ARID

Agroecosystem Resilience In Times of Drought

Final Groundwater Report

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Introduction

Agriculture is a leading factor in land-use/land-cover change (LULCC) and ecosystem shifts around the world (e.g., Pielke et al., 2016; Vadjunec et al., 2016). Poor management practices can lead to degradation of land, and when coupled with increasing climate variability and cyclical drought, increases pressure on land managers who are seeking to balance both ecological and economic sustainability (Bazemore, 2008). The Southern Great Plains (SGP) is a region that is a high-stakes agroecosystem as it is not only a center of agricultural production for North America, and the world, but is also historically prone to deep, prolonged drought such as the Dust Bowl. Resiliency of agricultural producers and communities in this region is critical, both in terms of management of the land itself, but also water resources. Much of this region is heavily reliant on groundwater as there are few perennial surface water sources for either agricultural uses or community/domestic use.

Ultimately, the resiliency of an agroecosystem is determined by the level of involvement by local stakeholders in research and application of research for the myriad issues that face these communities and producers. The Agroecosystem Resilience In times of Drought (ARID) Project sought to explore the efficacy of participatory research approaches (PAR) to increase resilience in agroecological communities in the SGP, specifically the tri-state area of New Mexico, Colorado, and Oklahoma (Figure 1). The ARID Project, in part, built on an existing grassroots, participatory groundwater project that began in Union County, New Mexico in 2010. This project was started by the local Soil and Water Conservation District (Northeastern SWCD) and is currently being led by the NESWCD, Union County, and a small geologic consulting company (Zeigler Geologic Consulting, LLC; ZGC). Communities and producers throughout the SGP are aware of the enormous stresses on groundwater resources (e.g., Wenger et al., 2017), but for some areas, there is little data available to determine a) strain on local aquifers via center pivot irrigation (CPI) versus livestock use, b) changes in quantity and quality of groundwater, and c) recharge potential for the various aquifers in use throughout the area.

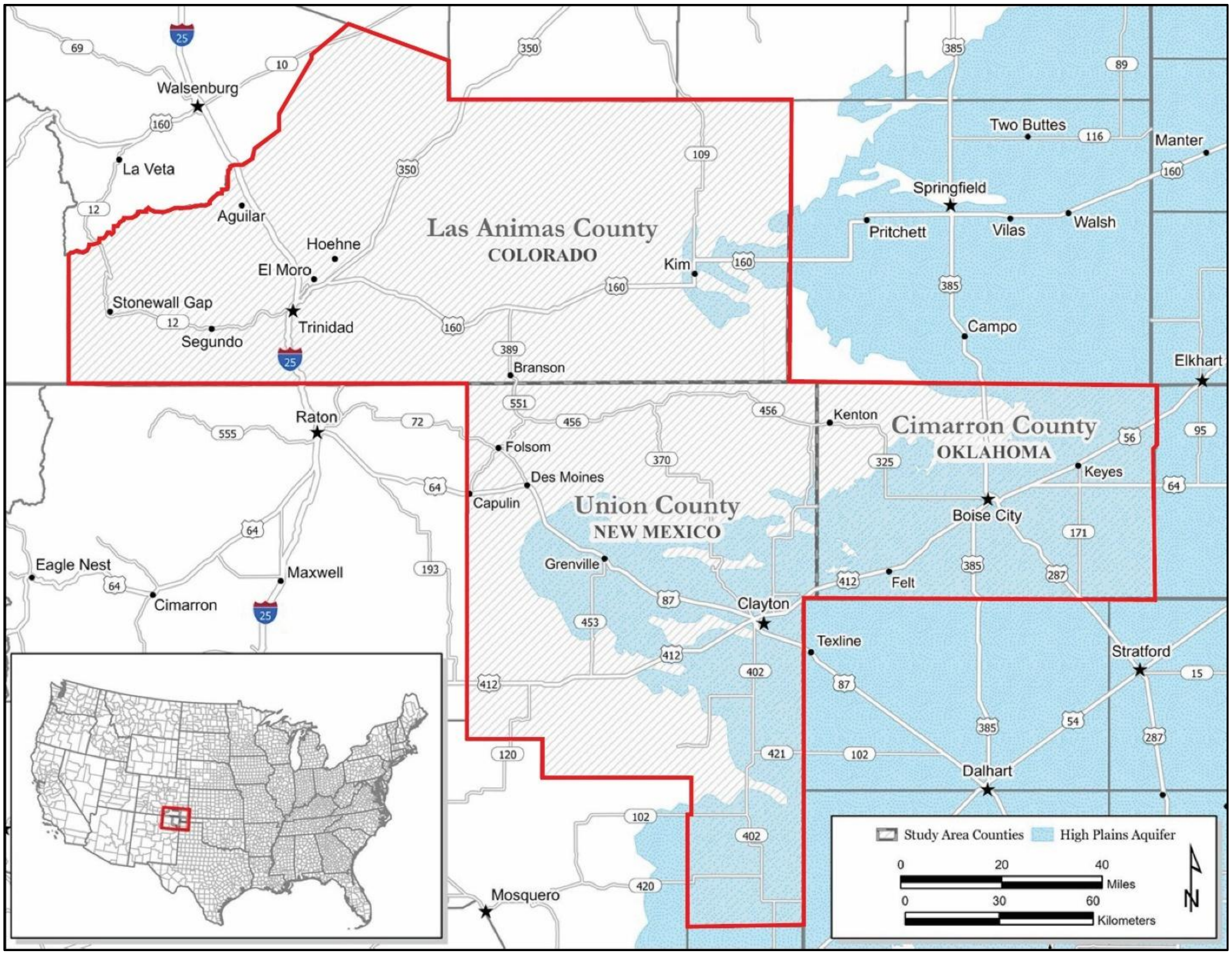


Figure 1. Location of counties involved in the ARID project.

ZGC led the groundwater-oriented portion of the greater ARID Project, which included 15 participating households in Union County (New Mexico), Las Animas County (Colorado), and Cimarron County (Oklahoma). Monitoring provided by the groundwater team included static water level measurements and analysis of water samples for general chemistry, trace metals, and tritium. In addition, the team interfaced with participants throughout the duration of the Project both in person during monitoring activities, local workshops, and community meetings, but also by means of regular progress reports summarizing data as it was gathered for each well. The aim of the groundwater component of the larger ARID project was to interface with local stakeholders to learn about their groundwater use, evaluate the aquifer(s) being used, and develop appropriate conservation strategies where warranted. This is the final report summarizing results of the data collection efforts, as well as providing preliminary conclusions about the groundwater resources tapped by these wells, and potential conservation strategies for rural communities with similar geohydrologic situations.

Methods

Participant Selection

In each county, the groundwater team Principal Investigator (PI, K. Zeigler) attended local recruitment events in 2018 in all three counties and presented on the types of data that would be collected, along with lessons learned from ongoing groundwater monitoring efforts in northeastern New Mexico. Participants self-selected the groundwater component of the larger ARID project. In the fall of 2018, the team began reaching out to individual participants to discuss their well(s) and their particular concerns regarding their groundwater resources.

Monitoring of wells began in January of 2019 and each participant selected one or two wells to be monitored every six months for static water levels for four to five years. In some cases, a third well was selected for installation of a pressure transducer to monitor water level changes daily. Stakeholders usually chose the one or two wells most critical to their operation (either cattle ranching or farming, or both). The most critical of the two wells (hereafter referred to as “the critical well”) was also sampled for general chemistry, trace metals, and tritium. All data gathered each monitoring season was shared with each participant annually or biannually via a written progress report in order to provide information about changes in water quantity and quality in a relatively rapid timeframe to facilitate on-the-ground decision-making. Team members were also available to participants either while at their well or via phone or email to answer questions and address concerns.

Static Water Levels

A 300-foot engineering-grade steel tape was used to measure the depth to water for most of the wells and a 500-foot steel tape for wells deeper than 300 feet to water (per U.S. Geological Survey methods: Cunningham and Schalk, 2011). Measurements with the steel tape were repeated until two values that were within 0.01 ft of one another were obtained. If it was not possible to obtain two measurements within 0.01 ft of one another, the closest values were averaged and the data was flagged in the reports as of lower precision. For wells that are abandoned and have no plumbing in place, an e-tape with a maximum length of 300 or 500 feet was used. The measuring point, or height of the entrance to the well above land surface, was subtracted from the static water level measurement such that the final static water level for all wells is calculated and reported relative to the land surface ("below ground surface" or bgs). Irrigation wells were generally not monitored in summer seasons as they were in use and it was not practical to have them shut off long enough for the water table to recover. Four wells in the Sangre de Cristo Mountains in western Las Animas County were not measured in the winter as the wells were inaccessible due to snow cover.

In order to create an individualized interpretation for each well, we used seasonal water level change data for each well and combined it with the total depth of the well (where known) to obtain the percentage amount that each well changed between seasons. This individualized approach allows us to spot shallow wells that may be more heavily impacted by a relatively small change in water levels.

Precipitation Analyses

To evaluate potential relationships between precipitation and groundwater, we combined precipitation data from multiple stations across each county provided by the Community Collaborative Rain, Hail and Snow Network (CoCoRaHS). To reduce error in this data, stations were mainly selected on the basis of reporting frequency where each station had between 97% and 100% daily reporting between January 1st, 2019 and July 31st, 2023. An average was then calculated for every 30 measurements for each station. A 30 measurement interval created rough monthly averages, with some error pertaining to how often measurements were taken. These results were then combined and averaged again to a create a monthly average for each county. These analyses can then be compared to the county water level change maps to examine relationships between precipitation and groundwater change (primarily for shallow wells in unconfined aquifers).

Water Chemistry Analyses

Approximately half a liter of water was collected from the critical well for each stakeholder for analyses of major cations and anions as well as trace metals. Water samples were taken in high density polyethylene (HDPE) bottles but were not acidified nor filtered. As these samples were being used to characterize the aquifer, the analyses are meant to encompass all possible solid and dissolved analytes present in the groundwater. The analytical work was conducted by the Analytical Chemistry Laboratory at the New Mexico Bureau of Geology and Mineral Resources in Socorro. Major cation/anion analyses included the cations calcium (Ca), sodium (Na), magnesium (Mg), and potassium (K), and the anions carbonate (CO_3), bicarbonate (HCO_3), sulfate (SO_4), and chloride (Cl). Trace metal analyses include 27+ different analytes ranging from aluminum to zinc.

Tritium Analyses

One liter of water was collected from each critical well in HDPE bottles for analysis for tritium. Samples were analyzed at the Tritium Laboratory at the University of Miami. Presence or absence of tritium, an isotope of hydrogen, is used as a marker for modern recharge. Samples are not filtered, nor acidified for tritium analyses.

Background Geology

Groundwater, by nature an invisible resource, is controlled entirely by local and regional geology. Deposits and rock units with appropriate porosity and permeability to provide useful quantities of water for irrigation, livestock, and/or domestic use vary in thickness, depth, and other characteristics. Thus, an understanding of both the greater regional geologic context of the SGP as well as the intricacies of the subsurface in the immediate vicinity of any given well is required in order to understand changes in quantity and quality, and potential for significant recharge of that resource. A short geologic history and brief description of individual rock units within the project area is helpful for putting the observations into perspective.

The geology of the western High Plains is dominated by Mesozoic-age sedimentary rocks that were incised into and then filled in by younger alluvial deposits of Miocene-Pliocene age (Zeigler et al., 2019a). Young volcanism associated with the Raton-Clayton volcanic field produced small cinder cones and lava flows that cap local mesas and buttes in Union and Las Animas Counties. Much of the lower relief terrain in the eastern project area is blanketed with modern eolian sheetwash deposits that are locally heavily vegetated. Exposures of older bedrock units occur in deeper drainages, such as Perico Creek south of Clayton, or in canyonlands, such as the Dry Cimarron in northern Union County or the tributary canyons to the Purgatoire River in southern Las Animas County. The bedrock geology is similar in Union, eastern Las Animas, and Cimarron County, with western Las Animas County featuring much younger strata preserved along the eastern flanks of the Sangre de Cristo Mountains and Spanish Peaks. Overall, the geologic subscape is quite complicated and this leads to partitioning of local aquifers (Zeigler et al., 2019b; Figure 2).

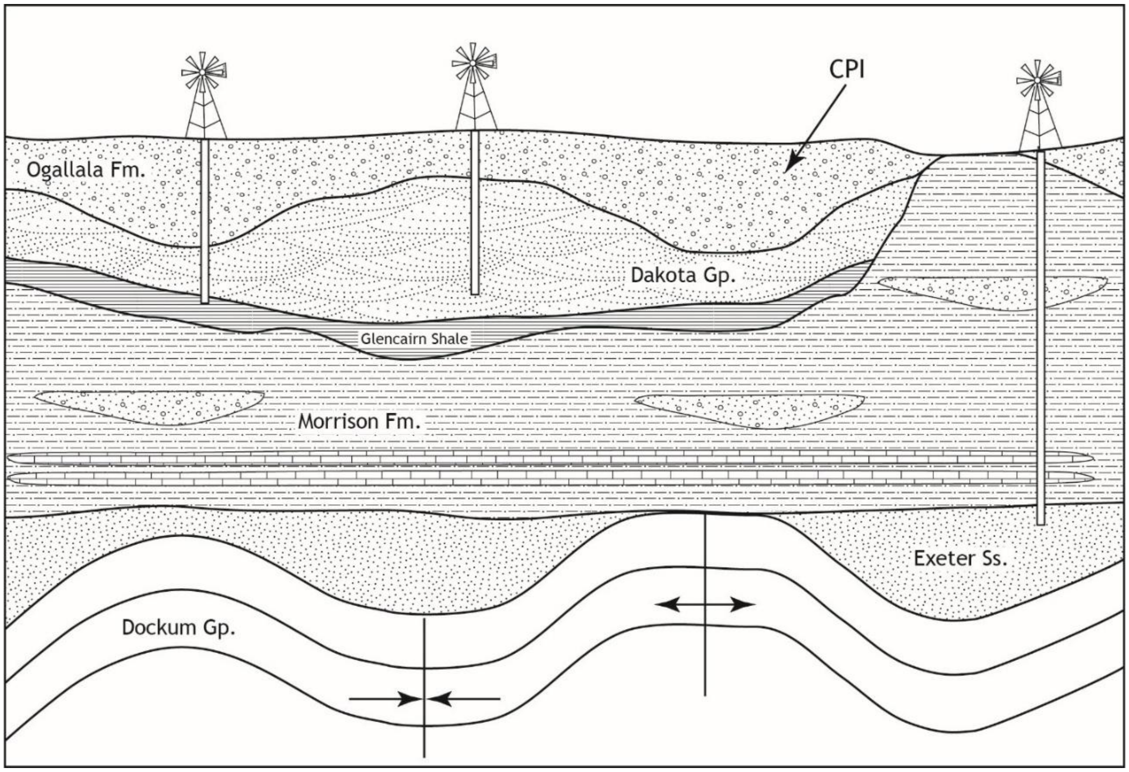


Figure 2. Example of subsurface geologic complexities for Union County (from Zeigler et al., 2019b).

Triassic Strata

The oldest strata exposed in the three counties are those of the Upper Triassic Dockum Group. The Dockum Group consists of dark red to purple mudstones and orange siltstones, with intermittent grayish-green to grayish-purple sandstone and conglomerate beds that were deposited in a complex terrestrial environment when the American Southwest was much wetter (Baldwin and Muehlberger, 1959; Lucas et al., 1987; Kues and Lucas, 1987, Zeigler et al., 2019a, b). The landscape at the time was dominated by large river systems and swampy floodplains inhabited by a diverse array of reptiles, as well as the earliest North American dinosaurs. The lowest unit of the Dockum Group is the Santa Rosa Sandstone, a relatively thick sandstone and conglomerate sequence. This is followed by a succession of mudstone and siltstone beds with occasional moderately thick fine-grained sandstone beds that are not laterally continuous. Sandstone and conglomerate beds are lithic arenites with a variety of minerals that will contribute dissolved ions to groundwater resources. The Dockum Group beds are gently folded in Union County, with fold hingelines trending generally north-south, creating an angular unconformity with the overlying Exeter Sandstone.

Jurassic Strata

Above the Dockum Group are the gold and red cliffs of the Exeter Sandstone, which is Middle Jurassic in age, and records a much drier climate for the region which saw the formation of extensive dune systems. The Exeter Sandstone, which varies significantly in thickness due to the folding of the underlying Dockum Group, preserves eolian beds deposited at the edges of the Four Corners dune fields as is predominantly a quartz sandstone with few other mineral types (Heaton, 1939; Zeigler et al., 2019a, b). Over time, as the climate slowly returned to wetter conditions, the dune field transitioned into a complex network of playa lakes. During dry years, these playas dried up, with evaporation leading to the formation of gypsum (a calcium sulfate mineral). Gradually, this system of playa lakes and inter-playa areas deposited the relatively thick gypsum and mudstone deposits of the Bell Ranch Formation.

By the time the Morrison Formation was deposited in the Middle to Late Jurassic, the three-county area was once again a river and lake-dominated ecosystem (Prince, 1988), now inhabited by a wide variety of dinosaur groups, whose bones are sometimes found eroding out of the hillslopes of blue and green mudstone and white sandstone. The Morrison Formation varies in rock type, although it is dominated by blue to purple-gray or maroon mudstone with lenses of coarse-grained muddy white arkosic (=feldspar-rich) sandstone. Zeigler et al. (2019b) note the presence of an informal division of the Morrison Formation into two parts: a lower member consisting of mudstone, sandstone, and lacustrine limestone beds, and an upper member that includes mudstone and lenses of sandstone. In eastern Las Animas County, sandstone beds are extremely rare, whereas in Union County and western Cimarron County, sandstone beds are more prevalent. The top of the Morrison Formation was heavily eroded, resulting in paleotopography that can, in places, result in thickness variations of tens to hundreds of feet. Paleovalleys incised into the Morrison were infilled by either the overlying Lytle Sandstone or younger units, including the Dakota Sandstone and/or the Ogallala Formation.

Cretaceous Strata

The Lytle Sandstone, a white coarse-grained arkosic sandstone and siltstone, grades upwards into the overlying Glencairn Formation, a package of gray shales and sandstone and siltstone beds (collectively referred to as the Purgatoire Formation on older maps and in southeastern Colorado). The Lytle Sandstone (=Cheyenne Sandstone in Oklahoma) may be Jurassic in age (Bartnik et al., 2019), but the overlying Glencairn Formation (=Kiowa Shale in Oklahoma) includes fossil oyster shells, indicated a Cretaceous age. The Glencairn Formation records the first flooding of the center of North America by a shallow and warm inland sea, the Cretaceous Interior Seaway, which eventually covered all the Great Plains region.

Above the Glencairn Shale, and capping many canyon rims in the region, is the Dakota Sandstone, which reflects deposition along the beach of the Cretaceous Interior Seaway. This shoreline was frequently traveled by groups of dinosaurs who left thousands of fossil footprints. The Dakota Sandstone is subdivided into the lower Mesa Rica Sandstone, the shales of the medial Pajarito Formation, and the upper Romeroville Sandstone. The Romeroville Sandstone grades upwards into the Graneros Shale, which is overlain by the Greenhorn Limestone and Carlile Shale. These units are predominantly gray and black shale, with thin beds of limestone or calcareous sandstone that are locally rich in fossil seashells, that record the first major high-stand of the Cretaceous Interior Seaway.

In western Las Animas County, younger units are preserved, including the Cretaceous Niobrara Group, Pierre Shale, Trinidad Sandstone, and Vermejo Formation, Cretaceous-Paleocene Raton Formation and the Paleocene Poison Canyon Formation. These units are not preserved in Union or Cimarron County, nor in eastern Las Animas County. The Niobrara Group includes the lower Fort Hays Limestone, composed of interbedded limestone and gray shale, and the upper Smoky Hills Shale, which includes gray shale, with some sandier shale beds in the lower portion. The Pierre Shale overlies the Niobrara Group and is a very thick sequence of black shale that includes sandier intervals in the upper portion of the unit. It should be noted that many of the shale-dominated units throughout the Cretaceous and earliest portion of the Paleocene include both gypsum, a calcium sulfate, and halite (rock salt).

The Trinidad Sandstone, exposed in the cliffs along the north face of Johnson Mesa in Las Animas County, includes beds of light gray arkosic sandstone deposits in a large delta and barrier-bar complex that formed as the Cretaceous Interior Seaway began to slowly retreat from the region (Cather, 2004). The overlying Vermejo Formation, consisting of sandstone, shale, and coal beds, was deposited in a coastal plain environment and the coal beds are a source for coal and coal-bed methane extraction taking place in the Raton Basin in western Las Animas County (Cather, 2004).

Tertiary Strata

As the Cretaceous Interior Seaway retreated at the end of the Cretaceous, the region gradually returned to a river-system dominated ecosystem. The Raton Formation preserves the depositional environment during the Cretaceous-Paleocene transition, which saw the demise of the dinosaurs (Tschudy, 1973; Pillmore et al., 1984; Shoemaker et al, 1987; Cather, 2004). The Raton Formation includes beds of coal, organic-rich shale, arkosic sandstone, and conglomerate (Griggs, 1948; Cather, 2004). The overlying Poison Canyon Formation includes interbedded gray to white very coarse-grained sandstone beds with conglomerate, shale, and siltstone. The unit becomes redder in color up section and significantly coarser grained, reflecting deposition off of the first phase of the modern Rocky Mountain uplift (Colpitts and Smith, 1990).

As the modern Rocky Mountains rose in the early Tertiary, many of these older rock units were eventually eroded away and the sands and gravels of the Ogallala Formation filled in a deeply incised landscape, resulting in highly variable thicknesses of this unit, which has a strong control on local center-pivot irrigation (Zeigler et al., 2019b). The Ogallala Formation, preserved in eastern Las Animas County, as well as Union and Cimarron Counties, is Miocene-Pliocene in age and known for its characteristics as one of the primary aquifer units in the High Plains (Baldwin and Muehlberger, 1959; Blumenberg, 2018; Zeigler et al., 2019b; Phan et al., 2021). These deposits include fluvial, eolian, and aggradational fan sediments carried eastward from the newly uplifted Rocky Mountains. The unit grades upwards from very coarse-grained conglomerates to sandy mudstone beds that became pervasively cemented with calcium carbonate into the hard caliche caprock exposed in eastern New Mexico and West Texas.

Locally, the top of the Ogallala has been scoured out and infilled with Quaternary-age fluvial deposits and blanketed with young eolian sheetwash deposits. In addition, young basalt flows from local cinder cones in the Raton-Clayton volcanic field blanket older sediments and cap mesas and canyon rims. In many places these lava flows preserve softer, more erodible units, such as the Cretaceous shale beds, that have been stripped away elsewhere. This volcanism ranges in age from 9 million years old to 36,000 years old (Zimmerer, 2019).

Union County Geology

Of the rock units described here, Union County hosts exposures of the Dockum Group, Exeter Sandstone, Bell Ranch Formation, Morrison Formation, Lytle Sandstone, Glencairn Formation, Dakota Sandstone, Graneros Shale, Greenhorn Limestone, Ogallala Formation, and younger volcanic units (Figure 3). These are locally covered with young eolian and fluvial deposits. Exposures are limited to local drainages and the canyonlands of the Dry Cimarron in northern Union County, as well as along the flanks of mesas capped with lava flows. In Union County, the Ogallala Formation is locally inset into the Dakota Sandstone and Morrison Formation. Due to this relationship, CPI wells are geographically confined to these Ogallala paleovalleys.

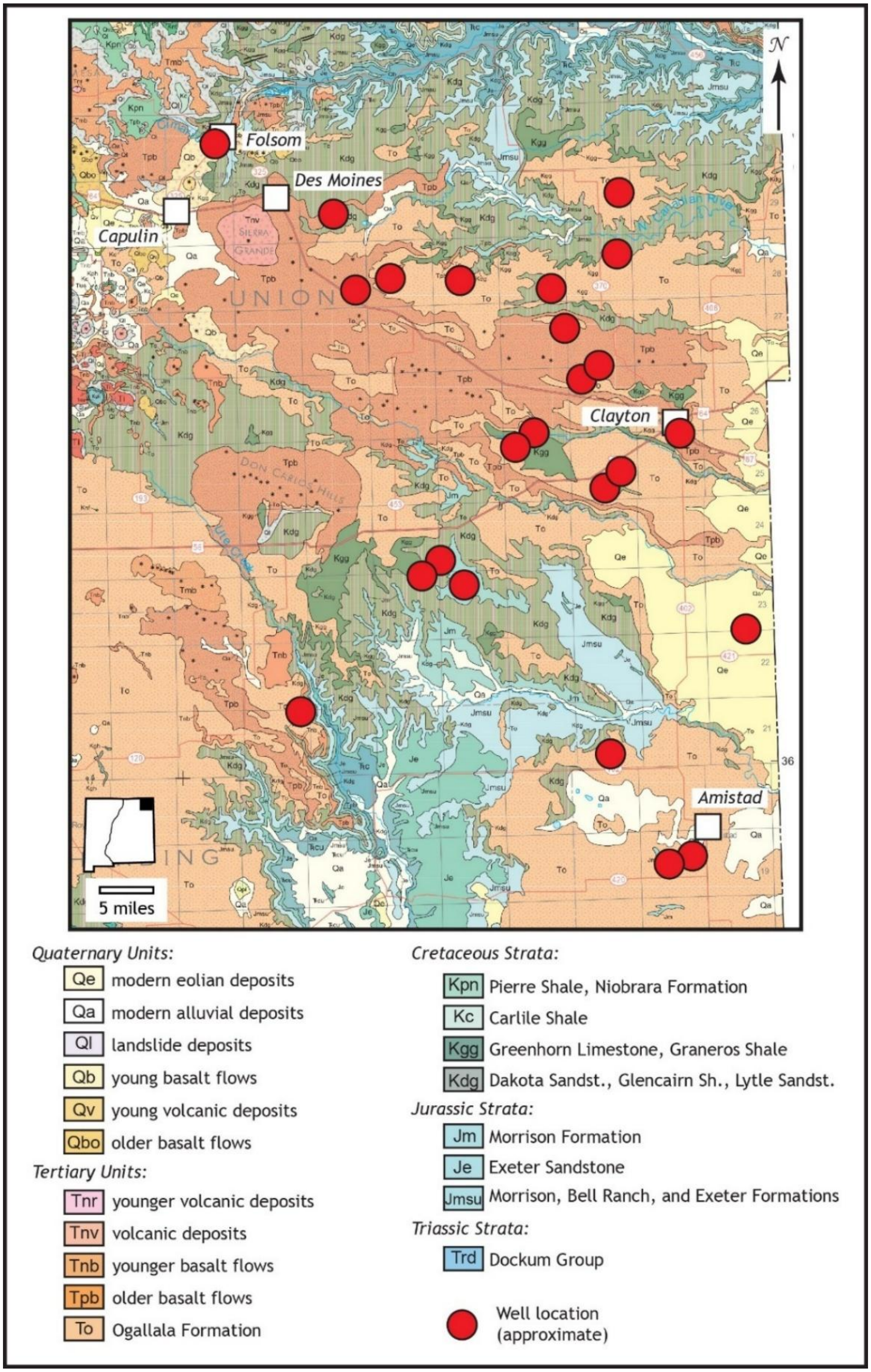


Figure 3. Geologic map of Union County (from Anderson and Jones, 2003). Note well positions are offset to maintain anonymity of locational data.

Western Las Animas County Geology

Western Las Animas County includes the transition westward from the High Plains into the southern Rocky Mountains and is dominated by exposures of younger rock units, including the Graneros Shale, Greenhorn Limestone, Carlile Shale, Niobrara Group, Pierre Shale, Trinidad Sandstone, Vermejo Formation, Raton Formation, and Poison Canyon Formation (Figure 4). In the Spanish Peaks area, myriad vertically-oriented igneous intrusions, called dikes, penetrate the Poison Canyon Formation and older units, and these create a complex hydrology in this area. To the east, the Dakota Sandstone rises up along the eastern limb of the Raton Basin and becomes exposed in local drainages.

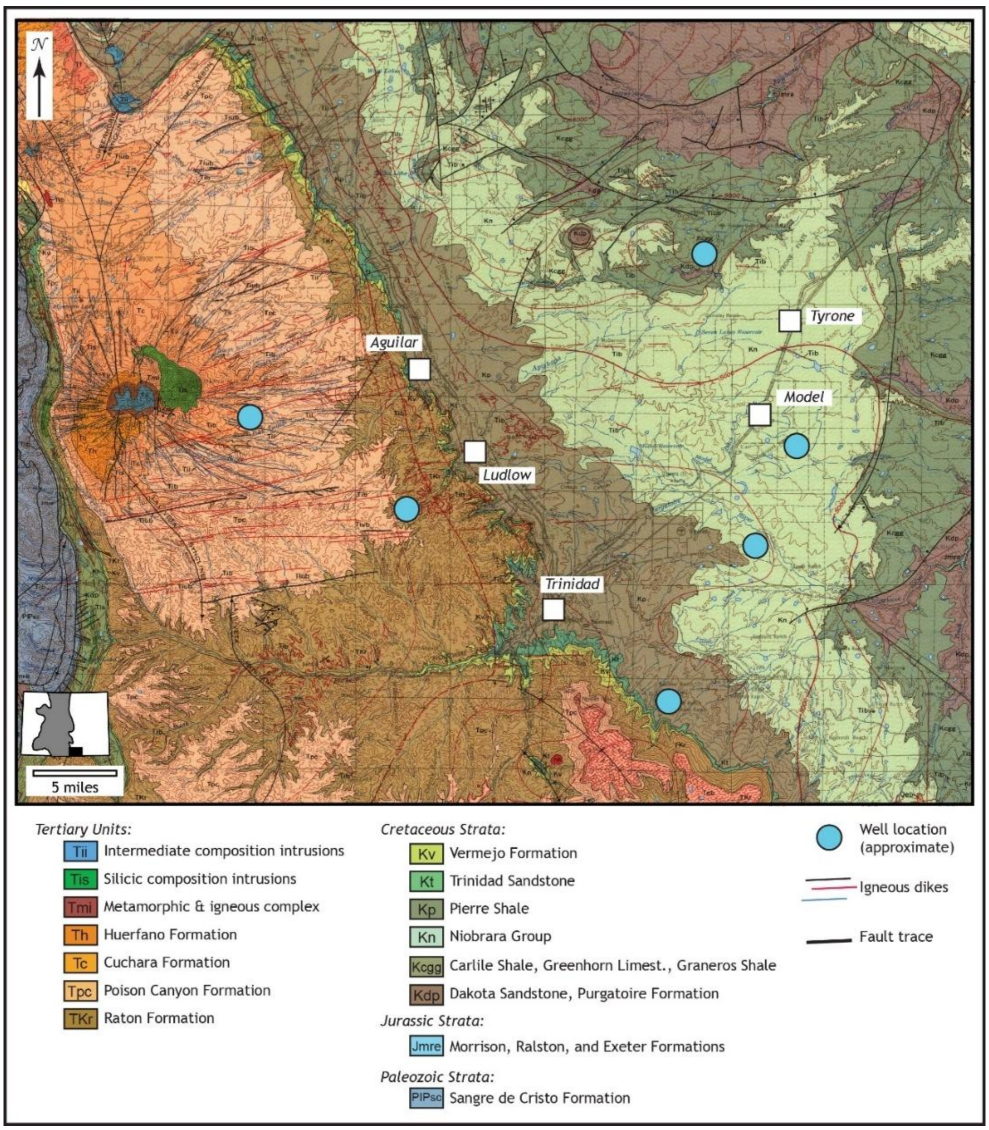


Figure 4. Geologic map of western Las Animas County (from Johnson, 1969). Note well positions are offset to maintain anonymity of locational data.

Eastern Las Animas County Geology

In eastern Las Animas County, exposures are similar to those in Union County to the south, with the Dockum Group, Exeter Sandstone, Bell Ranch Formation, Morrison Formation, Purgatoire Formation (=Lytle Sandstone and Glencairn Shale), Dakota Sandstone, Graneros Shale, and Greenhorn Limestone, with outcrops of the Carlile Shale and Niobrara Group preserved under basalt-capped mesas such as Mesa de Maya (Figure 5). Local remnants of the Ogallala Formation are also preserved under basalt flows or as small pockets along the eastern boundary of the county and are inset into the Purgatoire Formation.

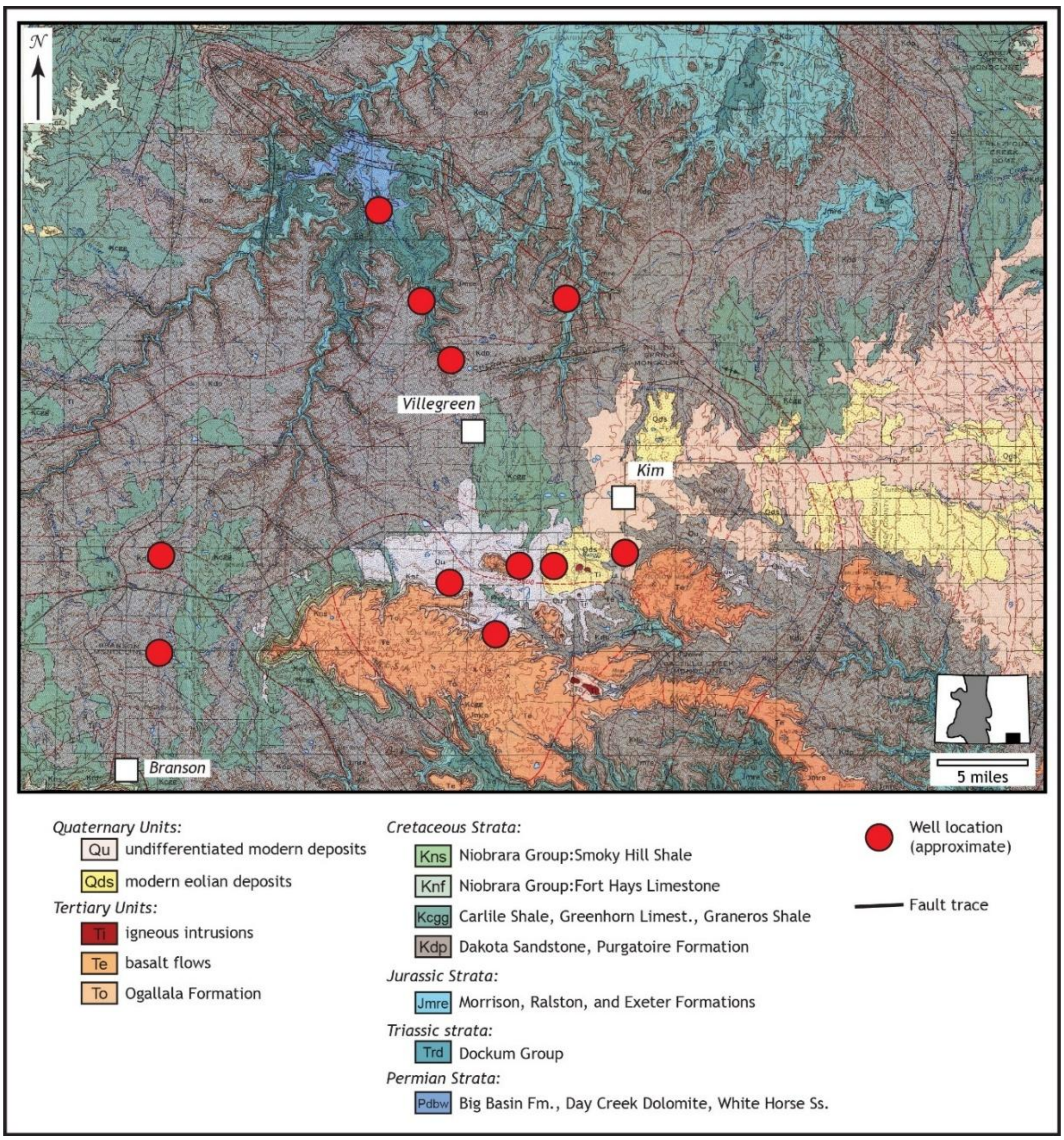


Figure 5. Geologic map of eastern Las Animas County (from Scott, 1968). Note well positions are offset to maintain anonymity of locational data.

Cimarron County Geology

Much of Cimarron County is dominated by modern eolian sheetwash and fluvial deposits, but exposures in small drainages and in the eastern Dry Cimarron in the northwest corner of the county, include exposures of older bedrock units. These include the Dockum Group in the eastern edge of the county, Exeter Sandstone, Bell Ranch Formation, Morrison Formation, Cheyenne Sandstone and Kiowa Shale (=Lytle Sandstone and Glencairn Shale = Purgatoire Formation), Dakota Sandstone, Graneros Shale, Greenhorn Limestone, and Ogallala Formation (Figure 6). In Cimarron County, the Ogallala Formation is inset into Dockum Group and Morrison Formation with CPI geographically concentrated over the deeper portions of the Ogallala paleovalleys.

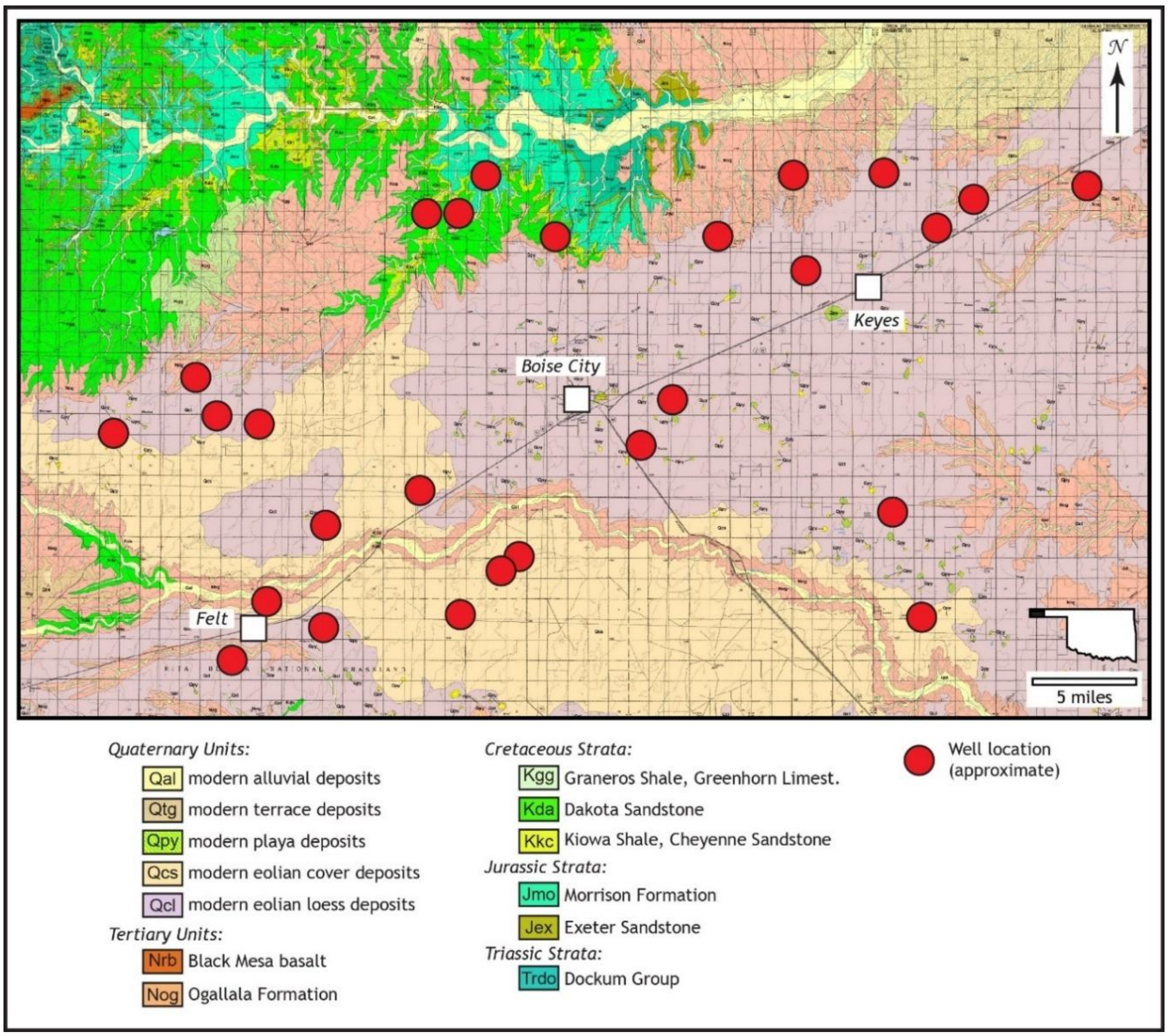


Figure 6. Geologic map of Cimarron County (from Luza and Fay, 2003). Note well positions are offset to maintain anonymity of locational data.

Groundwater Resources

Union County

Major water-bearing units in Union County include unconfined alluvial deposits along drainages, Ogallala Formation, Dakota Sandstone, sandstone beds within the Morrison Formation, the Exeter Sandstone, and to a lesser extent, the Dockum Group (Figure 7). Based on information gained in other monitoring efforts in the region, even moderate volume wells are rare, occurring at Sedan, Seneca, and Gladstone, where paleovalleys and pockets of the Ogallala Formation include a great enough saturated thickness to provide for high volumes of water. Moderately deep wells (depth to water of 150-300 feet below ground surface) are generally tapping into the Dakota Sandstone, although the paleotopography on the top of the Morrison Formation means that some wells drilled to the same depth encounter Morrison sandstone lenses that provide moderate quantities of water. Wells in the southern portion of the county are drawing from the Dockum Group as these strata are tilted down to the north, such that the Dockum eventually intersects the surface near Amistad.

In terms of quantity, most Dakota and Dockum wells will produce 5 to 15 gallons per minute (gpm), although the average is closer to 5 to 10 gpm. The Exeter can be variable in production, ranging from just a few gallons per minute to in excess of 300 gpm in West Texas. (No Exeter wells in northeastern New Mexico have been identified as being such high producers and there are no wells in this study that produce only from the Exeter.) In terms of water quality, Dakota and Exeter groundwater is higher quality, with low total dissolved solids and low salt content. The Morrison sandstone lenses and the Dockum Group generally show higher total dissolved solids, and the Morrison has higher sodium and potassium levels due to the presence of the mineral feldspar, which dissolves to release sodium and potassium into the groundwater.

Of greatest concern for water quality are the Bell Ranch Formation and Cretaceous shale beds, such as the Graneros Shale. The high gypsum content of these units can cause high levels of sulfate in groundwater. Sulfate levels over approximately 800 mg/L can be toxic for livestock, and evaporation of water in drinkers and dirt tanks can cause toxicity issues during the summer months.

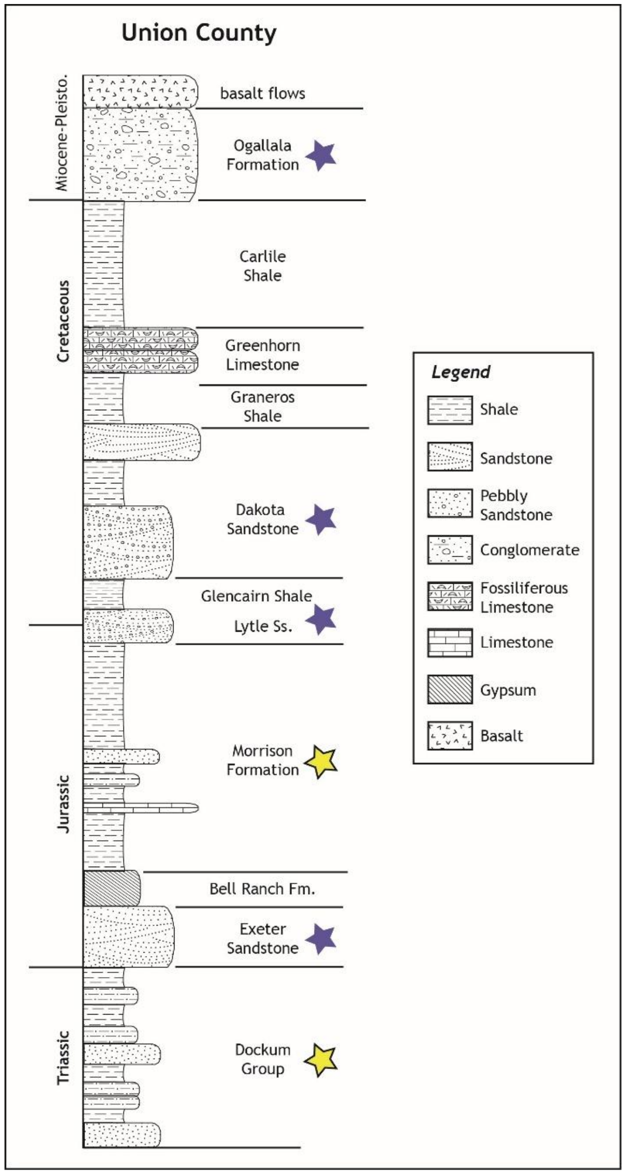


Figure 7. Schematic stratigraphic column for Union County. Blue stars indicate primary aquifer units, yellow stars indicate secondary aquifer units. Adapted from Zeigler et al., 2019b.

Western Las Animas County

Major water-bearing units in western Las Animas County include shallow alluvial aquifers along drainages, the Poison Canyon Formation, Raton Formation, Trinidad Sandstone, Niobrara Group, limestone beds in the Carlile Shale, Greenhorn Limestone, and Graneros Shale, as well as the Dakota Sandstone (Figure 8). Wells located to the west of I-25 tap waters associated either with local unconfined aquifer systems along drainages or sandstone beds in the Raton and Poison Canyon Formations. To the east of I-25, wells are generally very deep and are frequently hydrocarbon exploration wells that were turned over to the landowner if they proved to be nonviable from an economic production standpoint. Many of these wells were drilled to the Dakota Sandstone or deeper Permian units, but the waters the wells draw from include a mixture from the Dakota and overlying limestone and shale beds.

Wells producing from shale-dominated units tend by low-volume and very slow to recover, frequently taking up to 24 hours for the water table to level after the well has been shut off. Water quality is a major issue in many of these wells, with high total dissolved solids, occasional methane, sulfur/sulfate problems, and increasing observations of iron slime bacteria.

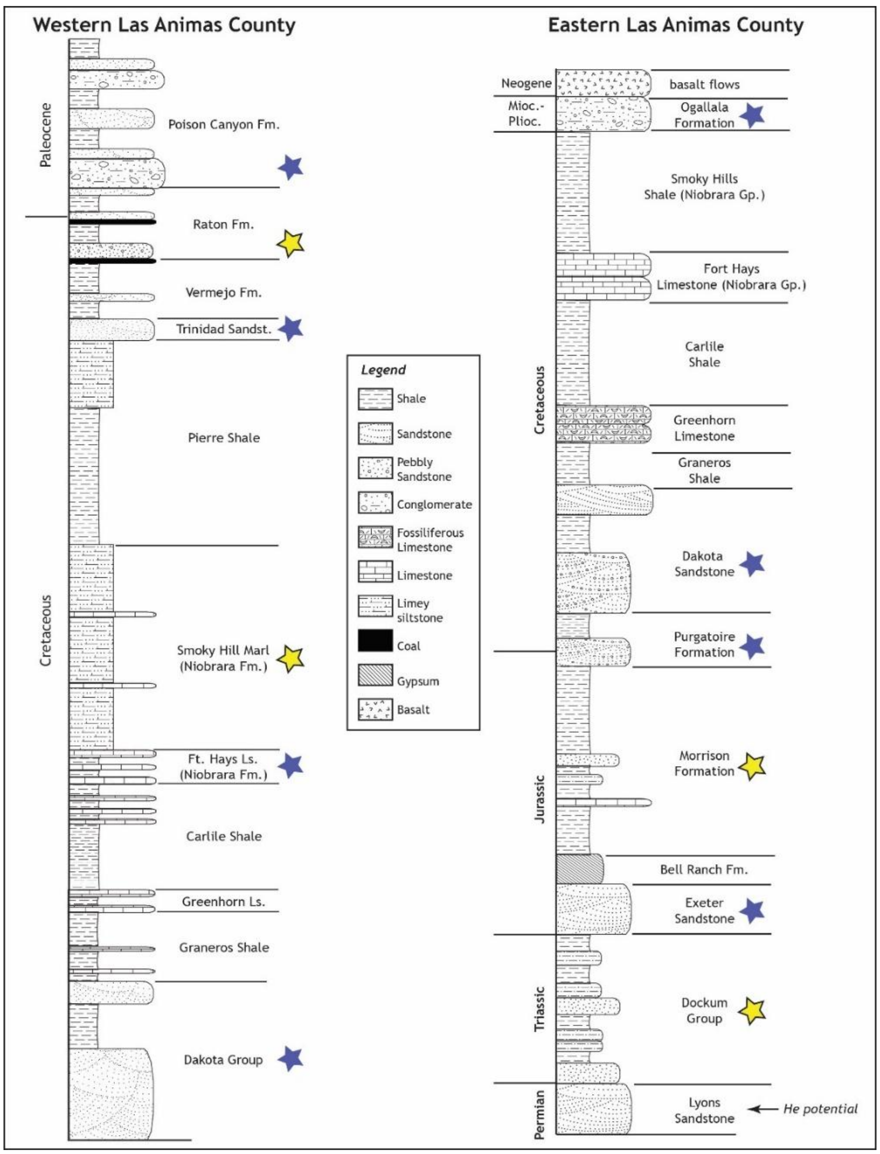


Figure 8. Schematic stratigraphy for western and eastern Las Animas County. Blue stars indicate primary aquifer units, yellow stars indicate secondary aquifer units.

Eastern Las Animas County

Major water-bearing units in eastern Las Animas County include shallow alluvial deposits along drainages, the Dakota Sandstone, Purgatoire Formation, small sandstone lenses within the Morrison Formation, the Exeter Sandstone, and the Dockum Group (Figure 8). High to moderate volume wells are exceedingly rare in the area, occurring along the eastern boundary of the county, where significant deposits of the Ogallala Formation provide the proper conditions for high volume water. Moderately deep wells are generally tapping into the Dakota Sandstone and Purgatoire Formation. Contrary to Union County and Cimarron County, the Morrison Formation in eastern Las Animas County is almost entirely mudstone-dominated, with sandstone beds proving to be exceedingly rare. This has led to numerous dry holes drilled in search of water in the area. Deeper wells or wells in the canyon bottoms are drawing from the Dockum Group.

Water quality and production volumes are similar in these units as for the other counties, although the greatest concern for water quality issues is for wells drilled into or through the Bell Ranch Formation. The extremely high gypsum content of this unit can provide high levels of sulfate in groundwater that is in contact with the Bell Ranch Formation. Casing a well through the Bell Ranch Formation is an important step to prevent high sulfate levels in well water; however, in examination of outcrops of the underlying Exeter Sandstone, pervasive gypsum has intruded into fractures in the sandstone, which could cause leaching of sulfate into groundwater hosted in the Exeter Sandstone.

Cimarron County

Major water-bearing units in the area include the Ogallala Formation, Dakota Sandstone, sandstone beds within the Morrison Formation, and the Dockum Group (Figure 9). High volume wells that can support CPI occur within Ogallala Formation paleovalleys with appropriate saturated thickness to provide the proper conditions for high volume water. Low-producing, moderately deep wells are generally tapping into the Dakota Sandstone and some Morrison Formation sandstone lenses to the west and Dockum Group to the east. In addition, some wells completed in the Ogallala Formation are low to moderate volume wells, suggesting variable thickness and degrees of caliche cement locally influence production from Ogallala wells. Wells along the Dry Cimarron are drawing water from sandstone beds in the Morrison Formation and/or Cheyenne Sandstone.

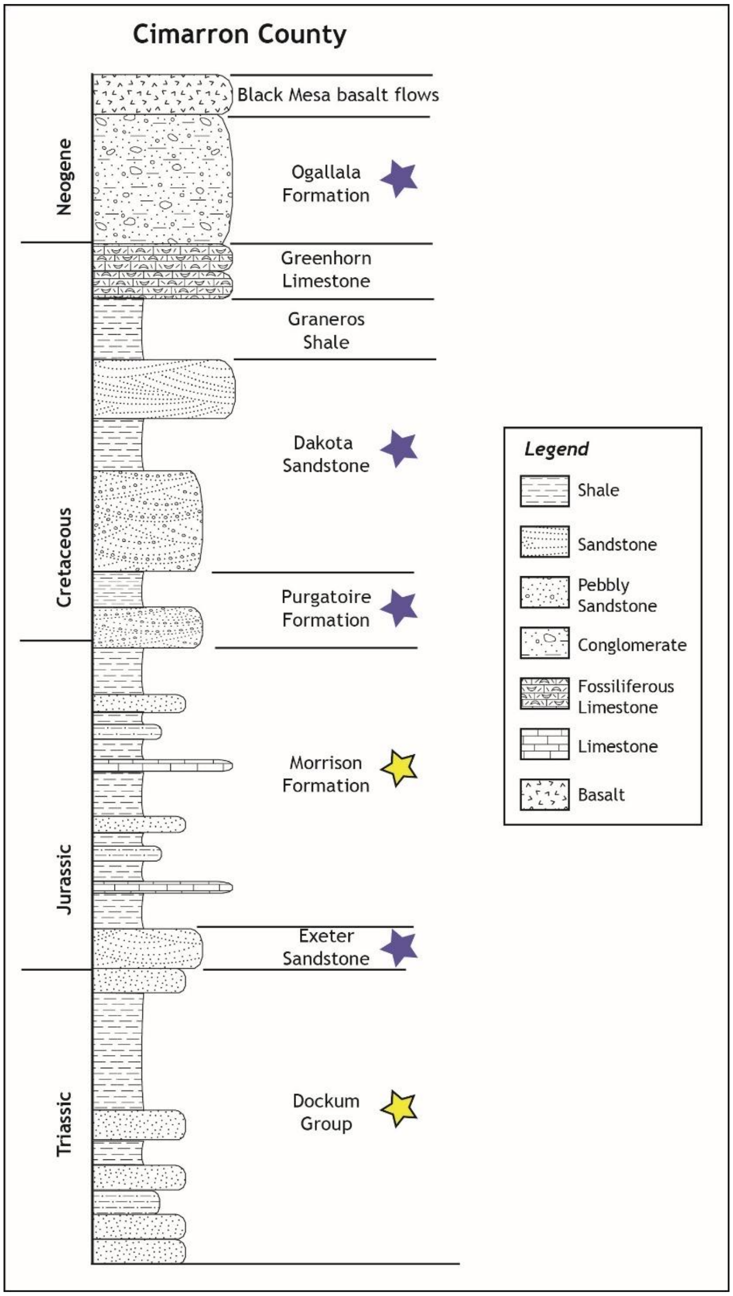


Figure 9. Schematic stratigraphy of Cimarron County. Blue stars indicate primary aquifer units, yellow stars indicate secondary aquifer units.

Results: Static Water Levels

Static water level data (in feet below ground surface, bgs) considered here is for both the critical wells and secondary wells, where the team was able to gather more than four seasons worth of measurements (Appendix I, II, III). Wells that had very little data are not considered in the tallies below. Reasons for poor data include: team members could not access the casing due to weather conditions or maintenance at the well head, the well was consistently on and could not be turned off long enough for a static measurement for more than one season, or the well was removed from the study for other reasons. Hydrographs have a gap in measurement data for 2020 and part of 2021, which was due to the COVID-19 pandemic, which prevented the team's ability to travel and gather data for these wells. In addition, not all wells are included in all water level change maps below as some wells were monitored only in the summer or only in the winter, or there was a season (or more than one season) where the team could not obtain a measurement.

Winter to Winter Comparisons

Comparing winter to winter measurements tends to show the true behavior of a water table surface over time as the winter is generally the time of least use on most aquifers. Comparing measurements over many winters shows the overall behavior of the water table through time. Key patterns to watch for are if wells are recovering completely to the same water level as the previous winter, or if they are recovering, but not to the same level as the previous winter, which indicates a permanent to semi-permanent decline of the water table.

Most of the wells in this study show only a partial recovery of the static water level from winter to winter, indicating the majority of the wells observed are witnessing a permanent or semi-permanent water level decline (Figure 10). However, the changes in water table from the winter 2019-2020 comparison to the winter 2022-2023 comparison show a lessening of declining water tables, especially in Las Animas and Union Counties. The greatest area of decline is within and along the margins of the Ogallala paleovalleys that host CPI in Cimarron and eastern Union Counties. The prolonged drought of the last 20 years has had a significant impact on the majority of wells throughout the region, although shallow wells along drainages and/or adjacent to major uplifts do show a better response to recharge events. Deeper wells and wells that are in use year-round have generally uniformly declining water tables. It is important to note that during drought years, groundwater sources are relied upon more heavily in the face of little to no surface water in streams and dirt tanks, putting an additional strain on all groundwater resources, regardless of depth to water.

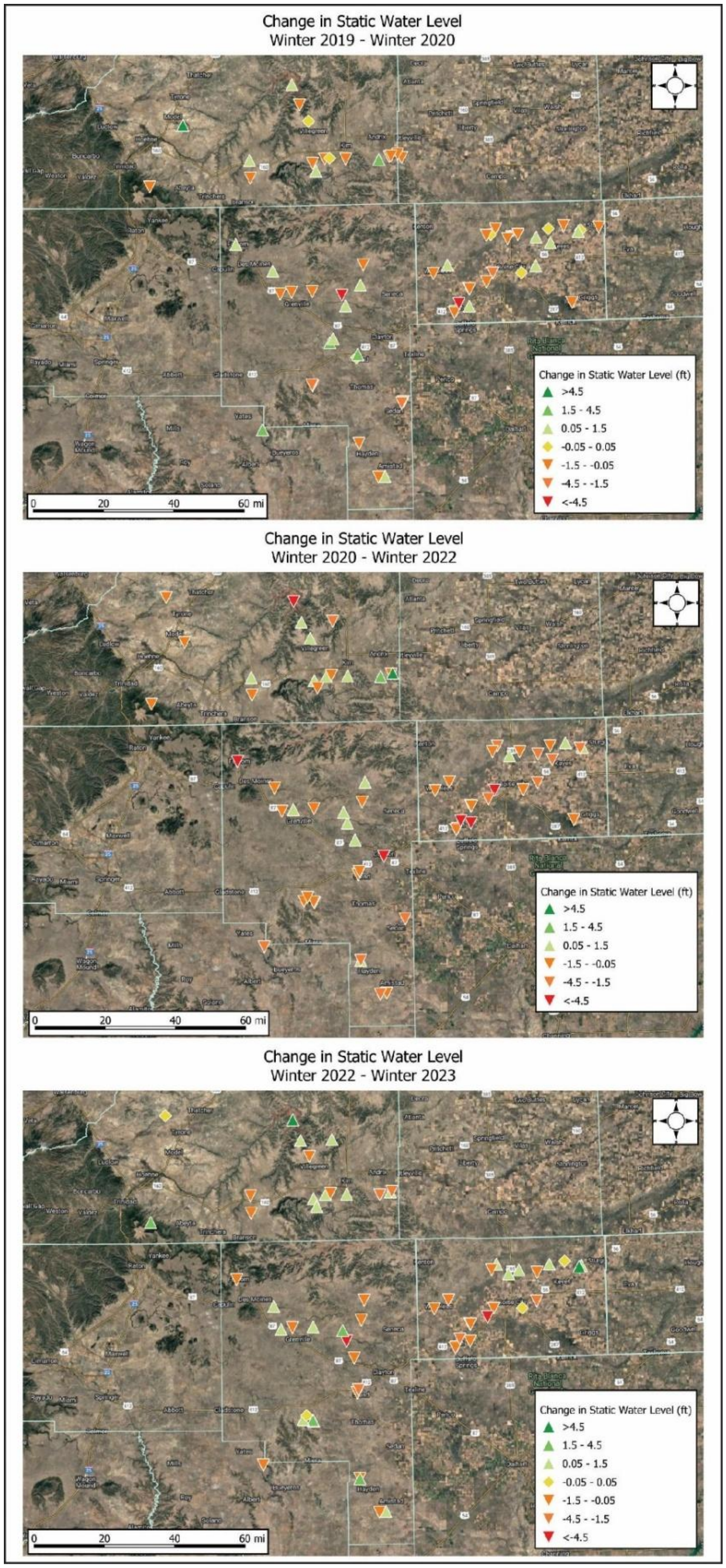


Figure 10. Water level change maps for each of the winters for which there is comparable data. Full-size maps are in Appendix II.

Summer to Summer Comparisons

Comparisons of static water levels from summer to summer are mostly useful to observe the influence of heavier usage patterns over the spring and summer. These comparisons are also helpful to examine influence in high-use CPI areas on surrounding wells (Figure 11). Since the CPI wells could not be turned off for summer measurements, these maps reflect the influence (or lack thereof) on neighboring wells. Wells in western Las Animas County that cannot be accessed in the winter are also depicted on these maps and are, in part, reflecting recharge potential from winter snowpack as these wells are all relatively shallow.

Increasing values on these maps may reflect producers relying less on groundwater during years with good precipitation, even though it can take years to centuries for infiltration to replenish even shallower aquifers (see discussion on precipitation below). Eastern Cimarron County shows an unexpected net rise in wells in the summer 2022-2023 comparisons. This portion of the county also has much less CPI use than the western portion of the county, which may account for some of the change observed. Wells in the high country in western Las Animas County show a variable response, which is to be expected as these wells are shallow and highly influenced by local precipitation, especially winter snowpack levels.

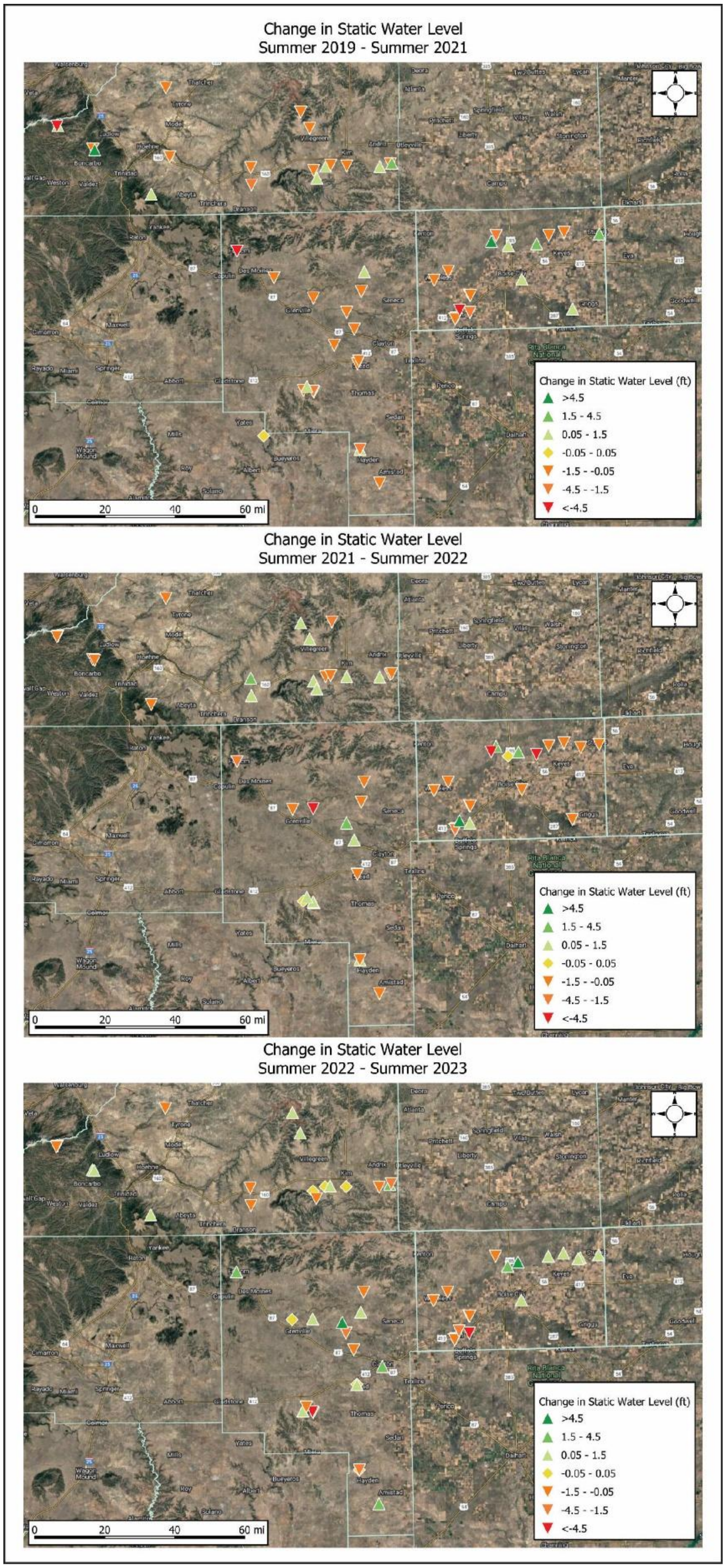


Figure 11. Water level change maps for each of the summers for which there is comparable data.

Winter to Summer Comparisons

Comparisons of winter to summer water level changes helps demonstrate the full potential drawdown for these wells from minimum use in the winter to maximum use in the summer. The majority of the wells observed show a declining water table from winter to summer with this increased use and some may also reflect additive drawdown effects from nearby CPI wells in Oklahoma and eastern Union County (Figure 12). Some wells do not show a decline that may, in part, be due to pasture rotation schedules that see wells being shut off as cattle are moved to summer pasture.

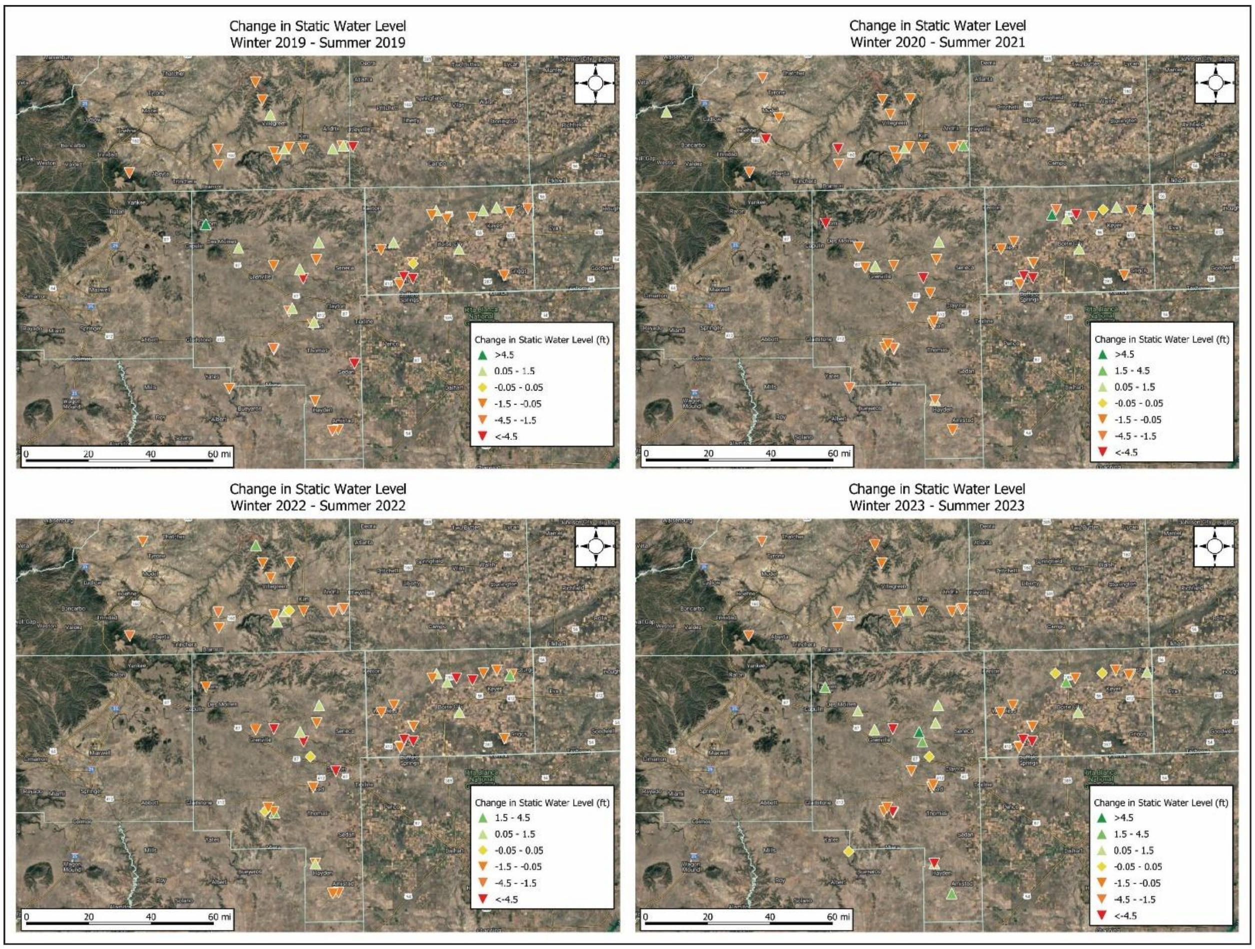


Figure 12. Water level change maps for winter to summer for years with comparable data.

Water Level Changes By County

In examining the behavior of all wells monitored throughout the duration of the data collection phase of this project, the majority of the wells had reasonably small changes in their local water table(s), but with an overall net decline in the majority of the aquifers observed (Figure 13). Only a handful of wells had a net gain in the water table over the period of observation. Prolonged drought and physical barriers to meaningful recharge mean that discharge rates for the vast majority of wells is greater than recharge. This is especially true for wells in areas of concentrated CPI use, although shallow alluvial aquifers can also show extreme fluctuations in water tables due to influence of drought. In addition, the ever-increasing reliance on groundwater resources in the face of prolonged drought and diminished surface water resources, including stock pond water, will cause increasing declines in water levels over time.

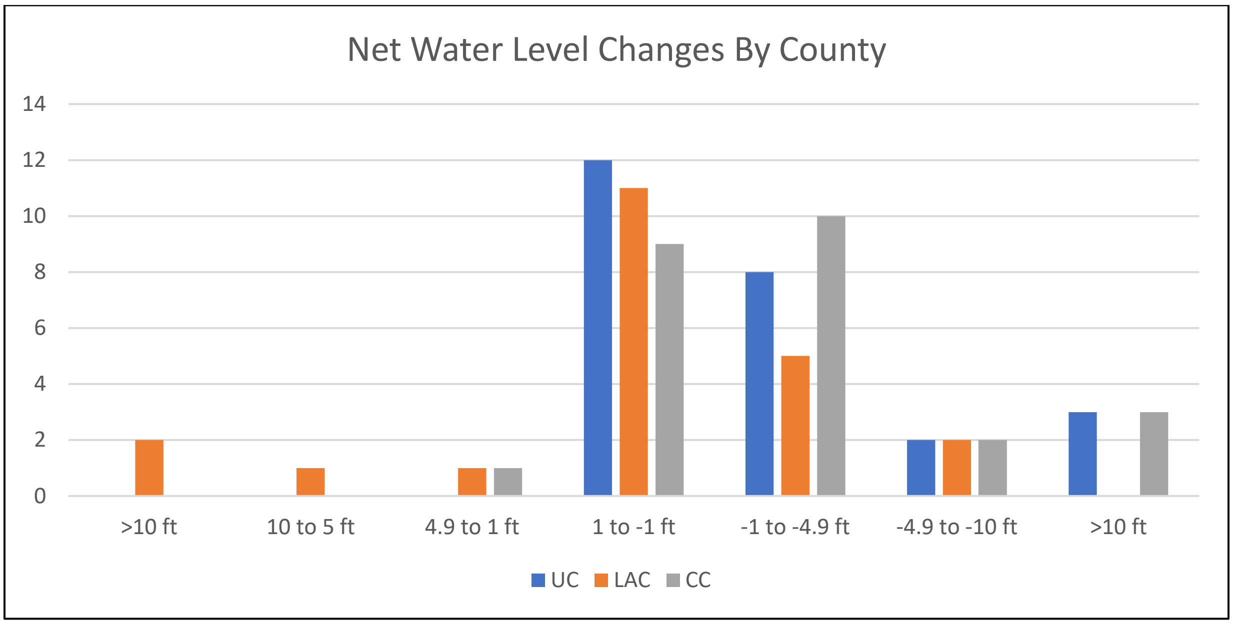


Figure 13. Net changes in water level from first measurement (2019) to last measurement (2023) for wells in all three counties.

Union County

Twenty five wells were monitored in Union County, beginning in January of 2019. Static water levels range from approximately 16 feet below ground surface (bgs) to over 319 feet bgs. Areas of greatest decline are centered around areas of CPI, most notably in the area surrounding the community of Sedan in the east-central portion of the county. The majority of the wells monitored are for livestock and/or domestic use and are drawing water from a variety of hydrostratigraphic units, although the majority of the wells observed for this study draw from the Dakota Sandstone and Morrison Formation sandstone beds. Shallow wells with potential for recharge show variable behavior in their hydrographs (Appendix I), but overall are clearly influenced by the prolonged drought in the region, with declining water levels and poor recovery. Deeper wells that access water in bedrock units show either variable behavior or steady declines in water tables. Changes in the depth to water over the period of observation range from less than a foot greater than 12 feet. Two of the wells showing the greatest decline over the period of measurement are shallow wells near drainages that have undoubtedly been impacted primarily by prolonged drought. The single irrigation well included in this study fell a little over four feet from 2019 through 2022.

Western Las Animas County

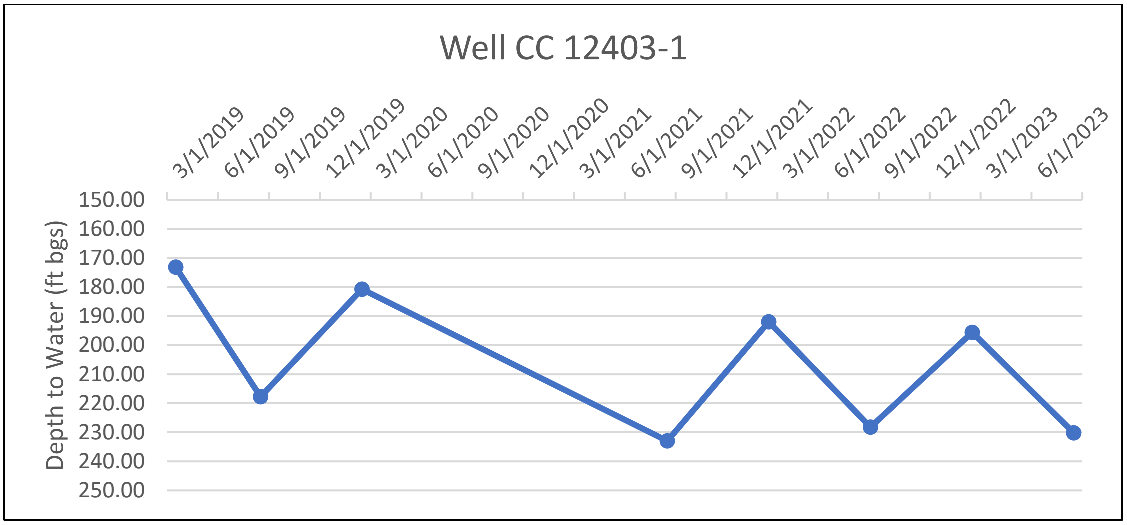
Western Las Animas County includes some of the shallowest wells, as well as some of the deepest wells monitoring for this project. Water level monitoring began for these eight wells in January of 2019 for wells that could be accessed. Wells in the higher terrain around the Spanish Peaks were only monitored in the summers as these wells were frequently buried under snowfall during the winter. Static water levels range from one foot bgs to 407 feet bgs. The shallow wells respond quickly to changes in precipitation patterns and have been strongly influenced by prolonged regional drought. Deeper wells generally show declining water level trends, with some variability. Both of the deepest wells in the study saw a net increase in water level of just over ten feet, which is surprising. However, both wells were difficult to obtain precise measurements for with significant streaking of mud and water on the tape. Therefore, these changes may not be truly reflecting the change in water tables during the period of observation. Shallow wells near drainages showed declining water tables, primarily as a function of prolonged drought.

Eastern Las Animas County

Fourteen wells were monitored in eastern Las Animas County, beginning in January of 2019. Static water levels range from 30 feet to over 180 feet bgs. In the eastern portion of the county, significant concern was raised regarding the influence of local center pivot irrigation along the county line on adjacent wells, many of which had gone dry in years leading up to this study. The majority of the wells observed in this portion of Las Animas County showed minor net changes. A pressure transducer installed in an abandoned well near CPI wells along the eastern county border did not show changes in water levels that were synchronous with when the pivots to the east were turned on or off, suggesting that wells to the west of this concentration of CPI wells are not directly impacted by their use.

Cimarron County

Twenty five wells were monitoring in Cimarron County, although center pivot wells were only measured during the winter when the wells were shut off. These wells were not checked in the summer as turning off the wells for measurement would put the irrigation cycle behind too much. Similar to eastern Las Animas County, there was extreme concern expressed by stakeholders about the impact of expansion of center pivot irrigation, especially in the western portion of the county where large-scale commercial agriculture has led to the drilling of numerous wells in close proximity to one another and to wells monitored in this study. Depth to water ranges from 30 feet to 307 feet bgs. As with the other counties, shallow wells show variable behavior and respond to precipitation events, but are overall strongly influenced by the prolonged drought. Deeper wells show variable behavior with an overall pattern of decline. Perhaps the most dramatic change in static water levels recorded anywhere in the entire three-county project area occurs in a well situated along the edge of Ogallala Formation deposits that have seen a very large increase in the number of CPI wells drilled in the last ten years (figure 14). The water level in this well (#12403-1) can fall by over 70 feet between winter and summer. Over the course of the study, the water table appears to have permanently declined by nearly 30 feet.



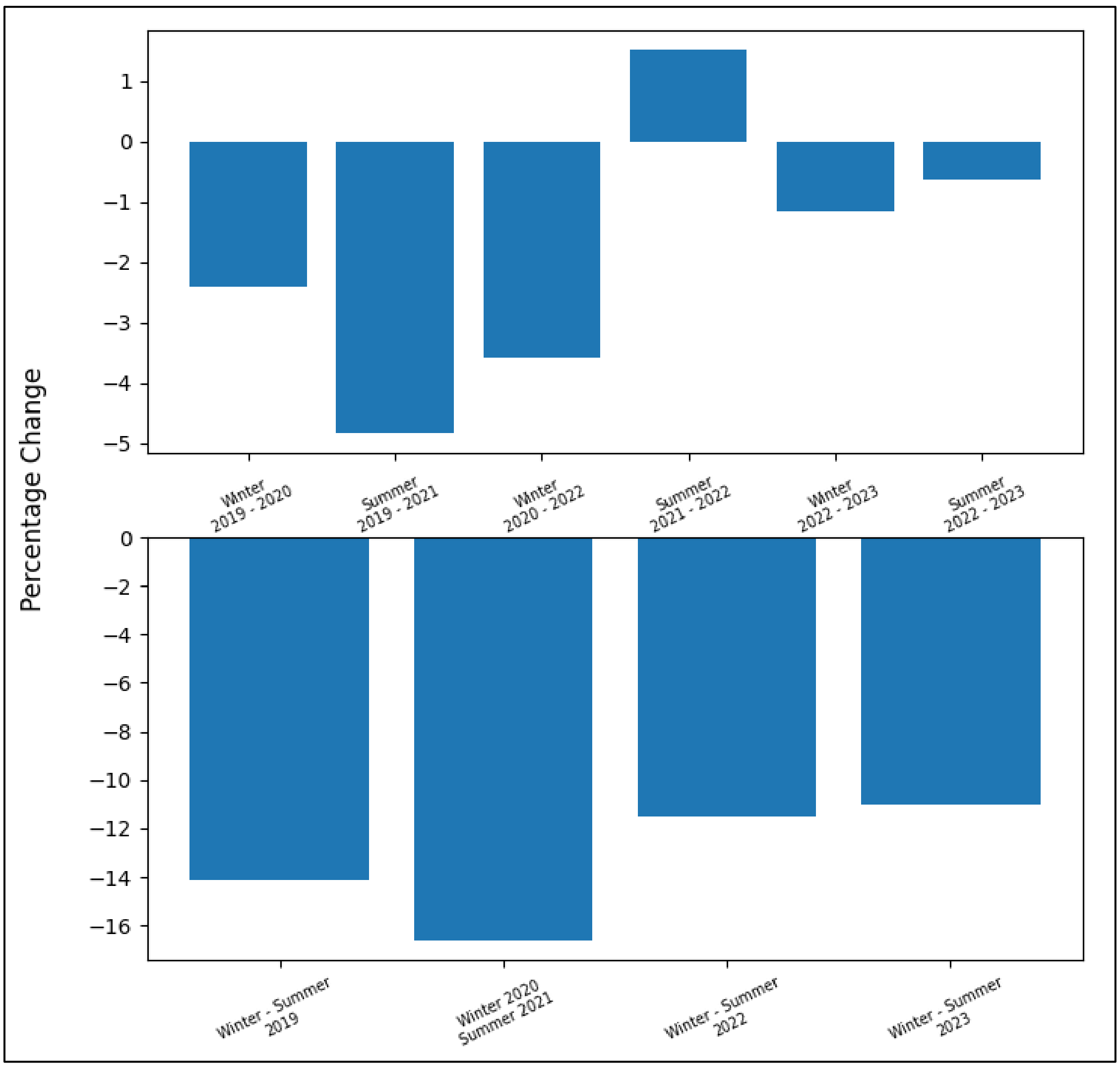


Figure 14. Top: Hydrograph for CC 12403-1, showing the most extreme fluctuations in water level observed during this study. Bottom: Percentage change in water level for CC 12403-1.

Water Level Changes By Hydrostratigraphy

When net water level changes are compared by hydrostratigraphic unit, an unexpected picture emerged in that wells completed in the Ogallala were not always the ones to suffer the greatest net decline (Figure 15), although the majority of the Ogallala wells showed a net decline over the period of observation. In part, net declines are also driven by prolonged drought resulting in a greater use of groundwater resources across the region, regardless of aquifer unit in use. The Dakota Sandstone is the "workhorse" of the region and sees high demand, especially for rangeland use. Waters in the Morrison Formation are frequently in isolated sandstone beds that are not laterally continuous and are geologically isolated by impermeable units (e.g., mudstone or shale), such that it is rare to see increasing water tables for wells completed in Morrison beds.

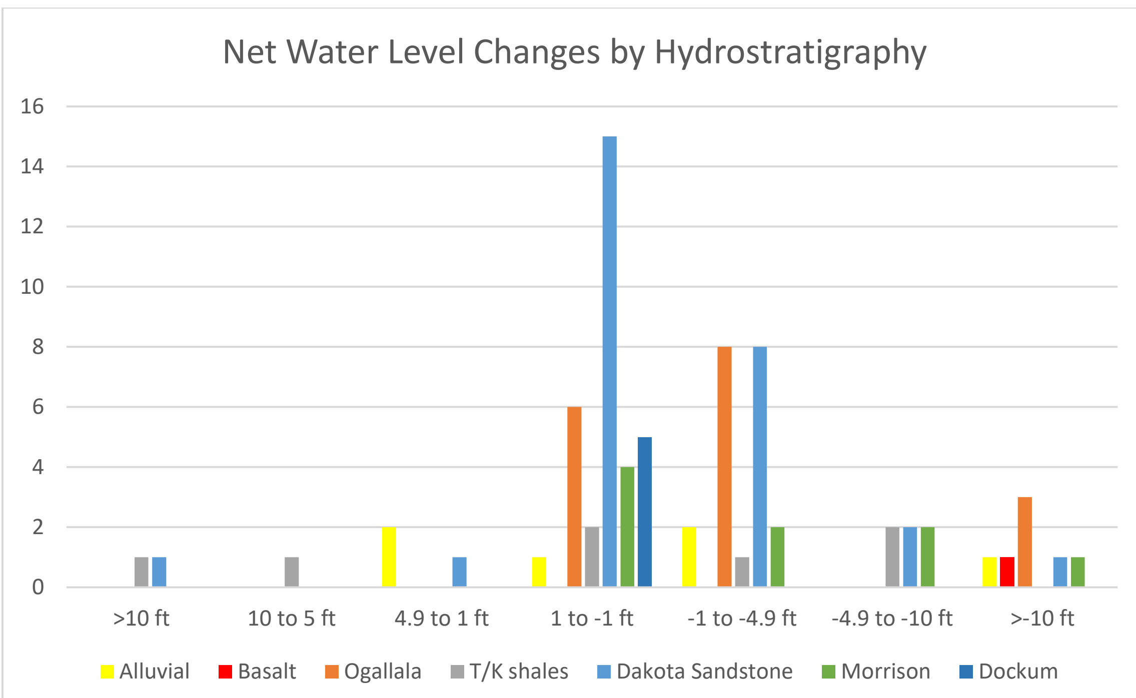


Figure 15. Net water level change by hydrostratigraphic unit.

Alluvial Wells

Shallow wells tend to show significant variability in static water level measurements and are impacted primarily by prolonged drought (Figure 16). These wells tend to exhibit increasing static water levels after winters with good snowpack and, to a lesser extent, after summers with reasonably good monsoon events. These wells have water levels ranging from 10 feet bgs to 60 feet bgs.

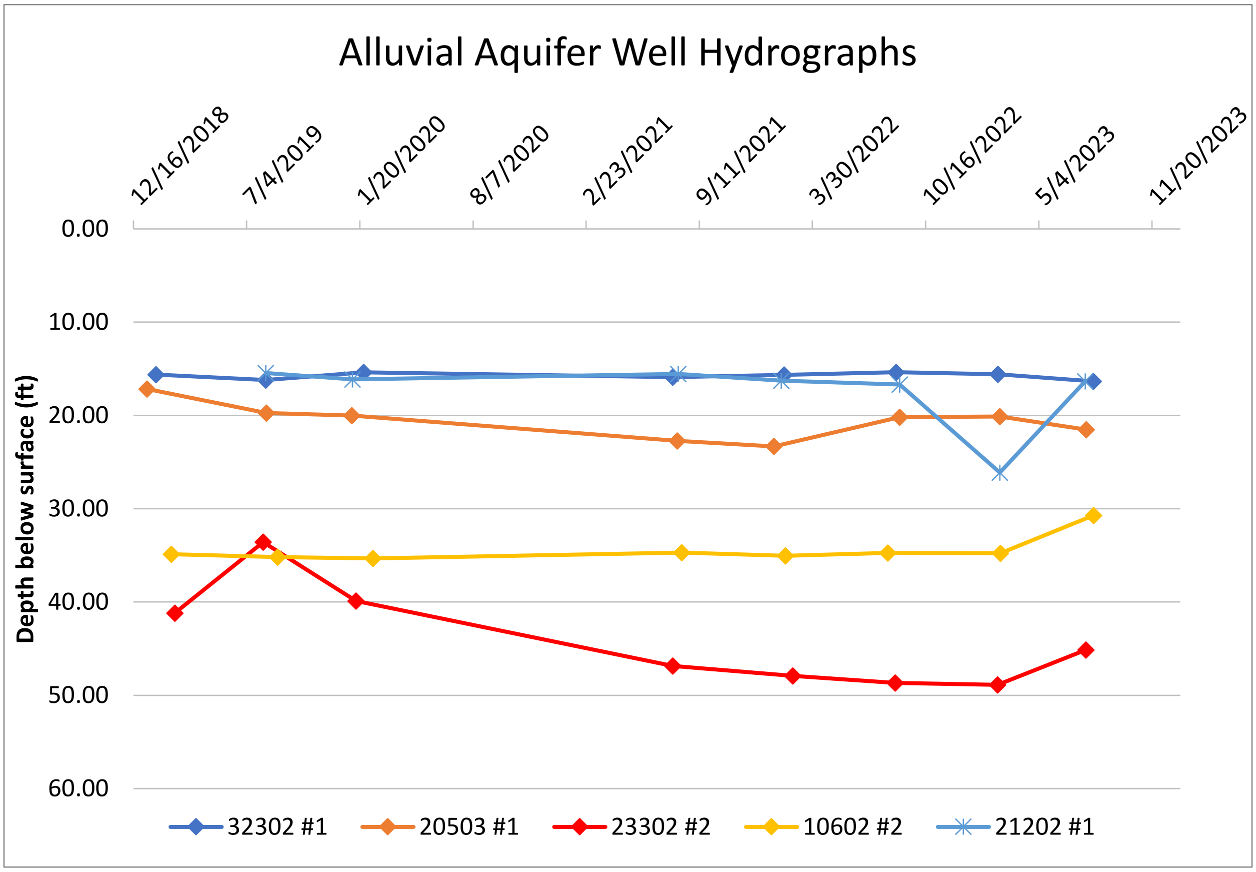


Figure 16. Hydrographs for wells completed in unconfined alluvial aquifers.

Ogallala Formation Wells

Wells drawing from the Ogallala Formation are bimodal: high-production CPI wells and lower producing wells along the fringes of thicker deposits of the formation (Figure 17). High-production wells generally have deeper depths to water and show declines in the water table. The lower production Ogallala Formation wells have shallower depths to water and also show declines. Of particular concern is Well 12403, which shows an extreme summer drawdown response and permanently declining water table.

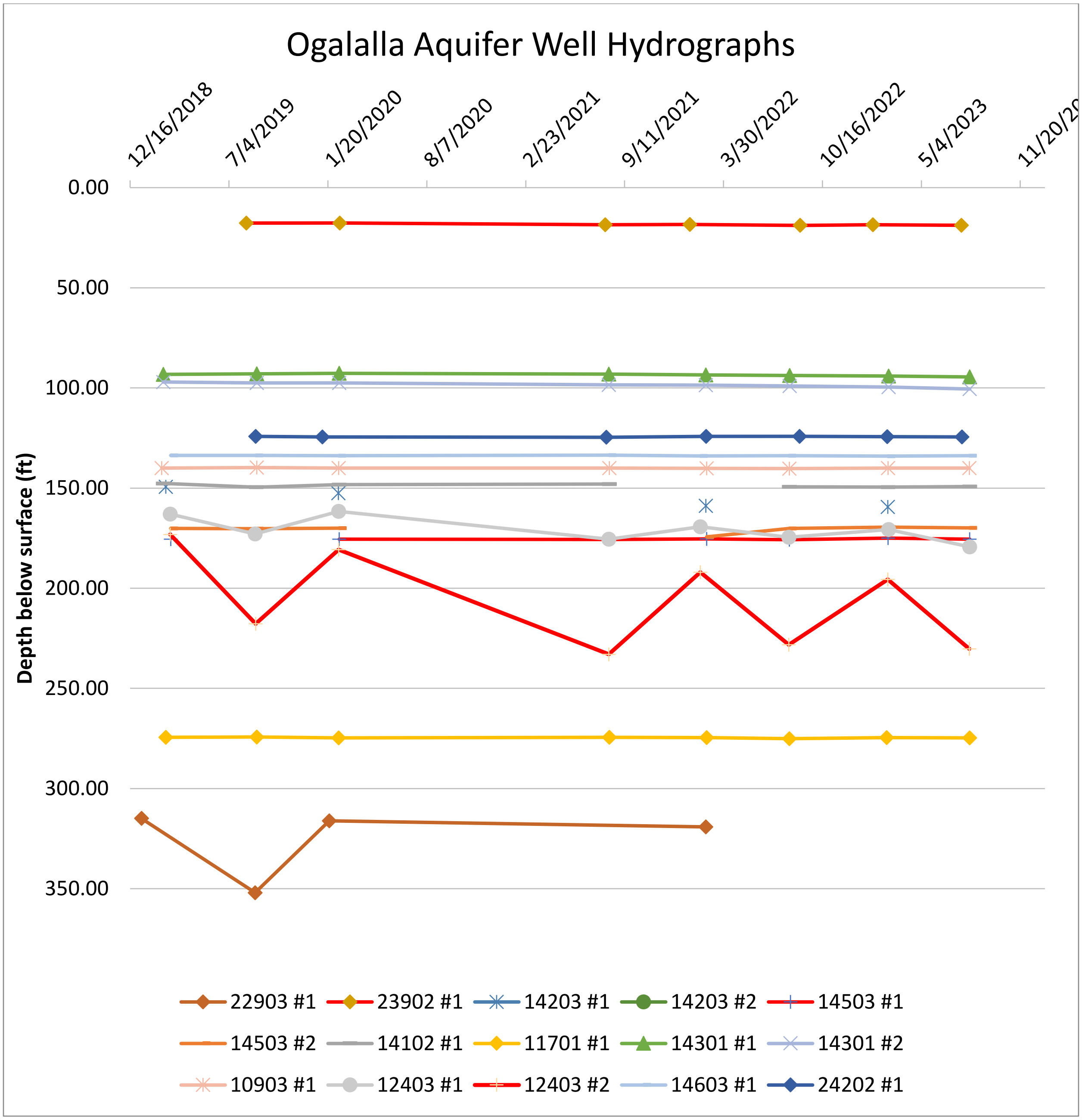


Figure 17. Hydrographs for wells completed in the Ogallala Formation.

Tertiary and Cretaceous Shale Aquifer Wells

Wells drawing water from shale-dominated units are either shallow and located adjacent to drainages or are extremely deep (Figure 18). The shallower wells tend to show variable behavior that indicates connectivity to the nearby drainages and potential recharge from these.

The deepest well showed an increasing water level trend, although this was also one of the most difficult to obtain consistent accurate measurements for.

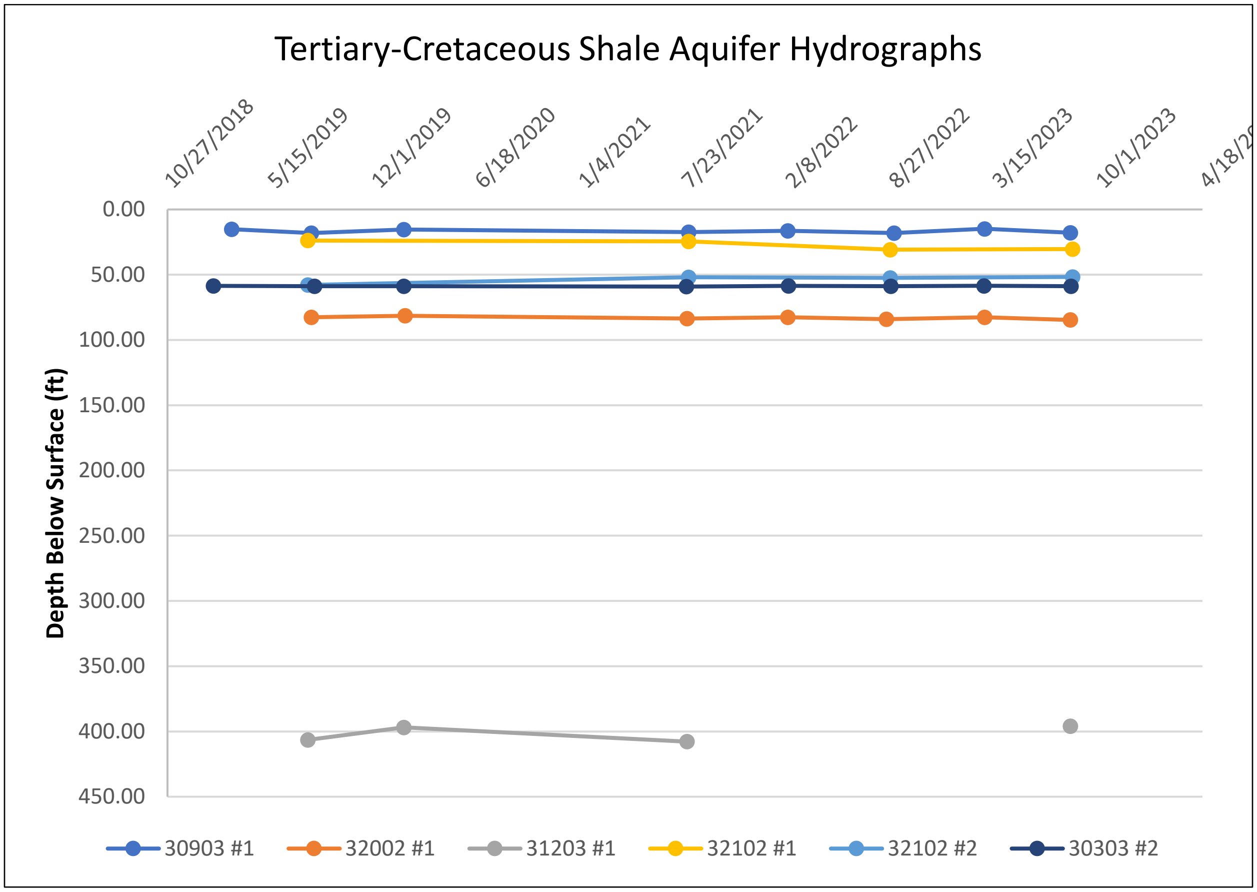


Figure 18. Hydrographs for wells drawing water from Tertiary-Cretaceous shale-dominated units.

Dakota Sandstone Wells

Wells completed in the Dakota Sandstone vary in depth from around 90 feet to over 240 feet bgs. Due to the high proportion of Dakota wells and the variation in depth to water, the hydrographs have been split into intermediate depth wells (80 feet to 140 feet to water; Figure 19) and deep wells (greater than 140 feet bgs to water; Figure 20). Dakota wells show variable behavior with many of the wells showing a net change that is effectively quite minimal, whereas others show strong net declines. Four of these wells in Cimarron County are adjacent to areas with a significant concentration of Ogallala-based CPI, suggesting some degree of hydraulic connectivity between Dakota beds and inset Ogallala deposits. As Dakota wells are generally lower volume producers, they are used almost entirely for livestock and/or domestic use.

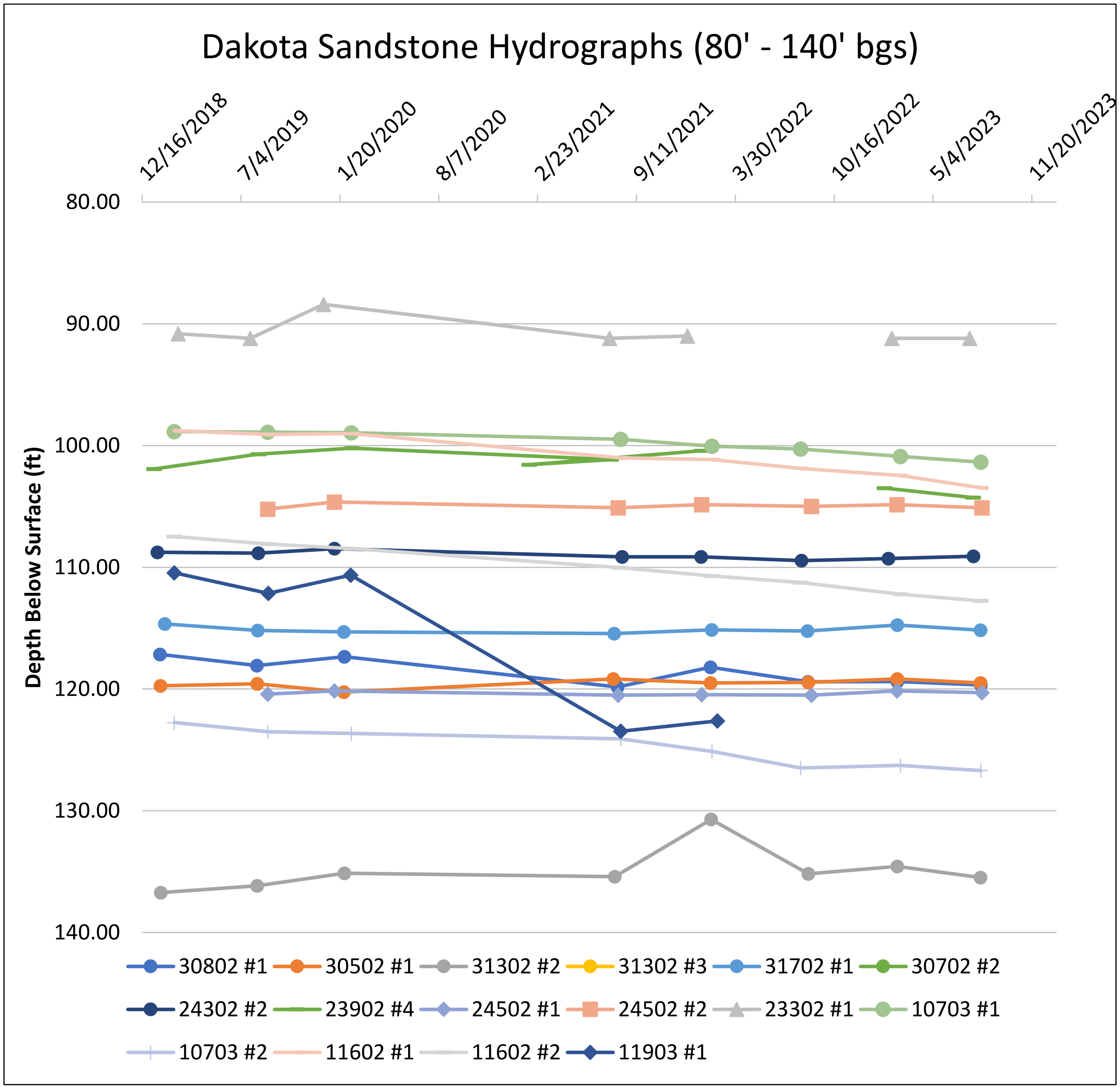


Figure 19. Hydrographs for intermediate depth Dakota wells.

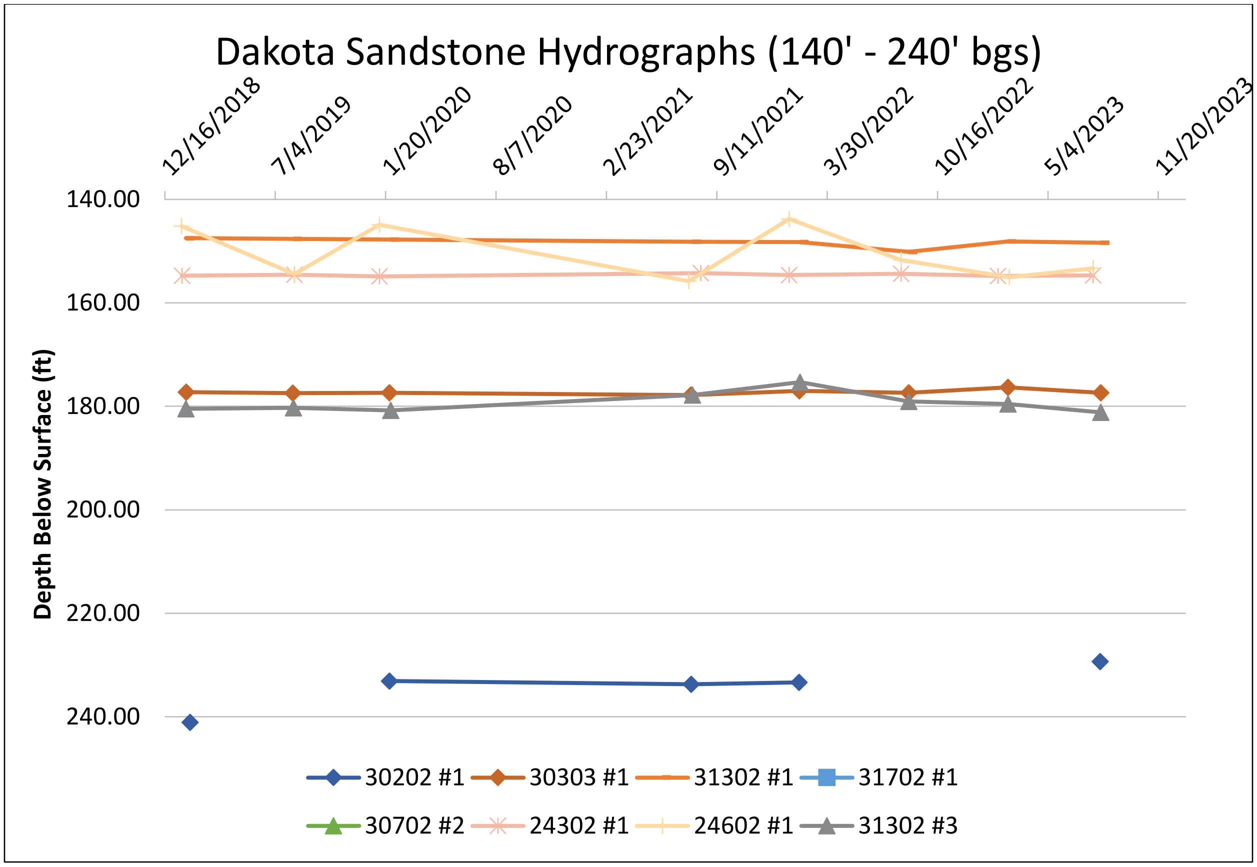


Figure 20. Hydrographs for deep Dakota wells.

Morrison and Dockum Wells

Morrison wells range from 20 feet to over 180 feet bgs to water and show moderately variable behavior (Figure 21). The only Dockum wells in the study are two wells in southern Union County that are shallow and near drainages, one well in eastern Las Animas County that is in the floor of a canyon system, and a single well in eastern Cimarron County, which is deeper than the other three (Figure 22). All Dockum wells show moderately variable behavior.

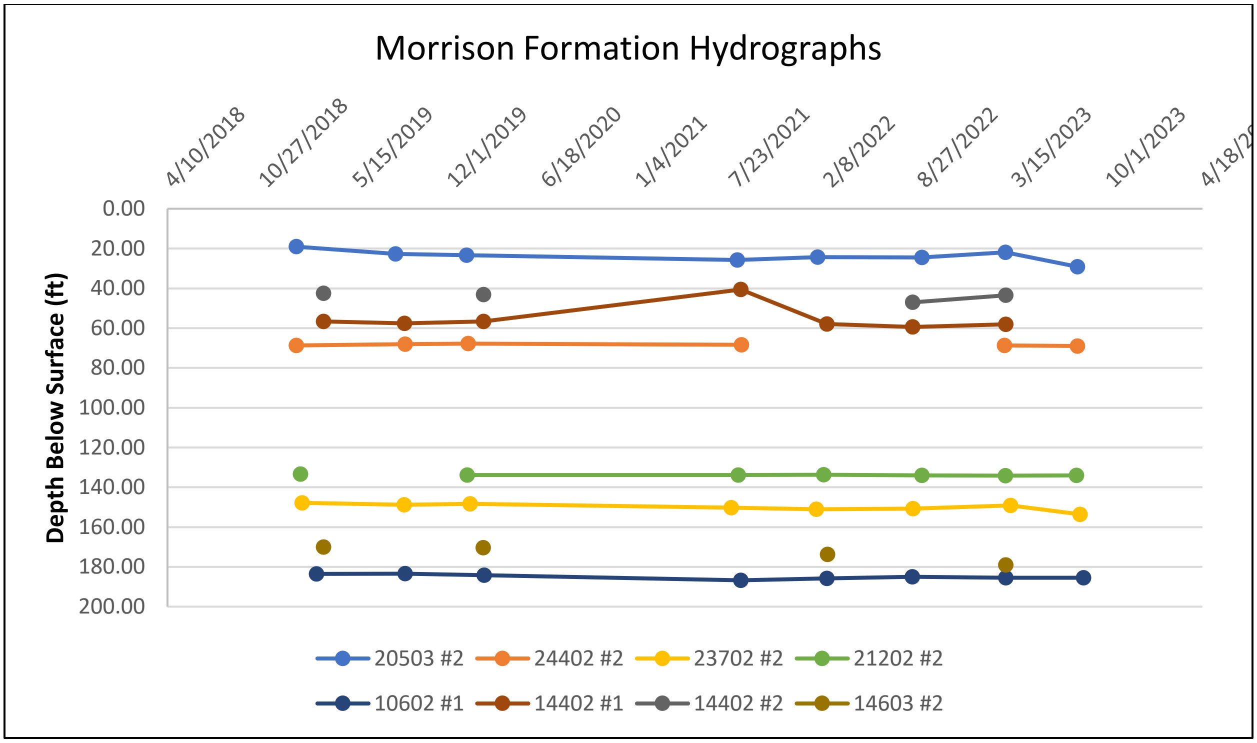


Figure 21. Hydrographs for Morrison wells.

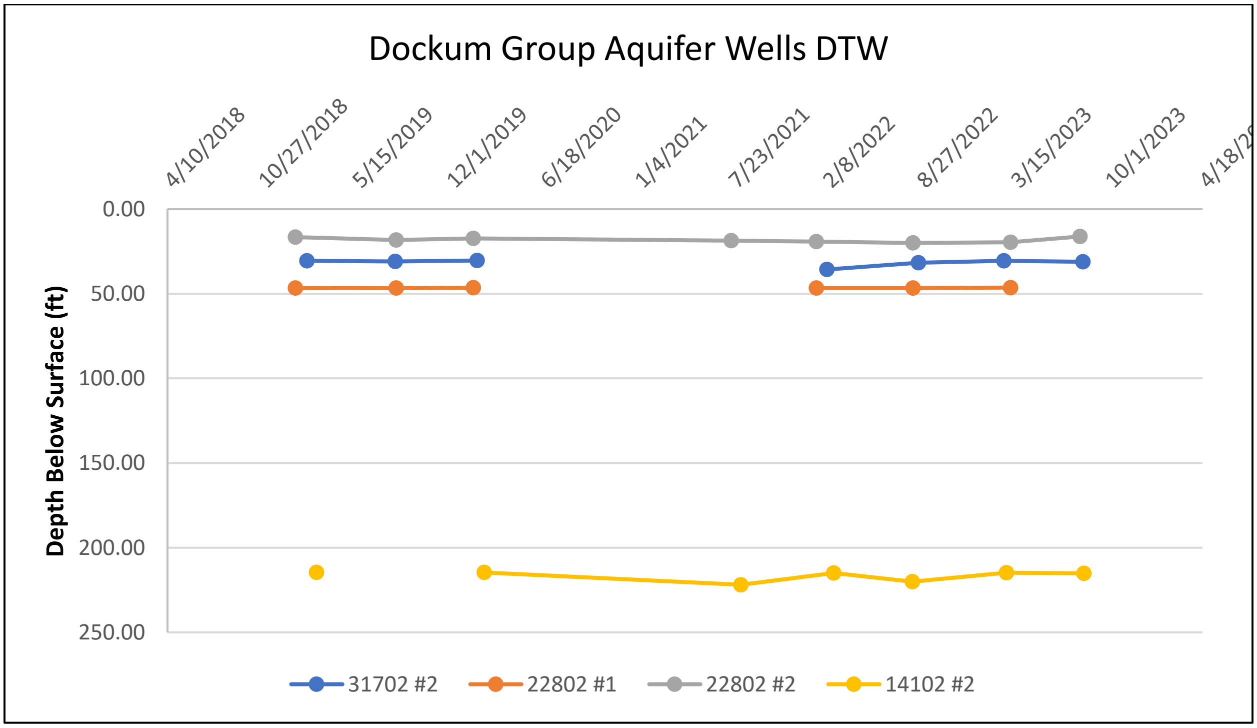


Figure 22. Hydrographs for Dockum wells.

Static Water Levels Versus Precipitation

In comparing precipitation data gathered from CoCoRaHS stations, we observe interesting patterns in the timing and spatial distribution of precipitation for all three counties (Figure 23). Monthly average precipitations reached their highest in summer months, although 2019 and 2021 showed a staggered pattern of late winter to early summer precipitation, resulting in a “sawtooth” pattern, whereas other years received the majority of the precipitation in a more discrete window. Highest precipitation seasons varied by county, with 2022 being the best year for Union County, whereas Las Animas County saw highest average precipitation in 2021 and Cimarron County had higher precipitation in 2020 and 2023.

The SWL change maps for winter to winter are dominated by falling water tables, as are the summer to summer SWL change maps. Given that the majority of the wells access deeper waters that either cannot receive recharge due to geologic barriers to downwards infiltration or recharge waters move so slowly that it will take years to centuries for water to reach deeper water tables, it is not a surprise that even in good years, we see no immediate response to precipitation for most of these wells. In the summer of 2023, there is a very modest upwards response across the map, but it’s unlikely this directly corresponds to the precipitation recorded for that year. In addition, calculations of total percent change for wells where a total depth was known show net declines in the majority of these wells (Appendix III).

Observations at a ranch in western Mora County in New Mexico suggest that even in very high precipitation years, the wetting front in soils may only penetrate six inches or less. Explosive plant growth in good years will uptake much of the moisture before it can infiltrate down to the local water tables. For shifts in water table behavior, another factor that needs to be taken into account is shifting management strategies being employed on farms and ranches throughout the area. Transition to pipeline and storage systems with wells being shut off when not in use, changes in crop types that require less use, and other strategies can lead to a lowering of intense demand on individual wells or clusters of wells.

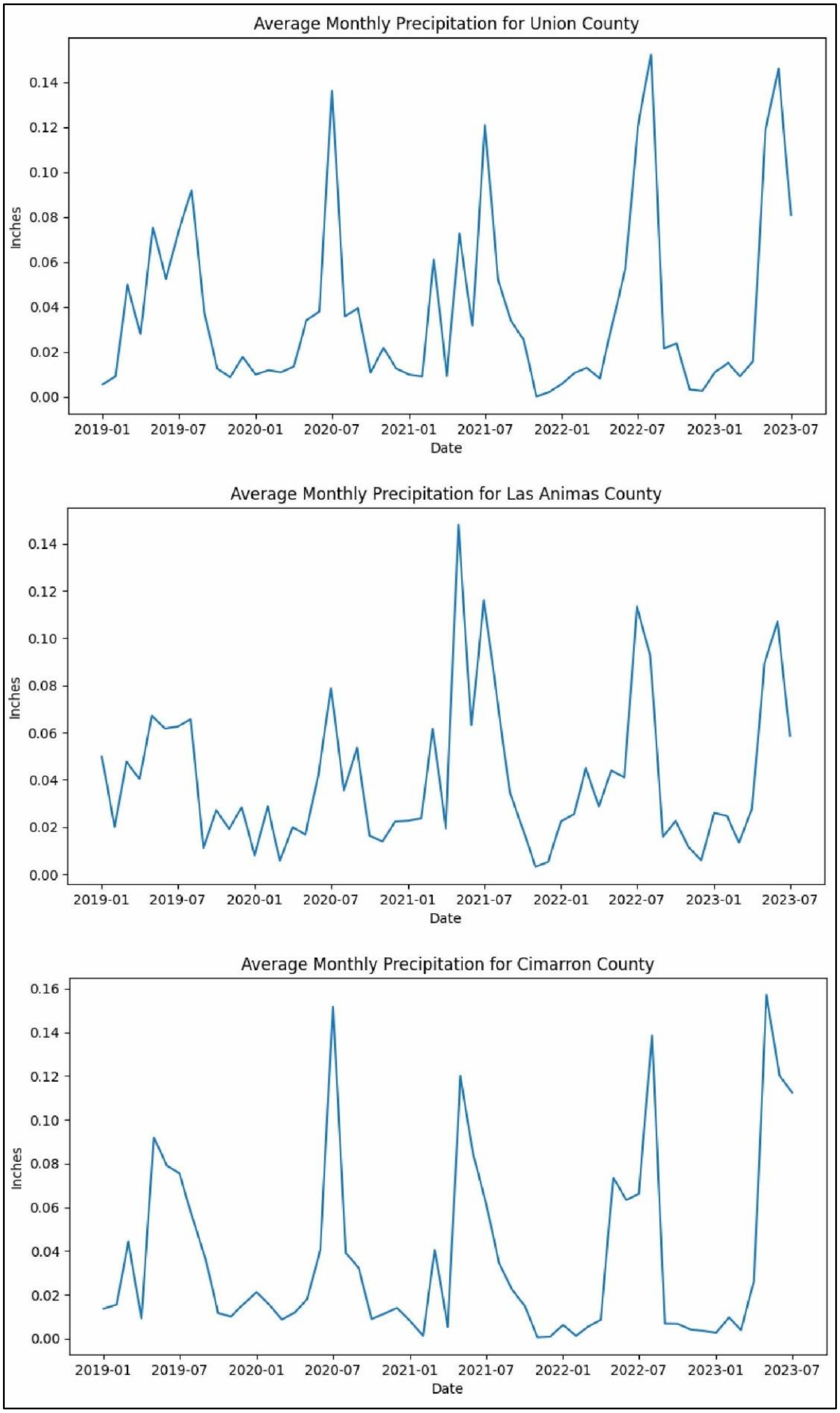


Figure 23. Average precipitation for each county from CoCoRaHS network stations.

Results: Water Chemistry

Analyzing water samples from these wells for major ion chemistry and trace metals can provide insight into the aquifer systems that are being used in the three counties. Major cations and anions can be used to characterize aquifer quality and can also help for discerning the contributions of water from different geologic units (Appendix III; Hem, 1985). Both Piper and Stiff diagrams are used to show the proportions of major cations and anions, as well as to show groupings of water types, and calculated total dissolved solids.

A Piper diagram is, effectively, two ternary diagrams (one for cations and one for anions) compiled into a single diagram that shows clustering of water types, along with calculate total dissolved solids (Figures 24-26). We deviate here from the more traditional mode of reporting groundwater cation-anion group types and will discuss waters based on their predominant hydrostratigraphic host unit in order to more directly tie together the geologic units in use as aquifers. It should be noted that Ogallala Formation and Dakota Sandstone waters generally correspond to the Ca-Mg-HCO_3 type, and Na-HCO_3 type waters are associated with Dockum Group, Morrison Formation, and some basalt flows. Ca-Mg-SO_4 type waters are associated with wells completed in Paleocene and Cretaceous black shales, as well as wells with a contribution of water from the Bell Ranch Formation. Several wells include mixed water types that suggest these wells intersect multiple hydrostratigraphic units with different cation and anion contributions (e.g., extremely deep wells in western LAC that could include contributions from the Morrison Formation, Dakota Sandstone, and/or overlying younger black shale beds).

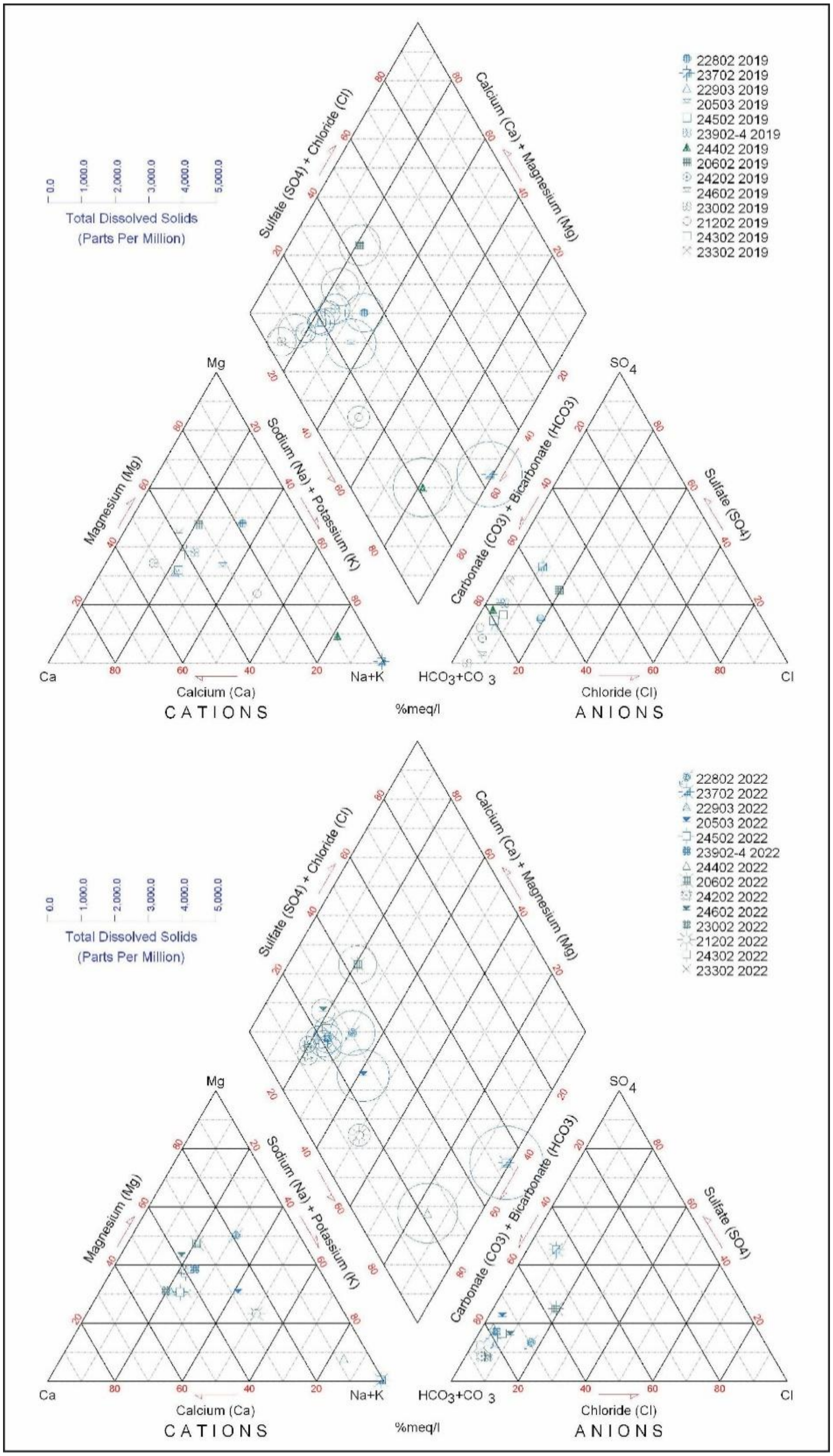


Figure 24. Piper diagrams for Union County samples for 2019 (top) and 2022 (bottom).

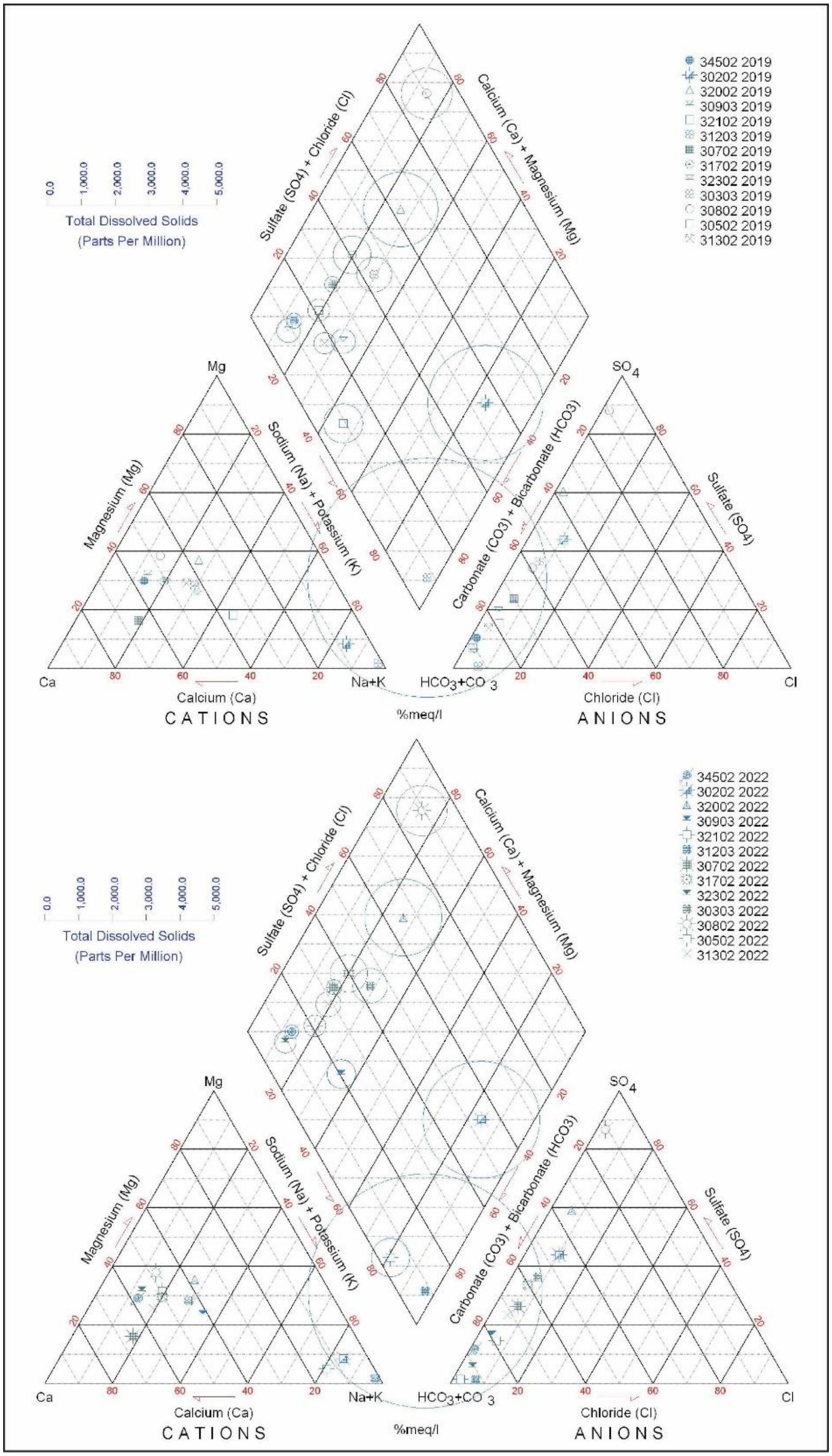


Figure 25. Piper diagrams for Las Animas County samples for 2019 (top) and 2022 (bottom).

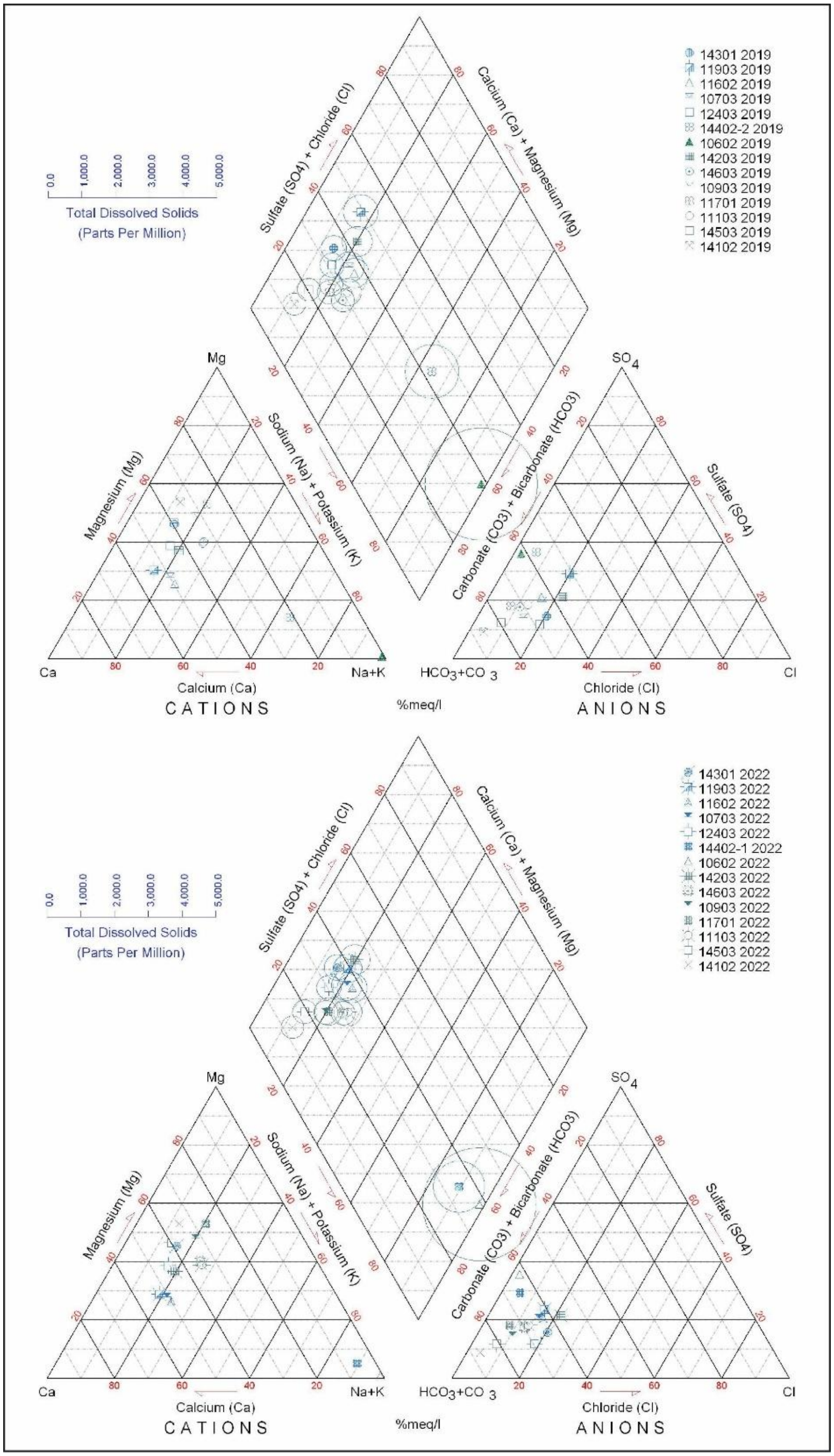


Figure 26. Piper diagrams for Cimarron County samples for 2019 (top) and 2022 (bottom).

A Stiff diagram is used to show the proportions of major cations and anions from a water sample (Figure 27). Anions on are shown on the left and cations on the right of the vertical axis. The farther from the vertical axis an ion's point is from the axis, the more of that ion is present in the water sample. Generally, waters from quartz sandstones such as the Dakota Sandstone, which have few minerals in them that can dissolve into the water, have a small polygon with low values of major cations and anions. By contrast, waters from black shales can have much higher values for sulfate and sodium due to the presence of gypsum, a calcium sulfate, and halite (rock salt). The Morrison Formation includes sandstone bodies that are arkosic, meaning that the sand grains include quartz, as well as feldspar, which is a sodium- and potassium-bearing silicate mineral. Thus, a "Na+K spike" on a Stiff diagram is a marker for Morrison Formation waters. The overall shape of the Stiff diagram, when combined with knowledge of local geology, can thus aid in assessing which water-bearing horizon(s) a well is drawing water from. Example Stiff diagrams are shown for each hydrostratigraphic unit below and all Stiff diagrams are in Appendix IV.

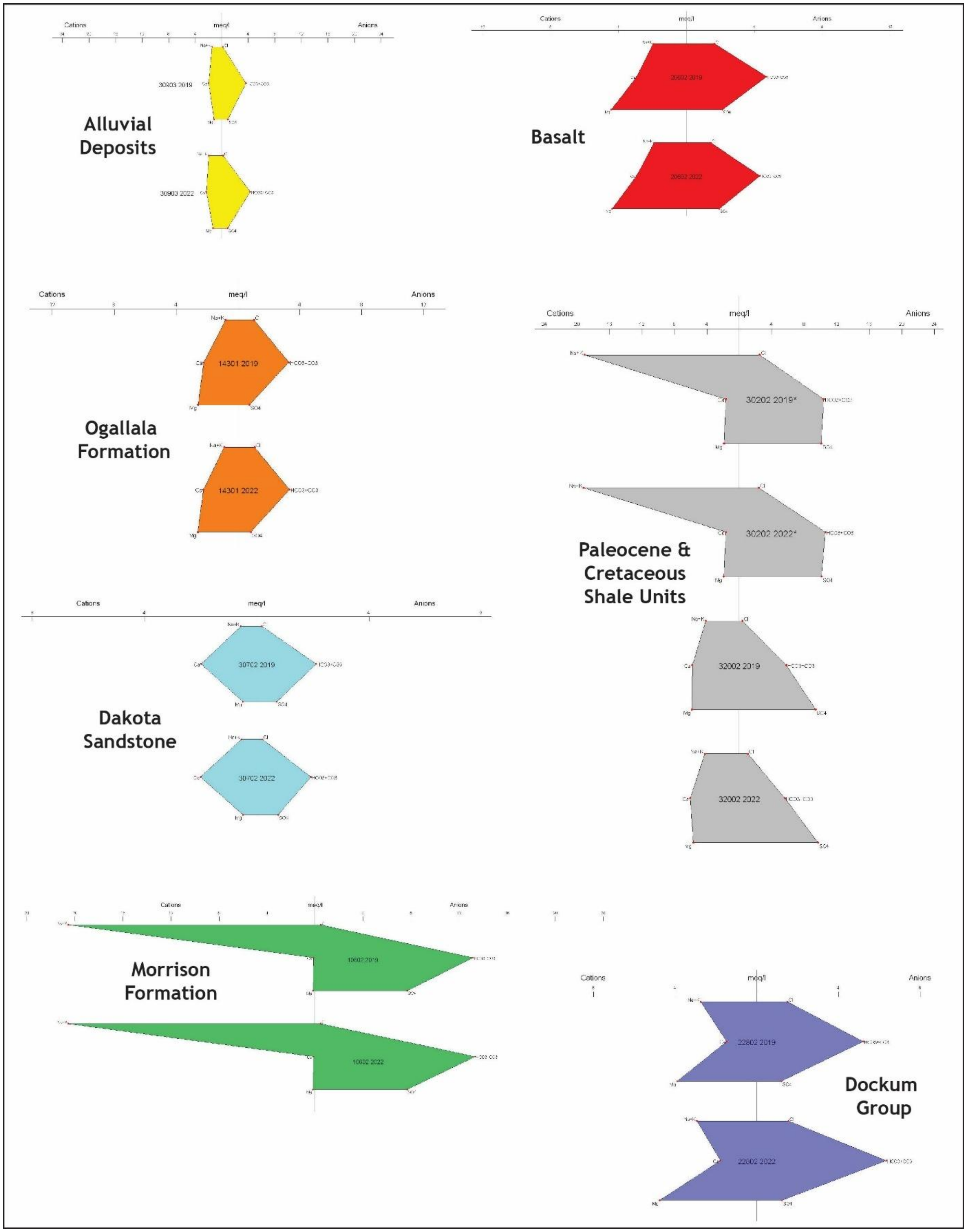


Figure 27. Example Stiff diagrams for hydrostratigraphic units in the project area. Note the characteristic Na+K "spike" for Morrison waters. Well 30202* is a very deep well that includes contributions from the Dakota Sandstone as well as overlying shales and limestones.

Alluvial Wells

Water from alluvial wells (coded yellow, Figure 27) generally show moderate to low levels of cations, anions, and trace metals. These waters can recharge when there is significant precipitation and water moves relatively quickly through these deposits, resulting in little residence time of the waters for minerals to begin to dissolve.

Volcanic Wells

Only a single well in Union County was (partially) completed in a basalt flow, and this well shows elevated levels of magnesium, sodium, and potassium, with minor elevation of sulfate (coded red, Figure 27). This well also exhibited elevated magnesium, arsenic, chromium, lithium, uranium, and zinc compared to other wells in the study. When compared with the local geology and water level depth, this suggests this well draws water from the Clayton basalt, and may also have potentially encountered the Graneros Shale below the basalt. Basalts contain minerals such as feldspar, pyroxene, and amphibole, which are susceptible to dissolution in water and contain magnesium, sodium, potassium, along with other trace metals. The Graneros Shale, or a shale bed within the Dakota Sandstone, includes gypsum, a calcium sulfate mineral.

Ogallala Formation Wells

Wells that draw from the Ogallala wells show low levels of most cations and anions. Stiff diagrams for these wells are very similar to those for Dakota wells, with the exception of moderately elevated magnesium (coded orange, Figure 27). Many wells that were initially considered to be completed in Dakota because they had relatively low production levels were determined to be drawing waters from the Ogallala, but these wells are situated along the edges of pockets or paleovalleys of Ogallala deposits, resulting in lower flow rates compared to the "classic" Ogallala high-volume wells that drive CPI in the region.

Cretaceous and Paleocene Shale Wells

Wells completed in or through gray and black shales are characterized by elevated sulfate levels due to the presence of significant quantities of gypsum (coded gray, Figure 27). Gypsum can dissolve fairly easily in water and water sources that contain elevated sulfate should be treated with caution – evaporation of water in drinkers or dirt tanks, as well as increasing levels of dissolved salts in groundwater as aquifer levels diminish can lead to extremely high levels of sulfate, which is toxic to livestock. This can also be problematic when livestock are brought in from areas where the water has much lower levels of sulfate and they are not habituated to higher sulfate.

Dakota Wells

The Dakota Sandstone is a quartz-rich sandstone that has few minerals that can dissolve into groundwater. Thus, Stiff diagrams for Dakota waters have low proportions of cations and anions when compared to waters from other hydrostratigraphic units (coded light blue, Figure 27). These wells have low TDS compared to other water sources with the water sometimes described as being “sweet” to the taste.

Morrison Wells

Morrison Formation sandstone beds contain quartz, feldspar, and other minerals. Feldspars, a family of minerals that are sodium-potassium-calcium aluminosilicates, are susceptible to hydrolysis in the presence of groundwater over time and contain higher levels of sodium and potassium as these ions are released into solution as the feldspar minerals convert to clay minerals. Thus, Morrison Stiff diagrams have a characteristic “spike” of sodium and potassium (coded green, Figure 27).

Dockum Group Wells

Dockum Group wells show a cation and anion chemistry that is intermediate between Dakota Sandstone and Morrison Formation (coded purple, Figure 27). Dockum Group sandstones and siltstones frequently include a variety of different minerals that can contribute to the chemistry of these waters, but are not as arkosic as Morrison sandstone beds. They generally have elevated TDS levels that are similar to Morrison wells.

Water Chemistry and Hydrostratigraphy

The majority of the wells observed in this study appear to be drawing water primarily from the Dakota Sandstone in Union and Las Animas Counties, with the Ogallala Formation being the most-utilized hydrostratigraphic unit in Cimarron County (Figure 28, 29). Many wells are incorporating water from more than one water-bearing horizon and here we utilized a combination of well total depth, depth to water, major cation and anion chemistry, and local geologic mapping to determine the primary aquifer unit in use for each well.

Table 1. Proportions of wells in different hydrostratigraphic units by county.

County	Alluvial	Basalt	Ogallala Formation	Shale Units	Dakota Sandstone	Morrison Formation	Dockum Group
LAC	2	0	0	7	11	0	1
UC	3	1	3	0	11	6	2
CC	1	0	14	0	6	5	2
Totals	**6**	**1**	**17**	**7**	**28**	**11**	**5**

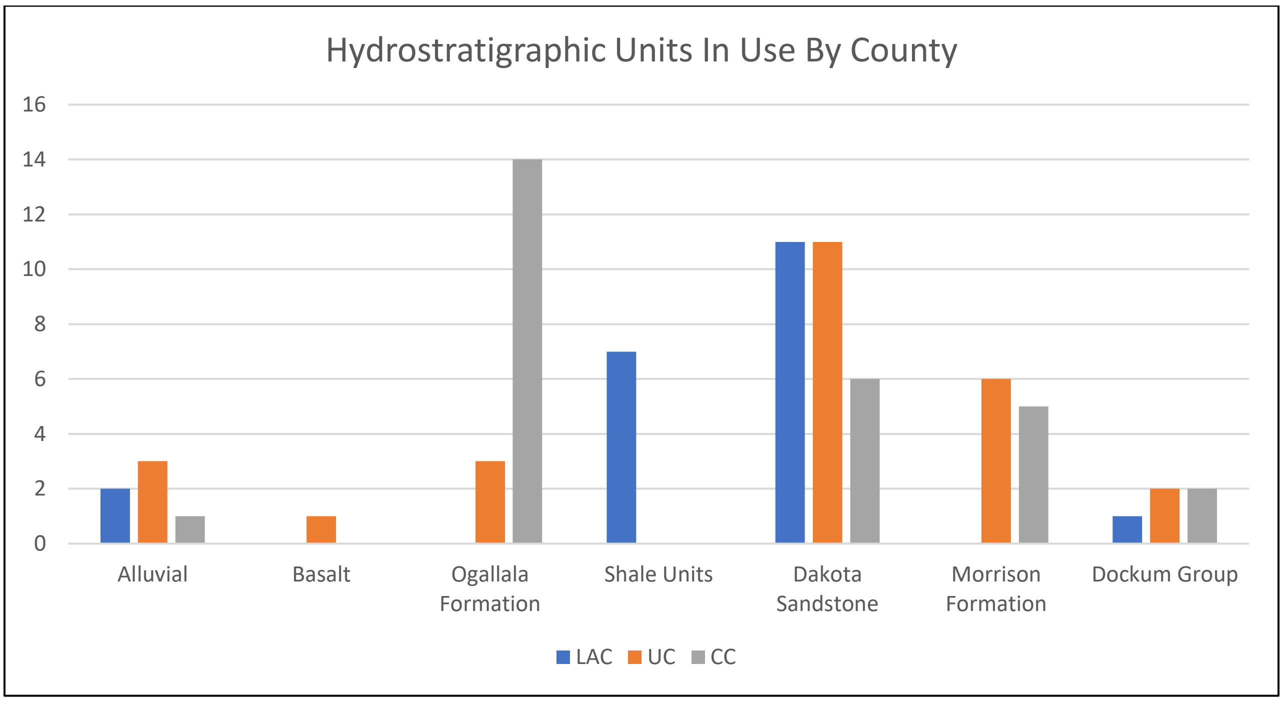


Figure 28. Hydrostratigraphic units utilized in each county for all wells observed with sufficient data.

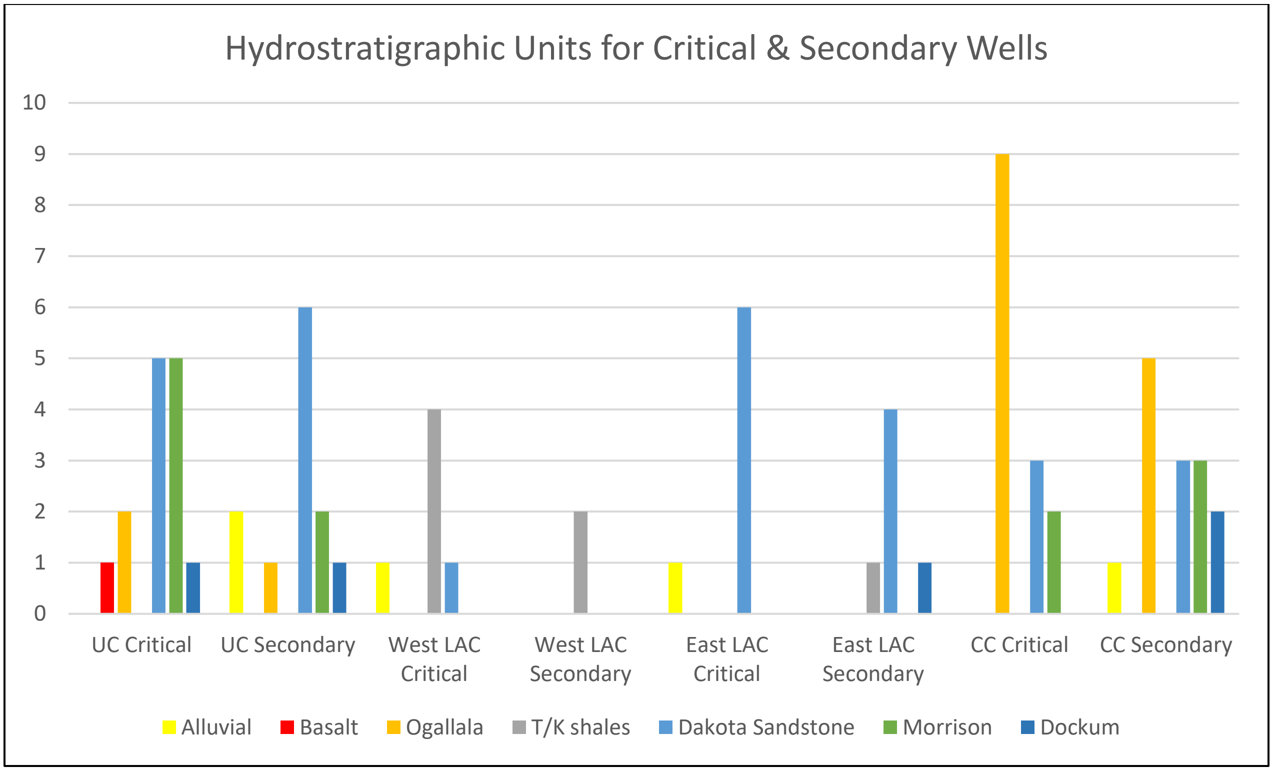


Figure 29. Hydrostratigraphic units utilized in each county divided by critical and secondary well.

Total Dissolved Solids and Residence Time

Wells with the highest proportion of total dissolved solids (TDS) are associated with wells completed in very deep aquifer units, such as in western Las Animas County, or with Morrison wells. On Piper diagrams, the size of the circle around each well's point is proportionate to TDS. Groundwater residence time is significantly greater for extremely deep aquifer units, such as the Dakota Sandstone in western Las Animas County, which is encountered in two of the wells observed here at depths greater than 600 feet below land surface. In addition, these wells include a contribution of water interacting with the thick sequence of gray shales and limestone beds that overlie the Dakota Sandstone and these beds contribute sodium, calcium, sulfate, and chloride from the dissolution of mineral such as halite and gypsum. Morrison water-bearing sandstone beds tend to be at intermediate depth and geologically isolated by overlying shale beds, such that they are not usually receiving influx of modern recharge. In addition, the higher proportion of feldspar in these units yields elevated proportions of sodium and potassium via hydrolysis of these minerals.

Results: Tritium & Recharge Potential

The most difficult part of the hydrologic cycle to quantify is recharge into the subsurface reservoirs. Once a drop of water lands on the surface (as rain or snow), there are multiple pathways for that molecule to travel: surface water discharge, evaporation, shallow infiltration and subsequent uptake by vegetation (resulting in evapotranspiration), and deeper infiltration, along with cross-formational flow (Bethke and Johnson, 2008). Downward movement of water molecules into deeper unconfined or confined aquifers can take years to centuries and the pathways taken by individual molecules are not linearly downward. Molecules must travel along pathways dictated by porosity and permeability within the host geologic units, which may sometimes direct water molecules laterally for substantial distances. In addition, the gradual downward progression of water is a very slow process with the average rate of travel in centimeters per year. Thus, if the water table is 150 feet bgs, it will be decades before water molecules falling today reach that depth.

Tritium is a radioactive isotope of hydrogen with a short half-life of approximately 12.3 years that is most commonly used to determine relative age of waters less than 70 years old. Tritium is produced both naturally by cosmic radiation interacting with the upper atmosphere, but also was produced during the testing of thermonuclear bombs in the 1950s in the western U.S. Tritium is helpful as a marker for the presence or absence of modern (post-1950s) recharge. In general, a groundwater sample with 5 to 15 tritium units (TUs) is considered to be modern groundwater, indicating that the water table can receive volumetrically significant recharge in years with good precipitation. Samples with 0.8 to 4.9 TUs are a mixture of modern and older waters and samples with less than 0.8 TUs indicate older waters and a water table that is not receiving modern recharge in a human generation. However, recent tritium testing in New Mexico indicated that tritium levels can fluctuate significantly in shallow wells that should be capable to recharging, and samples in shallow wells with values between 0.2 and 0.8 are now considered to signify a prolonged drought signature that suppresses the observed tritium values. It is important to note that “older” waters as considered here does not equate in all cases to “ancient” water (e.g., Pleistocene-age), as preliminary groundwater stable isotope data suggests that few wells in the region are drawing from these “paleowaters” (Blumenberg, 2018).

Each critical well was sampled for tritium in 2019 and again in 2023 to determine recharge potential and observe changes to that potential over time (Appendix V). The majority of wells in each county did not show potential for significant modern recharge (Figure 30, Table 2). This reflects the complex geology and barriers to recharge for the majority of the wells observed in this study. Sustained drought in the region has also played a significant role in a lack of recharge for this wells that are physically able to receive new water (e.g., shallow wells situated near drainages and completed in appropriate aquifer units).

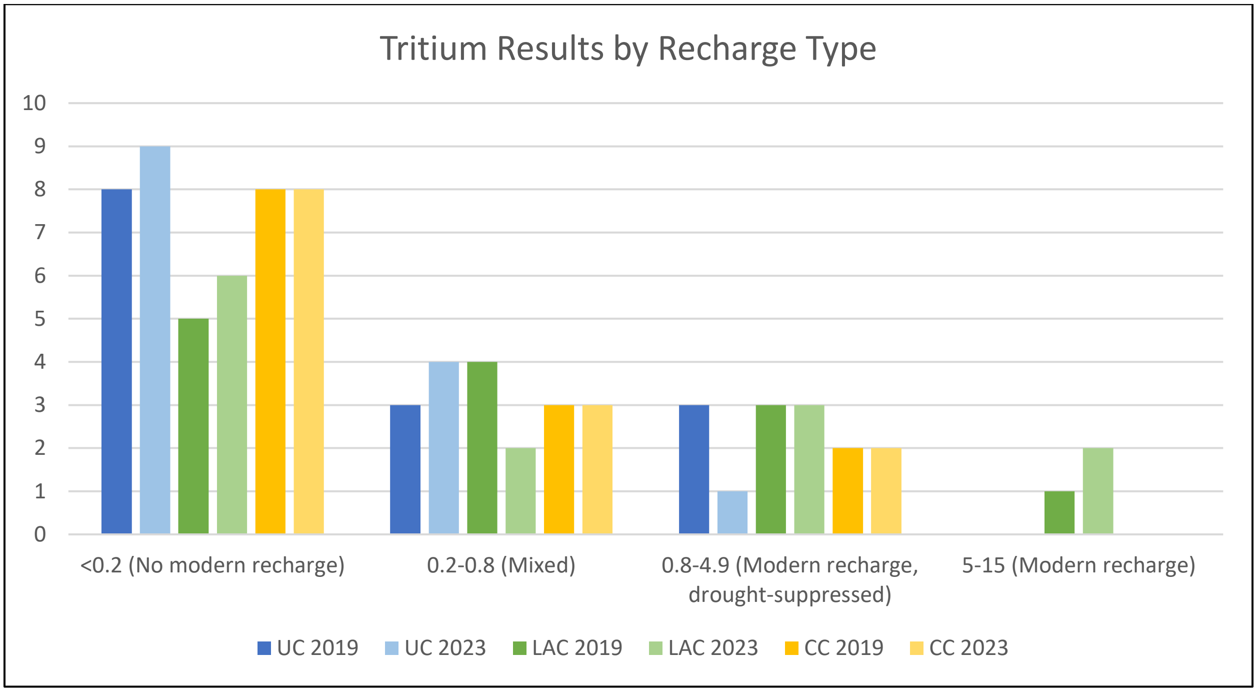


Figure 30. Tritium results by county and by sampling year, showing recharge types.

Table 2: Recharge potential by county. TU = tritium unit.

County	No modern recharge (<0.2 TUs)	Mixed waters (0.2-0.8 TUs)	Mixed or drought-suppressed (0.8-4.9 TUs)	Modern recharge (5-15 Tus)
2019 Sampling (N=40 samples)				
LAC	5	4	3	1
CC	7	3	3	0
UC	8	3	3	0
2023 Sampling				
LAC	6	2	3	2
CC	7	4	2	0
UC	9	4	1	0

When compared to hydrostratigraphic unit, deeper units such as the Ogallala and Morrison Formation tend to be associated with no realistic expectation of significant recharge (Figure 31, Table 3). Patterns remained effectively the same between the 2019 and 2023 sampling efforts, suggesting little change in potential recharge for any of the wells observed. This, in part, does reflect the continuation of over twenty years of drought in the region, along with geologic partitioning of aquifer units throughout the three counties. Shallow alluvial wells and gray shale wells had the highest proportions of tritium. For gray shale wells, several of these are shallow and adjacent to drainages where there is both a contribution from alluvial waters, as well as lateral fracture flow into the well bore. The only Dockum well sampled is a shallow well that has the ability to receive modern recharge.

Of interest is a shallow well in Union County with a static water level around 10 to 15 feet bgs that returned tritium results of 0.06 TUs in 2019 and 0.02 TUs in 2023. The well's total depth is approximately 200 feet bgs and the chemistry results indicate the well is sourcing water from the Morrison Formation. Thus, in spite of the very shallow water table, this well is not a shallow alluvial well as anticipated, but rather a Morrison well. This well is an excellent example of why multiple sources of data are necessary to truly understand the groundwater resource(s) utilized by any particular well.

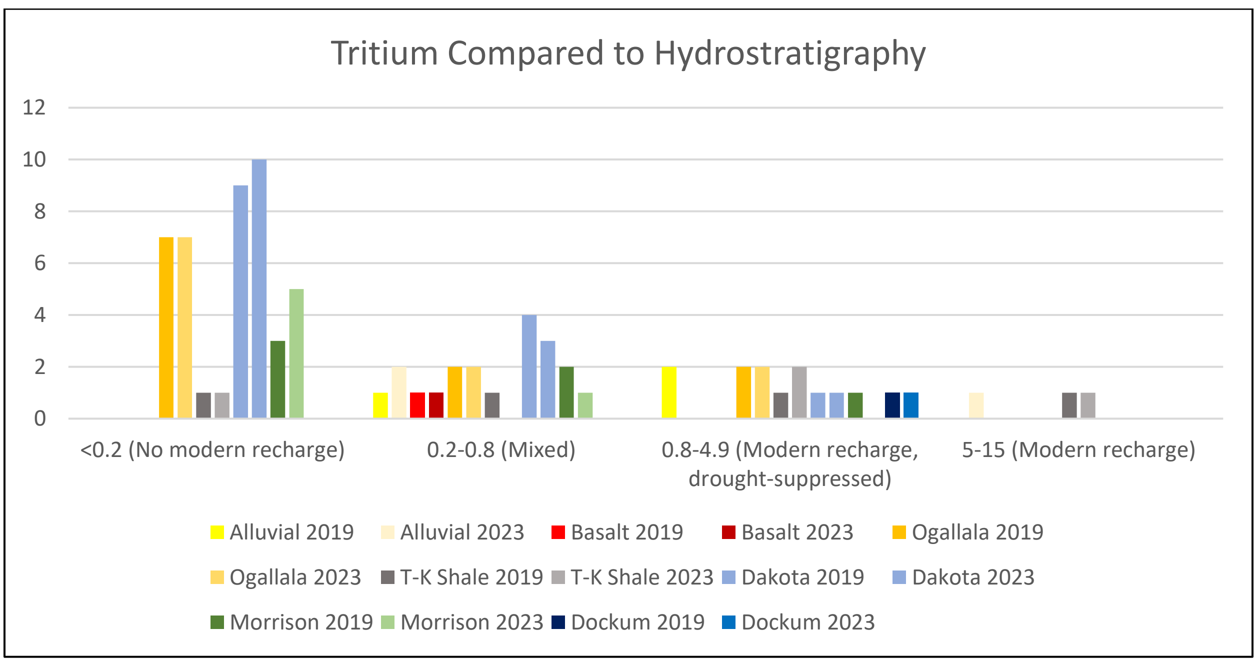


Figure 31. Recharge potential in relation to hydrostratigraphic unit.

Table 3: Recharge potential compared to hydrostratigraphic unit.

Aquifer Unit	No modern recharge (<0.2 TUs)	Mixed waters (0.2-0.8 TUs)	Mixed or drought-suppressed (0.8-4.9 TUs)	Modern recharge (5-15 Tus)
2019 Sampling				
Alluvial	0	1	2	0
Basalt	0	1	0	0
Ogallala	7	2	2	0
Shales	1	1	1	1
Dakota	9	4	1	0
Morrison	3	2	1	0
Dockum	0	0	1	0
2023 Sampling				
Alluvial	0	2	0	1
Basalt	0	1	0	0
Ogallala	7	2	2	0
Shales	1	0	2	1
Dakota	10	3	1	0
Morrison	5	1	0	0
Dockum	0	0	1	0

Results: Stakeholder Observations and Relationships

A core part of the ARID Project was the participatory aspect of engaging stakeholders in data collection, interpretation, and strategic decision-making as a result of having a group of scientists effectively embedded in the communities. As the groundwater monitoring component of the project began, the team spent time with each participant, discussing their observations related both to their own well(s) as well as the bigger picture of resource issues facing their communities. They also attended community meetings and workshops throughout the course of data collection to both listen to concerns and to share the progress of this component of the greater ARID Project. Some participants only had a single well that they relied on whereas others had multiple wells spread over larger areas. All participants expressed some degree of concern about the lifetime of aquifers in their area. Individuals who were near areas of center pivot irrigation but did not use irrigation wells had the highest concern over loss of groundwater and there were multiple anecdotes of wells in these areas going dry, caving in, or pulling up increased amounts of sand.

When discussing local geohydrology, many participants understand their resources as "underground streams" or "underground lakes" and felt that they were within or directly adjacent to the "Ogallala aquifer". Participants in all three counties were invited to participate in workshops where the geologic concept of an aquifer was discussed: any rock or thickness of deposits that is porous and permeable enough to provide useful quantities of water. In addition, hand-samples of the various rock types were used to demonstrate the actual media that groundwater resources come from in these areas. The "rock box" activity provided a means for participants to both understand that groundwater resources in the region are primarily hosted in solid rock and to conceptualize the differences in the rock units that lead to different well behavior. This also helped participants to recognize that the concept of an "underground lake" does not reflect the true nature of aquifer systems in the region.

The concept of aquifers as underground lakes or rivers is common and while not entirely accurate, the idea is also not entirely incorrect. For example, Morrison wells are completed in lenses of sandstone that represent (effectively) "fossil" river channels that meandered across the Jurassic landscape and now meander through the subscape. Thus, the observation of windmills and other wells tending to fall in line with each other is frequently reflecting wells completed in these ancient river channels. Broader and more laterally continuous units, such as the Dakota Sandstone, still have internal variability in thickness, porosity, and permeability that limit the groundwater resource geographically. And, the paleotopography on the tops of the Dockum Group and Morrison Formation, as well as the base of the Ogallala Formation, creates a complex subscape with groundwater resources being locally partitioned.

In addition, the groundwater team observed many participants communicating directly with one another about what they were learning about their wells and these communal dialogues proved fruitful for groups of producers to consider how to manage groundwater resources jointly where appropriate. State lines are still proving to be a significant barrier to communication with producers tending to communicate within the smaller geographic area. It is important to reiterate that geology and thus groundwater resources have no relationship to imposed geographic barriers such as county and state lines. Some aquifers are shared across county and state lines, whereas other aquifers are geologically partitioned and occur only in certain areas.

Western Las Animas County

In western Las Animas County, concern focused not only on loss of groundwater resources but in changes in water quality. Many of these wells have less than optimal water quality that is due to the hydrostratigraphy and is not caused by any anthropogenic contamination. In addition, increased use of groundwater resources and the resulting decline in volume of water in local aquifers has increased the potential for higher dissolved solid levels, including levels of sulfate where the hydrostratigraphy includes significant gypsum. Residence time of water is also an influence on poor water quality: two of the wells monitored are extremely deep, with total depths greater than 600 feet, resulting in high volumes of standing water in these wells, but poor water quality due to the length of time water has spent in association with a variety of minerals present throughout the rock column. One of these wells actively produces methane, which degasses as it travels through the plumbing of the well and has led to issues with pipes breaking as gas builds up in the system. Iron slime bacteria is also becoming increasingly problematic in many of these wells as there is a higher proportion of dissolved iron in many black shale wells. Changes in aquifer temperatures and subtle shifts in pH may be responsible for the growth of these bacterial colonies.

Eastern Las Animas County

In eastern Las Animas County, concern was focused entirely on loss of groundwater, either due to prolonged drought or proximity to CPI areas, especially for the easternmost participants. Water quality was only brought up as an issue for one well that had sickened people in the area on one occasion and was already known to be related to higher sulfate due to local geology. In addition, a subsidiary issue in this portion of Las Animas County is the probability of finding groundwater, as dozens of dry holes have been drilled through the area. The lack of sandstone bodies in the Morrison Formation is a major hindrance to finding water in this area, as the Dakota Sandstone is not as laterally continuous of an aquifer body here as it is in other areas. A regional westward tilt to the geology also means that older rock units, such as the Purgatoire, Morrison, and Dockum intersect the surface to the east. A site visit to a tributary canyon to the Purgatoire River revealed that the Exeter Sandstone, considered a reasonable target as an aquifer elsewhere, has had significant fracture fill with gypsum from the overlying Bell Ranch Formation, which both reduces porosity and permeability, but also lowers water quality significantly.

Union County

Groundwater monitoring has been an ongoing effort in Union County and was started in 2007 by the NESWCD with the ZGC team joining their efforts in late 2010 (Zeigler et al., 2019b). Thus, there was a significantly better understanding of local groundwater resources in Union County when compared to Las Animas and Cimarron Counties as this project began. Participants in the Union County portion of the effort were not participating in the ongoing project, but expressed concerns similar to those of eastern Las Animas and Cimarron Counties. Concerns expressed were two-fold: the impact of local centers of CPI and the devastating impacts of prolonged drought in the area. CPI is confined to discrete areas along the eastern border of Union County and at Gladstone. However, many producers were deeply concerned that CPI use could influence wells several miles away. The geologic complexities in this county (and the other two) effectively isolate the influence of CPI to the Ogallala paleovalleys and to a very limited margin of hydraulically connected wells along the margins of the paleovalleys. Union County producers have already been taking measures to protect and prolong their groundwater resources since their monitoring project has been ongoing for some time. There is significant ear-to-ear communication among producers and within local communities such that the information gained in the ARID Project merely reinforced the local communal knowledge built by the NESWCD's monitoring project.

Conclusions and Recommendations

The ARID Project as a whole has been an invaluable effort both for an opportunity to broaden our understanding of groundwater resources across these three counties, but also as a means to engage with local stakeholders and communities to become strategic in protecting this most important resource. The ability to integrate into these communities and work alongside our producers has led to a two-way sharing of knowledge that will benefit these counties and their agroecosystems.

The wells monitored in these counties for the project draw water from a wide array of hydrostratigraphic units that range from unconfined alluvial aquifers to bedrock units that are locally high volume and good quality (Ogallala Formation) to low volume and poor quality (shale wells). The geologic subscape is quite complex beneath these counties, such that most of the wells observed here are effectively isolated from one another and can be treated as "each to their own bathtub" in terms of managing groundwater resources. However, communal decision-making would be of significant benefit to producers and communities that are using groundwater resource from the Ogallala Formation paleovalleys, especially for CPI. These wells are not only declining in their own right, but can locally have significant and severe impact on adjacent wells completed in hydraulically connected units, such as the Dakota Sandstone, that are of lower porosity and permeability than the neighboring Ogallala Formation.

For the majority of the bedrock hydrostratigraphic units, there is not significant modern recharge entering these aquifers to replace the water withdrawn, leading to permanent declines in water tables, regardless of aquifer unit. The prolonged drought and localization of summer precipitation ("laser rains") have put extreme stress on all groundwater resources in the area. Shallow alluvial resources are not receiving recharge and deeper aquifer units, which are unlikely to recharge due to depth to the water table and geologic barriers to deeper infiltration, are now more heavily relied on as surface water resources (including stock ponds) fail with the continued drought. A lack of recharge also means aquifers capable of receiving recharge are not flushed with new waters and water quality concerns will continue to grow. The targeting of deeper aquifer units (such as Permian strata) comes with an entirely new set of challenges, including potentially prohibitively high costs of drilling and installing pump-related infrastructure. In addition, deeper waters frequently have such long residence times that the water quality is extremely poor, to the point of requiring expensive filtration systems to bring salt levels down to potable standards (even for livestock). In the face of these continued challenges, it is critical to continue monitoring of groundwater resources in this region to provide data to support the resiliency of agricultural producers and rural communities.

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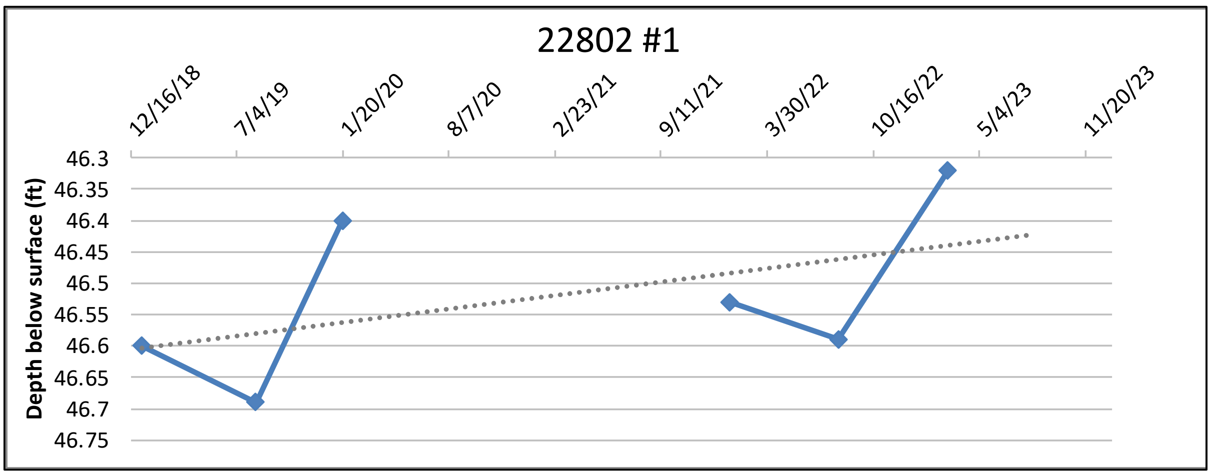
Appendix I: Static Water Level Data

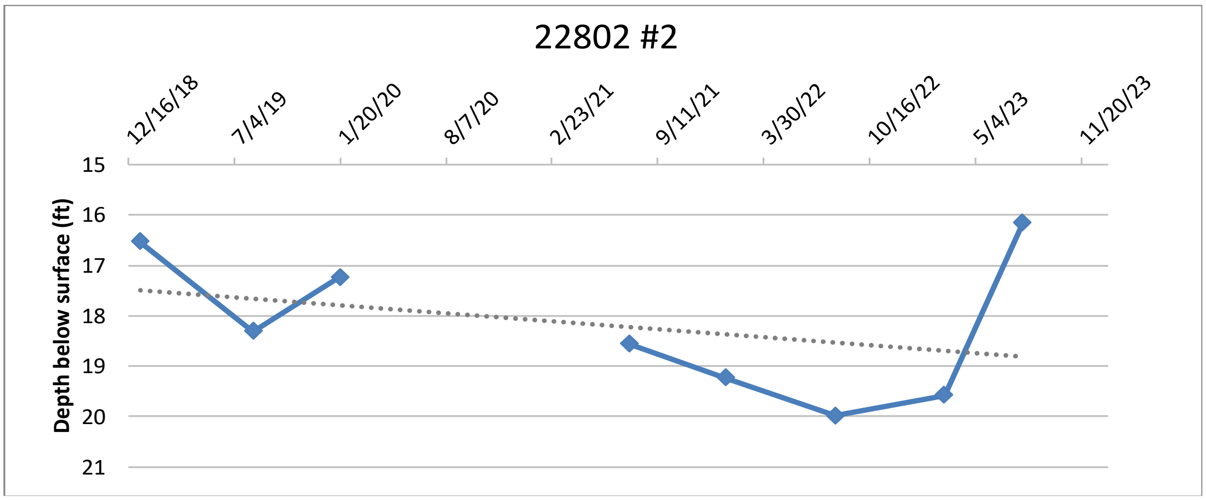
Data tables and hydrographs depicting depth to water measurements for wells in the ARID Project. DTW = Depth to Water, TD = Total Depth, Notes(*): NS = Not successful, NM = Not Measured, AVG = Measurements averaged.

Union County Well Data

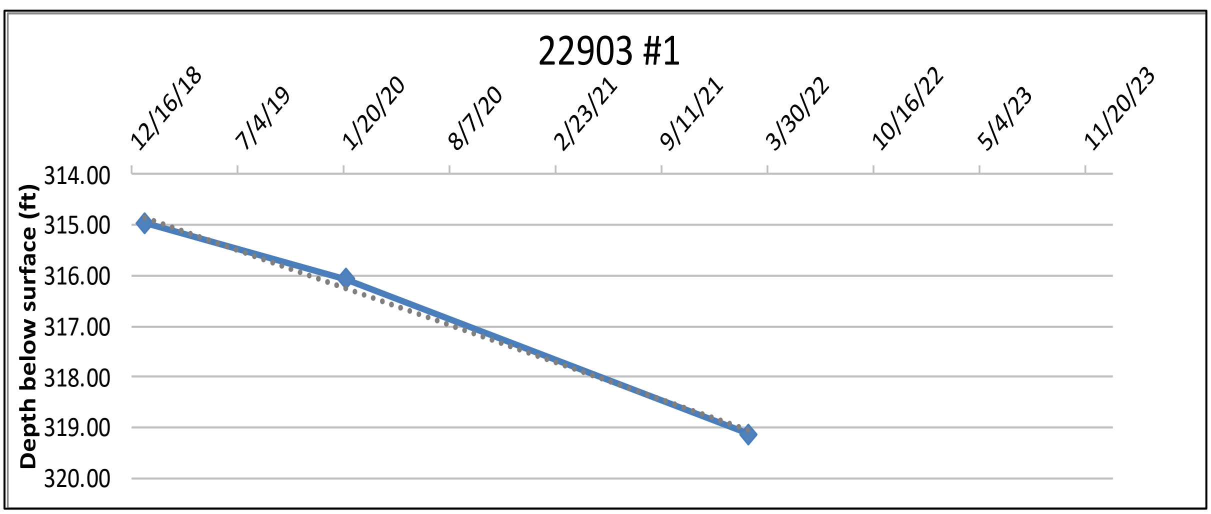
Well ID	TD	Date	DTW	Notes*
22802 #1	~53’	1/7/2019	46.6	
		8/9/2019	46.69	
		1/20/2020	46.4	
		7/21/2021		NM
		1/18/2022	46.53	AVG
		8/12/2022	46.59	
		3/7/2023	46.32	
		8/2/2023		NM



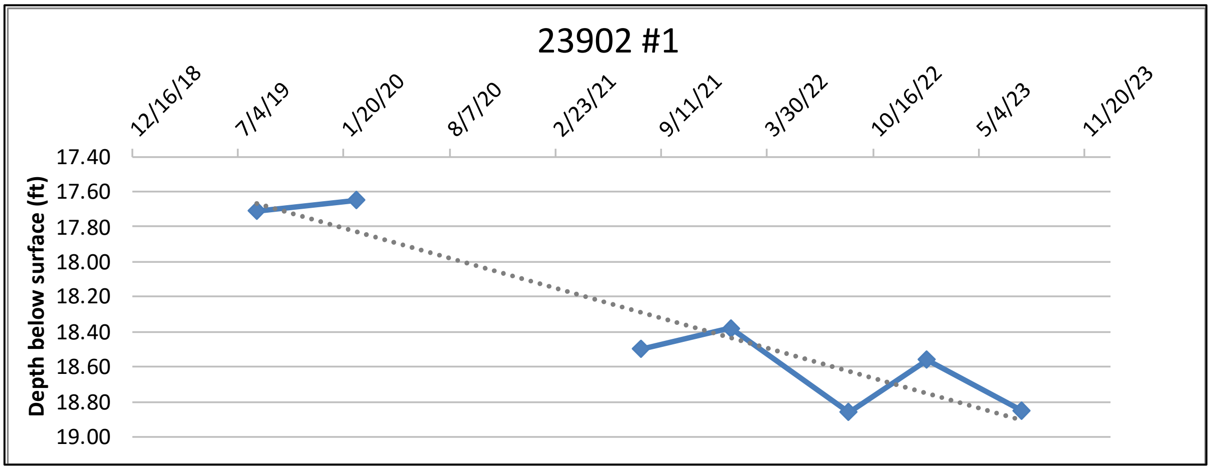
Well ID	TD	Date	DTW	Notes*
22802 #2	~53’	1/7/2019	46.6	
		8/9/2019	46.69	
		1/20/2020	46.4	
		7/21/2021		NM
		1/18/2022	46.53	AVG
		8/12/2022	46.59	
		3/7/2023	46.32	
		8/2/2023		NM



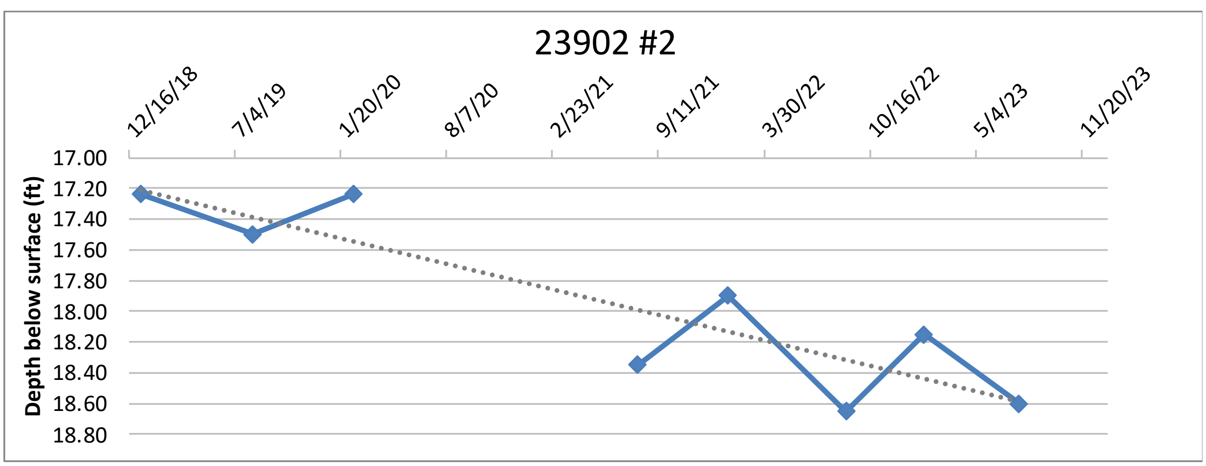
Well ID	TD	Date	DTW	Notes*
22903 #1	~382’	1/8/2019	314.96	
		1/23/2020	316.07	
		2/22/2022	319.12	



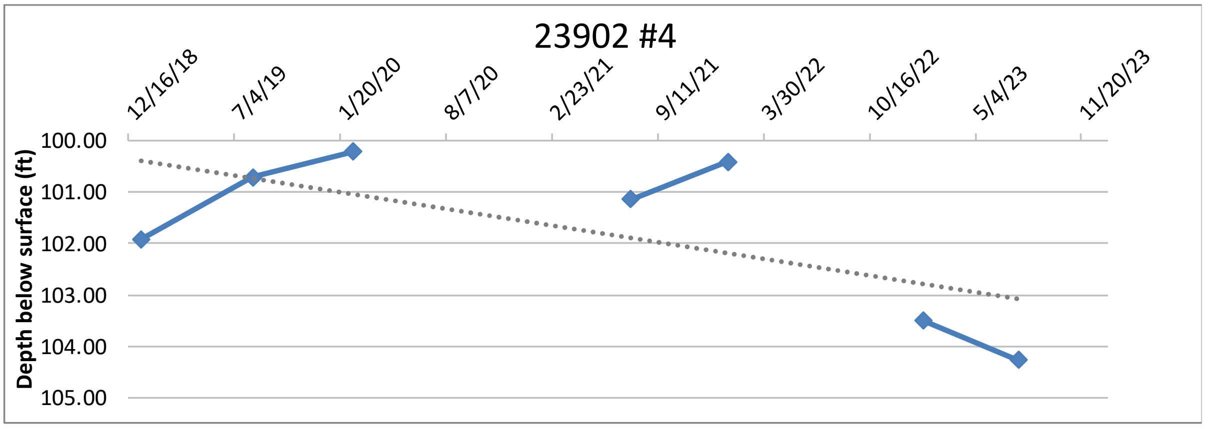
Well ID	TD	Date	DTW	Notes*
23902 #1	~60'	8/8/2019	17.71	
		2/13/2020	17.65	
		8/3/2021	18.50	
		1/21/2022	18.38	
		9/1/2022	18.86	
		1/26/2023	18.56	
		7/24/2023	18.85	



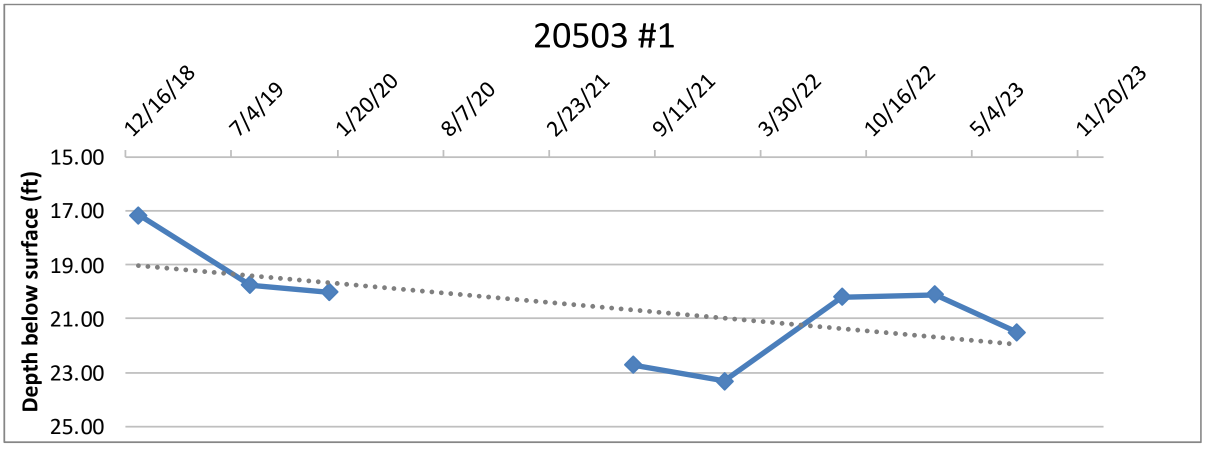
Well ID	TD	Date	DTW	Notes*
23902 #2	~51'	1/9/2019	17.24	AVG
		8/8/2019	17.50	
		2/13/2020	17.24	
		8/3/2021	18.35	
		1/21/2022	17.90	
		9/1/2022	18.65	
		1/26/2023	18.15	
		7/24/2023	18.60	



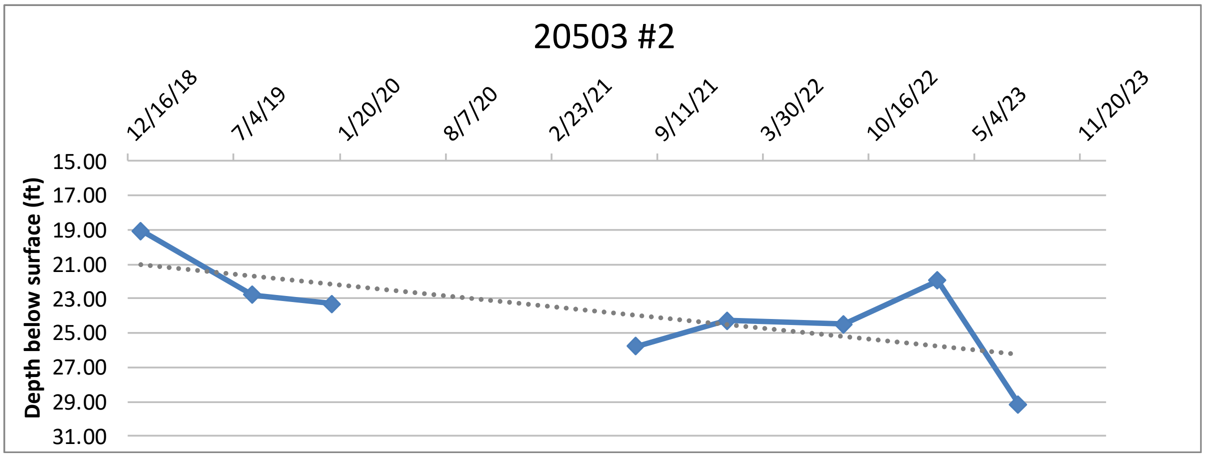
Well ID	TD	Date	DTW	Notes*
23902 #4	~188'	1/9/2019	101.91	Still rising
		8/8/2019	100.71	
		2/13/2020	100.21	
		7/22/2021	101.14	
		1/21/2022	100.41	
		9/1/2022		NM
		1/26/2023	103.50	
		7/24/2023	104.27	



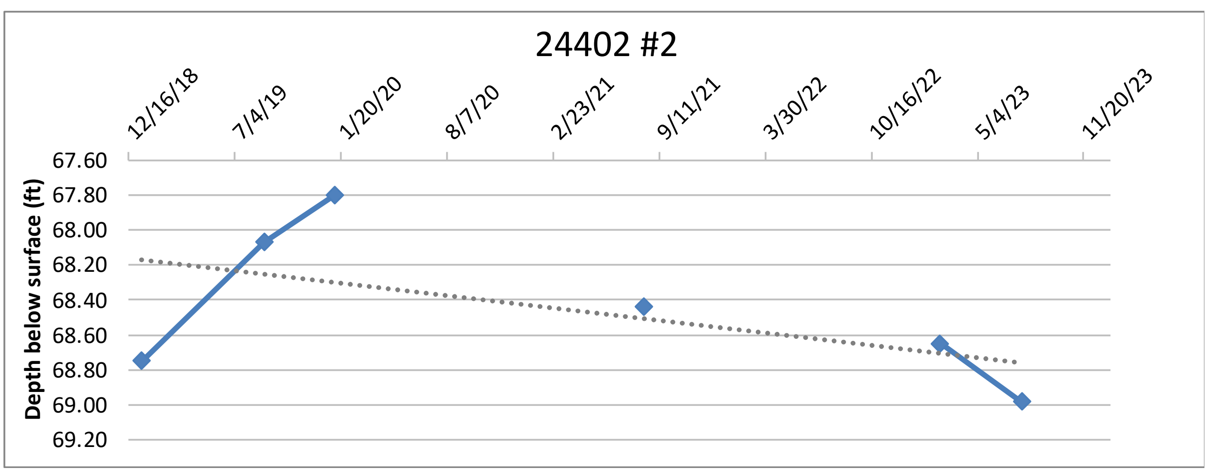
Well ID	TD	Date	DTW	Notes*
20503 #1	~156'	1/9/2019	17.16	
		8/8/2019	19.75	
		1/6/2020	20.01	
		8/3/2021	22.72	
		1/21/2022	23.32	
		8/31/2022	20.19	
		2/24/2023	20.10	
		1/9/2019	17.16	



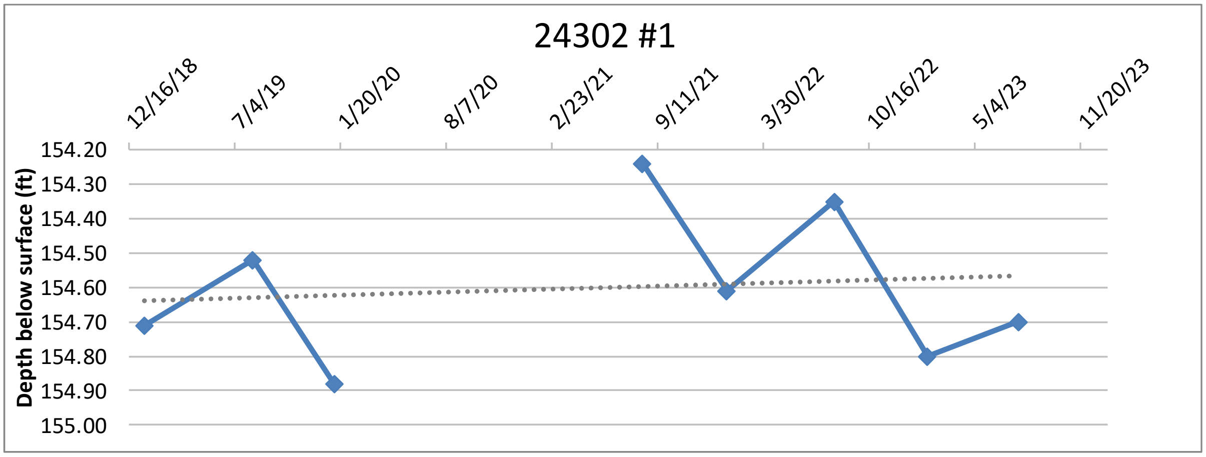
Well ID	TD	Date	DTW	Notes*
20503 #2	~45'	1/9/2019	19.07	
		8/8/2019	22.77	
		1/6/2020	23.29	
		8/3/2021	25.79	
		1/21/2022	24.29	
		8/31/2022	24.50	
		2/24/2023	21.94	
		7/27/2023	29.14	



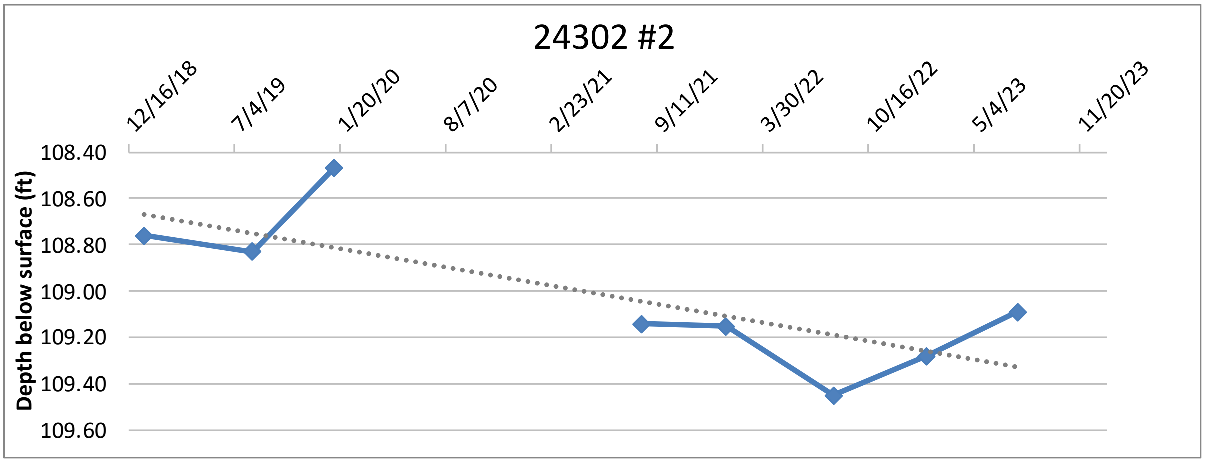
Well ID	TD	Date	DTW	Notes*
24402 #2	~96'	1/9/2019	68.75	
		8/28/2019	68.07	
		1/9/2020	67.80	
		8/12/2021	68.44	
		2/23/2022		NM
		9/1/2022		NM
		2/22/2023	68.65	AVG
		7/27/2023	68.98	



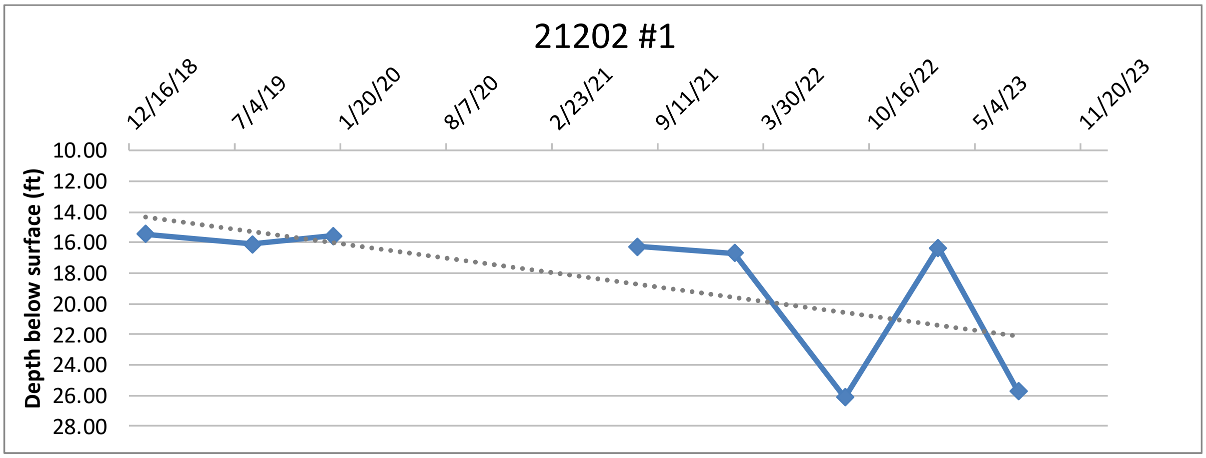
Well ID	TD	Date	DTW	Notes*
24302 #1	~250'	1/16/2019	154.71	
		8/8/2019	154.52	
		1/9/2020	154.88	
		8/13/2021	154.24	
		1/20/2022	154.61	
		8/11/2022	154.35	
		2/3/2023	154.80	
		7/25/2023	154.7	



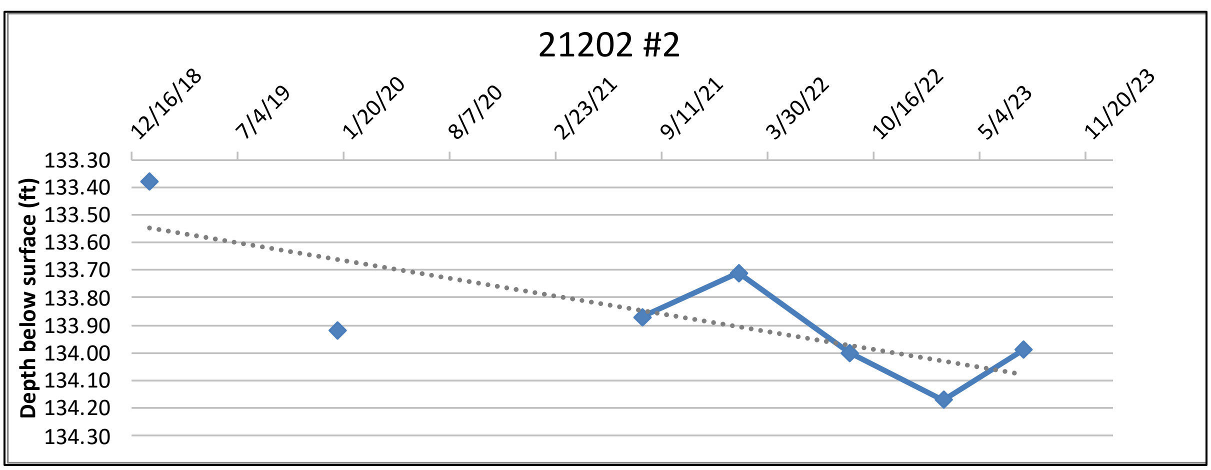
Well ID	TD	Date	DTW	Notes*
24302 #2	~122'	1/16/2019	108.76	
		8/8/2019	108.83	AVG
		1/9/2020	108.47	
		8/13/2021	109.14	
		1/20/2022	109.15	
		8/11/2022	109.45	
		2/3/2023	109.28	
		7/25/2023	109.09	



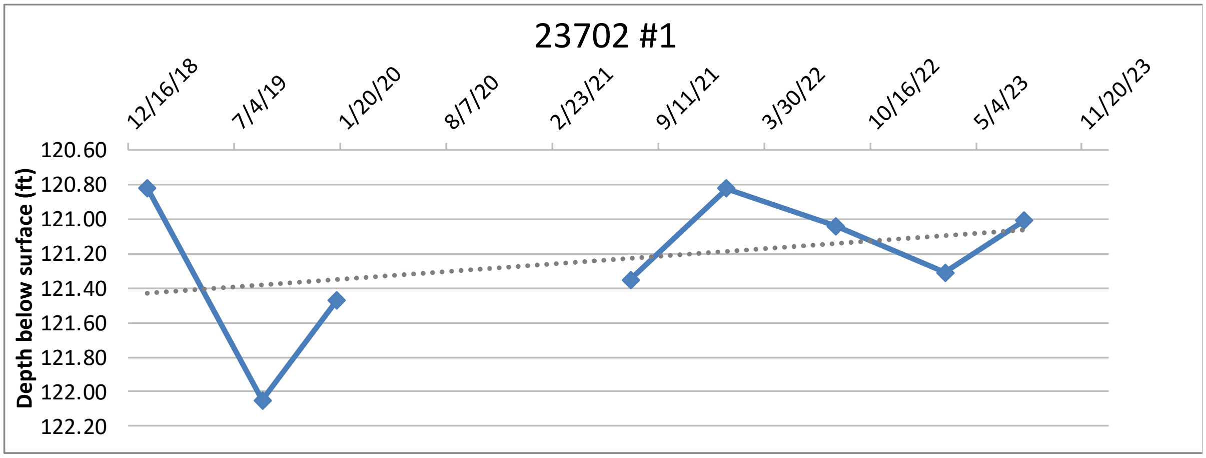
Well ID	TD	Date	DTW	Notes*
21202 #1	~200'	1/18/2019	15.45	
		8/7/2019	16.12	
		1/7/2020	15.56	
		8/5/2021	16.26	
		2/3/2022	16.69	
		8/31/2022	26.12	
		2/24/2023	16.34	
		7/25/2023	25.75	



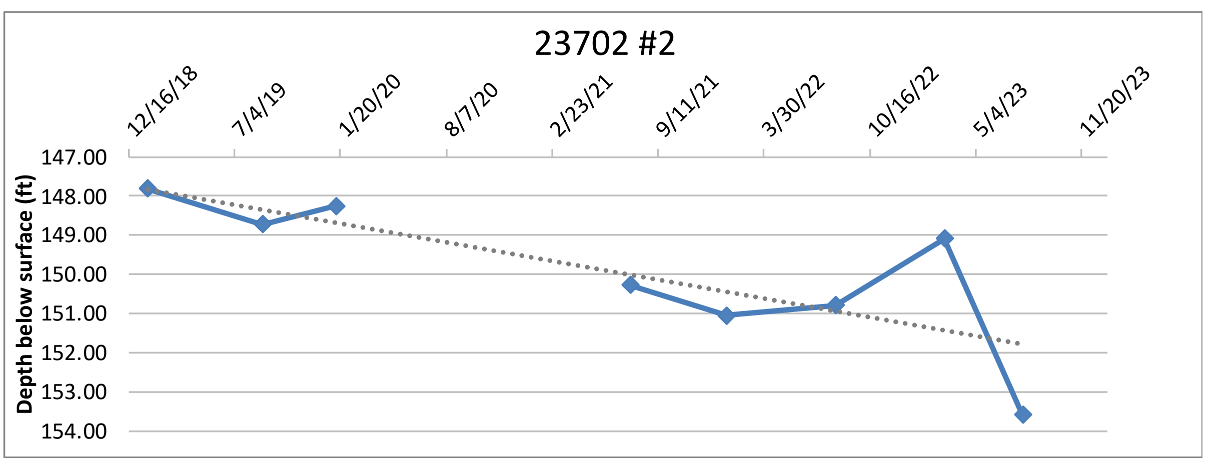
Well ID	TD	Date	DTW	Notes*
21202 #2	~165'	1/18/2019	133.38	
		8/7/2019		NM
		1/7/2020	133.92	
		8/5/2021	133.87	
		2/3/2022	133.71	
		8/31/2022	134.00	
		2/24/2023	134.17	
		7/25/2023	133.99	



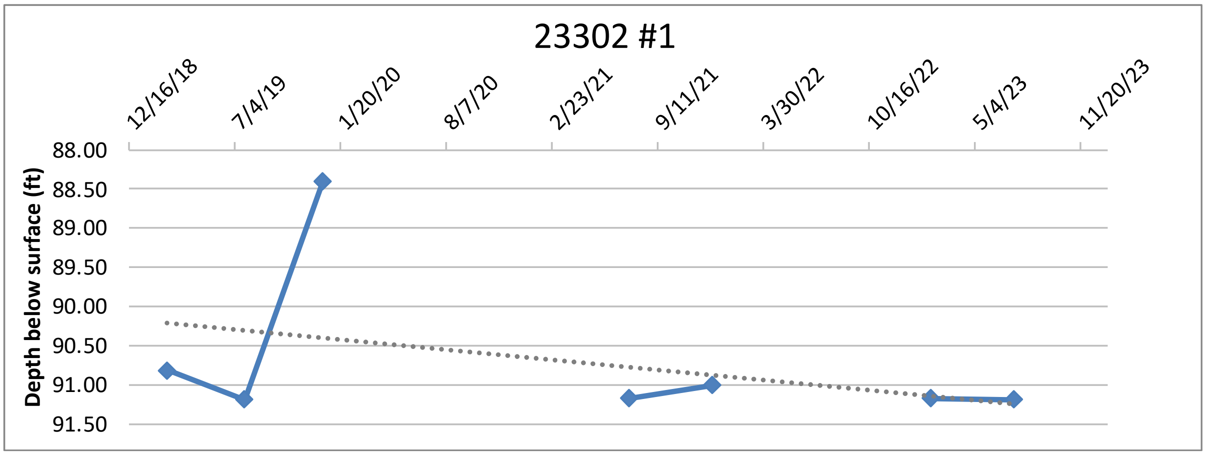
Well ID	TD	Date	DTW	Notes*
23702 #1	~135'	1/21/2019	120.82	AVG
		8/26/2019	122.05	
		1/13/2020	121.47	
		7/21/2021	121.35	
		1/18/2022	120.82	
		8/12/2022	121.04	
		3/7/2023	121.31	AVG
		8/2/2023	121.01	



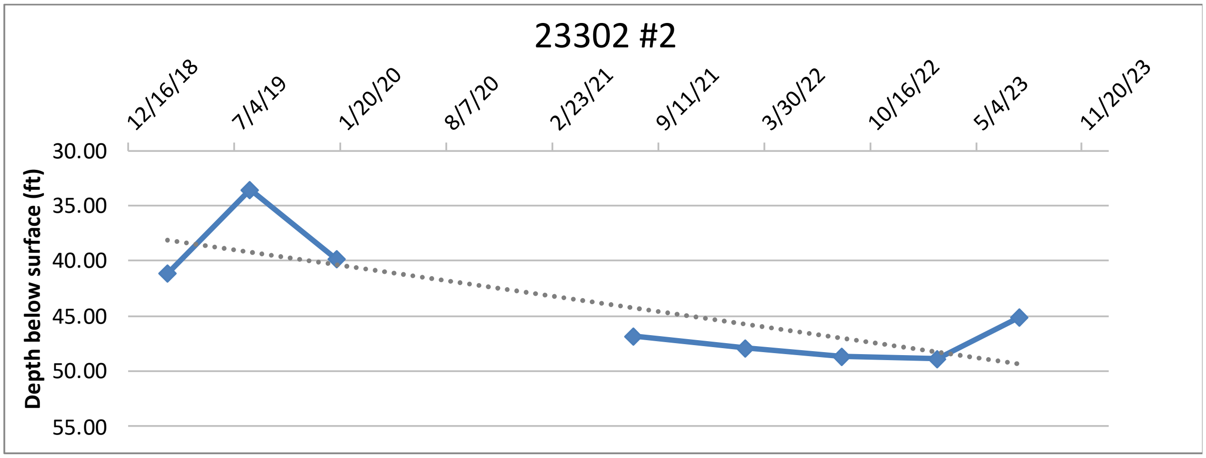
Well ID	TD	Date	DTW	Notes*
23702 #2	~497'	1/21/2019	147.81	
		8/26/2019	148.73	
		1/13/2020	148.25	
		7/21/2021	150.28	
		1/18/2022	151.06	
		8/12/2022	150.79	
		3/7/2023	149.09	
		8/2/2023	153.6	



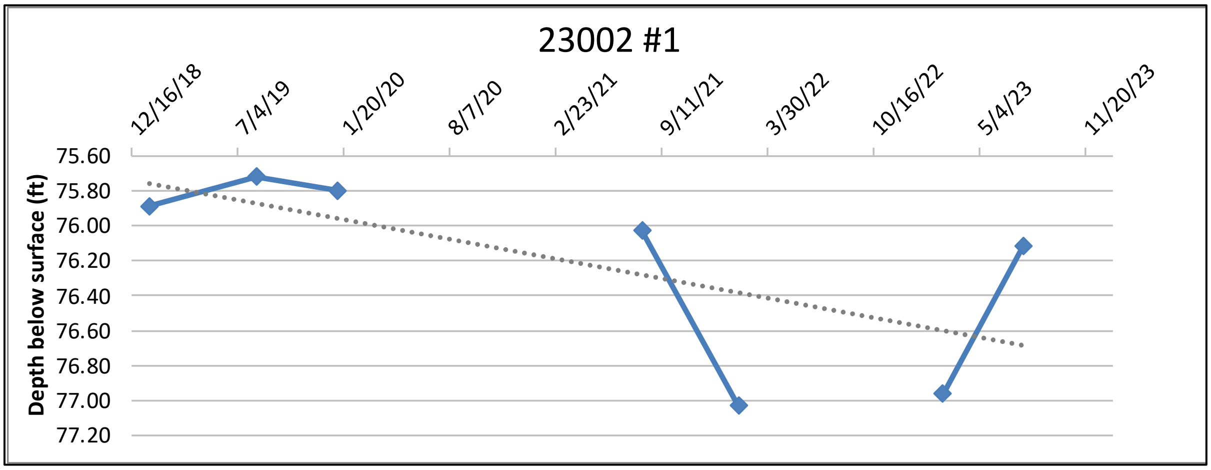
Well ID	TD	Date	DTW	Notes*
23302 #1	~120'	2/27/2019	90.82	
		7/23/2019	91.19	
		12/18/2019	88.40	
		7/19/2021	91.18	
		12/23/2021	91.01	
		8/23/2022		NS
		2/10/2023	91.18	
		7/17/2023	91.19	



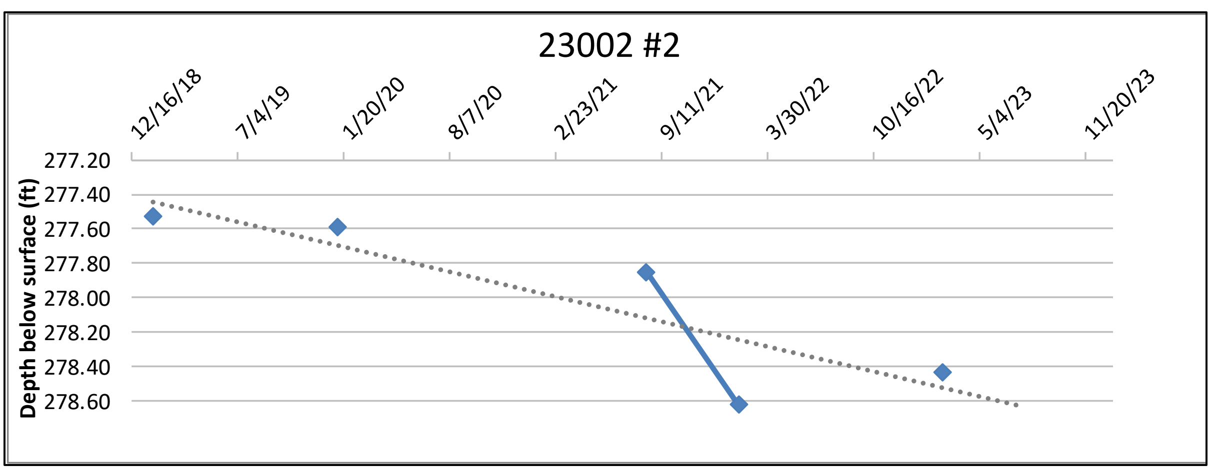
Well ID	TD	Date	DTW	Notes*
23302 #2	~70'	2/27/2019	41.20	
		8/2/2019	33.58	
		1/13/2020	39.87	
		7/26/2021	46.85	
		2/23/2022	47.93	
		8/23/2022	48.66	
		2/20/2023	48.88	
		7/26/2023	45.14	



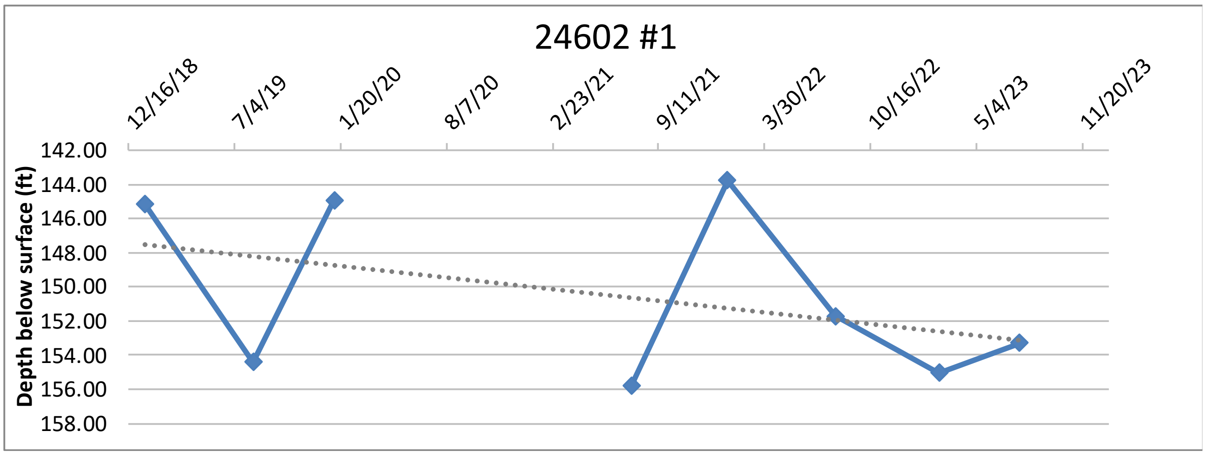
Well ID	TD	Date	DTW	Notes*
23002 #1	N/A	1/18/2019	75.89	
		8/7/2019	75.72	
		1/7/2020	75.80	
		8/5/2021	76.03	
		2/3/2022	77.03	
		8/31/2022		NM
		2/23/2023	76.96	
		7/25/2023	76.12	



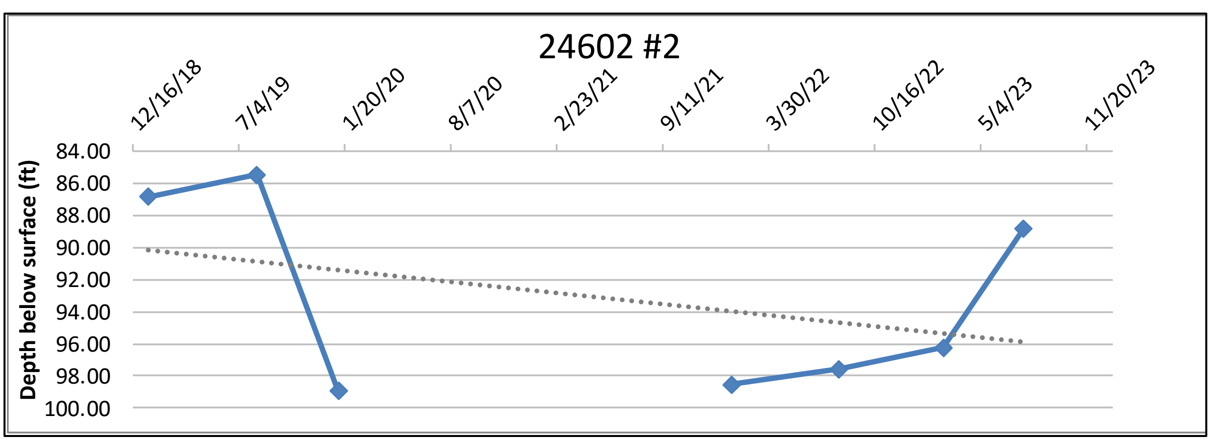
Well ID	TD	Date	DTW	Notes*
23002 #2	~388'	1/25/2019	277.53	
		8/7/2019		NS
		1/7/2020	277.59	
		8/12/2021	277.85	
		2/3/2022	278.62	AVG
		8/31/2022		NM
		2/23/2023	278.43	
		7/25/2023		NM



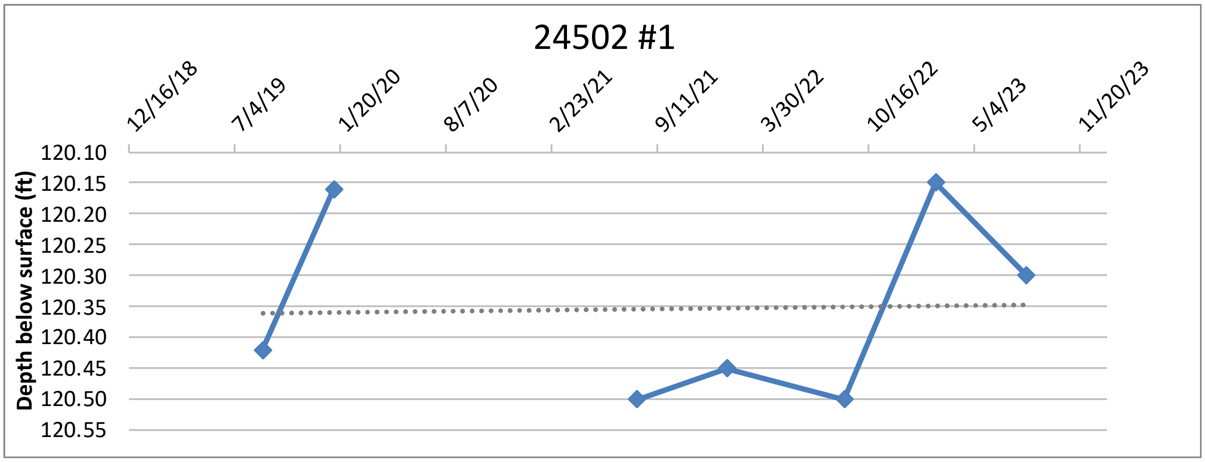
Well ID	TD	Date	DTW	Notes*
24602 #1	~171’	1/15/2019	145.13	
		8/8/2019	154.42	
		1/9/2020	144.92	
		7/22/2021	155.80	
		1/20/2022	143.78	
		8/11/2022	151.71	
		2/23/2023	155.02	
		7/25/2023	153.3	



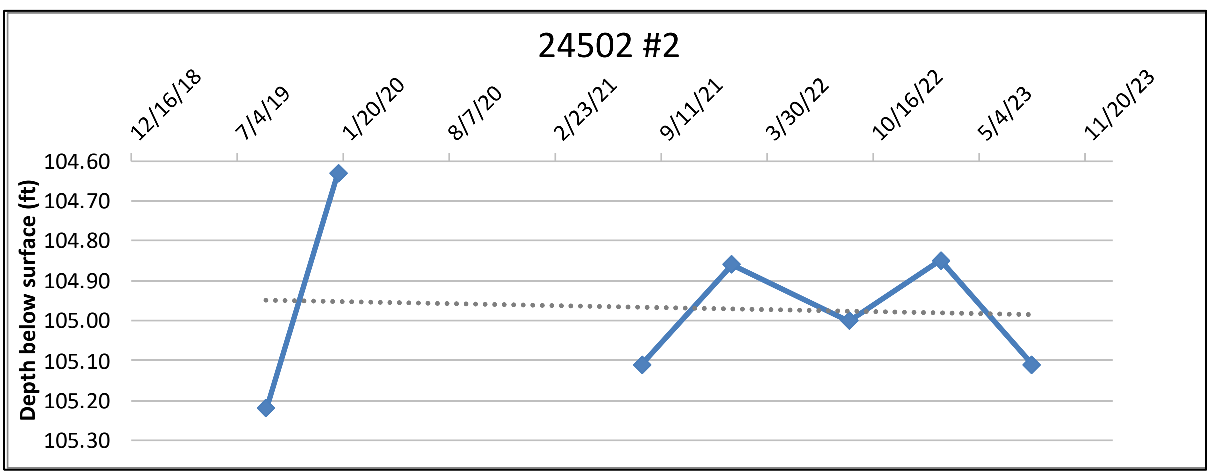
Well ID	TD	Date	DTW	Notes*
24602 #2	~175’	1/15/2019	86.85	AVG
		8/8/2019	85.46	AVG
		1/9/2020	98.93	AVG
		7/22/2021		NS
		1/20/2022	98.53	AVG
		8/11/2022	97.57	AVG
		2/23/2023	96.24	AVG
		7/25/2023	88.82	AVG



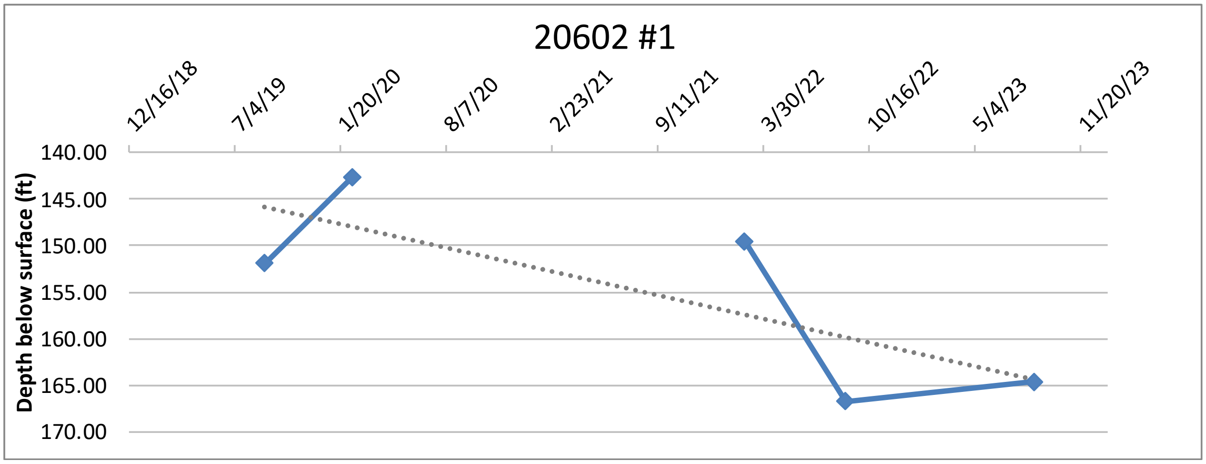
Well ID	TD	Date	DTW	Notes*
24502 #1	~205'	8/27/2019	120.42	
		1/9/2020	120.16	
		8/5/2021	120.50	
		1/21/2022	120.45	
		8/31/2022	120.50	
		2/20/2023	120.15	
		8/11/2023	120.30	



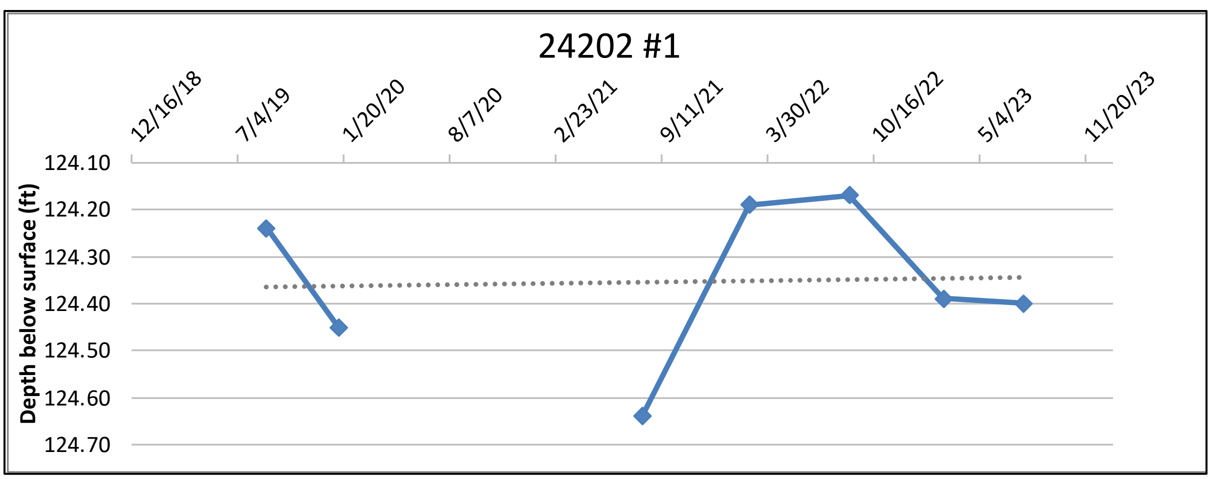
Well ID	TD	Date	DTW	Notes*
24502 #2	~154'	8/27/2019	105.22	
		1/9/2020	104.63	
		8/5/2021	105.11	
		1/21/2022	104.86	
		8/31/2022	105.00	
		2/20/2023	104.85	
		8/11/2023	105.11	



Well ID	TD	Date	DTW	Notes*
20602 #1	~270'	8/30/2019	151.86	AVG
		2/13/2020	142.61	AVG
		2/23/2022	149.53	AVG
		9/1/2022	166.72	AVG

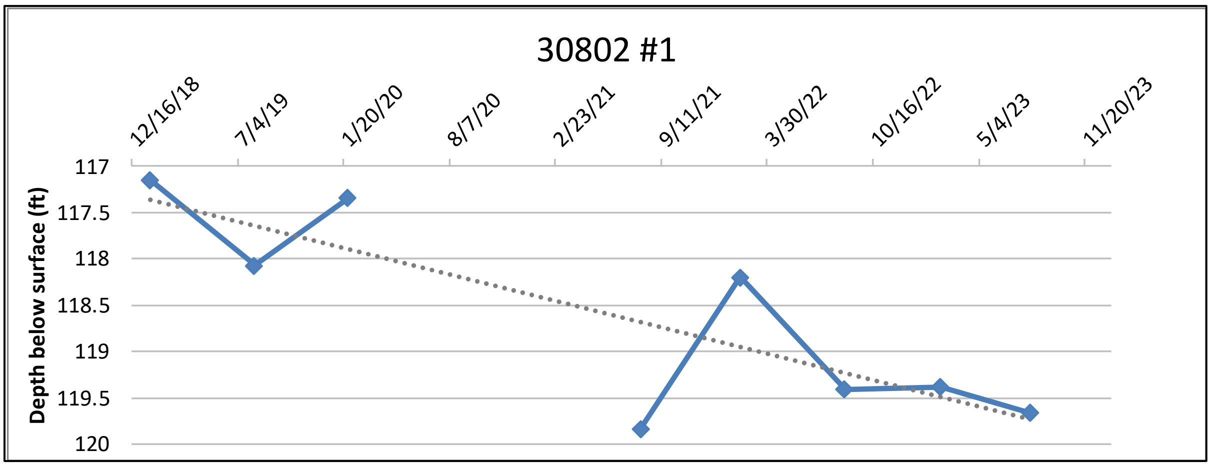


Well ID	TD	Date	DTW	Notes*
24202 #1	N/A	8/27/2019	124.24	
		1/9/2020	124.45	
		8/5/2021	124.64	
		2/23/2022	124.19	AVG
		8/31/2022	124.17	
		2/24/2023	124.39	
		7/25/2023	124.40	

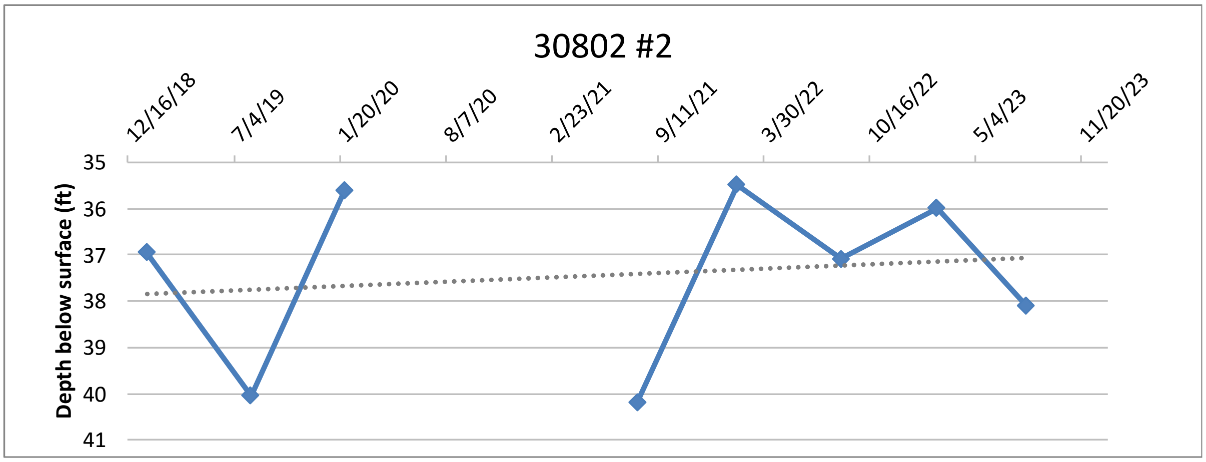


Las Animas County Well Data

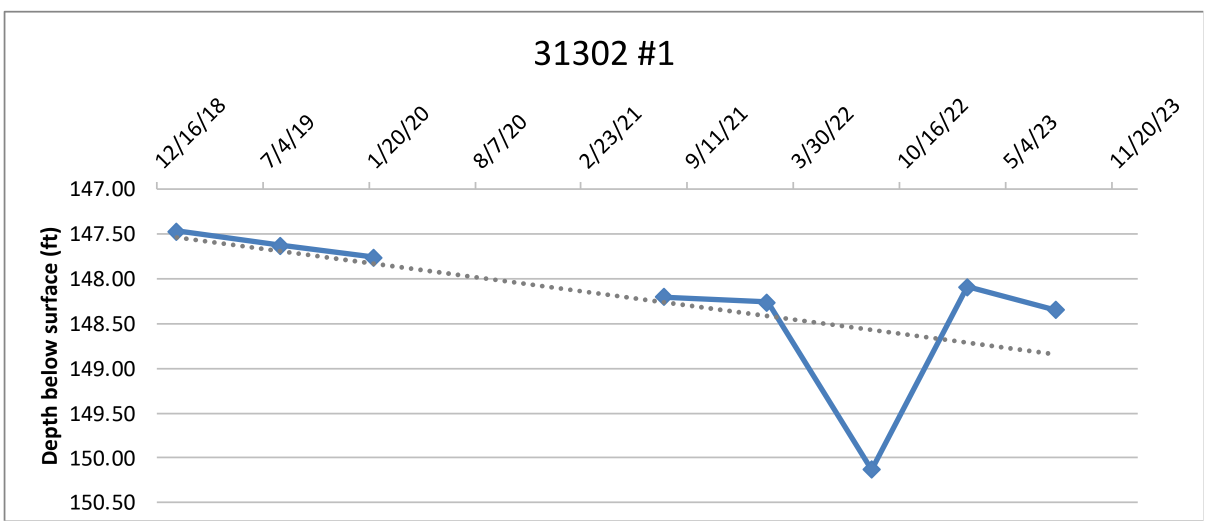
Well ID	TD	Date	DTW	Notes*
30802 #1	165’	1/21/19	117.15	
		8/5/19	118.07	
		1/29/20	117.34	
		8/4/21	119.83	
		2/8/22	118.2	
		8/24/22	119.41	
		2/21/23	119.38	
		8/9/23	119.66	



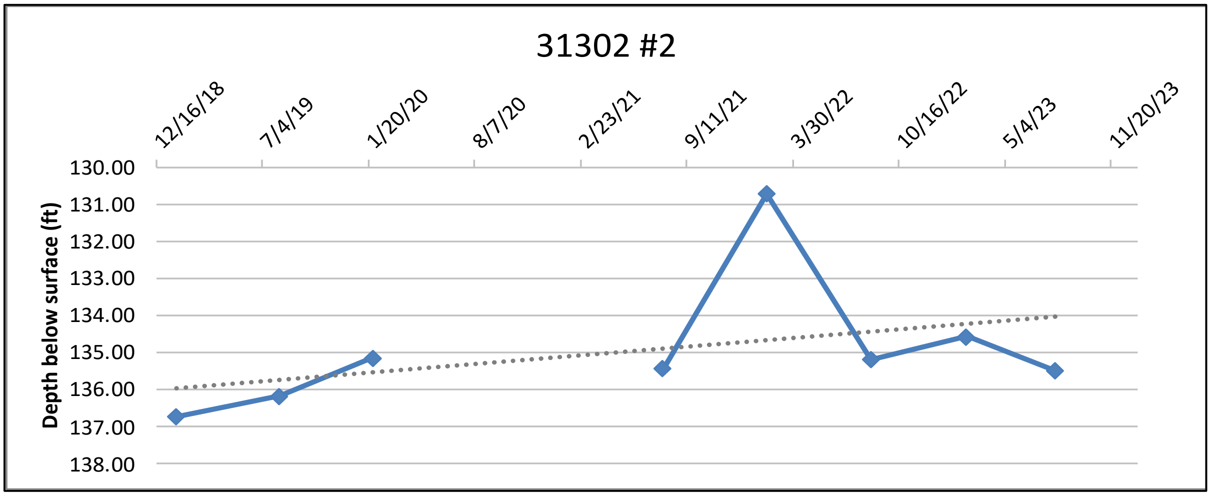
Well ID	TD	Date	DTW	Notes*
30802 #2	75’	1/21/19	36.95	
		8/5/19	40.04	
		1/29/20	35.61	
		8/4/21	40.18	
		2/8/22	35.49	
		8/24/22	37.08	
		2/21/23	35.99	
		8/9/23	38.1	



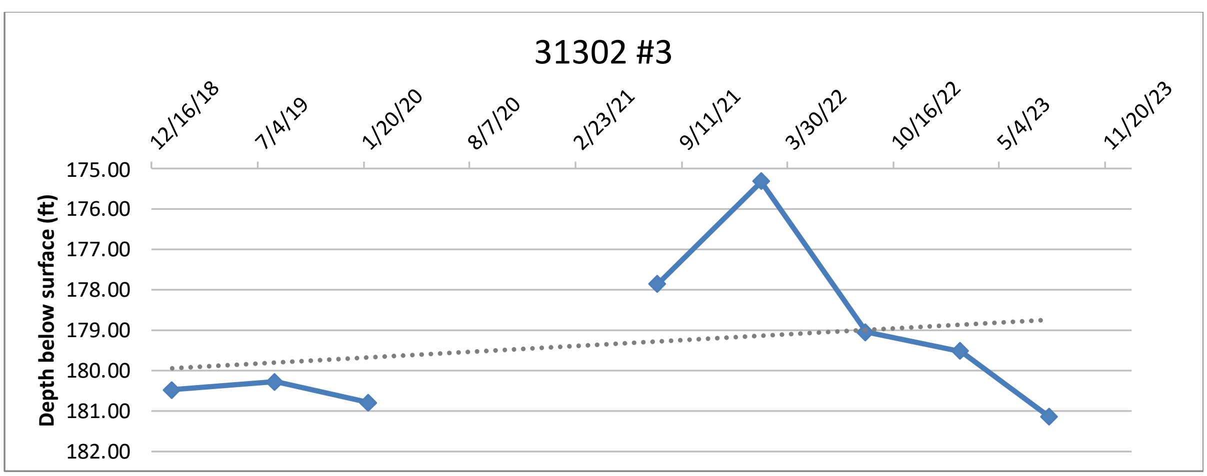
Well ID	TD	Date	DTW	Notes*
31302 #1	~168’	1/23/19	147.47	AVG
		8/6/19	147.63	AVG
		1/29/20	147.76	
		7/29/21	148.20	
		2/9/22	148.26	
		8/25/22	150.13	AVG
		2/21/23	148.09	
		8/8/23	148.35	



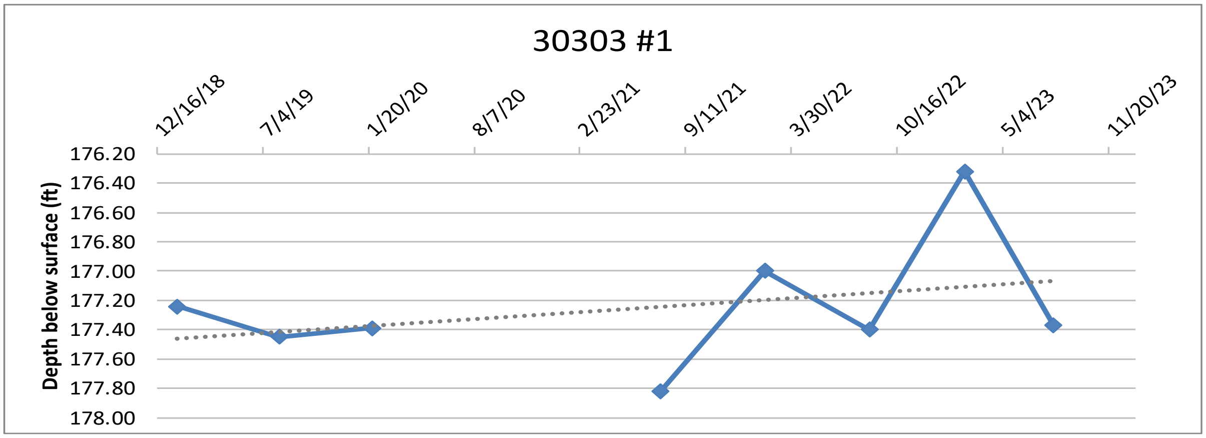
Well ID	TD	Date	DTW	Notes*
31302 #2	~168'	1/23/19	136.72	
		8/6/19	136.16	
		1/29/20	135.14	
		7/29/21	135.42	
		2/9/22	130.71	AVG
		8/25/22	135.18	AVG
		2/21/23	134.57	
		8/8/23	135.48	



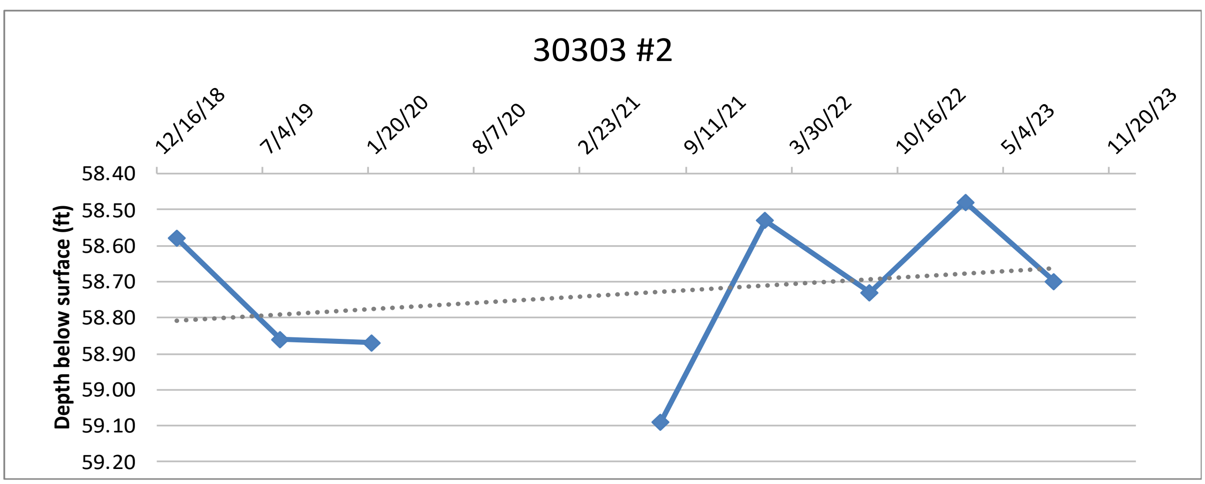
Well ID	TD	Date	DTW	Notes*
31302 #3	~188'	1/23/19	180.48	
		8/6/19	180.28	
		1/29/20	180.79	
		7/29/21	177.84	
		2/9/22	175.32	
		8/25/22	179.05	
		2/21/23	179.52	
		8/8/23	181.16	



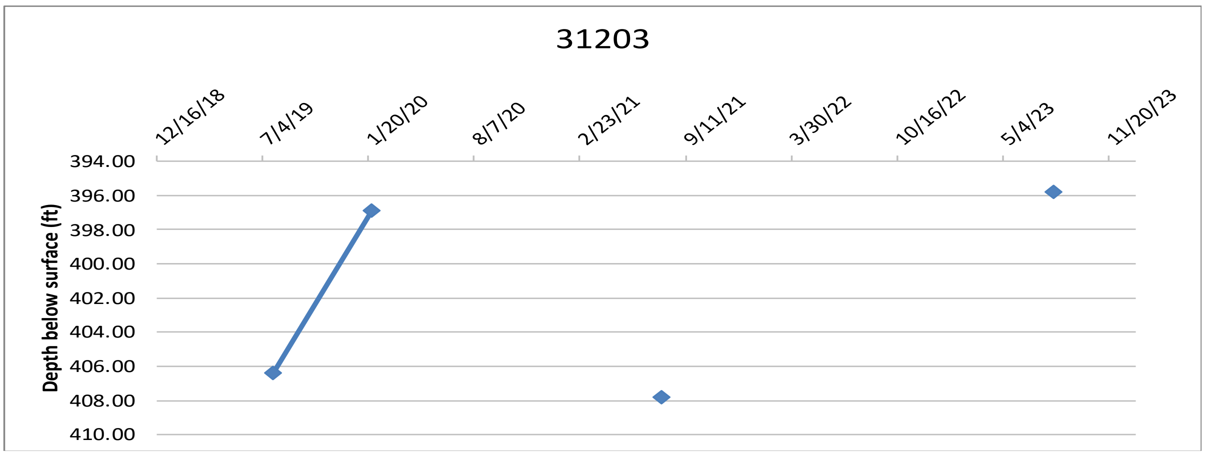
Well ID	TD	Date	DTW	Notes*
30303 #1	200’	1/24/19	177.24	
		8/5/19	177.45	
		1/27/20	177.39	
		7/26/21	177.82	
		2/8/22	177.00	
		8/25/22	177.40	
		2/21/23	176.32	
		8/8/23	177.37	



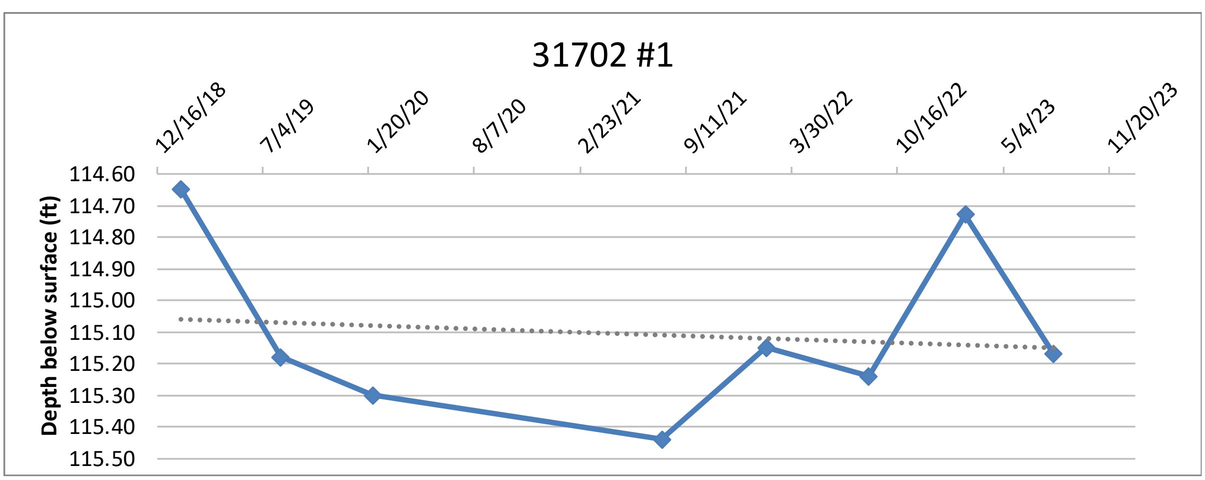
Well ID	TD	Date	DTW	Notes*
30303 #2	175’	1/24/19	58.58	
		8/7/19	58.86	
		1/27/20	58.87	
		7/26/21	59.09	
		2/8/22	58.53	
		8/25/22	58.73	
		2/21/23	58.48	
		8/8/23	58.7	



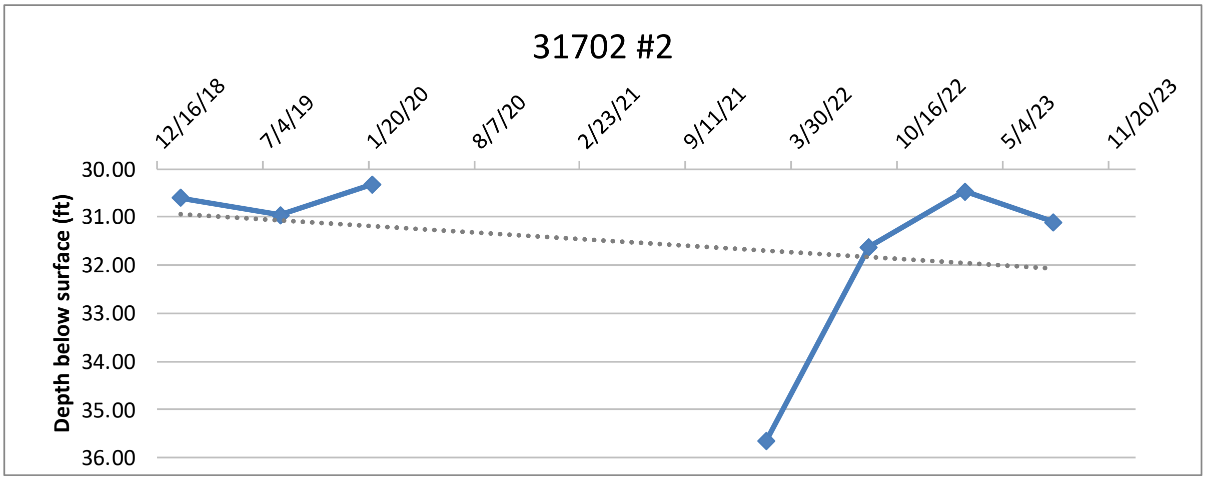
Well ID	TD	Date	DTW	Notes*
31203	1350’	1/24/19		NS
		7/25/19	406.36	Avg
		1/27/20	396.87	Avg
		7/27/21	407.82	
		2/8/22		NS
		8/16/22		NS
		2/22/23		NS
		8/7/23	395.81	



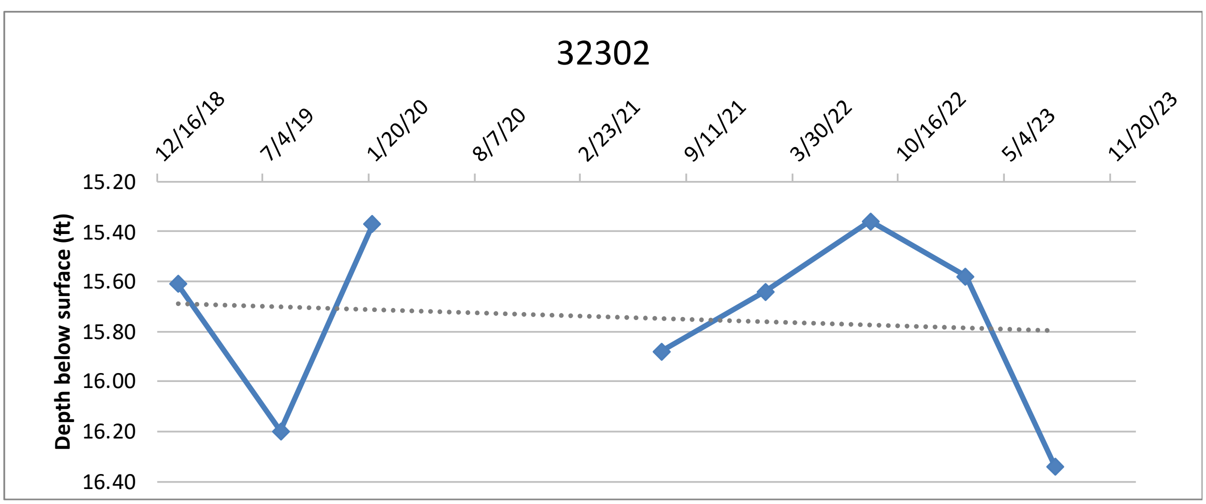
Well ID	TD	Date	DTW	Notes*
31702 #1	~250’	1/31/19	114.65	
		8/7/19	115.18	
		1/28/20	115.30	
		7/28/21	115.44	
		2/10/22	115.15	
		8/23/22	115.24	
		2/21/23	114.73	
		8/8/23	115.17	



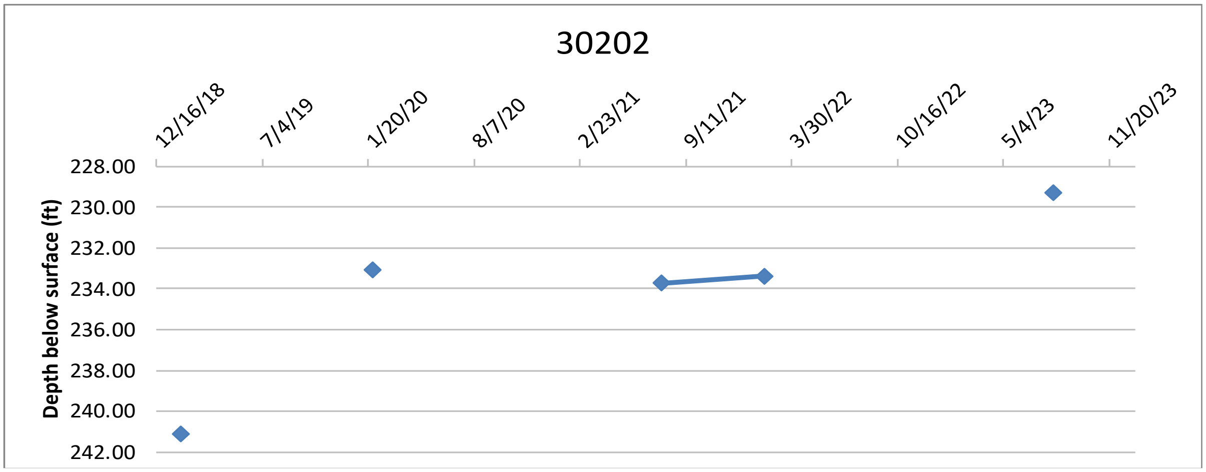
Well ID	TD	Date	DTW	Notes*
31702 #2	~55’	1/31/19	30.61	
		8/7/19	30.96	
		1/28/20	30.33	
		7/28/21		NM
		2/10/22	35.66	
		8/23/22	31.62	
		2/21/23	30.47	
		8/8/23	31.11	



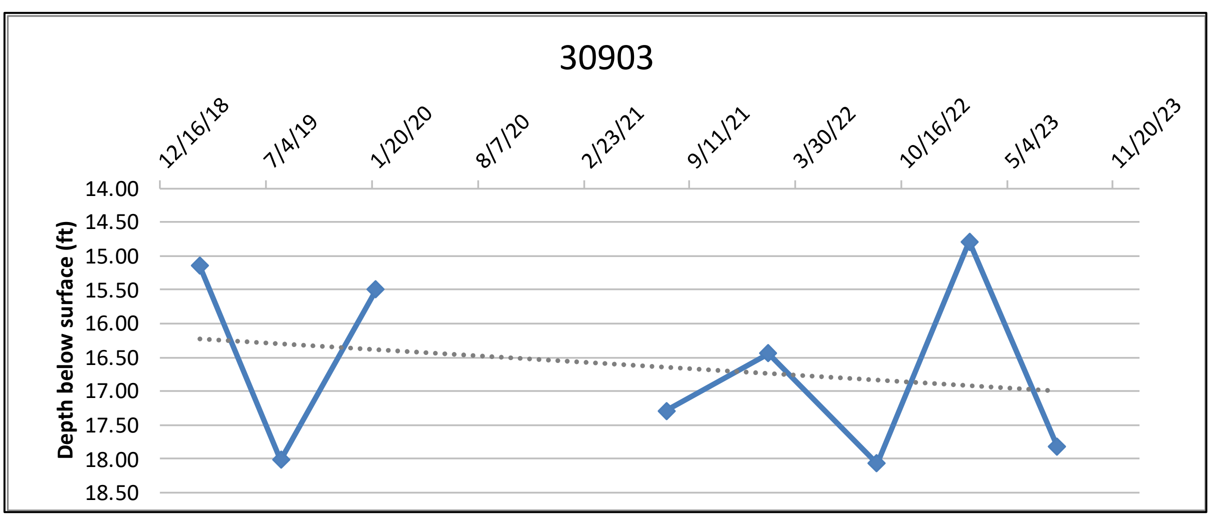
Well ID	TD	Date	DTW	Notes*
32302	40’	1/25/19	15.61	
		8/7/19	16.20	
		1/27/20	15.37	
		7/26/21	15.88	
		2/8/22	15.64	
		8/25/22	15.36	
		2/21/23	15.58	
		8/8/23	16.34	



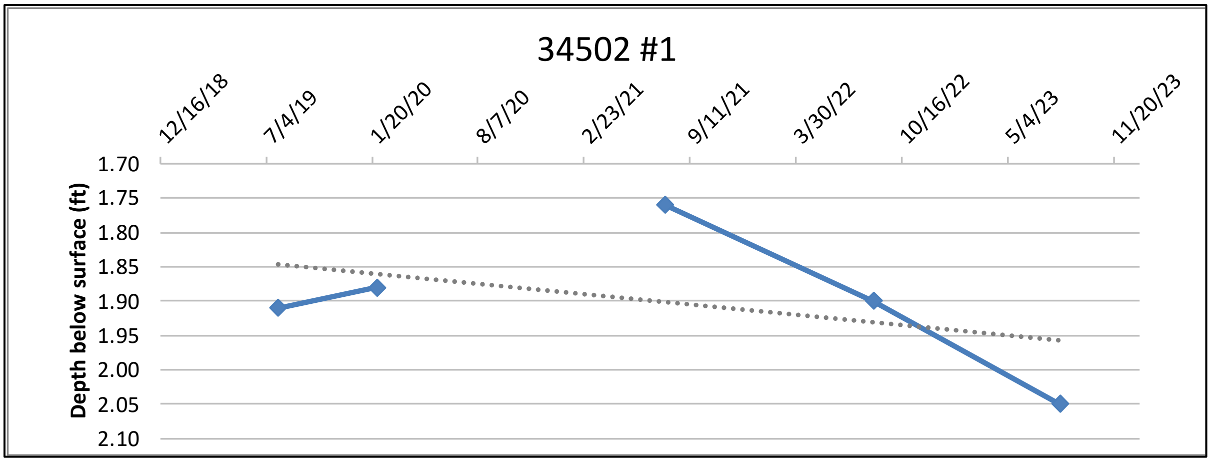
Well ID	TD	Date	DTW	Notes*
30202	~640’	1/31/19	241.11	
		8/15/19		NM
		1/27/20	233.09	
		7/27/21	233.72	
		2/7/22	233.37	AVG
		8/16/22		NS
		2/22/23		NS
		8/7/23	229.31	AVG



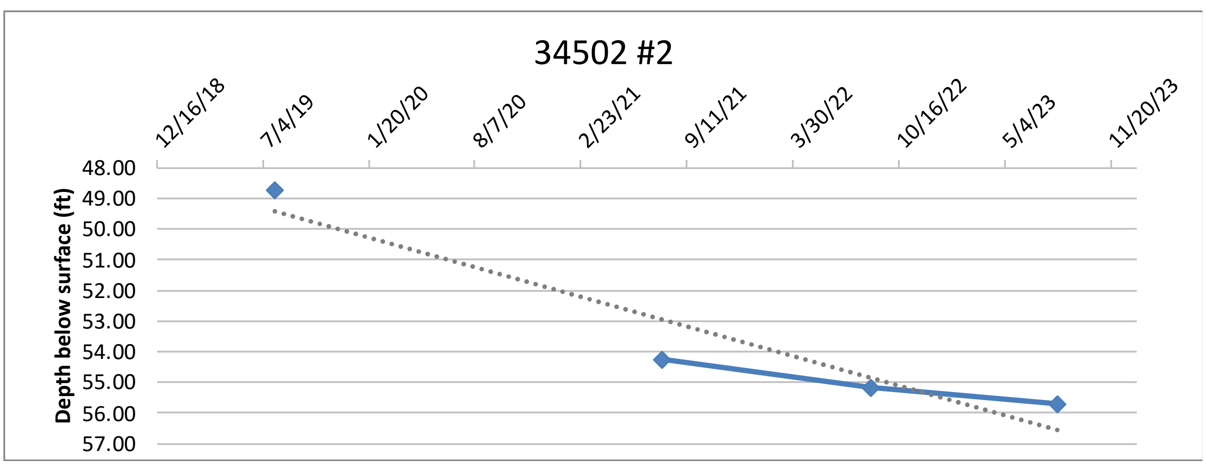
Well ID	TD	Date	DTW	Notes*
30903	~640’	2/28/19	15.14	
		8/1/19	18.02	
		1/27/20	15.50	
		7/30/21	17.29	
		2/7/22	16.44	
		8/31/22	18.07	
		2/22/23	14.79	
		8/7/23	17.82	



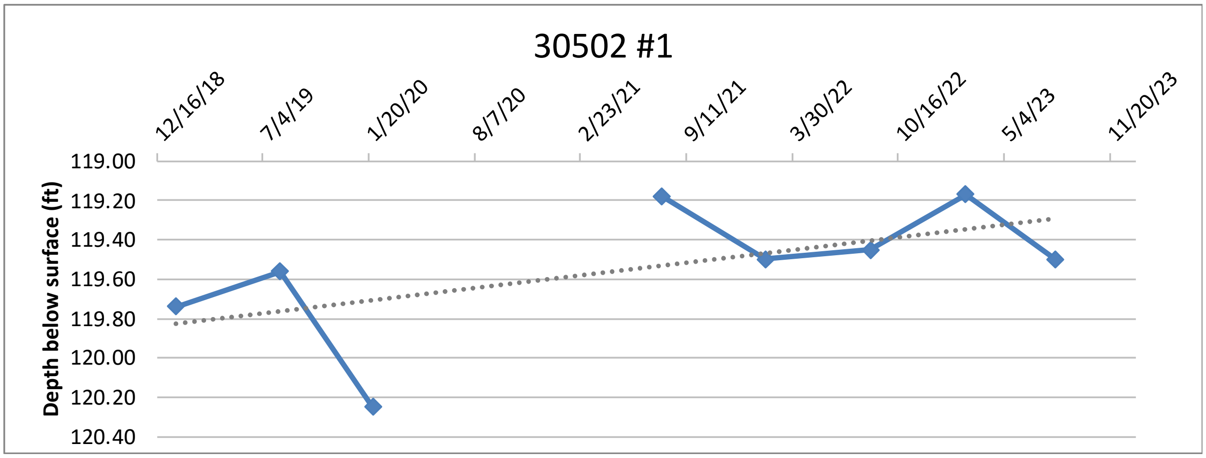
Well ID	TD	Date	DTW	Notes*
34502 #1	5'	7/26/19	1.91	
		1/29/20	1.88	
		7/27/21	1.76	
		8/24/22	1.90	
		8/11/23	2.05	



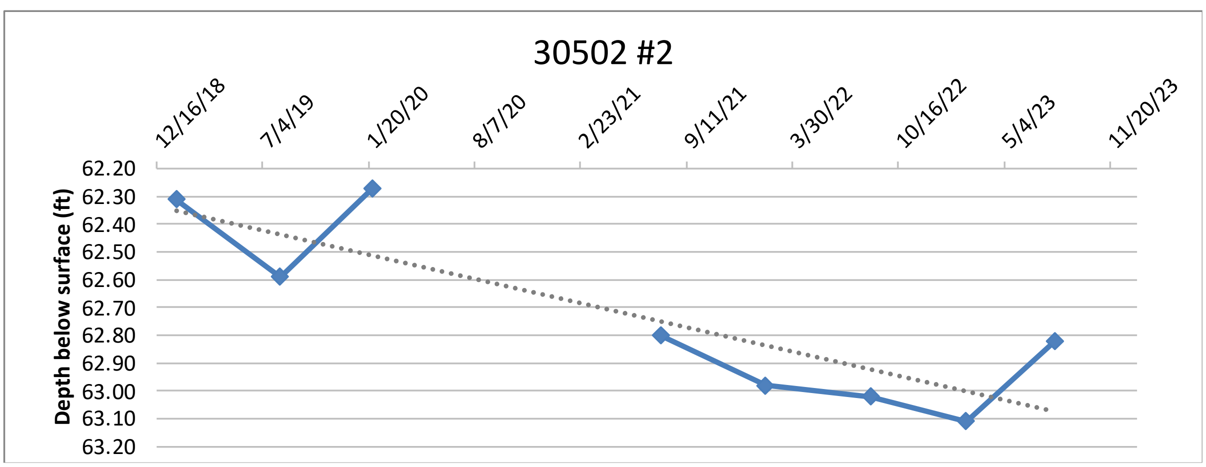
Well ID	TD	Date	DTW	Notes*
34502 #2	60'	7/26/19	48.72	
		7/27/21	54.26	
		8/24/22	55.18	
		8/11/23	55.70	



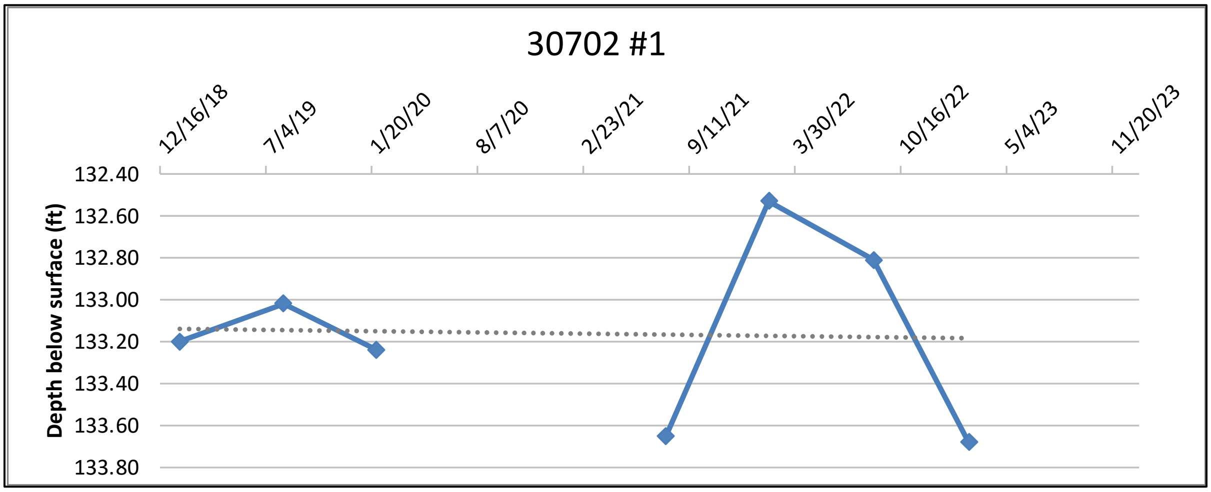
Well ID	TD	Date	DTW	Notes*
30502 #1	136’	1/22/19	119.74	
		8/6/19	119.56	
		1/28/20	120.25	
		7/26/21	119.18	
		2/8/22	119.50	
		8/25/22	119.45	
		2/21/23	119.17	
		8/8/23	119.50	



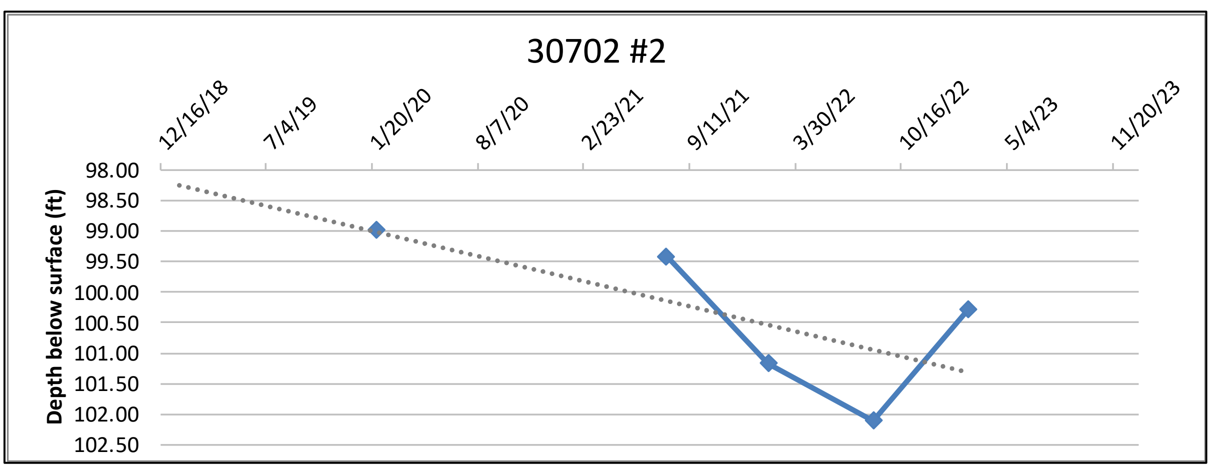
Well ID	TD	Date	DTW	Notes*
30502 #2	N/A	1/22/19	62.31	
		8/6/19	62.59	
		1/28/20	62.27	
		7/26/21	62.80	
		2/8/22	62.98	
		8/25/22	63.02	
		2/21/23	63.11	
		8/8/23	62.82	



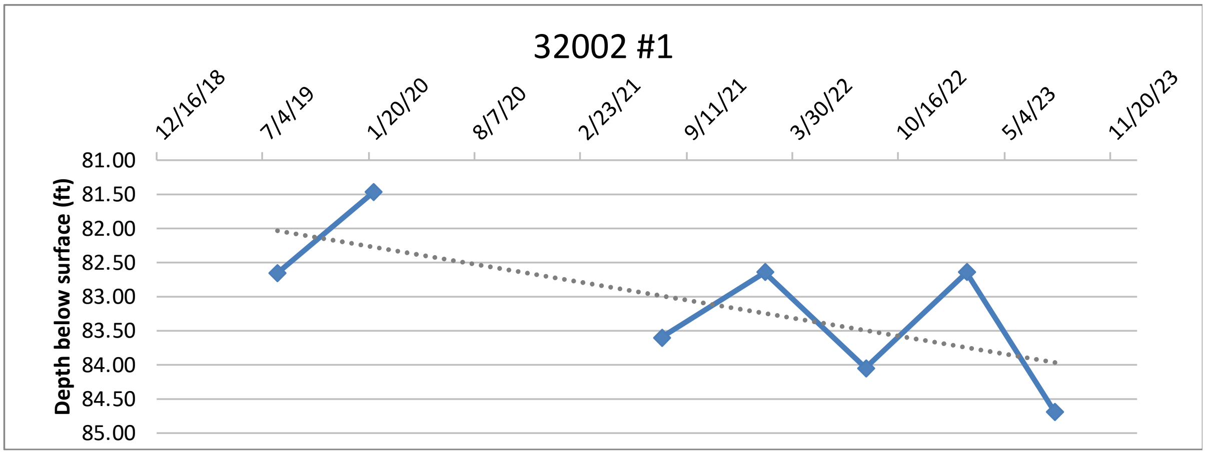
Well ID	TD	Date	DTW	Notes*
30702 #1	N/A	1/22/19	133.20	AVG
		8/6/19	133.02	
		1/28/20	133.24	AVG
		7/29/21	133.65	
		2/8/22	132.53	
		8/25/22	132.81	
		2/21/23	133.68	



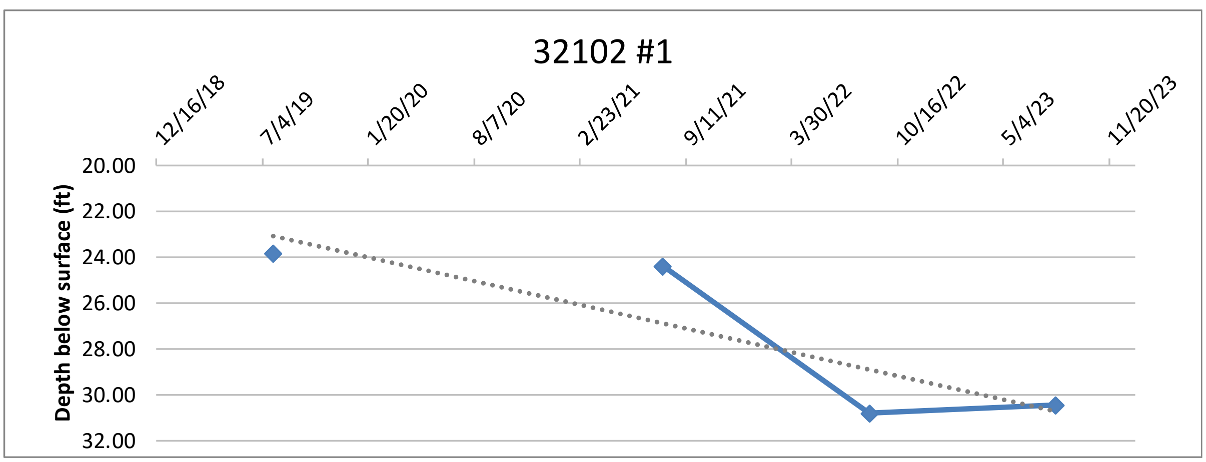
Well ID	TD	Date	DTW	Notes*
30702 #2	124’	1/22/19		NM
		8/6/19		NM
		1/28/20	98.98	
		7/29/21	99.41	
		2/8/22	101.17	
		8/25/22	102.11	AVG
		2/21/23	100.28	



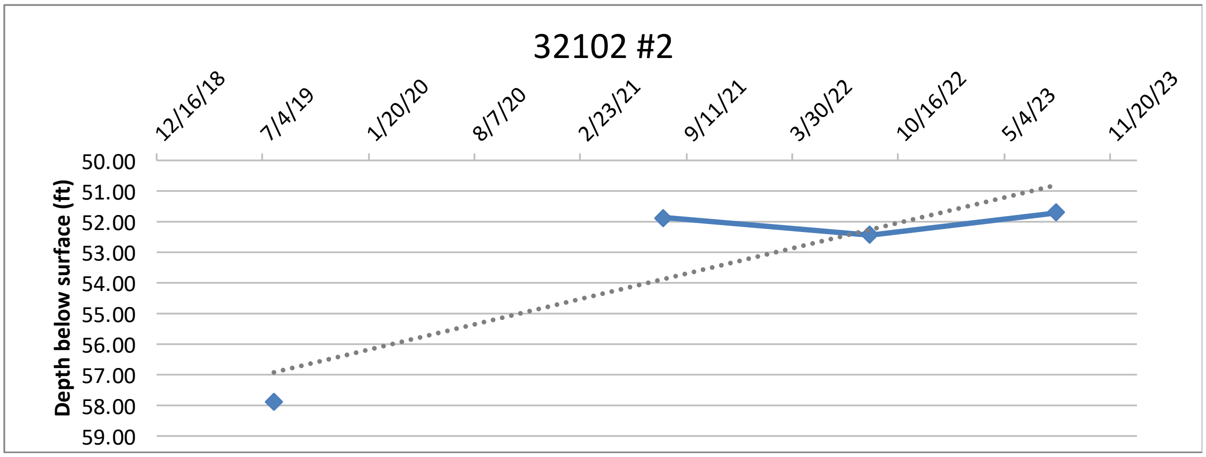
Well ID	TD	Date	DTW	Notes*
32002 #1	110’	8/1/19	82.66	
		1/29/20	81.48	
		7/27/21	83.60	
		2/7/22	82.65	
		8/16/22	84.05	
		2/22/23	82.65	
		8/7/23	84.69	



Well ID	TD	Date	DTW	Notes*
32102 #1	~70’	7/25/19	23.84	
		7/30/21	24.39	
		8/24/22	30.81	
		8/11/23	30.46	

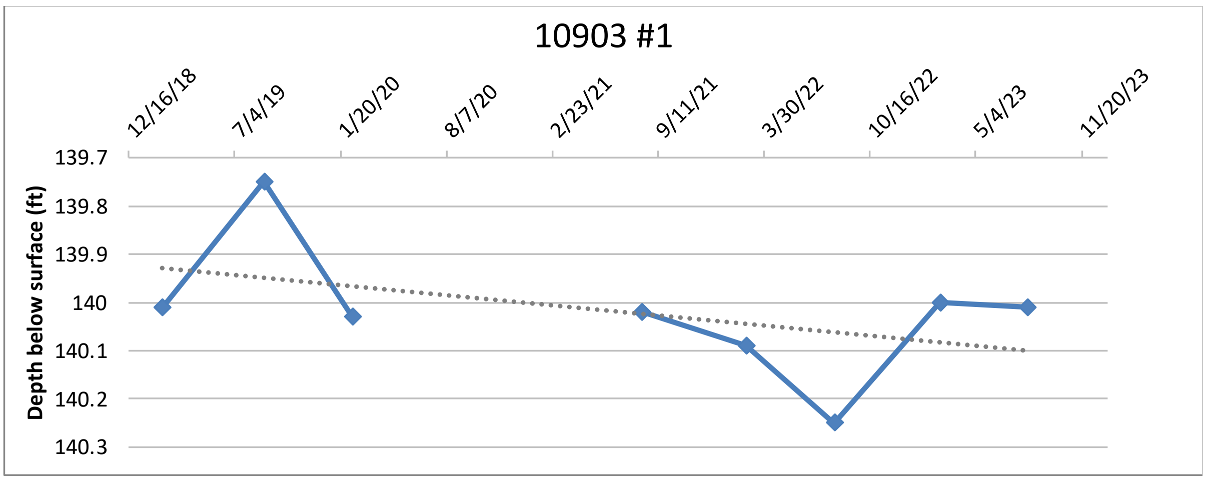


Well ID	TD	Date	DTW	Notes*
32102 #2	N/A	7/25/19	57.88	AVG
		7/30/21	51.85	
		8/24/22	52.41	
		8/11/23	51.69	

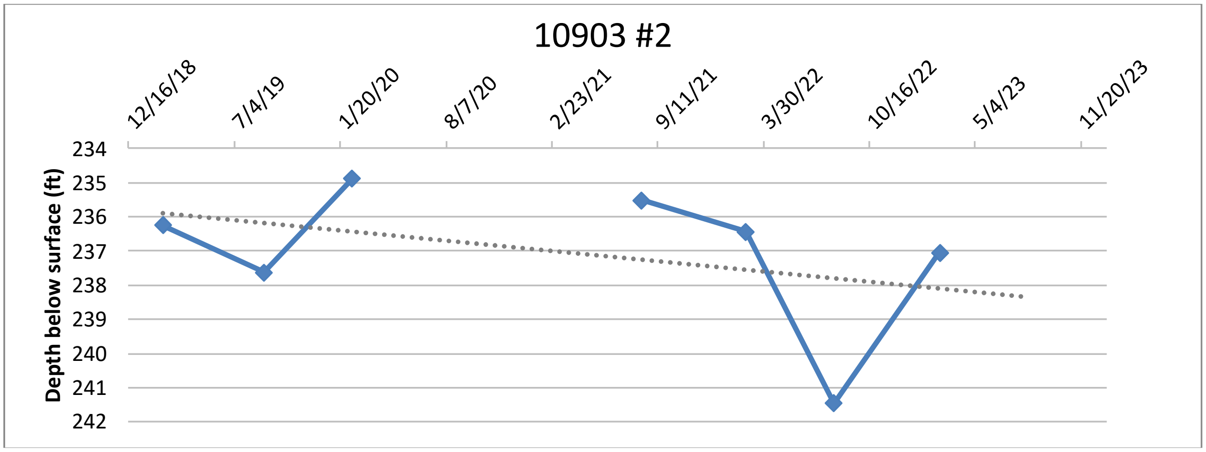


Cimarron County Well Data

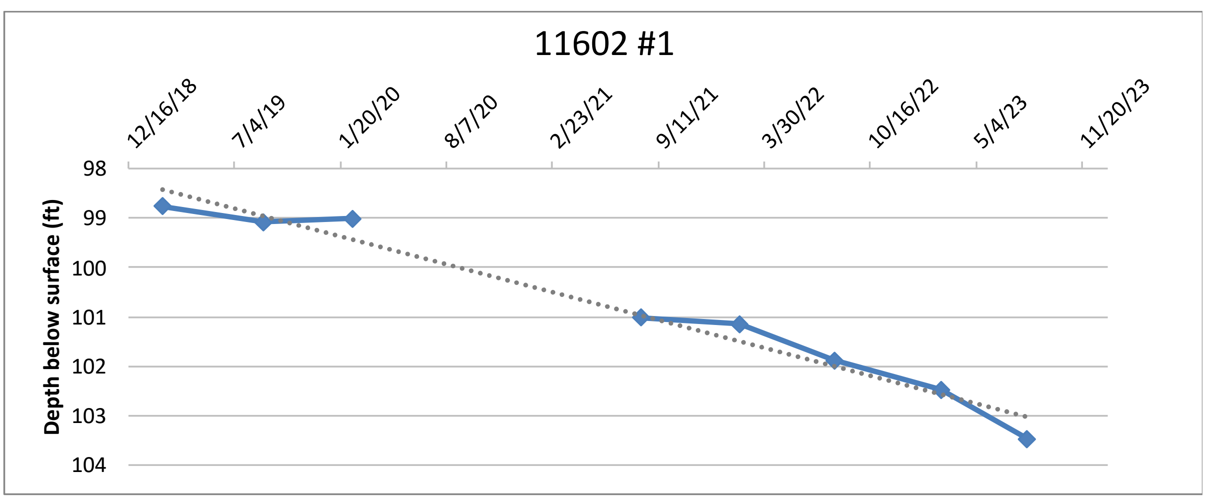
Well ID	TD	Date	DTW	Notes(*)
10903 #1	~175'	2/18/2019	140.01	
		8/29/2019	139.75	
		2/11/2020	140.03	AVG
		8/11/2021	140.02	AVG
		2/24/2022	140.09	
		8/10/2022	140.25	
		2/26/2023	140.00	
		8/9/2023	140.01	



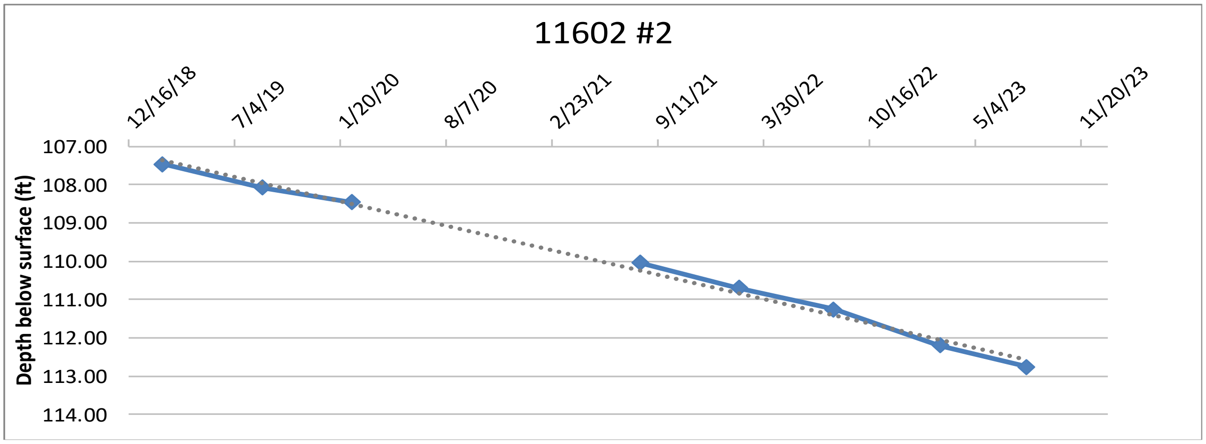
Well ID	TD	Date	DTW	Notes*
10903 #2	~175'	2/18/2019	140.01	
		8/29/2019	139.75	
		2/11/2020	140.03	AVG
		8/11/2021	140.02	AVG
		2/24/2022	140.09	
		8/10/2022	140.25	
		2/26/2023	140.00	
		8/9/2023	140.01	



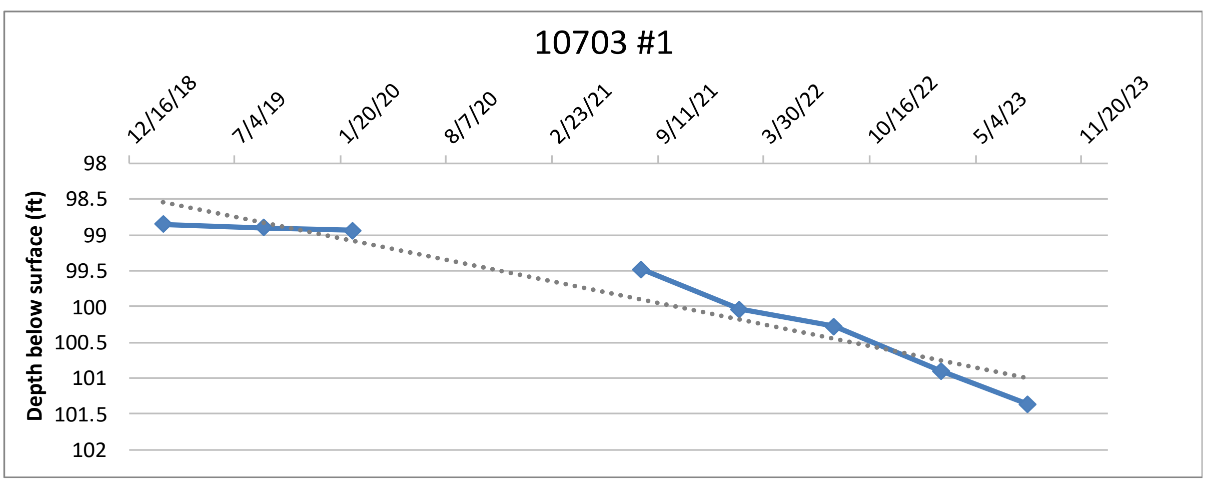
Well ID	TD	Date	DTW	Notes*
11602 #1	~135'	2/19/19	98.77	
		8/27/19	99.09	
		2/12/20	99.01	
		8/10/21	101.01	
		2/11/22	101.15	
		8/9/22	101.88	
		2/27/23	102.47	
		8/9/23	103.47	



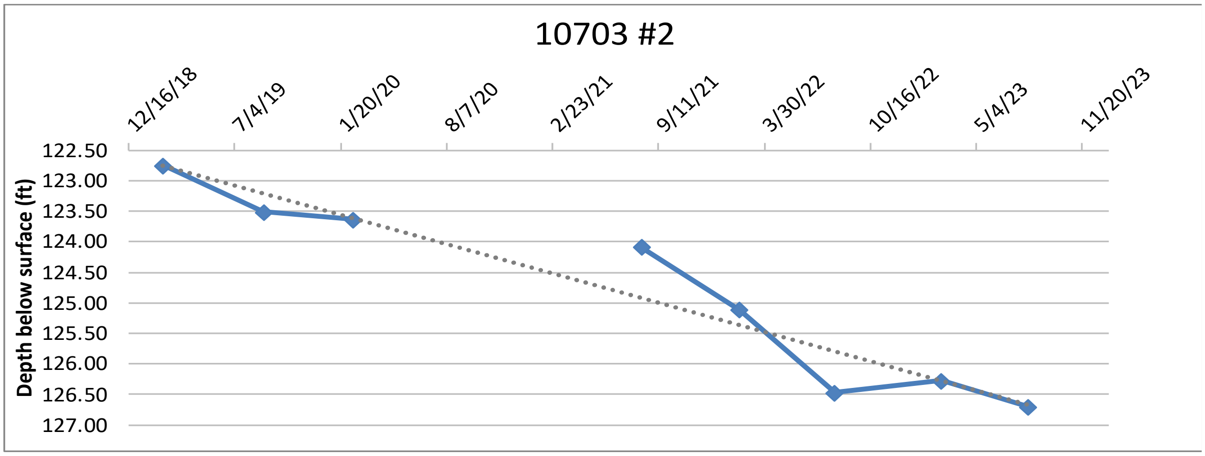
Well ID	TD	Date	DTW	Notes*
11602 #2	~150'	2/19/19	107.47	
		8/27/19	108.08	
		2/12/20	108.46	
		8/10/21	110.04	
		2/11/22	110.70	
		8/9/22	111.25	
		2/27/23	112.20	
		8/9/23	112.76	



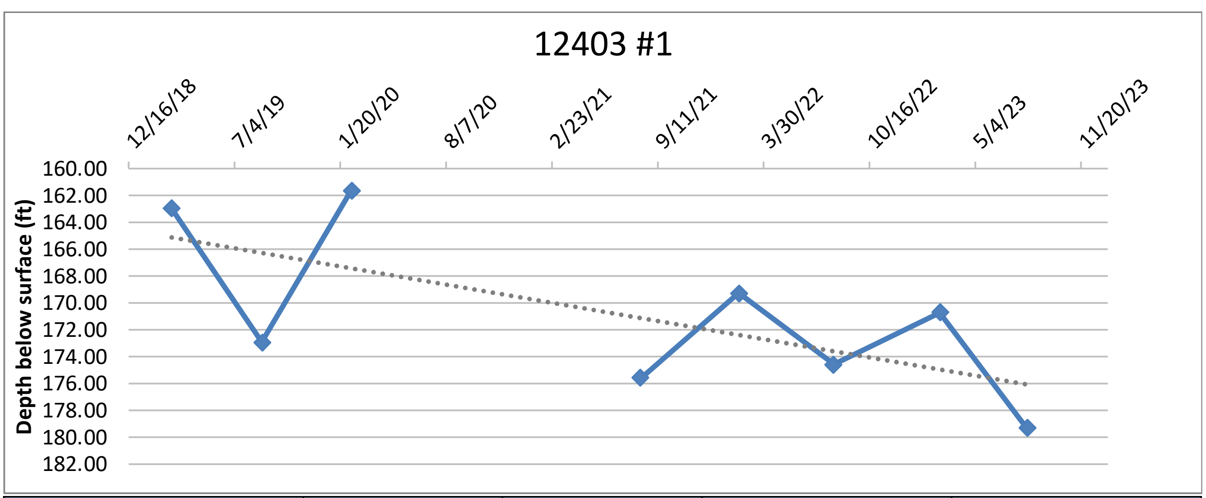
Well ID	TD	Date	DTW	Notes*
10703 #1	N/A	2/19/19	98.85	
		8/27/19	98.9	
		2/12/20	98.94	
		8/10/21	99.48	
		2/11/22	100.04	
		8/9/22	100.28	
		2/27/23	100.9	
		8/9/23	101.36	



Well ID	TD	Date	DTW	Notes*
10703 #2	~138’	2/19/19	122.75	AVG
		8/27/19	123.51	
		2/12/20	123.64	
		8/10/21	124.09	
		2/11/22	125.12	
		8/9/22	126.47	
		2/27/23	126.28	
		8/9/23	126.7	

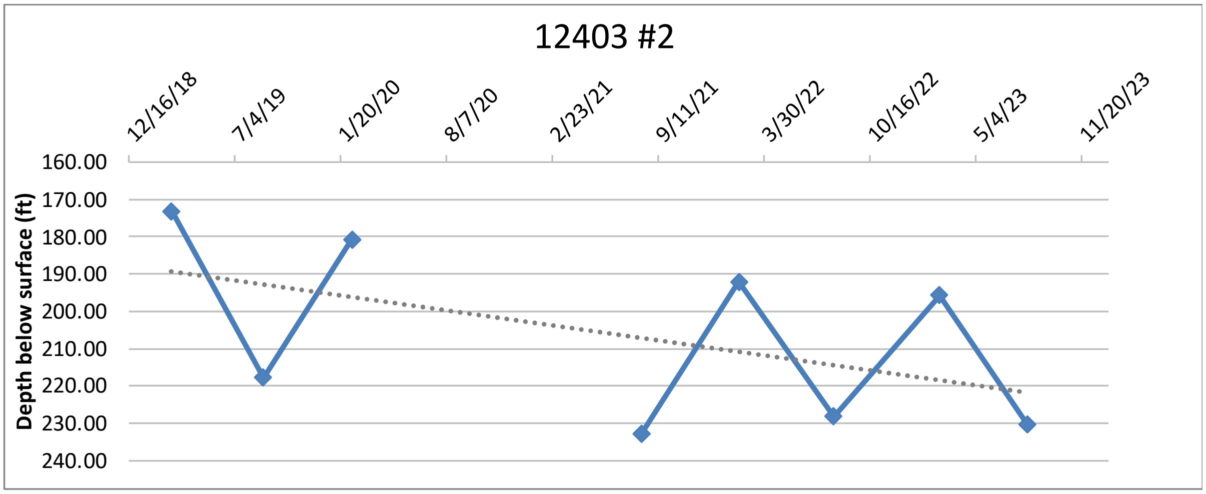


Well ID	TD	Date	DTW	Notes*
12403 #1	~275’	3/7/19	162.95	
		8/26/19	172.93	
		2/11/20	161.65	
		8/10/21	175.58	
		2/11/22	169.28	
		8/9/22	174.56	
		2/27/23	170.72	
		8/10/23	179.33	

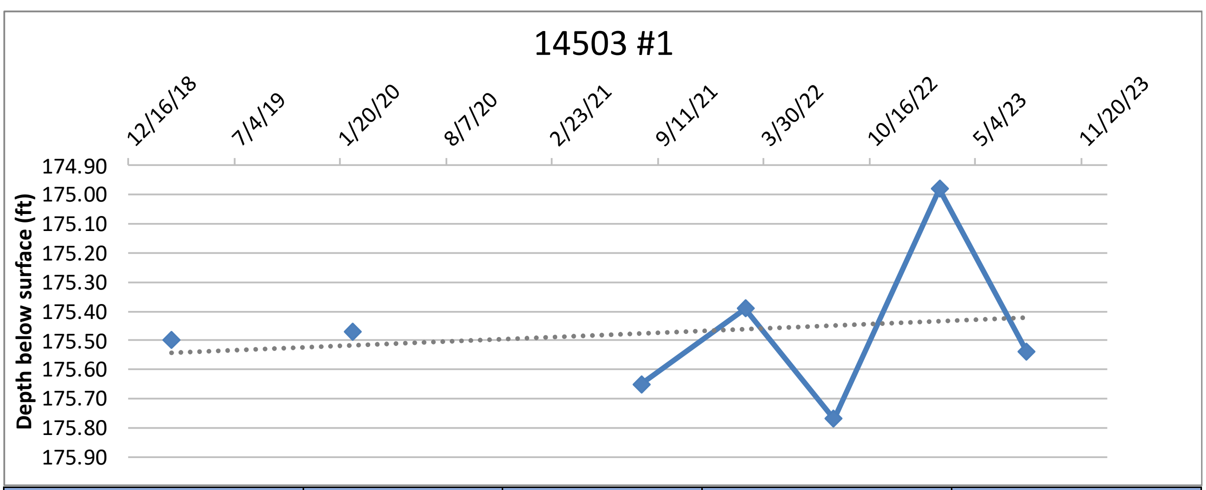


Well ID	TD	Date	DTW	Notes*

12403 #2	~315'	3/7/19	173.15	
		8/27/19	217.71	
		2/11/20	180.72	
		8/10/21	232.96	
		2/11/22	192.01	
		8/9/22	228.17	
		2/25/23	195.63	
		8/9/23	230.21	

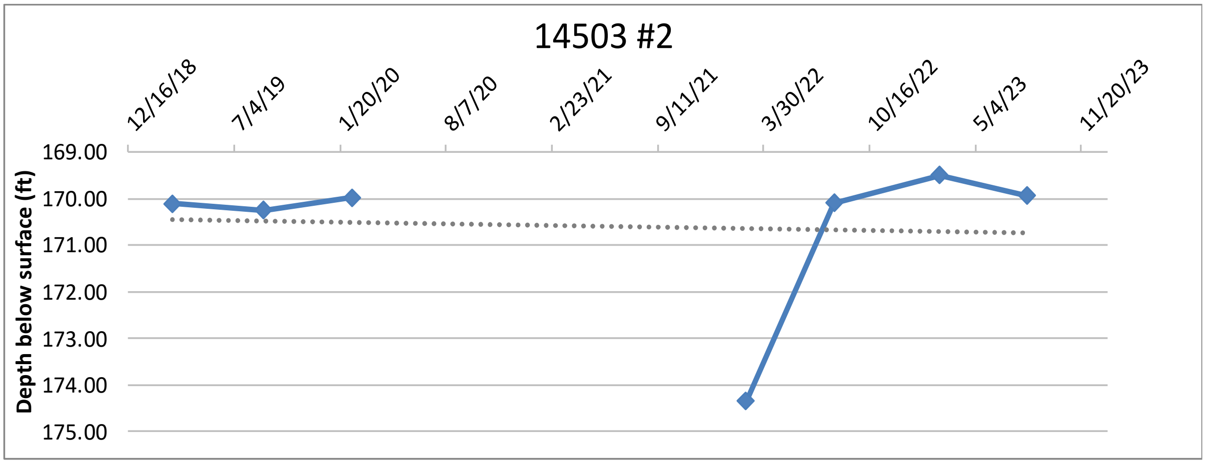


Well ID	TD	Date	DTW	Notes*
14503 #1	~200'	3/8/19	175.50	
		8/28/19		NM
		2/12/20	175.47	
		8/11/21	175.65	
		2/24/22	175.39	
		8/10/22	175.77	
		2/26/23	174.98	
		8/10/23	175.54	

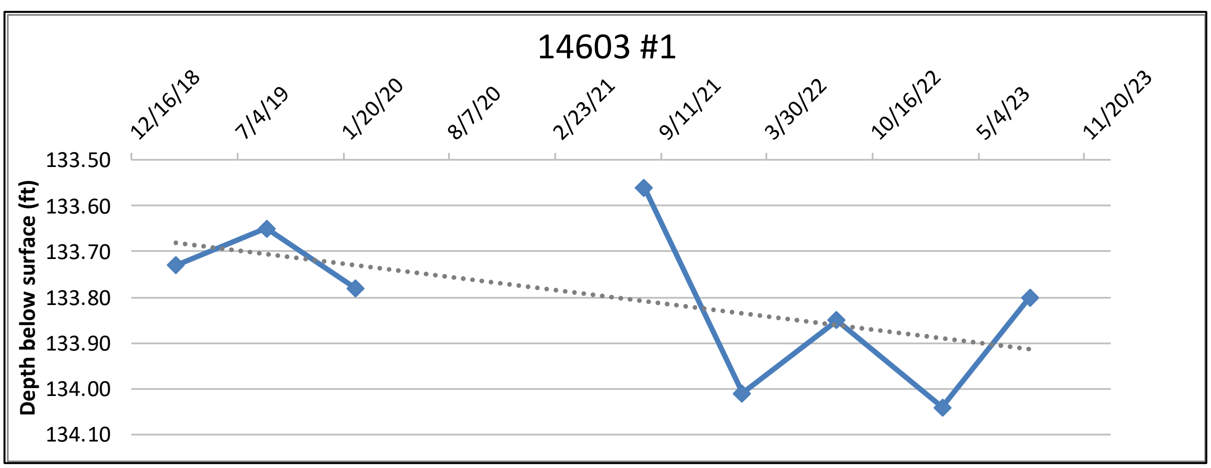


Well ID	TD	Date	DTW	Notes*

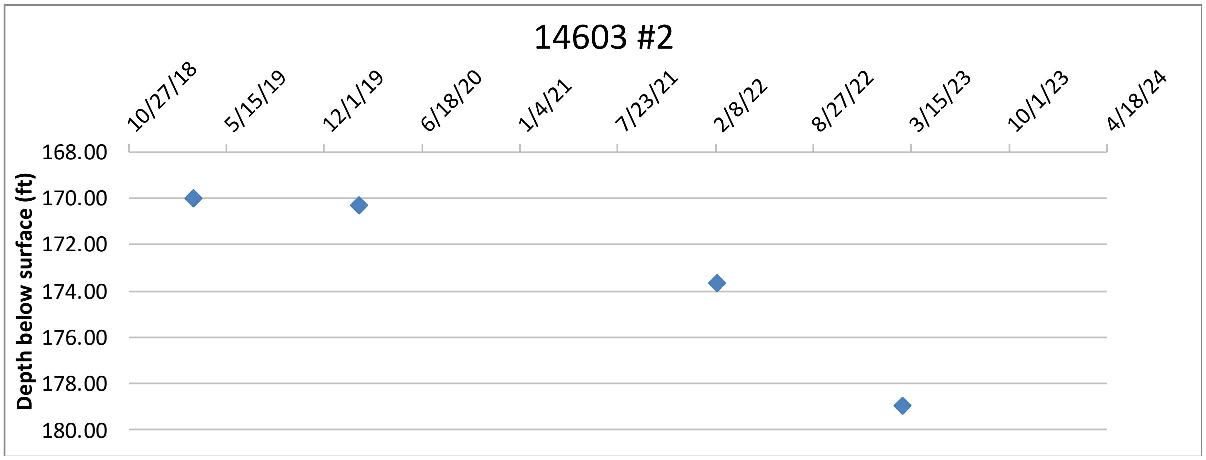
14503 #2	~205’	3/8/19	170.10	
		8/28/19	170.25	
		2/12/20	169.98	
		8/11/21		NS
		2/24/22	174.35	
		8/10/22	170.09	
		2/26/23	169.50	
		8/10/23	169.93	



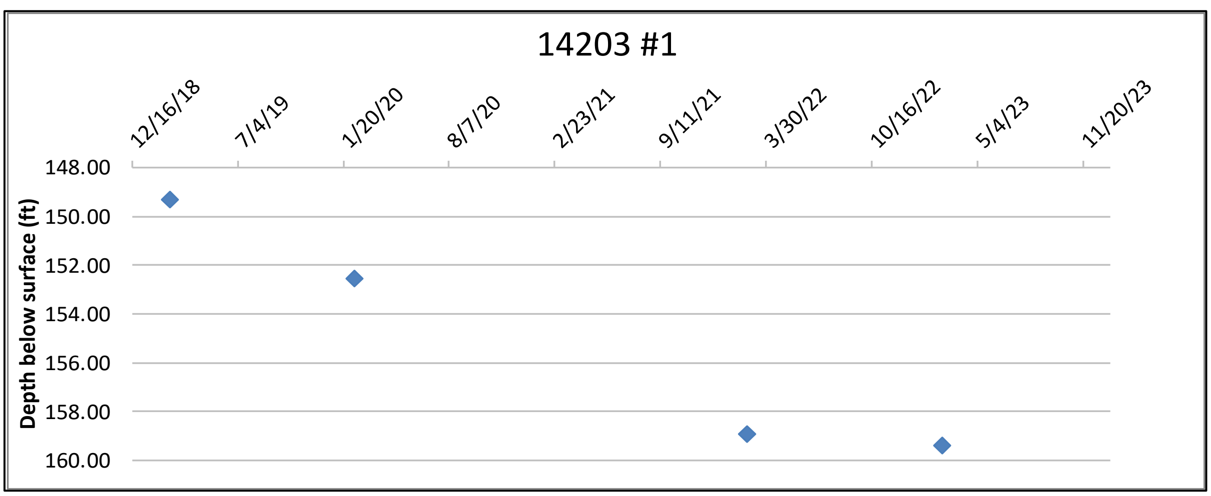
Well ID	TD	Date	DTW	Notes*
14603 #1	~255’	3/8/19	133.73	
		8/27/19	133.65	
		2/11/20	133.78	
		8/10/21	133.56	
		2/11/22	134.01	
		8/9/22	133.85	
		2/25/23	134.04	
		8/9/23	133.8	



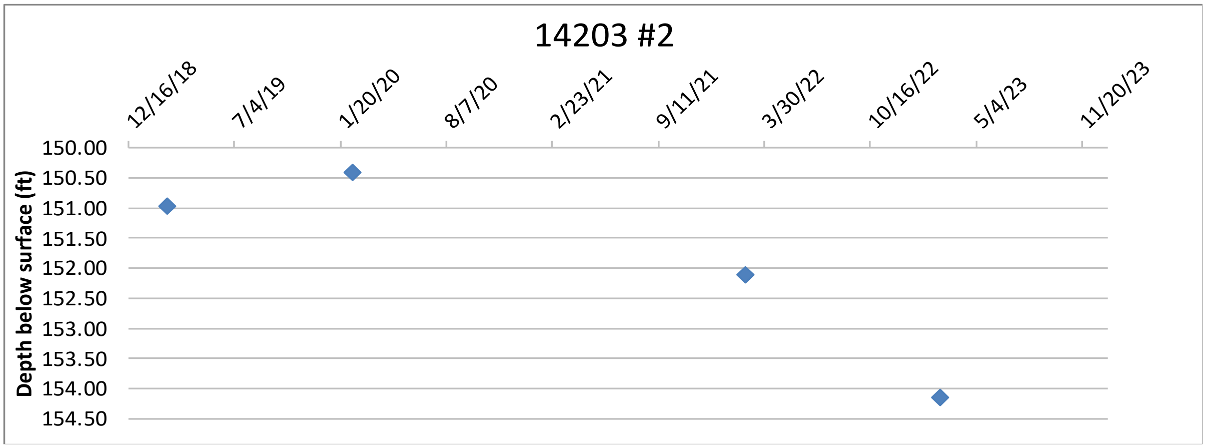
Well ID	TD	Date	DTW	Notes*
14603 #2	~240’	3/8/19	170.02	
		8/27/19		NM
		2/10/20	170.31	
		8/10/21		NM
		2/11/22	173.67	
		8/9/22		NM
		2/25/23	178.98	
		8/9/23		NM



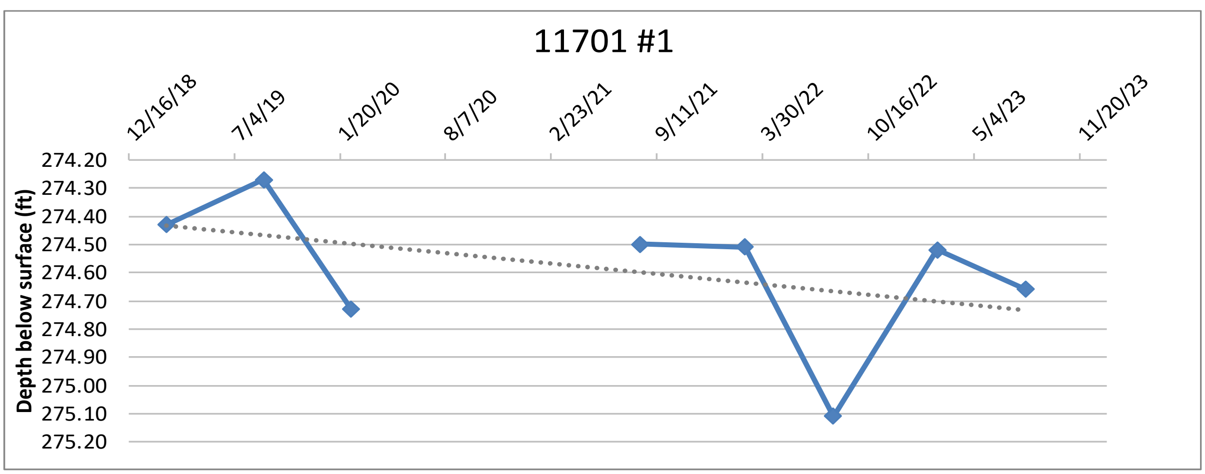
Well ID	TD	Date	DTW	Notes*
14203 #1	~285’	2/26/19	150.97	AVG
		Summer '19		NM
		2/11/20	150.40	
		8/11/21		NM
		2/22/22	152.11	
		8/9/22		NM
		2/25/23	154.15	AVG
		8/10/23		NS



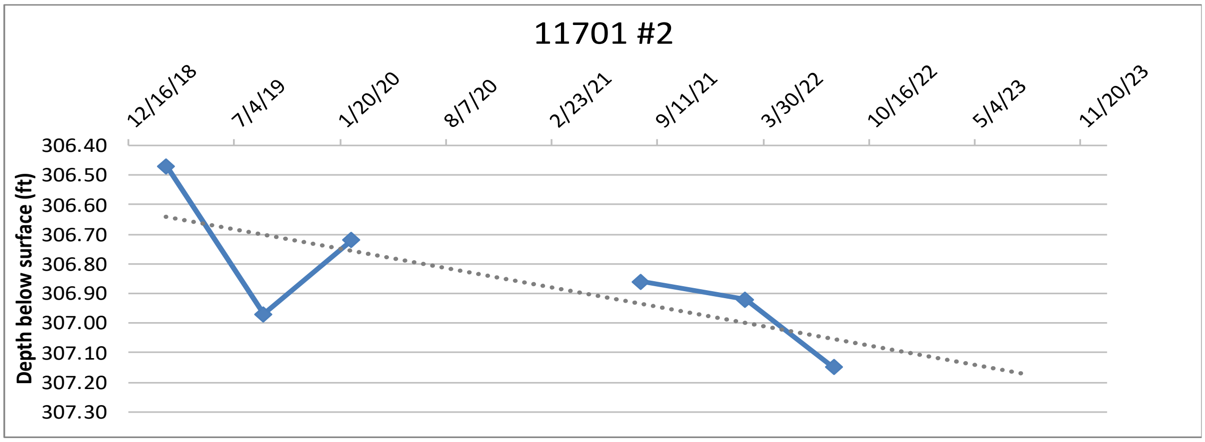
Well ID	TD	Date	DTW	Notes*
14203 #2	N/A	2/26/19	150.97	AVG
		Summer '19		NM
		2/11/20	150.40	
		8/11/21		NM
		2/22/22	152.11	
		8/9/22		NM
		2/25/23	154.15	AVG
		8/10/23		NS



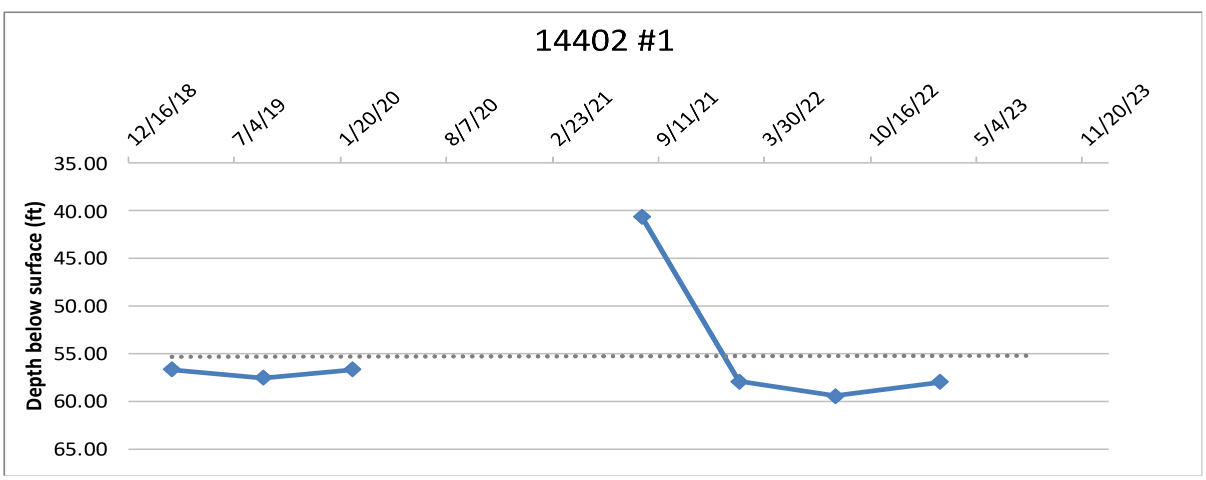
Well ID	TD	Date	DTW	Notes*
11701 #1	>294’	2/26/19	274.43	
		8/29/19	274.27	
		2/11/20	274.73	
		8/11/21	274.50	
		2/24/22	274.51	
		8/10/22	275.11	
		2/23/23	274.52	
		8/10/23	274.66	



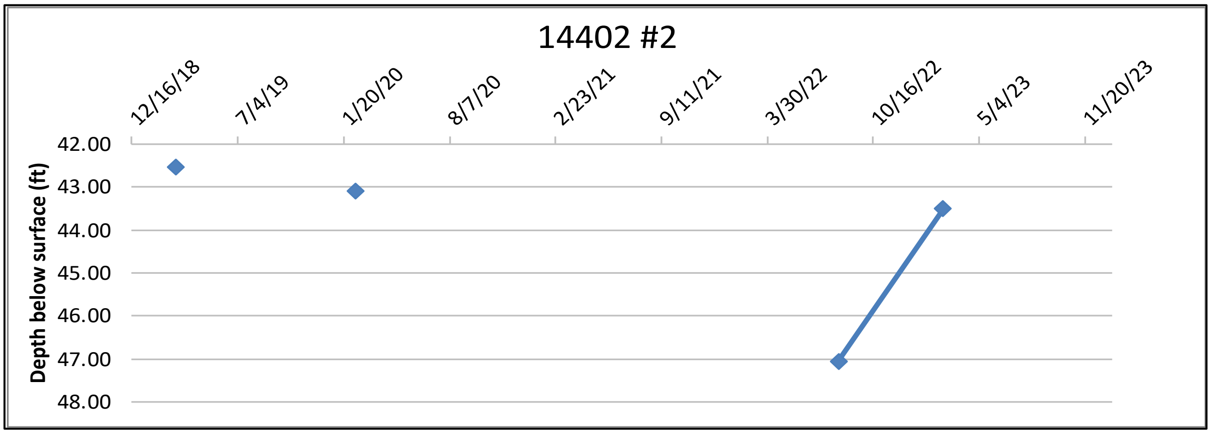
Well ID	TD	Date	DTW	Notes*
11701 #2	~330’	2/26/19	306.47	
		8/28/19	306.97	
		2/11/20	306.72	
		8/11/21	306.86	
		2/24/22	306.92	
		8/10/22	307.15	
		2/27/23		NS
		8/9/23		NM



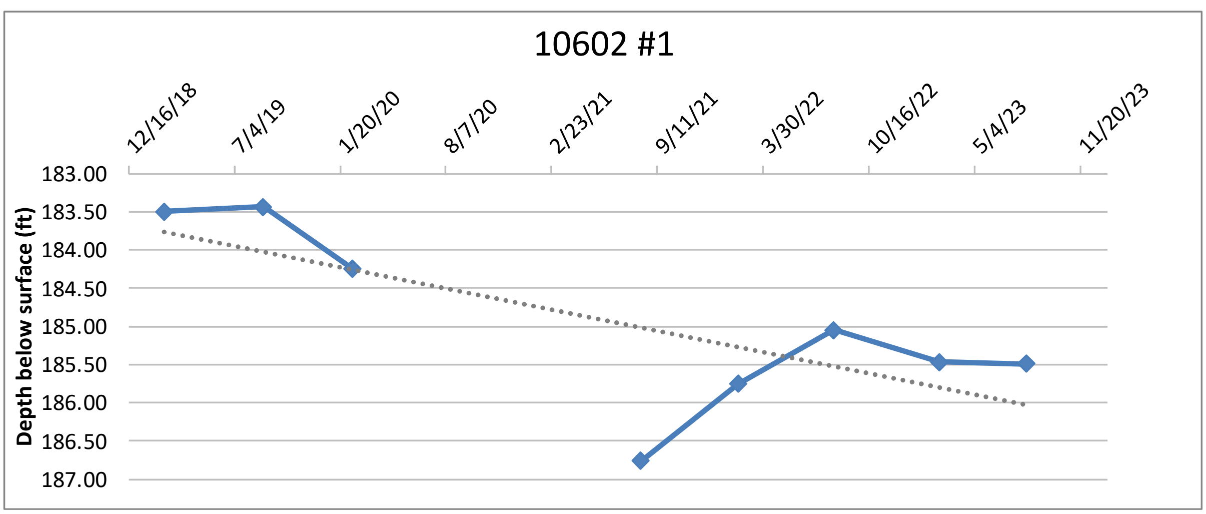
Well ID	TD	Date	DTW	Notes*
14402 #1	~100’	3/8/19	56.70	
		8/27/19	57.54	
		2/11/20	56.69	
		8/11/21	40.61	
		2/10/22	57.94	
		8/11/22	59.43	
		2/25/23	58.01	
		8/9/23		NM



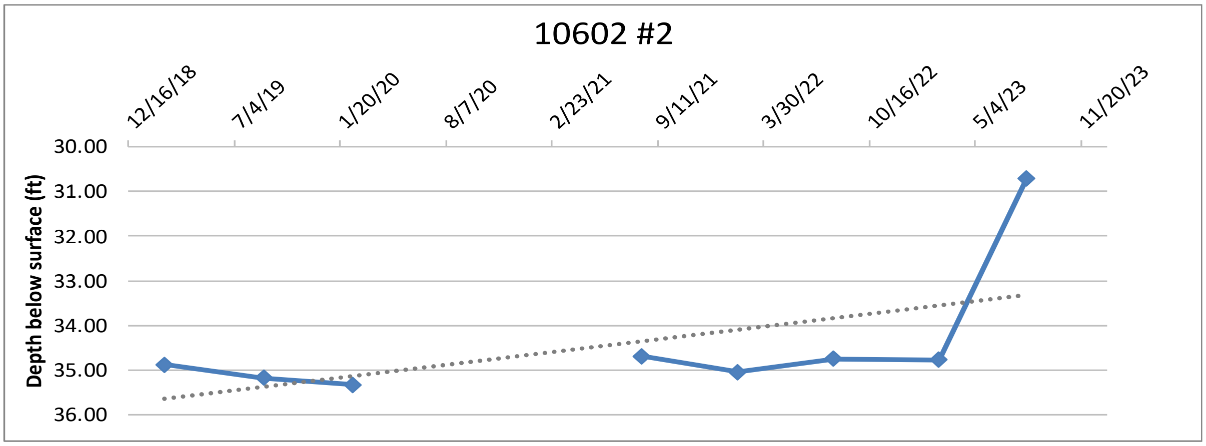
Well ID	TD	Date	DTW	Notes*
14402 #2	~115'	3/8/19	42.53	
		8/27/19		NS
		2/11/20	43.10	
		8/11/21		NM
		2/10/22		NS
		8/11/22	47.06	
		2/25/23	43.51	
		8/9/23		NM



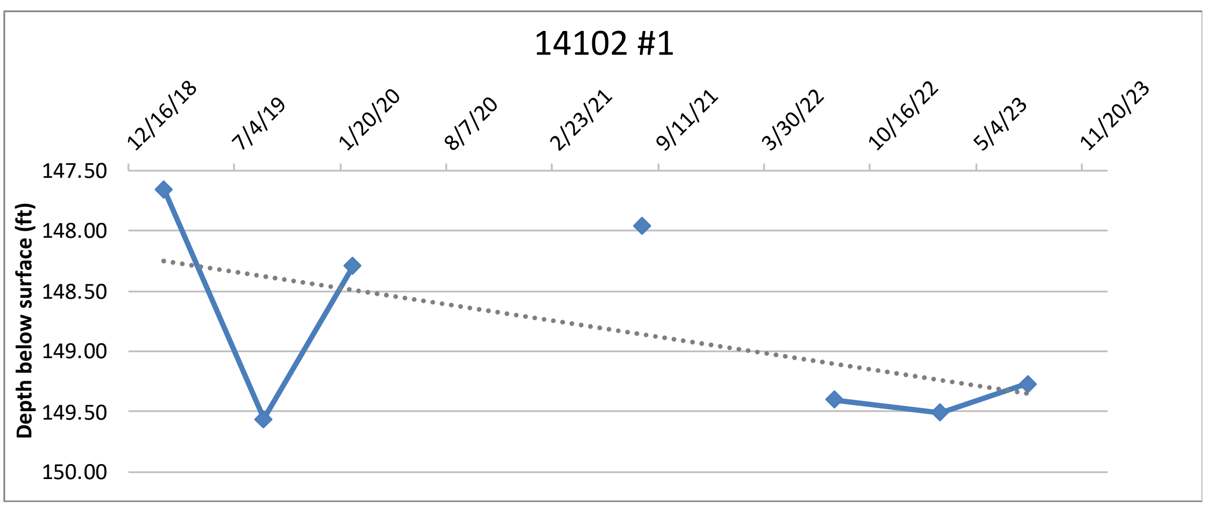
Well ID	TD	Date	DTW	Notes*
10602 #1	N/A	2/21/19	183.50	
		8/28/19	183.44	
		2/12/20	184.24	
		8/11/21	186.76	
		2/10/22	185.75	
		8/10/22	185.05	
		2/25/23	185.47	
		8/9/23	185.49	



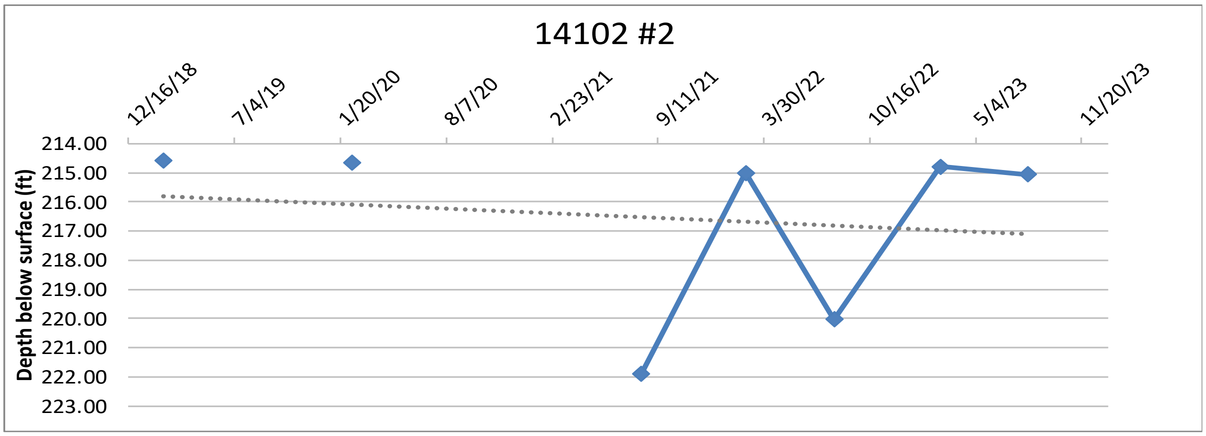
Well ID	TD	Date	DTW	Notes*
10602 #2	~100’	2/21/19	34.87	
		8/28/19	35.17	
		2/12/20	35.33	
		8/11/21	34.69	
		2/10/22	35.04	
		8/10/22	34.74	
		2/25/23	34.77	
		8/9/23	30.71	



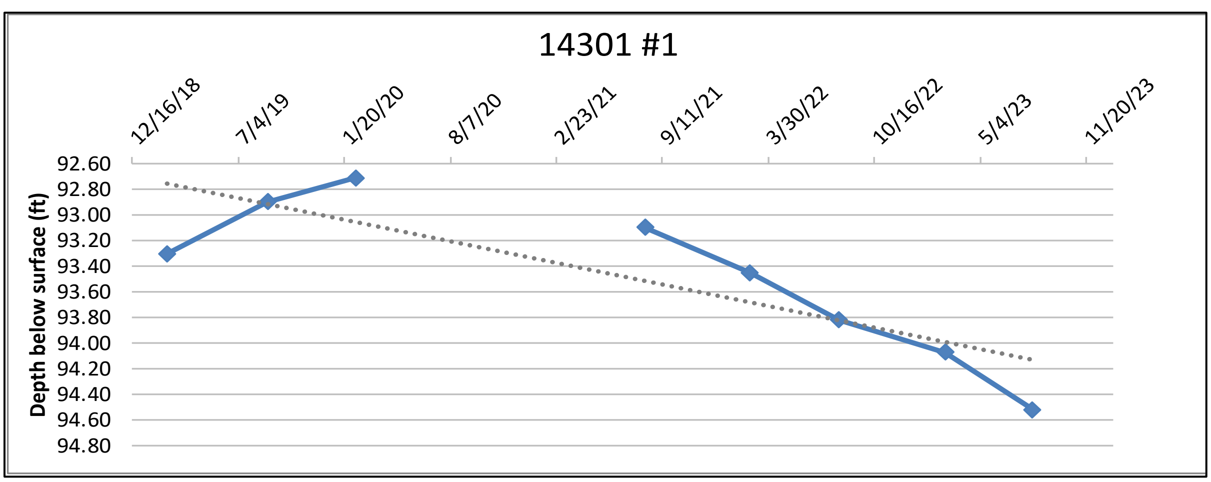
Well ID	TD	Date	DTW	Notes*
14102 #1	~200’	2/21/19	214.58	
		8/28/19		NS
		2/12/20	214.64	
		8/11/21	221.89	AVG
		2/24/22	215.00	
		8/10/22	220.03	AVG
		2/26/23	214.78	
		8/10/23	215.06	



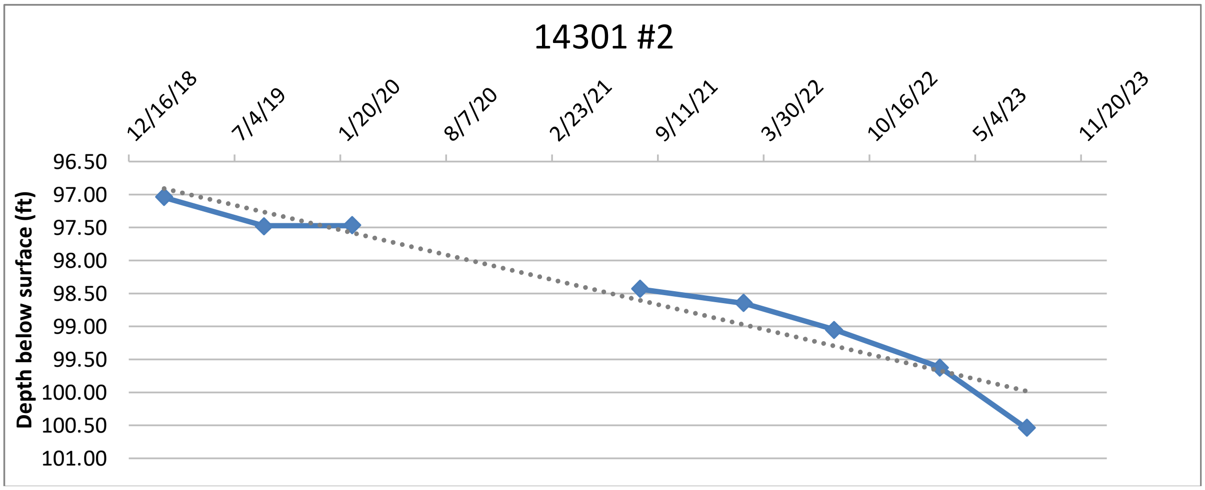
Well ID	TD	Date	DTW	Notes*
14102 #2	~283’	2/21/19	214.58	
		8/28/19		NS
		2/12/20	214.64	
		8/11/21	221.89	AVG
		2/24/22	215.00	
		8/10/22	220.03	AVG
		2/26/23	214.78	
		8/10/23	215.06	



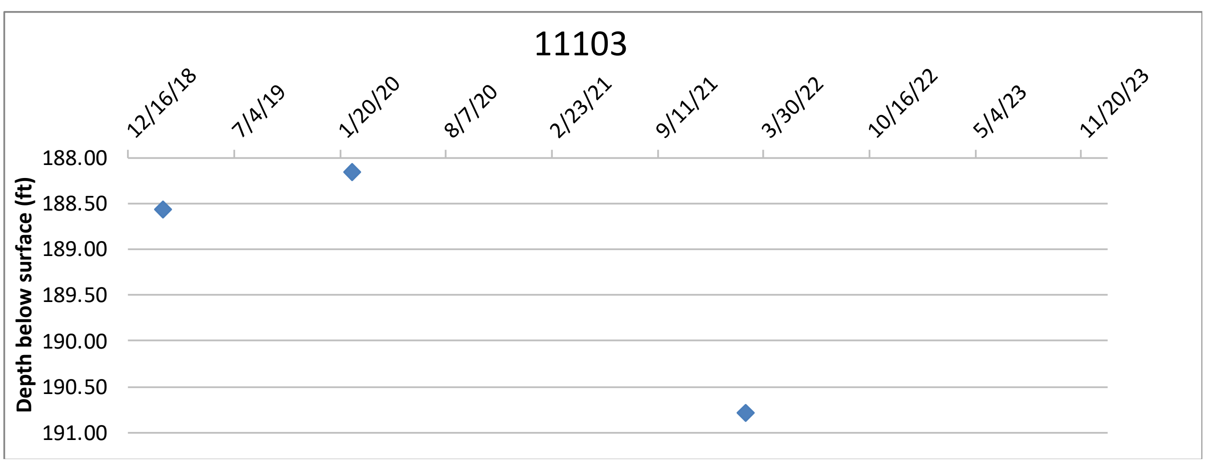
Well ID	TD	Date	DTW	Notes*
14301 #1	~300’	2/21/19	93.30	
		8/29/19	92.90	
		2/12/20	92.71	
		8/10/21	93.10	
		2/22/22	93.45	
		8/11/22	93.82	
		2/27/23	94.07	
		8/10/23	94.52	



Well ID	TD	Date	DTW	Notes*
14301 #2	~207'	2/21/19	97.04	
		8/29/19	97.48	
		2/12/20	97.47	
		8/10/21	98.43	
		2/22/22	98.65	
		8/11/22	99.05	
		2/27/23	99.62	
		8/10/23	100.54	



Well ID	TD	Date	DTW	Notes*
11103	N/A	2/19/19	188.57	
		8/29/19		NM
		2/11/20	188.16	
		8/11/21		NM
		2/24/22	190.79	AVG
		8/9/22		NM
		2/24/23		NS

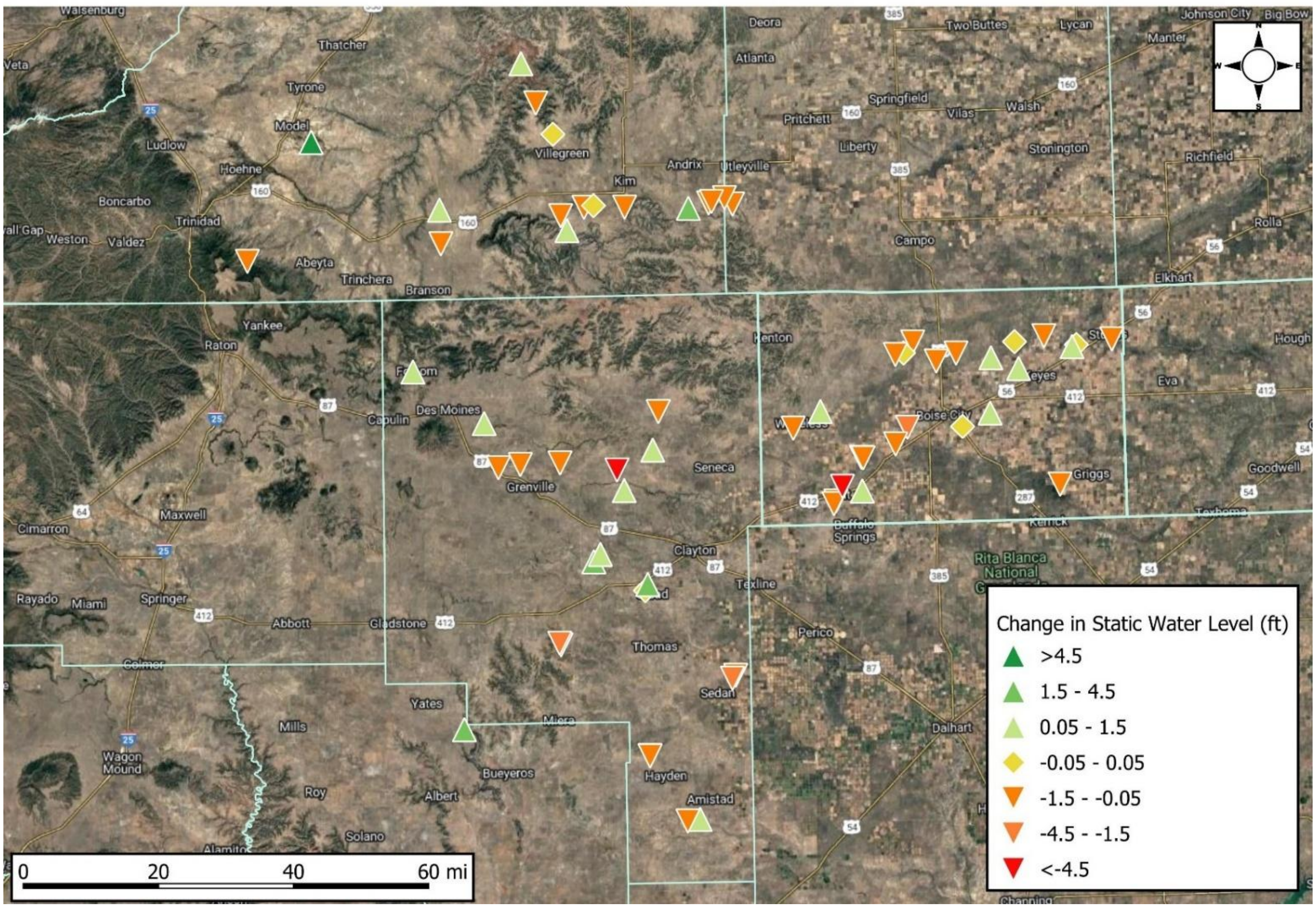


Appendix II: Water Level Change Maps

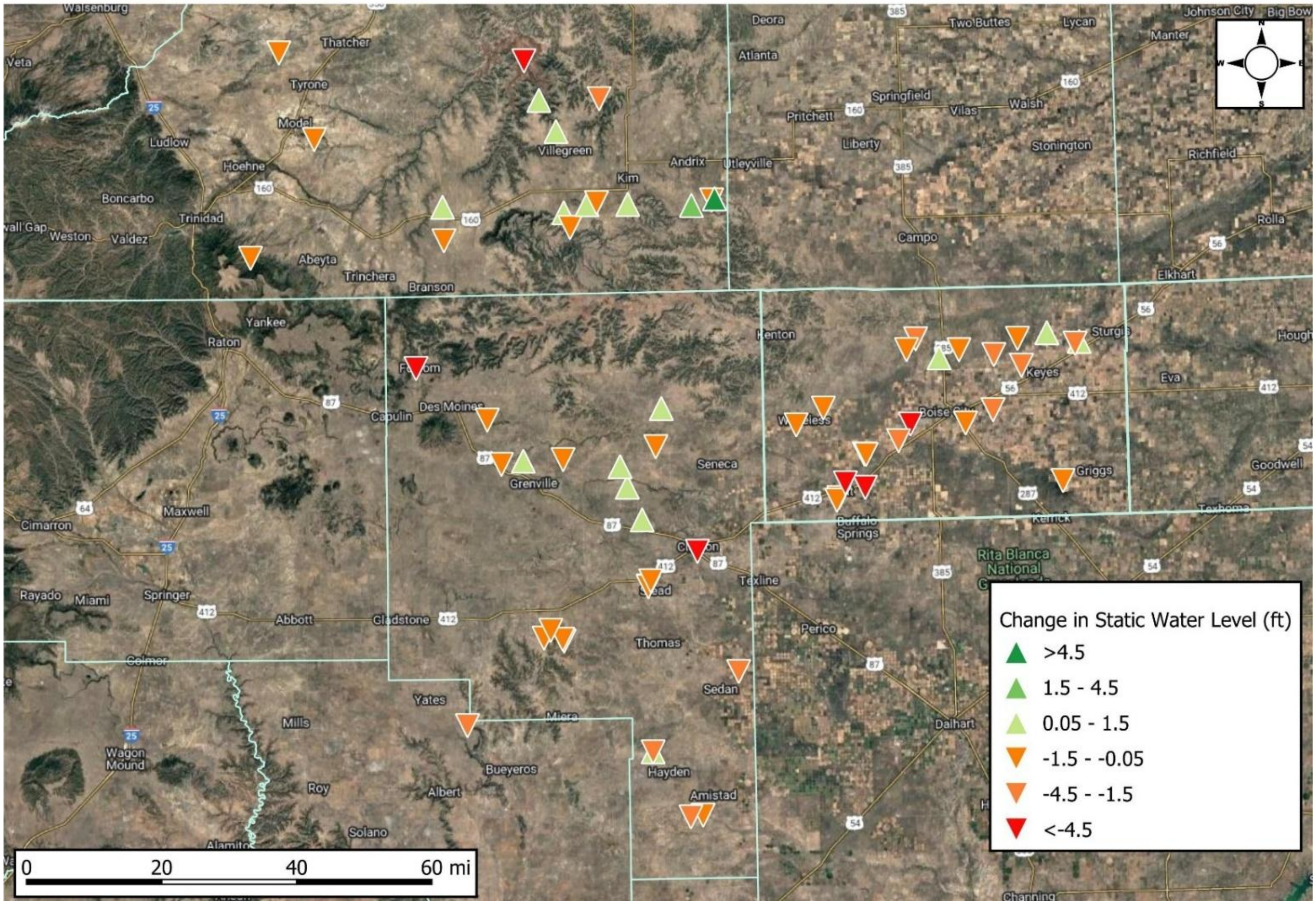
Full-size water level changes maps for each county, comparing winter to winter, summer to summer, and winter to summer.

Winter Vs. Winter Comparisons

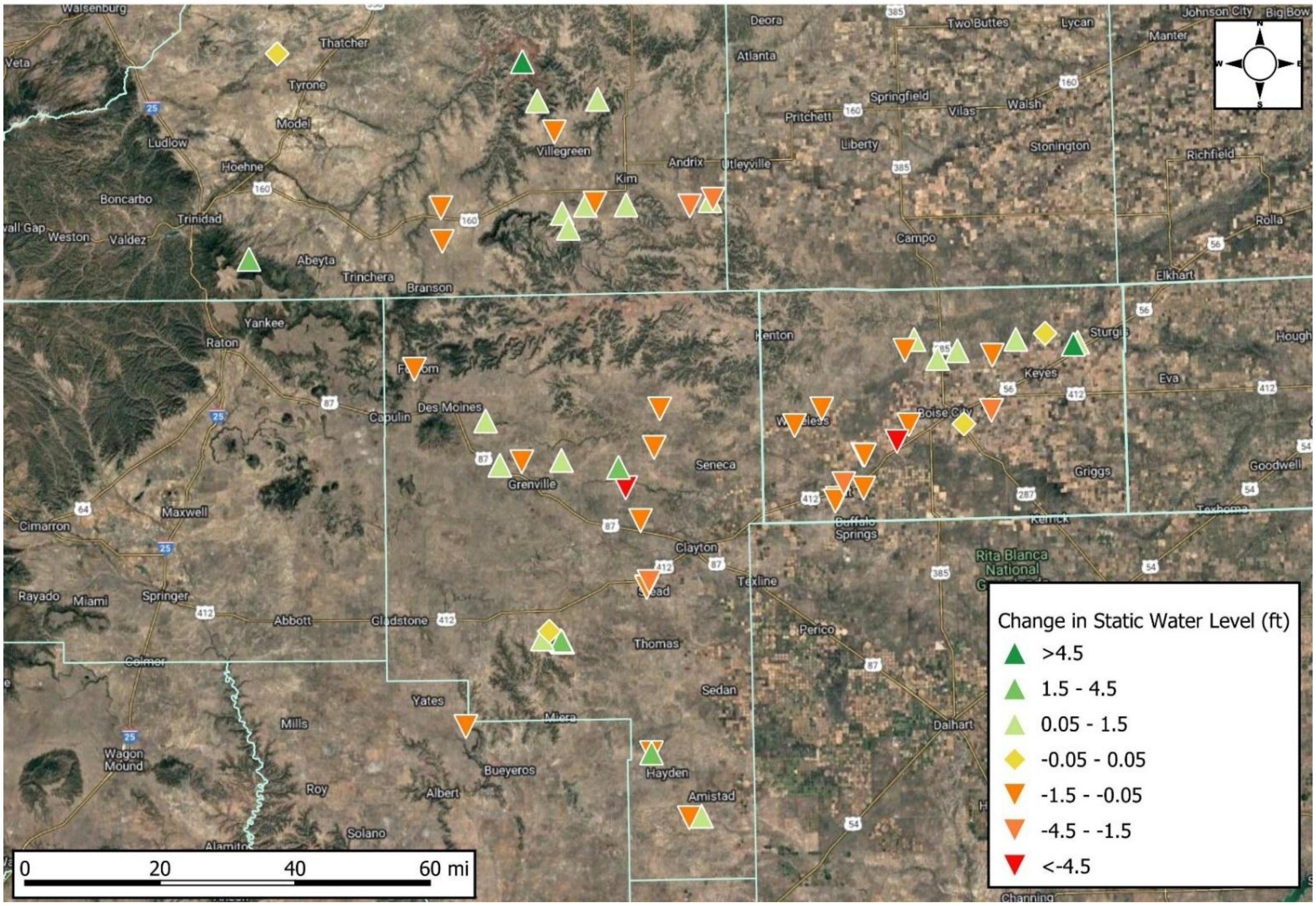
Change in Static Water Level
Winter 2019 - Winter 2020



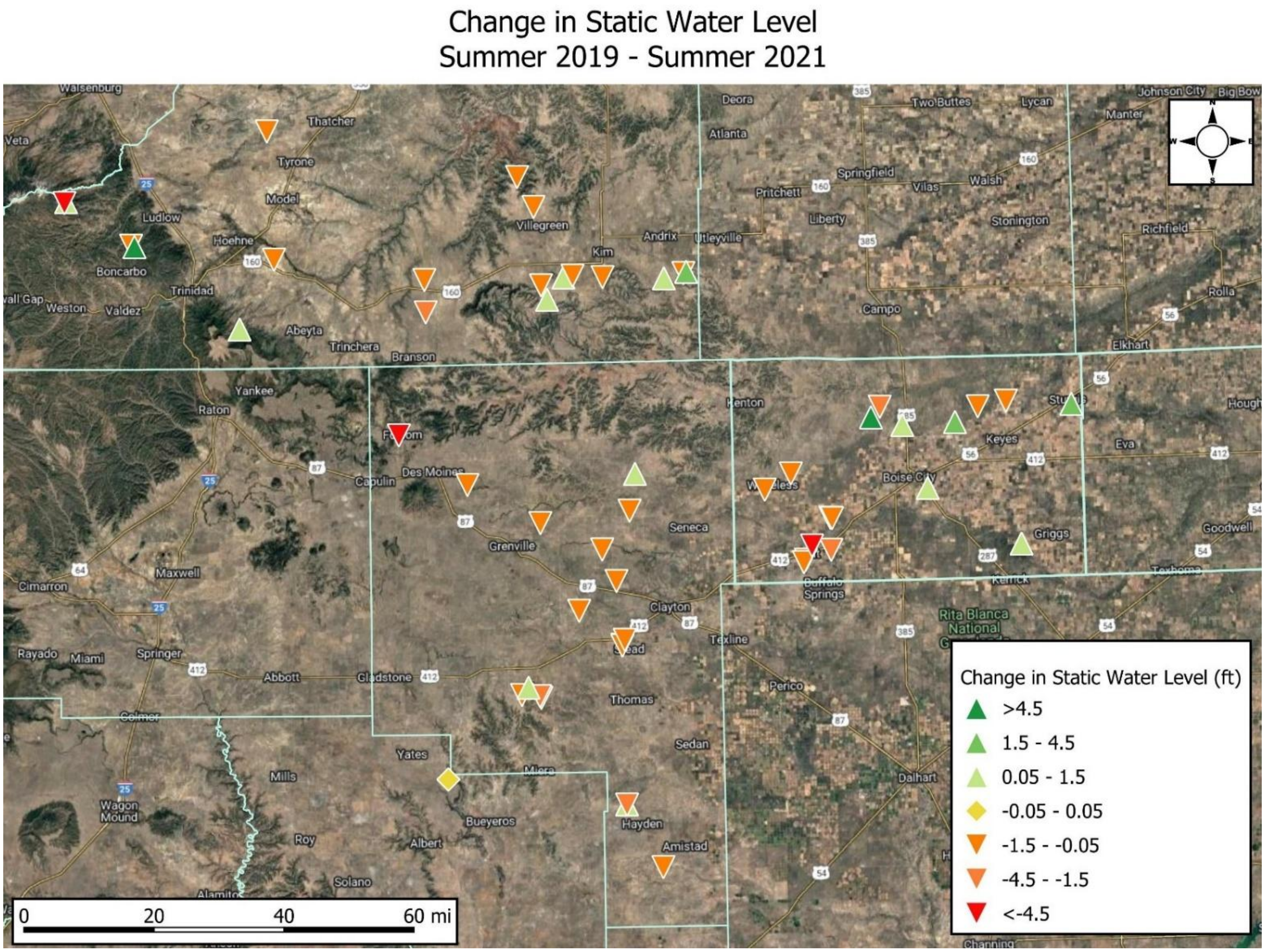
Change in Static Water Level
Winter 2020 - Winter 2022



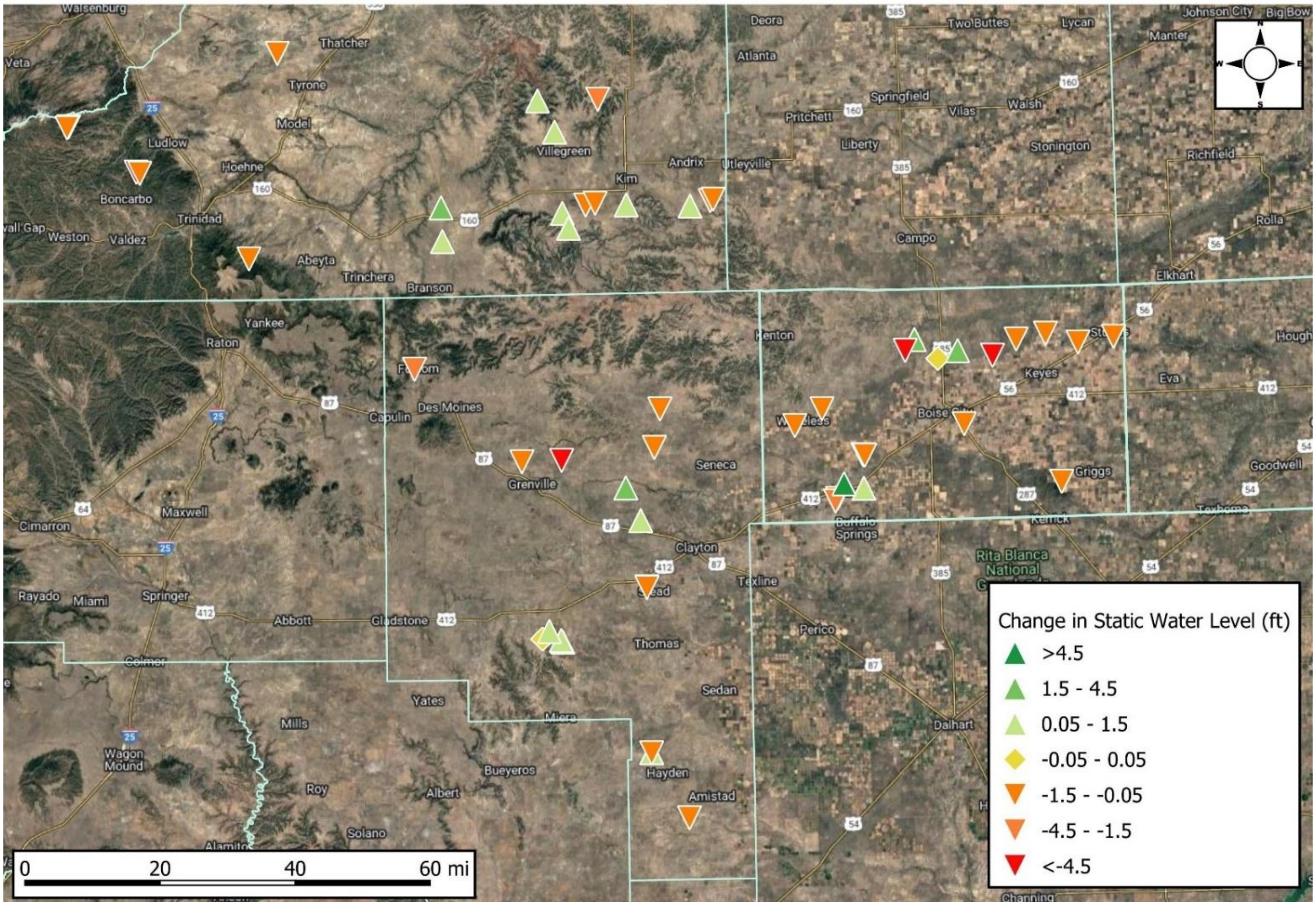
Change in Static Water Level
Winter 2022 - Winter 2023



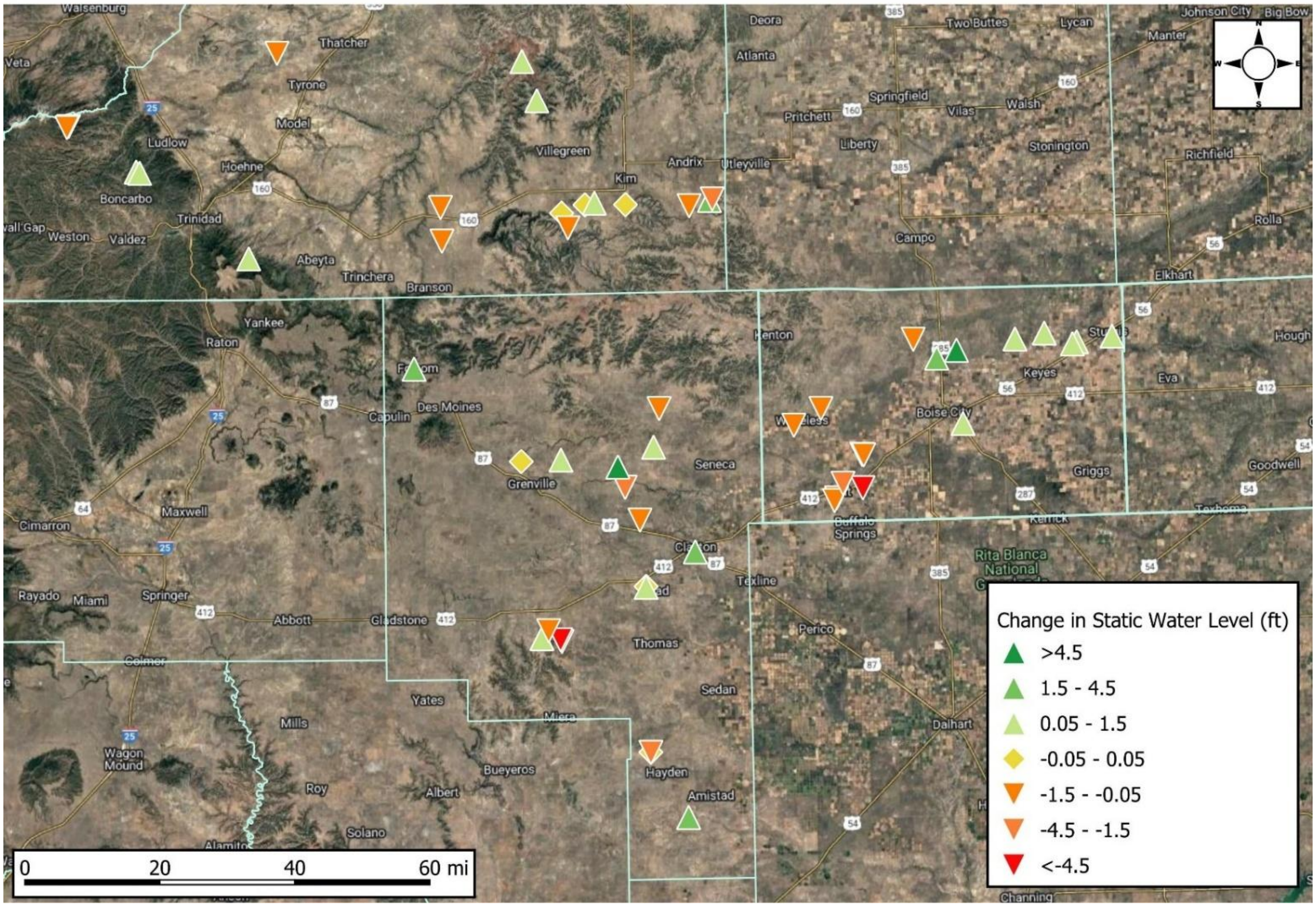
Summer Vs. Summer Comparisons



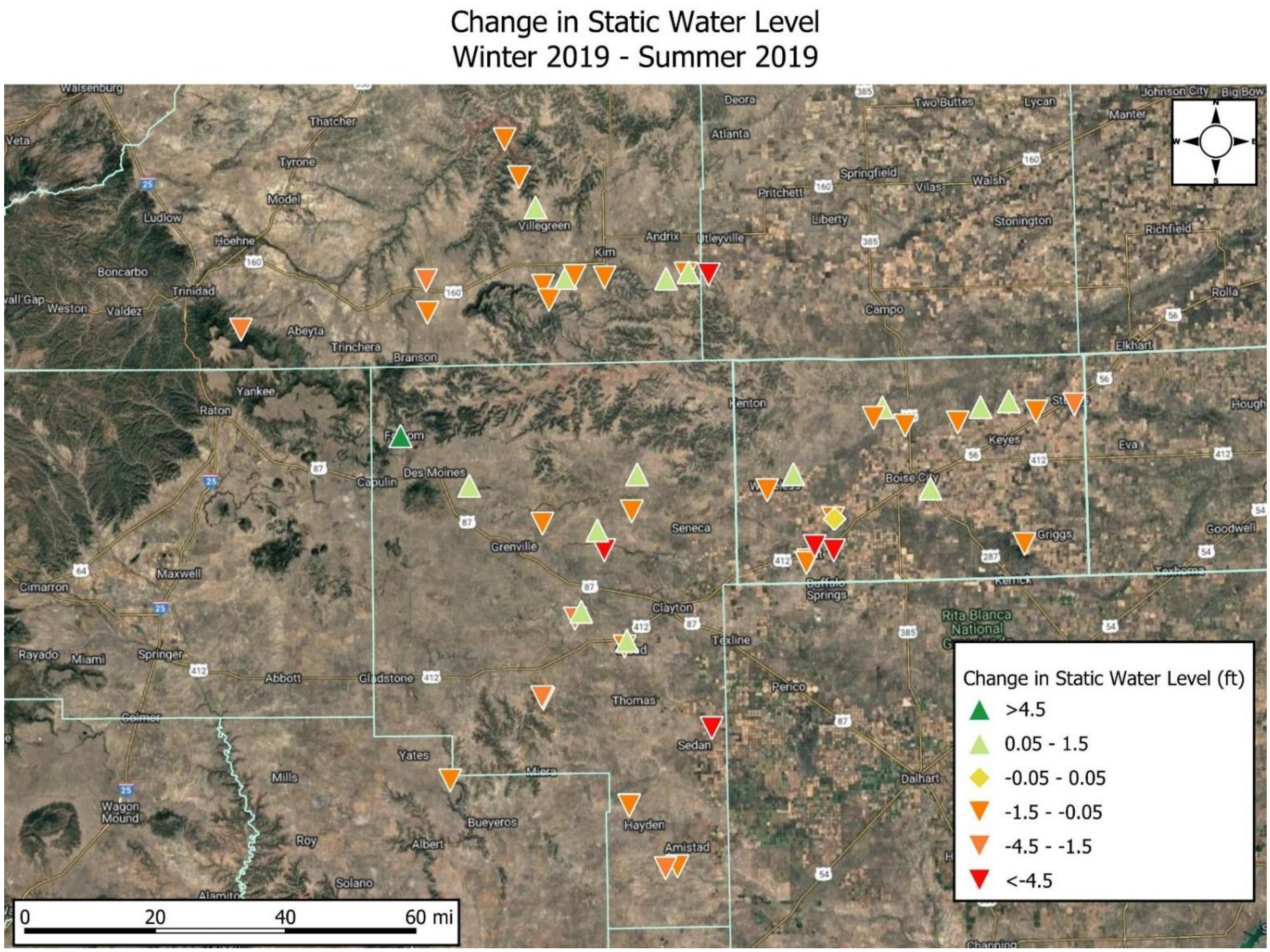
Change in Static Water Level
Summer 2021 - Summer 2022



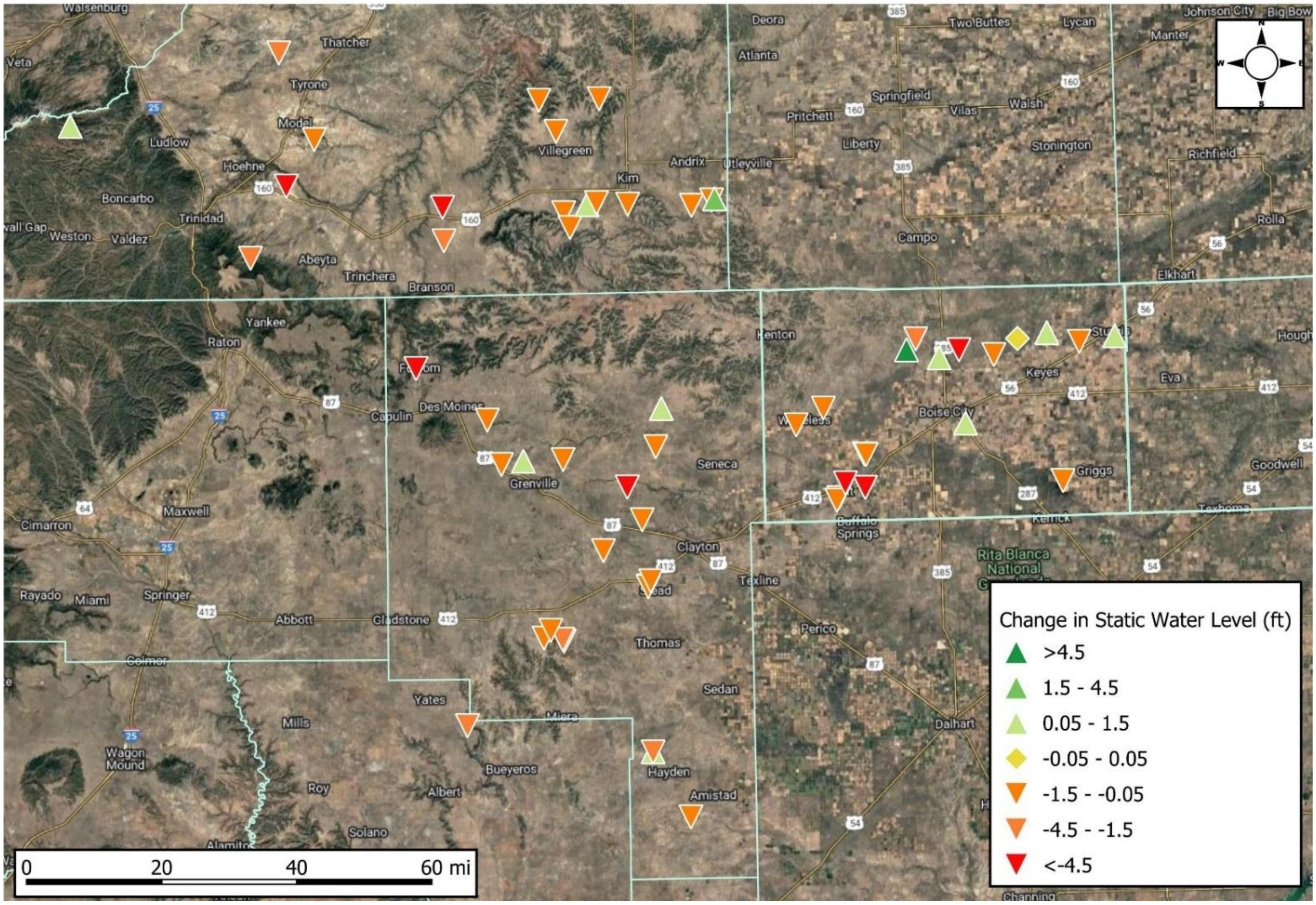
Change in Static Water Level
Summer 2022 - Summer 2023



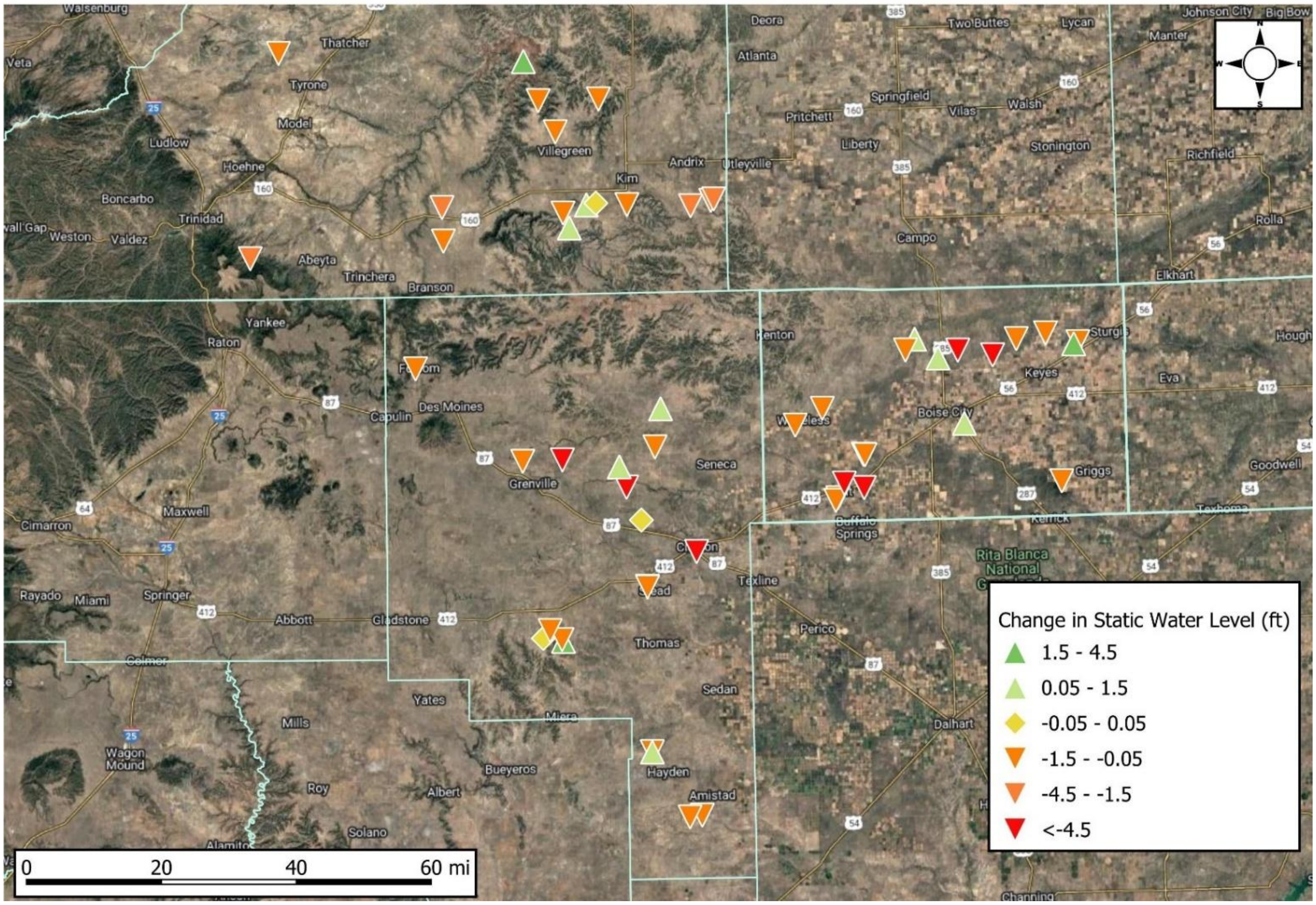
Winter Vs. Summer Comparisons



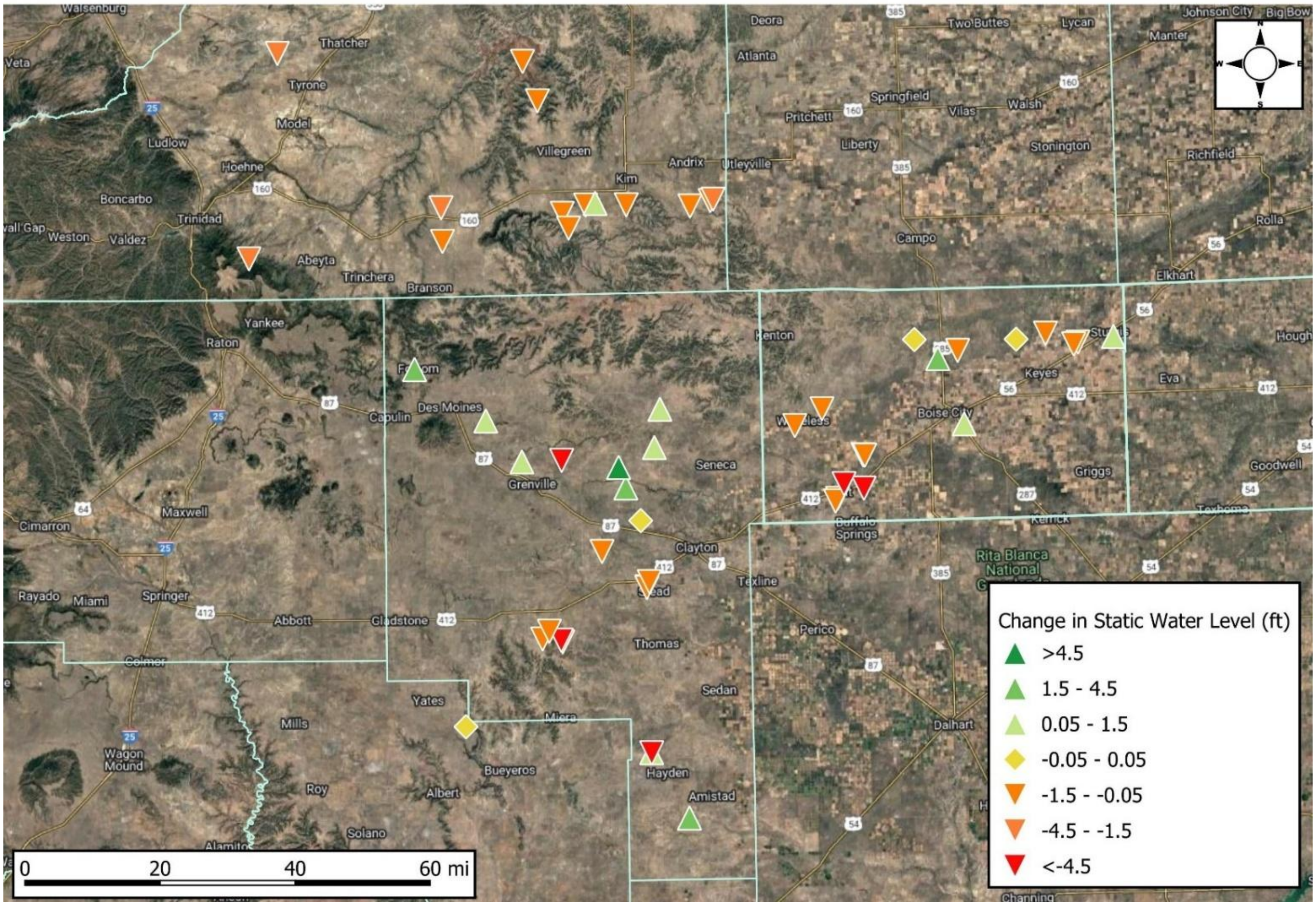
Change in Static Water Level
Winter 2020 - Summer 2021



Change in Static Water Level
Winter 2022 - Summer 2022

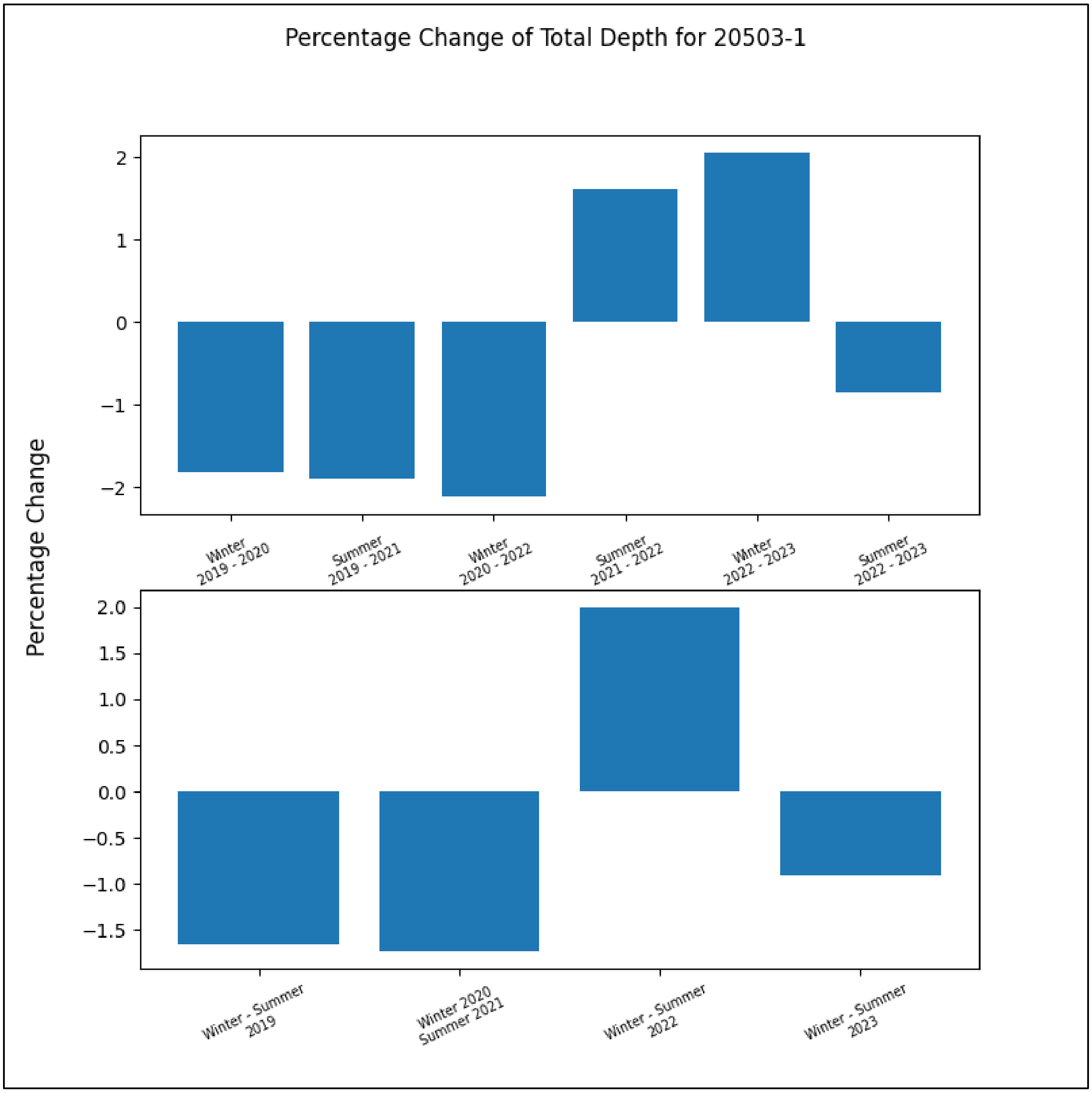


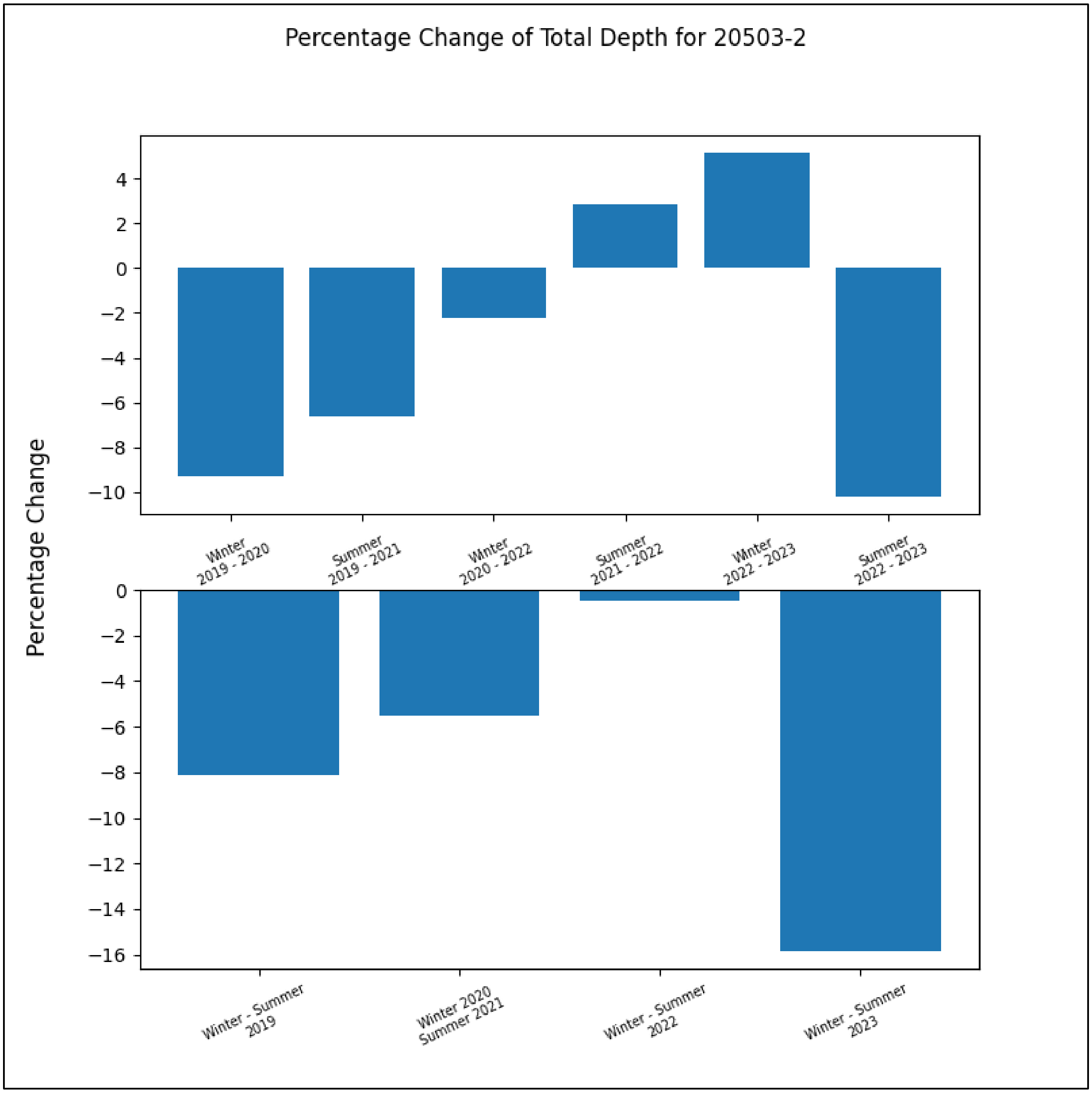
Change in Static Water Level
Winter 2023 - Summer 2023

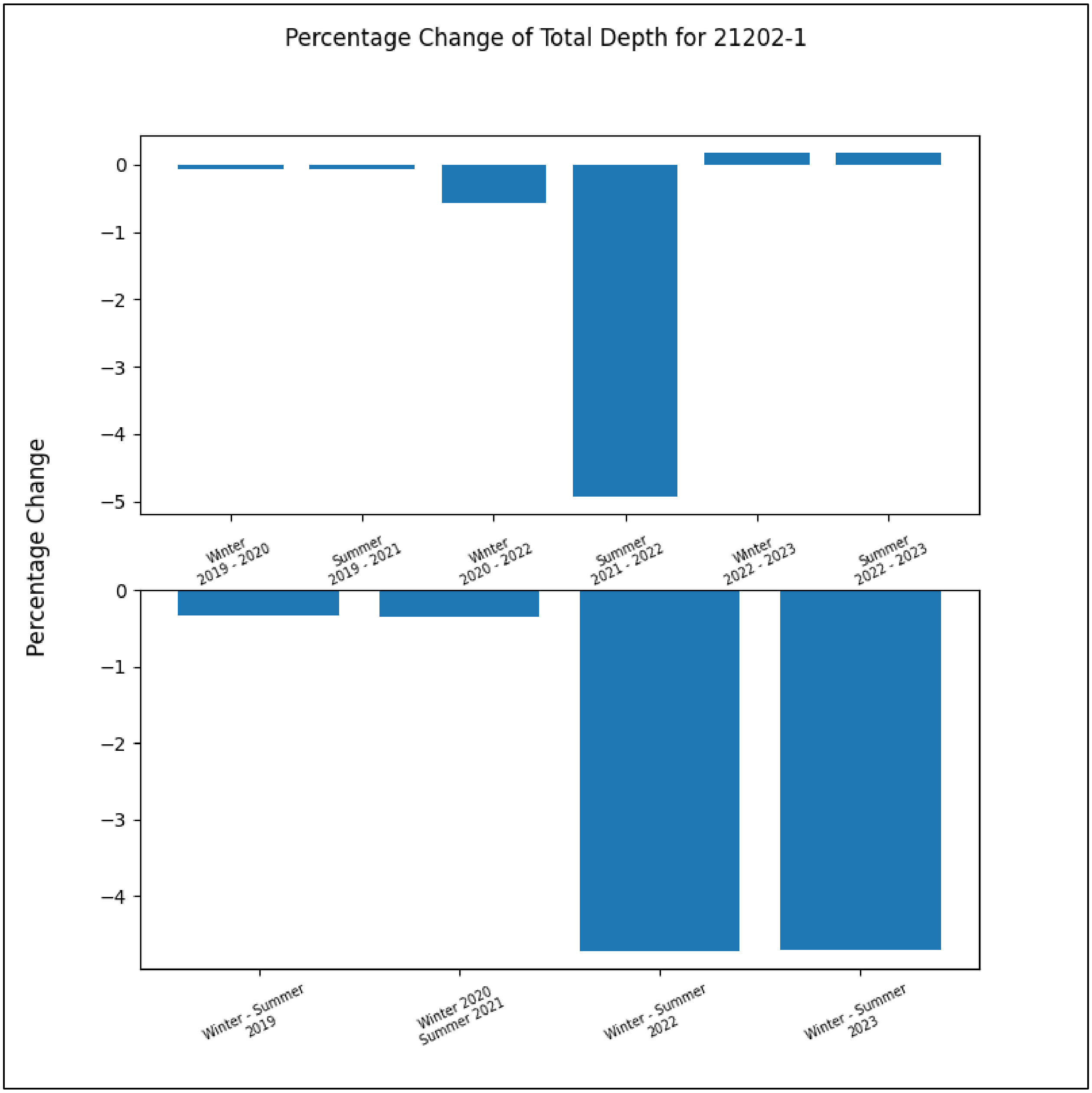


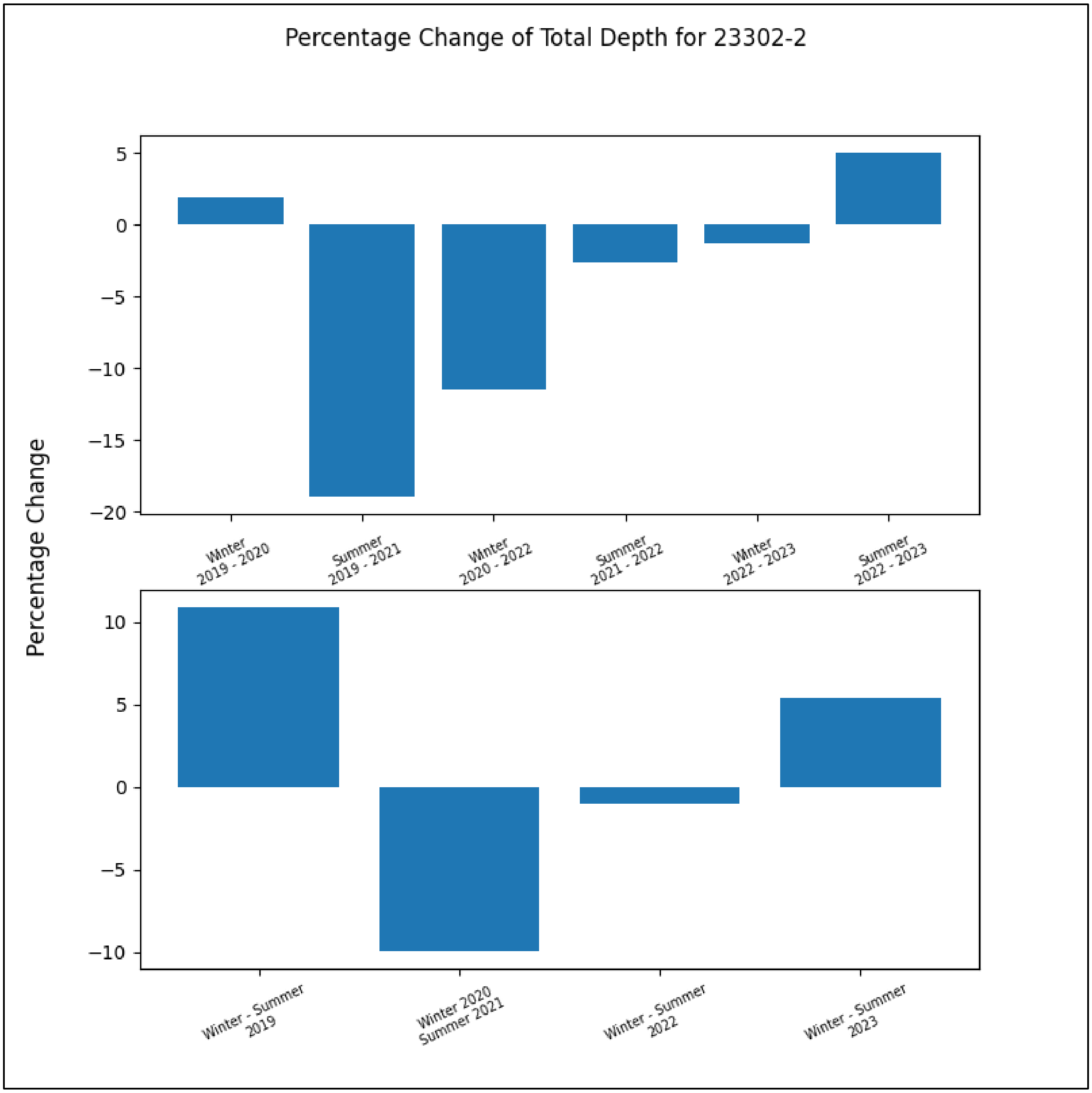
Appendix III: Percentage Change

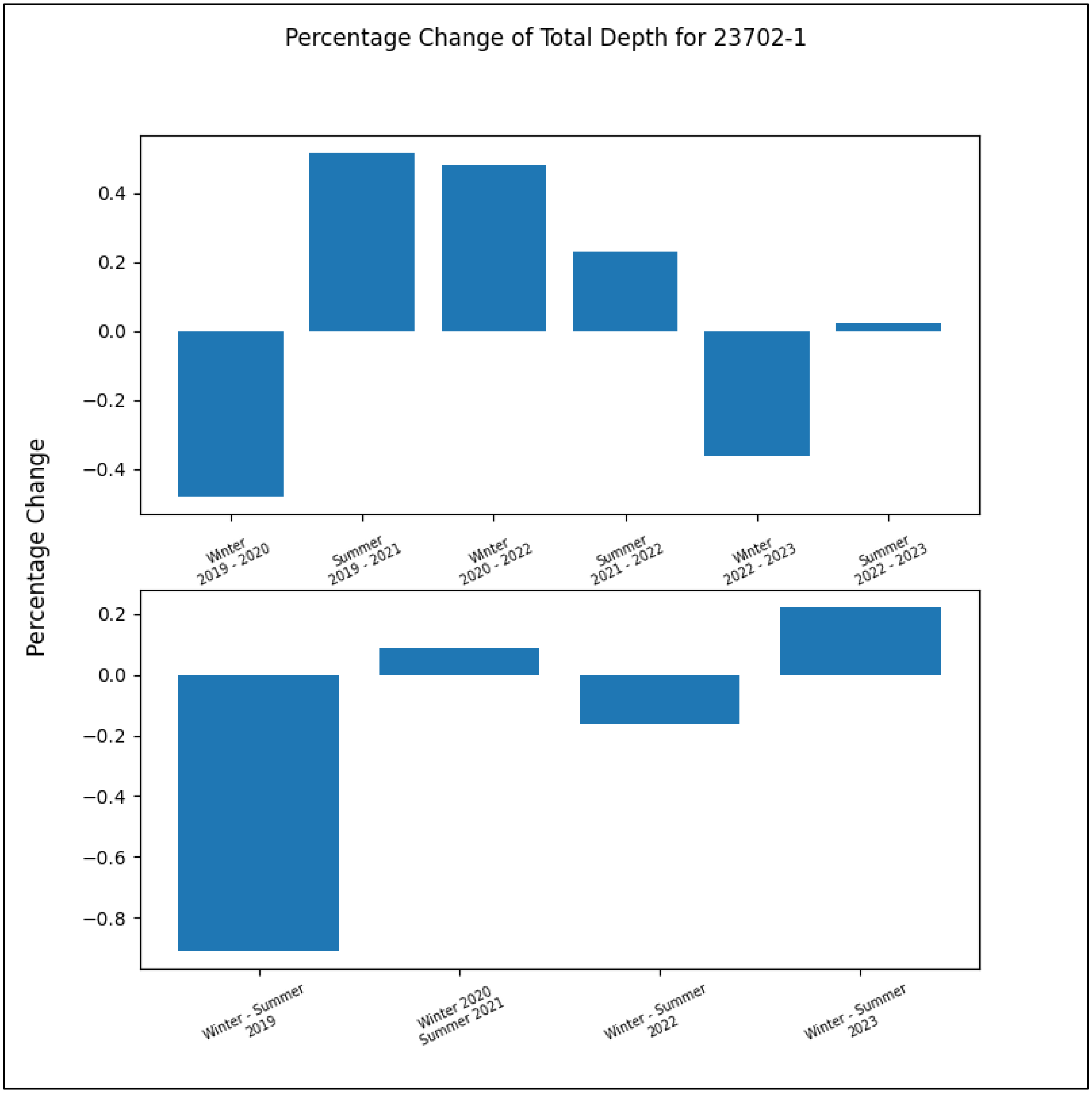
Union County

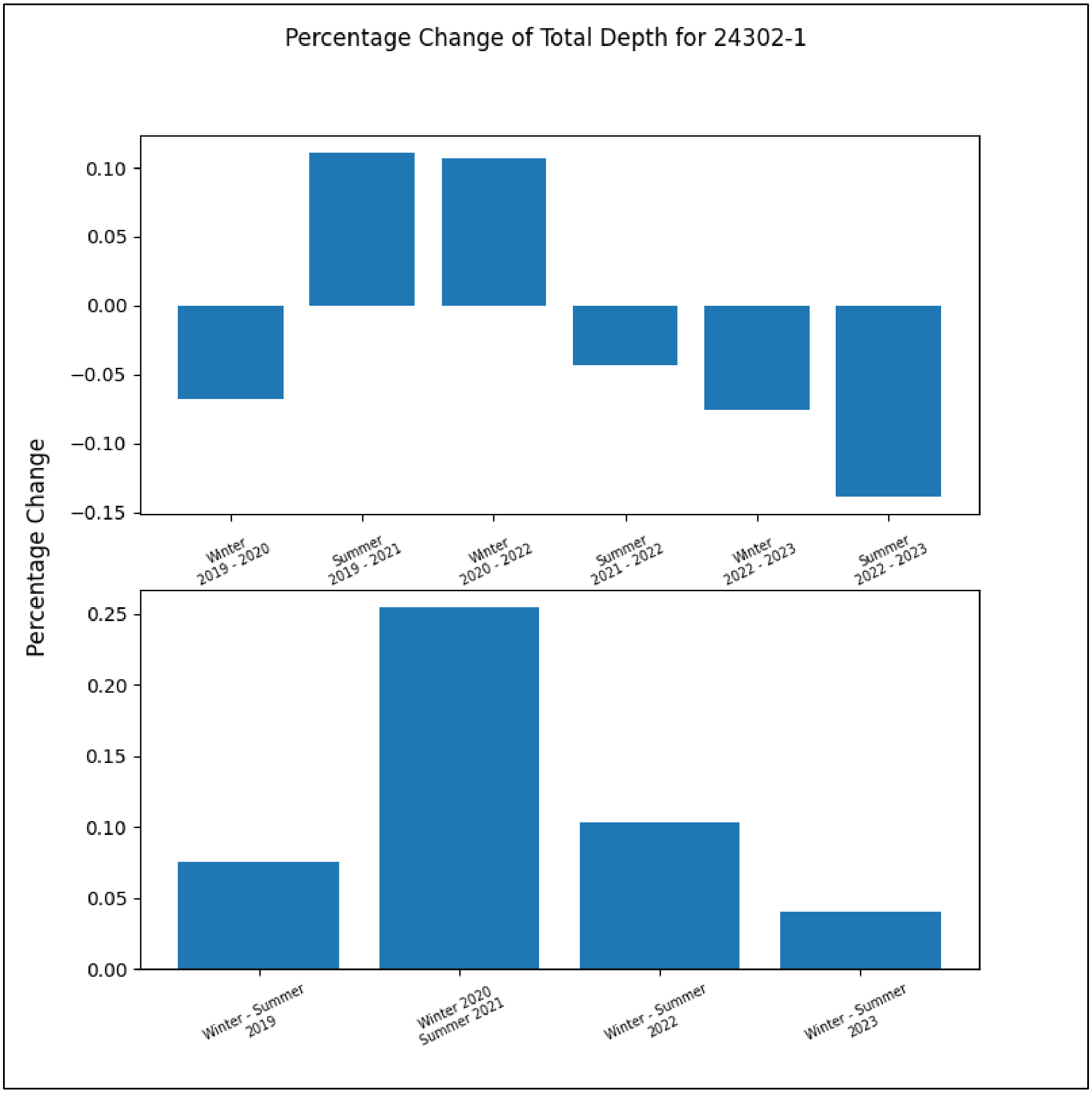



Percentage Change of Total Depth for 20503-2
Percentage Change
4
2
0
−2
−4
−6
−8
−10
Winter
2019 - 2020
Summer
2019 - 2021
Winter
2020 - 2022
Summer
2021 - 2022
Winter
2022 - 2023
Summer
2022 - 2023
0
−2
−4
−6
−8
−10
−12
−14
−16
Winter - Summer
2019
Winter 2020
Summer 2021
Winter - Summer
2022
Winter - Summer
2023

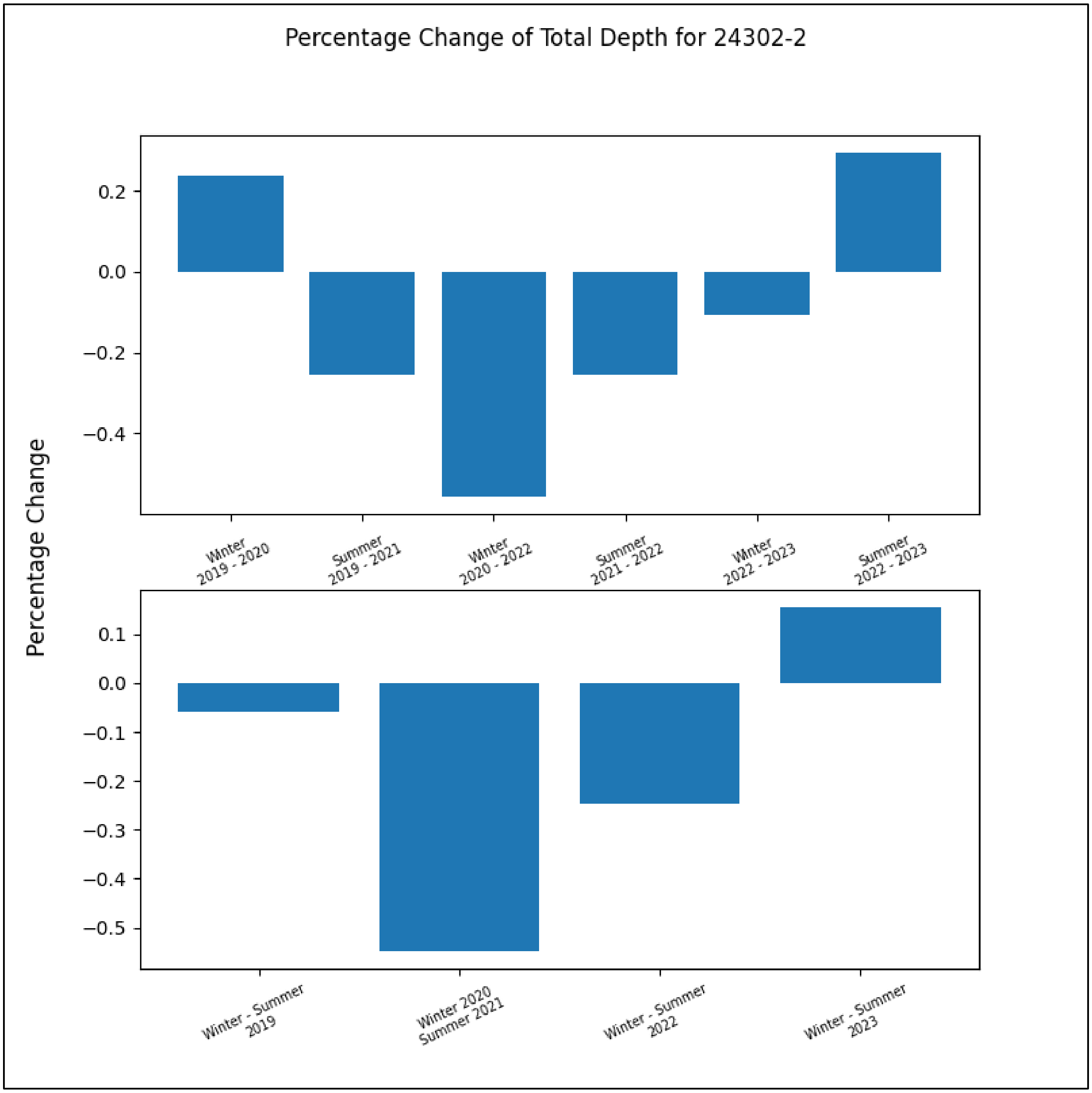

Percentage Change of Total Depth for 21202-1
Percentage Change
0
−1
−2
−3
−4
−5
Winter
2019 - 2020
Summer
2019 - 2021
Winter
2020 - 2022
Summer
2021 - 2022
Winter
2022 - 2023
Summer
2022 - 2023
Winter - Summer
2019
Winter 2020
Summer 2021
Winter - Summer
2022
Winter - Summer
2023


Percentage Change of Total Depth for 23302-2
Percentage Change
5
0
−5
−10
−15
−20
Winter 2019 - 2020
Summer 2019 - 2021
Winter 2020 - 2022
Summer 2021 - 2022
Winter 2022 - 2023
Summer 2022 - 2023
10
5
0
−5
−10
Winter - Summer 2019
Winter 2020 Summer 2021
Winter - Summer 2022
Winter - Summer 2023

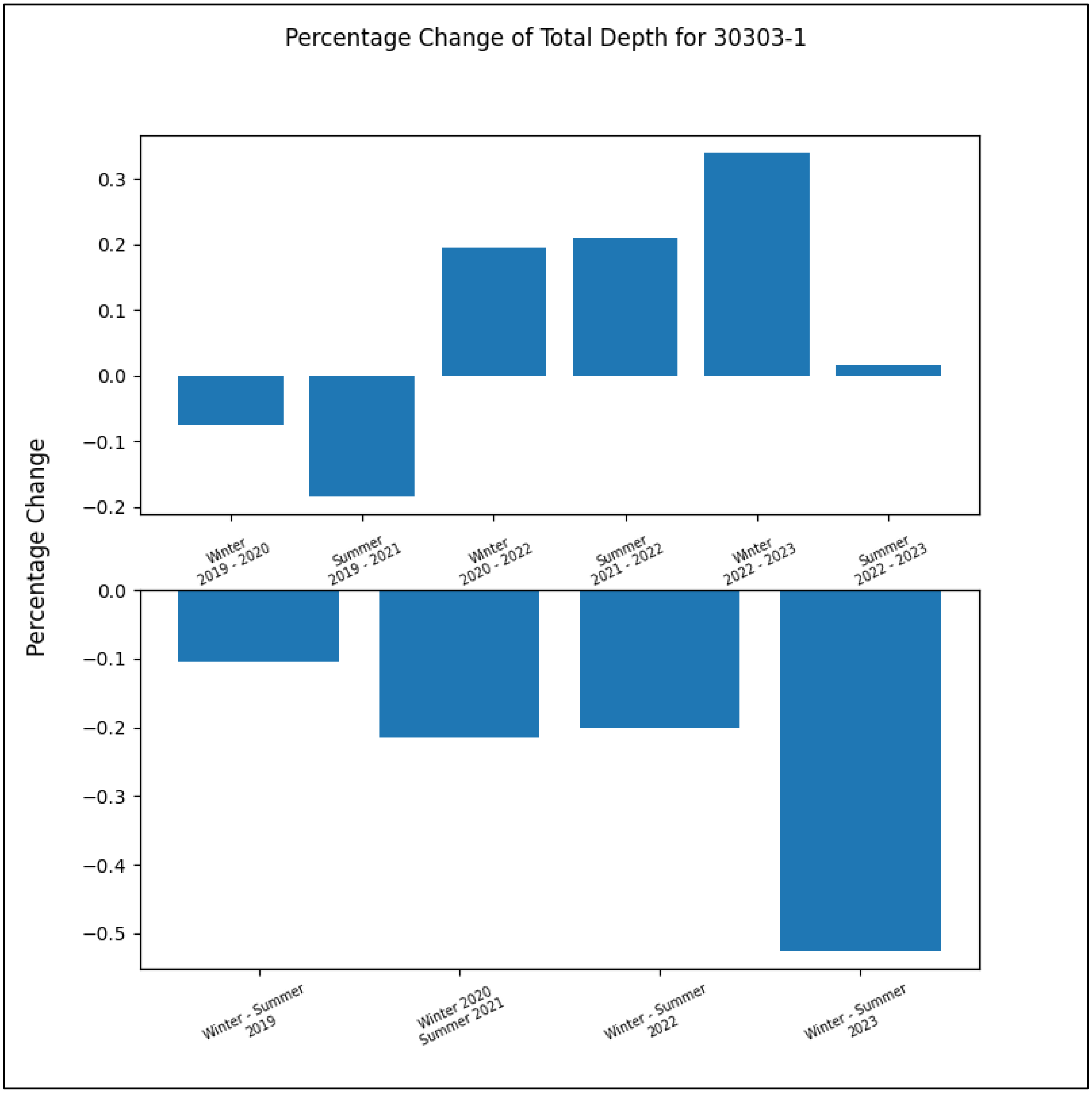

Percentage Change of Total Depth for 23702-1
Percentage Change
0.4
0.2
0.0
−0.2
−0.4
Winter 2019 - 2020
Summer 2019 - 2021
Winter 2020 - 2022
Summer 2021 - 2022
Winter 2022 - 2023
Summer 2022 - 2023
0.2
0.0
−0.2
−0.4
−0.6
−0.8
Winter - Summer 2019
Winter 2020 Summer 2021
Winter - Summer 2022
Winter - Summer 2023

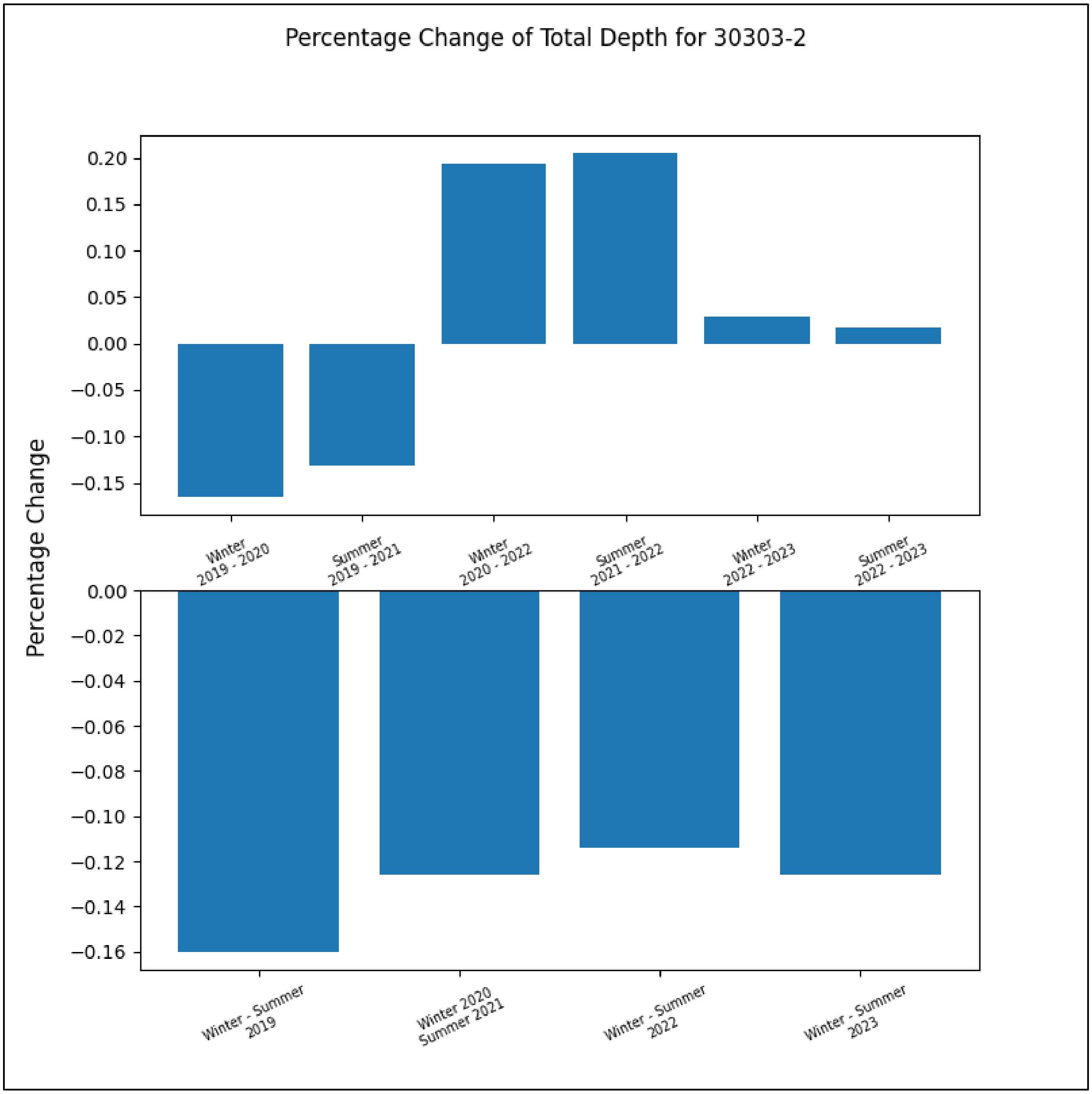


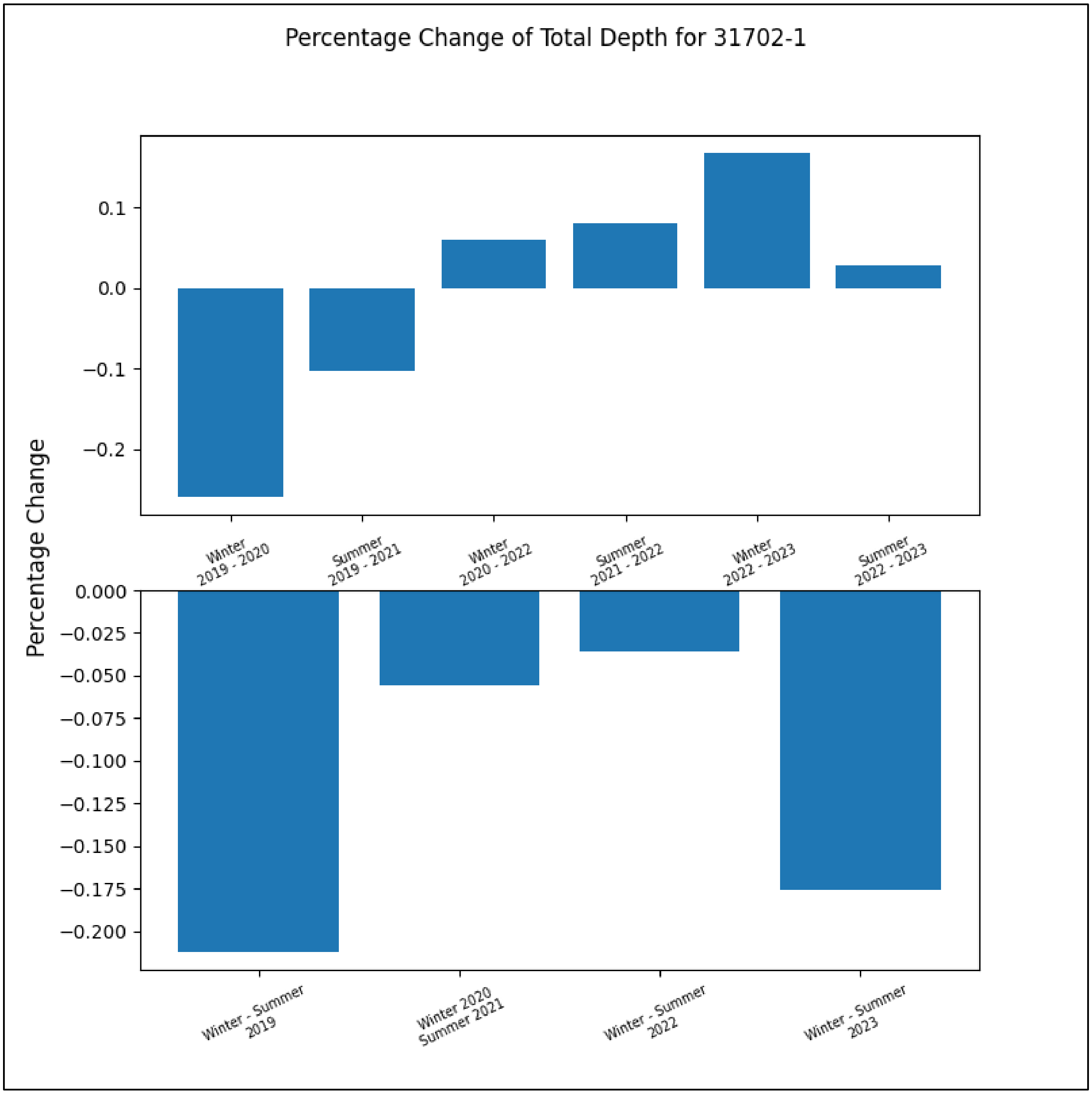
Percentage Change of Total Depth for 24302-1
Percentage Change
0.10
0.05
0.00
−0.05
−0.10
−0.15
Winter 2019 - 2020
Summer 2019 - 2021
Winter 2020 - 2022
Summer 2021 - 2022
Winter 2022 - 2023
Summer 2022 - 2023
0.25
0.20
0.15
0.10
0.05
0.00
Winter - Summer 2019
Winter 2020 Summer 2021
Winter - Summer 2022
Winter - Summer 2023

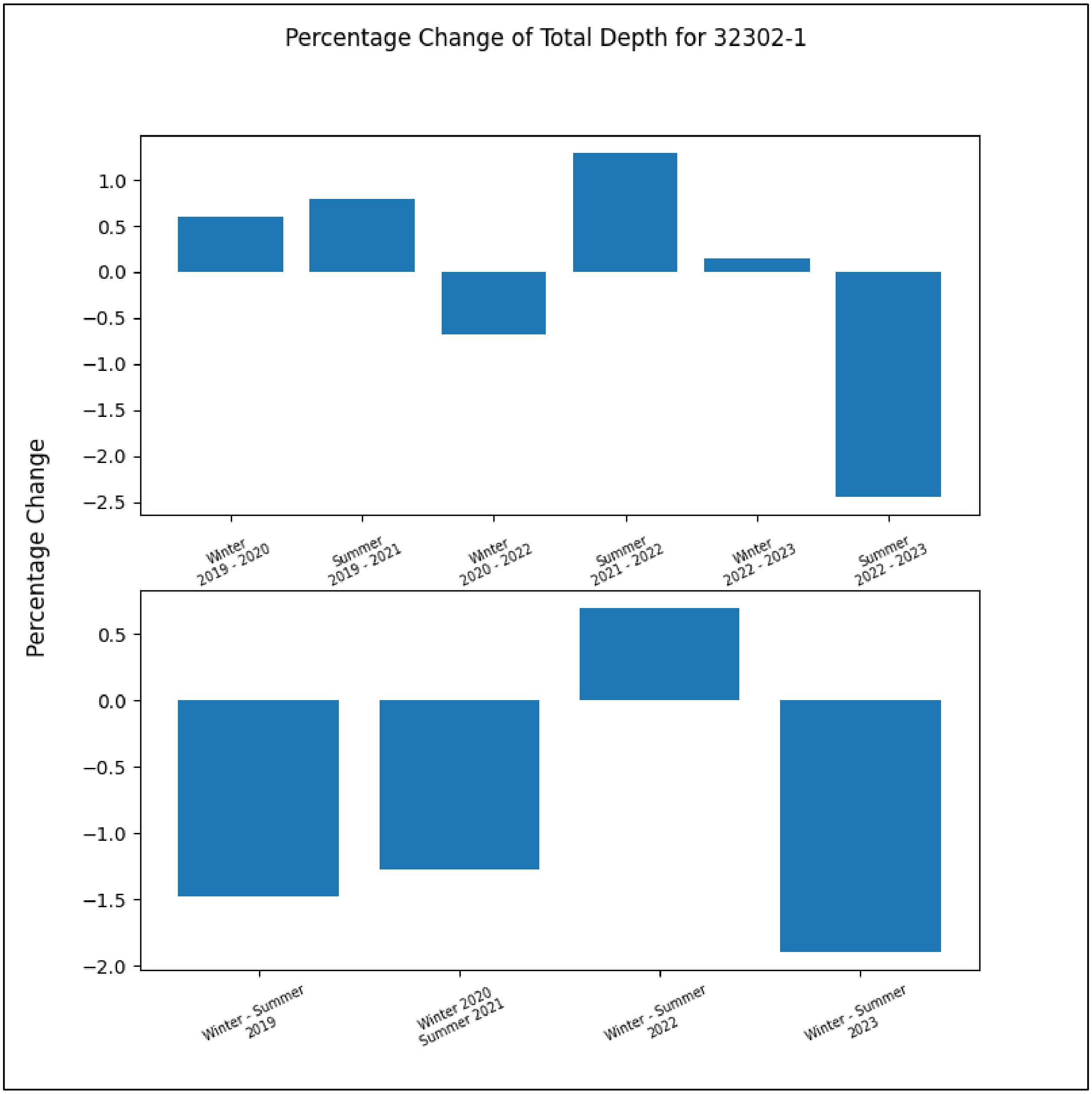


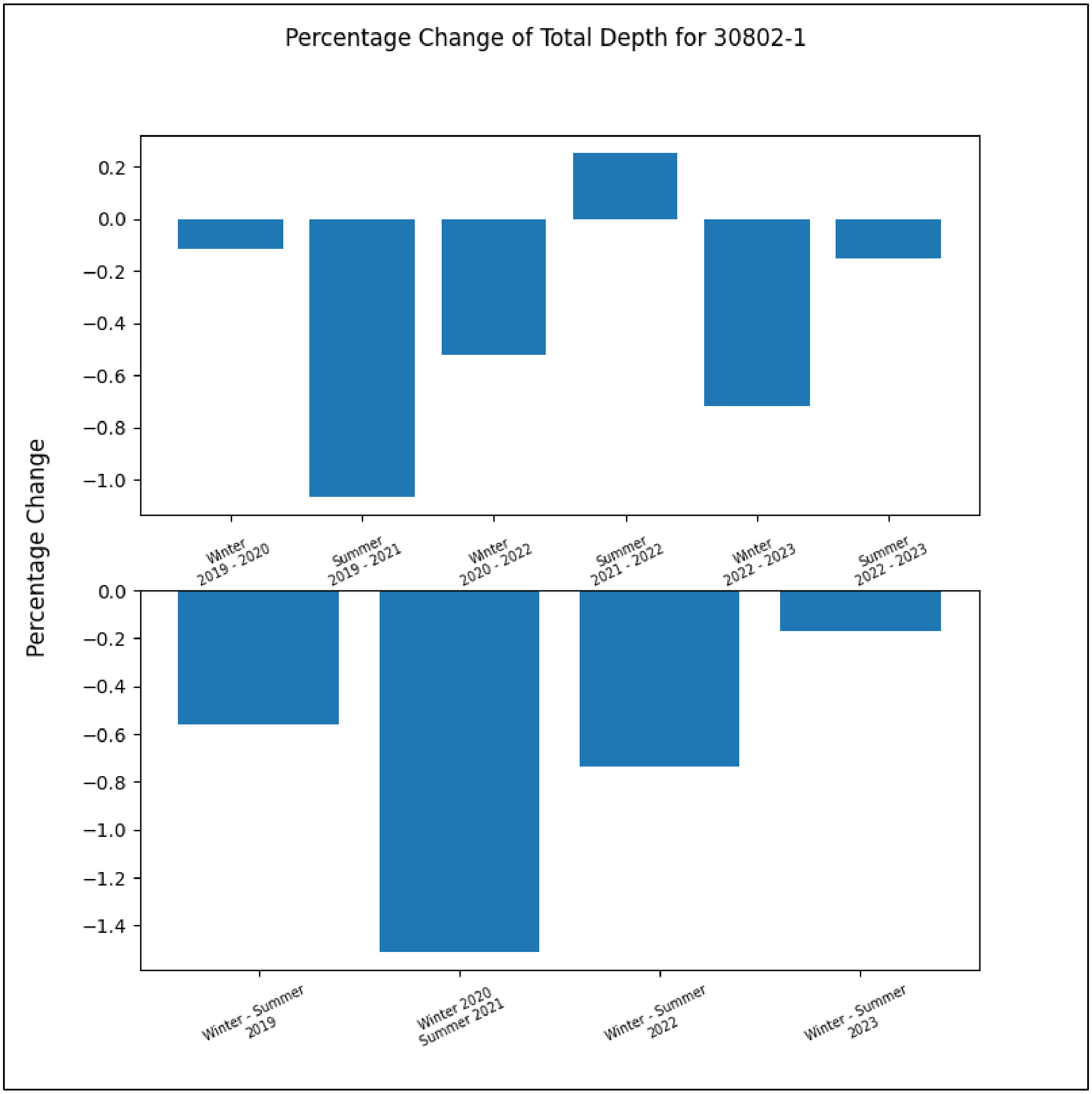
Percentage Change of Total Depth for 24302-2
Percentage Change
0.2
0.0
−0.2
−0.4
Winter 2019 - 2020
Summer 2019 - 2021
Winter 2020 - 2022
Summer 2021 - 2022
Winter 2022 - 2023
Summer 2022 - 2023
0.1
0.0
−0.1
−0.2
−0.3
−0.4
−0.5
Winter - Summer 2019
Winter 2020 Summer 2021
Winter - Summer 2022
Winter - Summer 2023

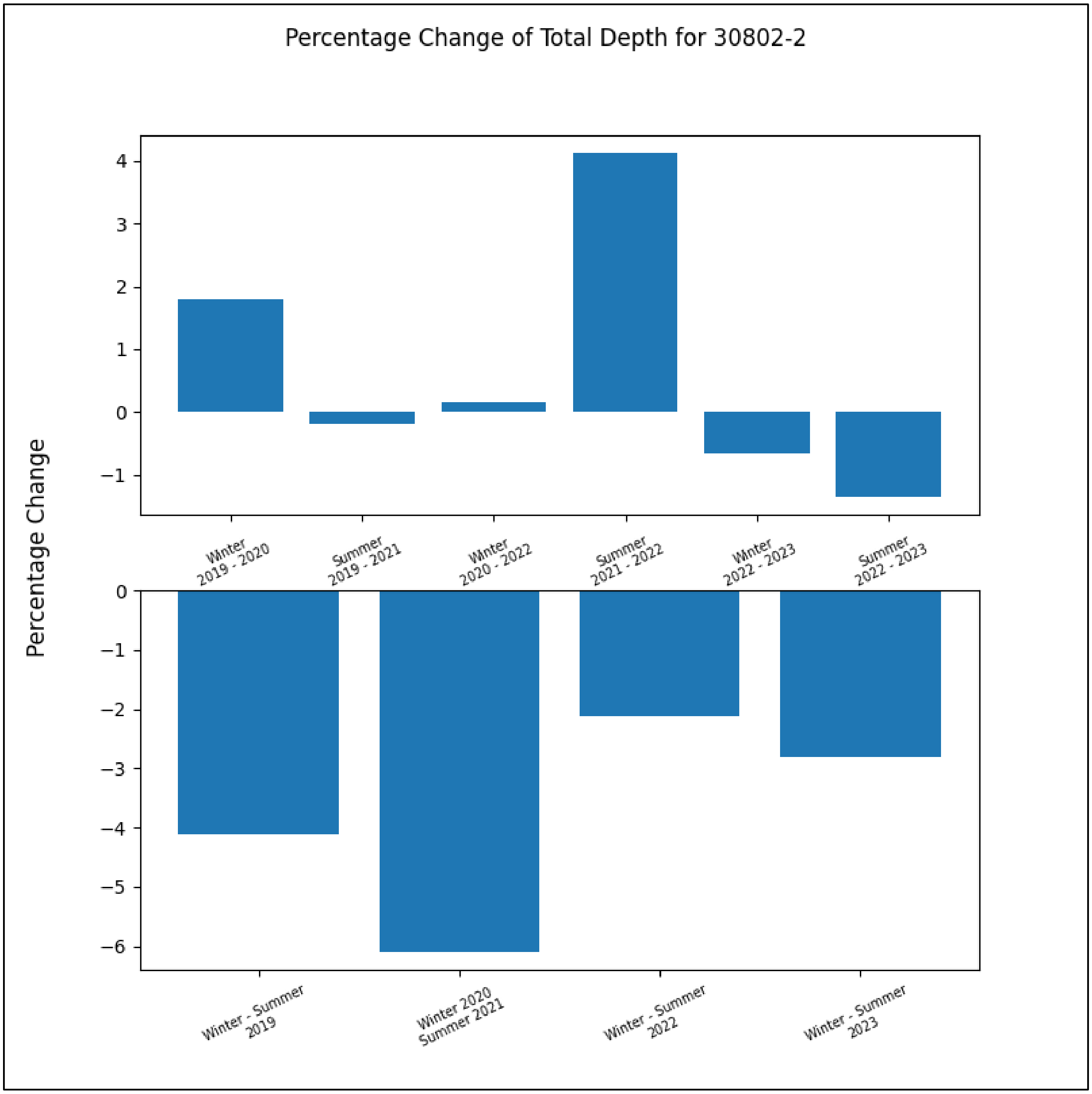

Percentage Change of Total Depth for 30303-1
Percentage Change
0.3
0.2
0.1
0.0
−0.1
−0.2
Winter 2019 - 2020
Summer 2019 - 2021
Winter 2020 - 2022
Summer 2021 - 2022
Winter 2022 - 2023
Summer 2022 - 2023
0.0
−0.1
−0.2
−0.3
−0.4
−0.5
Winter - Summer 2019
Winter 2020 Summer 2021
Winter - Summer 2022
Winter - Summer 2023


Percentage Change of Total Depth for 30303-2
Percentage Change
0.20
0.15
0.10
0.05
0.00
−0.05
−0.10
−0.15
Winter
2019 - 2020
Summer
2019 - 2021
Winter
2020 - 2022
Summer
2021 - 2022
Winter
2022 - 2023
Summer
2022 - 2023
0.00
−0.02
−0.04
−0.06
−0.08
−0.10
−0.12
−0.14
−0.16
Winter - Summer
2019
Winter 2020
Summer 2021
Winter - Summer
2022
Winter - Summer
2023

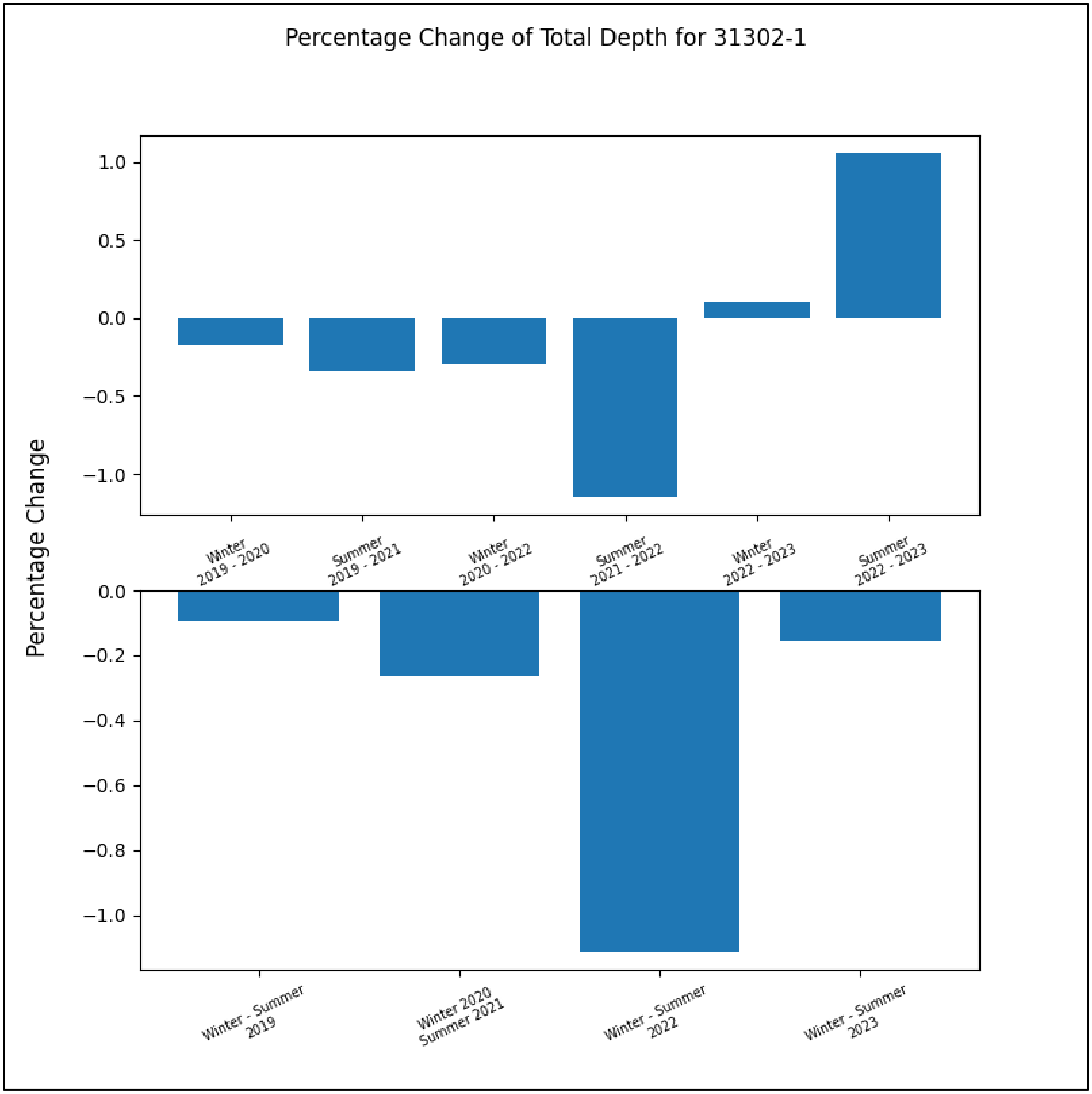

Percentage Change of Total Depth for 31702-1
Percentage Change
0.1
0.0
−0.1
−0.2
Winter 2019 - 2020
Summer 2019 - 2021
Winter 2020 - 2022
Summer 2021 - 2022
Winter 2022 - 2023
Summer 2022 - 2023
0.000
−0.025
−0.050
−0.075
−0.100
−0.125
−0.150
−0.175
−0.200
Winter - Summer 2019
Winter 2020 Summer 2021
Winter - Summer 2022
Winter - Summer 2023

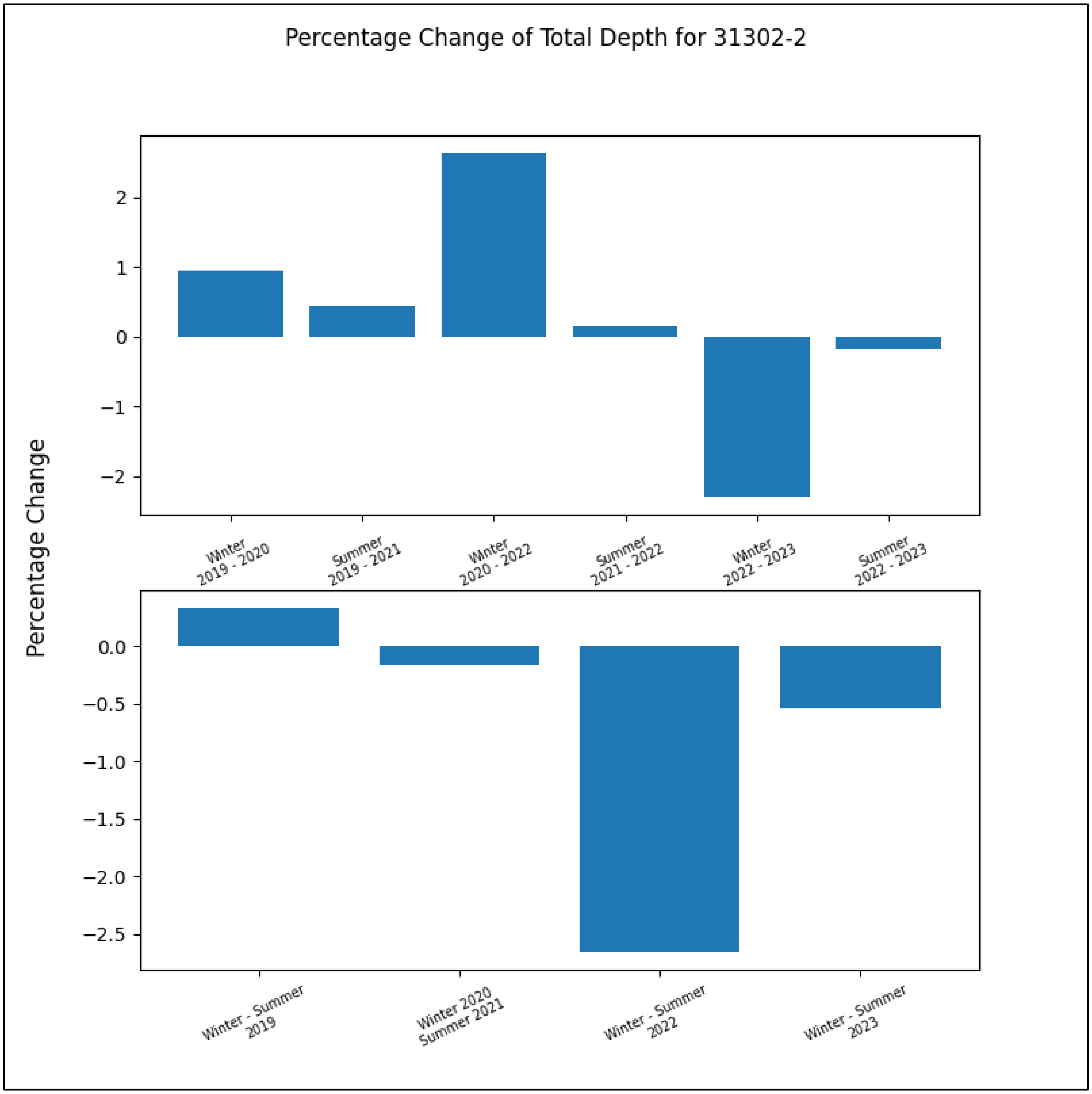

Percentage Change of Total Depth for 32302-1
Percentage Change
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
Winter 2019 - 2020
Summer 2019 - 2021
Winter 2020 - 2022
Summer 2021 - 2022
Winter 2022 - 2023
Summer 2022 - 2023
−2.0
Winter - Summer 2019
Winter 2020 Summer 2021
Winter - Summer 2022
Winter - Summer 2023

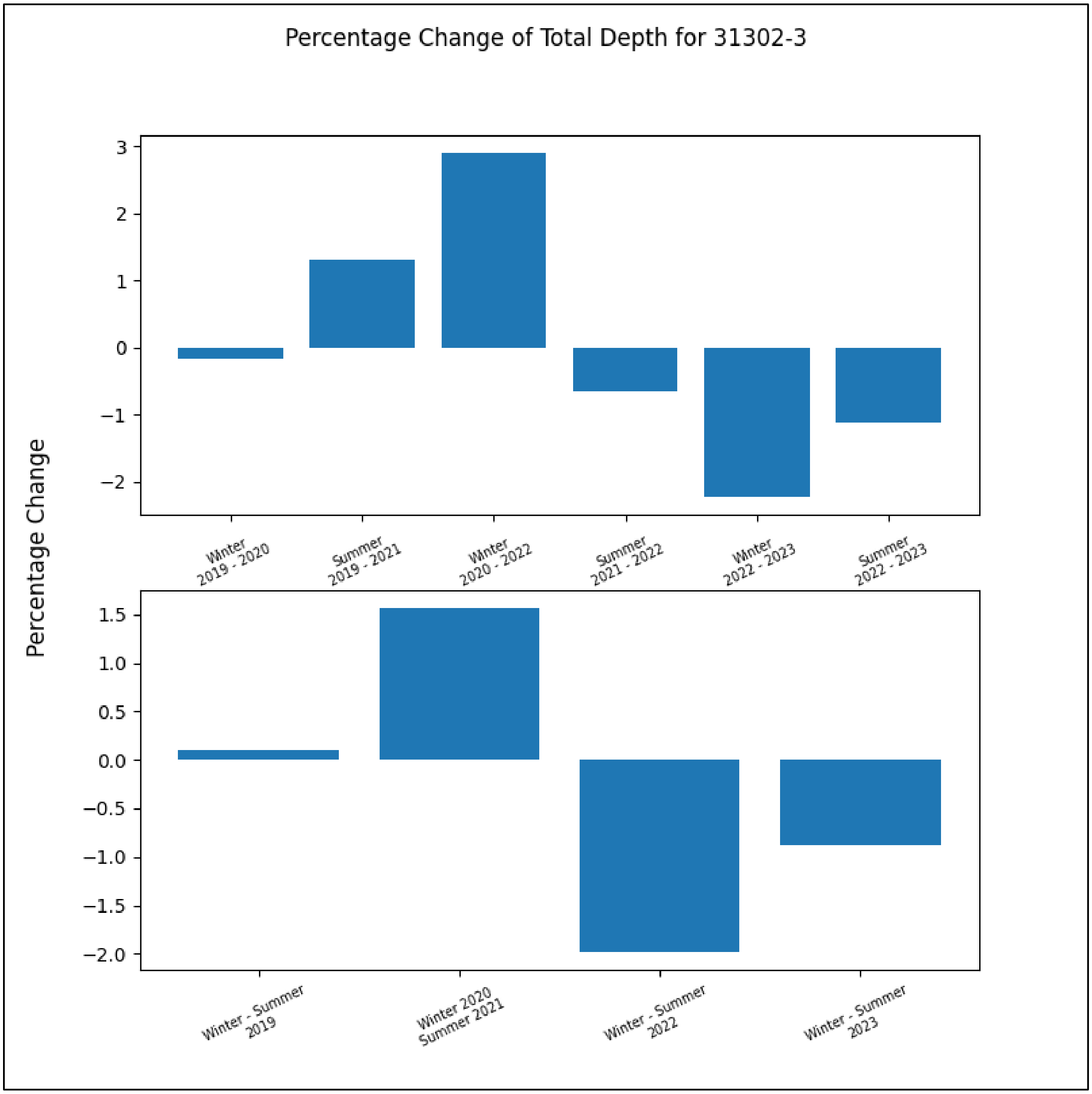

Percentage Change of Total Depth for 30802-1
Percentage Change
0.2
0.0
−0.2
−0.4
−0.6
−0.8
−1.0
Winter 2019 - 2020
Summer 2019 - 2021
Winter 2020 - 2022
Summer 2021 - 2022
Winter 2022 - 2023
Summer 2022 - 2023
0.0
−0.2
−0.4
−0.6
−0.8
−1.0
−1.2
−1.4
Winter - Summer 2019
Winter 2020 Summer 2021
Winter - Summer 2022
Winter - Summer 2023



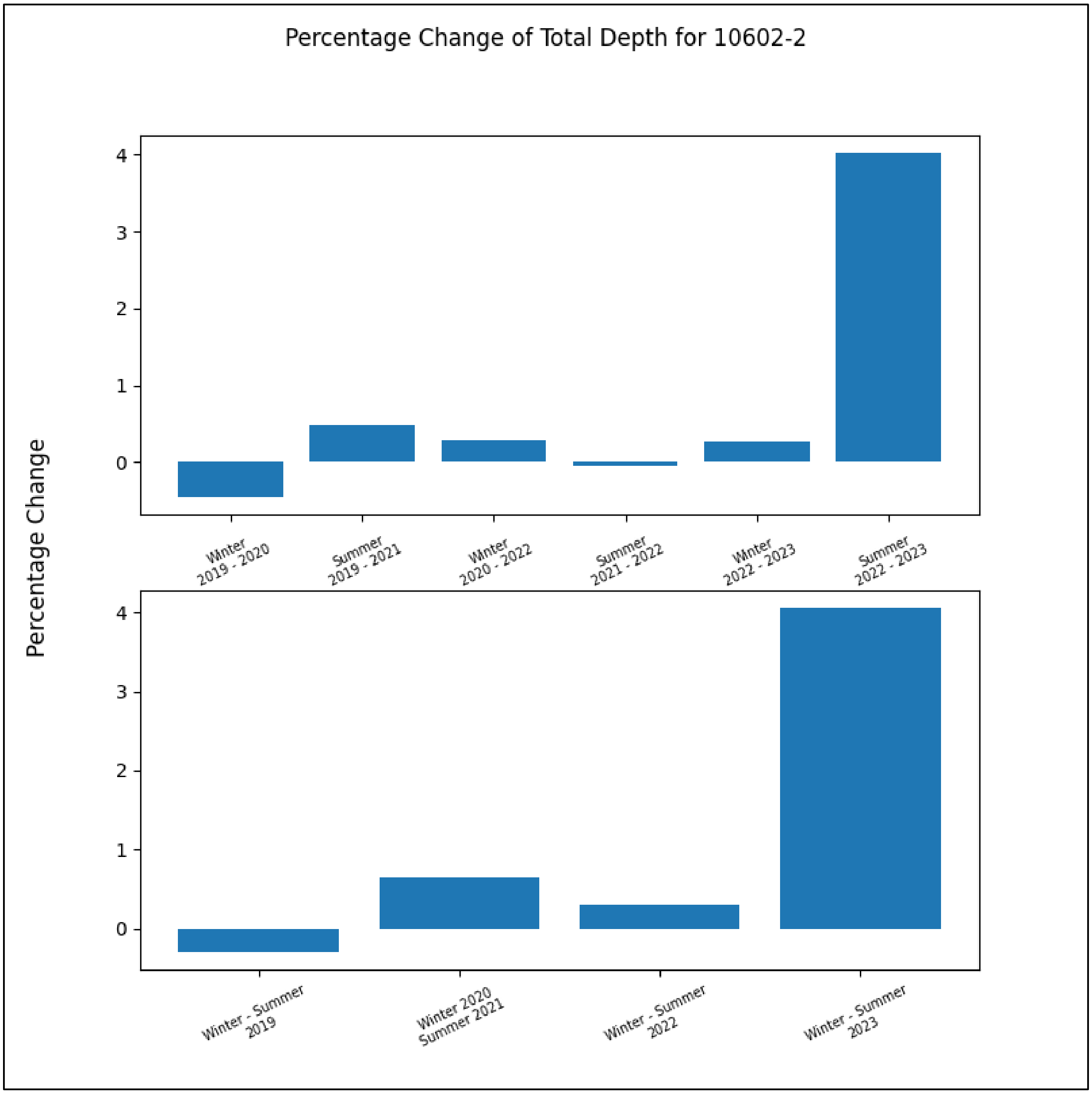
Percentage Change of Total Depth for 30802-2
Percentage Change
4
3
2
1
0
−1
Winter
2019 - 2020
Summer
2019 - 2021
Winter
2020 - 2022
Summer
2021 - 2022
Winter
2022 - 2023
Summer
2022 - 2023
0
−1
−2
−3
−4
−5
−6
Winter - Summer
2019
Winter 2020
Summer 2021
Winter - Summer
2022
Winter - Summer
2023

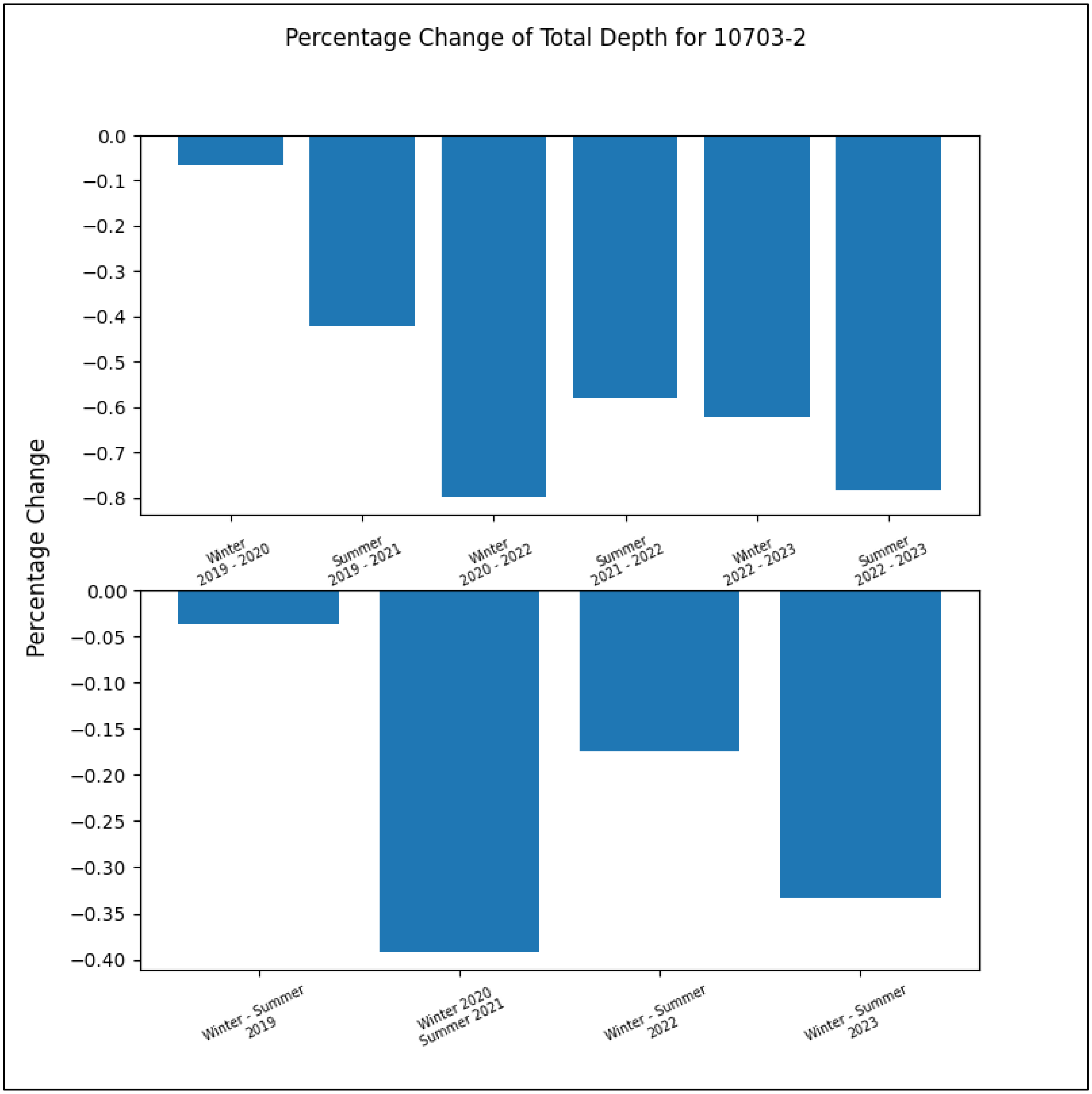

Percentage Change of Total Depth for 31302-1
Percentage Change
1.0
0.5
0.0
−0.5
−1.0
Winter 2019 - 2020
Summer 2019 - 2021
Winter 2020 - 2022
Summer 2021 - 2022
Winter 2022 - 2023
Summer 2022 - 2023
0.0
−0.2
−0.4
−0.6
−0.8
−1.0
Winter - Summer 2019
Winter 2020 Summer 2021
Winter - Summer 2022
Winter - Summer 2023


Percentage Change of Total Depth for 31302-2
Percentage Change
2
1
0
−1
−2
Winter 2019 - 2020
Summer 2019 - 2021
Winter 2020 - 2022
Summer 2021 - 2022
Winter 2022 - 2023
Summer 2022 - 2023
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
Winter - Summer 2019
Winter 2020 Summer 2021
Winter - Summer 2022
Winter - Summer 2023

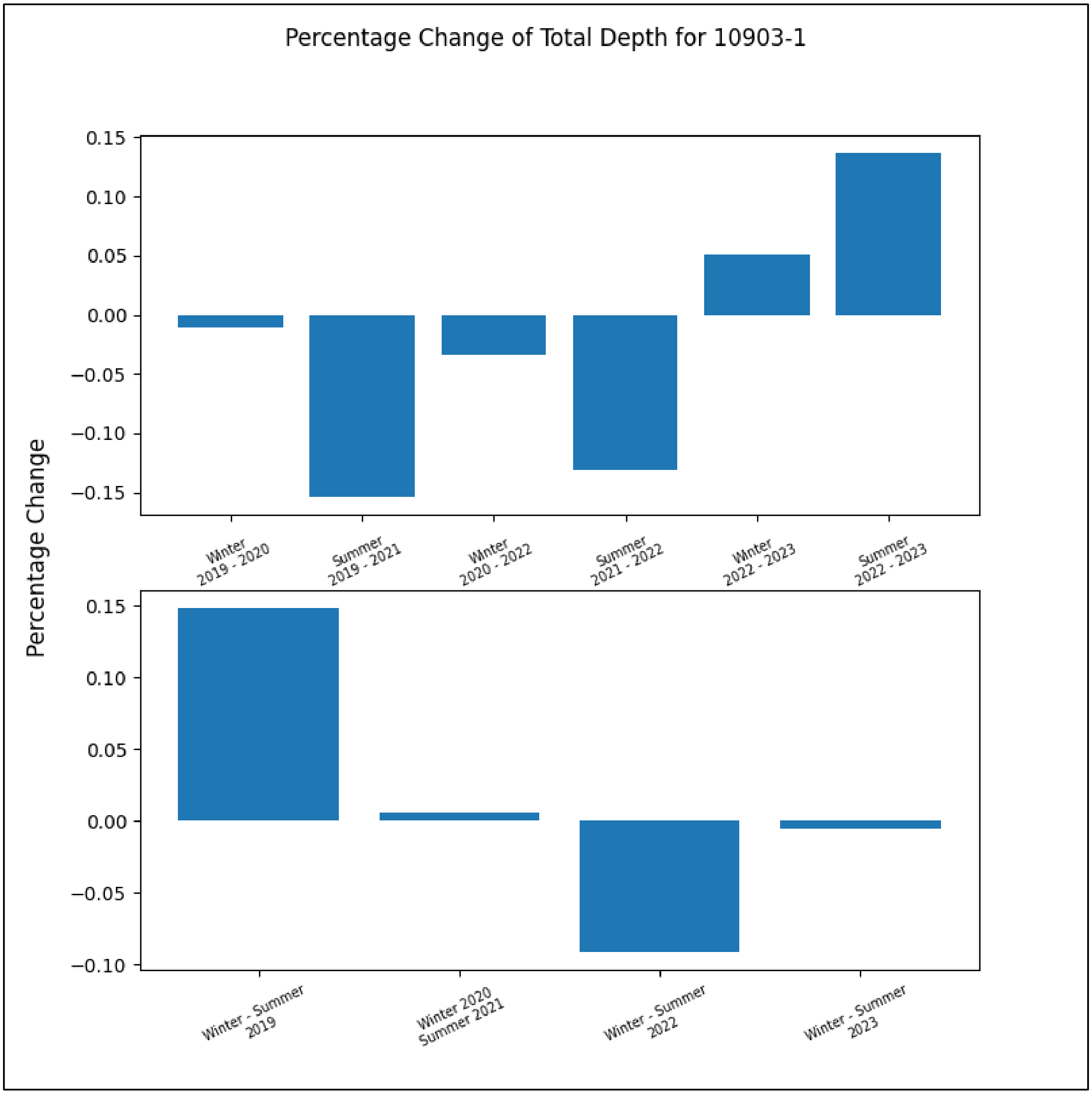

Percentage Change of Total Depth for 31302-3
Percentage Change
3
2
1
0
−1
−2
Winter 2019 - 2020
Summer 2019 - 2021
Winter 2020 - 2022
Summer 2021 - 2022
Winter 2022 - 2023
Summer 2022 - 2023
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
Winter - Summer 2019
Winter 2020 Summer 2021
Winter - Summer 2022
Winter - Summer 2023

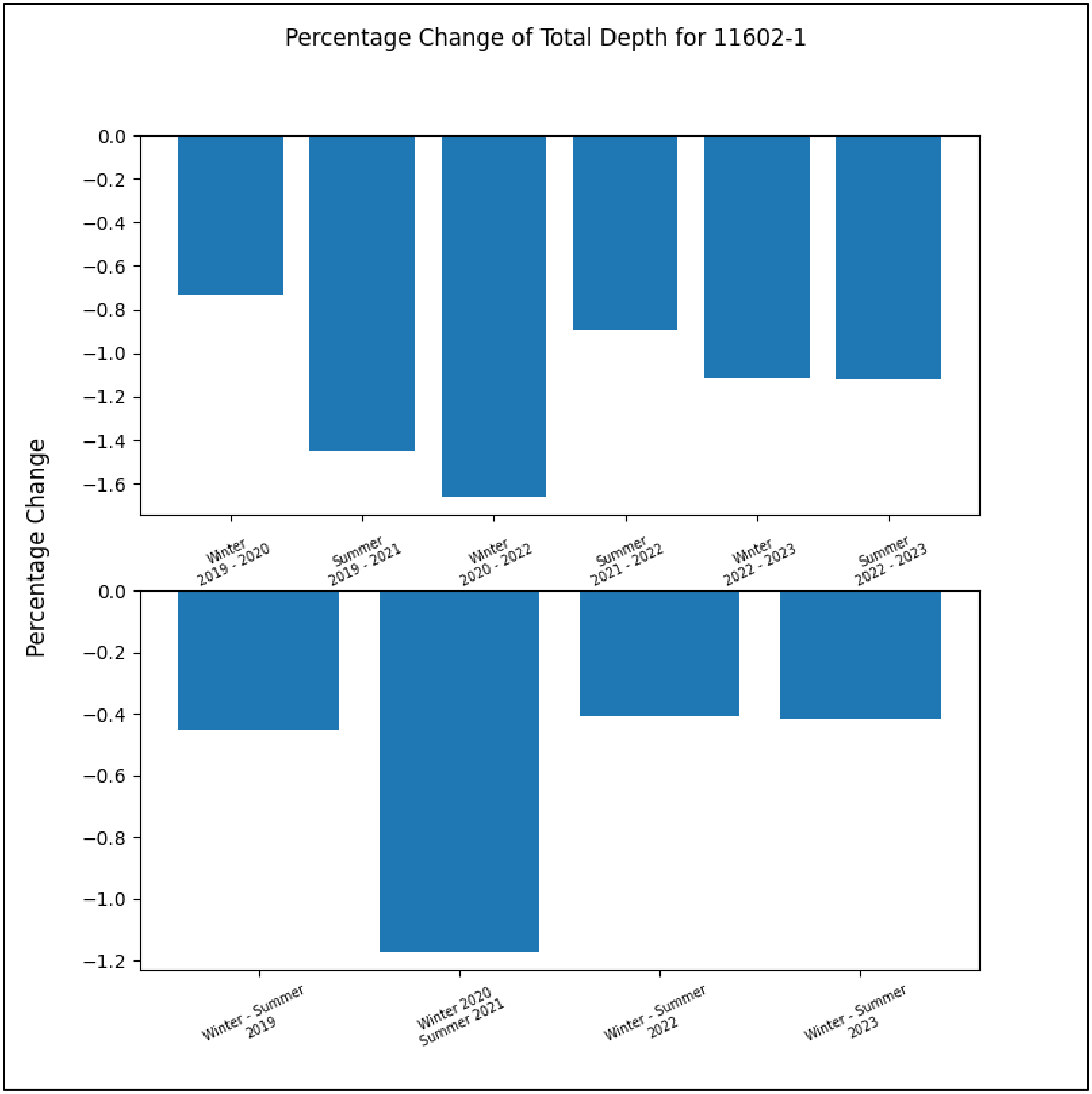
Cimarron County

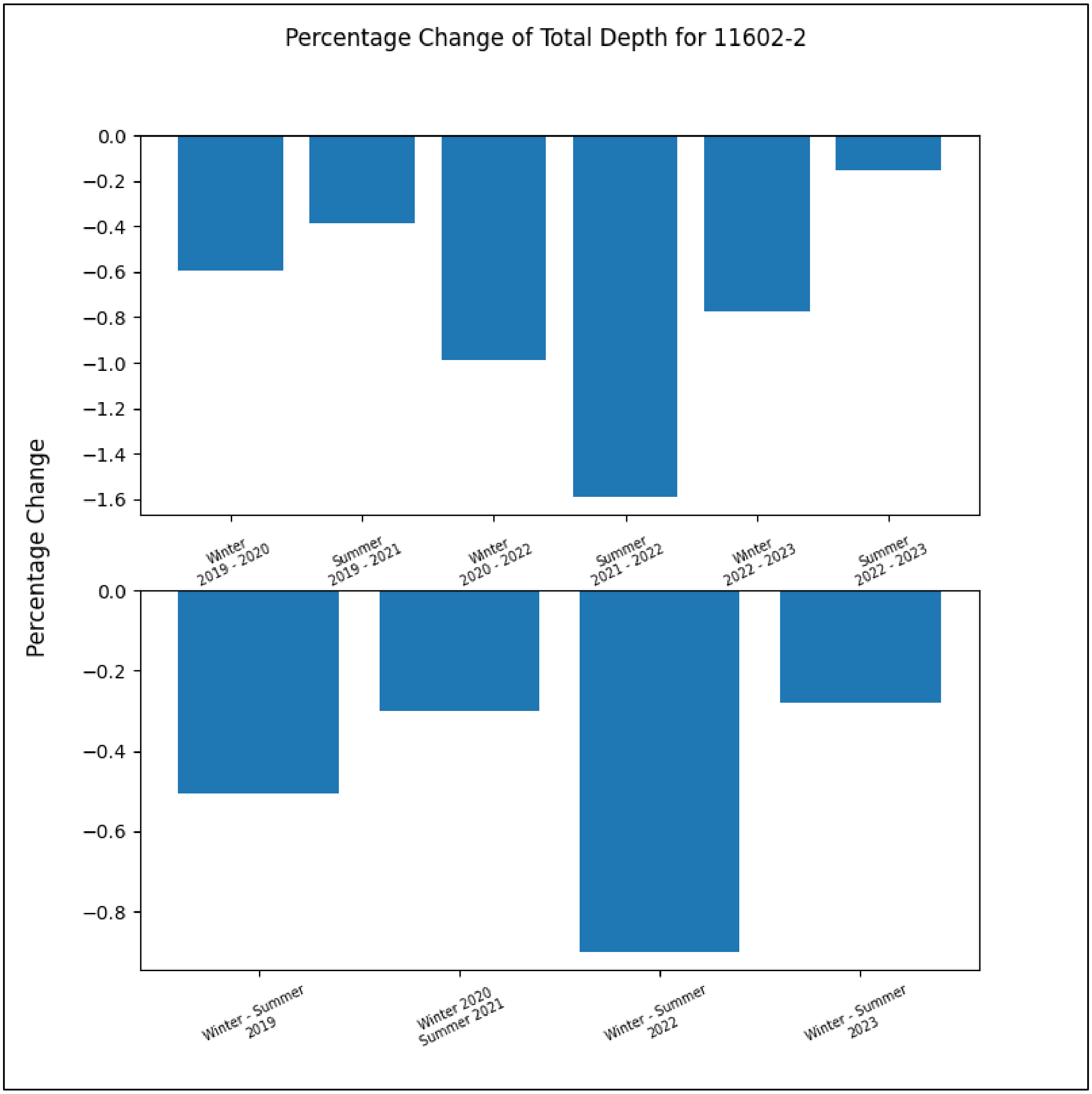


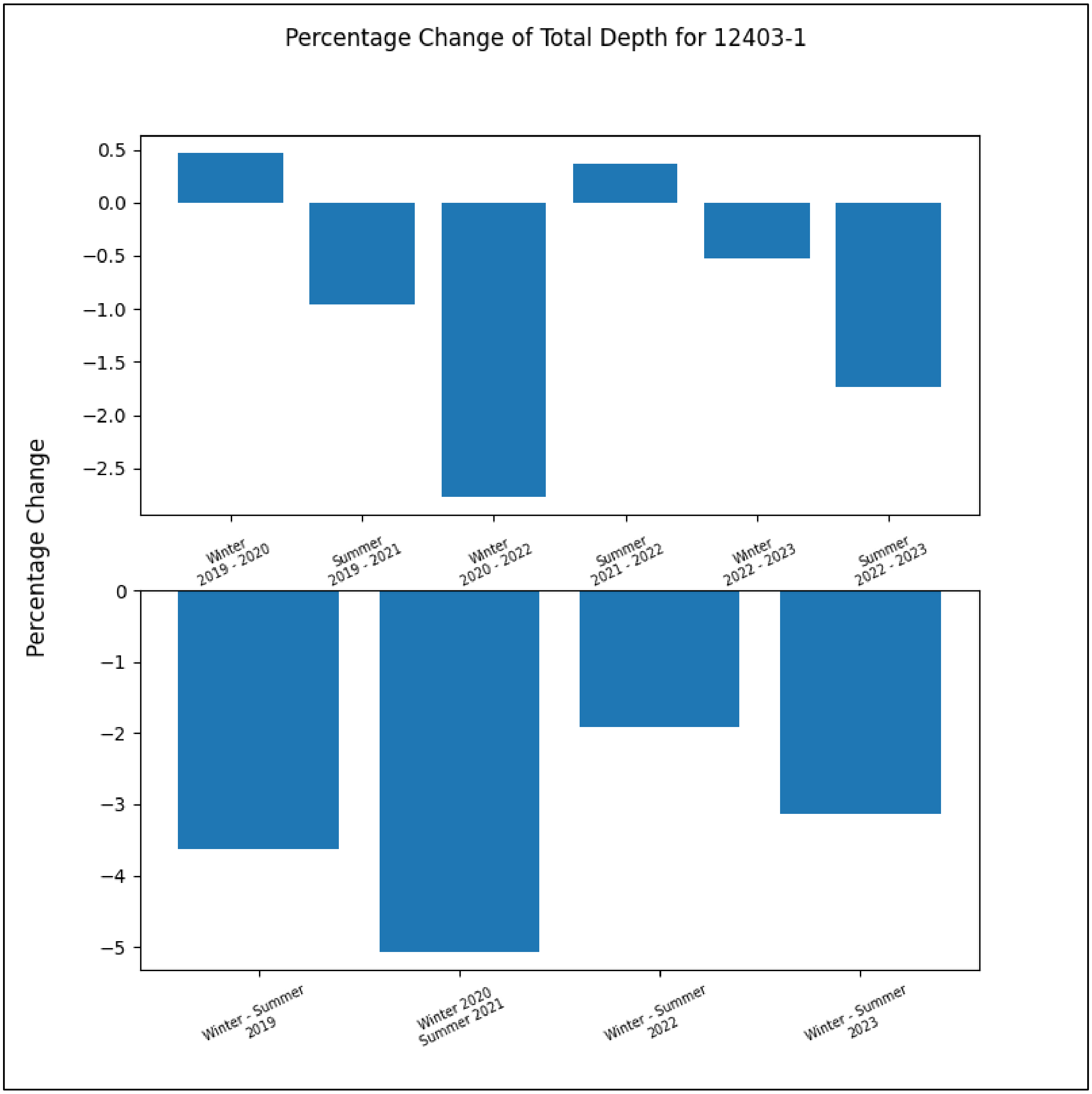


Percentage Change of Total Depth for 10703-2
Percentage Change
0.0
−0.1
−0.2
−0.3
−0.4
−0.5
−0.6
−0.7
−0.8
Winter 2019 - 2020
Summer 2019 - 2021
Winter 2020 - 2022
Summer 2021 - 2022
Winter 2022 - 2023
Summer 2022 - 2023
0.00
−0.05
−0.10
−0.15
−0.20
−0.25
−0.30
−0.35
−0.40
Winter - Summer 2019
Winter 2020 Summer 2021
Winter - Summer 2022
Winter - Summer 2023

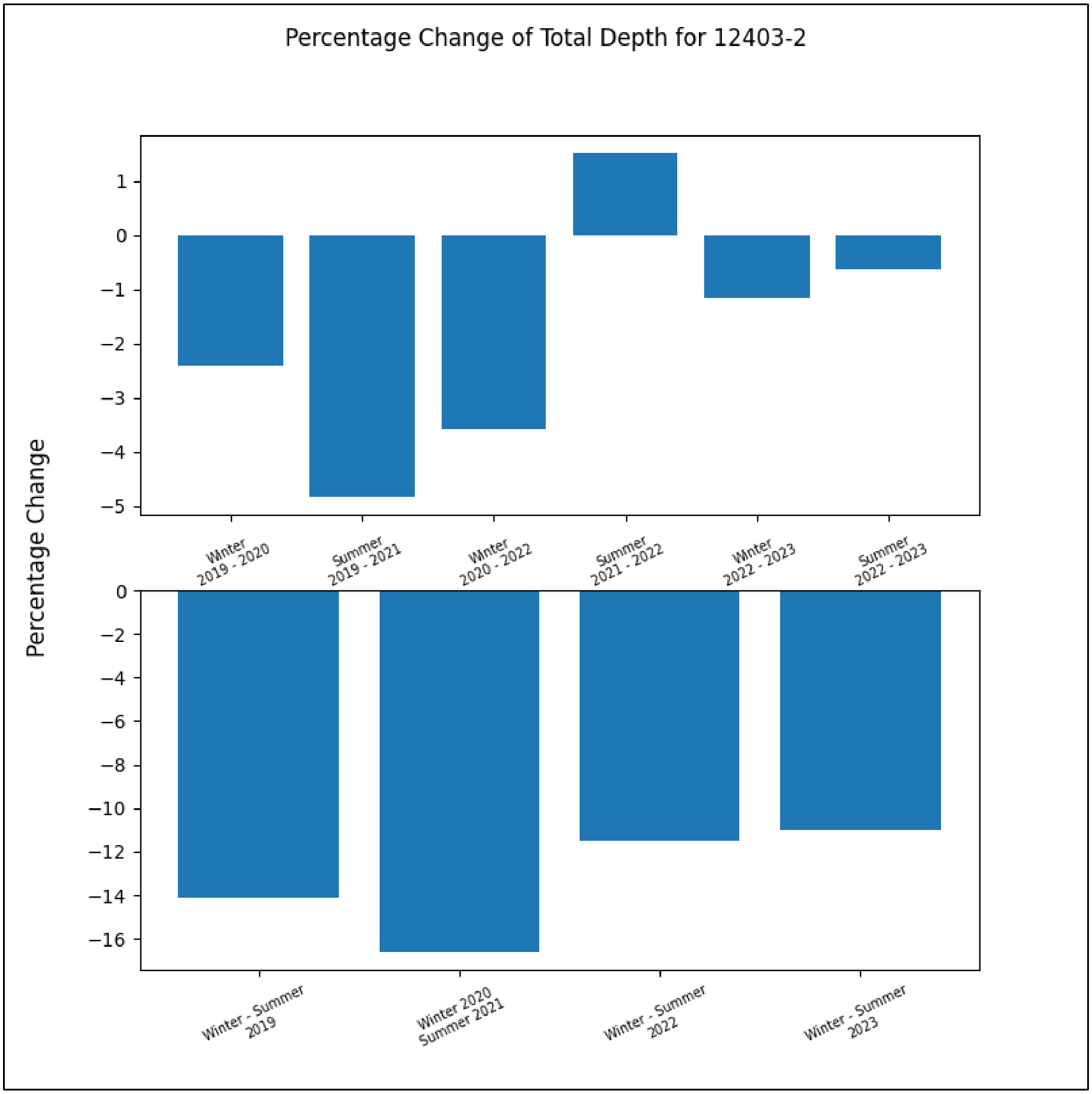

Percentage Change of Total Depth for 10903-1
Percentage Change
0.15
0.10
0.05
0.00
−0.05
−0.10
−0.15
Winter 2019 - 2020
Summer 2019 - 2021
Winter 2020 - 2022
Summer 2021 - 2022
Winter 2022 - 2023
Summer 2022 - 2023
Winter - Summer 2019
Winter 2020 Summer 2021
Winter - Summer 2022
Winter - Summer 2023

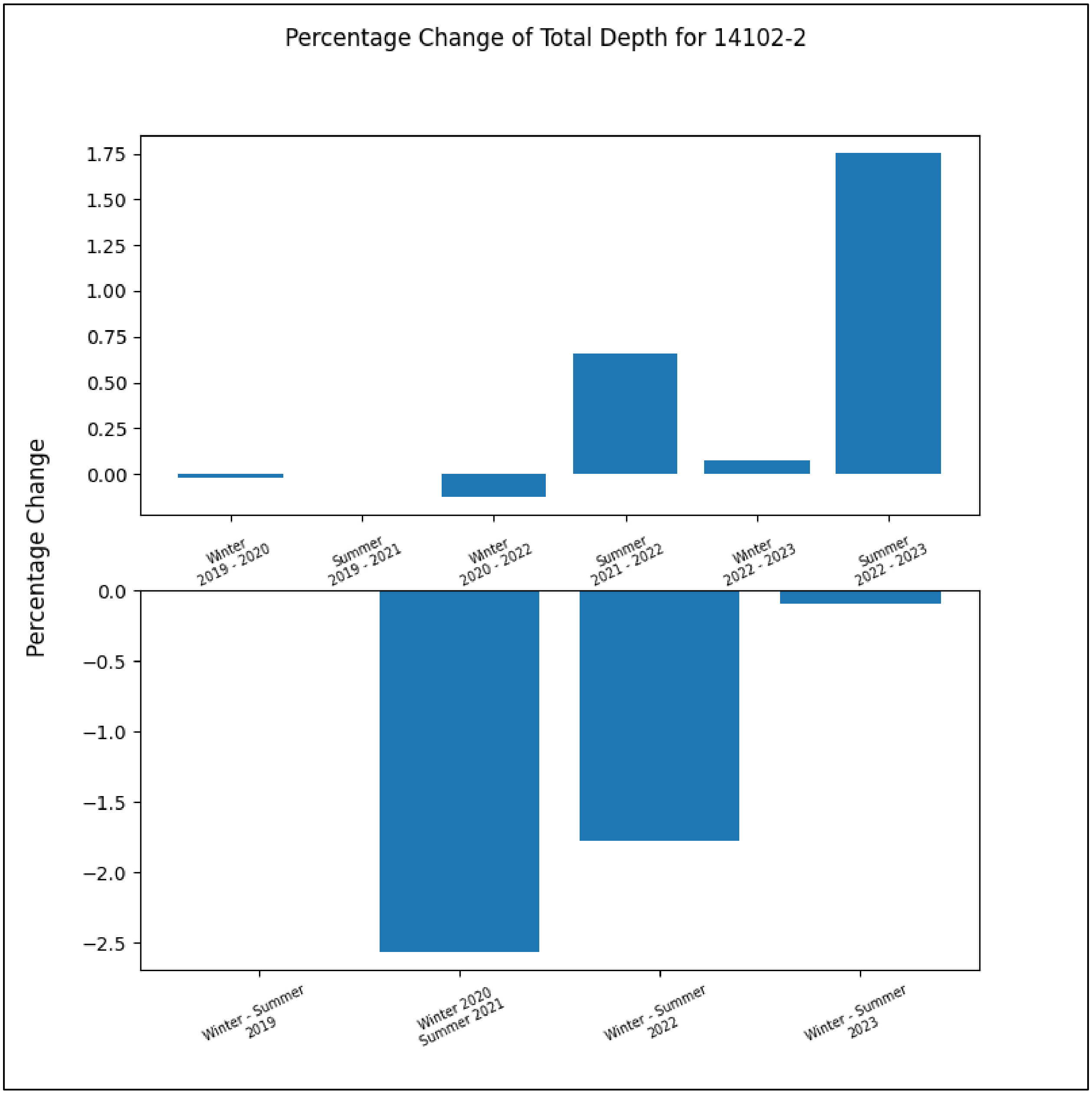

Percentage Change of Total Depth for 11602-1
Percentage Change
0.0
−0.2
−0.4
−0.6
−0.8
−1.0
−1.2
−1.4
−1.6
Winter 2019 - 2020
Summer 2019 - 2021
Winter 2020 - 2022
Summer 2021 - 2022
Winter 2022 - 2023
Summer 2022 - 2023
Winter - Summer 2019
Winter 2020 Summer 2021
Winter - Summer 2022
Winter - Summer 2023

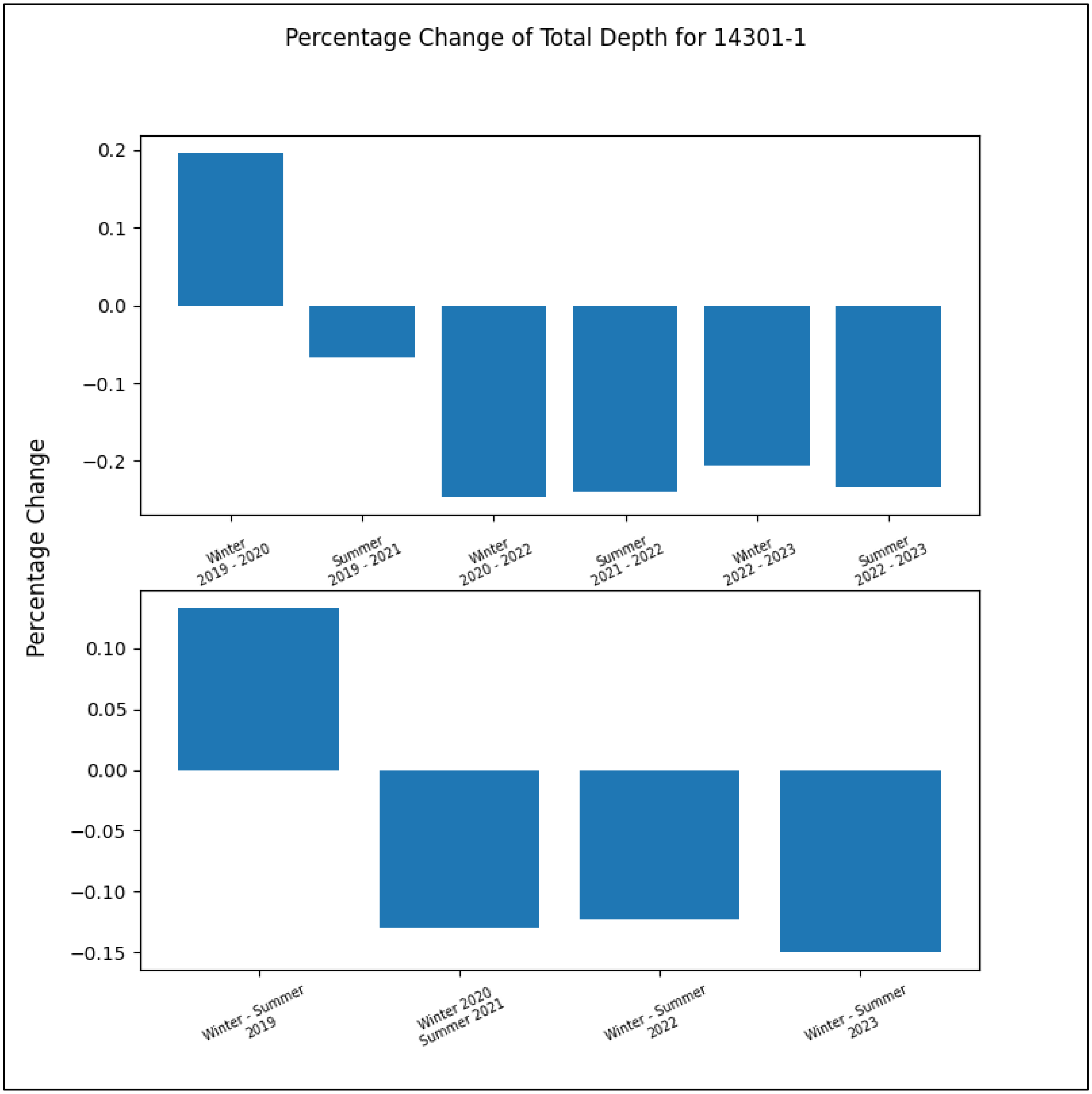

Percentage Change of Total Depth for 11602-2
Percentage Change
0.0
−0.2
−0.4
−0.6
−0.8
−1.0
−1.2
−1.4
−1.6
Winter 2019 - 2020
Summer 2019 - 2021
Winter 2020 - 2022
Summer 2021 - 2022
Winter 2022 - 2023
Summer 2022 - 2023
0.0
−0.2
−0.4
−0.6
−0.8
Winter - Summer 2019
Winter 2020 Summer 2021
Winter - Summer 2022
Winter - Summer 2023

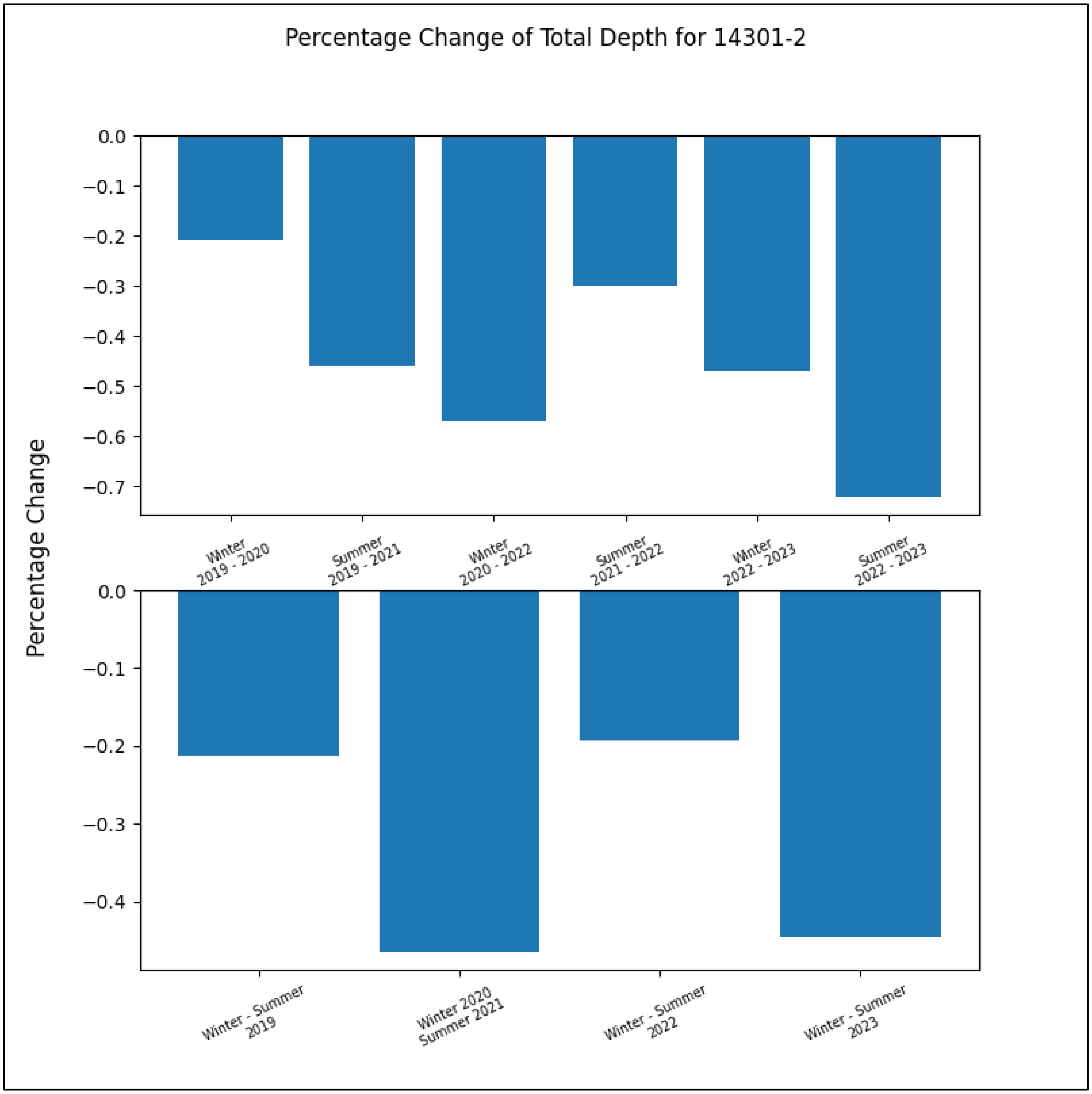


Percentage Change of Total Depth for 12403-1
Percentage Change
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
Winter 2019 - 2020
Summer 2019 - 2021
Winter 2020 - 2022
Summer 2021 - 2022
Winter 2022 - 2023
Summer 2022 - 2023
0
−1
−2
−3
−4
−5
Winter - Summer 2019
Winter 2020 Summer 2021
Winter - Summer 2022
Winter - Summer 2023

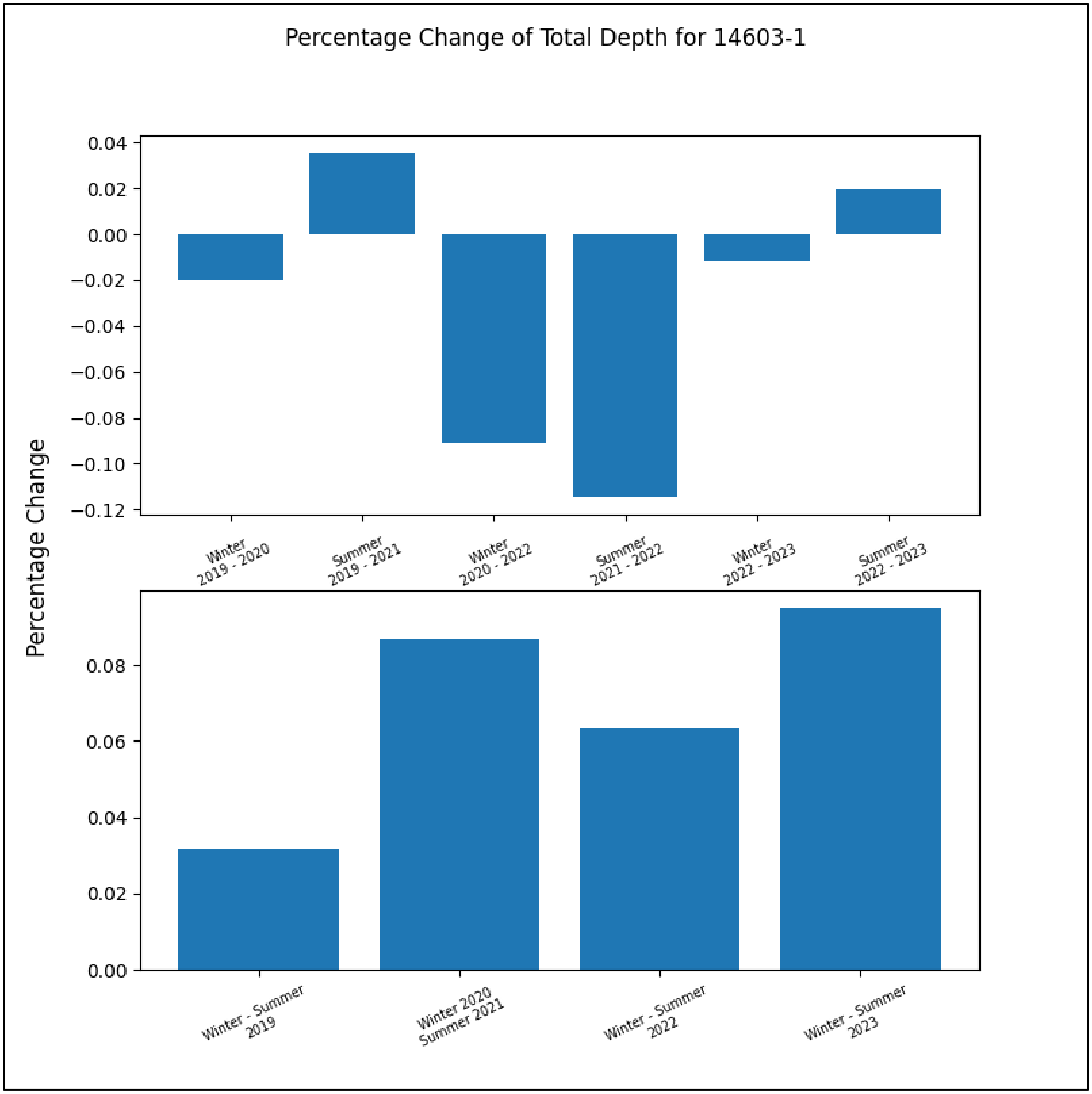

Percentage Change of Total Depth for 12403-2
Percentage Change
1
0
−1
−2
−3
−4
−5
Winter 2019 - 2020
Summer 2019 - 2021
Winter 2020 - 2022
Summer 2021 - 2022
Winter 2022 - 2023
Summer 2022 - 2023
0
−2
−4
−6
−8
−10
−12
−14
−16
Winter - Summer 2019
Winter 2020 Summer 2021
Winter - Summer 2022
Winter - Summer 2023


Percentage Change of Total Depth for 14102-2
Percentage Change
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Winter 2019 - 2020
Summer 2019 - 2021
Winter 2020 - 2022
Summer 2021 - 2022
Winter 2022 - 2023
Summer 2022 - 2023
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
Winter - Summer 2019
Winter 2020 Summer 2021
Winter - Summer 2022
Winter - Summer 2023


Percentage Change of Total Depth for 14301-1
Percentage Change
0.2
0.1
0.0
−0.1
−0.2
Winter 2019 - 2020
Summer 2019 - 2021
Winter 2020 - 2022
Summer 2021 - 2022
Winter 2022 - 2023
Summer 2022 - 2023
0.10
0.05
0.00
−0.05
−0.10
−0.15
Winter - Summer 2019
Winter 2020 Summer 2021
Winter - Summer 2022
Winter - Summer 2023



Percentage Change of Total Depth for 14301-2
Percentage Change
0.0
−0.1
−0.2
−0.3
−0.4
−0.5
−0.6
−0.7
Winter 2019 - 2020
Summer 2019 - 2021
Winter 2020 - 2022
Summer 2021 - 2022
Winter 2022 - 2023
Summer 2022 - 2023
0.0
−0.1
−0.2
−0.3
−0.4
Winter - Summer 2019
Winter 2020 Summer 2021
Winter - Summer 2022
Winter - Summer 2023


Percentage Change of Total Depth for 14603-1
Percentage Change
0.04
0.02
0.00
−0.02
−0.04
−0.06
−0.08
−0.10
−0.12
Winter
2019 - 2020
Summer
2019 - 2021
Winter
2020 - 2022
Summer
2021 - 2022
Winter
2022 - 2023
Summer
2022 - 2023
0.08
0.06
0.04
0.02
0.00
Winter - Summer
2019
Winter 2020
Summer 2021
Winter - Summer
2022
Winter - Summer
2023

Appendix III: Water Chemistry Data By Well

Cation, anion, and trace metals data for all critical wells sampled. ND = not detected.

Union County

	Drinking Water Reg:				
ID		**24202**	**24202**	**20503**	**20503**
Date Sampled		**2019**	**2022**	**2019**	**2022**
Field Parameters					
pH		8.0	7.7	7.7	8.1
Total Dissolved Solids (ppm)		238	245	552	781.6
Conductivity (uS)		364	369	849	865
Hardness		158.0	168.0	320.0	296.0
Cations (mg/L)					
Calcium (Ca)		31.5	34.3	62.3	57.0
Iron (Fe)	**0.3**	ND	ND	2.040	0.200
Magnesium (Mg)		19.20	19.90	39.8	37.3
Potassium (K)		3.90	6.95	4.52	5.39
Sodium (Na)		15.70	16.70	77.6	92.9
Strontium (Sr)	**190**	0.68	0.73	2.64	3.07
Anions (mg/L)					
Bromide (Br)		ND	ND	0.12	0.12
Chloride (Cl)	**250**	6.71	6.46	14.3	14.9
Fluoride (F)	**4**	0.66	0.64	1.07	1.04
Nitrate (NO_3)	**50**	8.90	8.54	8.78	2.7
Nitrite (NO_2)	**1**	ND	ND	ND	ND
Orthophosphate (PO_4)		ND	ND	ND	ND
Sulfate (SO_4)	**250**	15.80	16.20	97.2	109
Trace Metals (mg/L)					
Aluminum (Al)	**0.2**	ND	ND	0.0097	0.0041
Antimony (Sb-121)	**0.006**	ND	ND	ND	ND
Arsenic (As)	**0.01**	ND	0.0023	ND	ND
Barium (Ba)	**2**	0.1340	0.1240	0.0470	0.0330
Beryllium (Be)	**0.004**	ND	ND	ND	ND
Boron (B-11)	**1.4**	0.0400	0.0420	0.4050	0.5820
Cadmium (Cd)	**0.005**	ND	ND	ND	ND
Chromium (Cr)	**0.1**	ND	0.0008	0.0006	ND
Cobalt (Co)		ND	ND	0.0007	ND
Copper (Cu-65)	**1.3**	ND	0.0032	0.0053	0.0527
Lead (Pb)	**0.015**	ND	ND	0.0011	0.0027
Lithium (Li)		0.0180	0.0210	0.0630	0.0740
Manganese (Mn)	**0.05**	ND	ND	0.0730	0.0120

Molybdenum (Mo-95)		ND	0.0020	0.0010	0.0040
Nickel (Ni)		ND	ND	0.0012	0.0007
Selenium (Se)	**0.05**	ND	0.0010	0.0040	0.0030
Silicon (Si)		15.0000	14.8000	8.3400	6.9500
Silver (Ag)	**0.1**	ND	0.0008	ND	ND
Thallium (Tl)	**0.002**	ND	ND	ND	ND
Thorium (Th)		ND	ND	ND	ND
Tin (Sn)		ND	ND	ND	0.0006
Titanium (Ti)		ND	0.0010	0.0010	ND
Uranium (U)	**0.03**	ND	0.0018	0.0096	0.0070
Vanadium (V)		0.0165	0.0167	0.0016	0.0006
Zinc (Zn-66)	**5**	0.0293	0.0208	0.0106	0.1230
Alkalinity					
Alkalinity as $CaCO_3$		168.00	168.00	367	376
Bicarbonate (HCO_3)		205.00	205.00	447	458
Carbonate		ND	ND	ND	ND
Correctness of Analyses					
Anions		4.06	4.06	9.97	9.25
Cations		3.93	4.25	9.88	10.09
% Difference		-1.57	2.37	-0.45	4.4

	Drinking Water Reg:			
ID		**23702**	**23702**	**23702**
Date Sampled		**2019**	**2022 - Feb**	**2022-Aug**
Field Parameters				
pH		9.0	8.9	8.8
Total Dissolved Solids (ppm)		812	1121.3	934
Conductivity (uS)		1410	1420	1440
Hardness		7.6	7.4	7.2
Cations (mg/L)				
Calcium (Ca)		1.7	1.6	1.6
Iron (Fe)	**0.3**	ND	ND	ND
Magnesium (Mg)		0.821	0.83	0.79
Potassium (K)		2.25	2.37	2.86
Sodium (Na)		334	326.00	330.00
Strontium (Sr)	**190**	0.219	0.208	0.215
Anions (mg/L)				
Bromide (Br)		0.26	0.53	ND
Chloride (Cl)	**250**	44	44.10	43.60
Fluoride (F)	**4**	0.84	0.97	0.99
Nitrate (NO_3)	**50**	ND	ND	ND
Nitrite (NO_2)	**1**	ND	ND	ND
Orthophosphate (PO_4)		ND	ND	2.60
Sulfate (SO_4)	**250**	186	313.00	314.00
Trace Metals (mg/L)				
Aluminum (Al)	**0.2**	0.0487	0.0079	0.0056
Antimony (Sb-121)	**0.006**	ND	ND	ND
Arsenic (As)	**0.01**	ND	ND	ND
Barium (Ba)	**2**	0.0130	0.0140	ND
Beryllium (Be)	**0.004**	ND	ND	ND
Boron (B-11)	**1.4**	0.6240	0.6430	0.6250
Cadmium (Cd)	**0.005**	ND	ND	ND
Chromium (Cr)	**0.1**	ND	ND	ND
Cobalt (Co)		ND	ND	ND
Copper (Cu-65)	**1.3**	0.0063	0.0106	ND
Lead (Pb)	**0.015**	ND	ND	ND
Lithium (Li)		0.1550	0.1550	0.1660
Manganese (Mn)	**0.05**	ND	ND	ND
Molybdenum (Mo-95)		0.0060	0.0050	0.0060
Nickel (Ni)		ND	ND	ND
Selenium (Se)	**0.05**	ND	ND	ND
Silicon (Si)		4.7600	4.7800	3.1100
Silver (Ag)	**0.1**	ND	ND	ND

Thallium (Tl)	**0.002**	ND	ND	ND
Thorium (Th)		ND	ND	ND
Tin (Sn)		ND	ND	ND
Titanium (Ti)		ND	ND	ND
Uranium (U)	**0.03**	ND	ND	ND
Vanadium (V)		ND	ND	ND
Zinc (Zn-66)	**5**	0.0194	0.0478	ND
Alkalinity				
Alkalinity as $CaCO_3$		378	377.00	373.00
Bicarbonate (HCO_3)		403	404.00	409.00
Carbonate		28	28.00	23.00
Correctness of Analyses				
Anions		12.74	13.15	15.38
Cations		14.76	14.36	14.56
% Difference		7.35	4.4	-2.74

	Drinking Water Reg:				
ID		**24402**	**24402**	**24302**	**24302**
Date Sampled		**2019**	**2022**	**2019**	**2022**
Field Parameters					
pH		8.1	8.3	7.6	7.7
Total Dissolved Solids (ppm)		630	646	272	350.9
Conductivity (uS)		974	1000	421	419
Hardness		102.0	87.1	172.0	176.0
Cations (mg/L)					
Calcium (Ca)		20.3	17.3	35.5	36.6
Iron (Fe)	**0.3**	0.189	0.275	0.650	0.335
Magnesium (Mg)		12.5	10.6	20.2	20.6
Potassium (K)		6.17	6.91	3.08	2.7
Sodium (Na)		201	208	22.2	21.7
Strontium (Sr)	**190**	0.408	0.341	0.925	0.968
Anions (mg/L)					
Bromide (Br)		ND	ND	ND	ND
Chloride (Cl)	**250**	12.2	13.2	11.2	11.2
Fluoride (F)	**4**	3.67	4.28	1.27	1.32
Nitrate (NO_3)	**50**	1.29	1.75	5.73	6.17
Nitrite (NO_2)	**1**	ND	ND	ND	ND
Orthophosphate (PO_4)		ND	ND	ND	ND
Sulfate (SO_4)	**250**	96.9	99.9	35.6	36.2
Trace Metals (mg/L)					
Aluminum (Al)	**0.2**	0.0517	0.0594	0.0024	0.0009
Antimony (Sb-121)	**0.006**	ND	ND	ND	ND
Arsenic (As)	**0.01**	0.0025	ND	ND	ND
Barium (Ba)	**2**	0.0360	0.0310	0.0390	0.0400
Beryllium (Be)	**0.004**	ND	ND	ND	ND
Boron (B-11)	**1.4**	0.4700	0.5110	0.0810	0.0940
Cadmium (Cd)	**0.005**	ND	ND	ND	ND
Chromium (Cr)	**0.1**	ND	ND	0.0006	ND
Cobalt (Co)		ND	ND	ND	ND
Copper (Cu-65)	**1.3**	0.0028	ND	0.0139	0.0113
Lead (Pb)	**0.015**	ND	ND	ND	ND
Lithium (Li)		0.1160	0.1240	0.0470	0.0460
Manganese (Mn)	**0.05**	0.0290	ND	0.0040	0.0040
Molybdenum (Mo-95)		0.0110	0.0110	0.0030	0.0030
Nickel (Ni)		ND	ND	0.0006	0.0005
Selenium (Se)	**0.05**	ND	ND	0.0040	0.0040
Silicon (Si)		5.6600	5.5000	14.7000	15.1000
Silver (Ag)	**0.1**	ND	ND	ND	ND

Thallium (Tl)	**0.002**	ND	ND	ND	ND
Thorium (Th)		ND	ND	ND	ND
Tin (Sn)		ND	ND	ND	ND
Titanium (Ti)		ND	ND	0.0010	0.0010
Uranium (U)	**0.03**	ND	ND	0.0086	0.0078
Vanadium (V)		ND	ND	ND	0.0007
Zinc (Zn-66)	**5**	0.0066	0.0090	0.0549	0.0664
Alkalinity					
Alkalinity as $CaCO_3$		430	444	170	174
Bicarbonate (HCO_3)		525	535	208	213
Carbonate		ND	ND	ND	ND
Correctness of Analyses					
Anions		11.18	11.6	4.63	4.13
Cations		10.95	10.98	4.47	4.53
% Difference		-1.06	-2.74	-1.71	4.7

	Drinking Water Reg:				
ID		**24602**	**24602**	**20602**	**20602**
Date Sampled		**2019**	**2022**	**2019**	**2022**
Field Parameters					
pH		7.2	7.8	8.0	8.0
Total Dissolved Solids (ppm)		358	296	580	523
Conductivity (uS)		636	450	862	760
Hardness		222.0	204.0	369.0	367.0
Cations (mg/L)					
Calcium (Ca)		41.2	38.7	58.8	59.1
Iron (Fe)	**0.3**	13.000	0.101	ND	ND
Magnesium (Mg)		28.9	26.10	53.90	53.30
Potassium (K)		3.35	3.77	4.43	6.65
Sodium (Na)		18.3	18.90	42.30	40.00
Strontium (Sr)	**190**	0.904	0.85	2.08	2.06
Anions (mg/L)					
Bromide (Br)		ND	0.26	0.20	0.25
Chloride (Cl)	**250**	20	15.80	58.70	51.00
Fluoride (F)	**4**	1.98	1.79	1.56	1.43
Nitrate (NO_3)	**50**	0.77	12.40	65.80	43.40
Nitrite (NO_2)	**1**	ND	ND	ND	ND
Orthophosphate (PO_4)		ND	ND	ND	ND
Sulfate (SO_4)	**250**	8.38	35.70	102.00	92.60
Trace Metals (mg/L)					
Aluminum (Al)	**0.2**	0.0463	0.0015	ND	0.0009
Antimony (Sb-121)	**0.006**	ND	ND	ND	ND
Arsenic (As)	**0.01**	0.0094	0.0023	0.0039	0.0019
Barium (Ba)	**2**	0.0780	0.0450	0.0720	0.0740
Beryllium (Be)	**0.004**	ND	ND	ND	ND
Boron (B-11)	**1.4**	0.0950	0.0990	0.2090	0.2110
Cadmium (Cd)	**0.005**	0.0007	ND	ND	ND
Chromium (Cr)	**0.1**	0.0012	ND	0.0460	0.0116
Cobalt (Co)		0.0005	ND	ND	ND
Copper (Cu-65)	**1.3**	0.7940	0.0144	ND	0.0102
Lead (Pb)	**0.015**	0.0089	ND	0.0027	ND
Lithium (Li)		0.0310	0.0340	0.0850	0.0820
Manganese (Mn)	**0.05**	0.1460	ND	ND	0.0090
Molybdenum (Mo-95)		0.0040	0.0040	ND	0.0040
Nickel (Ni)		0.0039	ND	ND	0.0015
Selenium (Se)	**0.05**	0.0010	0.0030	ND	0.0050
Silicon (Si)		13.4000	15.1000	21.7000	18.9000
Silver (Ag)	**0.1**	ND	ND	ND	ND

Thallium (Tl)	**0.002**	ND	ND	ND	ND
Thorium (Th)		ND	ND	ND	ND
Tin (Sn)		ND	ND	ND	ND
Titanium (Ti)		0.0010	0.0020	ND	0.0010
Uranium (U)	**0.03**	0.0046	0.0056	0.0127	0.0112
Vanadium (V)		0.0455	0.0163	0.0257	0.0125
Zinc (Zn-66)	**5**	0.8840	0.0484	0.0847	0.0152
Alkalinity					
Alkalinity as $CaCO_3$		316	173.00	236.00	217.00
Bicarbonate (HCO_3)		385	211.00	288.00	264.00
Carbonate		ND	ND	ND	ND
Correctness of Analyses					
Anions		7.17	4.94	9.64	8.48
Cations		5.32	4.99	9.32	9.25
% Difference		-14.83	0.56	-1.71	4.33

	Drinking Water Reg:				
ID		**21202**	**21202**	**22903**	**22903**
Date Sampled		**2019**	**2022**	**2019**	**2022**
Field Parameters					
pH		7.5	8.3	8.0	7.7
Total Dissolved Solids (ppm)		232	233	268	267
Conductivity (uS)		388	372	408	415
Hardness		101.0	102.0	176.0	184.0
Cations (mg/L)					
Calcium (Ca)		21.0	21.5	42.3	44.7
Iron (Fe)	**0.3**	0.654	0.240	ND	ND
Magnesium (Mg)		11.8	11.60	17.20	17.50
Potassium (K)		4.62	5.29	3.41	3.54
Sodium (Na)		44.1	44.30	21.00	20.90
Strontium (Sr)	**190**	0.315	0.29	0.61	0.65
Anions (mg/L)					
Bromide (Br)		ND	ND	ND	0.17
Chloride (Cl)	**250**	3.56	3.75	10.40	10.20
Fluoride (F)	**4**	0.91	1.01	0.90	0.92
Nitrate (NO_3)	**50**	0.14	0.36	9.69	8.88
Nitrite (NO_2)	**1**	ND	ND	ND	ND
Orthophosphate (PO_4)		ND	ND	ND	ND
Sulfate (SO_4)	**250**	24.3	25.00	26.80	27.20
Trace Metals (mg/L)					
Aluminum (Al)	**0.2**	0.0327	0.0047	0.0076	0.0019
Antimony (Sb-121)	**0.006**	ND	ND	ND	ND
Arsenic (As)	**0.01**	ND	ND	ND	ND
Barium (Ba)	**2**	0.0470	0.0440	0.0940	0.0870
Beryllium (Be)	**0.004**	ND	ND	ND	ND
Boron (B-11)	**1.4**	0.0690	0.0700	0.0710	0.0690
Cadmium (Cd)	**0.005**	ND	ND	ND	ND
Chromium (Cr)	**0.1**	ND	ND	ND	ND
Cobalt (Co)		ND	ND	ND	ND
Copper (Cu-65)	**1.3**	0.0064	0.0327	ND	ND
Lead (Pb)	**0.015**	0.0012	0.0027	ND	ND
Lithium (Li)		0.0390	0.0350	0.0270	0.0270
Manganese (Mn)	**0.05**	0.0190	0.0200	ND	ND
Molybdenum (Mo-95)		0.0030	0.0020	ND	0.0030
Nickel (Ni)		ND	ND	ND	ND
Selenium (Se)	**0.05**	ND	ND	ND	0.0020
Silicon (Si)		5.2800	5.3100	11.7000	10.4000
Silver (Ag)	**0.1**	ND	0.0030	ND	ND

Thallium (Tl)	**0.002**	ND	ND	ND	ND
Thorium (Th)		ND	ND	ND	ND
Tin (Sn)		ND	ND	ND	ND
Titanium (Ti)		0.0010	0.0010	ND	0.0010
Uranium (U)	**0.03**	ND	ND	0.0042	0.0039
Vanadium (V)		ND	ND	0.0037	0.0038
Zinc (Zn-66)	**5**	0.0024	0.0262	ND	0.0265
Alkalinity					
Alkalinity as $CaCO_3$		178	178.00	181.00	177.00
Bicarbonate (HCO_3)		217	217.00	221.00	216.00
Carbonate		ND	ND	ND	ND
Correctness of Analyses					
Anions		4.23	4.25	4.68	4.60
Cations		4.06	4.09	4.52	4.67
% Difference		-2.05	-1.90	-1.70	0.77

	Drinking Water Reg:				
ID		**22802**	**22802**	**23902**	**23902**
Date Sampled		**2019**	**2022**	**2019**	**2022**
Field Parameters					
pH		8.0	7.9	7.3	7.6
Total Dissolved Solids (ppm)		488	696.4	328	312
Conductivity (uS)		776	844	539	502
Hardness		269.0	328.0	224.0	217.0
Cations (mg/L)					
Calcium (Ca)		29.5	35.8	44.6	42.3
Iron (Fe)	**0.3**	0.133	0.219	1.090	0.980
Magnesium (Mg)		47.3	57.8	27.5	27
Potassium (K)		6.94	7.72	5.32	4.37
Sodium (Na)		59.1	62.8	30.5	29.6
Strontium (Sr)	**190**	2.16	2.65	0.794	0.749
Anions (mg/L)					
Bromide (Br)		0.29	ND	0.14	ND
Chloride (Cl)	**250**	53	55	11.6	10.1
Fluoride (F)	**4**	3.14	2.76	1.16	1.26
Nitrate (NO_3)	**50**	22.4	25.1	0.12	0.18
Nitrite (NO_2)	**1**	ND	ND	ND	ND
Orthophosphate (PO_4)		ND	ND	ND	ND
Sulfate (SO_4)	**250**	57.8	59.3	58.9	47.4
Trace Metals (mg/L)					
Aluminum (Al)	**0.2**	0.0021	0.0119	0.0166	0.0008
Antimony (Sb-121)	**0.006**	ND	ND	ND	ND
Arsenic (As)	**0.01**	0.0073	0.0063	ND	ND
Barium (Ba)	**2**	0.0800	0.0920	0.0570	0.0450
Beryllium (Be)	**0.004**	ND	ND	ND	ND
Boron (B-11)	**1.4**	0.2210	0.2490	0.1260	0.1130
Cadmium (Cd)	**0.005**	ND	ND	ND	ND
Chromium (Cr)	**0.1**	0.0009	0.0005	ND	ND
Cobalt (Co)		ND	ND	ND	ND
Copper (Cu-65)	**1.3**	0.0115	0.0326	0.1560	0.0163
Lead (Pb)	**0.015**	0.0005	0.0010	0.0611	0.0078
Lithium (Li)		0.1390	0.1450	0.0530	0.0390
Manganese (Mn)	**0.05**	0.0010	0.0040	0.0840	0.0470
Molybdenum (Mo-95)		0.0040	0.0030	0.0030	0.0020
Nickel (Ni)		ND	0.0006	0.0015	ND
Selenium (Se)	**0.05**	0.0050	0.0050	ND	ND
Silicon (Si)		21.8000	21.9000	5.5500	5.4000
Silver (Ag)	**0.1**	ND	ND	ND	ND

Thallium (Tl)	**0.002**	ND	ND	ND	ND
Thorium (Th)		ND	ND	ND	ND
Tin (Sn)		ND	0.0009	0.0014	ND
Titanium (Ti)		0.0010	0.0020	0.0010	ND
Uranium (U)	**0.03**	0.0115	0.0163	0.0019	0.0010
Vanadium (V)		0.0566	0.0499	ND	ND
Zinc (Zn-66)	**5**	0.0350	0.0436	0.0210	0.0035
Alkalinity					
Alkalinity as $CaCO_3$		261	317	220	223
Bicarbonate (HCO_3)		318	387	268	272
Carbonate		ND	ND	ND	ND
Correctness of Analyses					
Anions		8.45	8.72	6.01	5.8
Cations		8.11	9.47	5.95	5.74
% Difference		-2.03	4.1	-0.52	-0.54

	Drinking Water Reg:				
ID		**24502**	**24502**	**23302**	**23302**
Date Sampled		**2019**	**2022**	**2019**	**2022**
Field Parameters					
pH		7.8	7.6	7.7	7.8
Total Dissolved Solids (ppm)		299	305	446	299
Conductivity (uS)		465	472	669	442
Hardness		197.0	207.0	291.0	185.0
Cations (mg/L)					
Calcium (Ca)		46.3	49.3	70.4	43.6
Iron (Fe)	**0.3**	ND	ND	ND	ND
Magnesium (Mg)		19.80	20.30	28.1	18.5
Potassium (K)		2.71	6.54	4.73	6
Sodium (Na)		25.30	26.20	35.8	26.9
Strontium (Sr)	**190**	0.67	0.70	0.897	0.647
Anions (mg/L)					
Bromide (Br)		ND	ND	ND	ND
Chloride (Cl)	**250**	9.48	9.11	8.44	7.03
Fluoride (F)	**4**	0.99	0.97	0.33	0.46
Nitrate (NO_3)	**50**	7.38	6.47	7.71	7.95
Nitrite (NO_2)	**1**	ND	ND	ND	ND
Orthophosphate (PO_4)		ND	ND	ND	ND
Sulfate (SO_4)	**250**	35.50	35.70	101	39
Trace Metals (mg/L)					
Aluminum (Al)	**0.2**	ND	ND	0.0019	0.0045
Antimony (Sb-121)	**0.006**	ND	ND	ND	ND
Arsenic (As)	**0.01**	ND	0.0017	0.0016	0.0018
Barium (Ba)	**2**	0.0920	0.0860	0.0610	0.0400
Beryllium (Be)	**0.004**	ND	ND	ND	ND
Boron (B-11)	**1.4**	0.0740	0.0780	0.0530	0.0380
Cadmium (Cd)	**0.005**	ND	ND	ND	ND
Chromium (Cr)	**0.1**	ND	ND	0.0010	0.0014
Cobalt (Co)		ND	ND	ND	ND
Copper (Cu-65)	**1.3**	ND	0.0006	0.0116	0.0030
Lead (Pb)	**0.015**	ND	ND	0.0006	ND
Lithium (Li)		0.0280	0.0280	0.0180	0.0110
Manganese (Mn)	**0.05**	ND	ND	ND	ND
Molybdenum (Mo-95)		ND	0.0030	0.0040	0.0040
Nickel (Ni)		ND	ND	0.0008	ND
Selenium (Se)	**0.05**	ND	0.0040	0.0030	0.0030
Silicon (Si)		12.7000	12.1000	15.1000	14.5000
Silver (Ag)	**0.1**	ND	0.0006	ND	0.0028

Thallium (Tl)	**0.002**	ND	ND	ND	ND
Thorium (Th)		ND	ND	ND	ND
Tin (Sn)		ND	ND	ND	ND
Titanium (Ti)		ND	0.0010	0.0010	0.0010
Uranium (U)	**0.03**	0.0055	0.0049	0.0040	0.0028
Vanadium (V)		0.0115	0.0114	0.0159	0.0235
Zinc (Zn-66)	**5**	ND	0.0012	0.0165	0.0067
Alkalinity					
Alkalinity as $CaCO_3$		203.00	201.00	255	193
Bicarbonate (HCO_3)		247.00	245.00	312	235
Carbonate		ND	ND	ND	ND
Correctness of Analyses					
Anions		5.23	5.18	7.61	5.03
Cations		5.11	5.44	7.5	5.03
% Difference		-1.15	2.42	-0.7	-0.07

	Drinking Water Reg:			
ID		**23002**	**23002**	**24103**
Date Sampled		**2019**	**2022**	**2019**
Field Parameters				
pH		7.8	8.0	7.8
Total Dissolved Solids (ppm)		301	234	1280
Conductivity (uS)		479	292	1700
Hardness		232.0	133.0	733
Cations (mg/L)				
Calcium (Ca)		55.6	32.5	142
Iron (Fe)	**0.3**	9.290	25.700	ND
Magnesium (Mg)		22.6	12.5	92.1
Potassium (K)		4.72	2.65	3.69
Sodium (Na)		15	13.2	138
Strontium (Sr)	**190**	0.874	0.509	2.97
Anions (mg/L)				
Bromide (Br)		0.37	ND	ND
Chloride (Cl)	**250**	8.93	7.48	33.3
Fluoride (F)	**4**	0.41	0.39	1.7
Nitrate (NO_3)	**50**	0.1	7.77	ND
Nitrite (NO_2)	**1**	ND	ND	ND
Orthophosphate (PO_4)		ND	ND	ND
Sulfate (SO_4)	**250**	ND	12.4	613
Trace Metals (mg/L)				
Aluminum (Al)	**0.2**	0.0041	0.0159	0.0025
Antimony (Sb-121)	**0.006**	ND	ND	ND
Arsenic (As)	**0.01**	0.0033	0.0046	ND
Barium (Ba)	**2**	0.4210	0.3830	0.017
Beryllium (Be)	**0.004**	ND	ND	ND
Boron (B-11)	**1.4**	0.0100	0.0210	0.216
Cadmium (Cd)	**0.005**	0.0008	ND	ND
Chromium (Cr)	**0.1**	0.0067	0.0213	ND
Cobalt (Co)		0.0005	0.0008	ND
Copper (Cu-65)	**1.3**	0.3650	0.8780	ND
Lead (Pb)	**0.015**	0.0068	0.0178	ND
Lithium (Li)		0.0090	0.0080	0.102
Manganese (Mn)	**0.05**	0.1490	0.1080	0.258
Molybdenum (Mo-95)		0.0020	0.0010	0.009
Nickel (Ni)		0.0036	0.0043	ND
Selenium (Se)	**0.05**	0.0010	0.0010	ND
Silicon (Si)		10.1000	18.2000	ND
Silver (Ag)	**0.1**	ND	ND	3.09

Thallium (Tl)	**0.002**	ND	ND	ND
Thorium (Th)		ND	ND	ND
Tin (Sn)		ND	ND	ND
Titanium (Ti)		0.0010	0.0020	ND
Uranium (U)	**0.03**	0.0007	0.0018	0.0157
Vanadium (V)		0.0233	0.0974	ND
Zinc (Zn-66)	**5**	0.6650	1.8900	ND
Alkalinity				
Alkalinity as $CaCO_3$		264	131	374
Bicarbonate (HCO_3)		322	160	456
Carbonate		ND	ND	ND
Correctness of Analyses				
Anions		5.58	3.24	21.26
Cations		5.41	3.29	20.76
% Difference		-1.56	0.76	-1.19

Las Animas County

	Drinking Water Reg:				
ID		**34502**	**34502**	**30502**	**30502**
Date Sampled		**2019**	**2022**	**2019**	**2022**
Field Parameters					
pH		7.3	7.4	7.9	8.2
Total Dissolved Solids (ppm)		162	145	264	260
Conductivity (uS)		266	233	387	380
Hardness		122.0	110.0	173.0	174.0
Cations (mg/L)					
Calcium (Ca)		32.0	29.4	41.7	42.6
Iron (Fe)	**0.3**	0.020	0.018	ND	0.024
Magnesium (Mg)		10.30	8.98	16.6	16.5
Potassium (K)		1.57	1.19	4.74	4.7
Sodium (Na)		7.90	6.92	15.9	15.9
Strontium (Sr)	**190**	0.45	0.41	0.774	0.77
Anions (mg/L)					
Bromide (Br)		ND	ND	0.11	ND
Chloride (Cl)	**250**	1.71	1.23	8.95	9.23
Fluoride (F)	**4**	0.15	0.15	0.55	0.56
Nitrate (NO_3)	**50**	1.85	1.08	7.74	7.54
Nitrite (NO_2)	**1**	ND	ND	ND	ND
Orthophosphate (PO_4)		ND	ND	ND	ND
Sulfate (SO_4)	**250**	14.70	14.50	31.1	29.1
Trace Metals (mg/L)					
Aluminum (Al)	**0.2**	0.0140	0.0134	0.0037	0.0033
Antimony (Sb-121)	**0.006**	ND	ND	ND	ND
Arsenic (As)	**0.01**	ND	ND	0.0023	0.0023
Barium (Ba)	**2**	0.1180	0.1110	0.0910	0.0880
Beryllium (Be)	**0.004**	ND	ND	ND	ND
Boron (B-11)	**1.4**	0.0090	0.0060	0.0330	0.0360
Cadmium (Cd)	**0.005**	ND	ND	ND	ND
Chromium (Cr)	**0.1**	ND	ND	0.0007	0.0006
Cobalt (Co)		ND	ND	ND	ND
Copper (Cu-65)	**1.3**	0.0057	0.0007	0.0040	0.0010
Lead (Pb)	**0.015**	ND	ND	0.0009	ND
Lithium (Li)		0.0070	ND	0.0100	0.0090
Manganese (Mn)	**0.05**	ND	ND	ND	ND
Molybdenum (Mo-95)		ND	ND	0.0030	0.0020
Nickel (Ni)		0.0005	ND	ND	ND
Selenium (Se)	**0.05**	0.0010	0.0010	0.0030	0.0030

Silicon (Si)		6.0500	4.8900	15.7000	15.5000
Silver (Ag)	**0.1**	ND	ND	0.0009	0.0019
Thallium (Tl)	**0.002**	ND	ND	ND	ND
Thorium (Th)		ND	ND	ND	ND
Tin (Sn)		ND	ND	ND	ND
Titanium (Ti)		0.0010	0.0010	0.0010	0.0010
Uranium (U)	**0.03**	ND	ND	0.0037	0.0036
Vanadium (V)		ND	ND	0.0170	0.0175
Zinc (Zn-66)	**5**	0.0162	0.0279	0.0147	0.0069
Alkalinity					
Alkalinity as $CaCO_3$		128.00	112.00	167	164
Bicarbonate (HCO_3)		156.00	136.00	203	200
Carbonate		ND	ND	ND	ND
Correctness of Analyses					
Anions		2.96	2.60	4.4	4.3
Cations		2.83	2.54	4.26	4.29
% Difference		-2.16	-1.29	-1.58	-0.11

	Drinking Water Reg:				
ID		**30202**	**30202**	**31302**	**31302**
Date Sampled		**2019**	**2022**	**2019**	**2022**
Field Parameters					
pH		7.9	7.7	7.6	8.0
Total Dissolved Solids (ppm)		1420	1420	247	301
Conductivity (uS)		2020	2070	371	438
Hardness		178.0	180.0	149.0	205.0
Cations (mg/L)					
Calcium (Ca)		33.3	33.2	35.9	56.1
Iron (Fe)	**0.3**	7.660	ND	0.104	1.090
Magnesium (Mg)		23	23.50	14.3	15.8
Potassium (K)		13.8	27.60	2.13	4.11
Sodium (Na)		430	425.00	23.3	20
Strontium (Sr)	**190**	1.38	1.40	0.521	0.598
Anions (mg/L)					
Bromide (Br)		ND	0.60	ND	ND
Chloride (Cl)	**250**	88.6	84.70	5.2	8.81
Fluoride (F)	**4**	4.58	5.06	0.73	0.62
Nitrate (NO_3)	**50**	ND	ND	3.53	7.59
Nitrite (NO_2)	**1**	ND	0.62	ND	ND
Orthophosphate (PO_4)		ND	ND	ND	ND
Sulfate (SO_4)	**250**	485	487.00	27.1	54.3
Trace Metals (mg/L)					
Aluminum (Al)	**0.2**	0.0175	0.0185	0.0147	0.0528
Antimony (Sb-121)	**0.006**	ND	ND	ND	ND
Arsenic (As)	**0.01**	ND	ND	0.0013	0.0030
Barium (Ba)	**2**	0.0250	ND	0.0410	0.0640
Beryllium (Be)	**0.004**	ND	ND	ND	ND
Boron (B-11)	**1.4**	0.2640	0.2390	0.0420	0.0550
Cadmium (Cd)	**0.005**	ND	ND	ND	ND
Chromium (Cr)	**0.1**	ND	ND	0.0006	0.0006
Cobalt (Co)		ND	ND	ND	ND
Copper (Cu-65)	**1.3**	0.0441	0.0074	0.0111	0.0076
Lead (Pb)	**0.015**	0.0104	ND	0.0023	0.0025
Lithium (Li)		0.7090	0.7260	0.0140	0.0130
Manganese (Mn)	**0.05**	0.0740	ND	0.0020	0.0150
Molybdenum (Mo-95)		ND	ND	0.0020	0.0030
Nickel (Ni)		ND	ND	0.0057	0.0011
Selenium (Se)	**0.05**	ND	ND	0.0020	0.0020
Silicon (Si)		5.7200	3.3100	14.5000	12.4000

Silver (Ag)	**0.1**	ND	ND	ND	ND
Thallium (Tl)	**0.002**	ND	ND	ND	ND
Thorium (Th)		ND	ND	ND	ND
Tin (Sn)		ND	ND	ND	ND
Titanium (Ti)		ND	ND	0.0010	0.0020
Uranium (U)	**0.03**	ND	ND	0.0034	0.0058
Vanadium (V)		ND	ND	0.0099	0.0116
Zinc (Zn-66)	**5**	0.0280	ND	0.0115	0.0172
Alkalinity					
Alkalinity as $CaCO_3$		520	530.00	169	172
Bicarbonate (HCO_3)		634	646.00	206	210
Carbonate		ND	ND	ND	ND
Correctness of Analyses					
Anions		23.27	23.45	4.19	4.98
Cations		22.62	22.77	4.04	5.08
% Difference		-1.4	-1.49	-1.86	0.95

	Drinking Water Reg:				
ID		**31702**	**31702**	**32002**	**32002**
Date Sampled		**2019**	**2022**	**2019**	**2022**
Field Parameters					
pH		7.6	7.6	7.4	7.4
Total Dissolved Solids (ppm)		443	439	942	984
Conductivity (uS)		674	665	1280	1340
Hardness		312.0	303.0	582.0	587.0
Cations (mg/L)					
Calcium (Ca)		78.8	76.4	116.0	121.0
Iron (Fe)	**0.3**	0.110	1.860	0.486	0.260
Magnesium (Mg)		27.9	27.10	71.00	68.90
Potassium (K)		2.5	3.94	11.00	13.50
Sodium (Na)		33.2	32.40	88.20	89.50
Strontium (Sr)	**190**	0.996	0.99	3.27	3.21
Anions (mg/L)					
Bromide (Br)		0.17	0.21	ND	ND
Chloride (Cl)	**250**	16.7	16.40	13.20	36.80
Fluoride (F)	**4**	1.32	1.39	0.43	0.56
Nitrate (NO_3)	**50**	6.48	6.35	0.67	1.41
Nitrite (NO_2)	**1**	ND	0.12	ND	ND
Orthophosphate (PO_4)		ND	ND	ND	ND
Sulfate (SO_4)	**250**	125	121.00	451.00	465.00
Trace Metals (mg/L)					
Aluminum (Al)	**0.2**	0.0164	0.0325	ND	ND
Antimony (Sb-121)	**0.006**	0.0005	0.0008	ND	ND
Arsenic (As)	**0.01**	0.0005	0.0010	ND	ND
Barium (Ba)	**2**	0.0400	0.0400	0.0140	ND
Beryllium (Be)	**0.004**	ND	ND	ND	ND
Boron (B-11)	**1.4**	0.0770	0.0780	0.0520	ND
Cadmium (Cd)	**0.005**	ND	ND	ND	ND
Chromium (Cr)	**0.1**	0.0032	0.3310	ND	ND
Cobalt (Co)		0.0007	ND	ND	ND
Copper (Cu-65)	**1.3**	0.0124	0.0275	ND	ND
Lead (Pb)	**0.015**	0.0013	0.0078	ND	ND
Lithium (Li)		0.0610	0.0570	0.1820	0.1840
Manganese (Mn)	**0.05**	0.0050	ND	0.0770	0.0600
Molybdenum (Mo-95)		0.0080	0.0090	ND	ND
Nickel (Ni)		0.0106	0.0133	ND	ND
Selenium (Se)	**0.05**	0.0150	0.0210	ND	ND
Silicon (Si)		6.1400	5.3000	4.5600	2.5800

Silver (Ag)	**0.1**	ND	0.0005	ND	ND
Thallium (Tl)	**0.002**	ND	ND	ND	ND
Thorium (Th)		ND	ND	ND	ND
Tin (Sn)		ND	0.0006	ND	ND
Titanium (Ti)		0.0010	0.0030	ND	ND
Uranium (U)	**0.03**	0.0202	0.0207	ND	ND
Vanadium (V)		ND	0.0010	ND	ND
Zinc (Zn-66)	**5**	0.0341	0.0081	0.0035	ND
Alkalinity					
Alkalinity as $CaCO_3$		224	225.00	289.00	281.00
Bicarbonate (HCO_3)		274	274.00	353.00	343.00
Carbonate		ND	ND	ND	ND
Correctness of Analyses					
Anions		7.73	7.66	15.58	16.46
Cations		7.74	7.56	15.76	15.97
% Difference		0.01	-0.69	0.58	-1.51

	Drinking Water Reg:				
ID		**30702**	**30702**	**30903**	**30903**
Date Sampled		**2019**	**2022**	**2019**	**2022**
Field Parameters					
pH		7.8	7.8	7.5	7.8
Total Dissolved Solids (ppm)		192	188	285	316
Conductivity (uS)		385	290	424	472
Hardness		124.0	125.0	157.0	181.0
Cations (mg/L)					
Calcium (Ca)		39.7	40.1	39.6	46.2
Iron (Fe)	**0.3**	0.429	0.095	5.710	0.233
Magnesium (Mg)		6.03	5.97	14	16
Potassium (K)		4.58	3.17	2.25	8.54
Sodium (Na)		10.4	10.7	32	39.7
Strontium (Sr)	**190**	0.284	0.27	0.451	0.527
Anions (mg/L)					
Bromide (Br)		ND	ND	ND	ND
Chloride (Cl)	**250**	6.44	7	6.14	7.56
Fluoride (F)	**4**	0.44	0.5	0.21	0.17
Nitrate (NO_3)	**50**	10.9	11.6	1.2	0.25
Nitrite (NO_2)	**1**	ND	ND	ND	ND
Orthophosphate (PO_4)		ND	ND	ND	ND
Sulfate (SO_4)	**250**	34.3	36.7	44.6	43
Trace Metals (mg/L)					
Aluminum (Al)	**0.2**	ND	0.0139	NS	0.0066
Antimony (Sb-121)	**0.006**	ND	ND	ND	ND
Arsenic (As)	**0.01**	0.0023	0.0022	ND	ND
Barium (Ba)	**2**	0.1630	0.1590	0.0860	0.0660
Beryllium (Be)	**0.004**	ND	ND	ND	ND
Boron (B-11)	**1.4**	0.0220	0.0230	0.0160	0.0190
Cadmium (Cd)	**0.005**	ND	ND	ND	ND
Chromium (Cr)	**0.1**	0.0019	ND	0.0008	ND
Cobalt (Co)		ND	ND	ND	ND
Copper (Cu-65)	**1.3**	0.0030	0.0014	0.0352	0.0130
Lead (Pb)	**0.015**	0.0010	ND	0.0053	ND
Lithium (Li)		0.0110	0.0100	0.0080	0.0080
Manganese (Mn)	**0.05**	0.0080	ND	0.3880	0.0060
Molybdenum (Mo-95)		0.0050	0.0060	ND	ND
Nickel (Ni)		0.0008	ND	0.0023	0.0011
Selenium (Se)	**0.05**	0.0030	0.0030	0.0010	0.0010
Silicon (Si)		6.3800	6.0000	12.6000	10.2000

Silver (Ag)	**0.1**	ND	0.0014	ND	ND
Thallium (Tl)	**0.002**	ND	ND	ND	ND
Thorium (Th)		ND	ND	ND	ND
Tin (Sn)		ND	ND	ND	ND
Titanium (Ti)		0.0050	0.0010	0.0010	0.0010
Uranium (U)	**0.03**	0.0012	0.0011	0.0005	0.0005
Vanadium (V)		0.0018	0.0016	0.0013	ND
Zinc (Zn-66)	**5**	0.0188	0.0030	0.0289	0.3090
Alkalinity					
Alkalinity as $CaCO_3$		105	97	182	215
Bicarbonate (HCO_3)		129	118	222	262
Carbonate		ND	ND	ND	ND
Correctness of Analyses					
Anions		3.2	3.12	4.77	5.43
Cations		3.05	3.04	4.58	5.57
% Difference		-2.48	-1.33	-2.12	1.25

	Drinking Water Reg:				
ID		**31203**	**31203**	**32302**	**32302**
Date Sampled		**2019**	**2022**	**2019**	**2022**
Field Parameters					
pH		8.2	8.0	7.6	7.8
Total Dissolved Solids (ppm)		2340	2280	281	257
Conductivity (uS)		3540	3510	413	386
Hardness		65.2	63.5	205.0	186.0
Cations (mg/L)					
Calcium (Ca)		10.7	10.7	51.6	47.3
Iron (Fe)	**0.3**	ND	ND	0.241	0.020
Magnesium (Mg)		9.37	8.91	18.4	16.40
Potassium (K)		10.4	13.40	2.07	1.12
Sodium (Na)		935	894.00	13.6	12.00
Strontium (Sr)	**190**	3.72	3.38	0.688	0.62
Anions (mg/L)					
Bromide (Br)		ND	0.77	ND	ND
Chloride (Cl)	**250**	108	104.00	5.65	5.44
Fluoride (F)	**4**	1.42	1.84	0.25	0.28
Nitrate (NO_3)	**50**	1.11	ND	11.3	10.70
Nitrite (NO_2)	**1**	ND	ND	ND	ND
Orthophosphate (PO_4)		ND	ND	ND	ND
Sulfate (SO_4)	**250**	14.6	29.00	11.4	11.40
Trace Metals (mg/L)					
Aluminum (Al)	**0.2**	ND	ND	0.1440	0.0012
Antimony (Sb-121)	**0.006**	ND	ND	ND	ND
Arsenic (As)	**0.01**	ND	ND	0.0018	0.0018
Barium (Ba)	**2**	4.4400	3.1600	0.2190	0.1960
Beryllium (Be)	**0.004**	ND	ND	ND	ND
Boron (B-11)	**1.4**	0.2300	0.2140	0.0250	0.0210
Cadmium (Cd)	**0.005**	ND	ND	ND	ND
Chromium (Cr)	**0.1**	ND	ND	0.0023	0.0007
Cobalt (Co)		ND	ND	ND	ND
Copper (Cu-65)	**1.3**	ND	ND	0.0119	0.0111
Lead (Pb)	**0.015**	ND	ND	0.0006	0.0014
Lithium (Li)		0.5120	0.5440	0.0060	0.0060
Manganese (Mn)	**0.05**	0.0170	ND	0.0210	ND
Molybdenum (Mo-95)		ND	ND	0.0010	0.0010
Nickel (Ni)		ND	ND	0.0016	ND
Selenium (Se)	**0.05**	ND	ND	0.0020	0.0020
Silicon (Si)		6.6800	3.9700	19.6000	16.5000

Silver (Ag)	**0.1**	ND	ND	ND	ND
Thallium (Tl)	**0.002**	ND	ND	ND	ND
Thorium (Th)		ND	ND	ND	ND
Tin (Sn)		ND	ND	ND	ND
Titanium (Ti)		ND	ND	0.0140	0.0020
Uranium (U)	**0.03**	ND	ND	0.0026	0.0022
Vanadium (V)		ND	ND	0.0172	0.0164
Zinc (Zn-66)	**5**	ND	0.0102	0.0090	0.0358
Alkalinity					
Alkalinity as $CaCO_3$		2010	1960.00	204	188.00
Bicarbonate (HCO_3)		2450	2400.00	249	229.00
Carbonate		ND	ND	ND	ND
Correctness of Analyses					
Anions		43.74	42.97	4.68	4.35
Cations		42.22	40.50	4.74	4.26
% Difference		-1.76	-2.96	0.54	-0.98

	Drinking Water Reg:				
ID		**30303**	**30303**	**32102**	**32102**
Date Sampled		**2019**	**2022**	**2019**	**2022**
Field Parameters					
pH		7.3	7.7	7.7	7.9
Total Dissolved Solids (ppm)		435	435	395	374
Conductivity (uS)		651	646	625	607
Hardness		250.0	253.0	202.0	64.3
Cations (mg/L)					
Calcium (Ca)		60.1	61.2	53.5	19.0
Iron (Fe)	**0.3**	1.010	0.345	0.881	ND
Magnesium (Mg)		24.2	24.3	16.50	4.13
Potassium (K)		5.48	3.87	2.45	1.97
Sodium (Na)		44.6	43.8	76.50	124.00
Strontium (Sr)	**190**	1.02	0.965	1.28	0.66
Anions (mg/L)					
Bromide (Br)		0.15	ND	ND	0.10
Chloride (Cl)	**250**	18.1	19.4	5.81	5.52
Fluoride (F)	**4**	0.76	0.95	0.47	1.28
Nitrate (NO_3)	**50**	13.4	16	1.01	0.24
Nitrite (NO_2)	**1**	ND	ND	ND	ND
Orthophosphate (PO_4)		ND	ND	ND	ND
Sulfate (SO_4)	**250**	123	122	24.30	4.87
Trace Metals (mg/L)					
Aluminum (Al)	**0.2**	0.0092	0.1980	0.0140	0.0008
Antimony (Sb-121)	**0.006**	ND	ND	ND	ND
Arsenic (As)	**0.01**	0.0011	0.0010	ND	ND
Barium (Ba)	**2**	0.0800	0.0780	0.4000	0.2560
Beryllium (Be)	**0.004**	ND	ND	ND	ND
Boron (B-11)	**1.4**	0.1040	0.1080	0.0160	0.0120
Cadmium (Cd)	**0.005**	ND	ND	ND	ND
Chromium (Cr)	**0.1**	0.0005	ND	0.0008	ND
Cobalt (Co)		ND	ND	ND	ND
Copper (Cu-65)	**1.3**	0.0031	0.0913	0.0109	0.0005
Lead (Pb)	**0.015**	0.0008	0.0080	ND	ND
Lithium (Li)		0.0520	0.0480	0.0080	0.0060
Manganese (Mn)	**0.05**	0.0440	0.0110	0.0930	ND
Molybdenum (Mo-95)		0.0020	0.0020	ND	0.0010
Nickel (Ni)		0.0009	ND	0.0015	ND
Selenium (Se)	**0.05**	0.0050	0.0050	0.0020	ND
Silicon (Si)		11.1000	10.6000	5.1200	5.2900

Silver (Ag)	**0.1**	ND	0.0026	ND	ND
Thallium (Tl)	**0.002**	ND	ND	ND	ND
Thorium (Th)		ND	ND	ND	ND
Tin (Sn)		ND	ND	ND	ND
Titanium (Ti)		0.0010	0.0040	ND	0.0010
Uranium (U)	**0.03**	0.0059	0.0062	0.0008	ND
Vanadium (V)		0.0066	0.0076	ND	ND
Zinc (Zn-66)	**5**	0.0459	0.0423	0.0623	0.0100
Alkalinity					
Alkalinity as $CaCO_3$		196	196	330.00	333.00
Bicarbonate (HCO_3)		240	239	402.00	407.00
Carbonate		ND	ND	ND	ND
Correctness of Analyses					
Anions		7.26	7.32	7.30	7.00
Cations		7.07	7.06	7.42	6.71
% Difference		-1.34	-1.85	0.80	-2.07

	Drinking Water Reg:		
ID		**30802**	**30802**
Date Sampled		**2019**	**2022**
Field Parameters			
pH		5.9	6.3
Total Dissolved Solids (ppm)		760	733
Conductivity (uS)		996	989
Hardness		466.0	477.0
Cations (mg/L)			
Calcium (Ca)		103.0	107.0
Iron (Fe)	**0.3**	23.400	8.300
Magnesium (Mg)		50.7	51.10
Potassium (K)		4.28	3.22
Sodium (Na)		32.5	33.30
Strontium (Sr)	**190**	1.83	1.84
Anions (mg/L)			
Bromide (Br)		ND	ND
Chloride (Cl)	**250**	8.99	10.10
Fluoride (F)	**4**	0.82	1.16
Nitrate (NO_3)	**50**	ND	0.10
Nitrite (NO_2)	**1**	ND	ND
Orthophosphate (PO_4)		ND	ND
Sulfate (SO_4)	**250**	485	469.00
Trace Metals (mg/L)			
Aluminum (Al)	**0.2**	35.1000	0.8680
Antimony (Sb-121)	**0.006**	ND	ND
Arsenic (As)	**0.01**	0.0488	ND
Barium (Ba)	**2**	0.0160	ND
Beryllium (Be)	**0.004**	0.0072	ND
Boron (B-11)	**1.4**	0.1620	0.1550
Cadmium (Cd)	**0.005**	0.0041	0.0088
Chromium (Cr)	**0.1**	0.0221	ND
Cobalt (Co)		0.0843	0.0544
Copper (Cu-65)	**1.3**	0.0381	0.0089
Lead (Pb)	**0.015**	0.0566	ND
Lithium (Li)		0.1630	0.1930
Manganese (Mn)	**0.05**	0.1040	0.1200
Molybdenum (Mo-95)		ND	ND
Nickel (Ni)		0.1240	0.0913
Selenium (Se)	**0.05**	ND	ND
Silicon (Si)		7.5800	5.0800

Silver (Ag)	**0.1**	ND	ND
Thallium (Tl)	**0.002**	ND	ND
Thorium (Th)		ND	ND
Tin (Sn)		ND	ND
Titanium (Ti)		ND	ND
Uranium (U)	**0.03**	0.7750	0.0092
Vanadium (V)		0.0200	ND
Zinc (Zn-66)	**5**	0.9820	0.6030
Alkalinity			
Alkalinity as $CaCO_3$		55	60.00
Bicarbonate (HCO_3)		68	73.00
Carbonate		ND	ND
Correctness of Analyses			
Anions		11.52	11.32
Cations		10.83	11.06
% Difference		-3.09	-1.14

Cimarron County

	Drinking Water Reg:				
ID		**11103**	**11103**	**10602**	**10602**
Date Sampled		**2019**	**2023**	**2019**	**2022**
Field Parameters					
pH		8.2	7.9	8.5	8.5
Total Dissolved Solids (ppm)		339	356	1300	1300
Conductivity (uS)		528	517	1930	1930
Hardness		209.0	214.0	16.2	16.7
Cations (mg/L)					
Calcium (Ca)		38.8	40.4	2.9	3.1
Iron (Fe)	**0.3**	ND	ND	ND	ND
Magnesium (Mg)		27.20	27.50	2.17	2.21
Potassium (K)		4.46	5.81	2.29	4.04
Sodium (Na)		31.00	31.90	471	470
Strontium (Sr)	**190**	1.04	1.08	0.328	0.34
Anions (mg/L)					
Bromide (Br)		0.15	ND	ND	ND
Chloride (Cl)	**250**	25.30	27.20	16.1	16.4
Fluoride (F)	**4**	1.68	1.65	2.98	3.16
Nitrate (NO_3)	**50**	13.50	14.60	ND	ND
Nitrite (NO_2)	**1**	ND	ND	ND	ND
Orthophosphate (PO_4)		ND	ND	ND	ND
Sulfate (SO_4)	**250**	49.40	49.50	368	368
Trace Metals (mg/L)					
Aluminum (Al)	**0.2**	0.0135	0.0054	ND	0.0078
Antimony (Sb-121)	**0.006**	ND	ND	ND	ND
Arsenic (As)	**0.01**	0.0039	0.0041	0.0241	0.0239
Barium (Ba)	**2**	0.0610	0.0570	0.0170	ND
Beryllium (Be)	**0.004**	ND	ND	ND	ND
Boron (B-11)	**1.4**	0.1400	0.1500	1.0600	1.0300
Cadmium (Cd)	**0.005**	ND	ND	ND	ND
Chromium (Cr)	**0.1**	ND	0.0012	ND	ND
Cobalt (Co)		ND	ND	ND	ND
Copper (Cu-65)	**1.3**	ND	0.0007	0.0217	0.0030
Lead (Pb)	**0.015**	ND	ND	ND	ND
Lithium (Li)		0.0890	0.0840	0.1870	0.1880
Manganese (Mn)	**0.05**	ND	ND	ND	ND
Molybdenum (Mo-95)		0.0060	0.0060	0.0650	0.0610
Nickel (Ni)		ND	ND	ND	ND
Selenium (Se)	**0.05**	ND	0.0040	ND	ND

Silicon (Si)		18.9	18.3	5.4	5.3
Silver (Ag)	**0.1**	ND	0.0012	ND	ND
Thallium (Tl)	**0.002**	ND	ND	ND	ND
Thorium (Th)		ND	ND	ND	ND
Tin (Sn)		ND	ND	ND	ND
Titanium (Ti)		ND	0.0010	ND	ND
Uranium (U)	**0.03**	0.0084	0.0077	0.0113	0.0085
Vanadium (V)		0.0262	0.0270	0.0322	0.0320
Zinc (Zn-66)	**5**	ND	0.0013	0.0100	ND
Alkalinity					
Alkalinity as $CaCO_3$		190.00	193.00	685	696
Bicarbonate (HCO3)		231.00	235.00	801	813
Carbonate		ND	ND	17	18
Correctness of Analyses					
Anions		5.84	5.98	21.96	22.2
Cations		5.63	5.82	20.88	20.88
% Difference		-1.82	-1.35	-2.54	-3.08

	Drinking Water Reg:				
ID		**14203**	**14203**	**11903**	**11903**
Date Sampled		**2019**	**2022**	**2019**	**2022**
Field Parameters					
pH		8.0	7.8	7.4	7.7
Total Dissolved Solids (ppm)		405	403	488	382
Conductivity (uS)		626	620	717	565
Hardness		259.0	265.0	317.0	248.0
Cations (mg/L)					
Calcium (Ca)		55.6	57.7	81.0	64.0
Iron (Fe)	**0.3**	ND	ND	ND	ND
Magnesium (Mg)		29.30	29.40	27.90	21.40
Potassium (K)		4.75	4.83	3.64	4.21
Sodium (Na)		27.30	26.80	25.80	24.10
Strontium (Sr)	**190**	1.21	1.24	1.14	0.81
Anions (mg/L)					
Bromide (Br)		0.27	0.42	0.20	0.30
Chloride (Cl)	**250**	48.40	47.40	50.20	31..7
Fluoride (F)	**4**	0.89	1.04	0.95	1.36
Nitrate (NO_3)	**50**	26.80	24.00	42.70	18.20
Nitrite (NO_2)	**1**	ND	0.28	1.36	0.15
Orthophosphate (PO_4)		ND	ND	ND	ND
Sulfate (SO_4)	**250**	63.70	63.90	100.00	64.90
Trace Metals (mg/L)					
Aluminum (Al)	**0.2**	ND	0.0012	ND	0.0007
Antimony (Sb-121)	**0.006**	ND	ND	ND	ND
Arsenic (As)	**0.01**	ND	0.0019	ND	0.0020
Barium (Ba)	**2**	0.0490	0.0470	0.0810	0.0760
Beryllium (Be)	**0.004**	ND	ND	ND	ND
Boron (B-11)	**1.4**	0.0820	0.0850	0.0740	0.0610
Cadmium (Cd)	**0.005**	ND	ND	ND	ND
Chromium (Cr)	**0.1**	ND	0.0007	ND	ND
Cobalt (Co)		ND	ND	ND	ND
Copper (Cu-65)	**1.3**	ND	0.0015	ND	0.0011
Lead (Pb)	**0.015**	ND	ND	ND	ND
Lithium (Li)		0.0610	0.0610	0.0810	0.0830
Manganese (Mn)	**0.05**	ND	ND	ND	ND
Molybdenum (Mo-95)		ND	0.0020	ND	0.0010
Nickel (Ni)		ND	ND	ND	ND
Selenium (Se)	**0.05**	0.0080	0.0090	0.0100	0.0070
Silicon (Si)		18.0	17.5	19.4	21.2

Silver (Ag)	**0.1**	ND	ND	ND	ND
Thallium (Tl)	**0.002**	ND	ND	ND	ND
Thorium (Th)		ND	ND	ND	ND
Tin (Sn)		ND	ND	ND	ND
Titanium (Ti)		ND	0.0020	ND	0.0030
Uranium (U)	**0.03**	0.0070	0.0069	0.0057	0.0062
Vanadium (V)		0.0112	0.0112	0.0062	0.0149
Zinc (Zn-66)	**5**	ND	0.0027	0.0042	0.0228
Alkalinity					
Alkalinity as $CaCO_3$		178.00	177.00	182.00	173.00
Bicarbonate (HCO_3)		217.00	216.00	221.00	212.00
Carbonate		ND	ND	ND	ND
Correctness of Analyses					
Anions		6.73	6.67	7.90	6.09
Cations		6.49	6.59	7.55	6.10
% Difference		-1.76	-0.61	-2.27	0.15

	Drinking Water Reg:				
ID		**14503**	**14503**	**14102**	**14102**
Date Sampled		**2019**	**2022**	**2019**	**2022**
Field Parameters					
pH		7.8	8.2	7.9	8.0
Total Dissolved Solids (ppm)		275	287	273	276
Conductivity (uS)		438	437	424	420
Hardness		195.0	209.0	203.0	208.0
Cations (mg/L)					
Calcium (Ca)		35.9	38.7	31.4	32.8
Iron (Fe)	**0.3**	0.075	0.028	ND	ND
Magnesium (Mg)		25.7	27.3	30.2	30.70
Potassium (K)		4.51	4.81	5.61	5.66
Sodium (Na)		11.9	12.3	9.69	10.50
Strontium (Sr)	**190**	1.11	1.21	1.18	1.25
Anions (mg/L)					
Bromide (Br)		ND	ND	ND	0.19
Chloride (Cl)	**250**	12.70	12.2	6.74	6.13
Fluoride (F)	**4**	1.51	1.77	1.47	1.65
Nitrate (NO_3)	**50**	11.7	13.3	20.2	18.40
Nitrite (NO_2)	**1**	ND	ND	ND	ND
Orthophosphate (PO_4)		ND	ND	ND	ND
Sulfate (SO_4)	**250**	26.8	26.6	19	18.50
Trace Metals (mg/L)					
Aluminum (Al)	**0.2**	0.0019	0.0026	0.0010	0.0009
Antimony (Sb-121)	**0.006**	ND	ND	ND	ND
Arsenic (As)	**0.01**	0.0029	0.0029	0.0024	0.0022
Barium (Ba)	**2**	0.1270	0.1190	0.1700	0.1660
Beryllium (Be)	**0.004**	ND	ND	ND	ND
Boron (B-11)	**1.4**	0.1070	0.1190	0.0900	0.0910
Cadmium (Cd)	**0.005**	ND	ND	ND	ND
Chromium (Cr)	**0.1**	0.0007	0.0005	0.0007	0.0008
Cobalt (Co)		ND	ND	ND	ND
Copper (Cu-65)	**1.3**	0.0010	0.0005	0.0087	0.0020
Lead (Pb)	**0.015**	ND	ND	ND	ND
Lithium (Li)		0.0690	0.0670	0.0630	0.0600
Manganese (Mn)	**0.05**	0.0010	ND	0.0020	ND
Molybdenum (Mo-95)		0.0040	0.0040	0.0050	0.0050
Nickel (Ni)		ND	ND	ND	ND
Selenium (Se)	**0.05**	0.0030	0.0030	0.0020	0.0020
Silicon (Si)		15.9	15.6	16.9	16.2

Silver (Ag)	**0.1**	ND	0.0013	ND	ND
Thallium (Tl)	**0.002**	ND	ND	ND	ND
Thorium (Th)		ND	ND	ND	ND
Tin (Sn)		0.0005	ND	ND	ND
Titanium (Ti)		0.0010	0.0010	0.0010	0.0020
Uranium (U)	**0.03**	0.0074	0.0076	0.0084	0.0086
Vanadium (V)		0.0175	0.0175	0.0167	0.0176
Zinc (Zn-66)	**5**	0.0255	0.0262	0.0287	0.0195
Alkalinity					
Alkalinity as $CaCO_3$		179	190	184	190.00
Bicarbonate (HCO_3)		218	232	225	231.00
Carbonate		ND	ND	ND	ND
Correctness of Analyses					
Anions		4.77	5	4.68	4.74
Cations		4.54	4.83	4.61	4.77
% Difference		-2.44	-1.73	-0.66	0.23

	Drinking Water Reg:				
ID		**11602**	**11602**	**11602**	**11602**
Date Sampled		**2019**	**2022**	**2019**	**2022**
Field Parameters					
pH		7.7	7.9	7.8	8.1
Total Dissolved Solids (ppm)		375	385	389	390
Conductivity (uS)		580	574	604	583
Hardness		232.0	240.0	246.0	251.0
Cations (mg/L)					
Calcium (Ca)		61.1	62.7	63.0	64.6
Iron (Fe)	**0.3**	0.050	ND	0.036	0.050
Magnesium (Mg)		19.2	20.2	21.5	21.7
Potassium (K)		4.51	4.37	3.89	4.24
Sodium (Na)		32.1	31.4	29.9	29.2
Strontium (Sr)	**190**	0.863	0.916	0.943	0.972
Anions (mg/L)					
Bromide (Br)		0.15	ND	0.2	ND
Chloride (Cl)	**250**	32.5	35.8	35.8	34.1
Fluoride (F)	**4**	0.83	0.91	0.73	0.82
Nitrate (NO_3)	**50**	16.7	19.8	19.5	16.8
Nitrite (NO_2)	**1**	ND	ND	ND	ND
Orthophosphate (PO_4)		ND	ND	ND	ND
Sulfate (SO_4)	**250**	59.5	59.2	57.4	60.9
Trace Metals (mg/L)					
Aluminum (Al)	**0.2**	ND	0.0016	0.0032	0.0342
Antimony (Sb-121)	**0.006**	ND	ND	ND	ND
Arsenic (As)	**0.01**	0.0014	0.0013	0.0018	0.0017
Barium (Ba)	**2**	0.0480	0.0460	0.0550	0.0500
Beryllium (Be)	**0.004**	ND	ND	ND	ND
Boron (B-11)	**1.4**	0.0910	0.0890	0.0860	0.0850
Cadmium (Cd)	**0.005**	ND	ND	ND	ND
Chromium (Cr)	**0.1**	0.0005	ND	0.0005	0.0009
Cobalt (Co)		ND	ND	ND	ND
Copper (Cu-65)	**1.3**	0.0005	0.0014	0.0006	0.0008
Lead (Pb)	**0.015**	ND	ND	ND	ND
Lithium (Li)		0.0460	0.0420	0.0480	0.0440
Manganese (Mn)	**0.05**	0.0010	ND	0.0020	ND
Molybdenum (Mo-95)		0.0010	0.0020	0.0020	0.0010
Nickel (Ni)		0.0006	ND	0.0007	ND

Selenium (Se)	**0.05**	0.0050	0.0050	0.0090	0.0060
Silicon (Si)		16.4	15.9	17.9	17.1
Silver (Ag)	**0.1**	ND	ND	ND	ND
Thallium (Tl)	**0.002**	ND	ND	ND	ND
Thorium (Th)		ND	ND	ND	ND
Tin (Sn)		ND	ND	ND	ND
Titanium (Ti)		0.0010	0.0010	0.0010	0.0020
Uranium (U)	**0.03**	0.0073	0.0069	0.0075	0.0073
Vanadium (V)		0.0069	0.0072	0.0095	0.0101
Zinc (Zn-66)	**5**	0.0028	0.0116	0.0071	0.0029
Alkalinity					
Alkalinity as $CaCO_3$		186	188	193	197
Bicarbonate (HCO_3)		227	230	235	240
Carbonate		ND	ND	ND	ND
Correctness of Analyses					
Anions		6.19	6.39	6.42	6.48
Cations		6.14	6.27	6.32	6.39
% Difference		-0.38	-0.92	-0.77	-0.72

	Drinking Water Reg:				
ID		**11701**	**11701**	**14301**	**14301**
Date Sampled		**2019**	**2022**	**2019**	**2022**
Field Parameters					
pH		8.0	8.2	7.9	8.1
Total Dissolved Solids (ppm)		288	332	348	360
Conductivity (uS)		456	511	514	526
Hardness		199.0	227.0	240.0	241.0
Cations (mg/L)					
Calcium (Ca)		26.4	30.3	44.3	44.7
Iron (Fe)	**0.3**	ND	0.024	0.035	0.036
Magnesium (Mg)		32.2	36.8	31.4	31.5
Potassium (K)		6.68	7.51	5.24	8.58
Sodium (Na)		19.7	22.7	15.3	15.5
Strontium (Sr)	**190**	1.22	1.43	1.45	1.5
Anions (mg/L)					
Bromide (Br)		0.1	ND	0.21	ND
Chloride (Cl)	**250**	13.5	15.8	36.6	38
Fluoride (F)	**4**	2.35	2.73	2.36	2.44
Nitrate (NO_3)	**50**	9.23	10.5	20.6	22
Nitrite (NO_2)	**1**	ND	ND	ND	ND
Orthophosphate (PO_4)		ND	ND	ND	ND
Sulfate (SO_4)	**250**	41.5	48.6	35.5	39.7
Trace Metals (mg/L)					
Aluminum (Al)	**0.2**	0.0022	0.0020	0.0035	0.0070
Antimony (Sb-121)	**0.006**	ND	ND	ND	ND
Arsenic (As)	**0.01**	0.0022	0.0024	0.0037	0.0036
Barium (Ba)	**2**	0.0600	0.0620	0.1220	0.1160
Beryllium (Be)	**0.004**	ND	ND	ND	ND
Boron (B-11)	**1.4**	0.1530	0.1710	0.1040	0.1080
Cadmium (Cd)	**0.005**	ND	ND	ND	ND
Chromium (Cr)	**0.1**	0.0016	0.0017	ND	ND
Cobalt (Co)		ND	ND	ND	ND
Copper (Cu-65)	**1.3**	0.0090	0.0008	0.0596	0.0022
Lead (Pb)	**0.015**	0.0006	ND	0.0038	ND
Lithium (Li)		0.0740	0.0790	0.1120	0.1000
Manganese (Mn)	**0.05**	0.0010	ND	0.0010	ND
Molybdenum (Mo-95)		0.0090	0.0100	0.0020	0.0020
Nickel (Ni)		ND	ND	0.0010	ND

Selenium (Se)	**0.05**	0.0050	0.0050	0.0070	0.0080
Silicon (Si)		13.6	14.3	26.3	25.5
Silver (Ag)	**0.1**	ND	ND	ND	0.0010
Thallium (Tl)	**0.002**	ND	ND	ND	ND
Thorium (Th)		ND	ND	ND	ND
Tin (Sn)		ND	ND	0.0011	ND
Titanium (Ti)		0.0010	0.0010	0.0020	0.0020
Uranium (U)	**0.03**	0.0110	0.0117	0.0064	0.0062
Vanadium (V)		0.0130	0.0141	0.0186	0.0184
Zinc (Zn-66)	**5**	0.1590	0.1360	0.0223	0.0064
Alkalinity					
Alkalinity as $CaCO_3$		177	205	165	167
Bicarbonate (HCO_3)		215	250	201	203
Carbonate		ND	ND	ND	ND
Correctness of Analyses					
Anions		5.05	5.87	5.53	5.72
Cations		5	5.72	5.6	5.72
% Difference		-0.55	-1.34	0.65	-0.01

	Drinking Water Reg:				
ID		**14402**	**14402**	**10903**	**10903**
Date Sampled		**2019**	**2022**	**2019**	**2022**
Field Parameters					
pH		8.1	8.4	8.0	7.9
Total Dissolved Solids (ppm)		669	587	289	287
Conductivity (uS)		1010	907	454	456
Hardness		196.0	52.5	201.0	202.0
Cations (mg/L)					
Calcium (Ca)		47.0	10.9	31.6	32.3
Iron (Fe)	**0.3**	1.980	ND	0.069	ND
Magnesium (Mg)		19.1	6.15	29.60	29.50
Potassium (K)		3.46	5.23	5.27	6.43
Sodium (Na)		162	199	19.60	19.40
Strontium (Sr)	**190**	0.576	0.222	1.30	1.29
Anions (mg/L)					
Bromide (Br)		0.1	ND	0.16	0.17
Chloride (Cl)	**250**	22.9	19.1	22.90	17.70
Fluoride (F)	**4**	2.9	3.2	1.63	1.96
Nitrate (NO_3)	**50**	30	1.24	16.30	12.90
Nitrite (NO_2)	**1**	ND	ND	ND	ND
Orthophosphate (PO_4)		ND	ND	ND	ND
Sulfate (SO_4)	**250**	182	136	32.00	33.00
Trace Metals (mg/L)					
Aluminum (Al)	**0.2**	0.0096	0.0102	0.0009	0.0018
Antimony (Sb-121)	**0.006**	ND	ND	ND	ND
Arsenic (As)	**0.01**	ND	ND	0.0013	0.0013
Barium (Ba)	**2**	0.1530	0.0380	0.0800	0.0720
Beryllium (Be)	**0.004**	ND	ND	ND	ND
Boron (B-11)	**1.4**	0.3560	0.3760	0.1130	0.1260
Cadmium (Cd)	**0.005**	ND	ND	ND	ND
Chromium (Cr)	**0.1**	ND	ND	0.0009	0.0011
Cobalt (Co)		ND	ND	ND	ND
Copper (Cu-65)	**1.3**	0.0602	0.0094	ND	0.0008
Lead (Pb)	**0.015**	ND	ND	ND	ND
Lithium (Li)		0.0870	0.1100	0.0580	0.0660
Manganese (Mn)	**0.05**	0.1290	ND	0.0020	ND
Molybdenum (Mo-95)		0.0090	0.0090	0.0090	0.0080
Nickel (Ni)		ND	ND	0.0014	ND

Selenium (Se)	**0.05**	ND	ND	0.0040	0.0040
Silicon (Si)		6.1	4.2	12.2	11.6
Silver (Ag)	**0.1**	ND	ND	ND	ND
Thallium (Tl)	**0.002**	ND	ND	ND	ND
Thorium (Th)		ND	ND	ND	ND
Tin (Sn)		ND	ND	ND	ND
Titanium (Ti)		ND	ND	0.0010	0.0010
Uranium (U)	**0.03**	0.0134	ND	0.0087	0.0096
Vanadium (V)		ND	ND	0.0103	0.0107
Zinc (Zn-66)	**5**	0.3920	0.0475	0.1740	0.1380
Alkalinity					
Alkalinity as $CaCO_3$		295	324	168.00	175.00
Bicarbonate (HCO_3)		360	384	206.00	214.00
Carbonate		ND	6	ND	ND
Correctness of Analyses					
Anions		10.97	10.03	5.03	5.01
Cations		11.05	9.83	5.00	5.05
% Difference		0.34	-1.03	-0.31	0.39

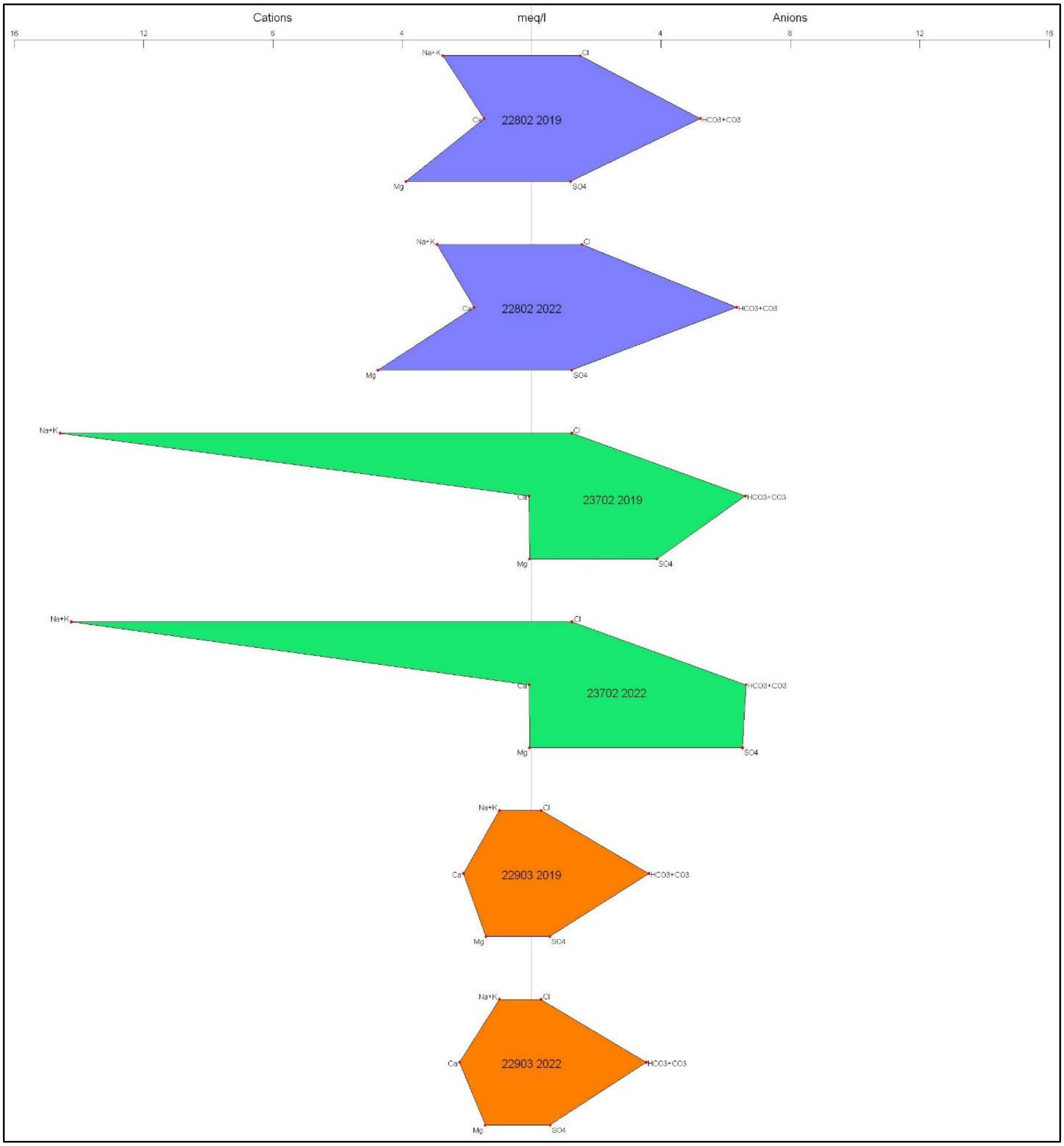
	Drinking Water Reg:				
ID		**12403**	**12403**	**14603**	**14603**
Date Sampled		**2019**	**2022**	**2019**	**2022**
Field Parameters					
pH		7.8	8.1	7.9	8.1
Total Dissolved Solids (ppm)		340	341	287	297
Conductivity (uS)		504	488	462	446
Hardness		221.0	220.0	173.0	182.0
Cations (mg/L)					
Calcium (Ca)		47.2	47.2	31.7	33.8
Iron (Fe)	**0.3**	0.020	1.120	ND	ND
Magnesium (Mg)		25	24.7	22.8	23.8
Potassium (K)		3.92	4.45	4.18	5.24
Sodium (Na)		18	17.5	25.4	25.3
Strontium (Sr)	**190**	0.8	0.791	0.937	0.995
Anions (mg/L)					
Bromide (Br)		0.16	ND	ND	ND
Chloride (Cl)	**250**	33.8	32.1	17.7	21.3
Fluoride (F)	**4**	1.65	1.87	2.09	2.25
Nitrate (NO_3)	**50**	23.7	23.2	8.75	10.5
Nitrite (NO_2)	**1**	ND	ND	ND	ND
Orthophosphate (PO_4)		ND	ND	ND	ND
Sulfate (SO_4)	**250**	27.4	27.7	39.4	39.8
Trace Metals (mg/L)					
Aluminum (Al)	**0.2**	ND	0.0064	0.0039	0.0046
Antimony (Sb-121)	**0.006**	ND	ND	ND	ND
Arsenic (As)	**0.01**	0.0027	0.0039	0.0045	0.0046
Barium (Ba)	**2**	0.1150	0.1140	0.0570	0.0570
Beryllium (Be)	**0.004**	ND	ND	ND	ND
Boron (B-11)	**1.4**	0.1210	0.1160	0.1390	0.1390
Cadmium (Cd)	**0.005**	ND	ND	ND	ND
Chromium (Cr)	**0.1**	0.0015	0.0034	0.0011	0.0010
Cobalt (Co)		ND	ND	ND	ND
Copper (Cu-65)	**1.3**	0.0005	0.0119	0.0078	0.0024
Lead (Pb)	**0.015**	ND	0.0032	0.0005	ND
Lithium (Li)		0.0580	0.0490	0.0640	0.0600
Manganese (Mn)	**0.05**	0.0010	ND	ND	ND
Molybdenum (Mo-95)		0.0050	0.0050	0.0090	0.0090
Nickel (Ni)		ND	ND	ND	ND

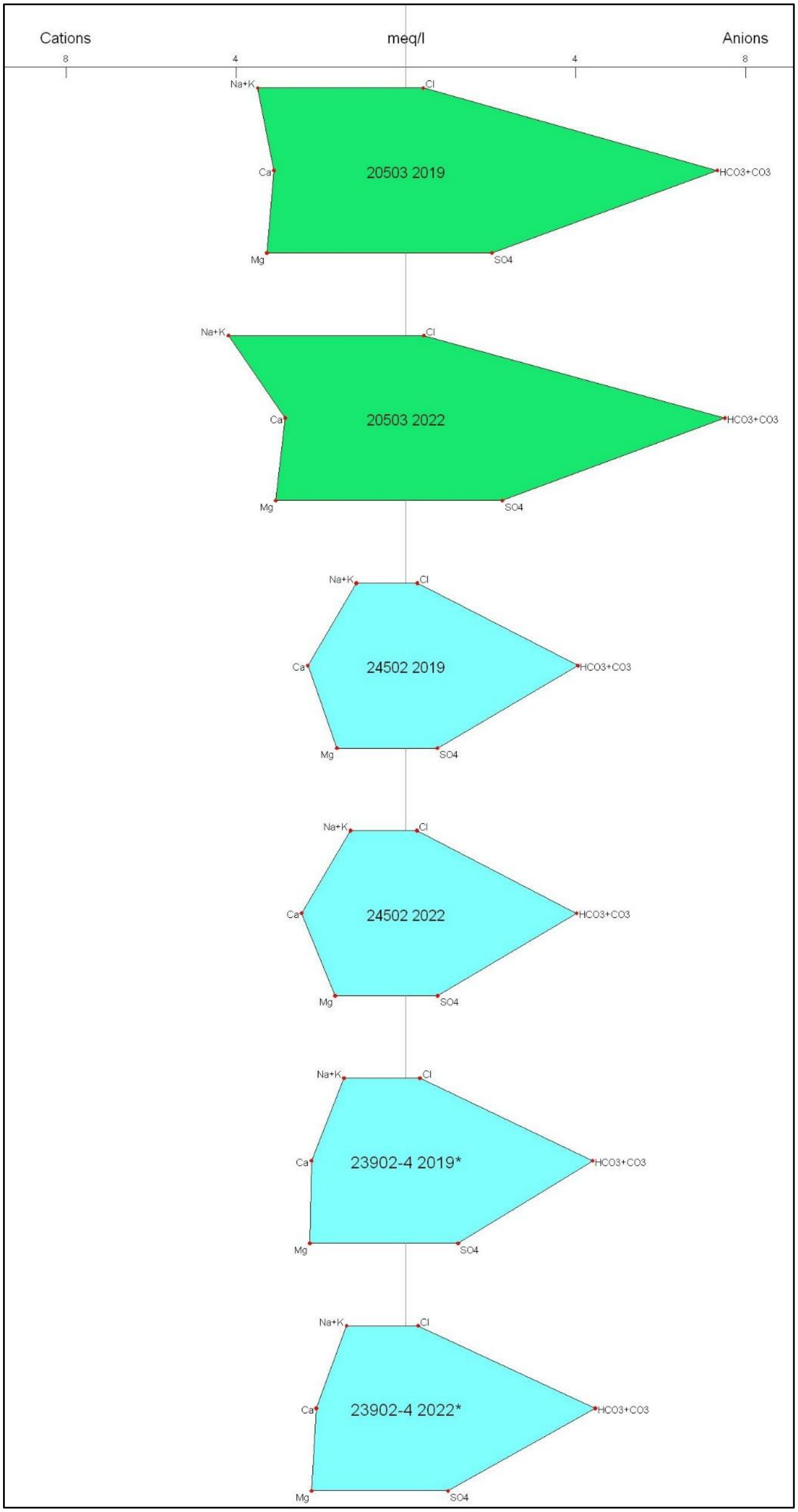
Selenium (Se)	**0.05**	0.0050	0.0040	0.0030	0.0030
Silicon (Si)		27.3	26.2	15.8	15.3
Silver (Ag)	**0.1**	ND	ND	ND	0.0013
Thallium (Tl)	**0.002**	ND	ND	ND	ND
Thorium (Th)		ND	ND	ND	ND
Tin (Sn)		ND	ND	ND	ND
Titanium (Ti)		0.0020	0.0020	0.0010	0.0010
Uranium (U)	**0.03**	0.0062	0.0060	0.0062	0.0060
Vanadium (V)		0.0142	0.0186	0.0254	0.0262
Zinc (Zn-66)	**5**	0.0380	0.1340	0.0079	0.0076
Alkalinity					
Alkalinity as $CaCO_3$		166	170	164	165
Bicarbonate (HCO_3)		202	207	200	201
Carbonate		ND	ND	ND	ND
Correctness of Analyses					
Anions		5.31	5.36	4.85	5.03
Cations		5.29	5.26	4.67	4.88
% Difference		-0.23	-0.91	-1.93	-1.48

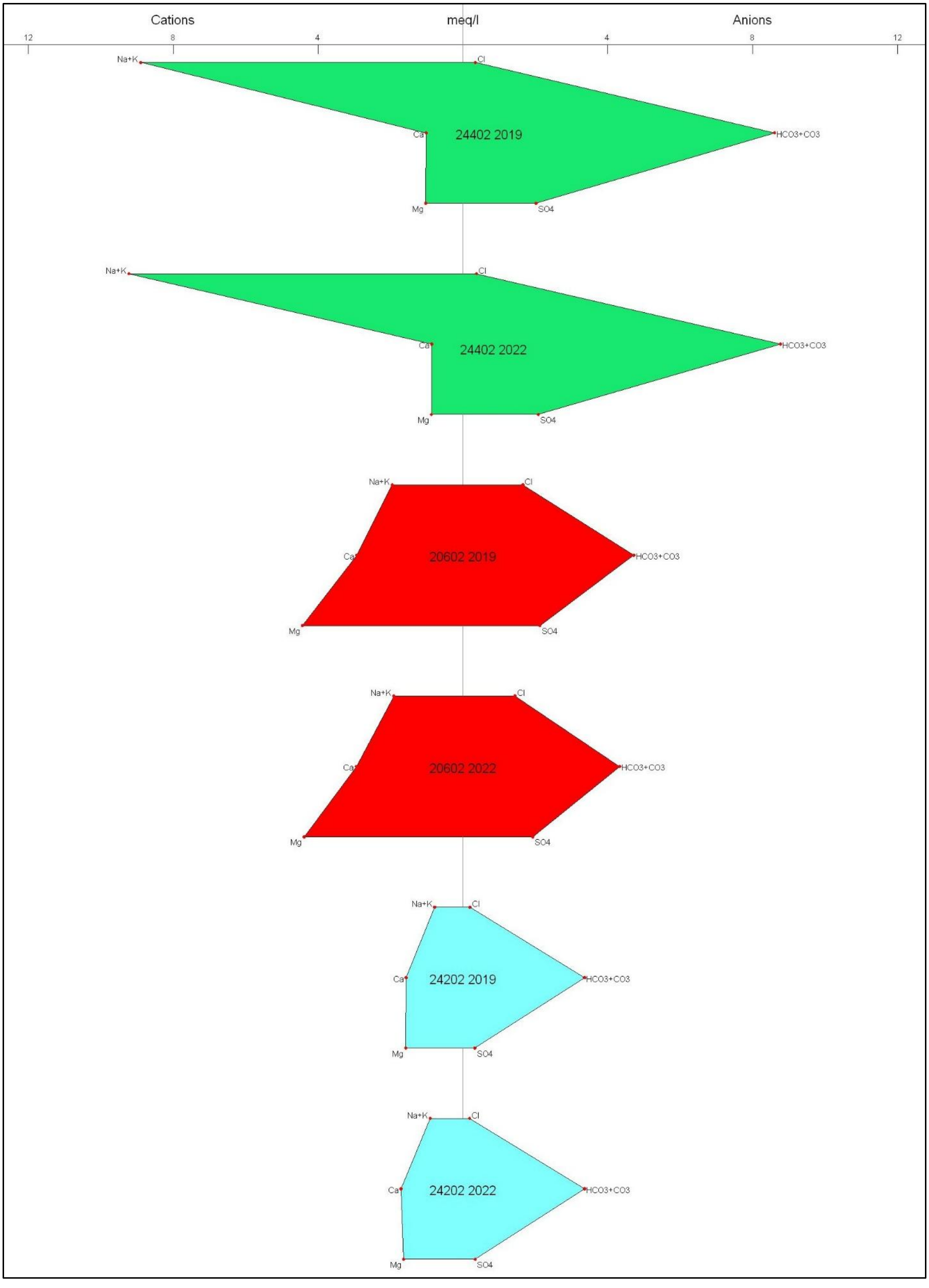
Appendix IV: Stiff Diagrams

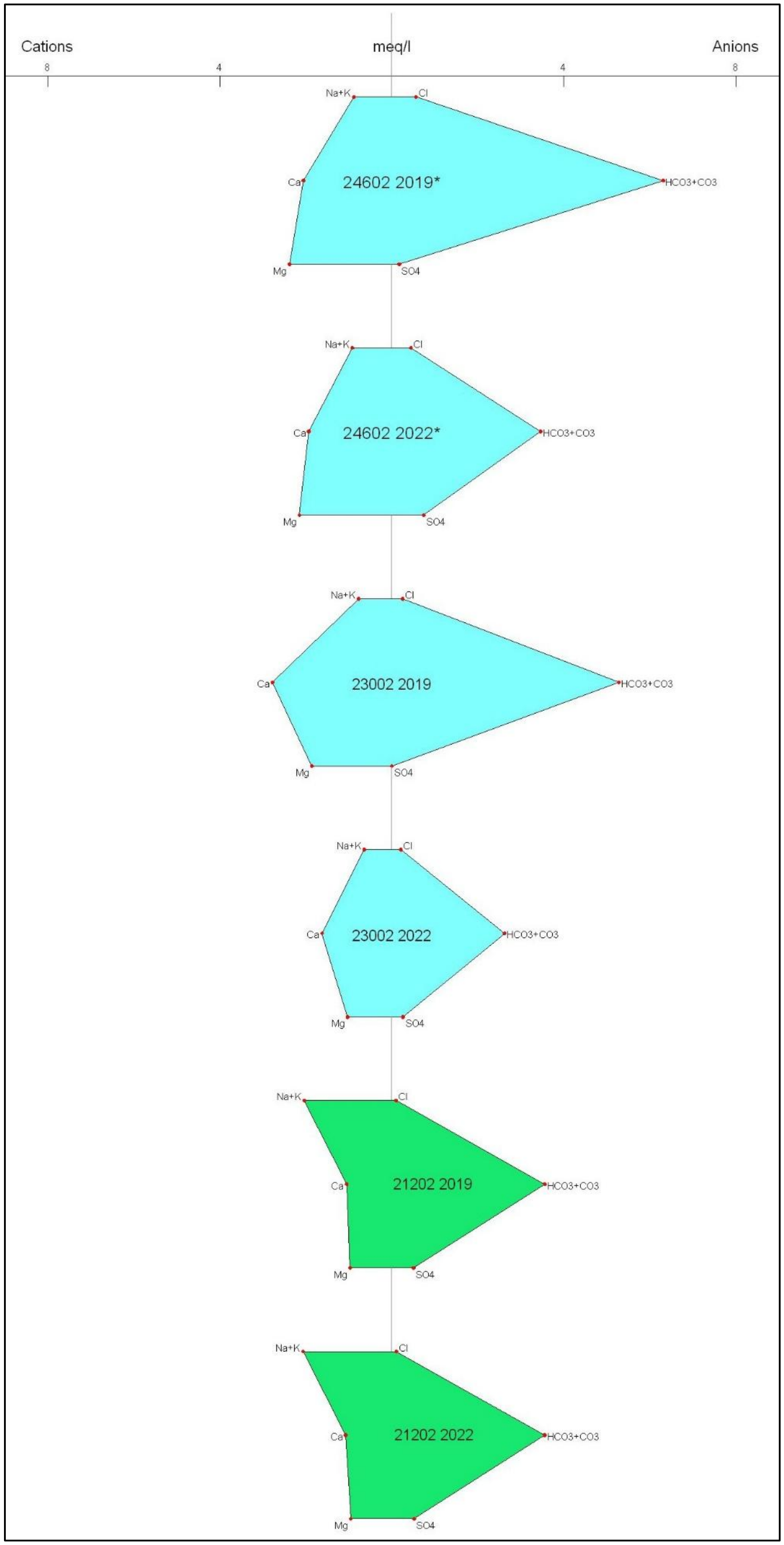
Individual Stiff diagrams for each well for each sampling season (2019 and 2023).

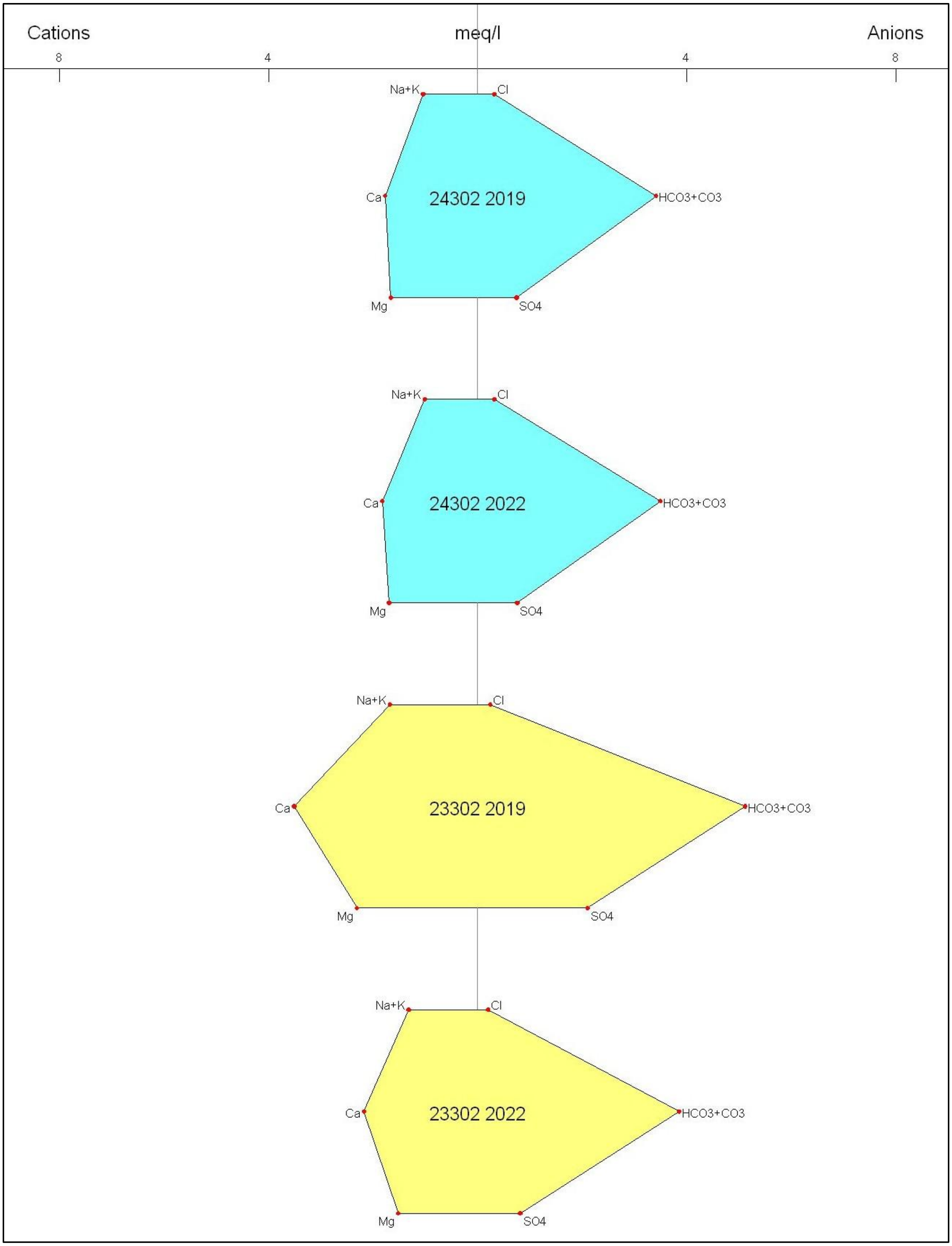
Union County



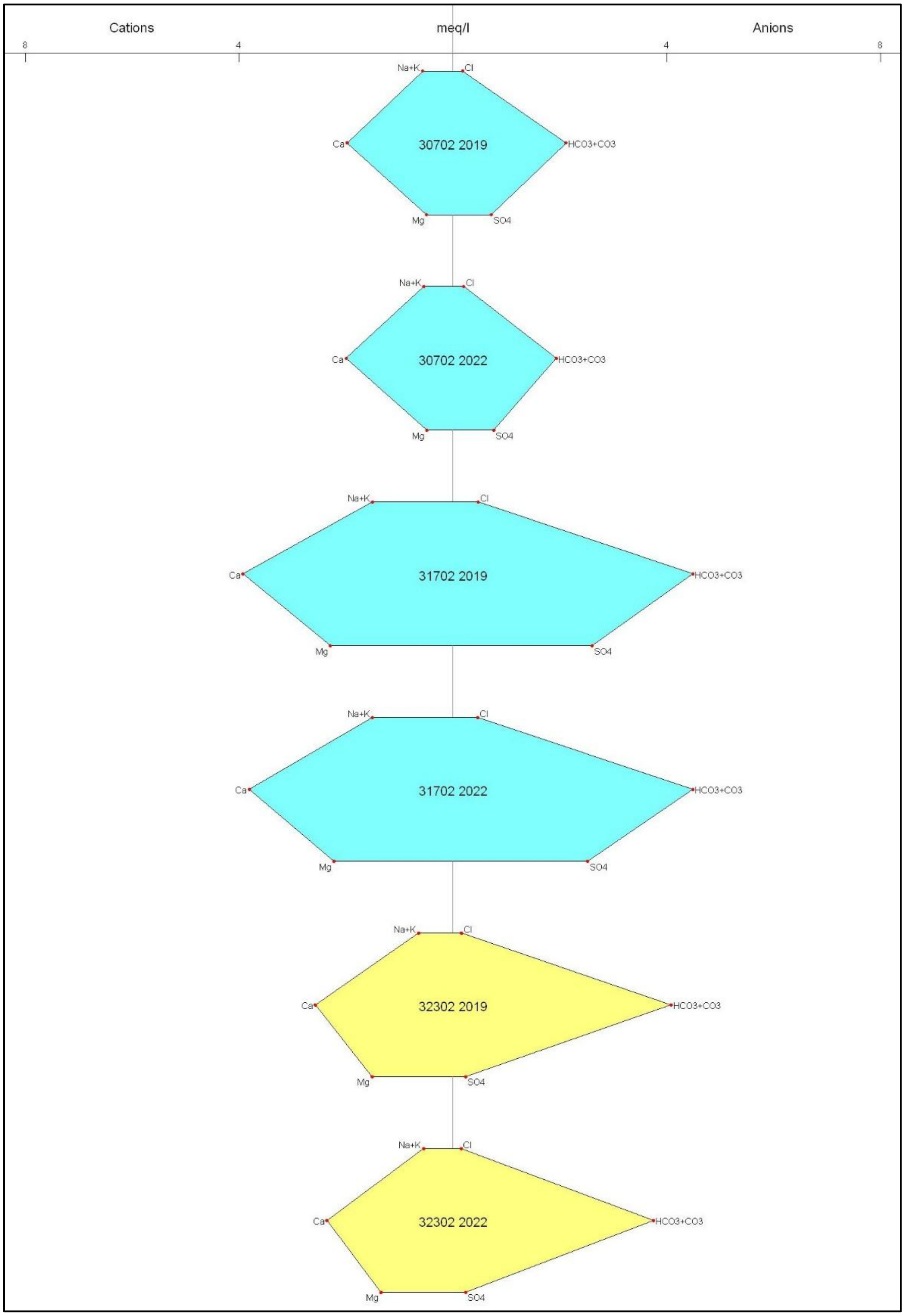

Cations
meq/l
Anions
8
4
4
8
Na+K
Cl
Ca
HCO3+CO3
Mg
SO4
20503 2019
20503 2022
24502 2019
24502 2022
23902-4 2019*
23902-4 2022*

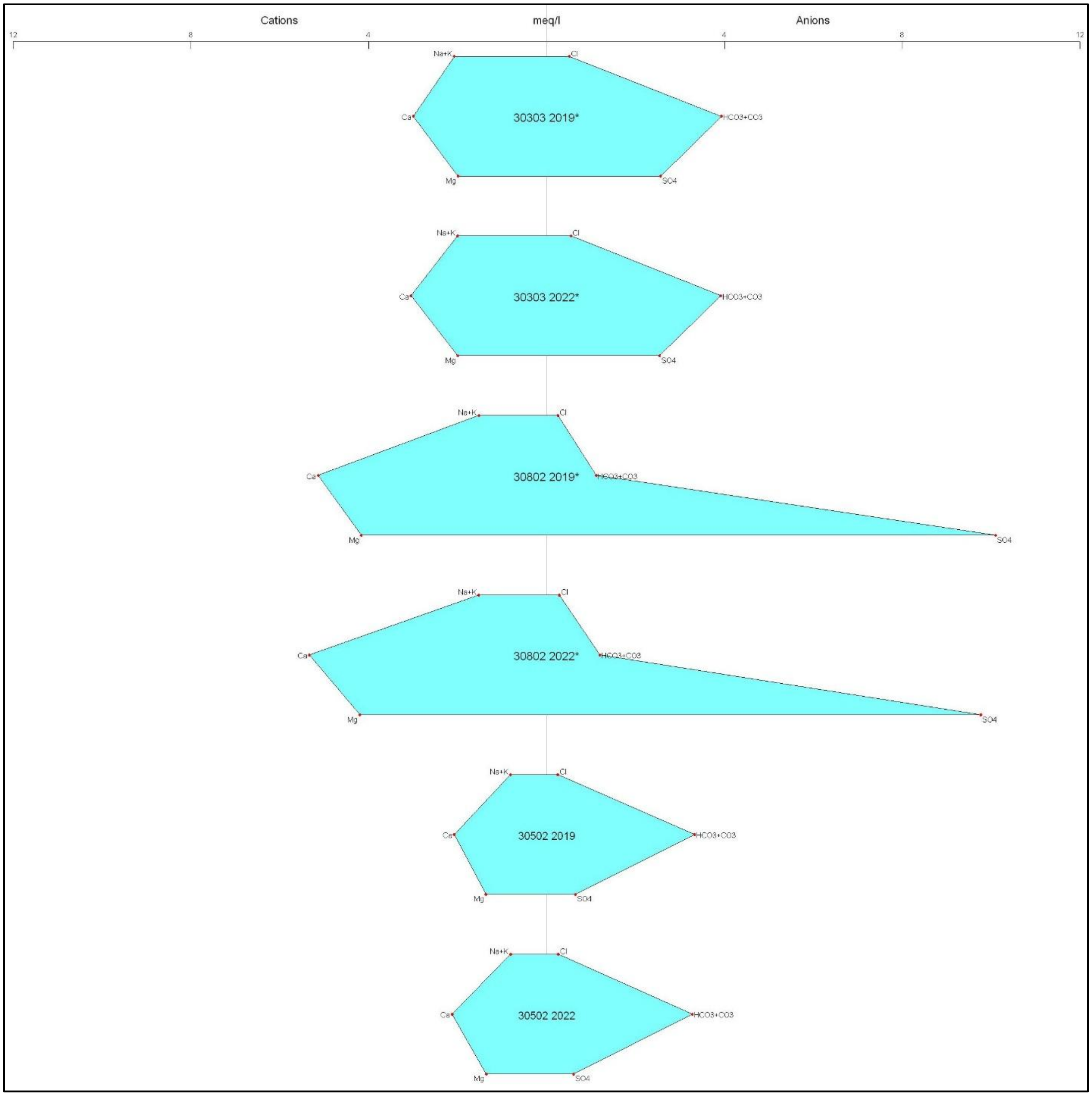

Cations
meq/l
Anions
12
8
4
4
8
12
Na+K
Cl
Ca
24402 2019
HCO3+CO3
Mg
SO4
Na+K
Cl
Ca
24402 2022
HCO3+CO3
Mg
SO4
Na+K
Cl
Ca
20602 2019
HCO3+CO3
Mg
SO4
Na+K
Cl
Ca
20602 2022
HCO3+CO3
Mg
SO4
Na+K
Cl
Ca
24202 2019
HCO3+CO3
Mg
SO4
Na+K
Cl
Ca
24202 2022
HCO3+CO3
Mg
SO4

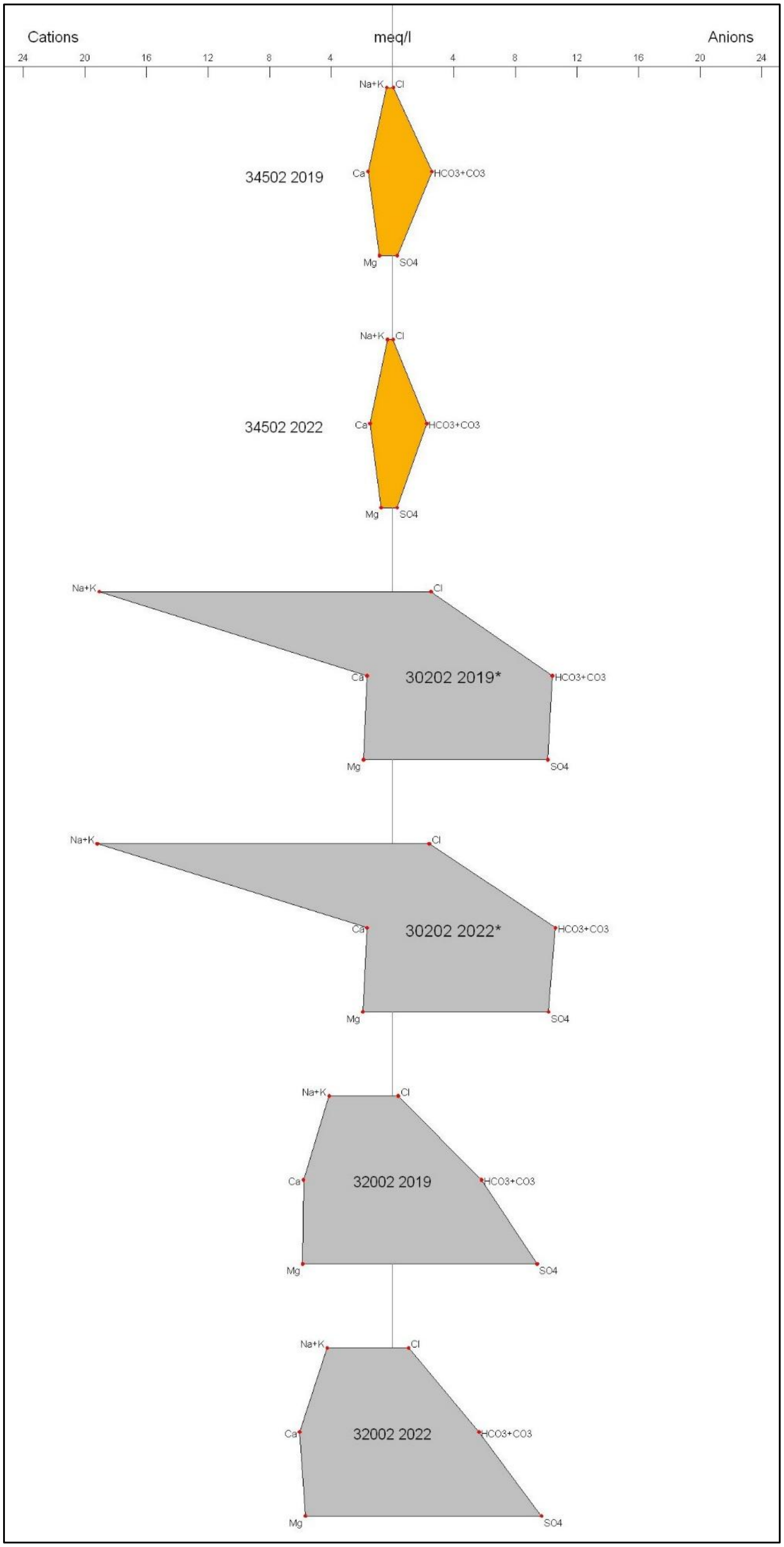

Cations
meq/l
Anions
8
4
4
8
Na+K
Cl
Ca
HCO3+CO3
Mg
SO4
24602 2019*
24602 2022*
23002 2019
23002 2022
21202 2019
21202 2022

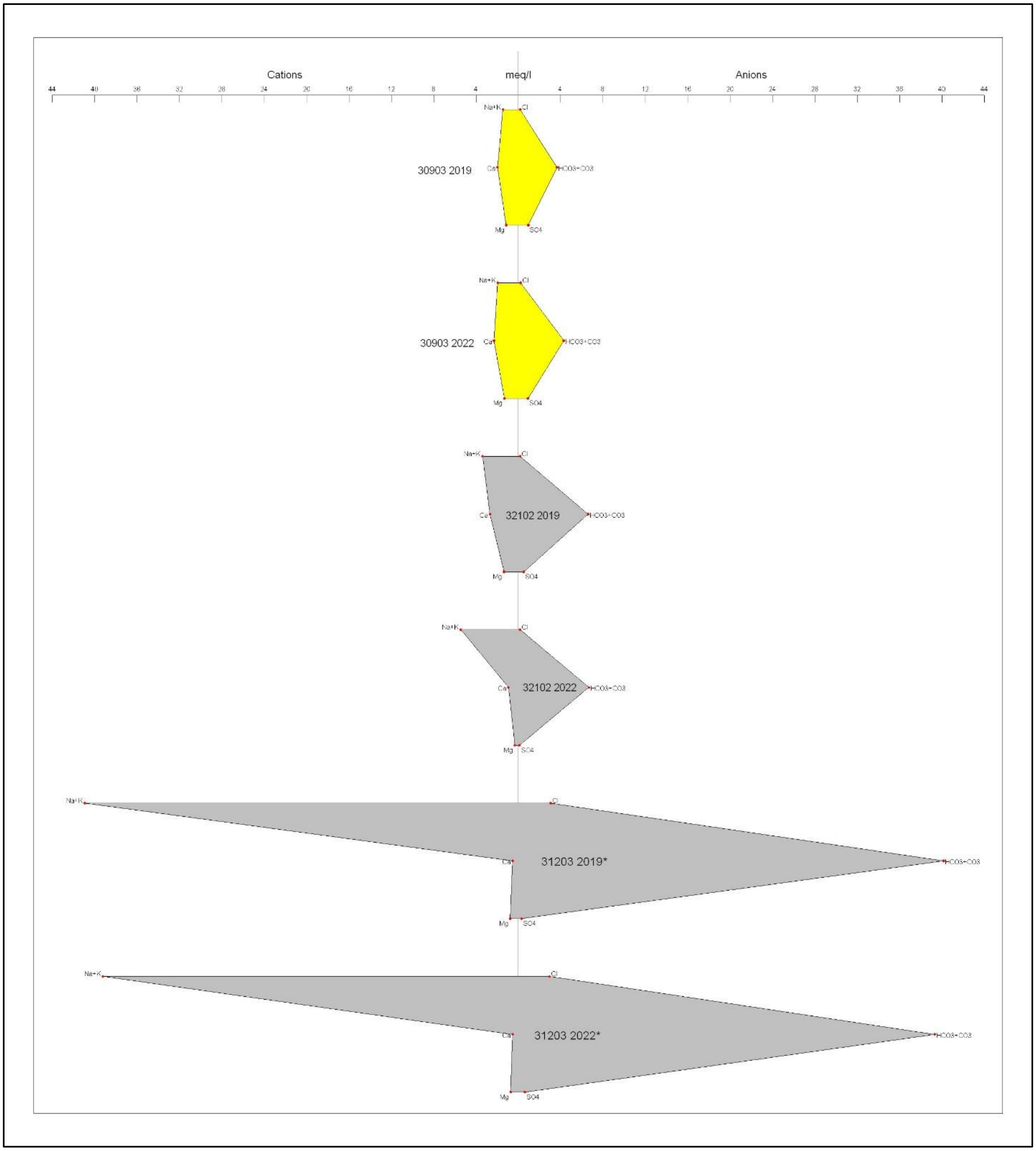

Cations
meq/l
Anions
8
4
4
8
Na+K
Cl
Ca
HCO3+CO3
Mg
SO4
24302 2019
24302 2022
23302 2019
23302 2022

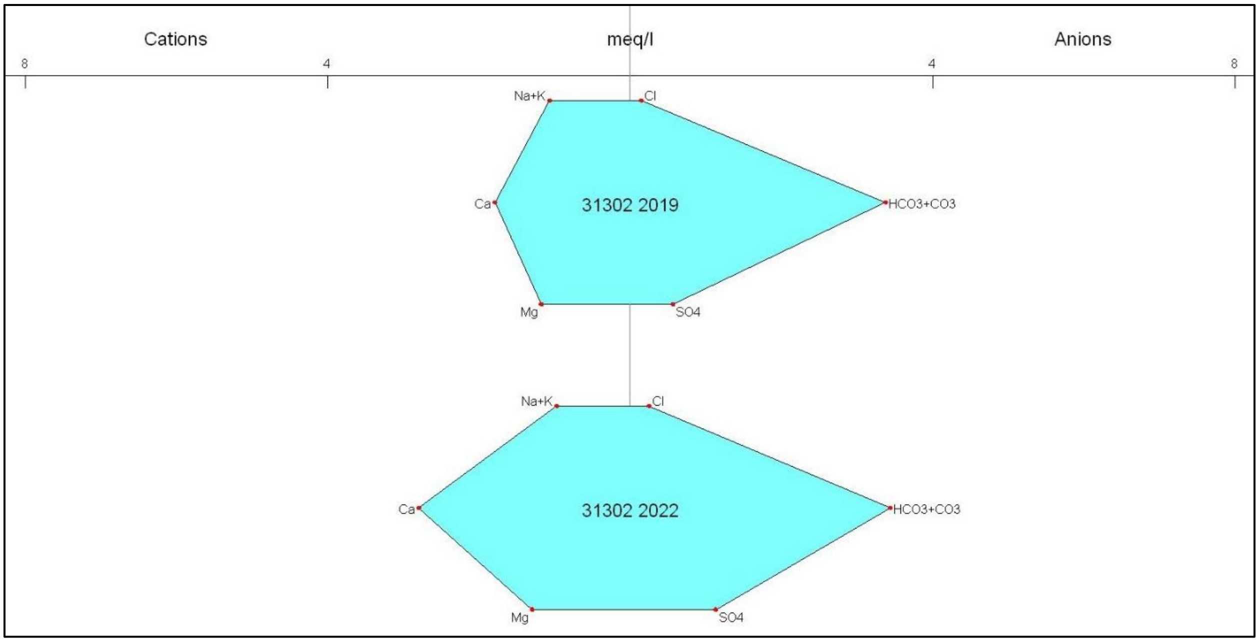
Las Animas County



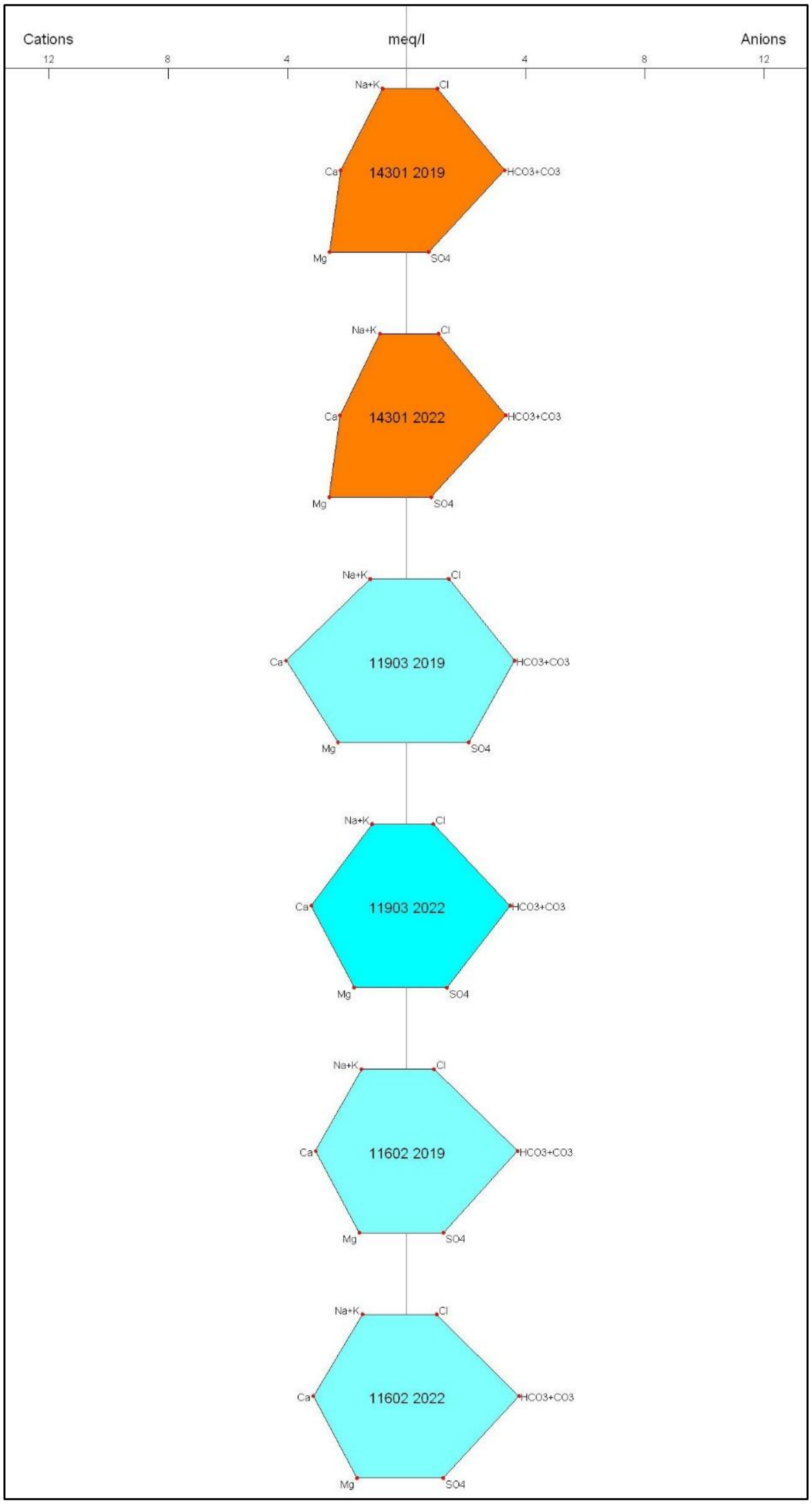

Cations
meq/l
Anions
12
8
4
4
8
12
Na+K
Cl
Ca
HCO3+CO3
Mg
SO4
30303 2019*
30303 2022*
30802 2019*
30802 2022*
30502 2019
30502 2022

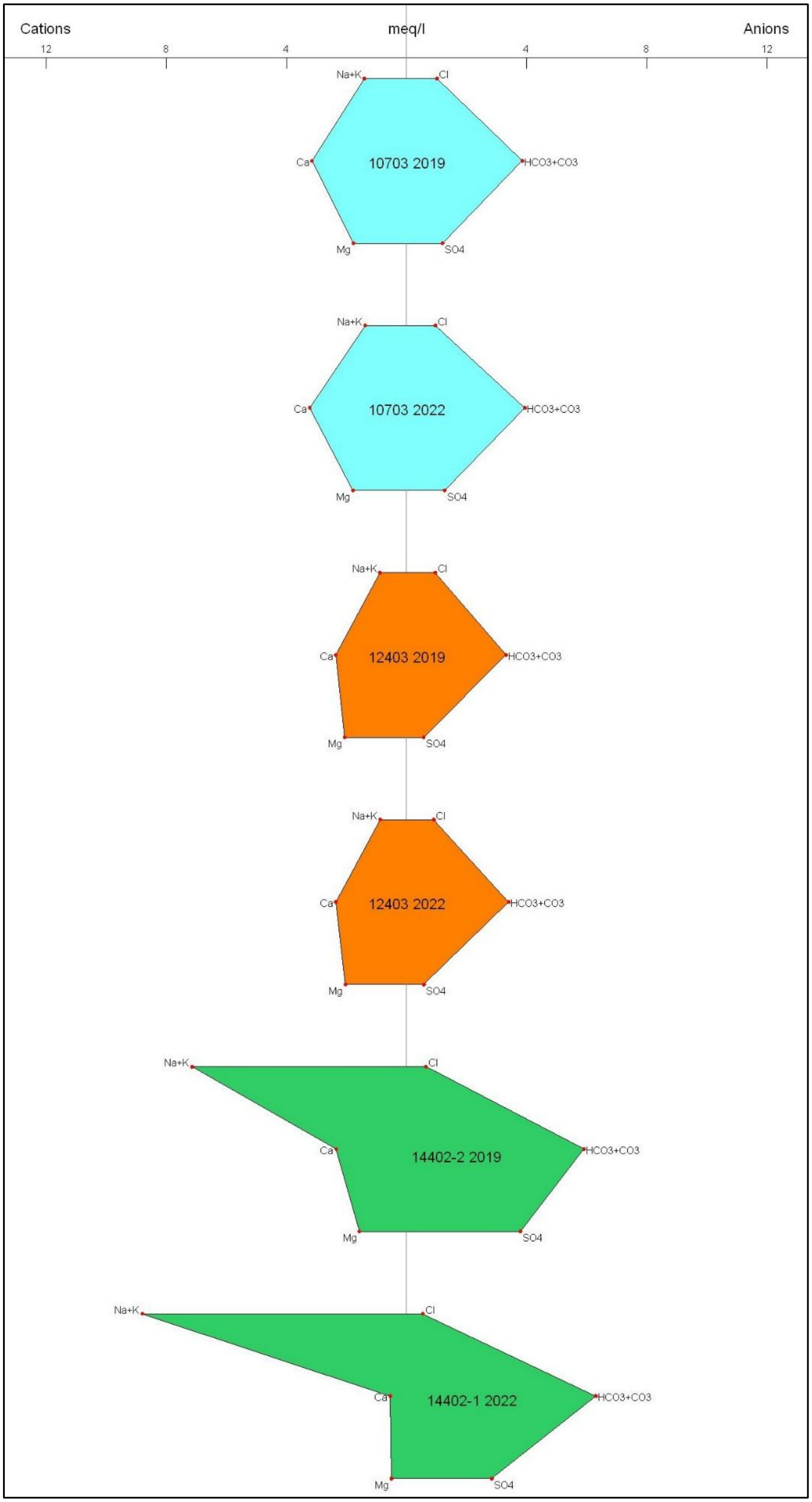

Cations
meq/l
Anions
24
20
16
12
8
4
4
8
12
16
20
24
Na+K
Cl
Ca
HCO3+CO3
Mg
SO4
34502 2019
34502 2022
30202 2019*
30202 2022*
32002 2019
32002 2022


Cations
meq/l
Anions
44 40 36 32 28 24 20 16 12 8 4 4 8 12 16 20 24 28 32 36 40 44
Na+K
Cl
Ca
HCO3+CO3
Mg
SO4
30903 2019
30903 2022
32102 2019
32102 2022
31203 2019*
31203 2022*

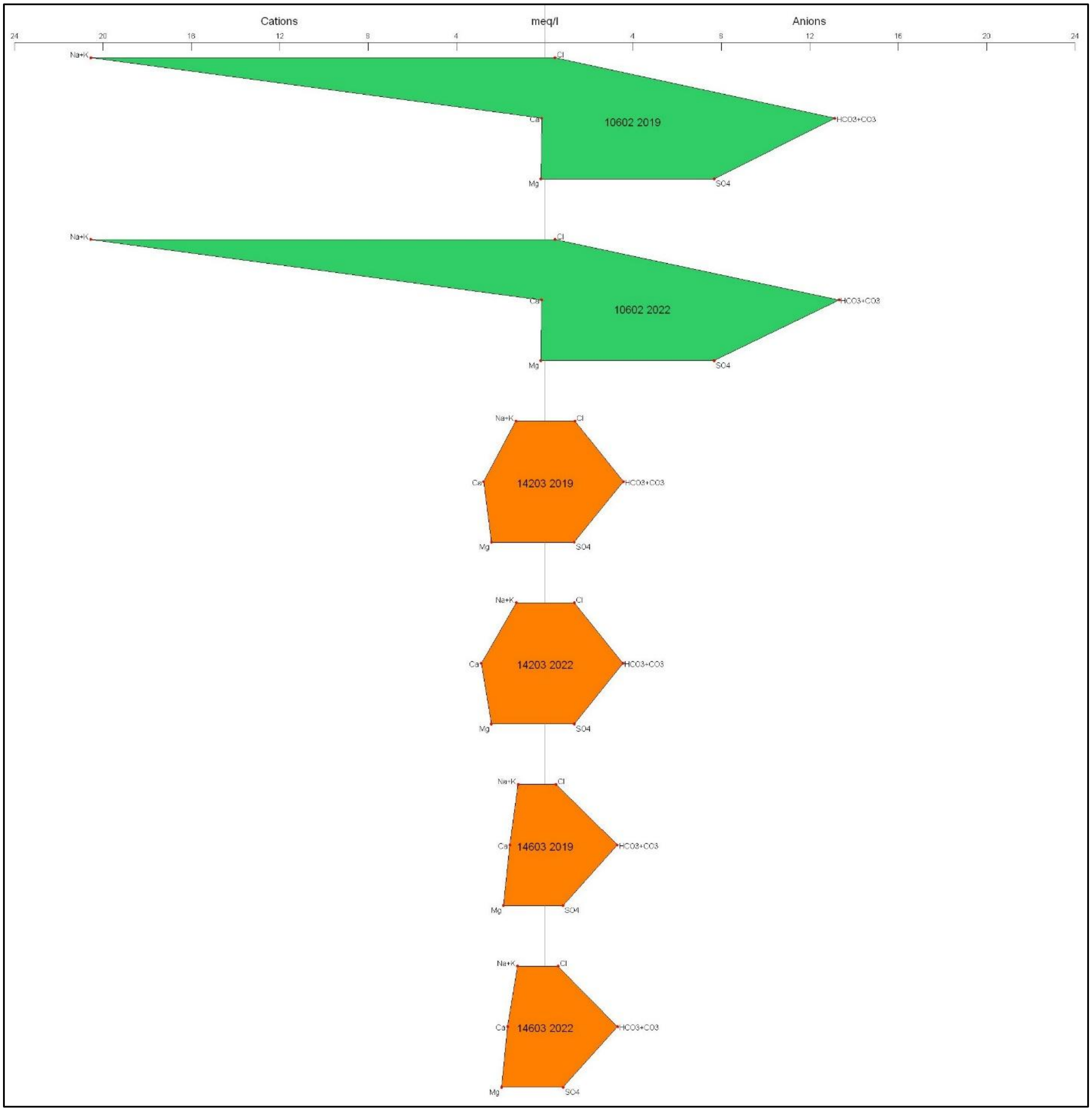

Cations
meq/l
Anions
8
4
4
8
Na+K
Cl
Ca
31302 2019
HCO3+CO3
Mg
SO4
Na+K
Cl
Ca
31302 2022
HCO3+CO3
Mg
SO4

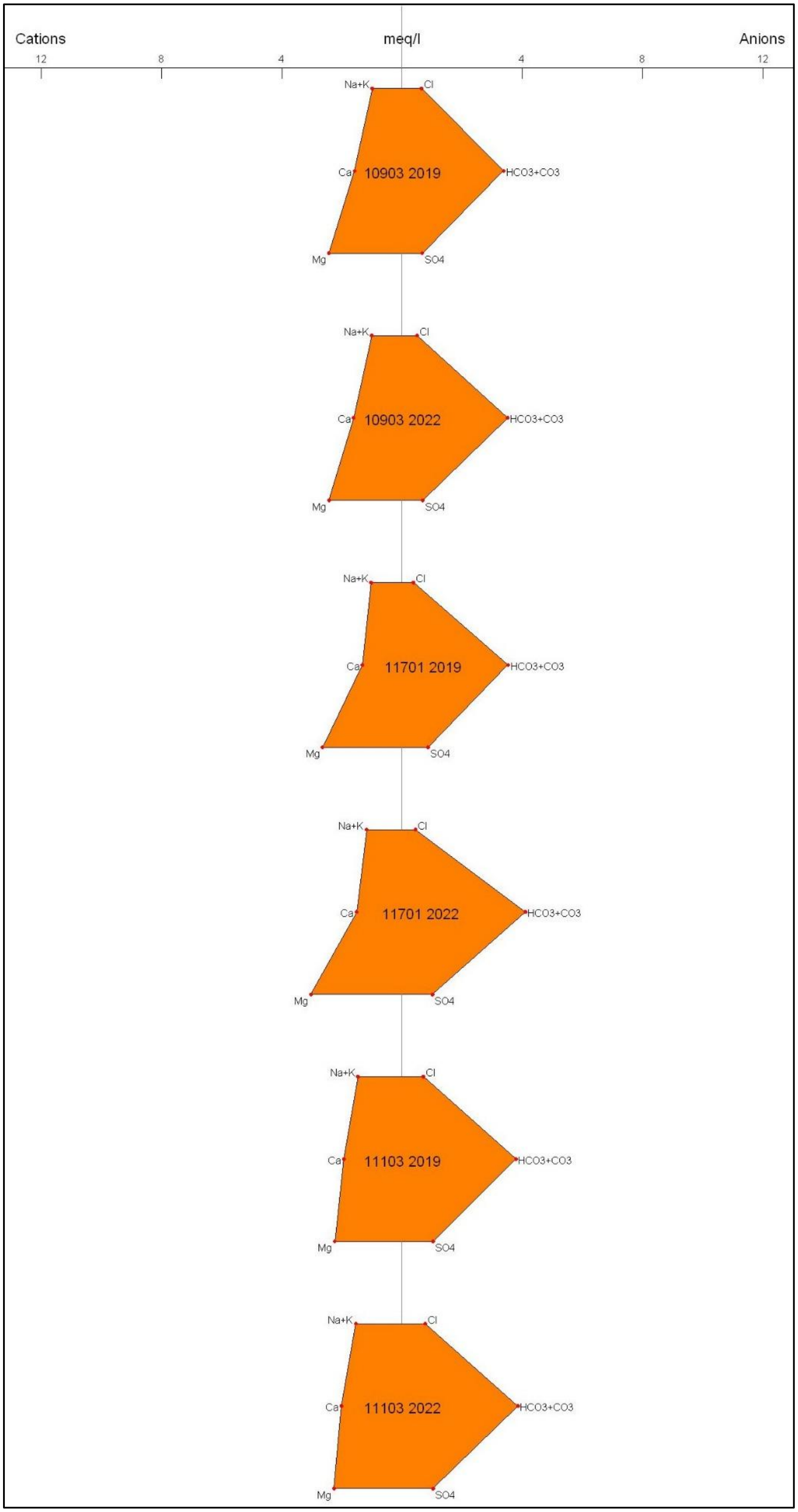
Cimarron County



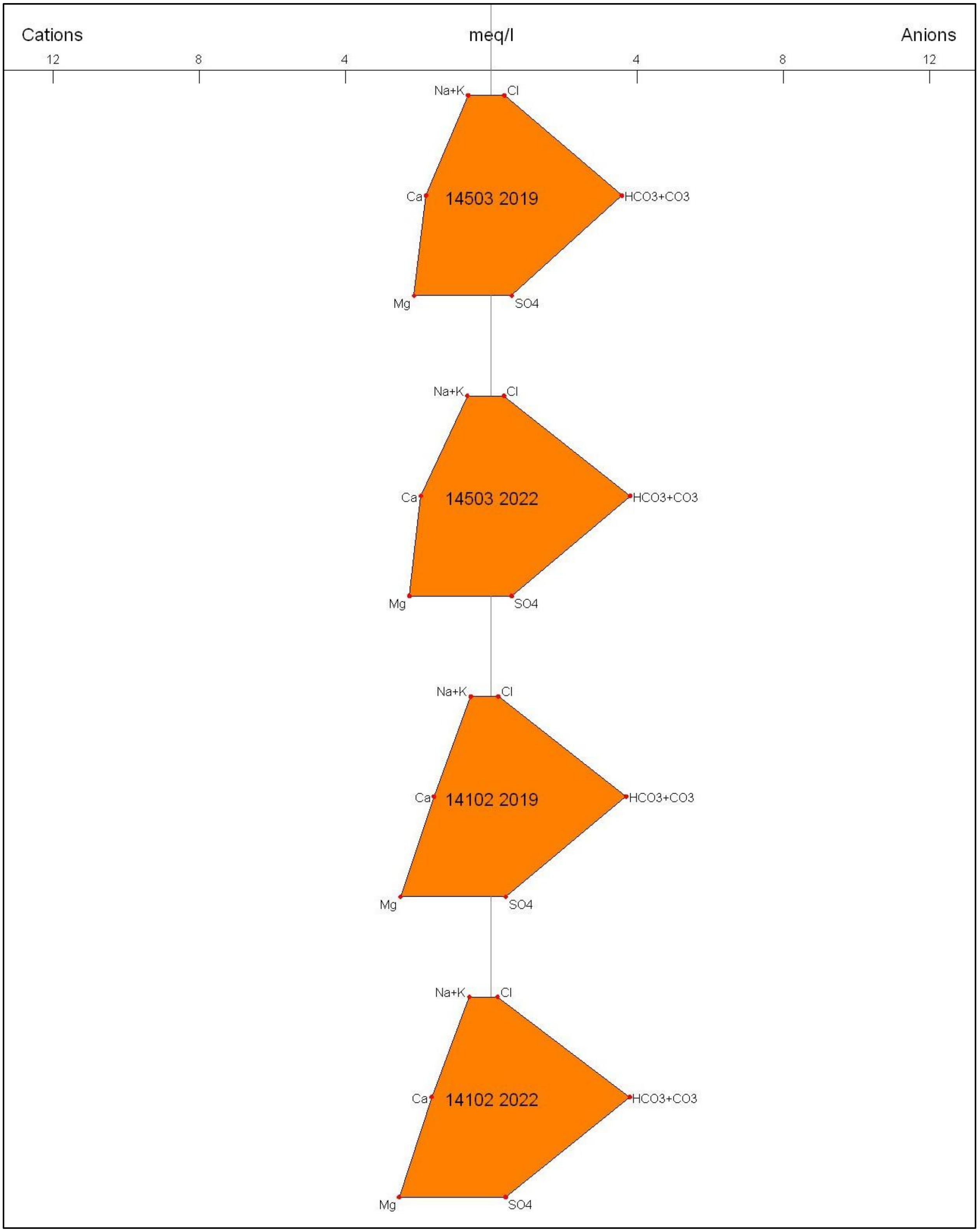


Cations
meq/l
Anions
12
8
4
4
8
12
Na+K
Cl
Ca
HCO3+CO3
Mg
SO4
10703 2019
10703 2022
12403 2019
12403 2022
14402-2 2019
14402-1 2022


Cations
meq/l
Anions
24
20
16
12
8
4
4
8
12
16
20
24
Na+K
Cl
Ca
HCO3+CO3
Mg
SO4
10602 2019
10602 2022
14203 2019
14203 2022
14603 2019
14603 2022



Cations
meq/l
Anions
12
8
4
4
8
12
Na+K
Cl
Ca
10903 2019
HCO3+CO3
Mg
SO4
Na+K
Cl
Ca
10903 2022
HCO3+CO3
Mg
SO4
Na+K
Cl
Ca
11701 2019
HCO3+CO3
Mg
SO4
Na+K
Cl
Ca
11701 2022
HCO3+CO3
Mg
SO4
Na+K
Cl
Ca
11103 2019
HCO3+CO3
Mg
SO4
Na+K
Cl
Ca
11103 2022
HCO3+CO3
Mg
SO4



Cations
meq/l
Anions
12
8
4
4
8
12
Na+K
Cl
Ca
14503 2019
HCO3+CO3
Mg
SO4
Na+K
Cl
Ca
14503 2022
HCO3+CO3
Mg
SO4
Na+K
Cl
Ca
14102 2019
HCO3+CO3
Mg
SO4
Na+K
Cl
Ca
14102 2022
HCO3+CO3
Mg
SO4

Appendix V: Tritium Data

Tritium results for critical wells sampled during the ARID Project. Units are in TU (tritium units).

Well ID	2019	2023
No modern recharge		
Las Animas Co.		
31203	-0.03	0.03
30202	-0.17	0.02
31702	0.03	0.13
30802	0.04	0.03
31302	0.02	0.08
Union Co.		
24402	-0.03	0.02
24502	-0.01	0.14
23702	-0.24	0.01
23902	0.01	-0.06
24202	0.04	0.15
22903	-0.01	0.04
23002	0.00	0.04
21202	-0.06	0.02
Cimarron Co.		
14603		0.01
10602	-0.03	0.00
10703	0.05	0.15
10903	0.07	0.04
11701	-0.10	0.05
12403	0.01	0.10
11103	0.12	Not sampled
10602	-0.03	0.00
Mixed modern/older waters		
Las Animas Co.		
32303	0.39	0.32
30502	0.36	0.24
30303	0.30	0.16
Union Co.		
24602	0.57	0.36
20602	0.56	0.54
24302	0.29	0.12

Cimarron Co.		
14402	0.38	-0.02
14203	0.20	0.24
11602	0.11	0.27
Modern recharge and/or drought suppressed		
Las Animas Co.		
32002	0.73	1.42
32102	2.40	1.19
30702	1.25	1.22
Union Co.		
23302	1.98	0.44
22802	0.95	1.06
20503	1.21	0.60
Cimarron Co.		
14503	2.49	2.89
14301	1.00	0.87
14102	0.80	0.70
Modern recharge		
Las Animas Co.		
34502	5.86	6.45
30903	4.89	5.07