquifer and well screen, scale formation (chemical precipitation) and sediment buildup blocking the perforations in the well screen, and long-term decline of aquifer water levels.

Microorganisms existed in the subsurface and groundwater even before the borehole was drilled and the well was installed. Introduction of water from another source during drilling, plus the introduction of oxygen, iron, and other elements during the well construction and groundwater with nutrients, provide a suitable environment for bacteria to flourish and form biomass. An extreme example is shown in Figure 4.1.

Figure 4.1 Buildup of biological slime and mineral crust on a submersible pump inlet. Source: Gary Hix

As water enters the well, it quickly goes from being under **hydrostatic** (water) pressures to atmospheric pressure. Entrapped gases are released, and some minerals come out of solution, **precipitate**, forming scale (just like the scale that may form on your tap). Years of drawing groundwater into the well brings with it trace amounts of clay, silts, and fine sands. Eventually, these minerals build up in the well, get trapped in biomass growth, and accumulate within the well screen, eventually reducing the flow of water into the well, as shown in Figure 4.2.

Low-yield wells are especially susceptible to water quality problems. When the water level changes often, the pump is more likely to cycle on and off, which introduces oxygen into the aquifer. Electricity use may also increase as groundwater levels drop. Some minerals in the aquifer that are exposed to oxygen can dissolve into the groundwater and release contaminants. If the aquifer

Figure 4.2 Scale formation on a well screen. Source: Artiola, Uhlman, Hix, 2017. *Arizona Well Owner's Guide to Water Supply 2nd Edition*

contains arsenic minerals, contact with oxygenated water may increase the concentration of dissolved arsenic.

Several factors can reduce a well's yield:

- Declining groundwater levels;
- The development of mineral scale on the screens or perforations; and,
- The accumulation of bacterial slime that plugs the pores in the aquifer and the well screen.

In extreme cases, the combined effect of scale and slime has been reported to reduce well yield by 75 percent within a year of well operation. Bacterial slime can also cause serious health problems (see Section 5).

4.2 How to Improve Well Yield

To properly rehabilitate a low-yielding groundwater well, you need to know the cause of the problem and the type of aquifer involved. The solutions may include deepening the well, hydraulic fracturing, shock-chlorinating (to remove microbial growth), buffered acid treatment to remove calcium scale, scrubbing or wire brushing, and/or redeveloping the well.

Shock Chlorination

The best method for control of the slow decline in well performance is to begin by making sure the well was properly disinfected when initially drilled and after any pumping equipment has been installed. This requires the pump installer, who may not be the well driller, to shock chlorinate the well. Wells should also be shock chlorinated after any maintenance inside the well or when new pumping equipment is replaced, and especially if the well water testing results are positive for bacteria.

An operating well plugged with biological slime can be shock chlorinated to kill the microorganisms and improve its yield. Hire a licensed and qualified water well contractor to shock chlorinate the well instead of trying it yourself. Be mindful that excessive well chlorination may dissolve any arsenic-bearing minerals present in the aquifer, increasing the concentration of arsenic and other contaminants in the groundwater. Therefore, after the shock chlorination is completed, the entire plumbing system should be flushed and refilled with sanitized water. Dead end or seldom used components of the distribution system also must be flushed. Additional water testing should be performed after shock chlorination and flushing.

Redevelopment

Well yield can be increased by the redevelopment of the well. Redevelopment consists of two steps: (1) scrubbing the interior of the well screen and (2) the temporary installation of a high-capacity pump to force water flow into the well at a velocity greater than the well's operation rate to remove fine sand accumulated near the well screen. Figure 4.3 depicts a cross section of well re-development, which pulls fine grained sediment into

Figure 4.3 Well re-development removes fine-grained sediment from around the well. Source: Artiola, Uhlman, Hix, 2017. *Arizona Well Owner's Guide to Water Supply 2nd Edition*

and out of the well. After redevelopment, the well will operate more efficiently.

Well Stimulation

Well stimulation, sometimes known as **hydraulic fracking**, is used in oil and gas production, in addition to water wells, to improve yield. Well stimulation is applicable only to open borehole wells with no screens, drilled in dense **consolidated**, hard rock such as shale. Well stimulation does not work in **unconsolidated** rock because the pressure needed to fracture the rock is rapidly dissipated. The process involves pumping water to pressurize short sections of an open borehole to enlarge fractures in the rock. For oil and gas wells, fine sand is pumped into the borehole to prop open the new mini fractures; this added step is not typical for water wells. Well stimulation has been used to increase the yield of large, municipal wells in the Coconino Formation of northern and central Arizona (a fractured consolidated sandstone formation), but is less common for domestic wells.

Carbon dioxide

Some well owners have increased their well yield by dropping dry ice in the well. As the carbon dioxide gas bubbles from the dry ice, the water becomes more acidic, which dissolves parts of the carbonate-based scale and kills some of the microorganisms. The agitation of the bubbling dry ice in the well casing may also loosen some of the particulate scale. The agitation caused by dry ice can become violent, throwing columns of water high into the air. **A well should never be capped or sealed when dry ice is used as an agitator, as it can produce very high pressures**.

Municipal water systems are beginning to use pressurized carbon dioxide gas to sanitize their well systems. The downside of using carbon dioxide is that acidifying the water can corrode metal plumbing.

4.3 Well Maintenance Tips

The amount of maintenance a homeowner can perform on their domestic water well is somewhat limited due to the location of the well on the property and the operating equipment installed in the well. Some owners may have unwittingly blocked well access, not thinking about what might need to be done to pull and replace the pump at a future date. Figure 4.4 is a photo of a well inside a metal sculpture, preventing easy access. Here are some tips that well owners can follow to better maintain their wells:

Figure 4.4 Photo of well inside a metal sculpture, preventing access. Source: Artiola, Uhlman, Hix, 2017. *Arizona Well Owner's Guide to Water Supply 2nd Edition*

- Protect the well and electrical controls from direct sunlight, rain, and extreme cold conditions.
- Protect the wellhead and electrical controls from vandalism and unauthorized access.
- Inspect and document the working conditions of your well and water system equipment periodically to detect subtle changes of performance that might be taking place.
- Keep a permanent record of your well's performance. Install a water meter and record your monthly pumpage to detect a change in your water usage that might indicate a leak.
- Troubleshooting some common issues can be found in Cooperative Extension Service Bulletin AZ1581 "Maintaining and Troubleshooting Wells."

Annual well inspections and testing can be performed by well owners. If they are not comfortable with performing these tasks, a local licensed water well contractor may be willing to perform an annual well inspection for a fee.

Most domestic water wells can, and do, give their owners many years of good service providing sufficient quantities of good quality water. Like other real estate improvements, wells require minor maintenance and proper management.

4.4 Well System Failure

All well systems are vulnerable to mechanical failure that can sometimes lead to pollution of the water supply. The water can become contaminated because of corroded steel well casings, cracked or broken sanitary surface seals, and standing water that slowly seeps back into the aquifer along the outside of the well casing.

Pump or plumbing failure should always be addressed by a licensed well professional or contractor. Figure 4.5 shows a pump that failed after being corroded by stray electrical currents. Stray electrical currents are caused by improper insulation of the electrical wires or improper grounding of the system. Water forced through a hole in the drop pipe suspending the pump can create a hole in the steel casing, causing the well to collapse and the system to fail.

In Arizona, the most common cause of well system failure is declining groundwater elevations associated with aquifer over pumping and/or drought. Water levels often drop seasonally or during severe droughts, and some low-yield aquifers that do not **recharge** quickly may be responding to a drought that started decades ago. If the groundwater level drops to a level near the pump inlet, air mixes with the groundwater, causing corrosion of the pump impellers.

The first sign of system failure due to declining groundwater elevations is the buildup of sediments in tanks, pipes, and plumbing fixtures, (see Figure 4.6), and pump cycling. If the well pump continues to produce gritty sand, the pump itself can be damaged and might have to be replaced. If the well runs dry regularly, consider installing a submersible pump protection device. The following are additional steps to identify and protect your system from dropping groundwater:

- Listen to the pump. If pumping causes the sounds of “sucking air,” turn the pump off and allow the well to rest for a few hours.
- If the pump is rapidly cycling, consider the installation of a pump/motor protection device, which monitors load and power conditions. Some systems monitor and diagnose motor load to prevent pump or motor failure due to conditions such as low-flow wells, pump damage, clogging, or power surges.
- Watch for milky water. Water that appears milky at first and then clears after standing can be caused by the pump drawing air and may indicate that the pump is pulling water near the level of the inlet.
- Consider lowering the pump in the well. Depending on the depth of the well and the capacity of the submersible pump motor, lowering the pump may be an option. Check with a licensed pump installer.
- Have the water tested (see Section 7). As the water level drops and pulls air into the aquifer, the chemistry of the groundwater can change. Sometimes exposing the aquifer to oxygen causes an increase in groundwater contaminants, including arsenic, uranium, iron, and manganese, among others. Send well water samples to the lab for testing regularly during and after a drought.
- Reduce the well’s pumping rate and increase storage capacity. Lowered pumping rates and increased storage capacity may protect your water supply equipment and preserve your groundwater resource.
- Schedule water use. Work with your neighbors to schedule common or heavy water use. For example, if everyone in the neighborhood typically washes laundry on Saturday, the wells may begin to go dry on Sunday. Distribute heavy water use over the week to allow individual wells to recover and sustain the water supply in your neighborhood.
- Conserve water. For tips on saving water in the kitchen, bathroom, laundry room, and outdoors, see the list of Extension publications #AZ1298, #AZ1458, and #AZ1610.

Figure 4.5 Stray electrical currents formed a hole in this submersible pump, causing the well to fail. Source: Artiola, Uhlman, Hix, 2017. *Arizona Well Owner’s Guide to Water Supply 2nd Edition*

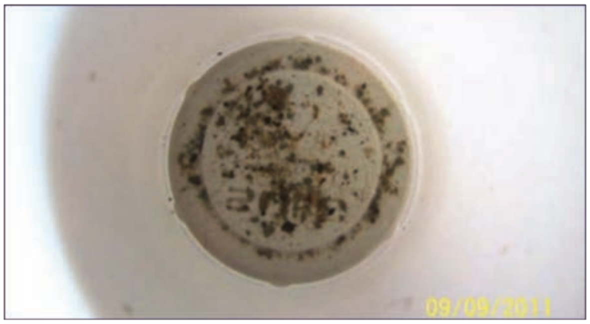


Figure 4.6 Sand and precipitated manganese particles, accumulated on the screen of an irrigation system. Source: Artiola, Uhlman, Hix, 2017. *Arizona Well Owner's Guide to Water Supply 2nd Edition*

- Consider installing a well water meter to measure, monitor, and manage your groundwater use.

4.5 What does this mean for well owners?

- Decreases in well yield can be caused by chemicals precipitating out of the water and/or biological growth within the well screen.
- Well yield can be improved in a variety of ways. In many cases a certified well driller should be consulted.
- Well owners can look out for signs of well system failure to catch issues early. These signs include pumps cycling or sucking air, sediment in the water, or milky water.

Resources

Videos:

- *Well Drilling and Pump Replacement*. 2013. UofAZCALS YouTube, https://www.youtube.com/watch?v=famolIL-kzo&list=PLk4rXk_uk7PkbZivdzVaZRbOM0lwhVd5Q&index=2

Hands-on:

- Arizona Community Science Alliance LABrary, https://azdeq.gov/ScienceAlliance
    - Sign up as a volunteer to borrow a water level meter to measure depth to groundwater for your well.

Publications:

- *Arizona Domestic Water Wells*. 2009. Extension Publication #AZ1504
- *Arizona Wells: Low Yield Domestic Water Wells*. 2011. Extension Publication #AZ1536.
- *Arizona Wells: Maintaining and Troubleshooting Wells*. 2012. Extension Publication #AZ1581.

SECTION 5

WHAT IS IN GROUNDWATER?

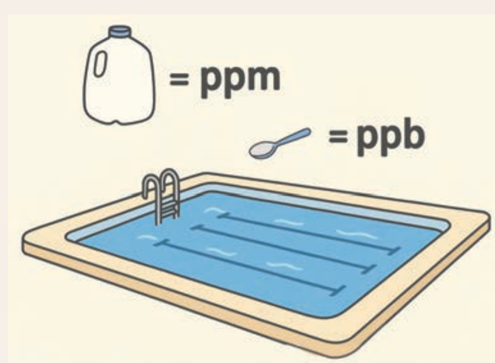
A nationwide study by the U.S. Geological Survey (2009) found that more than 20 percent of the private household wells tested contained one or more contaminants at a concentration greater than is recommended by the **US Environmental Protection Agency (EPA)**. A statewide groundwater sampling campaign found that this number is more than 30 percent in Arizona. In Arizona, the most common contaminants are arsenic, nitrate, fluoride, and gross alpha radiation. These contaminants have **Maximum Contaminant Levels (MCLs)** set by the EPA due to their known negative health consequences. Total dissolved solids (TDS) commonly exceed the EPA's **Secondary MCL (SMCL)** set for taste and odor. While domestic wells are not regulated, and therefore do not need to meet these drinking water standards, they are excellent references to ensure that your groundwater quality is safe. More information about MCLs and links to the EPA drinking water regulations are included in Section 6.

Groundwater includes a mix of minerals, organic matter, chemicals, and microorganisms that can (1) occur naturally, (2) be caused by humans, termed **anthropogenic**, or (3) be both naturally occurring and increased by humans. For example, nitrate contamination, although it can be naturally occurring in desert soils, is usually present 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. On the other hand, arsenic, fluoride, and gross alpha radiation are naturally occurring in groundwater, are dependent on aquifer geology, and are not likely to change in concentration over time.

It is important to remember that the presence of a contaminant in groundwater does not necessarily mean it will impact human health negatively. The duration of exposure (i.e., how long you have been drinking and/or cooking with the water), the concentration of the

What are all these units?

Before we get started discussing specific water quality components, we should first understand the units that we use to discuss them. When discussing water quality, we use units such as milligrams per liter that represent the mass of a substance per volume of water, similar to the way that soft drink labels display the mass of sugar per volume of drink. These units allow us to compare the water qualities in a standard way. Some of the common units for water quality are shown below:



- 1 milligram per liter (mg/L) = 1 part per million (ppm) = approximately ½ gallon in an Olympic sized swimming pool
- 1 microgram per liter (µg/L) = 1 part per billion (ppb) = approximately ½ tsp in an Olympic sized swimming pool

It has taken decades for scientists to develop instruments capable of measuring substances in water down to the ppb level. We are now able to measure water quality down to the parts per trillion level. That would be 1 drop in 20 Olympic-sized pools!

contaminant, how you use the water (do you drink it, cook with it, water your garden or yard), your health, and many other "puzzle pieces" factor into whether a contaminant can make you ill.

It is the well owner's responsibility to monitor, collect samples, and determine the water quality of domestic wells. The following sections provide additional insights into common water quality parameters in Arizona groundwater, including what they are, where they originate, and implications for water users.

Note: The threshold for water quality/water contamination is determined based on the water use. In this guide we will consider the use to be for drinking water. Other uses, such as for domestic, agricultural, livestock, and recreational, have different water quality requirements.

5.1 General Water Quality Parameters

Groundwater quality can be described by general water quality parameters. These parameters include **salinity** (measured as total dissolved solids (TDS)), hardness, and pH. They can give us an overall sense of what the water quality is, and many of these characteristics can help us to identify underlying issues with the water. Much like taking someone's temperature cannot diagnose a certain disease, general water quality parameters cannot inform us about specific contaminant levels or exceedances. However, these parameters can give us a good gauge and are relatively cheap to measure. For example, hardness and pH can be measured at home with simple test kits or test strips.

Total Dissolved Solids (TDS)

The level of dissolved minerals, including salts and dissolved minerals, in water is known as **TDS**. TDS is often referred to as a measure of salinity because the most common mineral in high-TDS water in Arizona is sodium chloride (NaCl). TDS can also be estimated from electrical conductivity measurements. Electrical conductivity measurements are typically recorded in micro-siemens per centimeter (µS/cm), where 1 µS/cm corresponds to approximately 0.6 mg/L TDS.

The following seven constituents make up about 95 percent of TDS in Arizona groundwater: bicarbonate, calcium, chloride, magnesium, potassium, sodium, and sulfate. These chemicals usually originate from the presence of common minerals like limestone, dolomite, gypsum, and salt in or near aquifers. There are other minor chemicals found in water like nitrate, fluoride, boron, selenium, and trace elements like iron, manganese, and arsenic. These constituents have very minor contributions to the overall TDS of the water, but are important to the quality of the well water.

The SMLC for TDS is 500 mg/L. Drinking water with more than 500 mg/L TDS is not necessarily unsafe. However, it may taste salty, clog pipes and water heaters, and stain laundry or plumbing fixtures, depending on the chemical composition. Additionally, water with high TDS can stunt the growth of crops and landscape plants. If your water has a high TDS, you may want to have it tested to determine the specific combination of minerals in the water supply. Then match the treatment method to the minerals in the water, or select the appropriate salt tolerant plant species.

There are a few regions in the state with especially high TDS, where groundwater exhibits salinities greater than 3,000 mg/L TDS, defined as brackish water (3,000 to 10,000 mg/L TDS). High salinity is either due to deep layers of salt, undrained desert basins, or playa formation, or in agricultural areas where evaporation of irrigation water concentrates naturally occurring salts. For reference, ocean water ranges between 30,000 and 40,000 mg/L TDS.

Additional information about some of the saline regions in the state is provided below:

- Holbrook Region: Naturally occurring salinity due to evaporated mineral deposits (evaporite deposits) from the evaporation of inland seas more than 260 million years ago.
- Gila River Valley (near Safford): Deep layers of salt that were penetrated by exploratory petroleum bore holes. Improperly sealed abandoned boreholes have discharged salt brines to local groundwater.
- Willcox Region: Naturally occurring salinity due to geologically recent evaporite deposits in shallow playa lakes; these surface water features are highly evaporative because they lack downgradient outlets. However, low salinity water is present in the deep aquifer in the Willcox Basin.

Salinity varies greatly throughout the state, as do other contaminants.

TABLE 5.1 WATER HARDNESS SCALE

Grains per Gallon	Milligrams per Liter (mg/L) or Parts per Million (ppm)	Classification
Less than 1.0	Less than 17.2	Soft
1.0 – 3.5	17.1 - 60	Slightly Hard
3.5 – 7.0	60 – 120	Moderately Hard
7.0 – 10.5	120 – 180	Hard
Over 10.5	Over 180	Very Hard

Conversion: 17.12 mg/L of $CaCO_3$ = 1 grain per gallon (gpg).

Table recreated from Artiola, Uhlman, Hix, 2017. *Arizona Well Owner's Guide to Water Supply 2nd Edition.*

Hardness

Hardness is a measurement of calcium, magnesium, and other minerals in water. The groundwater from a limestone aquifer is typically hard because of the calcium and magnesium dissolved from the rock. There are no primary or secondary standards for water hardness. However, hard water requires more soap for laundry and washing and causes scale to build up in dishwashers, washing machines, water heaters, and plumbing fixtures.

The hardness of water is often reported as an equivalent amount of calcium carbonate ($CaCO_3$) in mg/L or grains/gallon, see Table 5.1. High hardness is commonly treated with water softening units.

Acid or Basic Water: pH

The pH of groundwater is an important indicator of water quality because it affects how readily minerals dissolve into the water. Certain naturally occurring contaminants, such as arsenic and fluoride, are often associated with groundwater that has a higher pH. Other metals and minerals are more common in water with a low pH. Most groundwater sources in Arizona are slightly to moderately basic (pH greater than 7) and tend to be hard due to their mineral content.

pH also influences how water interacts with plumbing materials and affects taste. For example, low-pH (acidic) water can corrode metal pipes, leading to elevated concentrations of metals such as zinc and copper, which may cause a metallic taste. The recommended pH range for drinking water is **6.5 to 8.5**. Table 5.2 compares the pH of various common liquids to that of drinking water.

TABLE 5.2 pH SCALE

0	**Acidic**	Battery acid, strong hydrofluoric acid
1		Hydrochloric acid secreted by stomach lining
2		Lemon juice, gastric acid, vinegar
3		Grapefruit juice, orange juice, soda
4		Acid rain, tomato juice, beer
5		Soft drinking water, black coffee, pure rain
6		Urine, saliva, egg yolks, cow's milk
7	**Neutral**	Pure water
8		Sea water
9		Baking soda
10		Great Salt Lake, milk of magnesia
11		Ammonia solution, household cleaners
12		Soapy water
13		Bleaches, oven cleaner, household lye
14	**Basic**	Liquid drain cleaner

Table recreated from Artiola, Uhlman, Hix, 2017. *Arizona Well Owner's Guide to Water Supply 2nd Edition.*

5.2 Inorganic Contaminants

Inorganic contaminants include minerals and trace elements. They can be naturally occurring and/or anthropogenic. A groundwater quality sampling campaign by the Arizona Department of Water Quality (ADEQ) found that more than 30% of sites sampled had concentrations of inorganic contaminants above the EPA MCLs. The most common inorganic contaminants are arsenic, fluoride, and nitrate; however, other inorganic contaminants include copper, zinc, chromium, lithium, selenium, vanadium, sulfate, iron, manganese, and lead (typically from old plumbing rather than the groundwater itself). Inorganic contaminants are common in Arizona's groundwater and can be undetectable without testing because they can be colorless, odorless, and/or tasteless.

Arsenic

Arsenic is among the top three common contaminants found in Arizona's groundwater. Long-term exposure from drinking water increases the risk of cancer and damage to the skin, the nervous system, and the circulatory system. Exposure to arsenic has also been associated with fetal developmental effects, heart disease, and diabetes. In response to these and other potential health effects from arsenic in drinking water, in 2001, the EPA lowered the MCL for total arsenic in drinking water from 50 µg/L to 10 µg/L and required all public water utilities to meet this new standard.

Elevated concentrations of arsenic are found across the state (see Figure 5.2). Arsenic is naturally occurring in geology across the state, ranging from the sedimentary limestone and sandstone formations in Northern Arizona to the alluvium eroded from arsenic containing granite in Southern Arizona. The highest concentration of arsenic in groundwater in Arizona was found near Paulden, Yavapai County, with a concentration of 2,900 µg/L in a private, domestic well, more than 100 times greater than the EPA MCL for arsenic of 10 µg/L.

Like other minerals, the concentration of arsenic in water is dependent on the water's age in the aquifer, its

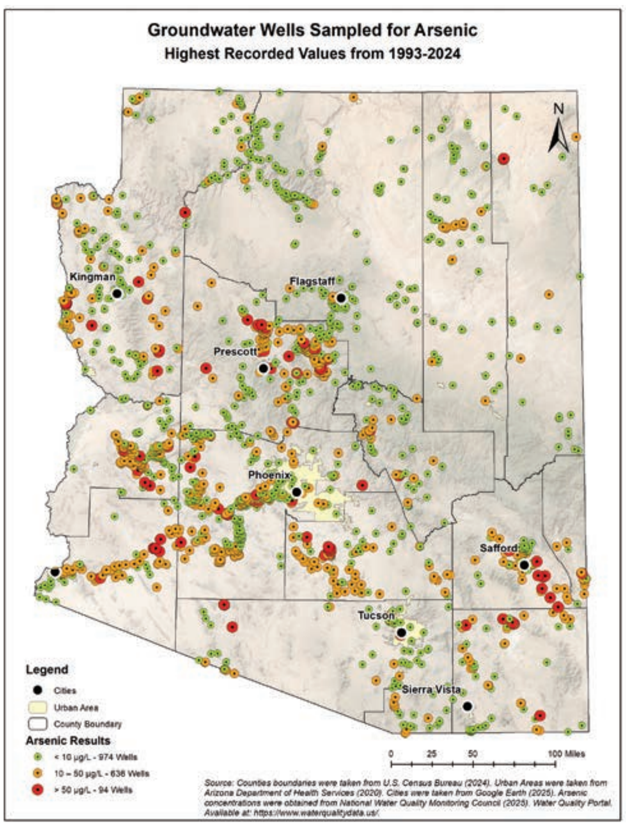


Figure 5.1 Arsenic water quality around the state from 1993-2024. More than 20% of groundwater samples from around the state exceeded the EPA MCL of 10 µg/L. Source: UA WRRC

mineral form in the sediment, the water pH, and the water's oxygen content. Changes to the water chemistry may increase or decrease arsenic concentrations in water. An example is the introduction of atmospheric oxygen as groundwater elevations dropped due to drought in the Verde Valley in the mid-1990s. The change in geochemistry resulted in an increased concentration of arsenic and subsequently caused arsenic poisoning in livestock. For more information about arsenic in the state, see Extension Publication #AZ1453.

Fluoride

Fluoride is a common element that is concentrated in volcanic ash, soils, and sediments that contain minerals rich in fluorine, like carbonates, clays, and fluorite. Fluoride minerals may also be present in granite rock. Most of the elevated concentrations are associated with **confined aquifers** because groundwater held in confined aquifers usually has not had the opportunity to mix with recently recharged water. Long residence time allows for natural fluoride to dissolve into groundwater.

Although it can be harmful at high concentrations, fluoride is essential for strong teeth and bones, and is essential for the development of tooth enamel. Many municipal water supply systems add fluoride to the water to support dental health. Excessive fluoride concentrations in drinking water, however, can discolor teeth and cause skeletal fluorosis. The current U.S. Public Health Service's (USPHS) recommended fluoride concentration for drinking water to promote dental health is 0.7 mg/L, well below the MCL. The MCL for fluoride is 4.0 mg/L, and the SMCL is 2.0 mg/L, a level at which tooth discoloration can occur. A statewide groundwater assessment by ADEQ found that greater than 10 percent of groundwater sources exceeded the MCL. The highest reported fluoride concentrations are found in La Paz, Lower Gila, Cochise, Mohave, and Graham, and along the Lower Gila River in Yuma County. Groundwater basins with a high probability of fluoride concentrations over 4.0 mg/L are shown in Figure 5.3.

For more information about fluoride in Arizona and the impact of high fluoride in livestock waters, see Extension Publication AZ2172.

Nitrate

Nitrate is undetectable without testing because it is colorless, odorless, and tasteless. However, when it originates from septic fields or agricultural activities,

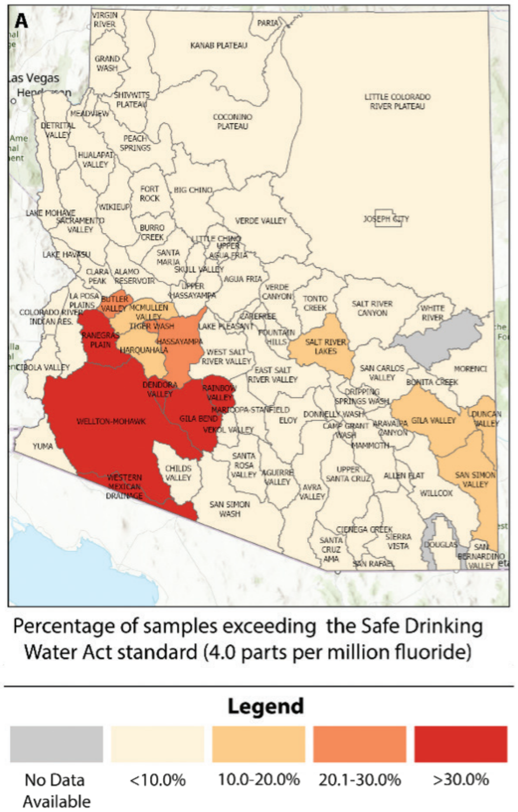


Figure 5.2 Percentage of water samples exceeding the drinking water MCL for fluoride by water basin. Source: Extension Publication AZ2172.

nitrate may be associated with higher-than-normal TDS, soluble organic matter, pathogens, and herbicides that can change water taste and color.

The EPA MCL for nitrate, reported by analytical laboratories as "**mg/L as nitrogen**" or "**in units of nitrogen**", in a public water supply is 10 mg/L as nitrogen. This standard is based on the risk of **acute** health effects, specifically the risk of methemoglobinemia, sometimes referred to as "blue baby syndrome", in which blood lacks the ability to carry sufficient oxygen to the individual body cells. This is especially dangerous for at risk communities, such as the elderly, infants, or those with preexisting health conditions, but uncommon.

High concentrations of nitrate in groundwater are usually due to human activities; however, some nitrate is naturally occurring in arid soils. Figure 5.3 shows probable locations across the state where groundwater is likely to have nitrate contamination above the EPA MCL. For more information on the development of this map, see Extension Publication #AZ1536.

Therefore, in areas with historic or current agricultural activities and/or served by individual septic systems and domestic wells, nitrate contamination may be prevalent. Large expanses of irrigated cropland are the most significant contributors to elevated nitrate concentrations. The groundwater basins in which more than 20 percent of the samples collected exceeded the MCL include Gila Bend, Harquahala, Pinal AMA, McMullen Valley, and Ranegras Plain—all regions of extensive irrigated farmland. Aquifers within the Salt River Valley, as well as areas in Glendale, Mesa, Chandler, and Phoenix, also contain groundwater with nitrate concentrations high enough to render the water unfit for potable use. In addition, high nitrate levels occur in Marana, St David, Bullhead City, and other areas in Arizona.

Quartzsite and Lake Havasu City have made significant efforts to address septic wastewater disposal problems that have contributed to groundwater pollution. Additional information regarding septic systems and groundwater protection is included in Section 9.

Other Inorganic Contaminants

Water that comes into contact with the natural environment always has minute amounts of dissolved

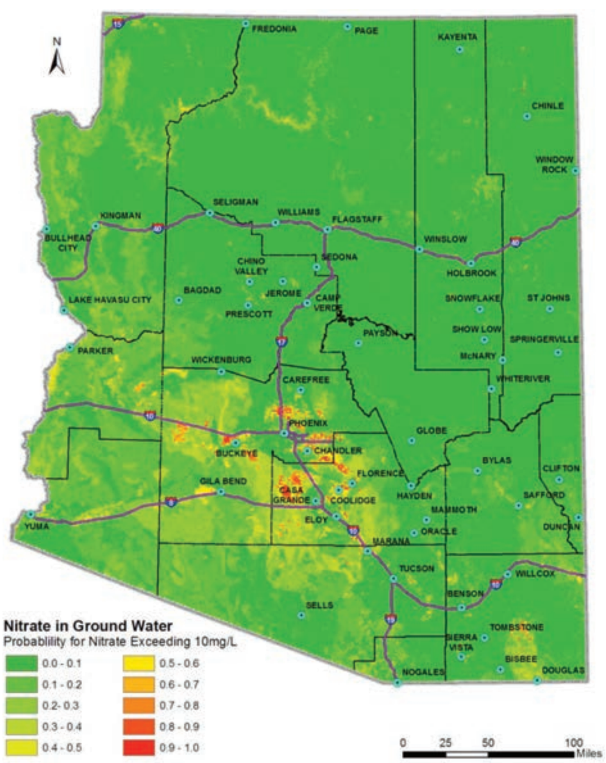


Figure 5.3 Predicted concentrations of nitrate as mg of N/L in groundwater. Less than 1%, or 226 square miles, has an 80% chance of nitrate groundwater levels exceeding the EPA MCL of 10 mg/L. Source: Extension Publication AZ1536

minerals that are not known to be a health threat. However, the mineral-rich geology of our state can result in elevated levels of contaminants. Other inorganic contaminants found around the state include chromium, copper, iron, lithium, manganese, sulfate, vanadium, and zinc. Of these, chromium, copper, and selenium have MCLs; copper, iron, manganese, sulfate, and zinc have SMCLs; and boron, lithium, and vanadium do not have federal standards as of 2025.

Elevated levels of these naturally occurring constituents have been found in wells across Arizona. Elevated levels of copper, zinc, and sulfate are occasionally found in groundwater near mining districts. Hexavalent chromium (CrVI) is both naturally occurring and augmented by industrial activity. It is also known to cause cancer, has been found in Paradise Valley, north of Phoenix, and in the Detrital Valley near Kingman. Lithium is found in the groundwater of the Gila Valley near Safford. Selenium and boron are also found in evaporite deposits, and these elements have also been detected in groundwaters near Kingman and in the Willcox area. Elevated levels of sulfates can be found in groundwater impacted by mining activities and from groundwater recharged with Colorado River water. Concentrations of sulfates in groundwater come from aquifers rich in gypsum, usually found in evaporite basins, and can be increased due to changes in groundwater flow patterns.

5.3 Radioactive Elements

Radioactivity is the release of energy from within atoms in the form of atomic particles (alpha and beta) and gamma radiation. 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 1.23 billion years), eventually becoming calcium and the gaseous element argon gas. Because potassium is a significant component of clay minerals, clay, bricks and pottery, as well as animals and plants, are all slightly radioactive.

Any element that emits radioactive particles or gamma radiation as it decays or ages is known as a radionuclide. As radionuclides decay, they produce daughter products (for example, potassium decays to argon) that may be shorter lived and possibly more radioactive. At high levels, radiation can cause an increased risk of cancer.

Uranium

Of particular concern in Arizona is naturally occurring uranium. Like arsenic, uranium is present in sedimentary sandstone and limestone layers in Northern Arizona, especially in the Supai Sandstone formation. Unlike arsenic, though, uranium has both a chemical toxicity and a contribution to radioactivity. The MCL for uranium is set at 30 µg/L based on its chemical toxicity.

Uranium mines are found throughout Northern Arizona. Increased levels of sulfate, nitrate, uranium, and arsenic have been observed in groundwater close to uranium mines.

Minerals containing uranium and its daughter product thorium (760 million and 4.46 billion years half-life, respectively) are also found in some Arizona granites. These elements 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

Radon is an odorless, colorless, tasteless gas that dissolves in groundwater and may migrate upward through the soil, eventually dissipating into the atmosphere. If there is dissolved radon gas in your well water, the water should be stored in a storage tank prior to being delivered to a house to allow for the radon gas to dissipate outside of the house. If radon gas is trapped within a structure, such as a bathroom or basement, the concentration of the gas may exceed health standards. It should be noted that radon in soil has a higher health risk compared to radon in water. The EPA estimates that 1 in 15 homes contains a high level of radon, which is considered to be the second leading cause of lung cancer in the country.

Gross Alpha

Gross alpha is a measurement of the amount of radioactivity in water and is due to the decay of uranium, radium, and/or radon. It is a gross measurement of overall radioactivity from alpha particles released from these and other radionuclides. Elevated gross alpha concentrations in groundwater are natural and common in Arizona bedrock aquifers or in **alluvial** aquifers composed of eroded granite. The MCL for gross alpha measured in **picocuries (pCi)** is 15 pCi/L. Statewide testing by ADEQ found that 16% of wells sampled exceeded the gross alpha MCL. Exceedances were most common in northwestern Arizona. (Towne & Jones, 2015)

5.4 Natural Organic Matter

Water color, odor, foaming, and taste are affected by the presence of **natural organic matter (NOM)** substances. NOM is usually found at much higher concentrations in surface water than groundwater, but even deep, old groundwater may have measurable levels of NOM. Most NOM is derived from vegetation, such as leaves, that fall into the surface water and decay. If well water contains NOM, it is usually derived from vegetation such as leaves or roots in the well. These constituents can impart taste and color to the water, like when tea leaves are brewed. Wells with water levels that respond quickly to rain storms and floods may also have elevated levels of NOM, sediments, and other unwanted contaminants, following rapid recharge of stormwater to the aquifer. NOM can serve as a food source for microorganisms and increase the growth of biofilm and slime.

5.5 Microorganisms

Groundwater can be contaminated with disease causing microorganisms, termed pathogens. Pathogens may be enteric, meaning that they live in our intestines, or nonenteric, meaning that they exist in environments outside of our intestines, such as in soil or water. An enteric pathogen can impact the digestive system and cause vomiting and/or diarrhea. In rural areas, biological contamination can be the result of failing septic systems, poor wellhead protection, and biofilm growth. Periods of high temperature, flooding, and/or heavy rain can increase the risk of disease outbreak.

Organisms that can contaminate groundwater include human-waste derived viruses such as adenovirus, rotavirus, hepatitis A, and norovirus; enteric bacteria such as *E. coli* 157:H7, *Salmonella*, *Campylobacter*, *Aeromonas*, *Vibrio cholerae*, and *Shigella*; nonenteric bacteria including *Pseudomonas*, *Legionella*, and *Helicobacter*; protozoan pathogens such as *Cryptosporidium*, and *Giardia* and, an amoeba called *Naegleria fowleri*. These organisms present a human health risk when ingesting contaminated water. Typical symptoms associated with an infection may include **acute** gastroenteritis, severe cramping, abdominal pain, dehydration, diarrhea, fever, and/or cough, depending on the pathogen.

A study by the University of Arizona detected the amoeba *Naegleria fowleri* in 29 of 188 water systems and private wells tested in Arizona. This organism thrives in warm water and in slow flowing or stagnant water systems such as storage tanks. Consuming this amoeba will not lead to infection. This amoeba usually infects humans by traveling through the nose to the brain and spinal cord, causing a painful death.

All the above-mentioned organisms are a risk to human health, but viruses are considered more of a threat to groundwater. Due to viruses' small size compared to bacteria or parasites, viruses can leach farther down the **vadose zone** and into aquifers. Viruses can be more persistent in the environment than many bacteria and therefore require stronger disinfection methods to **inactivate** them.

Approximately one-third of the groundwater drinking wells used by public utilities across the US contained human intestinal viruses (Morteza et al., 2003). However, two studies from the University of Arizona on 71 groundwater (22 from private wells) samples collected from seven counties in Arizona did not show the presence of pathogenic enteric viruses. More groundwater samples are needed to verify this trend. However, about one-half of the groundwater samples from private wells tested positive for total and fecal coliforms (Extension Publication #AZ1485). *Escherichia coli*, or *E. coli*, can be an indicator of fecal contamination. It can be present due to leaking septic systems, septic system overflow, or agricultural runoff. *E. coli* should be tested for once every year to ensure your water is safe from contamination.

In all cases, providing disinfection can serve as a protective barrier. See Section 8 for information about water disinfection.

5.6 Emerging Contaminants

The EPA evaluates contaminants that may need to be regulated in public water supply systems. Emerging contaminants are newly identified contaminants that are typically produced by people and are found in water as a result of human activities that release industrial and agricultural chemicals into the environment. The volumes released vary widely, and their movement within the environment depend on their chemical properties, physical properties, and the environmental conditions. Some contaminants are harmless or are not known to be toxic; others degrade, decomposing into harmless chemicals. Other contaminants can accumulate in our tissue and organs and be a potential danger to our health.

Emerging contaminants include chemicals that we can detect at lower levels with new or improved analytical methods. New instruments and techniques can routinely detect concentrations or contaminants previously not expected to occur in our water supply. For example, very small concentrations (part-per-trillion and lower) of chemicals such as: artificial sweeteners; caffeine; fabric fire retardants; antibiotics; common medications such as ibuprofen; the mosquito repellent DEET; and chemicals originating from products such as Teflon®, ScotchGard®, and Gore-Tex® have been found in our wastewaters and drinking water supplies.

A specific group of emerging contaminants of particular concern is **endocrine disruptor**s, which are chemicals that can affect the human endocrine system. Endocrine disruptors are found in pharmaceuticals and personal care products (PPCPs), steroids, and human hormones. These are passed through our bodies and end up in the environment. According to the EPA, PPCPs include therapeutic and veterinary drugs, fragrances, cosmetics, sunscreens, diagnostic agents, and vitamins.

National surveys have shown that many of these chemicals are not fully removed during treatment of municipal wastewaters or septic systems. Thus, **reclaimed wastewaters** and septic leachate discharged into the environment can affect the surrounding groundwater quality. The amount and spread of contamination depend on local conditions like soil type, groundwater flow, and how close a septic system is to a well. While concentrations are usually low, some studies have detected pharmaceuticals such as ibuprofen, diclofenac, and ciprofloxacin at levels that could harm aquatic life and affect water quality over time. New and more aggressive wastewater treatment approaches are being developed to address these contaminants.

The EPA has a couple of tools to address emerging contaminants. The first tool is to track and monitor emerging contaminants through the Unregulated Contaminant Monitoring Rule (UCMR). The second is to develop a National Primary Drinking Water Regulation, which may be preceded by an interim or provisional health advisory level. Extensive groundwater contamination that poses significant hazards may be deemed a **Superfund** site (inactive) or a Resource Conservation and Recovery Act (RCRA) corrective action site (active). A Superfund indication means that the EPA commits to the long-term cleanup of the site. For a list of Superfund sites, see: **https://www.epa.gov/superfund/search-superfund-sites-where-you-live**. RCRA corrective action sites are facilities overseen by the EPA and ADEQ. If there is a site in your neighborhood, you may want to follow up with the ADEQ to determine if your water supply is at risk of contamination.

Below are a few examples of anthropogenic contaminants in Arizona. Some of these contaminants are now regulated by the EPA or are being treated at Superfund sites. More information about the way contaminants become regulated is provided in Section 6.

- *Perchlorate*: Perchlorate has been known to exist in water for many years and is naturally occurring in some groundwater. It is a water **soluble**, mobile, and hard to degrade. Perchlorate is a major component of rocket propellants, munitions, and fireworks, and may also be found in fertilizers and bleach. It has been detected in Western water supplies such as the Colorado River and found naturally in brackish groundwaters. This chemical can affect the endocrine system (thyroid function) and, according to the US EPA, is a likely human carcinogen. The EPA proposed an MCL of 20 µ/L on January 6, 2026, and a final regulation is expected by May 2027.
- *Trichloroethylene (TCE)*: The solvent trichloroethylene (TCE), an industrial degreaser, is found in the groundwater in Tucson and Phoenix. TCE-contaminated groundwater is difficult and expensive to remediate, as this chemical does not easily degrade. TCE in its free-phase, liquid form is nearly 15 times denser than water, and sinks to the bottom of aquifers. This human-made chemical is so soluble in water that one pound of it can turn 24 million gallons of water unfit to drink. It has an EPA MCL of 5 ppb and is a known carcinogen. There are multiple TCE Superfund sites in Phoenix and Tucson.
- *Methyl tertiary-butyl ether (MTBE)*: The gasoline additive Methyl tertiary-butyl ether (MTBE) was used to reduce air pollution by boosting octane while replacing lead starting in the late 1970s. However, the fate of this chemical in the soil and water environment was not fully tested before its use, and MTBE turned out to be very mobile and water soluble and stable (slow to degrade) in water. This has resulted in the contamination of numerous groundwater supplies from leaky underground storage tanks. Although some states like California regulate MTBE in drinking water, to date, the EPA has not set an MCL for this chemical in potable water.

Superfund Site Example – Tucson Airport Remediation Project (TARP)

Groundwater cleanup at the Tucson Airport Remediation Project (TARP) Superfund site area began in 1994, when Tucson Water launched a system of extraction wells and a central treatment plant to remove trichloroethylene (TCE) and stop the spread of contamination toward the city's central wellfield. Over time, the project has continually evolved to address newly identified contaminants and protect Tucson's groundwater.

In 2013, Tucson Water added an advanced treatment process to remove both TCE and 1,4-dioxane after a new health advisory for 1,4-dioxane was issued by the U.S. EPA. Later, in 2017, per- and polyfluoroalkyl substances (PFAS) were detected in the area's groundwater, prompting another phase of adaptation. In anticipation of new federal regulations establishing enforceable PFAS limits in 2025, the Arizona Department of Environmental Quality allocated $25 million to construct a PFAS pretreatment system to remove these chemicals before water enters the TARP facility. Construction began in early 2025, and the system is expected to be operational by late summer 2026.

Through these ongoing upgrades, the TARP demonstrates adaptation to emerging groundwater challenges and ensuring a safe and reliable public water supply.

- *Per- and Polyfluoroalkyl Substances (PFAS)*: PFAS is a group of nearly 15,000 anthropogenic chemicals often termed "forever chemicals." These chemicals have been used in numerous consumer, commercial, and industrial products ranging from non-stick pans to firefighting foam. They are not naturally occurring and are very stable. This has led to their low-level presence worldwide in a variety of environments, including water, air, blood, and soil. Exposure to certain PFAS may lead to adverse health outcomes, such as reproductive effects, developmental effects, increased risk of cancer, and/or increased risk of obesity, to name a few. In Arizona, it is estimated that 36% of domestic well water users are using water affected by PFAS. (Tokranoy et al., 2024) As of 2024, EPA set National Primary Drinking Water Regulation for six of the thousands of PFAS compounds.

- *Microplastics*: Microplastics are generally defined as pieces of plastic that are less than or equal to 5 mm in size. They can come from many sources, including cosmetics, paints, and the fragmentation of larger plastic products. Microplastics are found throughout the environment, including in water, air, soil, and even our bodies. Microplastics have been linked to serious health issues, including cancer, infertility, and Parkinson's disease. As of March 2026, there are no regulations for microplastics in drinking water. There are petitions for the EPA to begin monitoring microplastics in drinking water.

These are just a few examples of emerging contaminants around the state. Researchers and regulators will continue to monitor emerging contaminants in groundwater to provide informed recommendations and regulations for the protection of human health.

Information on water treatment can be found in Section 8.

5.7 What does this mean for well owners?

- Groundwater contaminants may be naturally occurring, human derived, or both.
- The most common contaminants in Arizona wells are arsenic, nitrate, fluoride, gross alpha radiation, and microorganisms.
- Water contaminants can cause negative health effects. For example, long-term exposure to arsenic has been associated with fetal developmental effects, heart disease, and diabetes.
- It is the well owner's responsibility to monitor, collect samples, and determine water quality of domestic wells.

Resources

Websites:
- ADEQ Ambient Groundwater Quality Monitoring, **https://azdeq.gov/GW_quality_n_monitoring**

Videos:
- *Well Water Testing*. 2013. UofAZCALS YouTube, **https://www.youtube.com/watch?v=rRjqCgMdBts**

Publications:
- *Arizona Salt*. 2013. Extension Publication #SWES13.

- *Arsenic in Arizona Ground Water – Source and Transport Characteristics*. 2008. Extension Publication #AZ1453.
- *Arizona Drinking Water Well Contaminants*. 2009. Extension Publication #AZ1536.
- *Nitrate Contamination Potential in Arizona Groundwater: Implications for Drinking Water Wells*. 2011. Extension Publication #AZ1536.
- *Private Well Components*. 2011. Extension Publication #AZ1486
- *Surveillance for Waterborne Disease Outbreaks Associated with Drinking Water – United States*, 2011—2012. 2015. **https://www.cdc.gov**
- *Groundwater Quality in Arizona: A 20-Year Overview of the ADEQ Ambient Groundwater Monitoring Program 1995-2015*. 2015. **https://static.azdeq.gov/wqd/gw/fs/16-02_20year_final_ofr.pdf**
- Morteza, Abbaszadegan, Lechevallier Mark, and Gerba Charles. "Occurrence of Viruses in US Groundwaters." *AWWA* 95, no. 9 (2003). **https://awwa.onlinelibrary.wiley.com/doi/epdf/10.1002/j.1551-8833.2003.tb10458.x?saml_referrer**.
- Tokranov, Andrea K., Katherine M. Ransom, Laura M. Bexfield, et al. "Predictions of Groundwater PFAS Occurrence at Drinking Water Supply Depths in the United States." *Science* 386, no. 6723 (2024): 748–55. **https://doi.org/10.1126/science.ado6638**.
- Towne, Douglas C., and Jason D. Jones. *Groundwater Quality in Arizona: A 20-Year Overview of the ADEQ Ambiant Groundwater Monitoring Program 1995-2015*. ADEQ Water Quality Division - Surface Water Section - Monitoring Unit, 2015.
- *The quality of our nation's waters: Quality of water from domestic wells in principal aquifers of the United States, 1991–2004— Overview of major findings: U.S. Geological Survey Circular 1332*, 2009., **https://doi.org/10.3133/cir1332**.

SECTION 6

STATE AND FEDERAL LAW AND REGULATION

There are many state and federal laws that govern water, both quantity and quality, in Arizona. Arizona State Law prevents the state from adopting more stringent water quality guidelines than federal law. Thus, in Arizona, water quality standards are consistent with those set by the EPA. Most domestic wells are exempt from regulation and reporting beyond initial permitting with the Arizona Department of Water Resources (ADWR) or the appropriate Tribal department, highlighted in Section 3.1. Thus, the responsibility of maintaining the well and ensuring safe water quality falls onto well owners. This section provides an overview of Arizona groundwater law and federal drinking water standards.

6.1 Arizona Groundwater Law

Management of groundwater requires the measurement of quantifiable attributes to allow for consistency in the application of the rule. This is difficult. As the state of Ohio Supreme Court ruling in 1861 put it, groundwater was so "secret, occult and concealed" that to regulate would be hopeless. This confusion about how to manage the resource continues to this day; however, efforts have been made and varied across the United States. The concept of "safe yield" has been a key concept in management, suggesting that restricting extraction to that volume recharging the aquifer will protect from depletion, yet accurately measuring **recharge** (and sometimes extraction rate) has failed in many efforts to protect from over-extraction.

One key piece of legislation in Arizona is the Arizona Groundwater Management Act (Title 45 of the Arizona Revised Statutes). The Act 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 resource 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 ADWR to administer the Act's provisions. Four Active Management Areas (AMAs) and two Irrigation Non-Expansion Areas (INAs) were established by the 1980 Act, and more have been created in recent years to manage excessive pumping and aquifer **overdraft**. See Figure 6.1 for a map of the AMAs and INAs as of March 2026. AMAs are the highest level of management. Most of the AMAs have established a goal of "safe yield." Safe yield is achieved when the volume of groundwater extracted does not exceed the volume of groundwater recharging the system. INAs are less restrictive management areas that are meant to protect existing farms and communities from steep declines in groundwater levels by prohibiting new irrigated acreage within the INA boundary. Excessive pumping can result in **land subsidence** and fissuring as the **water table** drops. In addition, pumping costs and mineral content (TDS) of the water may increase with deeper wells.

Who owns groundwater?

In Arizona, groundwater is viewed as a public resource that is managed for everyone's benefit, not private property. Landowners do not own the groundwater beneath their property but rather have the right to withdraw those waters "for reasonable and beneficial use." Within AMAs and INAs, groundwater users must have a claim of entitlement, such as a groundwater right or permit to extract groundwater.

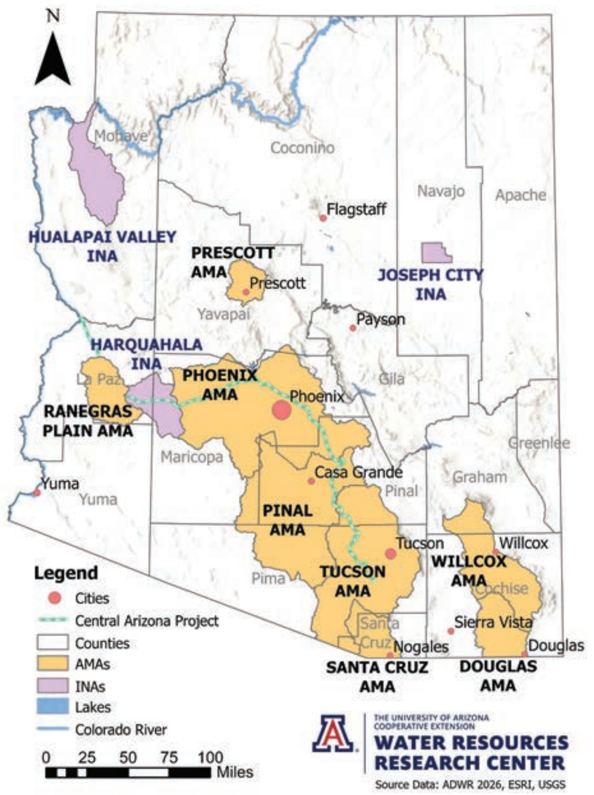


Figure 6.1 Map of AMAs and INAs in Arizona as of March 2026. City size represents population. Source: UA WRRC

The Arizona Groundwater Management Act of 1980 classifies wells with a pump capacity less than or equal to 35 gallons per minute (gpm) as "exempt wells." Within the AMA or INA, these well owners are not required to report how much water they pump. These exempt wells are typically used for domestic or household purposes and may also be used for irrigation on a parcel of less than 2 acres of land. Larger capacity wells, such as those used for agricultural purposes, must report their use to ADWR annually. It is important to note that within AMAs and INAs, well owners must have a claim of entitlement, such as a groundwater right or permit to drill or operate a non-exempt well. For more information about operating wells within AMAs and INAs, visit the ADWR website, **https://www.azwater.gov/ama/active-management-area-overview**.

As the number of exempt wells increases in the AMAs, the accumulated volume of unregulated groundwater extraction is causing concern. Future regulations may require additional monitoring throughout the state. See Section 10 for additional information on groundwater levels, land subsidence, and groundwater recharge.

6.2 Federal Drinking Water Guidelines and Standards

The EPA's mission is to protect human health and the environment. To achieve this, the EPA sets national drinking water standards and provides guidelines for treatment technologies for **Public Water Systems (PWS)**. PWS are water systems that have at least 15 service connections or serve more than 25 individuals. Individual or shared wells that serve fewer than 25 individuals are not defined as PWS. The development of drinking water standards and treatment guidelines is done in collaboration with public water utilities, scientists, scientific studies, state, local agencies, and the public. States and Native American Communities often facilitate the implementation and enforcement of drinking water standards for public water utilities. These standards are published in the Code of Federal Regulations (see also Appendix I).

Drinking water standards are continuously evolving as new and more sensitive analytical methods are developed, scientific information becomes available, and new priorities are set in response to changing concerns about potential health effects of contaminants found in water. Drinking water standards are set considering the potential health impacts to the population exposed to a given contaminant using risk models. Also considered are the costs of monitoring and water treatment methods available to regulatory agencies and public water utilities.

Arizona wells that do not meet the definition of a PWS are neither subject to any federal or state monitoring nor required to meet water quality standards. It is the responsibility of private domestic well owners to test their well water regularly to determine whether the water

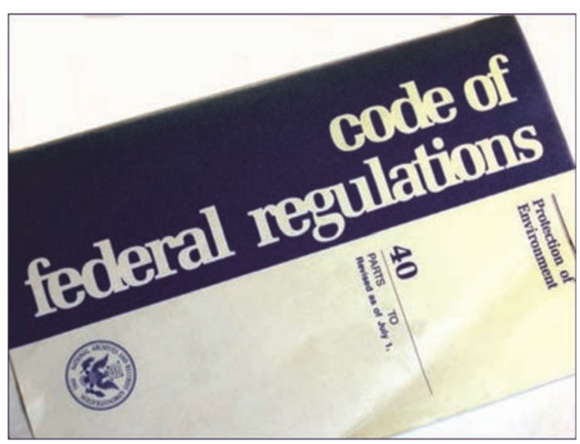


Figure 6.2 Code of Federal Regulations, Title 40, Protection of the Environment. Source: Artiola, Uhlman, Hix, 2017. *Arizona Well Owner's Guide to Water Supply 2nd Edition*.

meets the drinking water standards. The next sections are presented to familiarize private well owners with drinking water standards and to encourage well water testing.

National Primary Drinking Water Standards

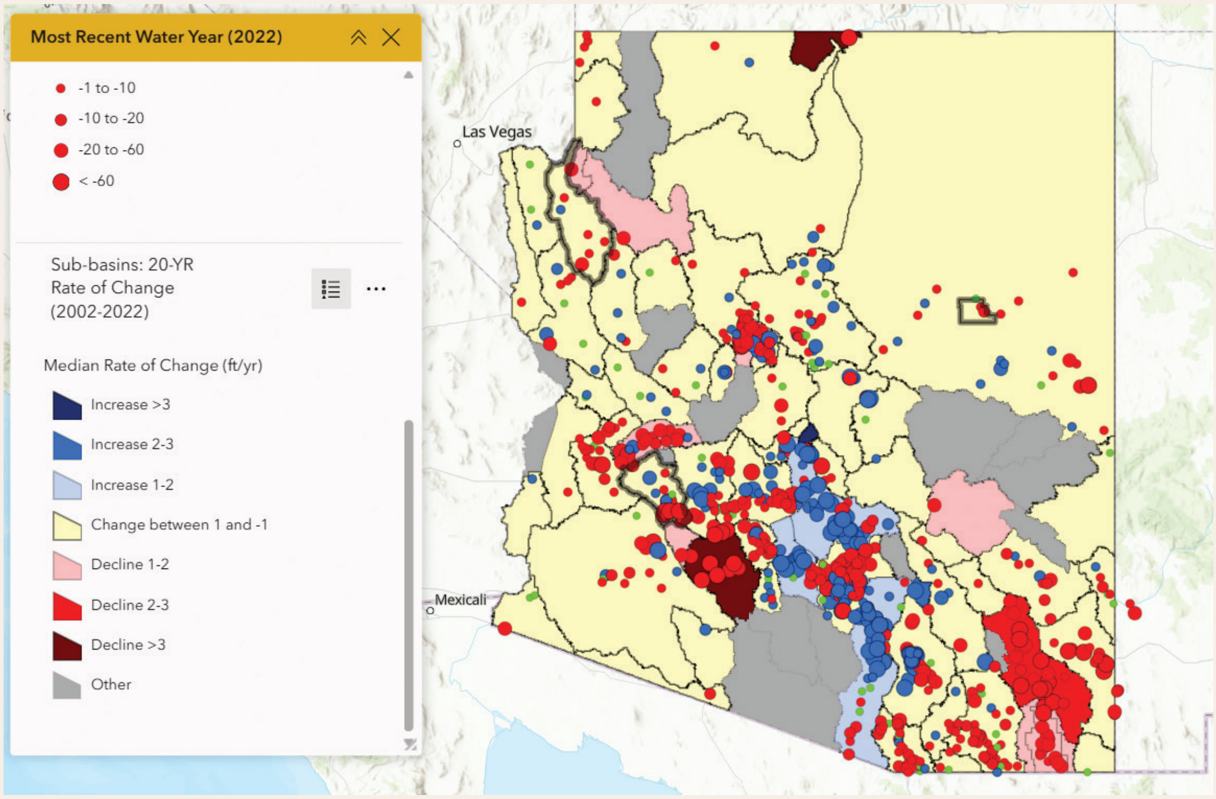
National Primary Drinking Water Standards (NPDWS) primarily consider the potential human health effects of a chemical. This is done by determining the toxicity, a risk assessment of the exposure (concentration of the chemical constituent, duration of the exposure, and route of exposure). The NPDWS are the legally enforceable Maximum Contaminant Levels (MCLs) for each chemical that may not be exceeded in drinking water delivered by a public water system. If an MCL is exceeded, then the water quality poses an unacceptable health risk.

How are groundwater levels changing in Arizona?

Understanding changes to groundwater level can be critical for well owners, especially those with shallow wells that may experience periodic dry spells. As a well owner, you can log seasonal changes to your water levels using a well sounder. See Extension Publication AZ1832 for a guide on how to build your own well sounder with a cord.

There may also be publicly available information about depth to water in your area available from the USGS, https://waterdata.usgs.gov/state/Arizona/ or ADWR, https://azwatermaps.azwater.gov/gwsiweb/#data_s=id%3AdataSource_17-GWSI_Layers_2453%3A11200642. Another great resource is the Arizona Water Blueprint's interactive groundwater level change map, https://experience.arcgis.com/experience/867a5e5600e64e5f9cee4ec34c88d16c. A screenshot of the site is provided below.

From here we can observe both water basins that have had average water level decline and increase over the time period of 2000 to 2020. We can also observe that changes in water level can vary even within a water basin. This can be due to a number of factors including local water use, geological conditions, and weather. Groundwater levels have risen in sub basins within the Phoenix, Pinal, and Tucson AMAs. This is in large part due to recharge efforts that have taken place within the AMAs. Other locations around the state have experienced dropping groundwater levels in recent years.



Screenshot of the Groundwater Level Change Map from Arizona Water Blueprint from June 2026.

MCLs are set based on different categories of chemicals: those chemicals that are not carcinogenic versus those that are "known to be," "probably are," and "possibly are" carcinogenic. The EPA has set MCL public health goals or MCLGs (see Appendix I) for chemicals known or suspected to be carcinogenic at "zero" in drinking water. However, limitations in the laboratory analysis of chemicals and water treatment technologies make this goal impossible to attain.

There are about 115 contaminants with MCLs regulated by the EPA, divided into four major categories: inorganics like arsenic and chromium; organics like pesticides, atrazine, and the solvent acetone; radionuclides like uranium and radium; and microbials like *Giardia* and general **microbial indicators** like coliform bacteria.

If a well owner tests the well water and finds one or more MCLs exceeded, he/she should consider the water to be a health risk and treat it, or seek an alternate source of drinking water. Testing well water is discussed in Section 8.

TABLE 6.1 NATIONAL SECONDARY DRINKING WATER STANDARD

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	1.3 mg/L
Corrosivity	Noncorrosive	-
Fluoride	2.0 mg/L	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	-

Link to EPA NPDWS: **https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations**

National Secondary Drinking Water Standards

The EPA has also established a set of National Secondary Drinking Water Standards (NSDWS) for public water systems; these are listed in Table 6.1. The EPA does not enforce these Secondary Maximum Contaminant Levels (SMCLs). These standards are established only as guidelines to assist public water systems in managing their water for aesthetic considerations, such as taste, color, and odor. Exceeding any of the contaminants listed in Table 7.1 is not considered a health risk; therefore, public water systems are not required to treat these chemicals below SMCLs. However, water utilities often control these constituents in their water supplies to reduce taste or odor-related consumer complaints.

If your well exceeds any SMCL listed in Table 6.1, but you find its taste and odor acceptable, there is no need to treat the water.

Link to EPA NSDWS: **https://www.epa.gov/sdwa/secondary-drinking-water-standards-guidance-nuisance-chemicals**

Best Available Technology and Treatment Technique

In addition to providing primary NPDWS and NSDWS, the Safe Drinking Water Act recommends best available technologies (BAT) or requires treatment techniques (TT) for contaminants. BATs are common water treatment technologies that are effective at removing contaminants and are economically achievable. Every MCL has a BAT. One example of a contaminant with BATs is nitrite. The SDWA lists ion exchange and reverse osmosis as BATs for treating nitrate in drinking water.

Similarly, TTs are common water treatment methods. TTs are required for certain contaminants that are difficult or expensive to measure. Using a TT ensures that there is a protective barrier in place. For example, water sources with high **turbidity** are required to use filters to reduce turbidity.

Additional information about BATs and water treatment technologies can be found in Section 8, Water Treatment Options.

Living regulations

The NPDWS are continually being revisited and adapted to ensure public health as we learn more about existing and new contaminants. At least once every six years the EPA reviews and may revise them to maintain or strengthen public health protection. Revisions may include changing a standard to make it more stringent, as was done for lead in 1991, or adding new standards that were considered on a Contaminants Candidate List, such as per- and polyfluoroalkyl substances (PFAS) in 2024.

Contaminants of emerging concern to drinking water are identified by the EPA and the public, and published in a Contaminant Candidate List (CCL). These can include any contaminant type (inorganics, organics, radionuclides, and biologics. For example, in 2022, CCL 5 included lithium, vanadium, PFAS, disinfection byproducts, and 1,4 dioxane.

6.3 What does this mean for well owners?

- In Arizona, there are many state and federal laws that govern water, both quantity and quality.
- Many domestic wells are considered "exempt" wells, meaning that there is no reporting or water testing/treatment requirement. Instead, the responsibility falls onto the well owner to ensure that they are providing safe water. Reach out to ADWR if you are unsure if your well is exempt.
- Regardless of the status of your well, water quality testing is recommended to ensure that the water meets recommended standards to protect health.

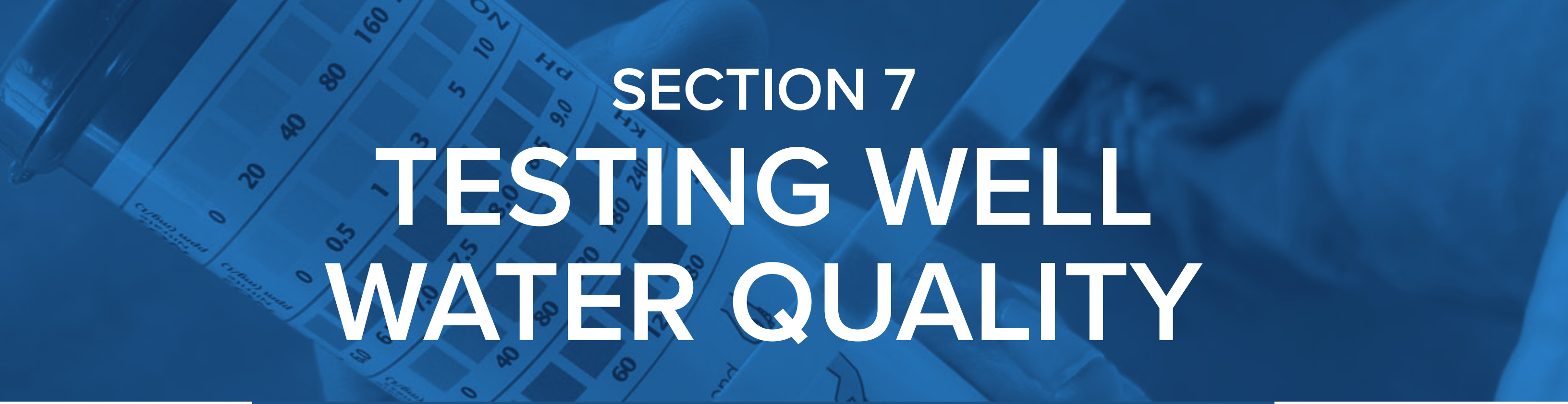
Resources

Videos:

- *Well Water Testing*. 2013. UofAZCALS YouTube, **https://www.youtube.com/watch?v=rRjqCgMdBts**

Publications:

- *An Arizona Guide to Water Quality and Uses*. 2014. Extension Publication #AZ1610.
- *Arroyo 2021 - Arizona Groundwater Management: Past, Present and Future*. 2021. **https://wrrc.arizona.edu/publication/arroyo-2021-arizona-groundwater-management-past-present-and-future**
- *Emerging Contaminants in Arizona Water*. 2016, ADEQ, **https://static.azdeq.gov/wqd/apec_emerging_cont_final.pdf**



SECTION 7
TESTING WELL WATER QUALITY

In Arizona, water testing is not required to register a pre-existing well or after drilling a new one. Some lending institutions may require some limited well water testing (bacteria contamination) before authorizing a loan. Therefore, it is the responsibility of the well owner to test the well water after completion and regularly thereafter. In deciding which parameters to test, it is helpful to gather as much information as possible about the groundwater quality from previous owners, neighbors, local water utilities, and state agencies (see Resources at the end of this section). It is also important to be familiar with local geology and nearby past or present land use activities, as these factors usually determine the quality of your well water and which contaminants are likely to be present.

Although elevated concentrations of arsenic, fluoride, nitrate, and gross alpha and/or uranium caused 98 percent of contaminant exceedances in a comprehensive study of public water supply wells in the state, the threat of these parameters varies by location. ADWR has divided Arizona into 52 groundwater basins, as shown on the map in the inside cover of this publication. Comprehensive groundwater characterizations have been completed on 36 of these basins, which provide a valuable resource for investigating Arizona's groundwater quality. These reports are found on the ADEQ website and are linked in Appendix V. Testing for contaminants is important since long-term consumption of water with exceedances of NPDWS may lead to avoidable negative health consequences. In Arizona, the most important contaminants to test for include arsenic, fluoride, nitrate, and gross alpha radiation, or radionuclides, including uranium.

It is important to prioritize pre-existing water quality information, since testing for all possible contaminants costs thousands of dollars per sample. Individual tests for nitrates, pH, and TDS may cost $50 or less. Table 7.1 presents a list of water quality tests that can initially establish the baseline water quality of your well. These tests include basic parameters such as TDS and hardness that indicate how the water may taste and if it may damage appliances. Additional testing can be informed by location specific water contaminants.

7.1 Sampling Your Well

Water sampling can be completed for different locations within a domestic system and during different seasons to determine sources of contamination if they arise.

For wells located near arroyos or washes or for shallow wells that are suspected of being impacted by surface water, seasonal sampling may be appropriate. Shallow wells may be sensitive to certain contaminants like bacteria or nitrates during the monsoon season, when storm runoff carries fertilizers/manure/ other contaminants through the watershed and into groundwater. If this is the case, sampling after storm events and during dry periods may be recommended to gain a better understanding of year-round water quality. This type of sampling is less important for deeper wells.

Water samples may be collected at the wellhead or inside your house at the point of use, usually your kitchen faucet. To test the aquifer water quality, collect a water sample as close to the wellhead as possible after the well has been purged several times. A typical domestic well will be adequately purged or cleared of stagnant water at the end of the day after doing several laundry loads and watering the garden.

If the water quality at the wellhead is acceptable, then any contamination (detected at the kitchen faucet, for example) may require further testing at several points inside the house to determine the contaminant source. Water quality can be impacted by pipes, storage, pressure tanks, and/or water heaters, especially in older homes. For example, lead is not likely to be found in groundwater, and if present, would be due to lead pipes or the use of lead-based solder. Sampling for lead

TABLE 7.1 RECOMMENDED WATER TESTING* SCHEDULE	
FREQUENCY	**ACTION**
Initial Baseline Tests†	TDS, hardness, pH, **alkalinity**, fluoride, nitrate, radionuclides, and arsenic. 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, *E. coli*, 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 II 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.

Table recreated from the Artiola, Uhlman, Hix, *2017. Arizona Well Owner's Guide to Water Supply 2nd Edition.*

should be at the faucet if lead has been used in the home plumbing. Testing at different locations within the plumbing can help to isolate where contamination is coming from.

7.2 Water Testing Using a Certified Lab

Well owners can collect water samples with containers and follow the guidelines provided by the laboratory. Sampling instructions should be followed carefully to avoid improper handling that can result in sample contamination and biased results.

The laboratory should be certified by the Arizona Department of Health Services (ADHS). See the Table of Arizona Certified Laboratories in Appendix III or call the ADHS to obtain an up-to-date list of Arizona laboratories certified to perform water quality analysis by this agency (602) 364-0720. See also the ADHS website link to access a list of certified labs and their test parameters: **https://ells-lab-search.azdhs.gov/DrinkingWaterTestingLabsVs2/drinkingwatersearchcontentpage**.

7.3 Well Water Test Kits

There are several types of water testing kits, including portable meters to measure pH, TDS, and other water quality parameters. These kits, while inexpensive, often lack the sensitivity and accuracy of modern laboratory methods and instruments. They are usually designed to perform a single test using a test strip with a color scale; see Figure 8.1. Other tests use a combination of two or more chemicals added to the water needed obtain a color change measured against a color scale. Compared to EPA-approved methods used in laboratories, testing kits have several limitations:

- Contaminant detection range is limited and can only read values at discrete intervals, lacking precision.
- Procedures may not be EPA approved.
- Their accuracy is hard to measure as their calibration status is hard to check.

- Results may be influenced by the presence of other constituents or by unusual levels of some water constituents such as dissolved iron and organic matter.
- They are often less accurate when measuring contaminant levels that are at or near the drinking water standards.

On the other hand, these kits may be useful if or when:

- They can offer an early warning of the presence of high levels of a contaminant in water.
- They are used for routine verification of well water quality together with less frequent analyses performed by certified laboratories.
- They are inexpensive and easy to use. They may use methods that are EPA certified or approved. *Note: Never use test strips or test kit chemicals past the expiration date posted on the box.*

Water testing kits are available from independent companies such as Hach, Lamotte, EMD Millipore, and Waterworks, and from resellers such as Ben Meadows (no endorsements implied).

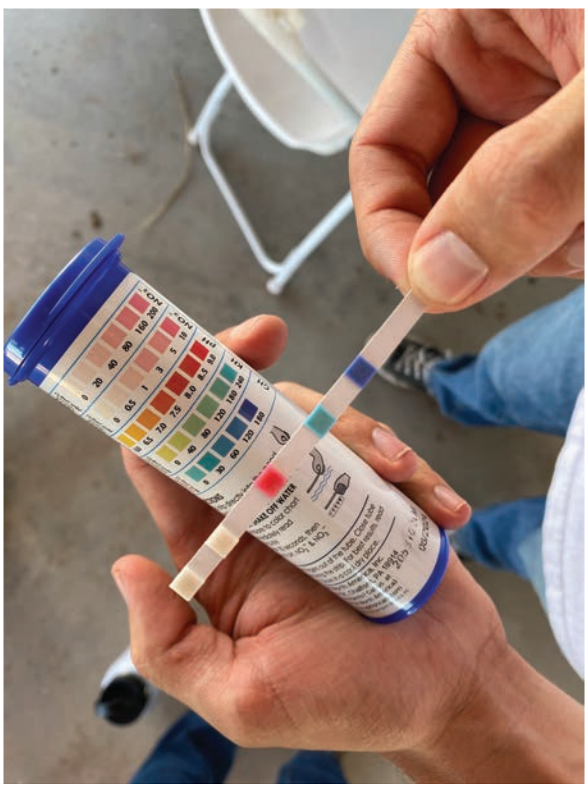


Figure 7.1 Home water-testing kits typically rely on a color change on a test strip to determine the concentration of a contaminant. Source: Lynn Carroll

7.4 Interpreting Well Test Results

When you receive your laboratory report, it should include your sample results and the appropriate units:

- milligrams per liter (mg/L), or parts per million (ppm);
- micrograms per liter (µg/L) or parts per billion (ppb);
- **picocuries per liter** (pCi/L); and other abbreviations or acronyms used.

The table of results may also have columns with the drinking water standards (when available), and individual results should also be associated with reporting limits (the lowest concentration at which the method and the laboratory's instrumentation can produce accurate results). Some sample values may be reported as "non detect" (ND) or "below detection limits" (BDL), meaning that the compound was not detected in the sample above method detection limits (method detection limits are usually lower than reporting limits; result accuracy decreases at these lower concentrations). The sample detection limit should be below the drinking water MCL. Check with the laboratory to ensure that this is the case, as some method detection limits may be above the MCL or SMCL you are interested in.

Example: your well water sample may have arsenic reported as "BDL" in the laboratory report. The report also lists the detection limit for arsenic as 1 ppb. This means that your sample meets the NPDWS of 10 ppb since the arsenic concentration in your sample is "BDL" and therefore less than 1 ppb.

Compare all the results to other MCL standards in Appendix I. Any water quality constituent that is above the primary MCLs may be a threat to human health or make the water unfit to drink.

Contact the laboratory for clarification of special terms or abbreviations if needed. Contact ADHS quality and/or your health care provider if you are concerned with any health-related issues about your water. Seek assistance from independent water quality/treatment specialists and reputable equipment vendors before deciding on water treatment options. If your well water exceeds one or more NPDWS, use an alternate source of water for drinking and cooking while exploring water treatment remedies.

7.5 What does this mean for well owners?

- It is the responsibility of the well owner to test their water quality. Water quality testing should be completed regularly (Table 7.1) and after any maintenance.
- Understanding the water quality in the area can help well owners to determine what water quality constituents to test for.
- There are certified labs across the state that can complete water quality testing. It is important to follow the water sampling instructions provided by the certified lab to ensure that the results are accurate.
- Water quality results should be compared to National Primary Drinking Water Standards (NPDWS) to determine if the water meets drinking water standards.

Resources

Websites:

- ADEQ's Arizona Water Quality Database, **https://azdeq.gov/azwqd-help**
- ADHS List of Certified Labs, **https://ells-lab-search.azdhs.gov/DrinkingWaterTestingLabsVs2/drinkingwatersearchcontentpage.**
- Cooperative Extension Wells and Septic Systems, **https://extension.arizona.edu/topics/wells-septic-systems**

Videos:

- *Well Water Testing*. 2013. UofAZCALS YouTube, **https://www.youtube.com/watch?v=rRjqCgMdBts**

Publications:

- *An Arizona Guide to Water Quality and Uses*. 2014. Extension Publication #AZ1610.
- *Well Water Testing and Understanding the Results*. 2011. Extension Publication #AZ1486.

SECTION 8

WATER TREATMENT OPTIONS

Domestic well owners have access to several water treatment options, but choosing the optimal one can be difficult without guidance, as it depends on the type and concentration of the constituents. Selecting a water treatment option can also be confusing, often due to incomplete or misleading information about what treatments can do to purify water by vendors who wish to sell their product. The consumer may not realize that, besides the initial purchase price, there are additional installation, routine maintenance, and testing costs not always anticipated or explained. Some water treatment systems may be installed and maintained by well owners, but complex systems will require professional assistance.

There are several methods to treat water, starting with simple filters to remove sediment particles. More complex water treatment systems add or remove chemicals or contaminants to/from the water and change the water's chemical composition. Water treatment methods scientifically proven to treat water safely and accepted by the EPA and organizations like the National Sanitation Foundation (NSF) are described in the following sections, and include: particle; micro-, ultra-, and nanofiltration; reverse osmosis; ion exchange; activated charcoal; media filters; distillation; and disinfection (including heat, chlorine, and UV light-based methods).

Home water treatment systems are usually set up to treat some or all of the water entering the house. A **point-of-use (POU)** system may be installed on the kitchen faucet or under the sink to treat only the water used for cooking and drinking. A **point-of-entry (POE)** system, such as a particle filter, may be installed as the water comes into the house and treat all the water used in the house. Some treatment systems, such as water softeners, only need to treat water in the hot water plumbing to prevent scale formation in the water heater and pipes. Figure 8.3 may be used as a guide for the initial selection of water treatment systems based on contaminant type and size.

8.1 Indications that Your Well Water Needs Treatment

Well owners may select water treatment options based on one, or more, of the four general symptoms shown in Table 8.1. Appendix II has a detailed contaminant specific list of water quality issues with causes and suggested treatments. These symptoms affect water quality, are nuisances, and usually require some form

TABLE 8.1 INDICATORS OF CONTAMINATION

VISUAL: CLOUDY, COLORS	BAD TASTE OR SMELL	ILLNESS: STOMACH	APPLIANCE HARDWARE DAMAGE
Fine Particles • Organic Matter • Rust	• Salts • Metals • Solvents • Hydrogen Sulfide • Algae	Pathogens: • Bacteria • Viruses • Parasites	• Salts • Scale Deposits • Acid pH • Corrosion

**See Appendix II table of symptoms and causes.*

Table recreated from Artiola, Uhlman, Hix, 2017. *Arizona Well Owner's Guide to Water Supply 2nd Edition*.

of water treatment. But other more serious health-threatening contaminants may be present in well water such as arsenic, nitrate, and pesticides that cannot be seen, tasted, or smelled. Thus, water quality testing, as described in Section 7, is recommended.

8.2 Certified Water Treatment Systems

There are numerous commercially available POU and POE water treatment systems available for purchase; however, it is important to understand the function and reliability of the system before purchasing anything. When possible, you should purchase a system that is certified to meet the National Sanitation Foundation/American National Standards Institute (NSF/ANSI) standards. The certifications ensure performance outcomes of POU and POE devices, including contaminant reduction claims and material safety. A list of NSF/ASTM certifications for POU and POE systems is provided below.

Figure 8.1 Example of an NSF certification marker. Look for this symbol when purchasing a water treatment system.

- **NSF/ANSI 42:** Filtration/absorption systems reduce aesthetic impurities, not health-related contaminants, such as chlorine and taste/odor.
- **NSF/ANSI 53:** Filtration/absorption systems reduce a contaminant(s) regulated by the EPA.
- **NSF/ANSI 44:** Cation exchange resin softens water by reducing calcium and magnesium hardness by replacing them with sodium or potassium.
- **NSF/ANSI 55:** Ultraviolet treatment systems **inactivate** or kill bacteria, viruses, and cysts in contaminated water to meet either Class A or Class B disinfection.
- **NSF/ANSI 58:** Reverse osmosis systems reduce a contaminant(s) regulated by the EPA.
- **NSF/ANSI 62:** Water distillation systems reduce a contaminant(s) regulated by the EPA.
- **NSF/ANSI 244:** Filtration systems can provide a secondary layer of microbiological protection by treating water from public water systems or water that is microbiologically safe.
- **NSF/ANSI 401:** Treatment systems reduce one or more emerging contaminants from drinking water.

Certified systems will include a description that "the system is certified by XXX to meet YYY certifications" and will have a certification marker, such as the one shown in Figure 8.1. A full list of certified systems is available on the NSF website: https://listings.nsf.org/#/certified-products-systems.

8.3 Treatment Options

It can be difficult to determine what type of treatment process is necessary to treat a certain water quality. To assist in the well water treatment selection, Table 8.2 includes a summary of common water treatment technologies, contaminants efficiently removed by each process per the EPA, and typical maintenance associated with their operation. It is important to understand the ongoing maintenance and waste products of each treatment method before selecting a treatment method. Specific maintenance requirements vary by technology and will be specified by the manufacturer.

In addition to understanding a specific water treatment technology, it is important to determine if the technology will require any pretreatment or post-treatment. A typical water treatment sequence is shown in Table 8.3. The treatment sequence is important, and in most cases, only one treatment step will be needed, but in other cases, two or more steps may be needed and should be installed in order. For example, if water is discolored, it may need to be filtered prior to ultraviolet (UV) disinfection. The treatment technology manufacturer's guide or manual will include the minimum water quality needed for proper treatment. If the well water source doesn't meet this, pretreatment will be required.

Aside from looking for the indicators described in Table 8.1, it is important to test and measure the concentration of the contaminant to properly size the treatment option. After the installation of the system, a follow-up water testing should be completed to evaluate the efficiency of the contaminant removal. For example, let's imagine that we purchased an arsenic treatment system that removes 80 percent of the contaminant form our groundwater, but the initial concentration is 100 µg/L. This would leave the water with 20 µg/L, which is over the MCL of 10 µg/L. Thus, we would need another system in-line to assure safe water or a different system.

TABLE 8.2 COMMON WATER TREATMENT TECHNOLOGIES		
Treatment Technology	**Contaminants**	**Maintenance[1]**
Activated Alumina (POU or POE)	Arsenic, Fluoride, Uranium	• Replace spent cartridges and particulate prefilters
Distillation (POU)	Arsenic, Copper, Lead, Nitrate†	• Replace carbon filter* • Clean with descaling solution
Granular Activated Carbon (GAC) (POU or POE)	SOCs, Radon	• Replace spent cartridges and particulate prefilters • Run periodic backwashing
Anion Exchange (AX) (POU or POE)	Arsenic, Antimony, Chromium, Nitrate†, Selenium, Uranium	• Replace spent cartridges and particulate prefilters* • Run periodic backwashing and regular regeneration • Replace salts for regeneration • Replace spent resin
Cation Exchange (CX) (POU or POE)	Barium, Beryllium, Cadmium, Copper, Lead, Radium, Thallium	• Replace spent cartridges and particulate prefilters* • Run periodic backwashing and regular regeneration • Replace salts for regeneration • Replace spent resin
Reverse Osmosis (RO) (POU or POE)	Antimony, Arsenic, Barium, Beryllium, Cadmium, Chromium, Copper, Lead, Fluoride, Nitrate†, Selenium, Radium, Thallium, Uranium, Microbial	• Replace spent cartridges and particulate prefilters* • Replace pre- and post-treatment GAC filters* • Maintain pressurization pumps (if used) • Dispose of the liquid waste stream (~7-8 gallons for every 2-3 gallons produced)
Ultraviolet Light (UV) (POU or POE)	Microbial	• Replace spent cartridges and particulate prefilters* • Replace UV bulbs • Clean bulb housing

*Only applies to some designs.

† When possible, nitrate should be treated with a POE device to ensure that all domestic water is treated. This is especially true for households with young children who may be more susceptible to nitrate poisoning.

More detailed information about different treatment technologies is provided in the following sections.

Sediment Filters and Microfiltration

Sediment filters and microfiltration are some of the simplest water treatment methods and are often used as pretreatment for other water treatment technologies. Filters are categorized based on the size of particles that they exclude, as shown in Figure 8.2. Sediment filters primarily remove sands and silt, whereas microfilters can remove finer clays, larger dissolved organic matter, and some microorganisms. Filters can be described by the following ratings:

- Average or nominal particle range size that will pass through the filter.
- Absolute particle size has a cut-off point above which no particle will pass through the filter.

TABLE 8.3 INDICATORS OF CONTAMINATION		
WATER TREATMENT SEQUENCE:	**INDICATORS:**	**IF YES, THEN:**
STEP 1 **REMOVE PARTICULATES** ***(cloudy water)***	***Cloudy, colors***	Particle Filtration
		Microfiltration
STEP 2 **TREAT CHEMICALS** ***Hardness, pH Iron, Manganese, Sulfides***	***Bad taste or smell, appliance damage***	Water Softener. Replace Hard ions (Ca + Mg) for soft ions (Na or K)
		Chemical Filters, Alkaline, Permanganate
STEP 3 **LOWER TOTAL DISSOLVED SOLIDS (TDS)** ***Salts, Metals, Organics***	***Bad taste***	Reverse Osmosis (salts, arsenic, metals, organics)
		Iron Filters (arsenic, fluoride)
		Resins (anion/cation) (salts, metals, arsenic, fluoride)
		Activated Carbon (ultrafiltration) (trace organics & some inorganics ONLY)
STEP 4 **DISINFECT** ***Pathogens***	***Illness: stomach***	Chemical Chlorination
		UV Radiation
		Heat Distillation

Commonly, sediment and microfiltration filter types are available as cartridge-based filters. Cartridge-based filters are very common and offer a practical solution of well water filtration since they can be installed in line without exposing the water to air, and remain under pressure as shown. The filters are made from synthetic fibers spun in different patterns and shapes, as shown in Figure 8.3, to produce different particle size cut offs.

Gravity-fed sand filters are another filtration option capable of filtering soil particles and some types of pathogens when the filter is properly designed and maintained. Maintenance of sand filters involves removing the top layer when biological matter forms an impermeable layer that limits flow through the filter. Sand filters may combine several layers of sand and coarser material to reproduce this natural process, as seen in Figure 8.4. Sand filters require periodic maintenance and monitoring to ensure constant flows and water quality.

When possible, filters should be located indoors to avoid extreme temperature changes and cleaned or replaced regularly to prevent the formation of unwanted biofilms that can quickly clog fiber filters.

Note: Ultrafiltration is a more aggressive form of microfiltration, used in special industrial and water treatment processes to remove viruses and dissolved large organic molecules like proteins, sugars, and NOM. These filters are not typically used for at-home systems.

Activated Carbon

Activated carbon is a common at-home filtration method found in many filters, including those found in filtration pitchers. Activated carbon filters contain chemically treated coconut shell (or other hardwood) charcoal either finely ground, as in granular activated carbon (GAC), and/or compacted, as in a carbon block filter. An example is shown in Figure 8.5. Activated carbon filters lower the levels of dissolved organic contaminants from water via physical interactions between contaminants and the carbon, trapping the contaminant.

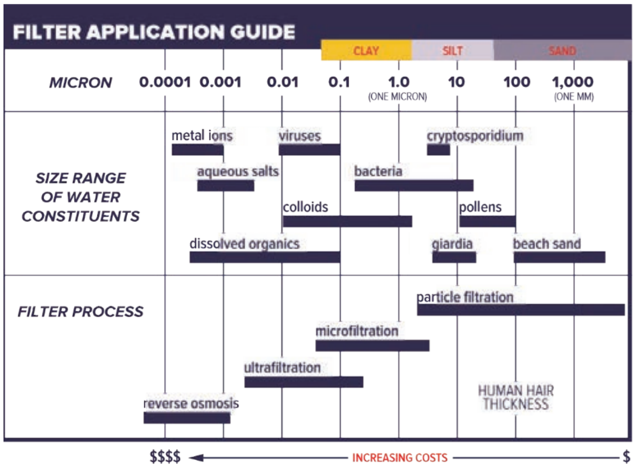


Figure 8.2 Filtration guide, showing the relative size of clay, silt, and sand particles to filters. Source: Artiola, Uhlman, Hix, 2017. *Arizona Well Owner's Guide to Water Supply 2nd Edition*.

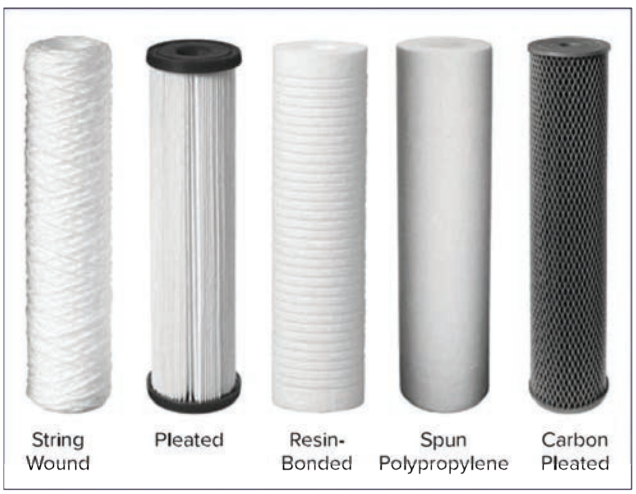


Figure 8.3 Types of cartridge filters. Courtesy: U.S. Filter, Plymouth Products Division and Water Conditioning & Purification. Source: Artiola, Uhlman, Hix, 2017. *Arizona Well Owner's Guide to Water Supply 2nd Edition*.

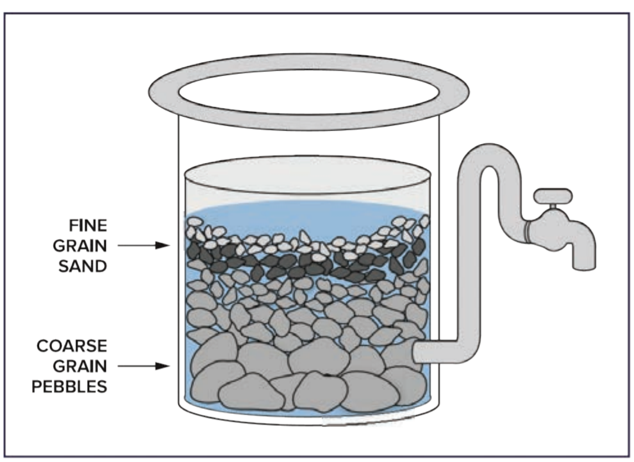


Figure 8.4 A simple filtration system. Source: Artiola, Uhlman, Hix, 2017. *Arizona Well Owner's Guide to Water Supply 2nd Edition*.

Carbon filters are commonly used to reduce the levels of residual chlorine taste if you are on municipal water, but are efficient in reducing odors, pesticides, solvents, semi-volatile organics, and emerging contaminants from well water, (see Section 5). Some activated carbon filters may also reduce the levels of radon gas and some metals like lead or uranium from water. Carbon filters will not remove or lower the levels of salts like sodium or calcium, nitrates, or chlorides from water. Activated carbon filters will not soften or disinfect water.

Particle-free water should be passed through carbon filters to avoid reduced efficiency and clogging of the pore space. These POU filters may be used in faucet attachments or in under the sink filter adaptors with a separate faucet. When treating potable well water, these filters may lower already very low levels or dampen a temporary surge of some contaminants. If well water has elevated levels of a contaminant consistently above drinking water standards, these filters must be sized professionally and tested regularly. It is important to replace these filters at the manufacturer's recommended intervals to avoid leaching of the captured contaminants.

Additionally, activated carbon filters may facilitate biological growth, which can plug the filters and increase the biological content of the water. Well owners who do not, or cannot, disinfect their household water should routinely test their systems and change the filters at recommended intervals, or more frequently, depending on use.

Reverse Osmosis

Although best known for their use in industrial scale desalination, reverse osmosis (RO) systems are commonly chosen to reduce water **salinity** levels (TDS), as well as arsenic, nitrate, and other contaminants in water. RO can also reduce the levels of many types of organic contaminants. Commercial POU RO systems may include a pump to achieve operating pressure (40-100 psi) and a series of filters, including a pretreatment filter (sediment filter or activated carbon), RO filter, and a polishing filter (activated carbon or remineralization cartridge). Contaminant removal takes place in the RO filter, a semi-porous membrane that serves as a physical barrier to filter out many types of soluble constituents.

Figure 8.5 An activated carbon point-of-use treatment installed on a faucet; the carbon media is shown in the photo insert. Source: Artiola, Uhlman, Hix, 2017. *Arizona Well Owner's Guide to Water Supply 2nd Edition*.

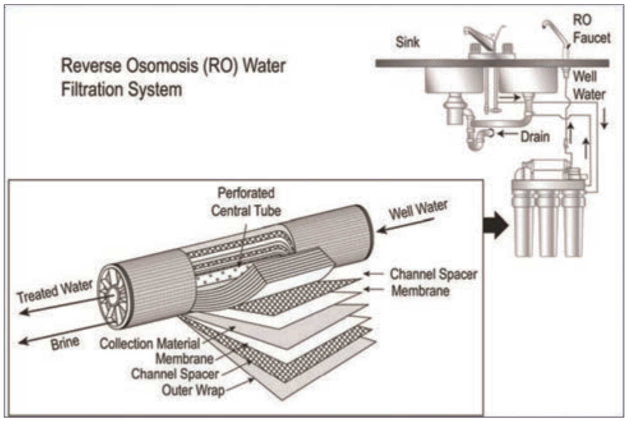


Figure 8.6 A home reverse-osmosis and cartridge filtration system installed under the sink. Source: Artiola, Uhlman, Hix, 2017. *Arizona Well Owner's Guide to Water Supply 2nd Edition*.

See Figure 8.6 for a cut-out drawing of a reverse osmosis treatment system.

Membranes are rated according to their ability to exclude or retain certain types of water constituents; thus, the filtering efficiencies vary with constituent and membrane type. Some contaminants may be prevented from passing 85 percent of the time, while others may be prevented by more than 99 percent. Because the filtering efficiencies can be affected by the overall water quality, testing should be completed after the RO treatment system is installed to determine system performance. In addition to removing contaminants, RO also removes beneficial minerals, including calcium, magnesium, and iron. Salinity removal may be so high that remineralization or blending is needed after filtering to add salts back into the water. Look for systems that include remineralization.

Although RO systems can filter particles, bacteria, and viruses, they are not recommended for particle filtration or water disinfection. As with all filter media, microbial biofilms can develop, which can plug and shorten the life of RO membranes, especially when not used regularly. Pretreatment can protect and extend the lifetime of the RO membrane, which is also one of the most expensive components of treatment systems. Well owners who do not, or cannot, disinfect their household water should routinely test their RO systems and change the membrane cartridges at recommended intervals, or more frequently, depending on use. Note that chlorination should never be used before RO, as free chlorine can damage the membrane, increasing the passage of contaminants.

Installing RO systems will increase the household water use. Of the feed water entering the RO systems, only 10-30% is treated water. RO systems produce large volumes of concentrated wastewater. For example, one gallon of potable water may produce ~2 to 9 gallons of concentrated brine wastewater, depending on the RO system and initial salinity and hardness of the well water. To prevent an increase in the wastewater load of the septic system, well owners can divert the backflow concentrate of their RO unit to safely irrigate salt-tolerant native plants and trees.

Nanofiltration

The nanofiltration (NF) process is similar to RO but uses more permeable membranes that block calcium and magnesium and many other water constituents, but allow small salts (sodium and potassium) to pass through. The NF process is a complex combination of sieving (filtering by size exclusion) and chemical interactions that occurs at the surface of the membrane. These "softening" membranes are more energy efficient since they work at lower pressures to produce equal volumes of water to RO units. The filtering capabilities of nanofiltration systems may be similar to those of RO for larger contaminants. Due to the lack of added salts, like ion exchange, NF is gaining popularity as an option for residential water softening; however, there are not yet many commercially available options.

Ion Exchange Water Softeners

These systems use ion exchange resins (beads) to replace calcium and magnesium with sodium or potassium ions. Water softeners may also remove varying amounts of other water constituents, such as uranium or iron, but they do not remove most other contaminants found in water. These units typically consist of two tanks, one

Water Treatment and Water Conservation

Ensuring that your domestic water meets health goals is critical. Picking a water treatment technology will not only impact your water quality, it will also impact your water use. For example, RO systems are common under the sink POU filters. They can be extremely effective at removing contaminants; however, they are big water users. RO systems produce a clean water stream and a brine stream. The clean water only makes up 10-30% of the total water used. This means for every one gallon of clean water produced, 3-9 gallons of brine are produced. This means that if your household just uses the RO system to treat one gallon a day, in a year that can add up to 3,650 gallons of water a year. That is equivalent to about 150 ten-minute showers. That is a lot of extra water. There are alternative water treatment technologies that use less water and are similarly priced. Adsorptive media and **anion exchange** are two effective water treatment technologies that recover nearly 100% of the water used.

for the resin and the other for the brine solution, (see Figure 8.7). Modern water softeners are automated with timed cycles that regenerate the resin with sodium or potassium, based on water hardness and household water consumption. The regeneration process removes the hardness that was captured by the media and recharges the media so that it can remove more. The process is usually done at night, and can be water intensive, typically using more than 50 gallons per cycle.

Installing a water softener will increase household water use and the wastewater load to the septic system. Saline soft water may degrade the performance of septic fields and increase the chances of groundwater contamination. Many communities in Arizona prohibit the use of sodium-based water softeners since they degrade the quality of reclaimed wastewater and add to the amount of sodium salts entering the environment. Softened water should not be used to water household or garden plants.

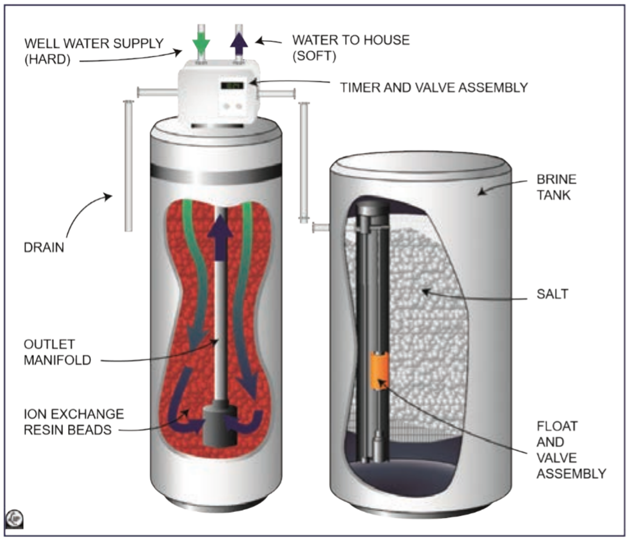


Figure 8.7 A water softener. Do not use soft water to irrigate household, garden, or landscape plants. Source: Artiola, Uhlman, Hix, 2017. *Arizona Well Owner's Guide to Water Supply 2nd Edition.*

Media Filters – Activated Alumina and Ion Exchange

Media filters may be a simpler option than RO systems. They are installed directly in the plumbing line and do not require electricity or extra water. Different types of filter media are designed to target different contaminants. For example, iron-based media can capture certain contaminants by binding them to the surface of the media, while activated alumina and ion exchange resins remove contaminants through chemical interactions. These filters do not reduce salt levels (TDS) and do not soften water. In some cases, pH adjustment or periodic media replacement is needed to keep them working properly.

Iron filters use tightly packed iron or iron coated particles (beads). Besides arsenic, they may also trap fluoride and selenium. Their performance can be affected by the presence of other common ions such as silica, bicarbonate, and chloride, so water testing is important. Small consumer units are not recommended for arsenic levels above 100 ppb; larger, professionally installed systems are typically needed for higher levels. See Extension Publication #AZ1650 for more details about these filters.

Activated alumina filters are another option for the treatment of arsenic, fluoride, uranium, and/or other contaminants. Activated alumina consists of an aluminum-based media that can remove up to 95% of arsenic. However, their performance drops in the presence of high sulfate levels.

Ion exchange filters are packed with an ion exchange resin that is specifically designed to remove one or more contaminants. The resins are designed to remove either negatively charged contaminants (**anion exchange**) or positively charged contaminants (**cation exchange**). For example, certain cation exchange resins can remove positively charged arsenic along with positively charged metals like lead or copper.

The performance of ion exchange resins may be reduced by the presence of certain water constituents, such as iron, manganese, silica, and hydrogen sulfate in the water. It is important to check the manufacturer's recommendations to determine if pretreatment is needed.

Distillation

Steam distillation is a process that evaporates water to steam and then condenses the steam to water. This process removes practically all contaminants from water and kills pathogens, effectively disinfecting the water. It also removes most non-volatile organic contaminants. However, volatile constituents, such as solvents, may not be removed unless the unit has a venting system or an activated carbon post filter, as shown in Figure 8.8.

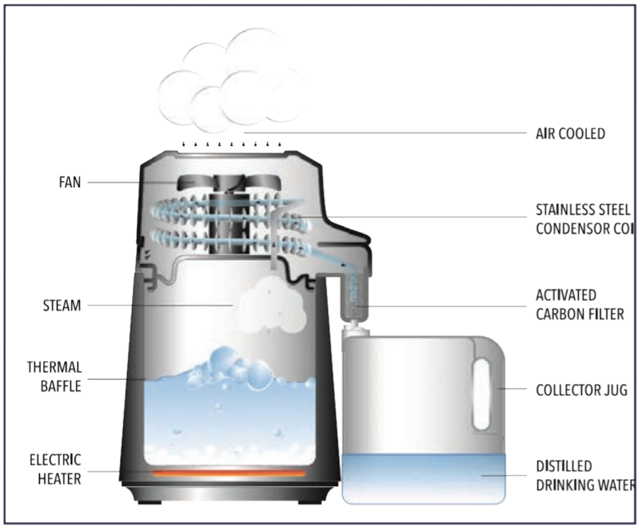


Figure 8.8 Water distillation with a venting system and an activated carbon post filter. Source: Artiola, Uhlman, Hix, 2017. *Arizona Well Owner's Guide to Water Supply 2nd Edition*.

Since distilled water has practically no salts, it is corrosive and has a flat to sweet taste. Distilled water should not be used to irrigate household or garden plants. The steam distillation process is extremely slow. A steam distillation system may only produce ~1 gallon in six hours. Additionally, steam distillation is energy intensive. Table top consumer units can use as much electricity as a toaster that is left on 24/7.

Chlorination

Chlorine-based chemicals are commonly used to disinfect potable water by public water utilities. These chemicals kill, or **inactivate**, most waterborne pathogens with some exceptions (some viruses and parasites). The most common chemicals are chlorine and chlorine dioxide gases, which are too dangerous for home use. However, liquids and solids that contain sodium or calcium hypochlorite, such as bleach, can be used for household disinfection. UV light (see next section) can also be used to disinfect well water.

Water chlorination systems can be continuous using chlorine pumps, suction devices, and solid feed units or batch disinfection. Continuous feed systems are automatic and flow-dependent with auto-shut off. Continuous chlorination systems should be professionally sized and installed since they usually require a holding tank to allow for sufficient contact time to disinfect the water, and a booster pump, as shown schematically on Figure 8.9.

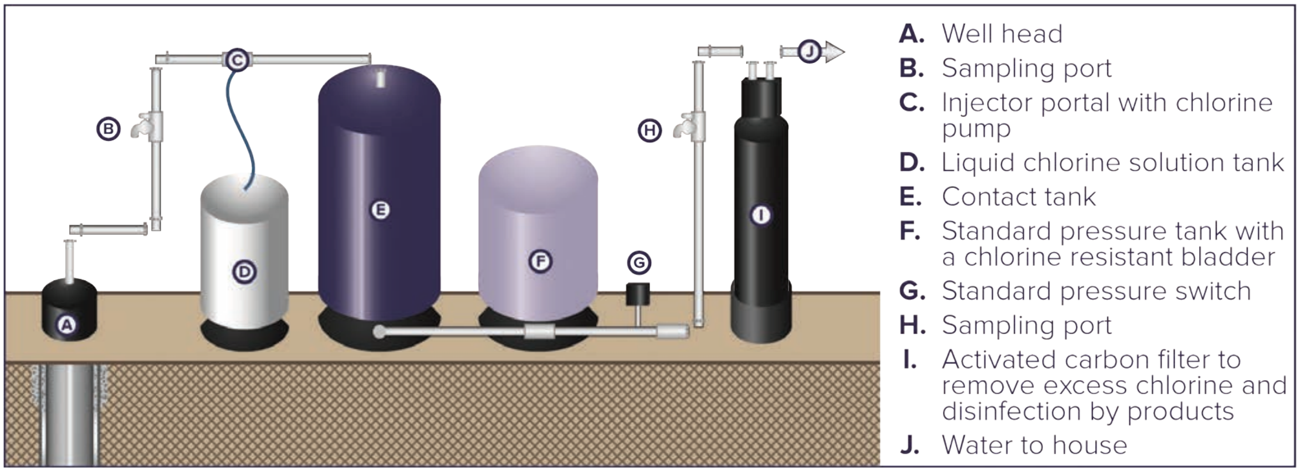


Figure 8.9 Chlorine feeding tank for domestic well water treatment. Source: Artiola, Uhlman, Hix, 2017. *Arizona Well Owner's Guide to Water Supply 2nd Edition*.

As with other forms of chemical treatment, water should be particle-free before disinfection, including chlorination. In the presence of residual organic matter, chemical disinfectants may produce toxic **disinfection by-products**. Since excessive levels of disinfection by-products in drinking water can be harmful to your health, chlorine disinfected water should be tested and, if needed, filtered through an activated carbon system to reduce the levels of these chemicals.

UV Disinfection

Ultraviolet (UV) light may be used to disinfect particle-free, clear water on a continuous flow mode using follow-through chambers with an enclosed UV light source. UV is damaging to living organisms and viruses that contain genetic material (RNA and DNA), stopping their ability to reproduce or infect other cells. Therefore, waterborne organisms like bacteria, viruses, and even some parasites may be quickly inactivated when exposed to a concentrated source of UV light.

UV light disinfection systems are simple and relatively maintenance-free, as shown in Figure 8.10. But their efficiencies depend on the design and UV light source type and power, the water flow rate, and the amounts and types of pathogens and other microorganisms present in the water source. UV light disinfection systems are rated by the NSF as Class A for more aggressive treatment of clear, but contaminated water (not wastewater). UV light Class B systems may be used to provide another layer of disinfection to safe drinking water. Both systems require particle-free water.

The two main types of UV light sources used for water disinfection are traditional mercury lamps and newer UV LEDs. Each has advantages and limitations. Mercury lamps produce a strong and energy-efficient UV output, but spent bulbs must be taken to a household hazardous waste center for proper disposal. UV LED systems are more compact and easier to dispose of because they contain no mercury. However, they generally produce lower UV intensity, which means water often has to move through the system more slowly to achieve effective disinfection.

UV light disinfection does not change the taste of water or produce any known disinfection by-products. Unlike chlorination, it does not provide any residual disinfection protection to the disinfected water. Thus, water that is treated by UV lamps should be consumed within a day of treatment to ensure that organisms are unable to repair themselves and continue reproducing. If the well water is contaminated, pre- and post-water testing for waterborne pathogens should be done to determine the effectiveness of the UV light system.

Other Disinfection Methods

In emergency situations, water may be boiled vigorously for at least two minutes to kill microorganisms. Household chemicals, such as bleach or iodine, may be used to disinfect water under emergency. For example, add up to six drops of household bleach per gallon of clear water and allow it to stand for 30 minutes. Add double the amount of bleach to the water if it does not have a faint smell of bleach or if the water is colored or turbid. For more details and guidelines for the use of bleach and other chemicals to disinfect water under

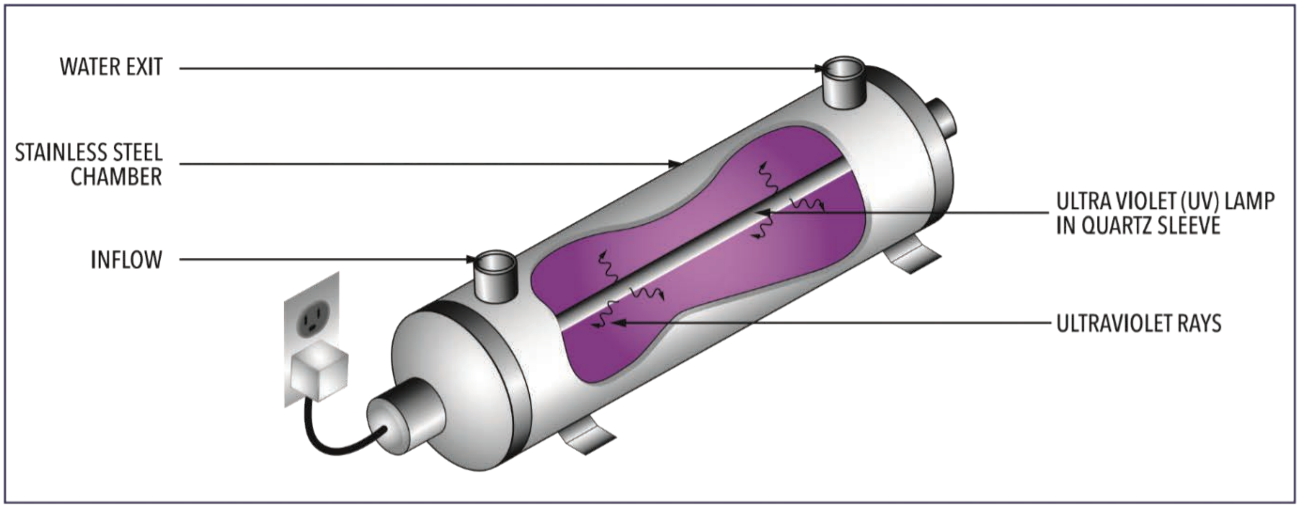


Figure 8.10 UV light disinfection systems are simple and relatively maintenance-free. Source: Artiola, Uhlman, Hix, 2017. *Arizona Well Owner's Guide to Water Supply 2nd Edition*.

emergency situations, visit the EPA website: **https://www.epa.gov/ground-water-and-drinking-water/emergency-disinfection-drinking-water**.

8.4 Alternative Sources of Potable Water

If your well does not provide enough water, or if the water quality cannot be treated to a safe level, there are several alternative sources of drinking water. These include properly collected and treated rainwater, bottled water, and hauled water.

Rainwater harvesting can be a practical option for many households, especially in remote areas. Rainwater can pick up contaminants such as organic material, dust, metals, and microorganisms as it moves across roofs and gutters. With appropriate treatment, harvested rainwater can be brought to safe drinking water standards. Extension Publication AZ1863 provides additional guidance on how to collect and treat rainwater safely.

Hauled water is another option for domestic use. This involves filling approved drinking-water containers at a permitted source such as a community water station, campground, rest stop, or truck stop. Hauling water requires a vehicle that can safely carry heavy loads and containers labeled for potable water. If water is stored for more than a few days, an additional disinfectant may be needed to keep the water microbiologically safe.

Figure 8.11 Domestic well powered by Solar cells. Source: Artiola, Uhlman, Hix, 2017. *Arizona Well Owner's Guide to Water Supply 2nd Edition*.

Bottled water is also commonly used as a supplemental or emergency source. Bottled water can be 100-1,000 times more expensive than piped water. Surveys have shown that bottled water is generally no safer than tap water from a regulated public water utility. Its main advantages are convenience and the fact that it usually has no noticeable taste from disinfectants, since most bottled water is treated with UV light and packaged in sterile containers. Bottled water quality is regulated differently from tap water, and manufacturers are not required to list all constituents.

Bottled water should be stored in a cool, shaded place and used within a reasonable amount of time. Over long periods, plastic bottles can begin to break down and may release small amounts of plastic into the water.

8.5 What does this mean for well owners?

- At home water treatment systems can be used to remove contaminants from water and bring it to a safe drinking water level.
- When choosing a treatment system, it is recommended that you purchase an NSF/ASTM certified system and consider the maintenance requirements.
- Some water treatment technologies require pretreatment. Check the water quality requirements for the technology to determine if you need any pretreatment.
- A professional may need to design large or complex treatment systems.

Resources

Websites:

- EPA's Emergency Disinfection of Drinking Water, **https://www.epa.gov/ground-water-and-drinking-water/emergency-disinfection-drinking-water**

Publications:

- *Water Facts: Home Water Treatment Options*. 2009. Extension Publication #AZ1498.
- *How to Lower the Levels of Arsenic in Water: What Choices do Consumers Have?* 2015. Extension Publication #AZ1650.
- *Preparing Rainwater for Potable Use*. 2021. Extension Publication #AZ1863

SECTION 9

PROTECTING YOUR WELL WATER QUALITY

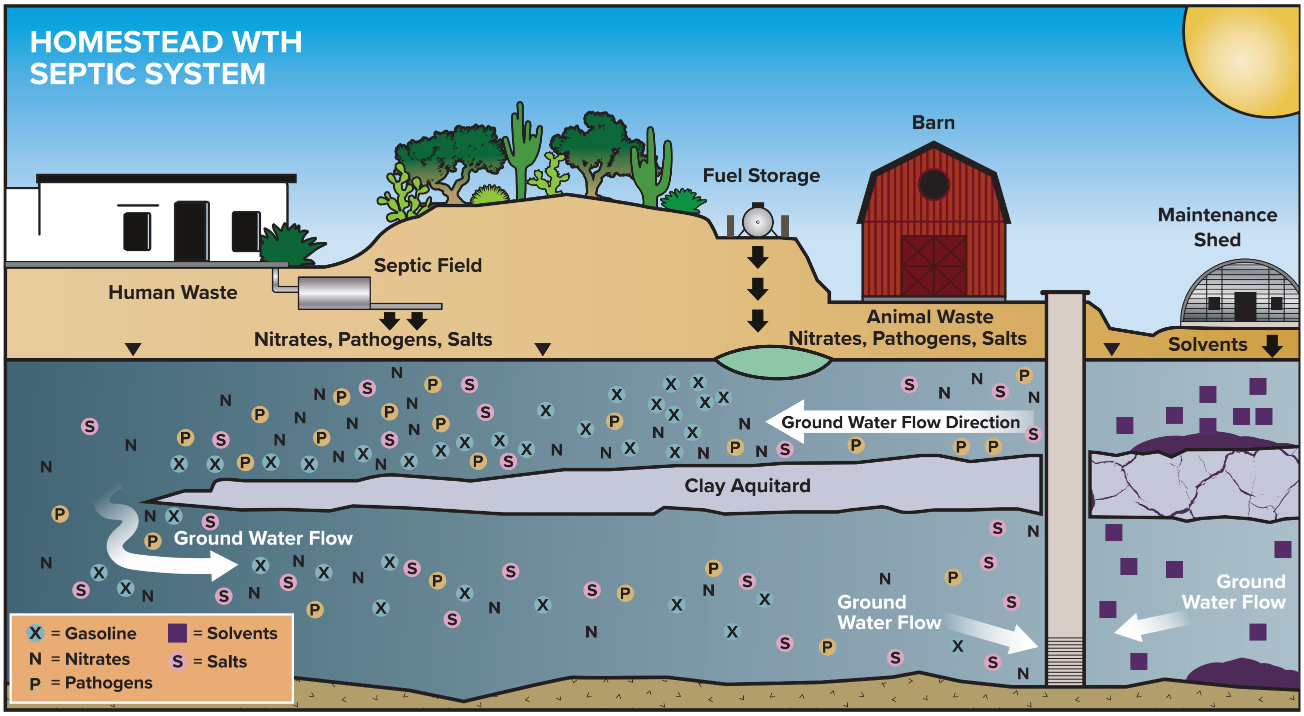


Figure 9.1 The sources of drinking water contaminant are often near the wellhead and may include septic leach fields and/or land use activities. U of A WRRC. Adapted from the Artiola, Uhlman, Hix, 2017. *Arizona Well Owner's Guide to Water Supply 2nd Edition*

Well water can be contaminated by manmade, rather than natural, sources as shown in Figure 9.1. The figure depicts the movement of anthropogenic contaminants that can be found near a domestic well, several of which are discussed in Section 7. There are five common sources of contaminants found in domestic wells:

- When the well is being installed or maintained;
- At the wellhead, where ponded surface water can seep into the well;
- From septic system leach fields or septic failure;
- By other land use activities near the well; and/or
- By weather events such as floods or fires.

This section provides suggestions for protecting your well against these common contaminant sources.

9.1 Well Installation and Maintenance

Although licensed well drillers and pump installers are trained to prevent contaminants from entering a well, bacteria sometimes still enter during well construction or routine maintenance. Follow these steps to prevent or reduce bacteria in your well water:

- Check your plumbing, water storage, and treatment systems on a regular basis and look for algae, slime, or discolored filter media. If biofilm or slime is present, the system components will need to be scrubbed and then rinsed with bleach, and the filtering media will need to be replaced.
- If you suspect any well casing or pump failure, have a licensed well driller or pump installer inspect the system. Only a licensed well driller can repair well

casing. A pump installer is licensed as a contractor and can only install and remove a pump or maintain well casing. Older wells, especially those made of black iron or mild steel, can corrode and break, allowing contaminants to enter the well.

- Test the groundwater for bacteria after any well maintenance. Coliform bacteria can be introduced when the pump or drop pipe is laid on the ground during maintenance. Some types of harmful coliforms and organisms such as amoebae can then be retained or grow in biofilm that develops naturally inside the well.
- If excessive slime develops that can plug up well screens and pump intakes, have the well's interior physically scrubbed and then shock chlorinated. Shock chlorination, well cleaning, and well and pump maintenance should be done by a licensed professional.
- If you notice an oily sheen or fuel odor, have the water tested for total petroleum hydrocarbons (TPH). Pump maintenance may introduce oils and grease into the well that can foul the water or provide a source of nutrition for naturally occurring bacteria. Purging the well immediately after maintenance is recommended to reduce the potential for this to occur.
- If there is any ponding of water or flooding near the wellhead, have the well water tested for bacteria.
- Make sure that all faucets with hose connections are equipped with backflow prevention devices, such as check valves. For example, a garden hose left in a kiddie pool may allow pool water to backflow into the water system, which could introduce bacteria.

9.2 Wellhead Protection

Because each well provides a direct route to the aquifer, you will need to take special precautions to protect the wellhead. The ADWR standards are the basic minimum standards. The well owner should discuss what additional construction may be appropriate with their driller; it may be necessary to increase casing stickup and surface seals.

Once groundwater or your well is contaminated, it is very difficult to restore, and most groundwater remediation or water treatment options are costly. As discussed in Section 3, the well protective casing should be at least 1 foot above the ground and be surrounded by a 4-inch-thick concrete pad for at least 2 feet in all horizontal directions. Older wells may not have been installed with the concrete pad. Updating your wellhead with this added protection is recommended. This configuration protects the well from flooding or ponded water and reduces the potential for contaminants to seep down into the aquifer around the well casing, (see Figure 9.1).

Some types of chemicals, such as fuels and solvents, pose serious threats to groundwater quality. Some can cause serious illness or death if consumed. Liquids that do not readily or fully dissolve in water are called non-aqueous phase liquids, or NAPLs. NAPLs may be lighter than water or denser and heavier than water:

- Light NAPLs (LNAPLs) will float on the groundwater level like oil floats over vinegar in some salad dressings. Examples of LNAPLs are petroleum-based fuels such as gasoline, motor oil, diesel, and home heating fuels. These fuels will pool on the water level and release chemicals such as benzene into the groundwater, as shown in Figure 9.1.
- Dense NAPLs (DNAPLs) are heavier than water and sink, displacing groundwater and leaving a trail of small liquid bubbles trapped in the pore spaces of the aquifer that dissolve slowly and can contaminate large volumes of groundwater. Typical DNAPLs are degreasers and solvents and may be used to clean an oil stain on the driveway. They are extremely difficult to remediate and can permanently contaminate the aquifer. Several cancers and childhood leukemia have been linked to parts-per-billion concentrations of chemical degreasers and solvents in groundwater.

Follow these steps to protect your well water from chemical contamination, as depicted in Figure 9.1:

- Do not store or use chemicals near the wellhead.
- Do not mix pesticides or store gasoline within 150 feet of a wellhead.
- If your well is in a storage shed or well house, do not store potential contaminates, such as fuels, pesticides, or fertilizers in the structure.

Following these additional guidelines will help prevent other types of contamination of your well water:

- Inspect the wellhead on a regular basis and address any breakage or soil disturbance by burrowing animals or insects. The well owner can repair and maintain the wellhead pad; casing repairs require a licensed well driller.

- Locate pet and livestock enclosures at least 150 feet away and downslope of the wellhead. Pet waste from dogs can contaminate groundwater.
- Build livestock corrals at least 150 feet away and downslope, and direct stormwater runoff away from the wellhead. Runoff from livestock pens and pastures can contaminate groundwater with bacteria, nitrates, and veterinary drugs.
- Line and cover compost stacks to prevent leachate waste from seeping or running off and entering the soil.

9.3 Household Wastewater Management and Onsite Septic Systems

Septic systems must be maintained regularly to reduce the chances of polluting the aquifer and causing health problems. To operate and maintain on onsite septic system effectively, first understand how it works and what affects it.

The most common onsite wastewater treatment system is a conventional septic system, as shown in Figure 9.2. The system treats wastewater in the tank and in the drain field. Wastewater flows through pipes from the house to the septic tank, which is a watertight container where solids are separated from liquid wastes. The wastewater contains salts, organic matter, nitrate, and some trace contaminants. In the septic tank, microorganisms begin to consume the solids, nutrients, and organic matter in the wastewater. Wastewater then moves through perforated pipes to a bed of gravel or similar material. From the gravel bed, the wastewater moves into the soil, where soil microbes and bacteria consume more of the contaminants as well as some of the nitrates. Finally, the water then percolates through the soil and either evaporates, is used by plants, and/or drains to the aquifer.

Different types of onsite wastewater treatment systems require different maintenance practices, and all systems need routine maintenance. The system will malfunction if not adequately maintained. Follow these guidelines to keep your system operating properly and to avoid contaminating your drinking water.

- Locate the septic tank and drain or leach field at least 100 feet from your well (preferably downhill or down gradient if known); the drain field should be at least 100 feet away. If installing a new well be aware of the location of your neighbor's septic system to protect your own water supply.
- Do not excessively use in-sink garbage disposals.
- Divert stormwater runoff coming from driveways and roofs away from the soil treatment area and wellhead. If the leach field is saturated, the system has failed.
- Do not dump grease or medications down the drain or into a toilet. Do not use the toilet as a trash can. Prescription medications and non-biodegradable artificial sweeteners have been found in groundwater downgradient from a failing septic system.
- If you are undergoing chemotherapy, ask your doctor about appropriate waste disposal methods to avoid discharging toxic drugs into the environment.
- Do not use chemicals to clean the septic system. They can interfere with the biological action in the tank, add toxic chemicals to groundwater, and clog the drain field by flushing sludge and scum into the field. Some septic cleaners contain solvents and degreasers and are banned in several states.
- Have the septic tank pumped every 2 to 3 years.
- Do not cover the drain field with an impervious surface such as a driveway or parking area.
- Do not drive heavy equipment over the components of a wastewater treatment system.
- Because septic systems do not remove nitrogen compounds efficiently (a common component in human waste), have the well water tested for nitrate every year. One of the most common pollutants found in domestic drinking water wells is nitrate.
- Conserve water in the home to reduce the amount of water that the wastewater treatment system must process. Excessive amounts of water can overload the system and cause it to fail.

Other problems to watch for include:

- Roots from trees and other vegetation may clog and damage the system.
- Some drinking water treatment systems, such as a reverse osmosis system and water softener systems, discharge waste brine and can increase the septic field load significantly. This increased volume of water may saturate your system, leading to failure.
- Spent brine discharge from reverse osmosis and water softeners will increase the concentrations of salt in the soil, which could change the soil

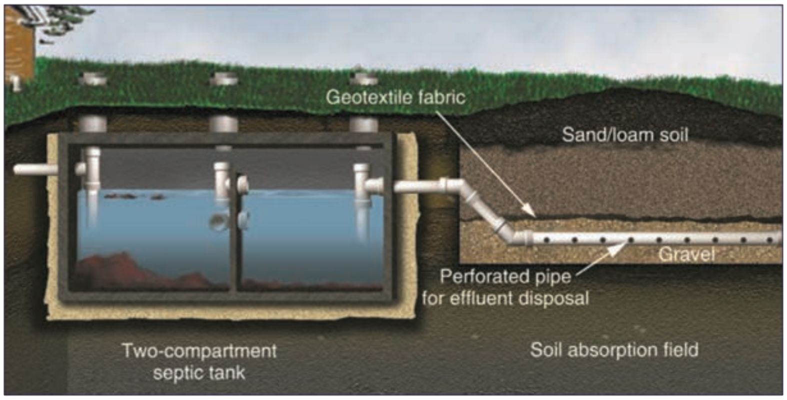


Figure 9.2 A septic tank and soil absorption field system. Source: Artiola, Uhlman, Hix, 2017. *Arizona Well Owner's Guide to Water Supply 2nd Edition*.

structure, causing the system to fail. Waste brine from reverse osmosis and/or water softeners may increase the amount of salt and untreated waste entering the aquifer.

9.4 Shock Chlorination of Water Wells

When a water system is contaminated with microorganisms, the well can be disinfected by shock chlorination. This process introduces very high concentrations of liquid chlorine, such as bleach, directly into the well and plumbing system. Chlorine is highly toxic to microorganisms and animals, including humans. For example, bleach can release harmful vapors and will damage skin when full-strength exposure occurs or when mixed with acids.

To reduce your risk of exposure to hazardous chemicals and to protect your pump and system components, have a licensed water well driller or pump installer conduct the procedure. See AZ1605 when considering well shock chlorination.

Downhole plumbing and pumps have been corroded with the excessive use of chlorine. To avoid expensive repair and replacement, the licensed contractor should take the responsibility of protecting your investment.

Schedule shock chlorination for when the water system will not be in use for at least 12 to 24 hours. In addition to the well, most water treatment equipment – including water heaters, softeners, filters, and pressure tanks – may need disinfection. During and immediately after the disinfection process, the water from the system will be unsuitable for consumption. You will need to flush the water system until all traces of chlorine are gone and the well water has been tested. Do not allow the water to be used for drinking until test results confirm the water is safe.

When chlorine chemicals are introduced into a well, some of the chemicals may enter the aquifer through the well screen. When the geologic material of the aquifer is exposed to chlorine, other constituents, such as arsenic, if present, may dissolve and enter the water supply. Always test your water after shock chlorination to assure safety.

In some cases, multiple shock chlorination procedures are not enough to resolve the problem. In those situations, a licensed well driller or pump installer will need to remove the pump and plumbing from the well and scrub the interior with brushes and chemicals made for this purpose.

9.5 Plugging Unused Water Wells

An abandoned well is a well that has been properly prepared and backfilled with a permitted aquifer sealing material by an Arizona licensed well driller after a Form 55-38 Notice of Intent to Abandon (NOIA) has been filed for approval with ADWR, and an abandonment authorization has been issued to the driller and the well owner. This legal authorization from ADWR is required prior to well abandonment, and the landowner may be liable for any groundwater contamination or injury that results from a lack of proper abandonment. Both the NOIA and a post abandonment completion report form must be signed by the Registered well owner.

An unused or improperly abandoned well is a direct channel from the ground surface to the aquifer below, depicted in Figure 9.3. Contaminants that enter the well move directly into the aquifer and may threaten human health and the environment. It also puts other wells in the same aquifer at risk for contamination, particularly those close to an open, unused non-abandoned well. A well owner who improperly abandons a well may be held liable for damage.

ADWR's well abandonment rule requires that well abandonment be accomplished "through filling or sealing the well so as to prevent the well, including the annular space outside the casing, from being a channel allowing the vertical movement of water" (A.A.C. R12-15-

816(G)). Specific materials and depths of fill are required based on which aquifer the well is located in, in addition to well depth. Only an Arizona licensed well driller can abandon a well.

Figure 9.3 Photo of an improperly capped unused well that should be abandoned. Improperly abandoned wells can be a source of groundwater pollution and maybe a safety concern. Source: Gary Hix

After abandonment, the well driller must file an Abandonment Completion Report, and the well owner must file a Well Owner's Notification of Abandonment. Additional information about filling a NOIA and abandonment procedures is available in the *"**Well Abandoned Handbook**"* available on the ADWR web site.

9.6 What does this mean for well owners?

- Groundwater can become contaminated by local sources, such as an over loaded septic system or chemicals stored by the wellhead.
- There are a number of protective measures that well owners can take to protect their well water quality.

Resources

Publications:

- *What Well Owners Should Know About Shock Chlorination*. 2013. Extension Publication #AZ1605.
- *Water Storage Tank Disinfection, Testing, and Maintenance*. 2012. Extension Publication #AZ1586.

SECTION 10
LOOKING TOWARDS THE FUTURE

Arizona's groundwater conditions are changing, and domestic well owners can play an important role in preparing for the years ahead. In many parts of the state, especially in basins without formal groundwater management, water levels are gradually declining as pumping exceeds **recharge**. Even within Active Management Areas (AMAs), the growing number of exempt wells has raised concerns about the cumulative volume of unregulated groundwater use. As water levels drop, some domestic wells may experience reduced production and worsened water quality as wells reach older water with higher mineral content and **salinity**. There have been ongoing discussions by policymakers in Arizona to address some of these challenges, but there are also actions that well owners can take to stay informed and mitigate future water insecurity.

10.1 Future Policy that May Impact Well Owners

Arizona is continuing to explore how future water policy may evolve. Discussions around rural groundwater management and the possible expansion or refinement of existing tools, such as Active Management Areas or Irrigation Non-Expansion Areas, may help communities plan for long-term water needs.

There is also interest in clarifying how groundwater withdrawals near streams should be identified and managed. As Tribal water settlements are finalized and stream adjudications are settled, understanding and establishing a separation between surface water under ground and groundwater is increasingly important to ensure that surface water is reaching the appropriate user. When surface water flows underground, it is called subflow. As of December 2025, the San Pedro River subflow zone, shown in Figure 10.1, is the only court-appointed subflow zone. However, ADWR has been creating subflow delineation reports for other rivers throughout the state including the Verde River, the Lower Colorado River, Upper San Pedro, Silver Creek, and Gila River among others. The status of these delineations and court approvals varies greatly. ADWR has an interactive map with updated subflow zones available at **https://azwater.maps.arcgis.com/apps/webappviewer/index.html?id=a4c748130c7b435ea72afebf90031f70**.

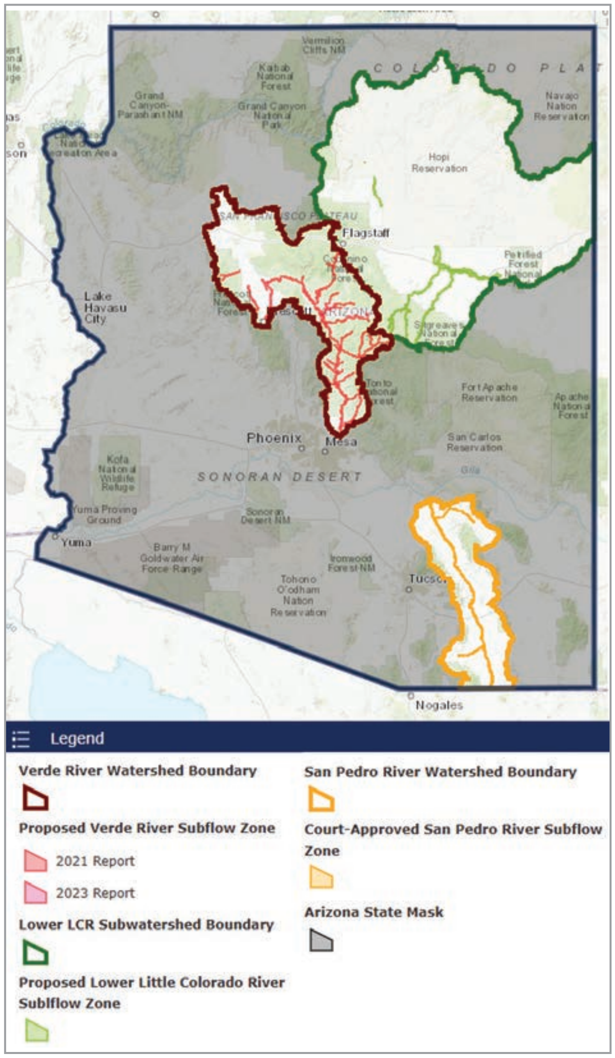


Figure 10.1 Screenshot of the ADWR's Subflow Zone Locator Map showing the Court-Approved San Pedro River Subflow Zone in yellow, the Proposed Lower Colorado River Subflow Zone in green, and the Proposed Verde River Subflow Zone in red. (Screenshot from November, 2025)

Figure 10.2 One of several groundwater recharge basins of the Southern Avra Valley Storage and Recovery Project (SAVSARP) used to recharge the aquifer with Colorado River water. Source: Artiola, Uhlman, Hix, 2017. *Arizona Well Owner's Guide to Water Supply 2nd Edition*.

Although the direction of future legislation is not yet known, these efforts share a common goal: supporting the long-term availability of groundwater for households, agriculture, and communities across the state. Staying informed may help domestic well owners take advantage of future programs, resources, or protections that emerge.

10.2 Increasing Local Water Infiltration

Large-scale recharge or storage projects in a basin, such as the Southern Avra Valley recharge basin near Tucson, shown in Figure 10.2, may influence local water levels as well, depending on geology and well depth. There are several strategies that domestic well owners can use today to support their wells and increase resilience, too. One strategy is to increase local rainwater infiltration on your property. On individual properties, practices such as imprinting, small check dams, and other soil-building approaches can help retain more moisture during storm events and support small-scale, localized recharge where conditions allow.

10.3 In-Home Water Conservation

In addition to increasing and monitoring groundwater, we can all work to reduce the amount of water we use. Inside the home, practical water conservation measures, such as efficient appliances, fixing leaks quickly, native landscaping, and responsible greywater harvesting, can significantly reduce daily water use. Many well owners find that combining several small actions can meaningfully extend the life and performance of their wells over time. For more ideas on water conservation, see Extension Publication #AZ1458.

10.4 Planning for the Future

Lastly, planning ahead for potential well deepening or pump replacement can help homeowners avoid unexpected disruptions in water service. Even if your system is performing well today, having a sense of timelines, costs, and local contractor availability ensures you can make informed decisions when the time comes. Thinking proactively about these possibilities keeps your water system resilient and ready for long-term use.

An additional benefit of protecting and preserving a domestic well is that it is a significant contribution to your real property investment. Should you need or desire to list and sell your real estate, a good working domestic water well is an asset to its overall value. What is the worth of land for a home if it has no groundwater to serve it?

Arizona's water future will require thoughtful planning, but domestic well owners are well positioned to succeed. Protecting local groundwater is a shared responsibility among all water users in a basin, and individual actions contribute to the strength of the whole community. With regular well maintenance, periodic water testing, smart water use, and awareness of upcoming policy discussions, domestic well owners can continue relying on their wells with confidence. Arizona communities have a long history of adapting to changing conditions, and the strategies outlined in this guide can help support a resilient groundwater future for everyone.

Resources

Publications:

- *Passive Water Harvesting.* 2012. Extension Publication #AZ1564.
- *Doing Our Part to Help Conserve Arizona's Water Resources and Reduce Global Warming by Saving Energy at Home*. 2008. Extension Publication #AZ1458

GLOSSARY

Acute - A rapid onset of an illness due to a one time or short time exposure to a chemical contaminant or waterborne pathogen. Example: gastrointestinal illness due to exposure to bacteria or water-borne toxin.

Alkalinity - The sum of all the ions that affect pH in water; these are: carbonates, bicarbonates and hydroxides. Alkalinity is usually reported as an equivalent amount $CaCO_3$ in mg/l or grains/gallon.

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

Anion/Cation Exchange - The replacement of one charged ion for another. Typical ion exchangers are ion exchange resins (porous gel polymers), zeolites, clays. Positively charged ions (cations) are replaced by cation exchangers, and negatively charged ions (anions) are replaced by anion exchangers. See water softeners in Section 8.

Aquifer - An aquifer is an underground geologic formation capable of producing (yielding or transmitting) usable quantities of water to a well or spring.

Aquitard - The aquitard is a low-permeability layer between ground level and the aquifer that forces water to flow around it rather than through it.

Artesian - Term applied to a well with groundwater under sufficient hydrostatic pressure to rise above the confined aquifer. If the pressure in a well is sufficient to bring the water to land surface, the artesian well is termed a 'flowing well.'

Confined - An aquifer bounded above and below by impermeable sediments or rock, or by geologic material of distinctly lower permeability (such as clay) than that of the aquifer itself.

Consolidated - Consolidated rock materials are bound or cemented hard rocks including granite formations.

Disinfection By-Products (DBPs) - Result from reactions between organic matter and some ions, like bromide, found in water and chemicals used to disinfect water. Typically, gaseous chlorine (Cl_2) or liquid sodium hypochlorite (bleach, NaOCl) is added to, and reacts with, water to form strong oxidizing agents, which disinfect the water. Potentially harmful compounds formed include trihalomethanes (THMs) and haloacetic acids (HAAs).

Domestic Purposes - In the state of Arizona, domestic purposes refer to the supply, service, and activities of household and private residences and includes the application of water to less than two acres of land to produce plants or parts of plants for sale or human consumption, or for use as feed for livestock, range livestock, or poultry.

Drawdown Cone or a Cone of Depression - The lowering of the water level in a well as a result of pumping. The water level is drawn-down, or depressed, in the shape of an inverted cone.

Endocrine Disruptors - Naturally occurring or man-made substances that may mimic or interfere with the function of hormones in the body. Endocrine disruptors may turn on, shut off, or modify signals that hormones carry and thus affect the normal functions of tissues and organs. The detection of numerous pharmaceutical agents and chemicals with endocrine disrupting potential in surface and groundwaters has raised concern about drinking water as a significant route of exposure.

Hydraulic Fracking - The process of injecting water with other liquids and sand at high pressure into the subsurface through boreholes to force open existing fissures and increase the flow of water, oil, or natural gas.

Hydrostatic - The pressure exerted by liquid. Hydrostatic pressure increases with depth because of the increasing weight of fluid.

Inactivate - With reference to disinfection, inactivation may not kill an organism, but causes damage so that the microorganism is unable to reproduce.

Land Subsidence - A gradual settling or sudden sinking of the Earth's surface owing to extraction of groundwater, oil, or mining.

mg/L of Nitrogen - Amount of nitrate in water expressed as the mass of the element nitrogen (N), excluding the mass of the three oxygens in nitrate, NO_3. The NPDWS is 10 mg/L as nitrogen, but the standard is 44 mg/L if written as the complete molecule NO_3. Most analytical laboratories measure nitrate in water as mg/L of nitrogen.

Microbial Indicators - Type of microbes easy to test for that indicate the likely presence or absence of pathogens that are difficult to test individually, in water. Public agencies therefore use the presence of other more abundant and more easily detected coliform bacteria as indicators of the presence of fecal and other pathogenic contamination.

Natural Organic Matter (NOM) - Found in all surface, ground and soil waters, NOM is the result of organic material dissolving in water, such as the soluble compounds in tea leaves being extracted by hot water to make a cup of tea.

Overburden - Layers of soil and rock that overlie an aquifer. This layer can serve as protection for deeper water sources by filtering contaminants, or serving as an impermeable layer (aquitard). When overburden is impermeable, this layer can create the pressure resulting in an artesian flow.

Overdraft - A deficit in a bank account is caused by drawing more money than the account holds. In hydrology, an overdraft is extracting more groundwater than the aquifer can sustain.

Picocuries (pCi/L) - Picocuries per liter (pCi/L) is a unit for measuring radioactivity concentrations. The curie (Ci) unit is the activity of 1 gram of pure radium 226. A "picocurie" is one-trillionth of a Curie. A Curie is equivalent to 37 billion radioactive disintegrations per second. One picocurie works out to 2.2 radioactive disintegrations per minute (dpm) in a liter of air.

Permeable - A porous material that allows liquids or gases to pass through it.

Point-of-Use (POU) and Point-of-Entry (POE) - Location where water treatment system is installed, with POE meaning "point of entry" into the home. POU indicates the system is installed at the "point of use," such as under the sink.

Porosity - Porosity is a measure of the total pore space in a material. This is measured as a volume or percent of space between the material particles. The amount of porosity in an aquifer depends on the particle size of minerals, their distribution, and the amount of sorting that occurs within the aquifer structure.

Precipitate/Precipitation - A precipitate is an insoluble solid that emerges from a liquid solution. The emergence of the insoluble solid from solution is called precipitation, which often forms scale.

Public Water System – These water systems serve at least 15 residential service connections year-round or at least 25 residents and are subject to state monitoring and adherence to NPDWS.

Radioactivity - Radioactivity is the release of energy from within unstable atoms in the form of atomic particles (alpha and beta) and gamma radiation. Radioactive atoms spontaneously break down (decay) to form more stable atoms.

Recharge - Recharge is the means by which the aquifer is filled with water, usually by rainfall or snowmelt infiltrating into the ground. Recharge tends to be the highest in mountain front regions.

Reclaimed Water - Or recycled water, is former wastewater (sewage) that is treated to remove solids, reduce organic matter, and disinfected enough to meet reuse standards. In Arizona, parks and golf courses must use reclaimed water for sustainable landscaping irrigation. It is also used to recharge groundwater aquifers, to sustain some riparian habitats, to meet commercial and industrial water needs, and, with additional treatment, for drinking.

Salinity (TDS) - Is the saltiness or dissolved salt content in water, reported as Total Dissolved Solids (TDS), measured in mg/L. The salt in the ocean is mostly made up of the elements sodium (Na) and chlorine (Cl), accounting for ~ 85 .7 percent of dissolved salt, and is measured at around 34,000 to 35,000 mg/L of TDS. Groundwater is considered 'fresh' when the TDS is below 3,000 mg/L, although the NSDWS recommends a TDS < 500 mg/L for drinking water. Groundwater is considered brackish between 3,000 to 10,000 mg/L, saline between 10,000 to 35,000 mg/L, and brine above 35,000 mg/L TDS.

Superfund - A U.S. federal government program designed to fund the cleanup of toxic wastes in the environment, established by the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). EPA may identify parties responsible for hazardous substances releases to the environment (polluters) and either compel them to clean up the sites, or it may undertake the cleanup on its own using the Superfund (a trust fund) and costs recovered from polluters by referring to the U.S. Department of Justice. In Arizona, the Superfund program sites are listed on the Water Quality Assurance Revolving Fund (WQARF) Registry, https://azdeq.gov/WQARF-Registry.

Turbidity - A measure of suspended solids in water in Nephelometric Turbidity Units (NTU).

Unconfined - An unconfined well or aquifer has only permeable material between ground level and the top of the water table, no aquitard. Water can recharge directly into these aquifers.

Unconsolidated - Unconsolidated rock materials are loose/unbound. Examples include the sands and gravels of river valleys, sand dunes, and the desert basins.

Vadose - The vadose zone, also termed the unsaturated zone, is the part of the aquifer between the land surface and the top of the water table. As precipitation filters through to recharge the aquifer, some moisture and many contaminants are retained within the vadose zone.

Water Table or Water Level - The upper portion of the aquifer, the line between the saturated and the unsaturated part. The term water table is only used for unconsolidated aquifers. Water level is the water depth from ground level for all geologies.

Well Logs - Also known as borehole logging, is the practice of making a detailed record (a well log) of the geologic formations penetrated by a borehole. Many logs will include the 'as-built' diagram of the well depth, screen length, and pump placement.

Yield - The amount of water produced by a well. Initial well yield is dependent on the hydrogeological conditions of the well. Well yield can be reduced by chemical precipitation and biological growth within the well screen.

ACRONYMS AND ABBREVIATIONS

ADHS - Arizona Department of Health Services

ADWR - Arizona Department of Water Resources

ADEQ - Arizona Department of Environmental Quality

AMA - Active Management Area

AZ ROC - Registrar of Contractors

BDL - Below Detection Limit

CDC - Center for Disease Control

EPA - United States Environmental Protection Agency

gpg - Grains per Gallon

gpm - Gallons per minute

INA – Irrigation Non-Expansion Area

MCL - Maximum Contaminant Level

MCLG - Maximum Contaminant Level Goal

mg/L –milligrams per liter

µg/L –micrograms per liter

ND - Not Detected

NOI - Notice of Intention

NOM - Natural Organic Matter

NPDWS - National Primary Drinking Water Standards

NSDWS - National Secondary Drinking Water Standards

NSF - National Sanitation Foundation

NTU - Nephelometric Turbidity Unit

pCi/L - picoCuries per liter

ppm - parts per million

PWS – Public Water Systems

SMCL – Secondary Maximum Contaminant Level

TDS - Total Dissolved Solids

USGS - United States Geological Survey

WHO - World Health Organization

APPENDIX I
National Primary Drinking Water Regulations

For the most up to date standards visit **https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations**.

Table Key:

- **D** Disinfectant
- **IOC** Inorganic Chemical
- **OC** Organic Chemical
- **DBP** Disinfection Byproduct
- **M** Microorganism
- **R** Radionuclides
- **PFAS** Per- and Poly-fluoroalkyl substances

	CONTAMINANT	MCL OR TT[1] (MG/l)[2]	POTENTIAL HEALTH EFFECTS FROM EXPOSURE ABOVE THE MCL	COMMON SOURCES OF CONTAMINANT IN WATER	PUBLIC HEALTH GOAL
OC	Acrylamide	TT[8]	Nervous system or blood problems; increased risk of cancer treatment	Added to water during sewage/ wastewater	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 1/23/2006	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	zero
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

	CONTAMINANT	MCL OR TT[1] (MG/l)[2]	POTENTIAL HEALTH EFFECTS FROM EXPOSURE ABOVE THE MCL	COMMON SOURCES OF CONTAMINANT IN WATER	PUBLIC HEALTH GOAL
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	0.01	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]
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	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

	CONTAMINANT	MCL OR TT[1] (MG/l)[2]	POTENTIAL HEALTH EFFECTS FROM EXPOSURE ABOVE THE MCL	COMMON SOURCES OF CONTAMINANT IN WATER	PUBLIC HEALTH GOAL
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-3chloropropane (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

	CONTAMINANT	MCL OR TT[1] (MG/l)[2]	POTENTIAL HEALTH EFFECTS FROM EXPOSURE ABOVE THE MCL	COMMON SOURCES OF CONTAMINANT IN WATER	PUBLIC HEALTH GOAL
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		0.1
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 systems, or kidneys: increased risk of cancer	Discharge from petroleum refineries	zero
IOC	Fluoride	4	Bone disease (pain and tenderness of the bones): Children may get mottled teeth		4
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)	0.06	Increased risk of cancer	Byproduct of drinking water disinfection	n/a
OC	Heptachlor	0.0004			zero
OC	Heptachlor epoxide	0.0002	Liver or kidney problems risk of cancer	Breakdown of heptachlor	zero

	CONTAMINANT	MCL OR TT[1] (MG/l)[2]	POTENTIAL HEALTH EFFECTS FROM EXPOSURE ABOVE THE MCL	COMMON SOURCES OF CONTAMINANT IN WATER	PUBLIC HEALTH GOAL
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

CONTAMINANT		MCL OR TT[1] (MG/l)[2]	POTENTIAL HEALTH EFFECTS FROM EXPOSURE ABOVE THE MCL	COMMON SOURCES OF CONTAMINANT IN WATER	PUBLIC HEALTH GOAL
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
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
PFAS	Hazard Index PFAS (HFPO-DA, PFBS, PFHxS, and PFNA)	1(unitless)	Low levels of multiple PFAS that individually would not likely result in increased risk of adverse health effects may result in adverse health effects when combined in a mixture. Increased health risks include liver, immune, and thyroid effects. Additionally, developmental and thyroid effects following repeated exposure during pregnancy and/or childhood.	Discharge from manufacturing and industrial chemical facilities, use of certain consumer products, occupational exposures, and certain firefighting activities.	1(unitless)
PFAS	HFPO-DA (commonly knowns as GenX Chemicals)	0.00001 HBWC=0.00001 [9]	Immune, liver and kidney effects; potential concern for cancer Developmental effects following repeated exposure during pregnancy and/ or childhood	Discharge from manufacturing and industrial chemical facilities, use of certain consumer products, occupational exposures, and certain firefighting activities.	0.00001
PFAS	PFBS	No individual MCL HBWC=0.002 [9]	See Hazard Index PFAS information	See Hazard Index PFAS information	No individual MCLG
PFAS	PFHxS	0.00001 HBWC=0.00001 [9]	Immune, thyroid, and liver effects; Developmental effects following repeated exposure during pregnancy and/or childhood	Discharge from manufacturing and industrial chemical facilities, use of certain consumer products, occupational exposures, and certain firefighting activities.	0.00001

	CONTAMINANT	MCL OR TT[1] (MG/l)[2]	POTENTIAL HEALTH EFFECTS FROM EXPOSURE ABOVE THE MCL	COMMON SOURCES OF CONTAMINANT IN WATER	PUBLIC HEALTH GOAL
PFAS	PFNA	0.00001 HBWC=0.00001 [9]	Elevated cholesterol levels and immune and liver effects; Developmental effects following repeated exposure during pregnancy and/or childhood	Discharge from manufacturing and industrial chemical facilities, use of certain consumer products, occupational exposures, and certain firefighting activities.	0.00001
PFAS	PFOA	0.000004	Cardiovascular, immune and liver effects; increased incidence of certain types of cancers including kidney and testicular; Developmental and immune effects following repeated exposure during pregnancy and/or childhood	Discharge from manufacturing and industrial chemical facilities, use of certain consumer products, occupational exposures, and certain firefighting activities.	zero
PFAS	PFOS	0.000004	Cardiovascular, immune and liver effects; increased incidence of certain types of cancers including liver. Developmental and immune effects following repeated exposure during pregnancy and/or childhood	Discharge from manufacturing and industrial chemical facilities, use of certain consumer products, occupational exposures, and certain firefighting activities.	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 rsk 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

	CONTAMINANT	MCL OR TT[1] (MG/l)[2]	POTENTIAL HEALTH EFFECTS FROM EXPOSURE ABOVE THE MCL	COMMON SOURCES OF CONTAMINANT IN WATER	PUBLIC HEALTH GOAL
IOC	Thallium	0.002	Hair loss; changes in blood; kidney, intestine, or liver problems	Leaching from oreprocessing 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 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 come from human and animal fecal waste.	zero
DBP	Total Trihalomethanes (TTHMs)	0.10 0.080 after 12/31/2003	Liver, kidney or central nervous system problems; increased risk of cancer	Byproduct of drinking water disinfection	n/a6
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	Allergic dermatitis; Changes in adrenal glands	Discharge from textile finishing factories	0.07
OC	1,1,1-Trichloroethane	0.2	Liver, nervous system, or circulatory problems	Dischargef from metal degreasing sites and other factories	0.2
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

CONTAMINANT		MCL OR TT[1] (MG/l)[2]	POTENTIAL HEALTH EFFECTS FROM EXPOSURE ABOVE THE MCL	COMMON SOURCES OF CONTAMINANT IN WATER	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 to Appendix I:

[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.
- Treatment Technique (TT) - A required process intended to reduce the level of a contaminant in drinking water.
- 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.

[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

A. Disinfect their water, and

B. Filter their water, or

C. Meet criteria for avoiding filtration so that the following contaminants are controlled at the following levels:

- *Cryptosporidium*: Unfiltered systems are required to include *Cryptosporidium* in their existing watershed control provisions
- *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, according to the treatment techniques in the Surface Water Treatment Rule, *Legionella* will also be controlled.

  - Turbidity: For systems that use conventional or direct filtration, at no time can turbidity (cloudiness of water) go higher than 1 Nephelometric Turbidity Unit (NTU), and samples for turbidity must be less than or equal to 0.3 NTUs in at least 95 percent of the samples in any month. Systems that use filtration other than the conventional or direct filtration must follow state limits, which must include turbidity at no time exceeding 5 NTUs.

- Heterotrophic Plate Count (HPC): No more than 500 bacterial colonies per milliliter.
- Long Term 1 Enhanced Surface Water Treatment: Surface water systems or groundwater under the direct influence (GWUDI) systems serving fewer than 10,000 people must comply with the applicable Long Term 1 Enhanced Surface Water Treatment Rule provisions (such as turbidity standards, individual filter monitoring, *Cryptosporidium* removal requirements, updated watershed control requirements for unfiltered systems).
- Long Term 2 Enhanced Surface Water Treatment Rule: This rule applies to all surface water systems or ground water systems under the direct influence of surface water. The rule targets additional *Cryptosporidium* treatment requirements for higher risk systems and includes provisions to reduce risks from uncovered finished water storage facilities and to ensure that the systems maintain microbial protection as they take steps to reduce the formation of disinfection byproducts.
- Filter Backwash Recycling: This 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 (TC-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:

- Trihalomethanes: bromodichloromethane (zero); bromoform (zero); dibromochloromethane (0.06 mg/L): chloroform (0.07 mg/L.
- Haloacetic acids: dichloroacetic acid (zero); trichloroacetic acid (0.02 mg/L); monochloroacetic acid (0.07mg/L). Bromoacetic acid and dibromoacetic acid are regulated with this group but have no MCLGs.

[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 0.010 mg/L.

[8]Each water system must certify, in writing, to the state (using third-party or manufacturer's certification) that when acrylamide and epichlorohydrin are used 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)

[9]Health Based Water Concentration (HBWC) - To calculate the Hazard Index, a ratio is developed for each PFAS by dividing the measured level of the PFAS in drinking water by the level below which adverse health effects are not likely to occur (i.e., the Health Based Water Concentration).

APPENDIX II
Water Problems: Symptoms, Test, and Possible Solutions

	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 in 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)
OTHER VISUALS	Houseplants stunted or with burned leaf tips	*Salinity	Reverse osmosis unit or distillation unit (POU)

	SYMPTOM	CAUSE	TREATMENT DEVICES
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 (geosmin 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.

Notes: **Indicates a common Arizona water quality issue*

NOM - *Natural Organic Matter* **POE** - *Point of entry*

VOC - *Volatile Organic Chemical* **POU** - *Point of use*

APPENDIX III
Certified Drinking Water Laboratories

For the most up to date laboratories visit **https://ells-lab-search.azdhs.gov/DrinkingWaterTestingLabsVs2/drinkingwatersearchcontentpage**.

Lab Name	Phone Number	City
Mohave Environmental Labs	(928) 754-8101	Bullhead City
Radiation Safety Engineering, Inc.	(480) 897-9459	Chandler
Inner Basin Environmental, LLC	(928) 440-5168	Flagstaff
Nortest Analytical	(928) 774-2312	Flagstaff
Mohave Environmental Labs	(928) 754-8101	Holbrook
Statewide Laboratory	(480) 981-8859	Mesa
Legend Technical Services of AZ, Inc.	(602) 324-6100	Phoenix
Motzz Laboratory, Inc.	(602) 454-2376	Phoenix
Alliance Technical Group, LLC – Phoenix	(714) 832-0064	Phoenix
Eurofins Environment Testing Southwest	(602) 437-3340	Phoenix
Fiberquant Analytical Services	(602) 276-6139	Phoenix
Bradshaw Mountain Environmental Inc.	(928) 778-4510	Prescott Valley
AGAT Laboratories	(480) 590-8839	Tempe
Aquatic Consulting & Testing, Inc.	(480) 921-8044	Tempe
A & B Labs Arizona Inc.	(602) 437-0762	Tempe
Turner Laboratories, Inc.	(520) 882-5880	Tucson
Complete Analytical Services, LLC	(520) 884-5811	Tucson
Legend Technical Services, Inc.	(520) 327-1234	Tucson
American Analytical	(928) 985-9399	Tucson
Fresh Terra Services, LLC.	(928) 257-3601	Yuma
Eurofins Microbiology Laboratories	(928) 317-1127	Yuma

APPENDIX IV
Water Treatment Technologies and Maintenance Requirements

The table below was developed based on exhibits presented in the EPA's *Point-of-Use or Point-of-Entry Treatment Options for Small Drinking Water Systems*.

Treatment Technology	POU/POE	Contaminants	Maintenance[1]	Notes
Activated Alumina	POU	Arsenic[a] Fluoride Uranium	Replacement of spent cartridges and particulate pre-filters (if used).	Recommended for flows 0.5-1 GPM
	POE	Arsenic Fluoride Uranium	Periodic backwashing. Replacement of spent media and particulate prefilters (if used).	Recommended for flow rates >4 GPM
Aeration (Diffused Bubble or Packed Tower)	POE	VOCs Radon	Replacement of particulate pre-filters, air filters, and of post-treatment GAC polishing filters. Maintenance of fan, motors, and repressurization pumps.	
Distillation	POU	Arsenic Copper Lead Nitrate[a]		
Granular Activated Carbon (GAC)	POU	SOCs[a]	Replacement of spent cartridges and particulate pre-filters (if used).	Recommended for flows 0.5-1 GPM
	POE	Radon[b]	Periodic backwashing. Replacement of spent media and particulate prefilters (if used).	Recommended for flow rates >4 GPM
Anion Exchange (AX)	POU	Arsenic Antimony[a] Chromium[a] Selenium[a] Uranium[a]	Replacement of spent resin cartridges and particulate pre-filters (if used).	Recommended for flows 0.5-1 GPM
	POE	Arsenic Nitrate Uranium	Regular regeneration and periodic backwashing. Replacement of salt used for resin regeneration. Replacement of lost or spent resin and replacement of particulate pre-filters.	Recommended for flow rates >4 GPM
Cation Exchange (CX)	POU POE	Barium[a] Beryllium[a] Cadmium[a] Copper[a] Lead[a] Radium[a] Thallium[a]	Replacement of spent resin cartridges and particulate pre-filters (if used).	Recommended for flows 0.5-1 GPM
		Copper Lead Radium	Regular regeneration and periodic backwashing. Replacement of salt used for resin regeneration. Replacement of lost or spent resin and replacement of particulate pre-filters.	Recommended for flow rates >4 GPM

Treatment Technology	POU/POE	Contaminants	Maintenance[1]	Notes
Reverse Osmosis (RO)	POU	Antimony[a] Arsenic[a] Barium[a] Beryllium[a] Cadmium[a] Chromium[a] Copper[a] Lead[a] Fluoride[a] Selenium[a] Radium[a] Thallium[a] Uranium[a]	Replacement of exhausted membranes, particulate pre-filters, and pre- and post- treatment GAC filters. Maintenance of (re) pressurization pumps (if used). Disposal of a liquid waste stream (~7-8 gallons for every 2-3 gallons produced).	Recommended for flows 10-100 GPD
	POE	Arsenic Copper Lead Fluoride Nitrate SOCs Radium Uranium Microbial	Replacement of exhausted membranes, particulate pre-filters, and pre- and post- treatment GAC filters. Maintenance of (re) pressurization pumps (if used). Disposal of a liquid waste stream (~7-8 gallons for every 2-3 gallons produced).	Recommended for flow rates >300 GPD
Other Adsorptive Media	POU	Arsenic	Replacement of spent cartridges and particulate pre-filters (if used).	Recommended for flows 0.5-1 GPM
	POE	Arsenic	Periodic backwashing. Replacement of spent media and particulate prefilters (if used	Recommended for flow rates >4 GPM
Ultraviolet Light (UV)	POE	Microbial	Replacement of UV bulbs. Cleaning bulb housing.	

[a]Indicates a recognized Small System Compliant Technology by the EPA

[b]Indicates a recognized Small System Compliant Technology by the EPA for systems serving < 500 people

[1]All POE devices require maintenance and cleaning of storage tank (if used).

APPENDIX V
ADEQ and ADWR Reports

The Arizona Department of Environmental Quality (ADEQ) and the Arizona Department of Water Resources (ADWR) have created many resources that may be of interest to well owners. Many of these reports are by water basin, shown in the map at the front of this guide. ADEQ has reported on groundwater quality for many basins. Basin water quality reports can be found by searching on the ADEQ web site **https://azdeq.gov/gw-basin-fs**. Statewide groundwater quality reports are available below as well.

- *Groundwater Quality in Arizona: A 20-Year Overview of the ADEQ Ambient Monitoring Program (1995-2015)* ADEQ Open File Report 16-02, 42 p., August 2016.
  https://static.azdeq.gov/wqd/gw/fs/16-02_20year_final_ofr.pdf
- *Groundwater Quality in Arizona: A 15-Year Overview of the ADEQ Ambient Monitoring Program (1995-2009)*, ADEQ Open File Report 11-04, 25 p., July 2011.
  https://static.azdeq.gov/wqd/gw/fs/11-04_gwq_az_ofr.pdf

ADWR has reported on basin groundwater use and levels in basin supply and demand reports and detailed groundwater level reports in open-file reports. Supply and demand reports are available on the Supply and Demand Program website, **https://www.azwater.gov/supply-demand**. More detailed hydrologic reports are available on the hydrology page, **https://www.azwater.gov/hydrology/field-services/groundwater-level-changes**.

APPENDIX VI
Tribal Water Management Entity

Tribal Water Management Entity		
Tribal Nation	**Water Management Entity**	**Website**
Ak-Chin Indian Community	Department of Water Operations	https://www.ak-chin.nsn.us/departments/ (520) 568-1000
Cocopah Indian Tribe	Environmental Protection Office	https://www.cocopah.com/departments.html (928) 627-2025
Colorado River Indian Tribes	Department of Water Resources	https://crit-nsn.gov/critwater/ (928) 669-1312
Fort McDowell Yavapai Nation	Environmental Department	https://fmyn.org/departments/ (480) 789-7163
Fort Mojave Indian Tribe	Department of Agriculture, Land, and Water Resources	https://www.fortmojaveindiantribe.com/tribal-departments/agriculture-land-water-resources/ (928) 346-1606
Gila River Indian Community	Department of Drinking Water	https://www.gricdeq.org/index.php/water-quality-program/drinking-water (520) 562-3343
Havasupai Tribe	-	https://theofficialhavasupaitribe.com/Havasupai-Government/havasupai-government.html
Hopi Tribe	Water Resources Department	https://www.hopi-nsn.gov/tribal-services/department-natural-resources-2/water-resources/ (928) 734-3712
Hualapai Tribe	Department of Natural Resources	https://hualapai-nsn.gov/services/natural_resources.php (928) 769-2254
Kaibab Band of Paiute Indians	-	https://www.kaibabpaiute-nsn.gov/index.php (928) 643-7245
Navajo Nation	Department of Water Resources	https://watercode.navajo-nsn.gov/private_well_development.html (928) 729-4132
Pascua Yaqui Tribe	Environmental Protection Agency	https://www.pascuayaqui-nsn.gov/health-services/community/environmental-protection-agency/ (520) 879-6124
Pueblo of Zuni	Department of Natural Resources	https://www.ashiwi.org/Programs.html#iqiuwy (505) 782-2484

Tribal Water Management Entity		
Tribal Nation	**Water Management Entity**	**Website**
Quechan Indian Tribe	Department of Water Management	https://quechantribe.com/departments-water-management.html (760) 919-3650
Salt River Pima-Maricopa Indian Community	Department of Public Works	https://srpmic-nsn.gov/government/public-works/ (480) 362-5600
San Carlos Apache Tribe	Department of Environmental Protection	https://www.scat-nsn.gov/natural-resources/departmentofenvironmentalprotection/ (928) 475-2218
Tohono O'odham Nation	Department of Water Resources	https://www.tonation-nsn.gov/water-resources/ (520) 383-2362
Tonto Apache Tribe	-	https://itcaonline.com/member-tribes/tonto-apache-tribe/ (928) 474-5000
White Mountain Apache Tribe	Environmental Protection Office	https://www.wmat.us/EPO/epo_home.html (928) 338-4325
Yavapai-Apache Nation	Utility Authority	https://yavapai-apache.org/directory/utility-authority/ (928) 649-6930
Yavapai-Prescott Indian Tribe	-	https://www.ypit.com/contact.htm (928) 445-8790

Note: The San Juan Southern Paiute Tribe was not included in this table since they did not have a reservation at the time that this document was published. Wells drilled by members would fall under the jurisdiction of ADWR or another tribe.

Arizona Groundwater Basins and Sub-basins

Source: University of Arizona Water Resources Research Center (2026), based on data from the Arizona Department of Water Resources (ADWR).

0 25 50 75 100 Miles

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