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Groundwater Quality Interpretation Guide

Understanding Your Water Quality Results

When you receive your water quality results from a laboratory, they will be in a table format that displays the test results alongside other information, such as the federal drinking water limits or the Colorado Department of Public Health and Environment groundwater standards, for each analyte tested. Some laboratories will include supplementary materials to aid with interpretation of the data or to answer questions about the findings, but every laboratory is different. To help you further, The Colorado Water and Energy Research Center (CWERC) has compiled a few data interpretation tips here. Below, you will find a few general pointers and a table that provides background information on each item in CWERC's *full suite* of analytes.

General Pointers:

- As you interpret your water quality results, please keep in mind that groundwater chemistry can shift for many reasons. You should consider the possibility of seasonal changes to your groundwater quality, as well as the influence of your local geology (for example, does the soil in your area contain high amounts of selenium?). Furthermore, you should consider *all* of the different land uses near you as you interpret your groundwater quality data. While CWERC highlights contaminants potentially associated with oil and gas development in this interpretation guide, these are not the only possible sources of groundwater contamination in your area. Common sources of groundwater pollutants include fertilizers, animal manure, herbicides, insecticides, pesticides, septic systems, leaking storage tanks and pipes, storm-water runoff, hazardous waste, and chemical spills. In an effort to provide you with as much information as possible to aid you in the interpretation of your results, CWERC includes information about these types of contaminants in addition to the context about oil and gas extraction.

- In addition to inspecting the results that come back from the laboratory, you should pay close attention to the **physical characteristics** of your water as you use it. You are your own best monitor of your water's physical state. Watch for changes in appearance such as color; increased sediment (turbidity); foaming, bubbling or spurting faucets (effervescence); and floating oil or film. Be attentive to changes in taste, including salty or metallic tastes, as well as changes in odor, such as a rotten egg or fuel smells. Note that some forms of water contamination have no obvious stains, odors, or tastes, which is why laboratory analysis is important.

- Whether or not a specific substance is harmful depends on its toxicity, its concentration, the length of time a person may have been drinking water contaminated by that substance (days? months? years?), as well as that person's age and health. Federal drinking water standards exist to regulate public water systems, as enforced by the Colorado Safe Drinking Water Program. These legal standards do *not* apply directly to individual private wells. As CWERC's monitoring guide explains, individual well owners are responsible for testing and maintaining their own wells. The federal drinking water standards can be useful for data interpretation, however, since they make for a solid benchmark against which to gauge your own water quality. Two tiers of water quality regulations exist at the federal level for public drinking water systems: the **National Primary Drinking Water Standards**, which are legally enforceable standards designed to regulate harmful contaminants, and the **National Secondary Drinking Water Regulations**, which are non-enforceable guidelines regulating contaminants that may cause cosmetic or aesthetic effects in drinking water. You can find information on both the primary and secondary standards at the Environmental Protection Agency's Website. **CWERC has included information on the federal limits in the Water Quality Interpretation Table that follows below. CWERC has also included the Colorado Department of Public Health and Environment (CDPHE) groundwater standards.** These state-level groundwater standards are enforceable by the Colorado Oil and Gas Conservation Commission (COGCC) and other state agencies involved in groundwater protection. State standards generally match the EPA public drinking water standards for the analytes CWERC selected. You can find more information about both the EPA public drinking water standards and the CDPHE groundwater standards on the CWERC website.

- If you have performed baseline testing in the fall and spring, you have begun to capture the **normal seasonal range** for the Full Index and Indicator analytes. Watch for variations in that range. In particular, look for cases in which the analyte concentration falls on the high side of your established range, particularly if an analyte **increases by 20 percent or more**. Pay special attention to cases where an analyte begins to **meet or exceed the federal drinking water limits** mentioned above and listed in the interpretation table below. (An exception: The stable isotopes of water – oxygen-18 and deuterium – may change more than 20 percent without concern.)

- You should be less concerned if an analyte jumps by more than 20 percent, but is still present only in a trace amount. A trace amount is a quantity that is so small that it is difficult to accurately measure. For example, if the **reporting limit** (the smallest amount a lab can detect and quantify) of a particular analyte is 0.0001 mg/L, and your sample jumps from 0.0001 mg/L to 0.0002 mg/L between the first and second rounds of sampling, you will have seen a 100% change, but the change may not be significant because it is still a **trace amount**.

- As you're looking over your water quality data, keep an eye out for changes described in the table below, which could indicate oil or gas drilling-related impacts, or other culprits. To gauge the potential for drilling-related impacts, start by looking for rapid **increases or decreases in specific conductance**, which could indicate the presence of **produced water** or **hydraulic fracturing fluid**. Produced water is deep subsurface fluid drawn from a gas well before or during oil or gas production, often a salty brine from ancient marine environments. Hydraulic fracturing fluid is the fluid that oil and gas service providers inject into the subsurface to fracture the target geologic formation and boost well productivity. It is typically a mix of water, chemicals, and a solid such as silica or sand.

WATER QUALITY INTERPRETATION TABLE

GENERAL WATER QUALITY PARAMETERS (Basic indicators of water chemistry and quality.)		
Analyte	**Description**	**Limit**
Alkalinity	A measure of the ability of a solution to neutralize acids and a buffer that prevents large variations in pH. Alkalinity is a function of the amount of bicarbonate, carbonate, or hydroxide in water. Changes in alkalinity may indicate other changes in water chemistry. Combined with hardness and high levels of total dissolved solids, high alkalinity (above 500 mg/L) can adversely affect plumbing systems, especially water heaters.	Not regulated in drinking water by EPA or CDPHE. A recommended range for drinking water is 30-400 mg/L, according to the Illinois Dept. of Public Health.
Conductance (or Specific Conductance)	A measure of water's ability to conduct an electrical current. It is a proxy for the amount of inorganic dissolved solids in water; as dissolved substances increase, so does conductance. Conductance is also used to describe the salinity of water. It can serve as a proxy for Total Dissolved Solids (TDS) that can be measured in the field. **It is also an inexpensive indicator for when more comprehensive testing may be needed.** Many land uses can affect specific conductance, which makes it a good preliminary indicator of change, but not a conclusive one. In an oil and gas context, changes in conductance could indicate contamination by produced water, which is usually high in salts, or hydrologic communication between geologic zones, seepage, or spills.	Not regulated in drinking water by EPA or CDPHE. Measured in microsiemens per centimeter (µs/cm), informal estimates put drinking water in the range of 50-1,500 uS/cm.
pH	A measure of acidity or basicity on a scale from 0-14. pH is sensitive to small changes in water chemistry. Like conductance, pH can be considered a good preliminary indicator that your water quality is changing for some reason, but it alone cannot be used to identify the culprit. In an oil and gas context, a reduced pH could indicate the presence of acids, which are used in fracturing fluids. Water with a pH lower than 6.5 or greater than 8.5 can corrode lead and copper from household plumbing.	National Secondary Drinking Water Standard: 6.5-8.5 CDPHE Human Health Standard: 6.5-8.5
Dissolved Organic Carbon (or Total Organic Carbon)	A broad classification for organic molecules in water. Organic molecules are any molecules that include carbon, including the hydrocarbons associated with oil and gas. Dissolved organic carbon (DOC) consists of tiny carbon molecules that have passed through a filter, while Total Organic Carbon (TOC) accounts for molecules of various sizes. Oil and gas are extracted from rock formations that contain lots of organic carbon. Water from such rock formations has	Not regulated in drinking water by EPA or CDPHE.

	the potential to contain increased amounts of DOC and TOC. **Thus, increases in the amount of DOC and/or TOC may be a relatively inexpensive indicator of the presence of oil or gas-related fluids or gasses in your water**. DOC and TOC may increase for other reasons as well, such as septic or fertilizer leakage, since carbon is present in all organic molecules.		
MAJOR IONS (Molecules with a net positive or negative charge.)			
Analyte	**Description and Sources**	**Notes**	**Limit**
Calcium	Calcium is a common ion in groundwater. Calcium often leaches into groundwater from limestone deposits. Changes in calcium may be tied to the presence or absence of other major ions, which can shift for numerous reasons. Calcium is a major contributor to water hardness.		Not regulated in drinking water by EPA or CDPHE.
Chloride	Chloride is a common ion in groundwater. Chloride can be found in fertilizers, industrial wastes, and sewage. In many rural areas, increases in chloride in surface water and shallow groundwater is the direct result of road salt application. In an oil and gas context, most produced water is high in chloride, but not all. (Produced water from coalbed methane wells isn't necessarily high in chloride.) A significant increase in chloride could indicate hydrologic communication between geologic zones, seepage or spills. Changes in chloride may also be tied to the presence or absence of other major ions, which can shift for many reasons.		National Secondary Drinking Water Standard: 250 mg/L CDPHE Drinking Water Standard: 250 mg/L
Fluoride	Fluoride is a common ion in groundwater. At low concentrations, fluoride can reduce the risk of dental cavities. Municipal water is often treated with low levels of fluoride. Fluoride naturally leaches into groundwater from bedrock. It also occurs in discharge from fertilizer and aluminum factories. Changes in fluoride may be tied to the presence or absence of other major ions, which can shift for many reasons. In an oil and gas context, naturally-occurring fluoride in bedrock could be mobilized in groundwater by drilling and fracturing processes.		National Primary Drinking Water Standard: 4.0 mg/L CDPHE Human Health Standard: 4.0 mg/L
Magnesium	Magnesium is a common ion in groundwater. Magnesium is a major contributor to water hardness. Magnesium often leaches into groundwater from dolomite deposits. Changes in magnesium may be tied to the presence or absence of other major ions, which can shift for many reasons. In an oil and gas context, naturally-occuring magnesium could be mobilized in groundwater by drilling and fracturing processes.		Not regulated by EPA or CDPHE.
Potassium	Potassium is a common ion in groundwater. Changes in potassium may be tied to the presence or absence of other major ions, which can shift for many reasons. In an oil and gas context, moderate levels of potassium can be found in produced water. A significant increase in chloride could indicate hydrologic communication between geologic zones, seepage or spills of produced water.		Not regulated in drinking water by EPA or CDPHE.

Sodium	Sodium is a common ion in groundwater. Changes in sodium may be tied to the presence or absence of other major ions, which can shift for many reasons. In an oil and gas context, high levels of sodium can be found in produced water. Produced water from coalbed methane formations is usually high in sodium bicarbonate or sodium chloride, making sodium a large presence. A significant increase in sodium may indicate hydrologic communication between geologic zones, seepage or spills of produced water.		Not regulated in drinking water by EPA or CDPHE. EPA informally recommends an upper limit of 20 mg/L for people on low-sodium diets.
Sulfate	Sulfate is a common ion in groundwater. Changes in sulfate may be tied to the presence or absence of other major ions, which can shift for many reasons. Sulfate often leaches into groundwater from shale deposits. Byproducts of coal mining, industrial wastes, and sewage are also high in sulfate. Bacterial process often change sulfate concentrations as well. For more information on sulfur bacteria, a nuisance bacteria that isn't particularly harmful but can be quite damaging to water systems, visit CDPHE's Laboratory Services Division website(http://www.colorado.gov/cs/Satellite/CDPHE-Lab/CBON/1251583470522).		National Secondary Drinking Water Standard: 250 mg/L CDPHE Drinking Water Standard: 250 mg/L
Nitrate + Nitrite (total)	Nitrate/nitrite is a major constituent of fertilizer, which can seep into groundwater supplies. Also found in leachate from septic tanks, sewage, and erosion of geologic deposits. Much more likely to come from agricultural operations or septic tank leakage than oil and gas drilling, but a recommended test regardless because it can help identify these other potentially dangerous contamination pathways. Generally, nitrate is not harmful to adults, but levels above 10 mg/L are quite harmful to infants.		National Primary Drinking Water Standard: 10 mg/L CDPHE Human Health Standard: 10 mg/L
METALS			
Analyte	**Description and Sources**	**Notes**	**Limit**
Arsenic	Arsenic is a highly poisonous metal when it is present in quantities over 0.010 mg/L. Arsenic often leaches into groundwater from granite deposits. It can also be found in runoff from orchards, as well as waste from glass and electronics production. Arsenic is sometimes included in biocides used in fracturing fluids, though this is less common in Colorado, where organic compounds are more typical.		National Primary Drinking Water Standard: 0.010 mg/L CDPHE Human Health Standard: 0.010 mg/L
Barium	Barium may also be found in discharge from metal refineries and erosion of natural deposits. In an oil and gas context, the mineral barite is a principal component of drilling muds. Barite is insoluble in water, so if it is present, it may be in solid form.		National Primary Drinking Water Standard: 2.0 mg/L. CDPHE Human Health Standard: 2.0 mg/L

Boron	Boron naturally occurs in certain geologic formations as borate, or in other forms. In an oil and gas context, it can be found in some hydraulic fracturing fluids.	Not regulated by EPA. CDPHE Agricultural Standard for Groundwater: 0.75 mg/L
Chromium	Chromium is a naturally occurring trace element in certain igneous geologic deposits. Chromium can be found in discharge from steel and pulp mills. In an oil and gas context, chromium can be found in drilling waste.	National Primary Drinking Water Standard: 0.1 mg/L CDPHE Human Health Standard: 0.1 mg/L
Copper	Copper is generally low in groundwater. May be introduced by mining, farming, manufacturing, or industrial wastewater. Can also occur in water due to corrosion of household plumbing systems by acidic water. In an oil and gas context, copper could be mobilized from deep oil- or gas-bearing geologic formations by drilling or fracturing processes.	EPA Action Level: 1.3 mg/L CDPHE Drinking Water Standard: 1 mg/L
Iron	Iron is commonly found in groundwater from weathering of iron-bearing minerals, rocks, and soils. It may also be introduced by industrial wastewater, acid-mine drainage, sewage, and landfill leachate, the leaching of cast-iron pipes in plumbing systems, or iron bacteria. For more information on iron bacteria, a nuisance bacteria that isn't particularly harmful but can be quite damaging to water systems, visit CDPHE's Laboratory Services Division website (http://www.colorado.gov/cs/Satellite/CDPHE-Lab/CBON/1251583470522). In an oil and gas context, iron is present in some oil- and gas-bearing geologic formations and could be mobilized by drilling or fracturing processes.	National Secondary Drinking Water Standard: 0.3 mg/L CDPHE Drinking Water Standard: 0.3 mg/L
Lead	Lead is a known neurotoxin. It occurs naturally in certain geologic deposits. Lead was also a component of plumbing solder used in homes with copper plumbing installed before 1985. May be leached from lead soldered joints, as well as from faucets and lead pipes. In an oil and gas context, naturally occurring lead in shale and other geologic formations could be mobilized by drilling or fracturing processes.	CDPHE Human Health Standard: 0.05 mg/L
Manganese	Manganese produces a black stain in the presence of oxygen. Commonly found in groundwater from weathering of manganese-bearing minerals, rocks, and soils. Changes in manganese may indicate the presence of bacteria (see iron and sulfur entries above).	National Secondary Drinking Water Standard: 0.05

	In an oil and gas context, manganese is present in deep oil- and gas-bearing geologic formations and may be mobilized by drilling or fracturing processes.		mg/L CDPHE Drinking Water Standard: 0.05 mg/L
Selenium	Selenium is present in many Colorado soils and geologic formations. Selenium can also occur in discharge from petroleum refineries and mines. In an oil and gas context, naturally-occurring selenium in shale and other geologic deposits could be mobilized by drilling or fracturing processes.		National Primary Drinking Water Standard 0.05 mg/L CDPHE Human Health Standard: 0.05 mg/L
VOLATILE ORGANIC COMPOUNDS **(Carbon-containing chemical compounds that are quick to volatize in the atmosphere.)**			
Analyte	**Description and Sources**	**Notes**	**Limit**
Methane	Dissolved methane occurs naturally in shallow aquifers due to decomposition of organic matter and/or natural seepage from methane-bearing geologic formations. In an oil and gas context, methane may be mobilized in the subsurface by drilling and fracturing processes or may leak through faulty well casing. Methane comes in two varieties from two different sources: thermogenic methane comes from deep oil- or gas-bearing deposits, while biogenic methane comes from shallow biological sources. An unusual change in the amount of methane in groundwater may indicate changing conditions underground, such as migration of gasses into aquifers due to drilling and production or some other perturbation. If the concentration of methane in drinking water is greater than 1 mg/L, COGCC will conduct an additional analysis of its isotopic content to determine the methane's source (i.e., if it is derived from biological processes or oil and gas formations – see entry on Stable Isotopes of Methane below).		U.S. Department of the Interior recommends venting of water wells that contain greater than 10 mg/L of dissolved methane to minimize explosion hazard from methane gas building up inside a home.
BTEX Compounds: Benzene, Toluene, Ethylbenzene, Xylene	BTEX compounds are dangerous organic chemicals that easily volatilize into gas. They occur naturally in shales and other geologic formations, and are also present in household and industrial solvents, gasoline, and fuel oil. In an oil and gas context, BTEX compounds may occur in produced water and hydrocarbons. BTEX compounds may also be added to fracturing fluids.		National Primary Drinking Water Standard: Benzene: 0.005 mg/L Toluene: 1.0 mg/L Ethylbenzene: 0.7 mg/L Xylene: 10.0 mg/L

OTHER			
Analyte	**Description and Sources**	**Notes**	**Limit**
Static Water Level	Static water level is the level of water in a well during normal conditions and prior to any pumping, and it is used as a preliminary measure of the amount of water in the aquifer. Changes to static water level may indicate changes to the physical integrity of an aquifer. In interpreting these changes, one must take care to consider recent use patterns, precipitation, season, effects of competing wells, well construction and maintenance, as well as whether the well is completed in a deep confined aquifer or a shallow alluvial aquifer.		N/A
Stable Isotopes of Water **Oxygen-18** **(^{18}O)**	Oxygen-18 (^{18}O) is a naturally occurring isotope of oxygen that has two more neutrons than most oxygen atoms. This gives oxygen-18 an atomic mass of 18 instead of the usual 16. The ratio of oxygen-16 and oxygen-18 in a water molecule can tell us a lot about where that water molecule came from, since different sources of water show different ratios (i.e., snow is lower in oxygen-18 than rain). When used in conjunction with other water quality data, such as ion concentrations, isotope data brings significant interpretive power. It can help us "fingerprint" different sources of water, even if they have been mixing together, such as groundwater in an aquifer and produced water from a gas well.		A natural component of water molecules. Not regulated in drinking water by EPA or CDPHE.
Stable Isotopes of Water **Deuterium** **(^{2}H)**	Deuterium (^{2}H) is a naturally occurring isotope of hydrogen that has one more neutron than most hydrogen atoms. This gives deuterium an atomic mass of 2 instead of the usual 1. The ratio of ^{1}H and ^{2}H (deuterium) can tell us a lot about where a water molecule came from, since different sources of water show different ratios (i.e., snow is lower in deuterium than rain). When used in conjunction with other water quality data, such as ion concentrations, isotope data brings significant interpretive power. It can help us "fingerprint" different sources of water, even if they have been mixing together, such as groundwater in an aquifer and produced water from a gas well.		A natural component of water molecules. Not regulated in drinking water by EPA or CDPHE.
Stable Isotopes of Methane **Carbon** **(^{13}C)**	Carbon-13 (^{13}C) is a naturally occurring isotope of methane gas that has one more neutron than most carbon atoms, which are Carbon-12 (^{12}C). The ^{13}C values can tell us a lot about whether methane gas came from a biogenic source, such as bacteria in the subsurface, or from a deep thermogenic source, which is the type of methane that natural gas operators extract. Generally speaking, carbon isotope ($\delta^{13}C$) values less negative than approximately −50‰ are indicative of deeper thermogenic methane, whereas values more negative than −64‰ are strongly indicative of biogenic methane. The odds of thermogenic sources increase as higher-chain hydrocarbons (such as ethane, propane, butane, and pentane) increase alongside the methane.		