OSMRE National Technology Transfer Team (NTTT), **Applied Science Final Report***

U.S. Department of the Interior, OFFICE OF SURFACE MINING RECLAMATION AND ENFORCEMENT

Developing a sulfate-isotope fingerprint of acid mine drainage to identify underground controls on groundwater flow paths

OSMRE Cooperative Agreement Number: # S16AC20070
Final Report

Reporting Period (10-1-2016 to 7-31-2020)

Chris Gammons[1], Shawn Kuzara[2]
October 2020

[1]Dept. of Geological Engineering, Montana Tech, 1300 West Park Street, Butte, MT 59701

[2]Montana Bureau of Mines and Geology, 101 Grand Ave., Billings MT, 59102

Disclaimer

Footnotes...

Abstract

Abandoned coal mines near Great Falls Montana have been discharging acid mine drainage (AMD) to the surrounding environment for over 100 years. Without mitigation, this metal-laden, acidic water has been mixing with streams and infiltrating into the soil and bedrock. The purpose of this study was to investigate the use of isotopic tracers of sulfur and oxygen of sulfate to identify the presence of acid mine drainage in domestic wells and to identify the regional extent of impact. The use of isotopes as tracers is not new to hydrogeologic studies; however, this setting is uniquely positioned to use isotopic tracers specific to AMD to identify flow paths and impacted aquifers.

The results of this study confirm that sulfur and oxygen of sulfate isotopes effectively fingerprint the presence of AMD in the Madison Aquifer in the Stockett–Sand Coulee area. Despite the influence of AMD on the aquifer, the limestone efficiently buffers the acidity and the water quality data show the groundwater meets US-EPA and Montana regulatory standards for pH and metals in drinking water. This isotope tracing technique will be successful in any setting that has a distinct sulfur and/or oxygen isotope signature in sulfates in AMD versus the unimpacted groundwater. However, this work has also shown the importance of using isotope tracers in conjunction with standard chemical analyses because of the mutability of these isotope tracers in the environment.

Footnotes...

Graphical Materials List

Table of Contents

Disclaimer....2
Abstract....3
Graphical Materials List....4
Figures....5
Tables....7
Introduction....8
Mining History....8
Geology and Hydrostratigraphy....8
Executive Summary....13
Experimental....14
Field Sampling....14
Inorganic Water-Quality Sampling....14
Stable Isotope Analysis....15
Water isotopes....15
Sulfate isotopes....15
Dissolved inorganic carbon isotopes....15
Results and Discussion....16
Madison Aquifer Groundwater System....16
Water Chemistry....18
General trends....18
Acid mine drainage chemistry....20
Chemical evidence for the presence of AMD in the Madison Aquifer....23
Stable Isotopes of Water....24
Stable Isotopes of Dissolved Sulfate....28
Mixing of AMD with Belt Creek....30
Seasonal and year-to-year variations in sulfate isotopes....31
Stable isotopes of dissolved inorganic carbon....31
Regional Sulfate Trends in the Madison Aquifer....33
Geochemical Modeling of AMD Mixing with Madison Aquifer Groundwater....38
Transferability of the Current Project to Other Locations....39
Conclusion....41
References....42
Appendices....45

Footnotes...

Figures

Figure 1. Location of the study area and sample sites 10

Figure 2. Stratigraphic column for the study area....11

Figure 3. A ditch referred to locally as “Rusty Ditch” transports AMD through the town of Sand Coulee 11

Figure 4. Kate’s coulee AMD and unimpacted spring water mix together, which raises the pH allowing aluminum to precipitate. 12

Figure 5. At some locations the AMD flows from hillsides and other locations the contaminated water is piped from the adit to a point of release 12

Figure 6. Generalized geologic cross-section showing major hydro-stratigraphic units (lumped together for simplicity) and structures in the study area. 17

Figure 7. Wells located in the recharge area (well 276129) respond rapidly compared to wells located in the regional water table (205599 and 261984) which show a dampened response 17

Figure 8. Histogram of pH values for samples collected in this study....18

Figure 9. Histogram of specific conductance (SC) values for samples collected in this study....19

Figure 10. Piper diagram showing the major ion composition of all samples collected in this study. 20

Figure 11. Plot of cumulative dissolved metal concentration (sum of Al, Co, Fe, Mn, Ni, Zn) vs. pH for the mine drainages listed in Table 1 23

Figure 12. Summary of all water isotope data collected in the project....24

Figure 13. Water isotope data for wells and springs in the Madison Aquifer....25

Figure 14. Water isotope data for wells in the Kootenai Fm. and Swift Fm. aquifers 26

Figure 15. Water isotope data for acid mine drainage (AMD) in the Stockett/Sand Coulee (SSC) area and the Belt Mine area, as well as water samples taken from the flooded mine pool at the Belt Mine 27

Figure 16. O- vs. S-isotope composition of dissolved sulfate for samples collected in the Stockett–Sand Coulee area 28

Figure 17. O- vs. S-isotope composition of dissolved sulfate for samples collected in the Foothills Subdivision area 29

Figure 18. O- vs. S-isotope composition of dissolved sulfate for samples collected in the Belt area....29

Figure 19. O- vs. S-isotope composition of dissolved sulfate for samples from Belt Creek collected above and below its confluence with AMD discharge from the Belt Mine 30

Figure 20. Comparison of the stable isotope composition of sulfate for locations that were sampled in more than one season....31

Figure 21. Sampled water sources fall into three groups based upon the primary source of DIC 33

Figure 22. Map showing regional variation in total dissolved solids (TDS) of groundwater in the Madison Aquifer....34

Figure 23. Piper diagram summarizing the chemical evolution of groundwater in the Madison Aquifer at a regional scale. 35

Figure 24. Plot of δ^{34}S-sulfate vs. sulfate concentration comparing the data from Plummer and others (1990) for Madison water samples from Montana vs. waters investigated in this study 36

Figure 25. Plot of δ^{34}S-sulfate vs. reciprocal sulfate concentration for waters investigated in this study as well as data from Plummer et al. (1990) for Madison Aquifer samples from Montana 37

Footnotes...

Figure 26. Plot of δ^{34}S-sulfate vs. reciprocal sulfate concentration showing groundwater evolution paths A, B, C (paths shown here are similar to Figure 24) 38

Footnotes...

Tables

Table 1. Concentrations of metals and pH values for acid mine drainage samples. 22

Footnotes...

Introduction

Historic coal mines around Great Falls, Montana have been discharging highly acidic, metal-laden water for over 100 years. Acidic mine drainage (AMD) infiltrates into the alluvial and bedrock aquifers, including the Madison Group limestone, which is an important regional aquifer in central Montana. The limestone is faulted, fractured, and karstified; these qualities have greatly increased aquifer storage and transmissivity—but in an anisotropic, highly irregular fashion. The faulted and karstic limestone surface can allow quick infiltration and direct pathways for acid mine drainage to travel downgradient, potentially affecting groundwater quality at wells. However, because it is difficult to predict where preferential flow paths exist in the karstic limestone, it is difficult to identify areas in the aquifer impacted by acid mine drainage and to target remediation efforts. Preliminary findings published by Gammons and others (2013) illustrate the potential for using sulfur and oxygen isotopes of sulfate to uniquely fingerprint the acid mine water entering the local flow system.

The presented work demonstrates the potential for using isotopic tracers of sulfur and oxygen of sulfate to inexpensively identify the presence and percent composition of acid mine drainage in downgradient wells, potentially identifying preferential flow paths in the limestone aquifer. The transferability of this technique to other locations impacted by acid mine drainage was evaluated by comparing two sources of acid mine drainage in Montana. The data and reports resulting from this work will be made available to the public on the Montana Bureau of Mines and Geology (MBMG) database and library.

Mining History

Montana's coal deposits were first exploited in the 1860s. Initially primarily used for domestic purposes, industrial use of coal grew with the expansion of the railroad, which made large-scale shipping economically feasible. After rail was introduced, statewide coal production increased from 41,467 tons in 1888 to 363,301 tons in 1889. The development of the railroads' coal mine at Sand Coulee (Fig. 1) started in early 1888. Most of the coal produced between 1889 and 1902 went to the trans-continental line and branches of the Great Northern Railway. Other important consumers were the copper smelter at Anaconda, a silver-lead smelter in Great Falls, and several smaller smelters elsewhere in Montana. During its most active period, the Stockett–Sand Coulee mines accounted for over 55 percent of Montana's coal output: approximately 7 million tons. In the Stockett–Sand Coulee area, broad benches are incised by ephemeral stream valleys. Most of the coal mines were accessed from the valleys, where horizontal tunnels led into extensive (multiple mile) underground room-and-pillar galleries that followed the shallow dip of the coal beds. Coal mines in the area are now abandoned (DEQ, 2009).

Geology and Hydrostratigraphy

The study area is located southeast of the city of Great Falls, Montana (Fig. 1), at the western edge of the Great Falls Coal Field (Silverman and Harris, 1967). The Sand Coulee Basin is a sub-area of the Great Falls Coal Field. The medium-grade bituminous coal is at the top of the Morrison Formation of the Jurassic Period and is overlain by sandstone and shale of the Cretaceous Kootenai Fm. (Fig. 2). The

Footnotes...

coal is interbedded with layers of carbonaceous shale, shale, and clay and is buried roughly 230 to 310 feet below ground surface. The coal bed in the Sand Coulee area averages 8.5 feet thick.

Except for public water supplies for the towns of Stockett and Sand Coulee, most residents in the area receive their drinking water from private wells completed in the Mississippian Madison Limestone aquifer. In central Montana, the Madison Aquifer feeds two very large natural springs: Giant Springs near Great Falls and Big Springs near Lewistown, Montana. Giant Springs, one of the largest fresh-water springs in the U.S., discharges ~300 CFS groundwater (Davis and others, 2001) near the banks of the Missouri River in the city of Great Falls (Fig. 1). The Madison Aquifer is recharged where it crops out on the flanks of structural and topographic uplifts, such as the Little Belt Mountains to the immediate south of the study area (Madison, 2016).

In the southern part of the field area, the Madison Group is overlain by marine sandstones and carbonates of the upper Mississippian Big Snowy Group that pinch out to the north and are completely absent near Great Falls. Jurassic sediments of the Swift Fm. and overlying Morrison Fm. unconformably overlie the Madison/Big Snowy strata (Fig. 2; Vuke and others, 2002). Sandstone beds of the Swift Fm. are primary aquifers for the community of Stockett. Recharge for groundwater in the Swift Fm. is more localized than that for the Madison Aquifer. In addition to the aquifers of the Swift Fm. and the Madison Group, the Kootenai Fm. makes up the third aquifer system in the study area. The lower Kootenai Fm. contains two sandstone units (the Cutbank and Sunburst Members) that contain groundwater that is perched several hundred feet above the regional groundwater table in the Madison and Swift aquifers (Duaime and others, 2004; Reiten and others, 2006). This groundwater infiltrates into the abandoned coal mines forming laterally extensive mine pools that discharge from adits or constructed horizontal drains. The drains direct groundwater to excavated channels or streams (Figs. 3, 4, 5). The discharges are typically acidic with high concentrations of metals and, because there are no mitigation measures in place, this has led to local contamination of streams (Osborne et al., 1983a, 1987; Karper, 1998; Gammons et al., 2010).

The chemistry and stable isotope characteristics of the AMD waters in the western part of the Great Falls Coal Field were summarized previously (Karper, 1998; Gammons and others, 2010). Most of the AMD waters are strongly acidic (pH 2.5 to 4.5) with typical metal concentrations of (geometric means; all concentrations in mg/L): Al (215), As (0.008), Cd (0.027), Co (1.06), Cu (0.069), Fe (315), Mn (1.50), Ni (2.07), SO_4 (3600), and Zn (8.67) (Karper, 1998). As shown by Gammons and others (2010), the isotopic composition of dissolved sulfate from the AMD drains is distinct from sulfate that occurs naturally within the Madison Aquifer. Thus, the isotopic composition of sulfate could potentially be used to test the extent to which AMD from the coal mines is draining into the underlying Madison Aquifer.

Footnotes...

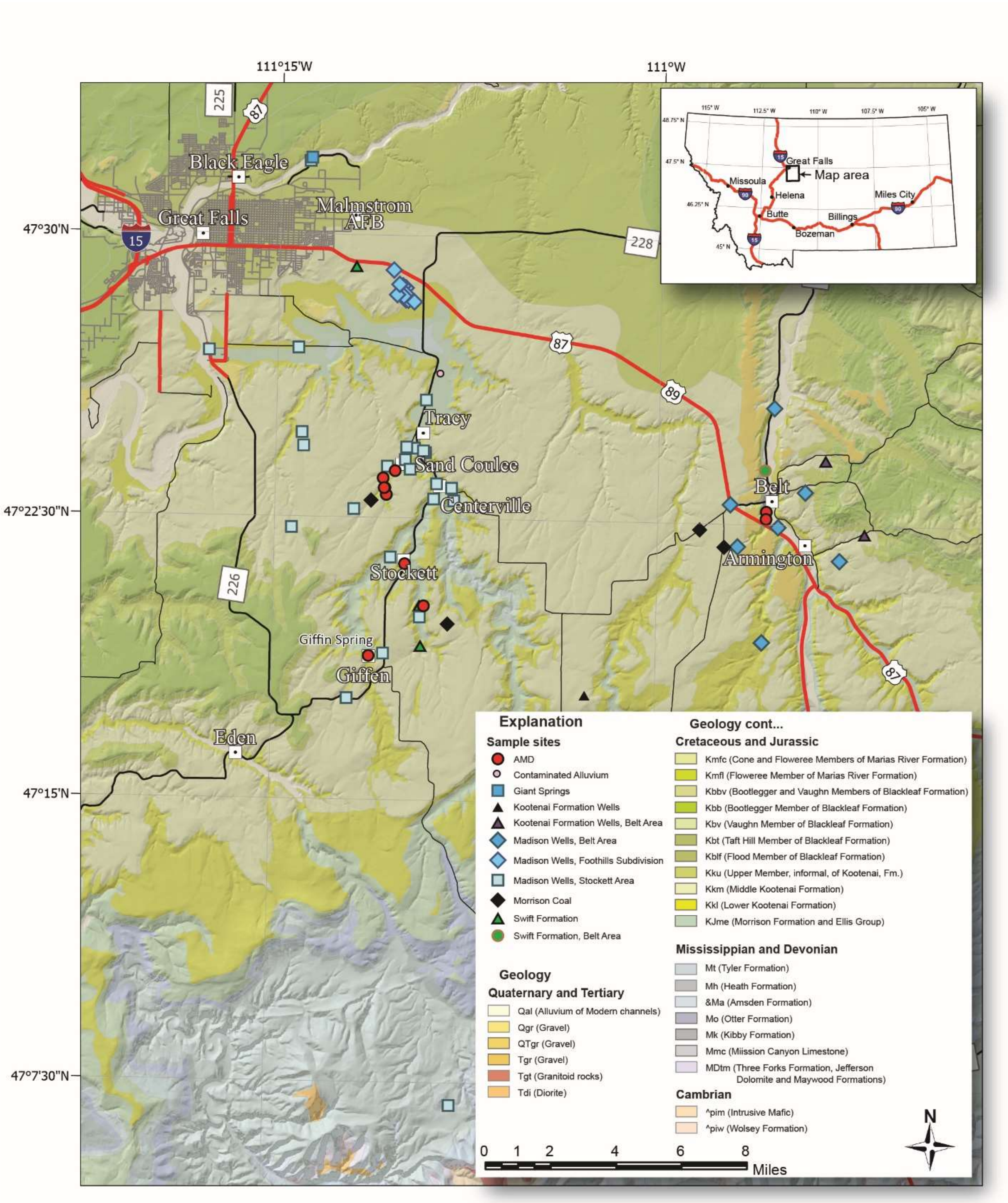

Figure 1. Location of the study area and sample sites. Map shows the outcrop area of the Madison Limestone (Mmc, gray), and green shades of the Cretaceous and Jurassic Formations (modified from Vuke and others,2002).

Footnotes...

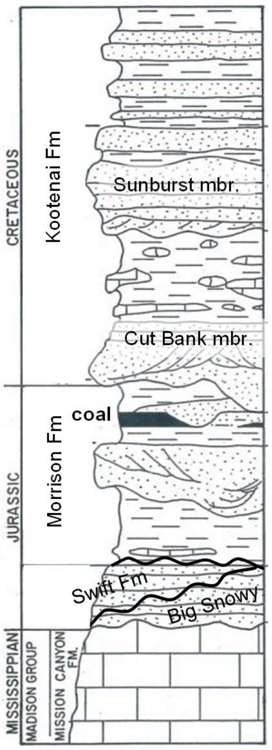

Figure 2. Stratigraphic column for the study area.

Figure 3. A ditch referred to locally as "Rusty Ditch" transports AMD through the town of Sand Coulee. The low pH water completely infiltrates into the ground over about 1 mile.

Footnotes...

Figure 4. Kate's coulee AMD and unimpacted spring water mix together, which raises the pH, allowing aluminum to precipitate (white suspended sediment shown here).

Figure 5. At some locations the AMD flows from hillsides, and at other locations the contaminated water is piped from the adit to a point of release.

Executive Summary

The main objective of this project was to test the hypothesis that stable S- and O-isotopes of dissolved sulfate (SO_4^{2-}) can be used as a tracer to evaluate whether acid mine drainage (AMD) associated with historic underground coal mines in central Montana has contaminated water wells in the underlying Madison Aquifer, a thick limestone aquifer that provides drinking water for many homes and municipalities in the area. Previous work (Gammons and others, 2013) has shown that the S-isotope ($\delta^{34}S$) and O-isotope ($\delta^{18}O$) of sulfate in AMD are distinct from the $\delta^{34}S$ and $\delta^{18}O$ of sulfate in Madison Aquifer groundwater. Furthermore, the concentrations of dissolved sulfate in the mine waters are much higher than in the Madison wells. Therefore, even a relatively small amount of mine water in the aquifer should cause a measurable shift in the stable isotope composition of sulfate in the Madison groundwater.

A total of 84 samples were collected in this study for isotopic analysis of sulfate. These were a mixture of domestic water wells, groundwater monitoring wells, acid mine drainage, unpolluted springs, and streams. Most of these samples were analyzed for a full suite of major and trace solutes, as well as the stable isotope composition ($\delta^{18}O$ and δD) of water. In addition, 26 samples were analyzed for $\delta^{13}C$ of dissolved inorganic carbon. The new chemical and isotopic data were combined with preexisting data to create a combined stable-isotope database for over 125 samples. An attempt was made to analyze a subset of groundwater wells by helium–tritium age dating to get information on groundwater residence time, but the results were inconclusive.

The results of this study confirm the hypothesis that AMD from the historic coal mines has locally infiltrated to the Madison Aquifer. On an isotope cross-plot ($\delta^{18}O$-sulfate vs. $\delta^{34}S$-sulfate), samples from wells in the Stockett–Sand Coulee area lie along a mixing line between background sulfate in the aquifer and sulfate from AMD, which is derived from oxidation of pyrite in the coal. The latter end-member is well-represented by samples of acidic mine drains as well as monitoring wells screened within the flooded mine pools. The majority of AMD-influenced wells are located in proximity to historic coal-mining centers. Many wells with the highest amount of AMD-sourced sulfate were drilled more than 50 years ago, when well-drilling and well-completion protocols were less strict than at present. However, a cluster of domestic water wells from a new subdivision located about 5 miles north and downgradient of the closest coal-mining center contains sulfate that appears to be derived, in part, from oxidation of pyrite from the coal. Additional monitoring wells along the inferred regional groundwater flow path are needed to say with certainty that the sulfate in domestic wells at the subdivision is mining-related or the result of natural weathering of unmined coal beds.

Despite sulfate-isotope evidence for the presence of AMD in aquifers, the vast majority of groundwater wells sampled in this study contain water that meets drinking water standards, based on US-EPA and Montana DEQ guidelines (http://water.epa.gov/aboutow/ogwdw/creg.cfm). In terms of water quality, indicators of AMD contamination include elevated sulfate concentration and slightly elevated concentrations of trace metals such as aluminum, manganese, cobalt, nickel, and zinc. None of the water wells had high dissolved iron concentration, consistent with the elevated dissolved oxygen values measured during sample collection. This also means that the isotopic composition of sulfate in the Madison

Footnotes...

Aquifer was not influenced by anaerobic processes, such as bacterial sulfate reduction. Overall, the absence of major water-quality problems in this study underscores the capacity of the Madison Aquifer to buffer groundwater chemistry to a range that is acceptable for human use.

Although they do not change the major conclusions outlined above, certain findings from this study make the interpretation of the stable isotope data more complicated. For example, instead of having a single “background” sulfate composition, the Madison Aquifer shows considerable variation depending on the distance groundwater has travelled from its inferred area of recharge. This is because the Madison Group contains localized deposits of sedimentary gypsum/anhydrite, which are readily dissolved by groundwater as it travels downgradient (to the north and east) away from recharge areas (south of the field area). For this reason, a high sulfate concentration, by itself, is not necessarily an indicator of AMD contamination. Likewise, just because a water contains dissolved sulfate that is isotopically similar to AMD does not mean that the water must have inherited its sulfate from AMD. An example of this line of reasoning includes several water wells and springs sourced by the Pennsylvanian Swift Formation, which sits atop the Madison Group. This water contains sulfate with an isotopic composition similar to that of the coal-mine AMD, but has much lower sulfate concentration than the Madison samples, and therefore is unlikely to have been influenced by mine drainage.

The approach used in this study has a high transferability to other watersheds in which contamination from coal-mine drainage is known or suspected. Isotopic analyses are relatively inexpensive and samples are easy to collect. For isotope fingerprinting using dissolved sulfate to be successful, a strong contrast is needed between the isotopic composition of sulfate in the mine water vs. sulfate in the background surface and groundwater in the study area. This study also shows the importance of supporting water-chemistry data in stable isotope studies.

Experimental

Field Sampling

Inorganic Water-Quality Sampling

Water-quality samples were collected from 56 wells (31 Madison, 11 Kootenai, 9 Morrison, 4 Swift, 1 Alluvium), 3 springs (1 Kootenai, 1 Madison, 1 Swift), and 45 acid mine drains. MBMG standard sampling procedures were followed. Groundwater samples were bottled after purging approximately three well-casing volumes and observation of stable field parameters of ±10 percent of three readings of one another in 15 minutes. Grab samples were collected from the spring and AMD sites. Field parameters include pH, temperature, and specific conductance. Nitric (1 percent) and sulfuric (0.5 percent) acids preserved the samples. A 0.45-micron filter was used for the filtered samples. Deionized water was used to rinse sampling equipment that was used at multiple sample sites. Nitrile powderless gloves were worn to prevent sample contamination. Water samples were analyzed by the Analytical Laboratory at the Montana Bureau of Mines and Geology in Butte, Montana for common ions and trace elements (Timmer, 2020).

Stable Isotope Analysis

Water isotopes

The O- and H- isotope compositions of filtered and unacidified water samples were measured on a Picarro L1102-i cavity ring-down spectrometer (CRDS) at the Montana Bureau of Mines and Geology. The analyses were calibrated using USGS 47 ($\delta^{18}O$ = -19.8‰, δD = -150.2‰) and USGS 48 ($\delta^{18}O$ = -2.22‰; δD = -2.0‰) isotope standards. The results are reported in units of per mil (‰) in the usual δ notation versus VSMOW for oxygen and hydrogen (general isotope reference here). The approximate analytical uncertainty is ±0.1‰ for $\delta^{18}O$-water and ±1‰ for δD-water.

Sulfate isotopes

Samples for sulfate isotope analysis were prepared at the lab of C. Gammons at Montana Tech. Dissolved sulfate in each water sample was first precipitated as barite ($BaSO_4$), following the methods of Carmody and others (1998). A rough estimate of the sulfate concentration in each sample was obtained using a HACH colorimeter (Hach method 8051). Based on this result, a weighed mass of water sample (usually 50 to 200 g) was transferred to an Erlenmeyer flask where the pH was adjusted to <4 by addition of dilute HCl, after which the sample was stirred and heated to T > 60ºC. A 3x excess of $BaCl_2$ was added to precipitate all of the dissolved sulfate as $BaSO_4$. The purpose of the pH adjustment was to avoid precipitation of $BaCO_3$ at this step. However, it is important not to drop the pH too low (<2), to avoid possible exchange of O-isotopes between SO_4 and H_2O. After cooling back to room temperature, the white precipitates were filtered, rinsed several times with deionized water, and placed in a drying oven at 60ºC overnight. By weighing the filter paper and keeping track of masses, it was possible to accurately estimate the dissolved SO_4 concentration in the water samples (the concentration of SO_4 was also determined by ion chromatography). The barite precipitate was transferred to a small glass vial and sent to the University of Nevada-Reno (UNR) for isotope analysis.

All isotope analyses of sulfate were performed at The Nevada Stable Isotope Laboratory at the University of Nevada Reno using a Eurovector elemental analyzer interfaced to a Micromass IsoPrime stable isotope ratio mass spectrometer (IRMS). The analyses followed the method of Giesemann et al. (1994) for $\delta^{34}S$-sulfate, and Kornexl et al. (1999) for $\delta^{18}O$-sulfate. The results are reported in units of per mil (‰) in the usual δ notation versus VSMOW for sulfate-O and VCDT for sulfate-S. Based on replicate analyses, the analytical uncertainties are ±0.2‰ for $\delta^{34}S$-sulfate and ±0.4‰ for $\delta^{18}O$-sulfate.

Dissolved inorganic carbon isotopes

Thirty-two water samples (filtered in the field into 20 mL glass vials and unacidified) were analyzed at the MBMG lab at Montana Tech for the isotopic composition of dissolved inorganic carbon ($\delta^{13}C$-DIC) using an Aurora 1030W TIC/TOC analyzer interfaced with a Picarro G2131-i CRDS carbon isotope analyzer. The analyses were calibrated using USGS 40 (glutamic acid, $\delta^{13}C$ = -26.39‰), USGS 41 (enriched glutamic acid, $\delta^{13}C$ = +37.63‰), and NBS 18 (calcite, $\delta^{13}C$ = -5.01‰), as well as in-house standard reference materials (Li_2CO_3 and $NaHCO_3$). The results are reported in units of per mil (‰) in the usual δ notation versus VPDB and have an estimated uncertainty of ±0.1‰ for $\delta^{13}C$-DIC.

Footnotes...

Results and Discussion

Madison Aquifer Groundwater System

A cross section illustrates our conceptual model of a flow path within the Madison aquifer, from recharge areas near the Little Belt Mountains to a known discharge point at Giant Springs (Fig. 6). Along the flow path, precipitation infiltrates into the aquifer in the Madison Limestone through bedding planes, joints, fractures, and stream loss in the recharge areas. The black dashed line in Figure 6 represents a potentiometric surface mapped from water levels reported from well logs or measured in wells. Some wells may be completed in portions of the Madison aquifer that are perched above (not hydraulically connected) the regionally saturated part of the formation (e.g., Ground-Water Information Center GWIC 276129; Fig. 6).

In the recharge area, where the regional water table is below the top of the Madison Limestone, the aquifer is generally unconfined. Recharge to the Madison aquifer occurs primarily from infiltration of precipitation in the outcrop areas and from stream loss across outcrops. The major recharge areas are in the uplifted areas of the Little Belt Mountains. Overlying aquifers, such as in the Swift or basal Kootenai sandstones, are also potential recharge sources. However, near Great Falls in the Giant Springs area, water levels in the Madison aquifer are higher than Swift or basal Kootenai aquifers, and therefore the Madison aquifer can potentially discharge to the stratigraphically higher aquifers.

Madison aquifer water levels were monitored in the Great Falls area and are presented in Figure 7. Monitoring well 276129 (black line) is located in the recharge area on the north side of the Little Belt Mountains (Fig. 7). In 2018 and 2019 the hydrograph shows a flashy response to late March snowmelt and early spring rain. The previous years did not have a strong recharge pulse. The dramatic water-level response in the recharge area is a characteristic of fracture-flow environments with limited storage (Weight, 2008)

Domestic monitoring wells show a dampened seasonal water-level response indicating the well locations have no direct preferential pathways from limestone outcrops nearby (Fig. 7, orange and blue lines).

Footnotes...

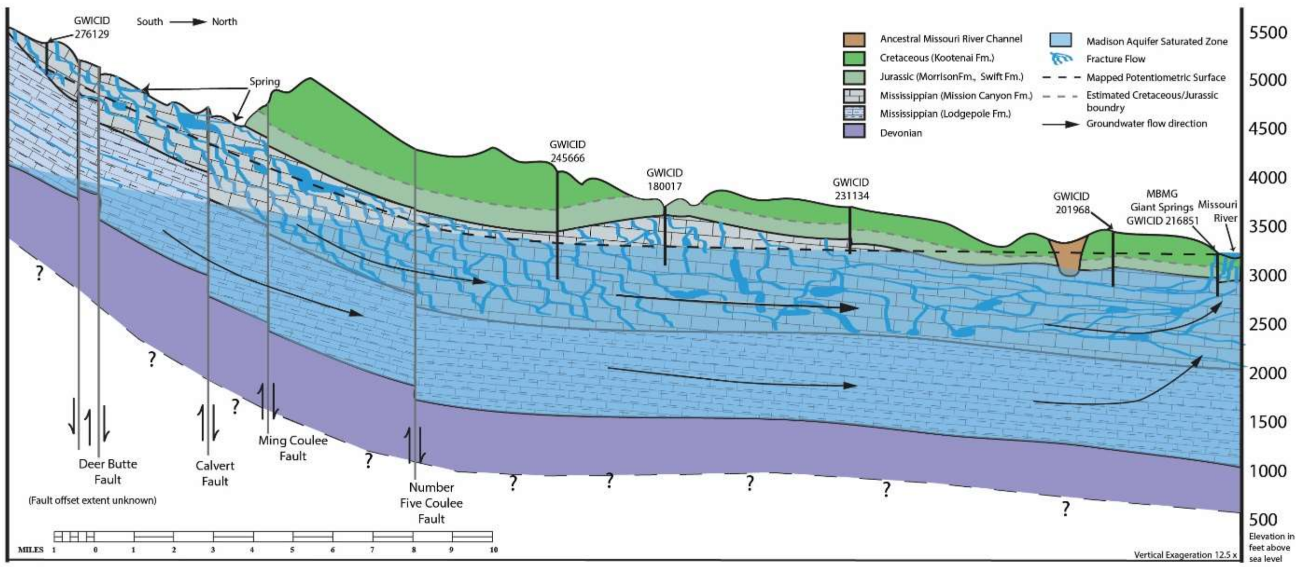

Figure 6. Generalized geologic cross-section showing major hydrostratigraphic units and structures in the study area. Wells completed in the Mission Canyon Formation were used for this cross-section. Study includes wells completed in the Cretaceous Kootenai and Jurassic Swift Fms. but they are not included in the cross-section.

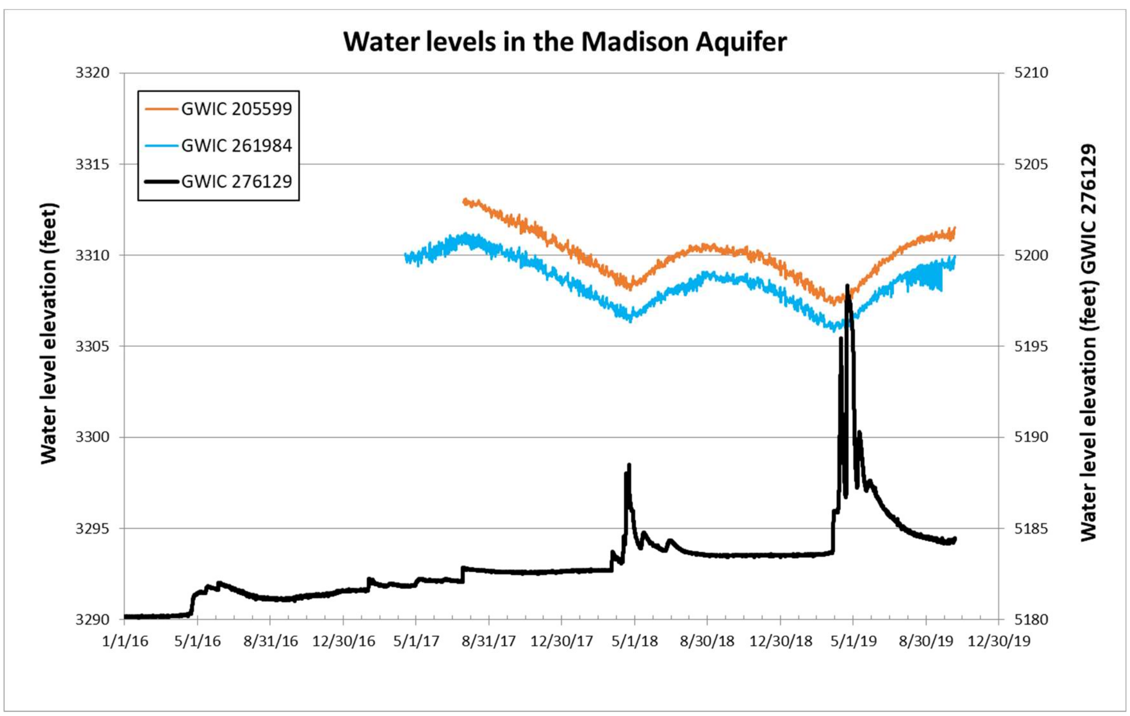

Figure 7. Wells located in the recharge area (well 276129) respond rapidly compared to wells located in the regional water table (205599 and 261984), which show a dampened response.

Water Chemistry

All water-quality data for samples collected in this study are included as Appendix B. Aspects of the analyses that have relevance to the presence of acid mine drainage (AMD) in the Madison Aquifer are discussed below.

General trends

The average and standard deviation of pH and specific conductance (SC, µS/cm) values of groundwater and springs in the Madison aquifer were 7.37 ± 0.22 and 755 ± 318, respectively (Figs. 8, 9). Water temperatures ranged from 9.5 to 15°C. With the exception of some of the AMD samples, all groundwaters contained measurable dissolved oxygen, indicating aerobic conditions within the Kootenai, Swift, and Madison Aquifers. Although there are relatively few samples, pH and SC values for the Swift and Kootenai groundwaters are similar to those in the Madison. By contrast, most of the acid mine drainage sites had pH between 2.5 and 3.5 and SC >2000 µS/cm (maximum of 9,860 µS/cm for the Nelson drain). One large-volume AMD discharge, the Giffen Spring, had a higher pH, near 6. As discussed by Gammons et al. (2010), this spring drains a large underground coal mine that is mostly inundated with groundwater, thereby limiting the extent of oxidation of pyrite in the coal. In contrast, the other AMD sites drain mines that are not completely flooded or partially flooded, with easy ingress of air to promote pyrite oxidation.

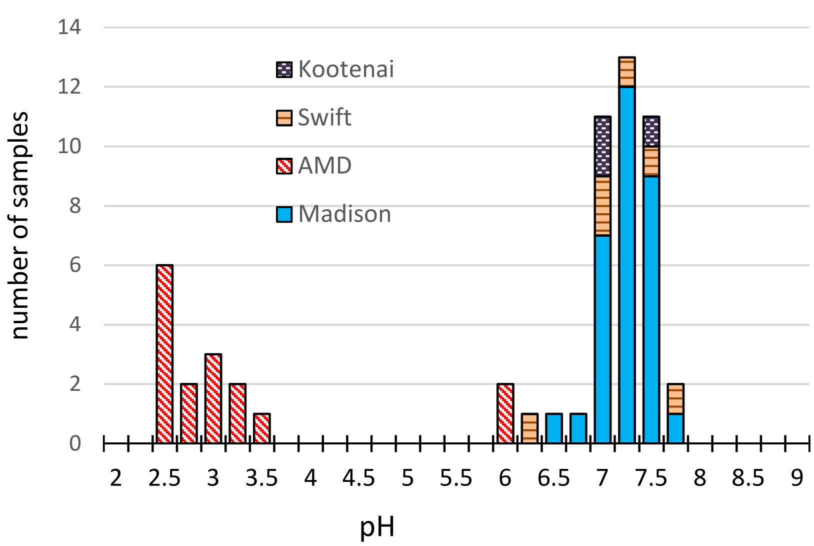

Figure 8. Histogram of pH values for samples collected in this study.

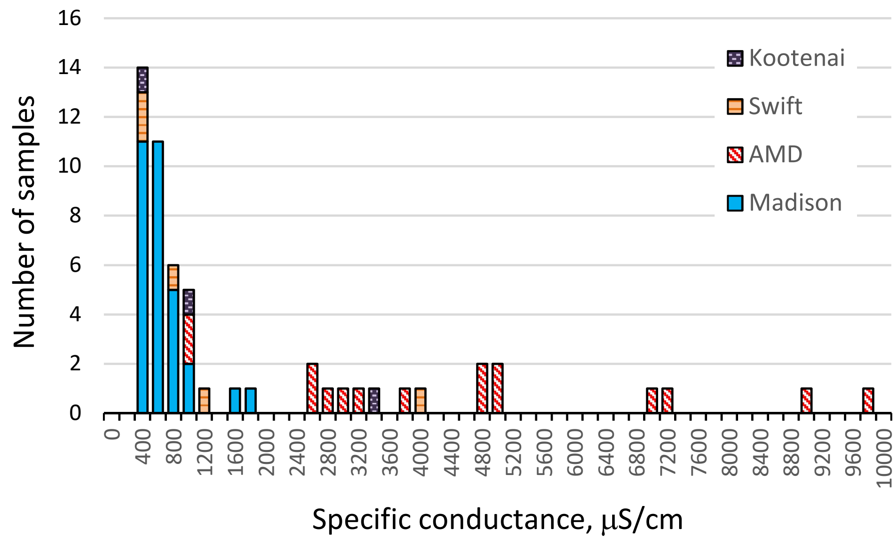

Figure 9. Histogram of specific conductance (SC) values for samples collected in this study.

The major element chemistry of all groundwater and AMD samples collected in this study is summarized in a Piper diagram (Fig. 10). As a whole, the groundwaters are Ca-Mg type in terms of cations, and HCO_3-SO_4 type in terms of anions. The anion makeup of the AMD samples is dominated by sulfate, consistent with pyrite oxidation. Although the AMD waters plot as Ca-Mg type for cations, this is somewhat misleading since most of the acidic seeps have higher concentrations of dissolved Fe and Al than the traditional major cations (see next section).

Samples of Madison aquifer groundwater have a wide range of SO_4 concentrations. This may result from: 1) regionally, groundwater in the Madison Aquifer becomes enriched in SO_4 as it flows north and east away from its mountainous recharge areas due to dissolution of salts (gypsum, anhydrite) in the Paleozoic formations (Plummer et al., 1990); or 2) some areas within the Madison Aquifer may receive acidic water from abandoned coal mines and the SO_4 reflects mixing of groundwater with this contamination. The relative importance of these two mechanisms is evaluated after a presentation of the stable isotope results.

The water-quality results (Fig. 10) indicate contaminated groundwater in the alluvium in a monitoring well downgradient of AMD areas. The shallow alluvium is not considered an aquifer in this area because it does not produce appreciable amounts of groundwater.

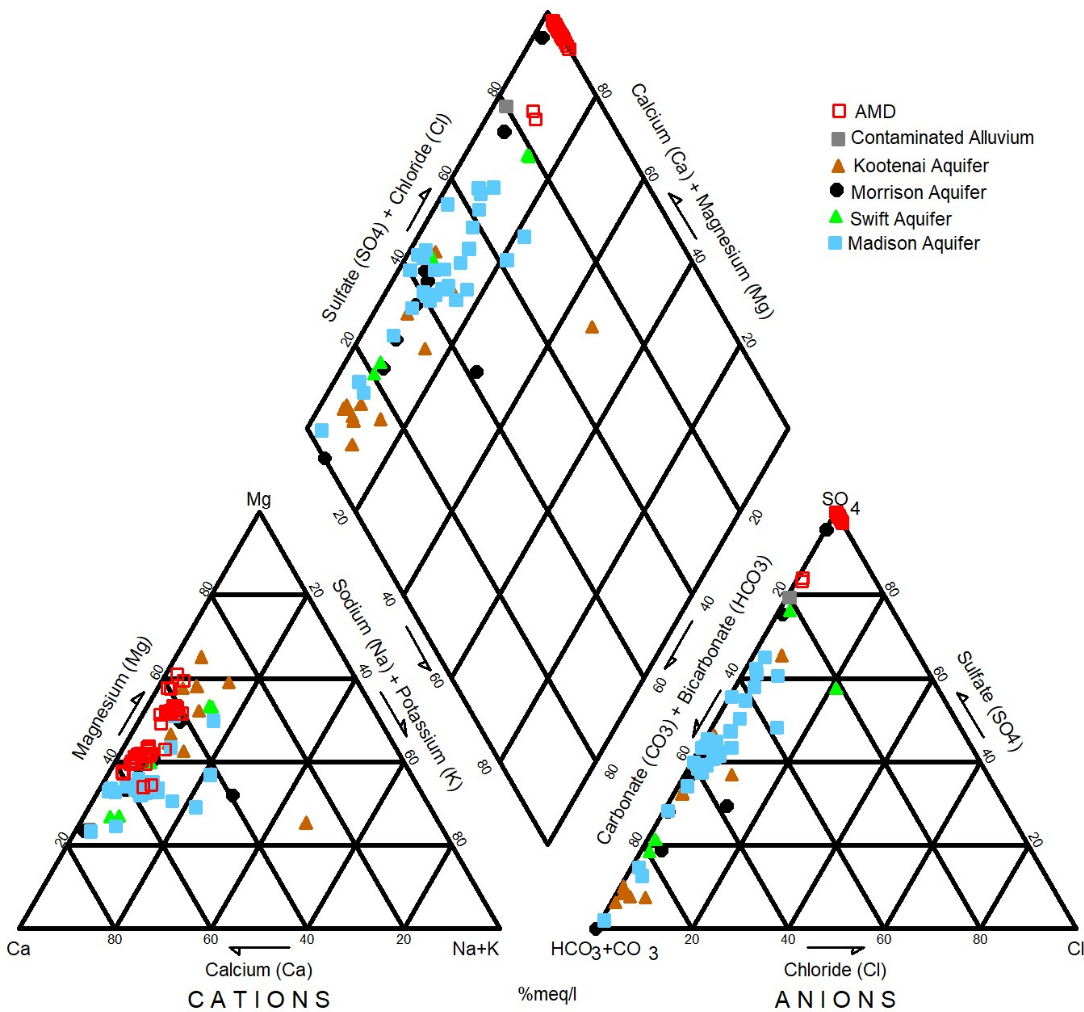

Figure 10. Piper diagram showing the major ion composition of all samples collected in this study.

Acid mine drainage chemistry

The water quality of most of the AMD seeps and springs discharging from abandoned coal mines in the Belt-Stockett–Sand Coulee area is extremely poor. Table 1 summarizes data for selected parameters, including most of the trace metals of interest. The data are also summarized in a plot of combined metal concentration (mmol/L of Al + Co + Cu + Fe + Mn + Ni + Zn) vs. pH (Fig. 11). As expected, the concentrations of metals are inversely related to pH. In general, the abundances (maximum values in parentheses) fall in the order of Fe (1,734 mg/L) > Al (1,166 mg/L) >> Zn (37 mg/L) > Ni, Mn (7 to 8 mg/L) > Co (4 mg/L) > Cu (1 mg/L) > Cd (0.08 mg/L) > Pb (0.025 mg/L). The discharge with the highest metal and sulfate concentrations is the Nelson Drain, whereas Mining Coulee had the lowest pH. As discussed by Gammons et al. (2010), the pH of several of the mine drains in the study area decreases after emerging to the surface due to oxidation of Fe^{2+} to Fe^{3+} and precipitation of ferric minerals such as jarosite or goethite. For example, although the pH of the Mt. Oregon drain is near 4 at the sampling point where it emerges from the ground, the pH is closer to 2.5 hundreds of meters downstream where the AMD sinks into the alluvium of an ephemeral stream and disappears from sight (Gammons and others, 2010). Speciation of dissolved Fe between the +2 and +3 oxidation states was not done in this study. Based on a comparison with previous work (Gammons and others, 2010), most of the Fe is Fe^{2+} (ferrous) for samples with pH >3 and a mix of Fe^{2+} and Fe^{3+} (ferric) for samples with pH <3.

Several of the mine discharges had high concentrations of dissolved rare earth elements (REE) (see Appendix B). Of the REEs, the MBMG lab routinely quantifies lanthanum (La), cerium (Ce), praseodymium (Pr), and neodymium (Nd). Some AMD samples had total concentrations of these four constituents >1 mg/L, with the Nelson drain (OSM-30) having the highest values (1.8 mg/L Ce, 0.65 mg/L La, 1.08 mg/L Nd, and 0.25 mg/L Pr). Although REEs are not known for their toxicity to humans or aquatic organisms (reviewed by Pagano et al., 2015), they have value, and it is interesting to speculate whether REEs could be recovered if a water treatment plant were ever built in the field area (e.g., see Ziemkiewicz et al., 2018).

Other trace metals and metalloids with detectable concentrations in many of the AMD waters include arsenic (As), beryllium (Be), chromium (Cr), and selenium (Se). Maximum concentrations for these four elements were 30, 127, 343, and 24 μg/L, respectively (Table 1). In addition, some of the mine waters had elevated concentrations of uranium (up to 365 μg/L) and vanadium (up to 406 μg/L) (see Appendix B).

Footnotes...

Table 1. Concentrations of metals and pH values for acid mine drainage samples.

Site	ID	pH	Dissolved concentration, mg/L													
			Al	As	Be	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Se	SO4	Zn
Anaconda drain	OSM-7	3.08	111	0.002	0.011	0.01	0.34	0.030	0.01	170	0.4	0.78	n.d.	0.004	1634	3.75
Cottonwood # 6	OSM-31	2.85	283	<.001	0.097	0.03	3.95	0.022	0.24	625	2.3	7.59	0.007	0.010	4280	37.0
Cottonwood # 2	OSM-58	3.22	161	<.005	0.014	0.04	0.85	0.009	0.11	24.4	0.7	1.47	0.004	0.003	3260	6.58
French Coulee	OSM-6	2.84	224	0.013	0.017	0.01	0.19	0.061	0.02	414	0.4	0.46	0.003	0.006	3006	2.29
Giffen	OSM-20	6.02	1.0	0.002	0.002	n.d.	0.09	<.001	0.02	68.2	0.4	0.18	0.003	<.001	555	0.65
Mining Coulee	OSM-33	2.58	726	0.003	0.047	0.08	2.05	0.220	0.82	829	2.1	4.68	0.007	0.019	7250	23.3
Mt. Oregon	OSM-21	3.52	185	0.020	0.026	0.01	0.66	0.023	0.10	267	1.2	1.48	0.011	0.006	2630	6.17
Nelson	OSM-30	2.72	1166	0.030	0.127	n.d.	2.40	0.343	1.09	1734	8.6	5.29	0.025	0.024	11400	20.2
No-Name	OSM-32	2.73	364	<.001	0.032	0.04	1.34	0.100	0.24	427	1.6	2.71	0.013	0.012	4250	14.7

n.d. = not detected

Footnotes...

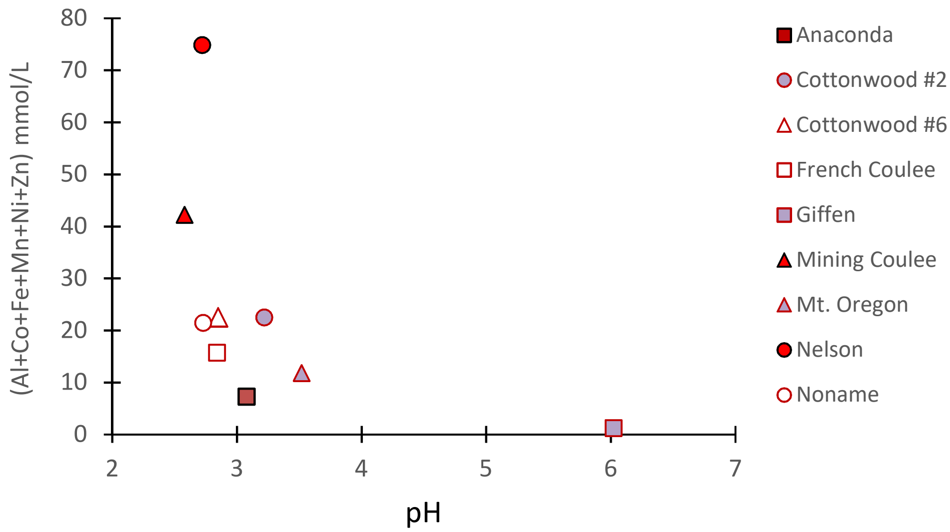

Figure 11. Plot of cumulative dissolved metal concentration (sum of Al, Co, Fe, Mn, Ni, Zn) vs. pH for the mine drainages listed in Table 1.

Chemical evidence for the presence of AMD in the Madison Aquifer

As stated above, all of the Madison wells had near-neutral pH water, regardless of their proximity to sources of acidic coal-mine drainage. This is not surprising, considering limestone's ability to neutralize acidity. Some wells in the Foothills Subdivision with higher SC and dissolved sulfate concentration also showed slightly elevated concentrations of metals. Reports of new water wells being drilled in the subdivision that were producing acidic water with high sulfate and aluminum provided the impetus for collecting a set of samples in this study. Although none of the Foothills wells investigated in this study were acidic (all were completed in the Madison Aquifer), the well with the highest sulfate content (407 mg/L) also had elevated concentrations of dissolved Al (44 µg/L), Co (20 µg/L), Mn (362 µg/L), Ni (95 µg/L), and Zn (133 µg/L). This set of trace elements could be sourced from coal-mine drainage, given the high concentrations of the same elements in the coal AMD (Table 1). This particular well had dissolved Fe levels below detection, indicating that, if sourced from AMD, the Fe precipitated out as ferric compounds as the groundwater migrated downgradient.

Two wells completed in the Madison Limestone in the Sand Coulee–Stockett area (OSM-23 and OSM-26) had anomalously high nitrate concentrations (9.6 and 6.6 mg/L NO_3-N, respectively), suggesting localized contamination of the aquifer. However, neither of these wells had high SO_4 or trace metal concentrations. In fact, none of the Madison wells in the vicinity of the AMD sources in Sand Coulee–Stockett showed convincing evidence of elevated trace metal concentrations, despite there being several wells with anomalously high sulfate that has an AMD signature (see below). This underscores the ability of the Madison Aquifer to buffer pH and preventing the degradation of the drinking water.

Footnotes...

Stable Isotopes of Water

The stable isotope compositions of all water samples collected in this study are summarized in Figure 12. The global meteoric water line (MWL) of Craig (1961) and the Butte meteoric water line of Gammons et al. (2006) are shown for reference. Groundwater samples that plot to more negative values of δD and $\delta^{18}O$ were recharged at colder temperatures and/or at higher elevations compared to samples with less negative values. As discussed by Gammons et al. (2006; see also Clark and Fritz, 1997), the intersection of the local MWL and local evaporation line (LEL) gives the isotopic composition of average groundwater recharge for the region. The local evaporation line for Butte, MT did not fit the field data very well, and consequently a new LEL was developed for the Stockett–Sand Coulee–Belt area: $\delta D = 5.0*\delta^{18}O - 51.5$. Groundwater or surface-water samples that plot further along the LEL experienced a greater degree of evaporation.

Groundwater samples from wells completed in the Madison Aquifer, as well as waters flowing to the surface at Giant Springs, show little or no evidence of evaporation (Fig. 13). Overall, Madison Aquifer samples from the Stockett–Sand Coulee area have similar isotopic compositions to samples from the Foothills Subdivision and the Belt area. This implies a common source of recharge for Madison groundwater in these three areas. The only exception to this rule was well 210668, which showed signs of evaporation for both sampling visits. Also, well 255442 was isotopically lighter compared to the majority of the Madison samples. The reasons for these two anomalous wells are not known at this time.

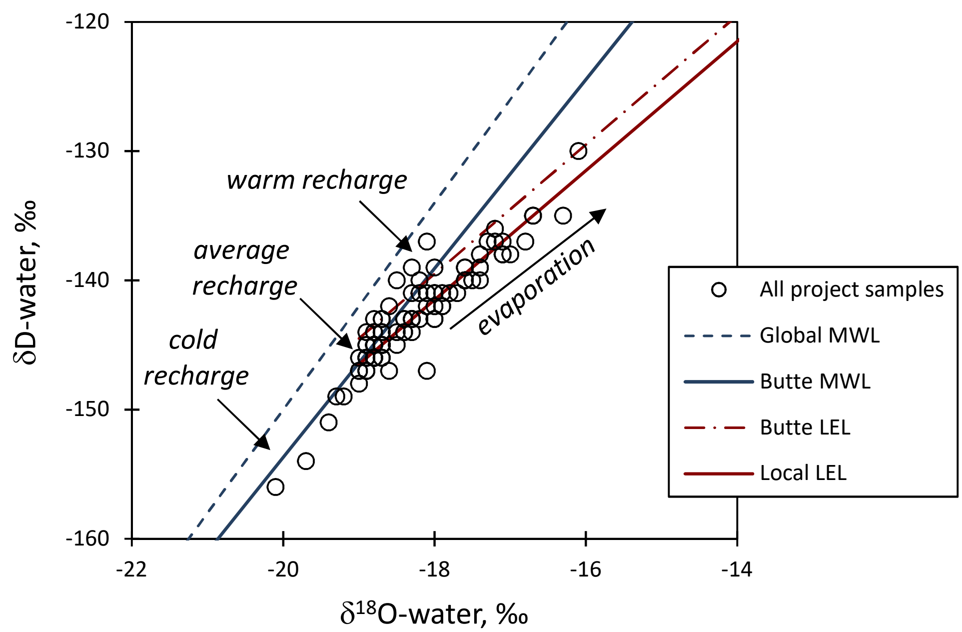

Figure 12. Summary of all water isotope data collected in the project. Global MWL = meteoric water line of Craig (1969); Butte MWL and Butte LEL = meteoric water line and evaporation line for Butte, MT (Gammons et al., 2006). Local LEL = local evaporation line (this study). The intersection of the local meteoric water line and the local evaporation line gives the isotopic composition of average groundwater recharge.

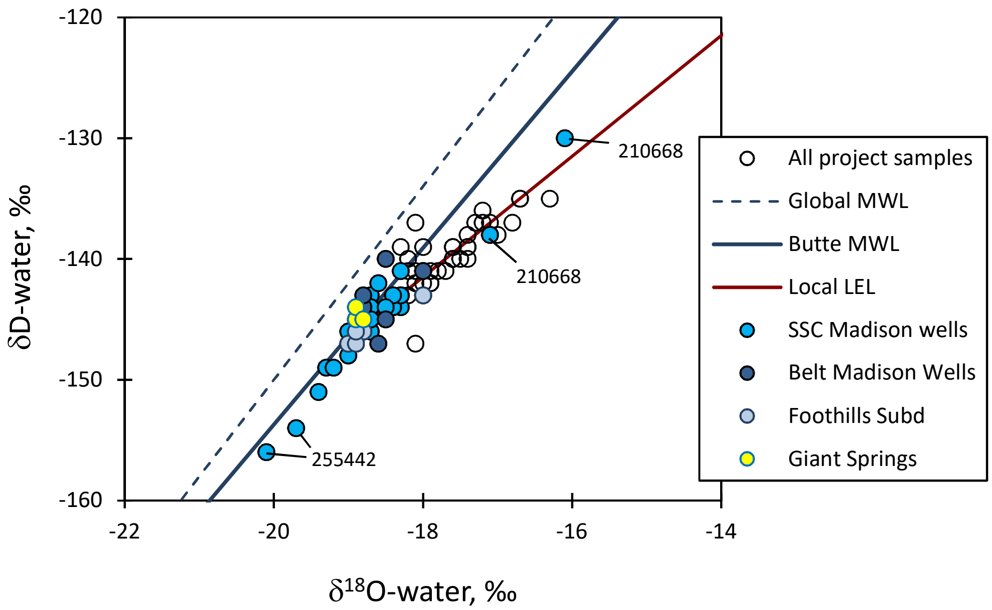

Figure 13. Water isotope data for wells and springs in the Madison Aquifer. Anomalous samples are labeled with GWIC ID numbers. SSC = Stockett–Sand Coulee.

Groundwater wells completed in the Swift and Kootenai Formations contain water that is shifted slightly along the evaporation line (Fig. 14), and that may have been recharged at higher temperature or lower elevation compared to the Madison wells. This makes sense, especially for the Kootenai Fm., which lies stratigraphically above the Morrison Fm. coal beds and does not crop out in the Little Belt Mountains. In some areas impermeable shale units create perched groundwater in the Kootenai Fm. Evidence with isotopes show the Kootenai Fm. was derived locally, by rain and snowmelt falling on treeless plateaus in the Stockett–Sand Coulee area. One Swift well (GWIC 236507) had an anomalous isotopic composition for reasons that are not known.

Footnotes...

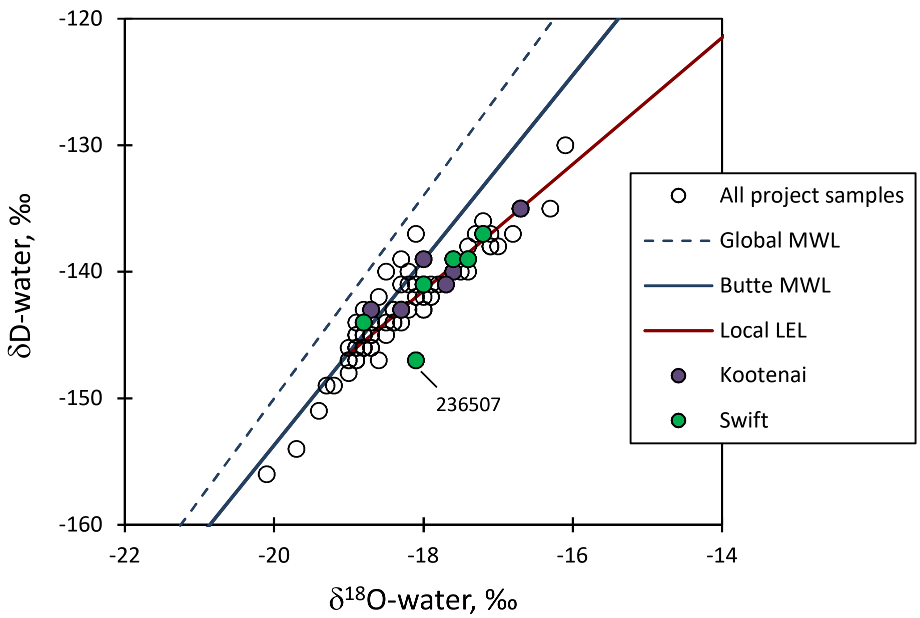

Figure 14. Water isotope data for wells in the Kootenai Fm. and Swift Fm. aquifers. One anomalous sample is labeled with its GWIC 236507.

Samples of acid mine drainage in the Stockett–Sand Coulee and Belt areas (Fig. 15) have water-isotope compositions that are similar to the Kootenai and Swift samples. This is also true for water in the Anaconda mine pool at Belt. These waters tend to cluster along the local evaporation line, and have inferred recharge water that is isotopically heavier than the Madison wells. Like the Kootenai wells discussed above, the mine-pool water and acidic drains are perched and are recharged by downwards percolation of rain and snowmelt falling on the surrounding foothills.

Footnotes...

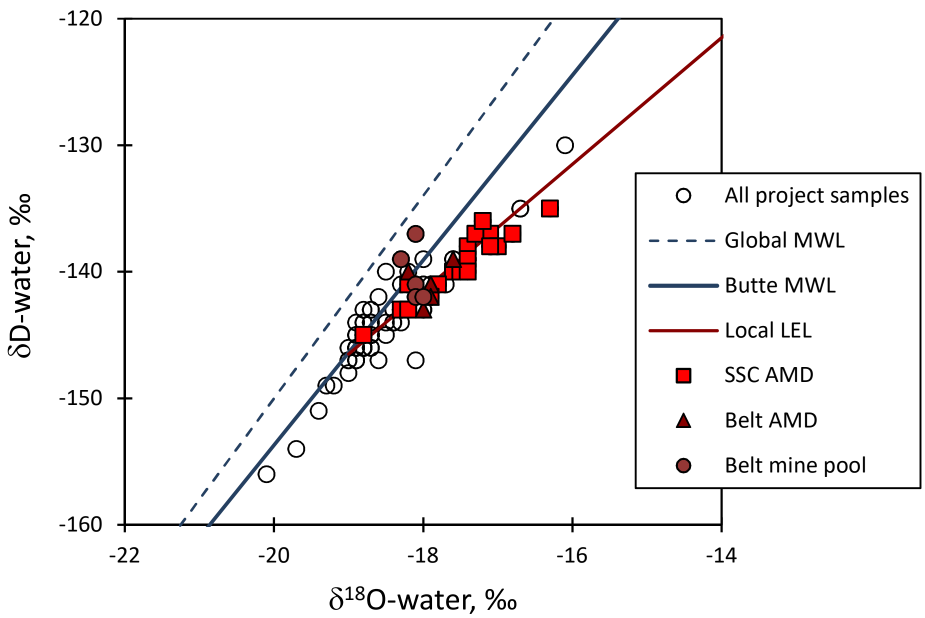

Figure 15. Water isotope data for acid mine drainage (AMD) in the Stockett–Sand Coulee (SSC) area and the Belt Mine area, as well as water samples taken from the flooded mine pool at the Belt Mine.

Overall, the water-isotope data obtained in this study support the conceptual model for how groundwater in the three aquifer systems is recharged. The regional water table lies in the Madison Limestone, and is recharged where this formation crops out on the north side of the Little Belt Mountains where infiltration of precipitation in the outcrop areas and from stream loss across outcrops occur. The Swift Fm. unconformably overlies the Madison (Fig. 6), and hydrogeologists often lump the two formations into the same aquifer system. However, the Swift does not crop out in the Little Belts, but rather comes to the surface immediately south of the study area. Therefore, groundwater in the Swift is partly recharged by local precipitation and partly by mixing with the regional flow of groundwater in the Madison Limestone. The third aquifer system includes perched groundwater that sits in the coal beds at the top of the Morrison Formation, as well as sandstone lenses in the overlying Kootenai Fm. This is the water that seeps into the abandoned coal mines, eventually discharging as acidic drains. This groundwater is exclusively recharged by local precipitation (rain and snowmelt) falling on the grassy plateaus in the Stockett–Sand Coulee–Belt area. Based on observed isotopic shifts away from the LEL, this water was partly evaporated, possibly when it was stored in the soil zone prior to infiltrating to the perched aquifer in the basal Kootenai Fm. Some of this ground is planted with hay, alfalfa, and wheat. However, loss of water by plant transpiration does not fractionate water isotopes (Clark and Fritz, 1997).

Footnotes...

Stable Isotopes of Dissolved Sulfate

An isotope cross plot ($\delta^{18}O$ vs. $\delta^{34}S$) for dissolved sulfate in samples from the Stockett–Sand Coulee area (Fig. 16) shows a linear trend, with AMD samples clustered at strongly negative values near -10 to -15‰, and background wells and springs in the Madison Aquifer extending to strongly positive values near +10 to +15‰. A number of domestic wells completed in the Madison contain sulfate with an isotopic composition more similar to the AMD source than the end-member Madison source. These wells, many of which also have anomalously high dissolved sulfate concentrations, most likely have a component of sulfate from AMD. Although several groundwater samples from the Swift, Kootenai, and Morrison Coal units also plot along the apparent mixing line, their sulfate may have a different origin (see below).

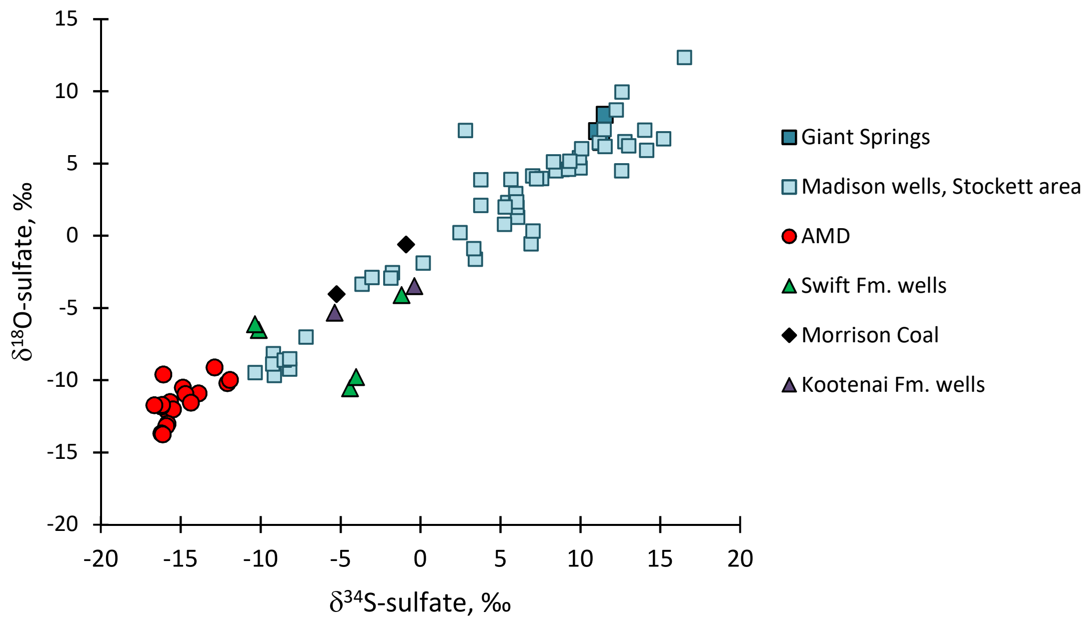

Figure 16. O- vs. S-isotope composition of dissolved sulfate for samples collected in the Stockett–Sand Coulee area. (Data for Giant Springs are added for comparison).

Figure 17 compares the isotopic composition of sulfate from Madison aquifer wells in the Stockett–Sand Coulee with domestic wells drilled into the Madison Aquifer in the Foothills Subdivision, near Great Falls. The Foothills samples also plot on an apparent mixing trend, but with a steeper slope than that for the Stockett–Sand Coulee samples. The mixing endmember for the Foothills samples appears to be shifted to lower $\delta^{18}O$ and/or higher $\delta^{34}S$ values. Acidic mine drains in the vicinity of Belt, Montana have $\delta^{18}O$ values similar to AMD from Stockett–Sand Coulee, but with more positive values of $\delta^{34}S$ (Fig. 18).

Footnotes...

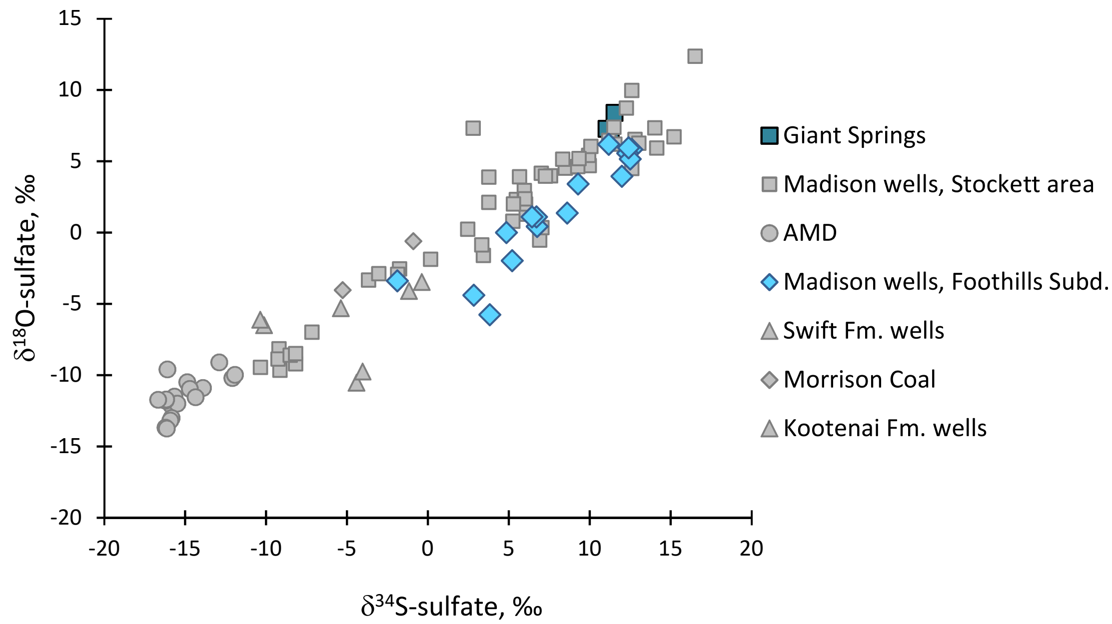

Figure 17. O- vs. S-isotope composition of dissolved sulfate for samples collected in the Foothills Subdivision area (blue symbols). Data from Stockett–Sand Coulee are shown in gray for comparison.

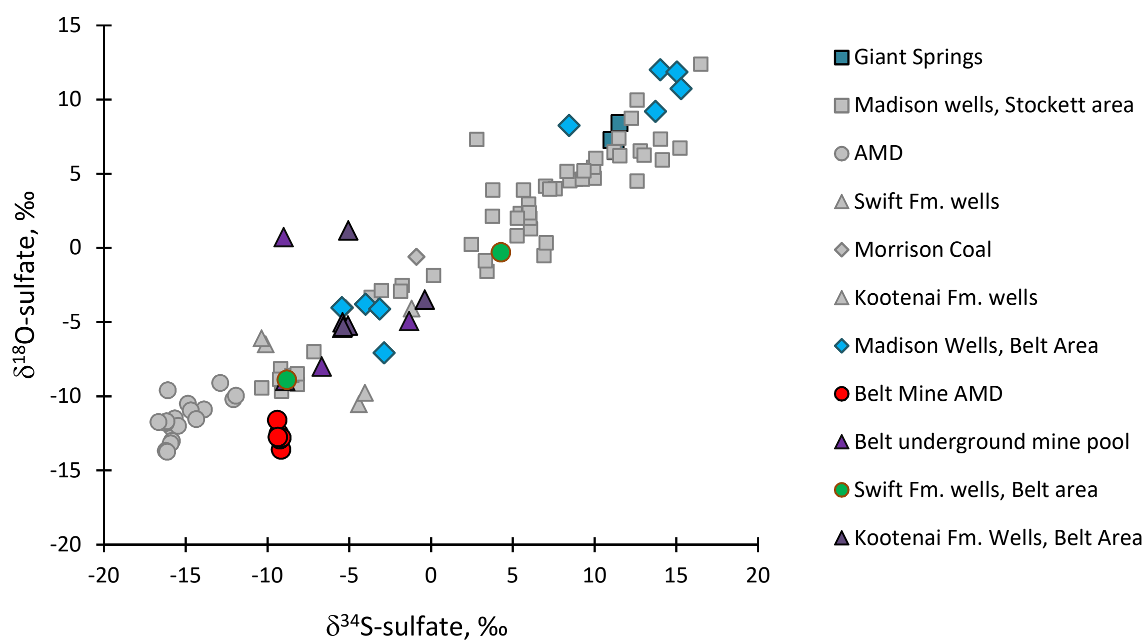

Figure 18. O- vs. S-isotope composition of dissolved sulfate for samples collected in the Belt area (colored symbols). Data from Stockett–Sand Coulee area are shown in gray for comparison.

Mixing of AMD with Belt Creek

Belt Creek is a clear mountain stream that begins in the Little Belt Mountains roughly 30 miles south of the field areas of this study. The upper and middle reaches of the watershed include extensive outcrops of Madison Limestone. Visual observations show after it leaves the mountains, Belt Creek loses some water to irrigation diversions and also to leakage to alluvium. As a result, the flow of lower Belt Creek can drop to very low levels in summer. Immediately upstream of the town of Belt, AMD from abandoned coal mines is discharged directly to the creek with no treatment. This degrades the quality of the creek, especially in summer's low-flow periods (Reiten et al., 2006).

Figure 19 summarizes the isotopic composition of dissolved sulfate in Belt Creek above and below the AMD discharges and the AMD. The upstream creek sample has a sulfate-isotope composition that is similar to background Madison Aquifer sulfate, as represented by Giant Springs. In contrast, sulfate in Belt Creek sampled 500 yards downstream (at a bridge in the center of town) has an isotopic composition that is approximately midway on the mixing line between the upstream and AMD end members. This means that roughly half of the dissolved sulfate in the downstream sample was derived from AMD. Thus, despite its relatively small flow, the fact that the AMD is highly concentrated in sulfate and other solutes means that the contributions from AMD are sufficient to degrade the water quality of Belt Creek.

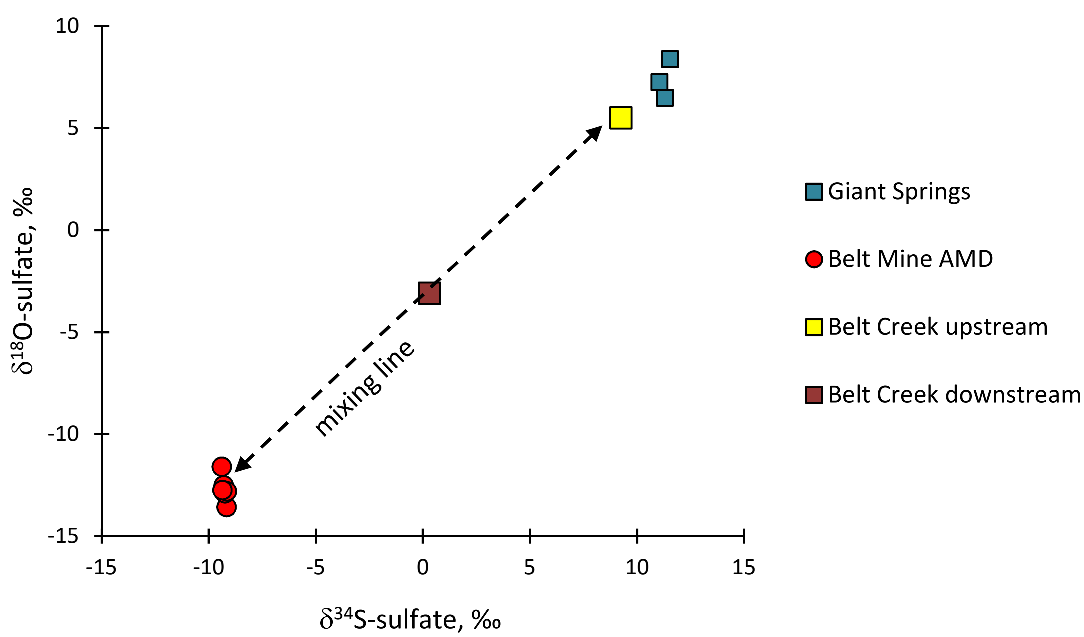

Figure 19. O- vs. S-isotope composition of dissolved sulfate for samples from Belt Creek collected above and below its confluence with AMD discharge from the Belt Mine. Based on the position of the downstream sample along the mixing line, it can be concluded that roughly half of the total dissolved sulfate in the downstream sample came from AMD, the other half being background sulfate in Belt Creek.

Footnotes...

Seasonal and year-to-year variations in sulfate isotopes

Many of the water wells and AMD seeps in this study were sampled on more than one visit. Figure 20 summarizes data for these locations. In most cases, the $\delta^{18}O$ and $\delta^{34}S$ values were similar between visits, some of which were separated by several months, and others by several years. The average standard deviation between repeat visit samples was ±0.7‰ for $\delta^{34}S$ and ±0.8‰ for $\delta^{18}O$. These variations are greater than the analytical uncertainty in the isotope analysis (±0.2‰ for $\delta^{34}S$ and ±0.4‰ for $\delta^{18}O$), but are still relatively small, which implies that seasonal or year-to-year variations in isotopic composition of dissolved sulfate are of secondary importance compared to the total spread in the data.

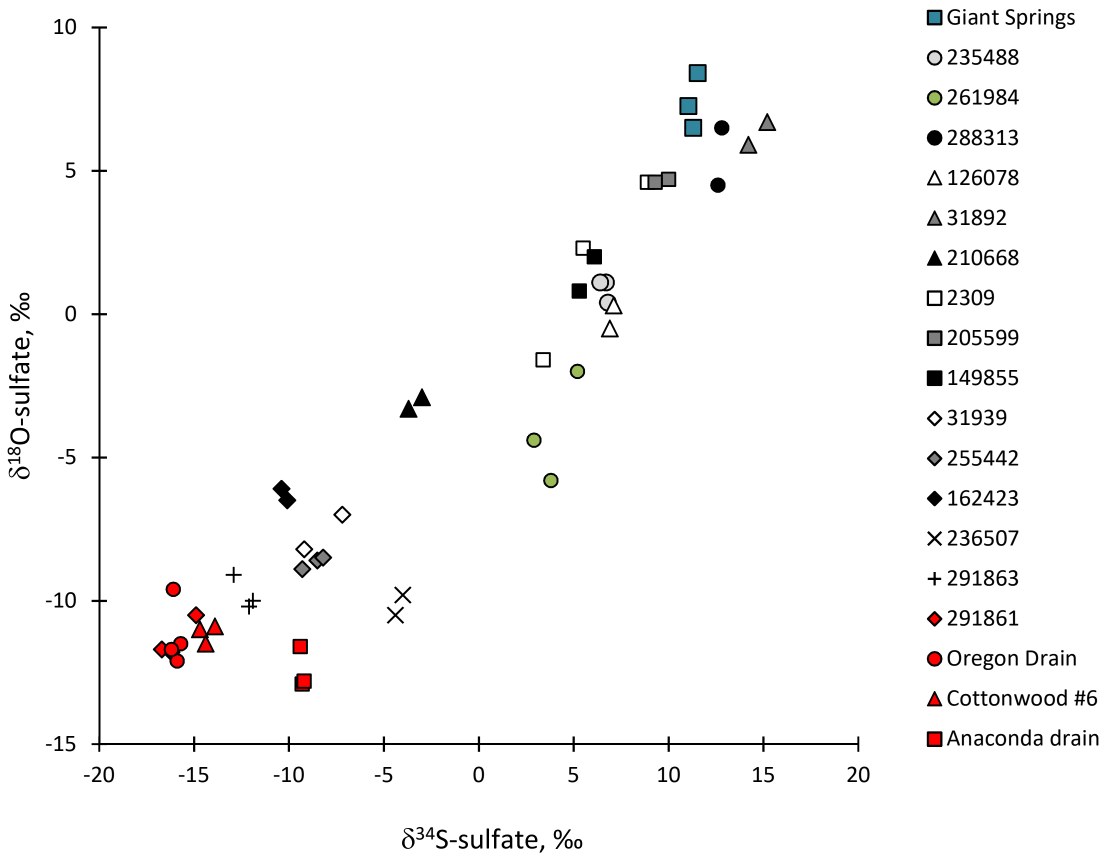

Figure 20. Comparison of the stable isotope composition of sulfate for locations that were sampled in more than one season (in most cases, different years). Numbers in legend are GWIC ID numbers for wells. The average standard deviation for locations sampled multiple times was ±0.7‰ for $\delta^{34}S$ and ±0.8‰ for $\delta^{18}O$.

Stable isotopes of dissolved inorganic carbon

A total of 32 water samples collected in this study were analyzed for the concentration of dissolved inorganic carbon (DIC) as well as the DIC-isotope composition ($\delta^{13}C$-DIC). The data are summarized in Appendix B and Figure 21. The parameter "DIC" is the sum of dissolved CO_2

Footnotes...

(H_2CO_3), bicarbonate ion (HCO_3^-), and carbonate ion (CO_3^{2-}). For the acidic AMD drains, H_2CO_3(aq) is the only significant DIC species present. However, for most of the groundwater samples with near-neutral pH, DIC will be a mix of H_2CO_3(aq) and HCO_3^-, with traces of CO_3^{2-}.

As shown in Figure 21, the C-isotope data fall into three groups. Group I includes three of the more acidic AMD drains. These low-pH waters have low DIC concentrations (<20 ppm) and isotopic compositions consistent with derivation of DIC from atmospheric CO_2 ($\delta^{13}C$ = -6.5‰ to -8‰). Group II includes water well samples from the Swift and Kootenai Formations, as well as two Madison samples and one mine-drain sample (Giffen Spring) that had a higher pH value of 5.4. The Group II waters have higher DIC concentrations (50 to 80 ppm) and lighter $\delta^{13}C$ values (-12‰ to -15‰). It is possible that the Group II water samples obtained much of their DIC from the soil zone. As discussed by Clark and Fritz (1997), DIC in soil water and shallow groundwater is a mixture of isotopically light CO_2 produced by the decay of organic matter, and heavier CO_2 derived from the atmosphere or by dissolution of carbonate minerals. In the case of the Swift and Kootenai samples, incorporation of soil-derived DIC makes sense given the fact that groundwater in these formations was recharged locally on fields that are mostly used to grow hay and alfalfa.

Group III (Fig. 21) includes most of the water samples from the Madison Aquifer, including Giant Springs and all of the Foothills Subdivision wells. These waters have $\delta^{13}C$-DIC values in the range of -6‰ to -10‰, and moderate DIC concentrations around 40 to 50 ppm. Given the long flow paths of groundwater in the Madison Aquifer, it is tempting to assume that the DIC in this groundwater would have equilibrated its carbon isotopes with the Madison Limestone. However, the average $\delta^{13}C$ of carbonate minerals in the Madison Group is +3.1 ± 1.2‰ (Plummer et al., 1990). If C-isotope exchange was occurring between the carbonate rock and the groundwater, then the range in $\delta^{13}C$-DIC should be heavier, approaching 0 to +3‰. In their regional study of the Madison Aquifer, Plummer et al. (1990) concluded that C-isotope exchange was minimal on the time scale of the groundwater flow paths investigated. This is consistent with the study of Gonfiantini and Zuppi (2003), who showed that C-isotope exchange between DIC and limestone can take thousands of years. The fact that C-isotope disequilibrium is widespread in the Madison groundwater suggests that the residence time of water in the aquifer is likely on the order of tens or hundreds of years, not thousands of years. This is consistent with the idea that groundwater flow in the Madison Limestone is focused along high-conductivity fractures and cave/karst features.

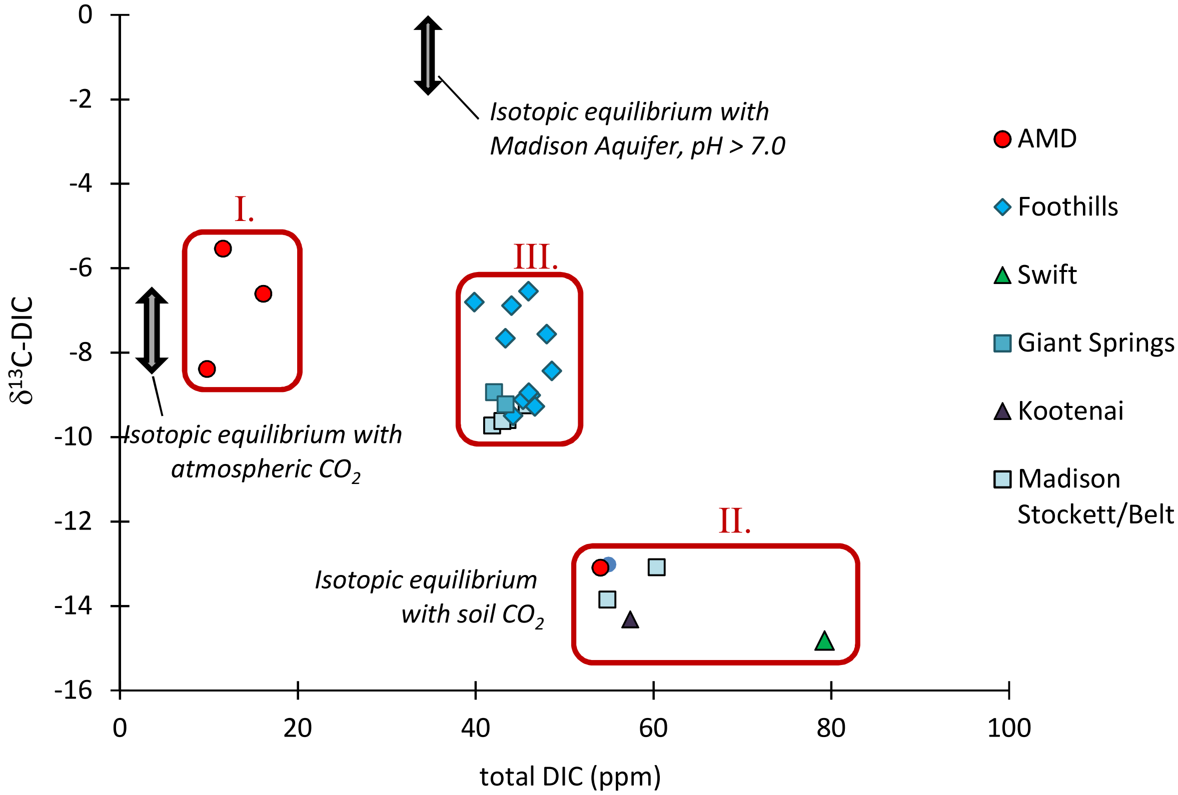

Figure 21. Sampled water sources fall into three groups based upon the primary source of DIC. Groundwater residence times are likely on the order of hundreds of years or less because no samples have been in contact with the Madison Limestone long enough to incorporate its average $\delta^{13}C$ of approximately +3‰.

Regional Sulfate Trends in the Madison Aquifer

Plummer and others (1990) conducted a regional study of the chemistry and isotopic composition of groundwater in the Madison Aquifer, and it is useful to consider some of their findings to help interpret the results of this study. Figure 22 shows changes in the concentration of total dissolved solids (TDS) of Madison groundwater in Montana and bordering states. The general pattern is an evolution from low TDS at high-elevation recharge areas to high TDS in downgradient wells to the north and east. Coincident with the rise in TDS, Plummer et al. (1990) documented an evolution in groundwater type from Ca-Mg-HCO_3 near the recharge sites, to Ca-SO_4 at middle flow-path distances and intermediate TDS values, and to Na-K-Cl type at longer flow paths and the highest TDS values (Fig. 23). As discussed by Plummer et al. (1990), these chemical changes are due to dissolution of ancient evaporite minerals in the Madison Group. Dissolution of gypsum explains the initial evolution towards Ca-SO_4 water, and this is followed by dissolution of halite and sylvite to form Na-K-Cl water (Fig. 23).

As shown by Figure 22, the present study area is located in a part of the Madison Aquifer where there is a steep increase in TDS from a recharge area to the south (Little Belt Mountains). In this region of the aquifer, the increase in TDS is mainly attributed to dissolution of gypsum

(Plummer et al., 1990). The presence of dissolved oxygen in all of the Madison wells sampled in this study indicates that dissolved sulfate concentrations and isotopic compositions should not be influenced by anaerobic reactions, such as bacterial sulfate reduction.

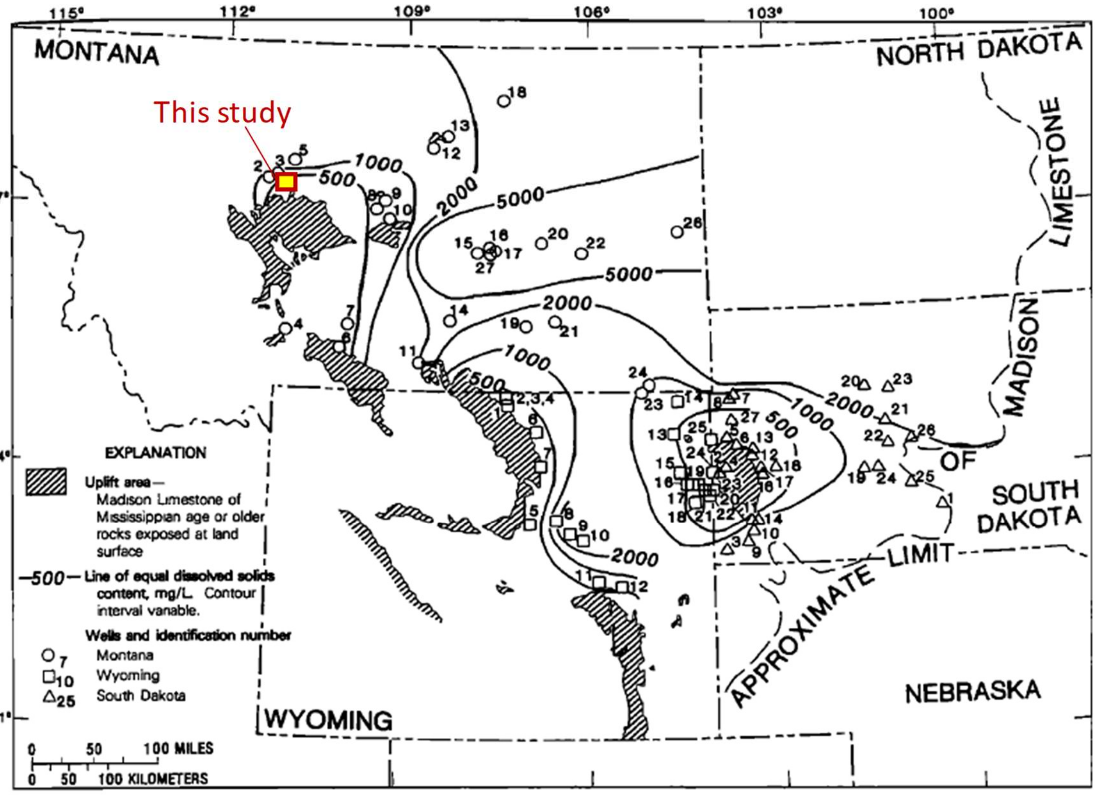

Figure 22. Map showing regional variation in total dissolved solids (TDS) of groundwater in the Madison Aquifer (taken from Plummer et al., 1990). The study area lies in an area where the TDS is changing quickly due to dissolution of sedimentary gypsum. The general flow of groundwater across the map is northward and eastward.

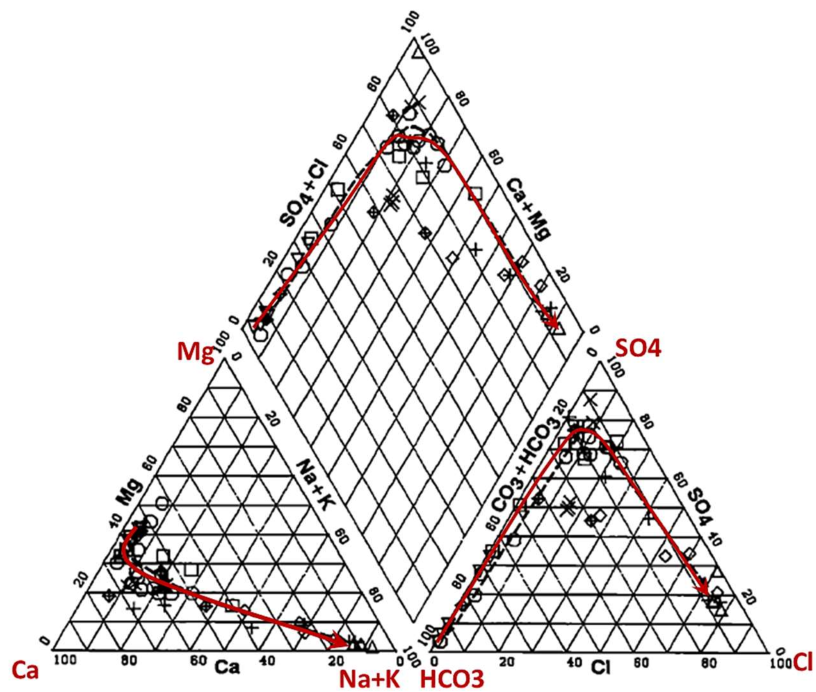

Figure 23. Piper diagram summarizing the chemical evolution of groundwater in the Madison Aquifer at a regional scale (modified from Plummer et al., 1990).

In their regional study, Plummer et al. (1990) included data on the S-isotope composition of dissolved sulfate in Madison groundwater. Data for samples from central Montana are summarized in Figure 24, along with results for the water samples of this study. The data of Plummer et al. (1990) (yellow circles) follow a trend labeled "Path A." This path connects water with very low sulfate concentration in the recharge area of the Madison Aquifer (Box I) with high-TDS groundwater that is saturated with gypsum (Box II). Note that SO_4 in Box II is isotopically heavy, with $\delta^{34}S > +20‰$. A heavy $\delta^{34}S$ value is typical of gypsum formed by evaporation of seawater. From the standpoint of the present study, Path A represents the regional "background" trend in evolution of $\delta^{34}S$-sulfate vs. sulfate concentration for the Madison Aquifer.

Groundwater Path B in Figure 24 is the pathway of most relevance to this study. In this case, recharge water for the Madison Aquifer follows Path A for a while, picking up some evaporite sulfate as it flows northward away from the Little Belt Mountains. However, when the water gets to the Sand Coulee–Stockett–Belt area, it mixes with sulfate-rich AMD. This causes the trajectory of Path B to bend sharply towards an isotopic composition corresponding to AMD (Box III). The more contaminated the well, the closer it plots to Box III.

Groundwater Path C in Figure 24 applies to some of the shallower aquifer systems, e.g., the Kootenai, Morrison coal, and Swift Fms. Path C begins with recharge water falling on the low-elevation plateaus surrounding and to the immediate south of the study area. This water infiltrates into the Kootenai Fm. and is the main source of water for the flooded coal mines at the top of the Morrison Fm. Once in contact with the abandoned mines, the water picks up isotopically light sulfate from the oxidation of pyrite in the coal and the isotopes evolve towards Type III (AMD). Some of this water may also penetrate deeper into the Swift Formation, which lies above the Madison.

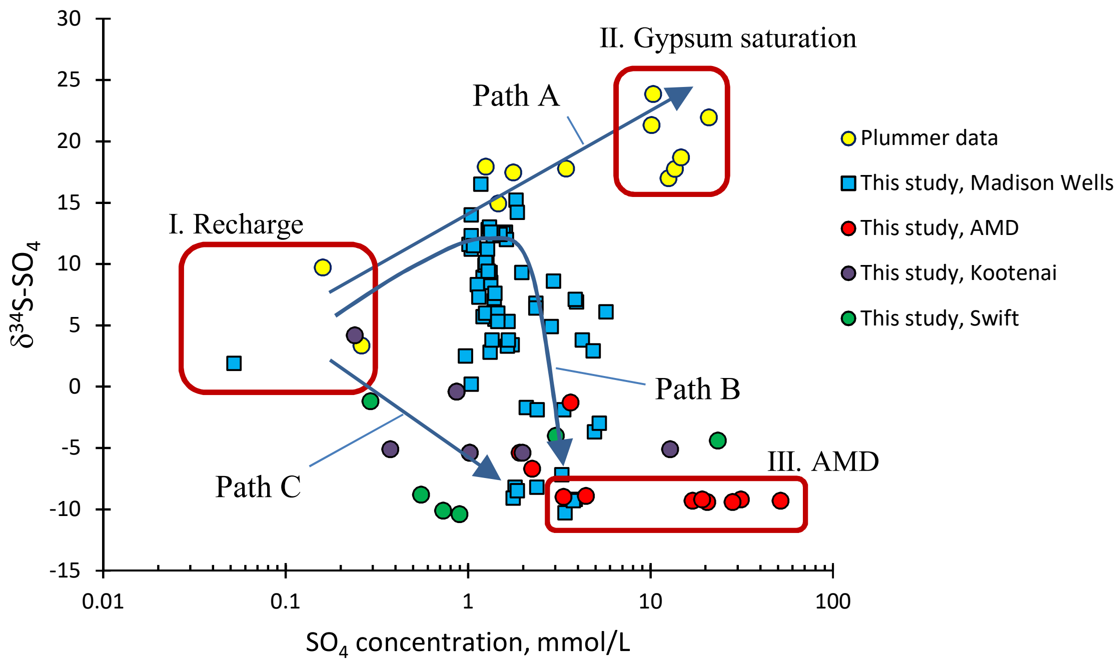

Figure 24. Plot of δ^{34}S-sulfate vs. sulfate concentration comparing the data from Plummer et al. (1990) for Madison water samples from Montana vs. waters investigated in this study. See text for explanation of the boxes and flow paths.

The data shown in Figure 24 are replotted vs. *reciprocal* sulfate concentration in Figures 25 and 26. The reason for doing this is that the end members for isotope mixing (Boxes I, II, and III) can be defined more accurately. Also, some of the subcategories in the data are separated out better in Figure 25 (e.g., Foothills Subdivision, Giant Springs, etc.). Figure 26 shows the same evolution pathways A, B, and C, where Path A is the regional path for the Madison Aquifer, Path C corresponds to the shallower aquifers (Kootenai, Morrison, Swift), and Path B shows the evolution of Madison groundwater as it mixes with AMD. Instead of following a single mixing line, the data for Paths B and C show a continuum of mixing lines. This is caused by differences in the relative proportion of mixing of the three sulfate end members (recharge, Madison gypsum, and AMD). For example, the Foothills Subdivision wells, being further north than the other Madison water samples in this study, appear to have dissolved more of the end member (Box II) evaporite sulfate in addition to potentially receiving acid drainage from the coal beds. Some of the Madison wells that fall closer to Path C in Figure 26 are located further south, and may not have dissolved much gypsum before receiving sulfate from oxidation of pyrite in the coal beds.

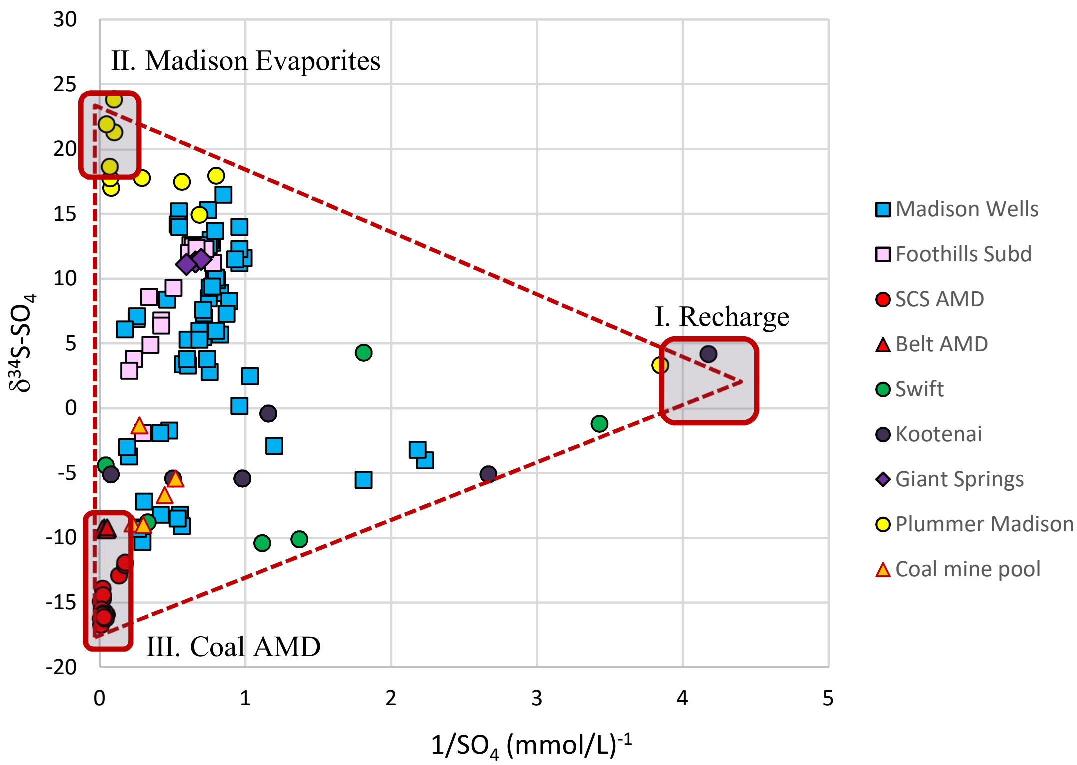

Figure 25. Plot of δ^{34}S-sulfate vs. reciprocal sulfate concentration for waters investigated in this study as well as data from Plummer et al. (1990) for Madison Aquifer samples from Montana.

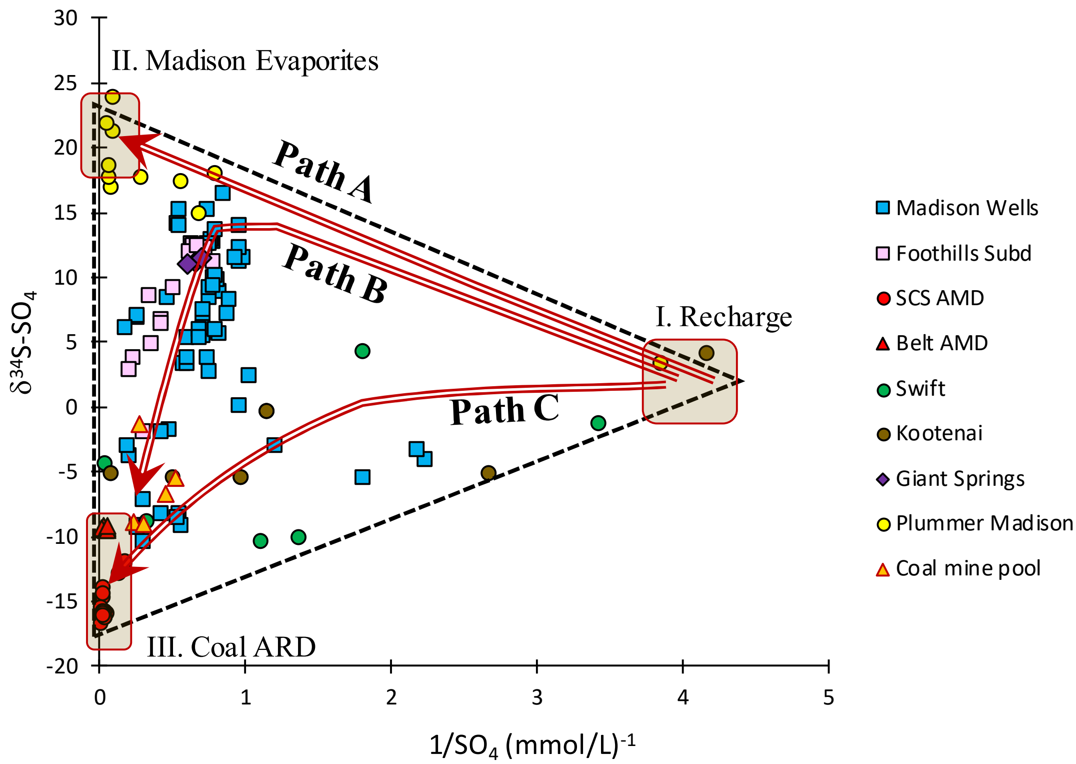

Figure 26. Plot of δ^{34}S-sulfate vs. reciprocal sulfate concentration showing groundwater evolution paths A, B, C (paths shown here are similar to Figure 24).

A final point that needs to be made with regards to the Foothills Subdivision wells is that just because many of the wells appear to have inherited sulfate from oxidation of pyrite in the Morrison coal beds (Path B of Fig. 26), this doesn't necessarily mean that this occurred from leakage of AMD from abandoned mines in the Sand Coulee–Stockett area. It is also possible that oxidation of pyrite in the coal occurred as a consequence of natural weathering. Several of the well logs in the subdivision mention drilling through coal before reaching the Madison Aquifer. However, considering that natural oxidation of unmined coal is likely to be a slow process taking thousands or even millions of years, it is unclear how much sulfate could be added to the Madison Aquifer by this mechanism. This question could possibly be addressed by installation of additional groundwater-monitoring wells in the Madison between the northern edge of the coal mines and the subdivisions on the outskirts of Great Falls.

Geochemical Modeling of AMD Mixing with Madison Aquifer Groundwater

Chemical data for all of the Madison aquifer samples and most of the AMD drains were input into the geochemical modeling program Visual Minteq (v. 3.1, a modification of the original Minteq program of Allison and others, 1991). The main purpose of this exercise was to evaluate the saturation state of the waters with minerals that may be buffering the water chemistry. Saturation indices (S.I.) were computed as the logarithm of the ratio of the ion activity quotient (Q) divided by the equilibrium constant (K_{eq}):

$$S.I. = \log (Q/K_{eq}) \ .$$

Footnotes...

The results showed that all of the Madison groundwater samples are close to equilibrium with calcite ($CaCO_3$), dolomite ($CaMg(CO_3)_2$), and chalcedony (fine-grained quartz), with S.I. values typically within ±0.2 log units of 0.0 (equilibrium). Most of the Madison waters are also near equilibrium with barite ($BaSO_4$), and an inverse relationship was noted between dissolved Ba^{2+} and SO_4^{2-} concentrations. However, because Ba is a trace element and SO_4 is a major ion, the precipitation of small amounts of barite in the aquifer would have a minimal effect on overall SO_4^{2-} concentrations. Gypsum ($CaSO_4 \cdot 2H_2O$) is likely to have a greater influence on dissolved sulfate. Most of the Madison samples were about an order of magnitude undersaturated with gypsum, which means that the waters have the capacity to dissolve any gypsum/anhydrite that could be present along the flow path. Plummer et al. (1990) demonstrated a link between gypsum dissolution and "de-dolomitization" in the Madison Aquifer according to the following reactions:

$$CaSO_4 \cdot 2H_2O_{gypsum} = Ca^{2+} + SO_4^{2-} + 2H_2O$$

$$Ca^{2+} + CaMg(CO_3)_{2,dolomite} = 2CaCO_{3,calcite} + Mg^{2+}$$

However, no chemical evidence for de-dolomitization was seen in the samples collected in this study. This is likely due to the lower saturation state with respect to gypsum compared to the waters examined by Plummer's group that were collected further north and east of the study area.

Geochemical modeling of the AMD waters shows the majority of samples were near-equilibrium saturation with amorphous silica and an aluminum phase (usually alunite, $KAl_3(SO_4)_2(OH)_6$ or jurbanite, $AlSO_4(OH)$). Modeling of iron minerals was hampered by a lack of data on the speciation of dissolved Fe between the +2 and +3 oxidation states. The strongly acidic and Fe-rich mine drains were likely precipitating a ferric oxide of some sort after emerging from the ground. In the pH range of 2.5 to 3.5, precipitation of K-jarosite ($KFe_3(SO_4)_2(OH)_6$) is likely, and could explain the complete lack of detectable K^+ in the most acidic waters. In a wetland below the Giffen Spring, rapid oxidation of Fe^{2+} at near-neutral pH has formed a sizeable deposit of unconsolidated ferrihydrite/goethite "muck," which is actually dangerous since a person or animal could sink up to their hips with a misstep. Similar precipitates are actively forming in Belt Creek below the confluence of the Anaconda drain, but are swept away each spring during high flow.

Transferability of the Current Project to Other Locations

To evaluate the transferability of the dual-isotopes of sulfate method to other basins impacted by AMD drainage, nearby watersheds and evidence from the scientific literature were evaluated. The field sites that were selected were: 1) the Foothills Subdivision, near Great Falls, and 2) the town of Belt and its surrounding area.

In the case of the Foothills Subdivision, a number of wells drilled into the Madison Aquifer were shown to have elevated SO_4 concentration with an isotopic signature that is consistent with AMD. The Foothills Subdivision is roughly 5 miles north and downgradient of the coal mining centers of Stockett and Sand Coulee. However, as discussed above, it is theoretically possible that some of the SO_4 in the Subdivision wells came from natural oxidation of pyrite in the overlying Morrison Fm. coal beds by rainwater and snowmelt that slowly infiltrated to the

Footnotes...

regional water table. Without more hydrological, chemical, and isotopic data, it is not possible to say with certainty that the elevated sulfate levels in the Subdivision wells came from the abandoned coal mines.

The situation is also ambiguous for the Belt area wells. As shown in Figure 18, wells drilled into the Madison Aquifer near Belt fall into two categories: a group of wells that show no presence of AMD, and another that suggests significant mixing with AMD. However, the two wells that show mixing are located upgradient from mining activities.

Many papers published in the last 12 years have used stable isotopes to track contamination of groundwater and surface water from coal AMD. The majority of these studies were done in China, including Bottrell (2007), Lang and others (2011), Li and others (2010, 2018), Sun and others (2017, 2019), Zang and others (2015), Zhang and others (2009, 2015), and Zhou and others (2018). Denimal and others (2002) and Migaszewski and others (2018) performed similar studies in France and Poland, respectively. The only previous study in the U.S. (aside from the work in the Belt–Stockett–Sand Coulee area by Gammons et al., 2010, 2013) is that of Vengosh and others (2013), who demonstrated that S-isotopes of dissolved sulfate in a West Virginia watershed could be used as a tracer of contamination from mountaintop mining of coal.

Overall, the transferability of the SO_4-isotope approach to other coal-mine areas in the U.S. and around the world should be very high. For any isotope-fingerprinting study, the only requirement to make the method work is a strong contrast between the stable isotope signature of sulfate in AMD and sulfate in background waters. Coal typically has isotopically light pyrite, and the majority of previous studies cited above reported AMD with negative values of $\delta^{34}S$-SO_4, as is the case for the AMD waters of this study. Interpretation can be complicated by "background" sulfate in a field area that is also isotopically light. For example, the Swift Aquifer of this study has $\delta^{34}S$-SO_4 and $\delta^{18}O$-SO_4 values that are indistinguishable from the AMD drains. However, the SO_4 *concentrations* in the Swift are low, much lower than water in the overlying coal beds or underlying Madison Limestone. Thus, although isotopes are useful, they should be used in conjunction with supporting chemical analyses.

A relevant question to ask with regard to future studies using sulfate isotopes is whether or not it is necessary to analyze both $\delta^{34}S$ and $\delta^{18}O$ of the sulfate molecule, or if one isotope analysis (e.g., $\delta^{34}S$) is sufficient. Many academic and commercial labs can analyze $\delta^{34}S$ of sulfate, but $\delta^{18}O$-sulfate is less commonly performed: it is a separate analysis that approximately doubles the cost per sample. However, for most projects the added value by using the dual-isotope approach should justify the additional costs, which likely will be a small fraction of the total project budget. In the present study, stable isotope mixing calculations based on $\delta^{34}S$-sulfate and based on $\delta^{18}O$-sulfate gave similar results, and served as independent checks on each other. At other sites, it might well be the case that the S-isotope composition of AMD sulfate and background sulfate are similar, whereas the O-isotope compositions are distinct. In this scenario, $\delta^{34}S$-sulfate would be useless from a fingerprinting point of view, whereas $\delta^{18}O$-sulfate would be an excellent tracer to sleuth out contributions from AMD vs. background sources. Overall, it is recommended that future studies employ both $\delta^{18}O$ and $\delta^{34}S$.

Conclusion

The following are four of the most important conclusions of this project:

- Stable S- and O-isotopes confirm that dissolved sulfate from abandoned coal mines in central Montana is present in the Madison limestone aquifer.
- Our data suggest that AMD may have migrated downgradient at least 5 miles to the vicinity of a new subdivision in the outskirts of the city of Great Falls. However, it is also possible that sulfate infiltrates to the Madison Aquifer by natural weathering of unmined coal beds in the Great Falls area.
- Despite isotopic evidence for the presence of AMD in the Madison Aquifer, the vast majority of the affected groundwater wells contain water that meets all U.S. EPA and Montana regulatory standards for drinking water. This underscores the ability of the Madison Aquifer to buffer groundwater chemistry to acceptable levels.
- The sulfate "dual-isotope" approach used in this study is easily transferable to other sites where groundwater and/or surface water is known or suspected of being contaminated by coal-mine drainage.

Some additional findings include the following:

- Collection of samples on multiple visits showed that seasonal changes in isotopic composition of sulfate in individual wells are relatively small, and are much smaller than the total spread in isotopic data between wells.
- Background sulfate concentrations in the Madison Aquifer increase as groundwater moves downgradient (northward) away from recharge zones. This is due to dissolution of evaporative salts (gypsum, anhydrite) in the formation. This "sliding scale" added a level of complexity to the interpretation of stable-isotope mixing diagrams.
- Water isotopes (δD and $\delta^{18}O$) support the conceptual model of regional hydrogeology, which includes recharge of the Madison Aquifer by higher-elevation snowmelt and rain as opposed to the overlying Swift and Kootenai aquifers, which are recharged by local precipitation falling directly on the grassy foothills in the vicinity of the abandoned coal mines.
- Geochemical modeling showed that groundwater in the Madison Aquifer is in chemical equilibrium with calcite and dolomite, but undersaturated with gypsum/anhydrite. Most of the AMD waters are near-equilibrium with an aluminous phase (e.g., jurbanite or alunite) and one or more Fe-bearing phases (e.g., jarosite, schwertmannite, ferrihydrite).
- Stable isotopes of dissolved inorganic carbon ($\delta^{13}C$-DIC) showed that Madison Aquifer groundwaters are in isotopic disequilibrium with their limestone host rock. This is explained by the slow kinetics of C-isotope exchange between water and rock at low temperature. This result also implies that the residence time of groundwater in the aquifer is probably on the order of tens or hundreds of years, not thousands of years, consistent with the idea that groundwater flow in the Madison is focused along fractures and open cavities.

Footnotes...

- Future investigation in this region should address the potential for wells constructed in the early 1900s to provide conduits for shallow groundwater in the coal mines to drain by gravity to the deeper, regional water table in the Madison aquifer.

References

Bottrell, S. H., 2007, Stable isotopes in aqueous sulphate as tracers of natural and contaminant sulphate sources: a reconnaissance study of the Xingwen karst aquifer, Sichuan, China: Geological Society, London, Special Publications, v. 279, p. 123-135.

Carmody, R. W., Plummer, L. N., Busenberg, E., and Coplen, T. B., 1998, Methods for collection of dissolved sulfate and sulfide and analysis of their sulfur isotopic composition: US Geological Survey, Open File Report 97-234.

Clark, I. D., and Fritz, P., 1997, Environmental Isotopes in Hydrogeology: Lewis Publishers, New York.

Craig, H., 1961, Isotopic variations in meteoric waters: Science, v. 133, p. 1702–1703.

Davis, S. N., Cecil, L. D., Zreda, M., and Moysey, S., 2001, Chlorine-36, bromide, and the origin of spring water: Chemical Geology, v. 179, p. 3–16.

Denimal, S., Tribovillard, N., Barbecot, F., and Dever, L., 2002, Leaching of coal-mine tips (Nord-Pas-de-Calais coal basin, France) and sulphate transfer to the chalk aquifer: example of acid mine drainage in a buffered environment: Environmental Geology, v. 42, p. 966-981.

Duaime, T. E., Sandau, K. L., Vuke, S. M., Hanson, J., Reddish, S., and Reiten, J. C., 2004, Reevaluation of the hydrologic system in the vicinity of the Anaconda Mine at Belt, Cascade County, Montana: Montana Bureau of Mines and Geology, Open-File Report 504, 116 p.

Epstein, S., and Mayeda, T., 1953, Variation of O-18 content of waters from natural sources: Geochimica et Cosmochimica Acta, v. 4, p. 213–224.

Fisher, C. A., 1909, Geology of the Great Falls Coal Field, Montana: U. S. Geological Survey, Bulletin 356.

Gammons, C. H., Poulson, S. R., Pellicori, D. A., Roesler A., Reed, P. J., and Petrescu, E. M., 2006, The hydrogen and oxygen isotopic composition of precipitation, evaporated mine water, and river water in Montana, USA: Journal of Hydrology, v. 328, p. 319-330.

Gammons, C. H., Duaime, T. E., Parker, S. R., Poulson, S. R., and Kennelly, P., 2010, Geochemistry and stable isotope investigation of acid mine drainage associated with abandoned coal mines in central Montana, USA: Chemical Geology, v. 269, p. 100-112.

Gammons, C. H., Brown, A., Poulson, S. R., and Henderson, T., 2013, Using stable isotopes (S, O) of sulfate to track contamination of the Madison karst aquifer, Montana, from coal mine drainage. Applied Geochemistry: v. 31, p. 228-238.

Giesemann, A., Jager, H. J., Norman, A. L., Krouse, H. P., and Brand, W. A., 1994, On-line sulfur-isotope determination using an elemental analyzer coupled to a mass spectrometer: Analytical Chemistry, v. 66, p. 2816–2819.

Gonfiantini, R., and Zuppi, G. M., 2003, Carbon isotope exchange rate of DIC in karst groundwater: Chemical Geology, v. 197, p. 319-336.

Karper, P. L., 1998, Water-quality data (July 1994 through September 1996) and statistical summaries of data from surface water in the Sand Coulee coal area, Montana: U.S. Geological Survey., Open-File Report 98-94.

Kornexl, B. E., Gehre, M., Höffling, R., and Werner, R. A., 1999, On-line $\delta^{18}O$ measurement of organic and inorganic substances: Rapid Communications in Mass Spectrometry, v. 13, p. 1685–1693.

Footnotes...

Lang, Y. C., Liu, C. Q., Li, S. L., Zhao, Z. Q., and Zhou, Z. H., 2011, Tracing natural and anthropogenic sources of dissolved sulfate in a karst region by using major ion chemistry and stable sulfur isotopes: Applied Geochemistry, v. 26, p. S202-S205.

Li, X. D., Liu, C. Q., Harue, M., Li, S. L., and Liu, X. L., 2010, The use of environmental isotopic (C, Sr, S) and hydrochemical tracers to characterize anthropogenic effects on karst groundwater quality: a case study of the Shuicheng Basin, SW China: Applied Geochemistry, v. 25, p. 1924-1936.

Li, X., Wu, P., Han, Z., Zha, X., Ye, H., and Qin, Y., 2018, Effects of mining activities on evolution of water quality of karst waters in Midwestern Guizhou, China: evidences from hydrochemistry and isotopic composition: Environmental Science and Pollution Research, v. 25, p. 1220-1230.

Madison, J.P., 2016, Potentiometric surface in the Madison Group Aquifer, Cascade County, north-central Montana: Montana Bureau of Mines and Geology Montana Ground-Water Assessment Atlas 7-04, 1 sheet.

Migaszewski, Z. M., Gałuszka, A., and Dołęgowska, S., 2018, Stable isotope geochemistry of acid mine drainage from the Wiśniówka area (south-central Poland): Applied Geochemistry, v. 95, p. 45-56.

Morrison, J., Brockwell, T., Merren, T., Fourel, F., and Phillips, A. M., 2001, On-line high precision stable hydrogen isotopic analyses on nanoliter water samples: Analytical Chemistry, v. 73, p. 3570–3575.

Osborne, T. J., Donovan, J. J., and Sonderegger, J. L., 1983a, Interaction between groundwater and surface water regimes and mining-induced acid mine drainage in the Stockett–Sand Coulee coal field: Montana Bureau of Mines and Geology, Open-File Report 109.

Osborne, T. J., Noble, R. A., Sonderegger, J. L., and Donovan, J. J., 1983b. Acid mine drainage contamination of the Madison Aquifer near Great Falls, Montana [abstr]: Geological Society of America, Abstracts with Programs, v. 15, no. 5, p. 312.

Osborne, T. J., Tomer, M. D., and Holzer, J. M., 1987, Acid mine drainage control in the Sand Coulee Creek and Belt Creek watersheds, Montana, 1983–1987: Montana Bureau of Mines and Geology, Open-File Report 197.

Pagano, G., Guida, M., Tommasi, F., and Oral, R., 2015, Health effects and toxicity mechanisms of rare earth elements—Knowledge gaps and research prospects: Ecotoxicology and Environmental Safety, v. 115, p. 40-48.

Plummer, L. N., Busby, J. F., Lee, R. W., and Hanshaw, B. B., 1990, Geochemical modeling of the Madison Aquifer in parts of Montana, Wyoming, and South Dakota: Water Resources Research, v. 26, p. 1981-2014.

Reiten, J., Reddish, S., and Brown, J., 2006, Hydrogeologic characterization of acid mine drainage along Belt Creek near Belt, Montana: Montana Bureau of Mines and Geology, Open-File Report 545.

Rossillon, M., McCormick, M., and Hufstetler, M., 2009, Great Falls Coal Field: Historic Overview

Sholes, M. A., and Daniel, J. A., 1992, Coal geology of Montana: Montana Bureau of Mines and Geology, Special Publication 102, 157 p.

Silverman, A. J., and Harris, W. L., 1967, Stratigraphy and economic geology of the Great Falls-Lewiston Coal Field, Central Montana: Montana Bureau of Mines and Geology, Bulletin 56.

Sun, J., Kobayashi, T., Strosnider, W. H., and Wu, P., 2017, Stable sulfur and oxygen isotopes as geochemical tracers of sulfate in karst waters: Journal of hydrology, v. 551, p. 245-252.

Sun, J., Yoshio, T., Strosnider, W. H., Kogure, T., Wu, P., and Cao, X., 2019, Tracing and quantifying contributions of end members to karst water at a coalfield in southwest China: Chemosphere, v. 234, p. 777-788.

Timmer, Jacqueline, 2020, MBMG Analytical Laboratory: Quality Assurance Manual: Montana Bureau of Mines and Geology Open-File Report 729, 8 p.

Vengosh, A., Lindberg T. T., Merola, B. R., Ruhl, L., Warner, N. R., White, A., Dwyer, G. S., and Di Giulio, R. T., 2013, Isotopic imprints of mountaintop mining contaminants: Environmental Science and Technology, v. 47, p. 10041-10048.

Vuke, S. M., Berg, R. B., Colton, R. B., and O'Brien, H. E., 2002, Geologic map of the Belt 30' x 60' quadrangle, central Montana: Montana Bureau of Mines and Geology, Open-File Report 450.

Weight, W.D., 2008, Hydrogeology field manual: New York, The McGraw-Hill Companies, Inc., 751 p.

Zang, H., Zheng, X., Qin, Z., and Jia, Z., 2015, A study of the characteristics of karst groundwater circulation based on multi-isotope approach in the Liulin spring area, North China: Isotopes in Environmental and Health Studies, v. 51, p. 271-284.

Zhang, J. H., Liang, Y. P., Wang, W. T., Han, X. R., and Hou, G. C., 2009, A practical use of 34S in the investigation of karst groundwater resource in North China: Carsologica Sinica, v. 28, p. 235-241.

Zhang, D., Li, X. D., Zhao, Z. Q., and Liu, C. Q., 2015, Using dual isotopic data to track the sources and behaviors of dissolved sulfate in the western North China Plain: Applied Geochemistry, v. 52, p. 43-56.

Zhou, J., Zhang, Q., Kang, F., Zhang, Y., Yuan, L., Wei, D., and Lin, S., 2018, Using multi-isotopes (34S, 18O, 2H) to track local contamination of the groundwater from Hongshan-Zhaili abandoned coal mine, Zibo city, Shandong province: International Biodeterioration & Biodegradation: v. 128, p. 48-55.

Ziemkiewicz, P., Vass, C., Liu, X., Ren, P. and Noble, A., 2018, Design and evaluation of an acid leaching/solvent extraction process to extract rare earth elements from acid mine drainage precipitates: Proc. 2018 Annual USDOE/NETL meeting, Pittsburg, USA.

Appendices

Appendix A. Summary of all stable isotope data for dissolved sulfate and water.

Identifier	GWIC ID	Sample date	Aquifer	Dissolved Sulfate			Water Isotopes	
				$\delta^{34}S$, ‰	$\delta^{18}O$, ‰	SO_4, mg/l	$\delta^{18}O$, ‰	δD, ‰
Foothills Subdivision								
OSM-01	235488	4/14/17	MDSN	6.8	0.4	226	-19.0	-147
OSM-152	235488	8/14/18	MDSN	6.7	1.1	n.a.	n.a.	n.a.
OSM-201	235488	7/17/19	MDSN	6.4	1.1	*226*	-18.8	-146
OSM-03	291365	4/13/17	MDSN	9.3	3.4	189	-18.9	-146
OSM-04	261984	4/13/17	MDSN	3.8	-5.8	407	-18.8	-146
OSM-153	261984	8/14/18	MDSN	5.2	-2.0	n.a.	n.a.	n.a.
OSM-202	261984	7/18/19	MDSN	2.9	-4.4	*466*	n.a.	n.a.
OSM-05	235689	4/14/17	MDSN	-1.9	-3.4	322	-18.8	-146
OSM-08	281405	6/21/17	MDSN	4.9	0.0	274	-18.9	-147
OSM-10	252467	6/20/17	MDSN	11.2	6.2	123	-18.8	-146
OSM-11	239236	6/21/17	MDSN	12.6	5.8	154	-18.0	-143
OSM-12	248664	6/20/17	MDSN	12.3	5.6	132	-18.8	-146
OSM-13	242151	6/20/17	MDSN	8.6	1.4	282	-18.9	-147
OSM-15	279108	6/21/17	MDSN	12.5	5.2	150	-18.9	-146
OSM-16	242153	6/20/17	MDSN	12.0	4.0	156	-18.9	-146
OSM-151	279137	8/14/18	MDSN	12.4	5.9	144	n.a.	n.a.
Stockett–Sand Coulee, Madison Wells								
DEQ100	P-13	2011	MDSN	14.0	7.3	100	n.a.	n.a.
DEQ110	C7	2011	MDSN	11.2	6.5	100	-18.3	-143
DEQ103	C5	2011	MDSN	11.6	6.2	97	-18.7	-143
OSM-35	288313	9/13/17	MDSN	12.6	4.5	131	-18.8	-145
OSM-203	288313	7/18/19	MDSN	12.8	6.5	*124*	-18.7	-145
OSM-37	126078	10/19/17	MDSN	6.9	-0.5	377	-18.8	-146
OSM-204	126078	7/18/19	MDSN	7.1	0.3	*371*	-18.9	-147
OSM-38	31892	10/19/17	MDSN	15.2	6.7	176	-18.9	-147
OSM-205	31892	7/18/19	MDSN	14.2	5.9	*179*	-18.8	-146
OSM-39	139022	10/19/17	MDSN	12.3	8.7	100	-18.7	-145
OSM-40	245668	10/19/17	MDSN	16.5	12.4	113	-18.7	-144
OSM-206	245668	7/16/19	MDSN	n.a.	n.a.	n.a.	-18.8	-145
OSM-43	141006	10/20/17	MDSN	2.8	7.3	127	-18.9	-146

Footnotes...

Identifier	GWIC ID	Sample Date	Aquifer	Dissolved Sulfate			Water Isotopes	
				δ^{34}S, ‰	δ^{18}O, ‰	SO_4, mg/l	δ^{18}O, ‰	δD, ‰
Stockett–Sand Coulee, Madison Wells (Cont.)								
OSM-26	276129	7/18/17	MDSN	1.9	n.a.	5	-18.6	-142
OSM-68	210668	6/20/18	MDSN	-3.7	-3.3	474	-16.1	-130
OSM-207	210668	7/18/19	MDSN	-3.0	-2.9	*504*	-17.1	-138
OSM-71	149852	6/21/18	MDSN	6.1	1.3	547	-19.0	-148
OSM-155	294553	8/14/18	MDSN	13.0	6.3	126	n.a.	n.a.
MT1	2309	8/28/09	MDSN	3.4	-1.6	168	-18.4	-143
OSM-27	2309	7/19/17	MDSN	8.9	4.6	116	-18.8	-145
OSM-208	2309	7/17/19	MDSN	5.5	2.3	*135*	-18.8	-146
MT2	2308	8/28/09	MDSN	3.3	-0.9	158	-18.7	-146
MT3	167881	8/28/09	MDSN	12.6	10.0	128	-19.0	-146
MT4	205599	8/29/09	MDSN	8.5	4.5	128	-18.8	-145
OSM-25	205599	7/19/17	MDSN	10.0	4.7	122	-18.7	-145
	205599	7/17/19	MDSN	9.3	4.6	*127*	-18.8	-146
MT5	2249	8/29/09	MDSN	7.0	4.2	134	-18.8	-145
MT6		8/29/09	MDSN	9.9	5.4	119	-18.7	-146
MT8	2295	8/29/09	MDSN	10.1	6.0	120	-18.8	-145
MT9	158293	9/19/09	MDSN	7.6	4.0	135	-18.8	-146
MT11	122947	9/19/09	MDSN	5.7	3.9	116	-18.7	-145
MT12	165613	9/19/09	MDSN	9.4	5.2	124	-18.7	-145
MT15	210883	9/11/10	MDSN	11.5	7.4	103	-18.9	-146
MT16	130732	9/11/10	MDSN	8.3	5.1	108	-18.8	-145
MT18	230156	10/23/10	MDSN	0.2	-1.9	100	-18.3	-144
MT19	254474	10/23/10	MDSN	2.5	0.2	93	-19.0	-147
MT21	149855	10/23/10	MDSN	6.1	2.0	134	-18.9	-145
OSM-24	149855	7/19/17	MDSN	5.3	0.8	159	-18.8	-145
DEQ101		2011	MDSN	-1.7	-2.5	200	n.a.	n.a.
DEQ102		2011	MDSN	-1.9	-2.9	230	n.a.	n.a.
DEQ104		2011	MDSN	3.8	2.1	130	-18.7	-144
DEQ105		2011	MDSN	7.3	4.0	110	-18.4	-144
DEQ106		2011	MDSN	6.0	2.9	120	-18.7	-145
DEQ107		2011	MDSN	6.0	2.4	140	-18.4	-144
DEQ108		2011	MDSN	5.3	2.0	140	-18.3	-143
DEQ109		2011	MDSN	3.8	3.9	160	-18.3	-143

Footnotes...

Identifier	GWIC ID	Sample Date	Aquifer	Dissolved Sulfate $\delta^{34}S$, ‰	Dissolved Sulfate $\delta^{18}O$, ‰	Dissolved Sulfate SO_4, mg/l	Water Isotopes $\delta^{18}O$, ‰	Water Isotopes δD, ‰
Stockett–Sand Coulee, Madison Wells (cont.)								
MT17		10/23/10	MDSN	-10.3	-9.5	326	-18.3	-141
MT20		10/23/10	MDSN	-8.2	-9.2	174	-19.3	-149
MT7	2305	8/29/09	MDSN	-9.1	-9.7	170	-19.4	-151
MT10	31939	9/19/09	MDSN	-9.2	-8.2	372	-18.4	-143
OSM-29	31939	7/19/17	MDSN	-7.2	-7.0	314	-18.5	-144
MT13	255442	9/11/10	MDSN	-9.3	-8.9	363	-19.2	-149
OSM-23	255442	7/19/17	MDSN	-8.5	-8.6	179	-20.1	-156
OSM-209	255442	7/18/19	MDSN	-8.2	-8.5	*229*	-19.7	-154
Stockett–Sand Coulee, Swift Fm. Aquifer								
MT14	162423	2009/10	SWIFT	-10.1	-6.5	70	-17.6	-139
OSM-41	162423	10/20/17	SWIFT	-10.4	-6.1	86	-17.4	-139
OSM-42	2174	10/20/17	SWIFT	-1.2	-4.1	28	-17.2	-137
OSM-02	236507	4/14/17	SWIFT	-4.4	-10.5	2246	-18.1	-147
OSM-154	236507	8/14/18	SWIFT	-4.0	-9.8	n.a.	n.a.	n.a.
Stockett–Sand Coulee, Kootenai Fm. Aquifer								
OSM-44		10/18/17	KOOT	-0.4	-3.5	83	-16.7	-135
OSM-45		10/12/17	KOOT	-5.4	-5.3	98	-17.6	-140
OSM-19	30542	8/3/17	KOOT	4.2	n.a.	23	-18.0	-139
Stockett–Sand Coulee, Contaminated Alluvium								
OSM-69	2441	6/21/18	ALVM	-13.0	-8.7	1061	-18.3	-143
Stockett–Sand Coulee, Morrison Fm. Coal								
OSM-146	152258	5/4/2018	MRSN	-0.9	-0.6	169	n.a.	n.a.
OSM-147	146929	5/4/2018	MRSN	-5.3	-4.0	77	n.a.	n.a.

Footnotes...

Identifier	GWIC ID	Sample Date	Aquifer	Dissolved Sulfate			Water Isotopes	
				$\delta^{34}S$, ‰	$\delta^{18}O$, ‰	SO_4, mg/l	$\delta^{18}O$, ‰	δD, ‰
Giant Springs, City of Great Falls								
OSM-28	2528	7/21/17	MDSN	11.3	6.5	146	-18.9	-145
	2528	11/18/05	MDSN	11.5	8.4	138	-18.9	-144
OSM-18	2526	6/20/17	MDSN	11.1	7.3	161	-18.8	-145
Coal Mine Discharges, Stockett–Sand Coulee Area								
Giffen	291863	11/18/05	AMD	-12.9	-9.1	721	-18.2	-141
OSM-20	291863	7/20/17	AMD	-12.1	-10.2	555	-18.3	-143
OSM-60	291863	5/22/18	AMD	-11.9	-10.0	549	-18.2	-143
Nelson	291861	11/18/05	AMD	-14.9	-10.5	12100	-17.1	-137
OSM-30	291861	7/20/17	AMD	-16.2	-11.8	11366	-17.0	-138
OSM-56	291861	5/22/18	AMD	-16.7	-11.7	10214	-16.8	-137
Oregon		11/18/05	AMD	-16.1	-9.6	2550	-17.6	-140
Oregon	MT-22	1/1/09	AMD	-15.9	-12.1	1920	-17.4	-138
OSM-21	291858	7/20/17	AMD	-15.7	-11.5	2628	-18.8	-145
OSM-55	291858	5/22/18	AMD	-16.2	-11.7	2822	-17.5	-140
C-wood 6	291859	11/18/05	AMD	-13.9	-10.9	4710	-17.3	-137
OSM-31	291859	7/20/17	AMD	-14.7	-11.0	4277	-17.2	-136
OSM-59	291859	5/22/18	AMD	-14.4	-11.5	4325	-16.3	-135
OSM-33	2276	7/20/17	AMD	-15.5	-12.0	7253	-17.1	-138
OSM-32	2262	7/20/17	AMD	-15.8	-13.0	4254	-17.4	-139
OSM-70	2262	5/22/18	AMD	-15.9	-13.2	4301	-17.4	-140
OSM-57	291865	5/22/18	AMD	-16.2	-13.7	2231	-17.8	-141
OSM-58	291865	5/22/18	AMD	-16.1	-13.7	3260	-17.9	-142

Footnotes...

Identifier	GWIC ID	Sample Date	Aquifer	Dissolved Sulfate $\delta^{34}S$, ‰	Dissolved Sulfate $\delta^{18}O$, ‰	Dissolved Sulfate SO_4, mg/l	Water Isotopes $\delta^{18}O$, ‰	Water Isotopes δD, ‰
Belt Area, Madison Wells								
OSM-09	196148	6/22/17	MDSN	-4.0	-3.8	43	-18.5	-145
Reddish	196148	11/1/07	MDSN	-5.5	-4.0	53	n.a.	n.a.
OSM-210	196148	7/19/19	MDSN	-3.2	-4.1	*44*	-18.6	-147
OSM-17	32069	6/22/17	MDSN	-2.9	-7.1	80	-18.0	-141
Belt-1A	217046	8/3/05	MDSN	14.0	12.0	175	-18.5	-140
Belt	188537	11/1/07	MDSN	15.0	11.9	n.a.	n.a.	n.a.
OSM-211	188537	7/17/19	MDSN	15.3	10.7	*129*	-18.8	-144
OSM-64	32009	6/20/18	MDSN	8.4	8.3	207	-18.8	-144
OSM-67	32000	6/20/18	MDSN	13.7	9.2	121	-18.8	-143
Belt Coal Mine, Mine Pool Water								
Belt-3B	217052	8/5/05	AMD	-8.9	-9.0	425	-18.1	-141
Belt-4B	215048	8/5/05	AMD	-5.4	-5.4	184	-18.3	-139
Belt-4A	217055	8/5/05	AMD	-9.0	0.7	320	-18.1	-137
OSM-34	999030	9/14/17	AMD	-6.7	-8.0	*215*	-18.1	-142
OSM-36	999030	9/12/17	AMD	-1.3	-4.9	*350*	-18.0	-142
Belt Mine, AMD Discharges								
OSM-06	217524	4/13/17	AMD	-9.2	-13.6	3006	-17.9	-141
Fr. Coul	217524	11/18/05	AMD	-9.3	-12.5	4950	-17.9	-141
OSM-62	217524	5/22/18	AMD	-9.4	-12.7	2700	-17.6	-139
OSM-07	200616	4/13/17	AMD	-9.3	-12.9	1634	-17.9	-142
Anaconda	200616	11/18/05	AMD	-9.4	-11.6	1960	-18.2	-140
OSM-61	200616	5/22/18	AMD	-9.2	-12.8	1844	-18.0	-143
Belt Area, Swift Aquifer								
OSM-14	31965	6/22/17	SWIFT	-8.8	-8.9	291	-18.0	-141
OSM-65	145604	6/20/18	SWIFT	4.3	-0.3	53	-18.8	-144
Belt Area, Kootenai Aquifer								
OSM-66	212233	6/20/18	KOOT	-5.4	-5.0	191	-18.7	-143
OSM-63	296888	5/23/18	KOOT	-5.1	-5.2	36	-18.3	-143
OSM-44	MW-102K	10/18/17	KOOT	-0.4	-3.5	83	-16.7	-135
OSM-45	MW-103K	10/12/17	KOOT	-5.4	-5.3	98	-17.6	-140
OSM-212	277205	7/18/19	KOOT	-5.1	1.2	1231	-17.7	-141
Belt Creek Mixing Samples								
OSM-148	8/14/18	Belt Bridge		0.3	-3.1		-18.1	-141
OSM-149	8/14/18	Belt Creek Upstream		9.2	5.5		-18.2	-142
OSM-150	8/14/18	Belt Creek Downstream		1.6	-1.7		-18.2	-141

Footnotes...

Appendix B: Stable isotopes of dissolved inorganic carbon (DIC).

Sample ID	GWIC ID#	Aquifer	Modifier	Date Sampled	DIC, mg/L as C	δ^{13}C-DIC, ‰
OSM-1	235488	Madison	Foothills Subd.	4/14/17	44.0	-6.9
OSM-3	291365	Madison	Foothills Subd.	4/13/17	43.3	-7.7
OSM-4	261984	Madison	Foothills Subd.	4/13/17	45.9	-6.5
OSM-5	235689	Madison	Foothills Subd.	4/14/17	39.8	-6.8
OSM-8	281405	Madison	Foothills Subd.	6/21/17	48.0	-7.6
OSM-9	196148	Madison		6/22/17	55.0	-13.0
OSM-10	252467	Madison	Foothills Subd.	6/20/17	44.2	-9.5
OSM-11	239236	Madison	Foothills Subd.	6/21/17	46.2	-9.0
OSM-12	248664	Madison	Foothills Subd.	6/20/17	45.3	-9.1
OSM-13	242151	Madison	Foothills Subd.	6/20/17	48.6	-8.4
OSM-14	31965	Swift		6/22/17	79.2	-14.8
OSM-15	279108	Madison	Foothills Subd.	6/21/17	46.7	-9.3
OSM-16	242153	Madison	Foothills Subd.	6/20/17	46.0	-9.0
OSM-18	2526	Madison	Giant Springs	6/20/17	42.1	-8.9
OSM-19	30542	Kootenai		8/3/17	57.4	-14.3
OSM-21	291858	AMD	Mt. Oregon Drain	7/20/17	16.1	-6.6
OSM-22	999030	AMD	Giffen Spring	7/20/17	54.0	-13.1
OSM-23	255442	Madison		7/19/17	60.4	-13.1
OSM-24	149855	Madison		7/19/17	45.7	-9.3
OSM-25	205599	Madison		7/19/17	43.6	-9.6
OSM-26	276129	Madison		7/18/17	54.8	-13.8
OSM-27	2309	Madison		7/19/17	41.9	-9.7
OSM-28	2528	Madison	Giant Springs	7/21/17	43.4	-9.2
OSM-29	31939	Madison		7/19/17	43.0	-9.6
OSM-31	291859	AMD	Cottonwood #6	7/20/17	11.6	-5.5
OSM-32	2262	AMD	No-name creek	7/20/17	9.8	-8.4

Appendix C: Helium Tritium

Fourteen groundwater samples collected from Madison aquifer were sent to the University of Utah Nobel Gas Lab for helium-tritium age dating. The copper tube method (https://noblegaslab.utah.edu/_resources/documents/services-pricing/cu_tube_sampling.pdf) was used to collect the dissolved gas. Results were inconclusive and are not discussed further in this report (Appendix C).

Appendix C. Helium
Tritium data

Sample I.D.	Utah Database ID	Dissolved Gas Collection Date	Dissolved Gas run ID	Tritium Collection Date	Tritium run ID	CO2 total (ccSTP/g)	CH4 total (ccSTP/g)	Ar total (ccSTP/g)	Ne total (ccSTP/g)
						Measured Dissolved Gas(ccSTP/g)			
196148	20-0100	08/17/19	12131901	08/17/19	Trit02032004.prc			4.23E-04	2.41E-07
245668	20-0101	08/18/19	12121902	08/18/19	Trit11221902.prc			4.01E-04	2.10E-07
31892	20-0102	08/18/19	12121903	08/18/19	Trit01272008.prc			3.93E-04	2.21E-07
126078	20-0103	08/18/19	12121905	08/18/19	Trit01242007.prc			5.73E-04	4.73E-07
205599	20-0104	08/19/19	12111904	08/19/19	Trit01242003.prc			3.95E-04	2.14E-07
255442	20-0105	08/19/19	12131906	08/19/19	Trit01232004.prc			3.80E-04	2.40E-07
2309	20-0106	08/19/19	12161904	08/19/19	Trit01272005.prc			4.18E-04	2.15E-07
294553	20-0107	08/19/19	12141903	08/19/19	Trit12121906.prc			3.67E-04	2.22E-07
210668	20-0108	08/19/19	12111903	08/19/19	Trit01282007.prc			4.40E-04	2.57E-07
288313	20-0109	08/20/19	12171902	08/20/19	Trit01232008.prc			4.02E-04	2.18E-07
261984	20-0110	08/20/19	12131904	08/20/19	Trit12031908.prc			3.96E-04	2.24E-07
235488	20-0111	08/20/19	12141901	08/20/19	Trit01242004.prc			3.89E-04	2.31E-07
188537	20-0112	08/20/19	12161903	08/20/19	Trit01172008.prc			4.28E-04	2.40E-07
2528 Giant Springs	20-0229	10/18/19	12131903	10/18/18	Trit01232005.prc			3.89E-04	2.27E-07
2262 - TU Only	20-0097			07/16/19	Trit01242006.prc				
200616 - TU Only	20-0098			07/18/19	Trit12031907.prc				
277205 - TU Only	20-0099	This sample needed to be analysed again, will be done in April.							

Appendix C. Helium
Tritium data

Sample I.D.	He4 (ccSTP/g)	R/Ra	TU	1-sigma error +/-	Ne only model	Ne only (1-sigma error +/-)	EA model	EA model (1-sigma error +/-)	Tritiogenic He3 - Ne only model (TU)	Gas Fractionation (F) (%)
			Measured Tritium (TU)							
196148	5.6E-08	1.176	2.20	0.13	18.5	3.8	22.9	2.3	3.98	0.6
245668	6.8E-08	1.256	5.73	0.36	26.8	1.4	26.6	1.3	19.74	0.0
31892	4.0E-05	0.075	3.47	0.23	Appears mixed		Appears mixed		1191.74	0.0
126078	3.8E-05	0.078	2.06	0.09	Appears mixed		Appears mixed		1149.76	0.2
205599	9.3E-06	0.086	4.75	0.19	Appears mixed		Appears mixed		308.30	0.0
255442	2.7E-07	0.317	3.34	0.11	Appears mixed		Appears mixed		12.73	0.0
2309	3.4E-06	0.087	4.46	0.29	Appears mixed		Appears mixed		95.46	0.7
294553	1.2E-05	0.084	4.68	0.16	Appears mixed		Appears mixed		405.30	0.0
210668	2.0E-05	0.079	3.65	0.12	Appears mixed		Appears mixed		623.22	0.5
288313	1.4E-05	0.082	4.25	0.14	Appears mixed		Appears mixed		441.86	0.7
261984	1.8E-05	0.082	3.45	0.46	Appears mixed		Appears mixed		569.51	0.6
235488	2.8E-05	0.079	3.28	0.13	Appears mixed		Appears mixed		871.13	0.6
188537	7.9E-08	1.503	5.59	0.21	Appears mixed		Appears mixed		33.27	0.6
2528 Giant Springs	7.5E-06	0.091	4.82	0.16	Appears mixed		Appears mixed		264.97	0.6
2262 - TU Only			9.23	0.70						
200616 - TU Only			5.31	0.95						
277205 - TU Only										

Appendix C. Helium
Tritium data

Sample I.D.	Excess Air (ccSTP/g)	Lab O2 (mg/l)	Chi^2	ΔNe(%)	Tot Dis Gas (atm)	Recharge Elevation (m)
196148	0.04	0.00	1.6	42.4	0.925	1647
245668	0.00	0.00	14.2	23.7	1.038	1674
31892	0.00	0.00	5.2	28.2	1.197	1647
126078	0.03	0.00	0.1	171.5	1.911	1647
205599	0.00	0.00	5.5	24.6	1.086	1674
255442	0.00	0.00	1.4	42.7	0.811	1674
2309	0.05	0.00	12.0	30.0	1.086	1674
294553	0.00	0.00	3.2	31.1	1.034	1674
210668	0.03	0.00	11.9	52.8	1.078	1674
288313	0.02	0.00	5.8	28.6	1.235	1674
261984	0.02	0.00	2.7	33.0	0.805	1674
235488	0.02	0.00	1.0	38.6	0.955	1674
188537	0.04	0.00	3.5	42.4	1.235	1674
2528 Giant Springs	0.02	0.00	1.6	34.3	1.111	1674
2262 - TU Only						
200616 - TU Only						
277205 - TU Only						

Appendix C. Helium
Tritium data

Sample I.D.	Water Temp (°C)	Water Salinity (‰)	Recharge Salinity (‰)	Field O2 (mg/l)	R-terrigenic	NOTES
196148	9.3		0.0	0.0	0.0	Model fits well,
245668	11.6		0.0	0.0	0.0	Model fit is ok, but there seems to be excess He. R/Ra indicates elevated titiogenic He but TU concentration is close to modern. It's likley the sample is a mixture of differing ages.
31892	15.9		0.0	0.0	0.0	Large He excess that seems to be radiogenic. Given the presents of tritium this sample is likely a mixture.
126078	15.7		0.0	0.0	0.0	Model fits well. He excess of apparent radiogenic origin. Likely a mixtue.
205599	13.7		0.0	0.0	0.0	Model fits well. He excess of apparent radiogenic origin. Likely a mixtue.
255442	11.0		0.0	0.0	0.0	Model fits well. He excess of apparent radiogenic origin. Likely a mixtue.
2309	12.1		0.0	0.0	0.0	Model fits well. He excess of apparent radiogenic origin. Likely a mixtue.
294553	13.4		0.0	0.0	0.0	Model fits well. He excess of apparent radiogenic origin. Likely a mixtue.
210668	11.2		0.0	0.0	0.0	Model fits well. He excess of apparent radiogenic origin. Likely a mixtue.
288313	15.3		0.0	0.0	0.0	Model fits well. He excess of apparent radiogenic origin. Likely a mixtue.
261984	13.7		0.0	0.0	0.0	Model fits well. He excess of apparent radiogenic origin. Likely a mixtue.
235488	13.9		0.0	0.0	0.0	Model fits well. He excess of apparent radiogenic origin. Likely a mixtue.
188537	10.3		0.0	0.0	0.0	Model fits well. He excess of apparent radiogenic origin. Likely a mixtue.
2528 Giant Springs	11.4		0.0	0.0	0.0	Model fits well. He excess of apparent radiogenic origin. Likely a mixtue.
2262 - TU Only						
200616 - TU Only						
277205 - TU Only						

sampleid	gwicid	site_name	latitude	longitude	geomethod	datum	basin	township	range	section	tract	county	type	aquifer	total_depth	comp_date	agency	sample_date_time
229753	2441	JOHNSON GENE * 10' W OF SAND COULEE CREE	47.4391	-111.143	UNKNOWN	NAD27	BB	20N	05E	31	DCBA	CASCADE	WELL	111SNGR	18		MBMG	6/21/2018 12:54
225185	2174	SHIRLEY WILLIAM AND MARY	47.31907	-111.15331	MAP	NAD27	BB	18N	05E	18	BBAB	CASCADE	SPRING	217KOTN			MBMG	10/20/2017 15:24
243556	217053	BELT WELL 3C	47.3726	-110.9724	NAV-GPS	NAD83	BE	19N	06E	28	CDC	CASCADE	WELL	217CBNK	159	10/30/2004	MBMG	11/17/2019 10:43
229752	212233	MURPHY, LARRY	47.4041	-110.891	NAV-GPS	NAD83	BE	19N	07E	18	CDCB	CASCADE	WELL	217CBNK	380	7/14/2004	MBMG	6/20/2018 12:50
243554	217048	BELT WELL 1C	47.3839	-110.9528	NAV-GPS	NAD83	BE	19N	06E	27	BACC	CASCADE	WELL	217KOTN	90	12/26/2004	MBMG	11/16/2019 14:45
243550	217056	BELT WELL 4C	47.3651	-110.9563	NAV-GPS	NAD83	BE	19N	06E	34	BC	CASCADE	WELL	217KOTN	127	10/7/2004	MBMG	11/15/2019 14:20
243549	217050	BELT WELL 2C	47.3789	-110.9474	NAV-GPS	NAD83	BE	19N	06E	27	CBBC	CASCADE	WELL	217KOTN	80	9/23/2004	MBMG	11/15/2019 11:25
222835	255442	LUOMA KEITH	47.39067	-111.1447	MAP	WGS84	BB	19N	05E	19	AB	CASCADE	WELL	217KOTN	305	4/28/2010	MBMG	7/19/2017 16:24
222789	30542	MENGHINI DUANE AND SHIRELY	47.29870819	-111.0457861	SUR-GPS	NAD83	BB	18N	05E	24	BCDB	CASCADE	WELL	217KOTN	65	4/26/1962	MBMG	6/20/2017 15:16
222791	2526	DEPT FISH WILDLIFE AND PARKS * KUNESH WELL	47.53273278	-111.2311984	SUR-GPS	NAD83	BB	21N	04E	33	BDDCB	CASCADE	WELL	217KOTN	40	8/28/1965	MBMG	6/20/2017 10:32
222675	279240	COULTER, GLEN	47.453667	-111.020717	NAV-GPS	NAD83	BE	20N	06E	31	BD	CASCADE	WELL	217KOTN	232	6/25/2014	MBMG	5/30/2017 15:09
239063	277205	DAWSON RANCH	47.37168	-110.86491	MAP	NAD83	BE	19N	07E	32	BAA	CASCADE	WELL	217KOTN	220	4/8/2014	MBMG	7/18/2019 18:08
225155	164111	HOYER, KEITH AND HEATHER	47.4516	-110.9184	NAV-GPS	NAD83	BE	20N	06E	35	DADA	CASCADE	WELL	217SBRS	90	6/20/1997	MBMG	10/4/2017 19:09
243557	217052	BELT WELL 3B	47.3726	-110.9725	NAV-GPS	NAD83	BE	19N	06E	28	CDC	CASCADE	WELL	221MRSN	282	12/1/2004	MBMG	11/17/2019 14:45
243553	223946	BELT WELL 14B	47.36878	-110.97809	NAV-GPS	NAD83	BB	19N	06E	32	A	CASCADE	WELL	221MRSN	272	10/19/2005	MBMG	11/16/2019 12:45
243552	215048	BELT WELL 4B COAL	47.3651	-110.9564	NAV-GPS	NAD83	BE	19N	06E	34	CB	CASCADE	WELL	221MRSN	284	10/6/2004	MBMG	11/16/2019 10:31
229577	152258	MBMG RESEARCH WELL T-1D	47.3287	-111.135881	MAP	NAD83	BB	18N	05E	7	ADDA	CASCADE	WELL	221MRSN	180	8/26/1995	MBMG	5/4/2018
229578	146929	MBMG RESEARCH WELL * C-5	47.382925	-111.187253	TRS-SEC	NAD83	BB	19N	04E	23	CADA	CASCADE	WELL	221MRSN	75	2/22/1984	MBMG	5/4/2018
243560	224151	BELT WELL 13B	47.37621	-110.96532	NAV-GPS	NAD83	BE	19N	06E	28	D	CASCADE	WELL	221MRSN	264	10/27/2005	MBMG	11/18/2019 11:39
243558	224150	BELT WELL 12B	47.37877	-110.96037	NAV-GPS	NAD83	BE	19N	06E	28	D	CASCADE	WELL	221MRSN	270	10/25/2005	MBMG	11/17/2019 16:30
243555	217047	BELT WELL 1B	47.384	-110.9527	NAV-GPS	NAD83	BE	19N	06E	27	BACC	CASCADE	WELL	221MRSN	216	12/1/2004	MBMG	11/16/2019 16:20
243551	224149	BELT WELL 11B	47.36752	-110.96501	NAV-GPS	NAD83	BB	19N	06E	33	A	CASCADE	WELL	221MRSN	271	10/11/2005	MBMG	11/15/2019 16:02
229751	145604	ASSELS STEVEN D. AND LINDA L.	47.3993	-110.9303	NAV-GPS	NAD83	BE	19N	06E	23	BDAB	CASCADE	WELL	221SWFT	66	8/17/1994	MBMG	6/20/2018 11:42
225179	162423	STOCKETT WATER AND SEWER DISTRICT SPRING 1	47.3369	-111.1545	MAP	NAD83	BB	18N	05E	6	CCAB	CASCADE	SPRING	221SWFT			MBMG	10/20/2017 10:43
222673	31992	HEPFNER JOE AND JEANIE	47.40041566	-110.9288605	SUR-GPS	NAD83	BE	19N	06E	23	BADA	CASCADE	WELL	221SWFT	75	10/31/1977	MBMG	5/24/2017 14:52
222498	236507	CALDWELL, DAVID	47.48665	-111.19978	MAP	NAD83	BB	20N	04E	15	DAAB	CASCADE	WELL	221SWFT	380	4/27/2007	MBMG	4/14/2017 13:31
222497	236507	CALDWELL, DAVID	47.48665	-111.19978	MAP	NAD83	BB	20N	04E	15	DAAB	CASCADE	WELL	221SWFT	380	4/27/2007	MBMG	4/14/2017 13:30
243559	217046	BELT WELL 1A	47.384	-110.9528	NAV-GPS	NAD27	BE	19N	06E	27	BDB	CASCADE	WELL	330MDSN	670	10/25/2004	MBMG	11/18/2019 10:31
229750	149852	STIFF JOHN	47.44830903	-111.2950274	SUR-GPS	NAD83	BB	20N	03E	36	ABCB	CASCADE	WELL	330MDSN	360	5/25/1995	MBMG	6/21/2018 10:17
229748	210668	PHILLIPS, RON	47.45002161	-111.2365665	SUR-GPS	NAD83	BB	20N	04E	33	BBAA	CASCADE	WELL	330MDSN	160	5/21/2004	MBMG	6/20/2018 15:30
229747	32000	MILOS RANCH	47.38978	-110.903942	TRS-SEC	NAD83	BE	19N	06E	24	DC	CASCADE	WELL	330MDSN	618	2/28/1981	MBMG	6/20/2018 13:43
229724	32009	STINSON JERRY	47.374192	-110.921365	TRS-SEC	NAD83	BE	19N	06E	26	DDC	CASCADE	WELL	330MDSN	520	5/29/1985	MBMG	6/20/2018 10:13
225183	141006	SHIRLEY MARY	47.3316	-111.1542	MAP	NAD83	BB	18N	05E	7	BBDC	CASCADE	WELL	330MDSN	725	1/27/1994	MBMG	10/20/2017 14:31
225182	139022	KONESKY GEORGE AND DIANE	47.37044	-111.23883	MAP	WGS84	BB	19N	04E	28	CBB	CASCADE	WELL	330MDSN	675	4/20/1993	MBMG	10/19/2017 17:48
225181	245668	KELLEY RANDALL	47.2952	-111.20074	MAP	NAD83	BB	18N	04E	22	BC	CASCADE	WELL	330MDSN	1120	6/20/2008	MBMG	10/19/2017 14:58
225184	126078	KNAUP DEAN	47.4125791	-111.2332318	SUR-GPS	NAD83	BB	19N	04E	9	CACA	CASCADE	WELL	330MDSN	450	10/3/1991	MBMG	10/19/2017 12:55
225180	31892	KNAUP RICHARD	47.40666	-111.23201	MAP	NAD83	BB	19N	04E	16	BAAB	CASCADE	WELL	330MDSN	400	10/28/1987	MBMG	10/19/2017 11:38
222836	2528	GIANT SPRINGS - MONTANA DEPT OF FISH WILDLIFE AND PARKS	47.5342	-111.2301	NAV-GPS	NAD83	BB	21N	04E	33	BDAD	CASCADE	SPRING	330MDSN			MBMG	7/21/2017 11:17
222834	31939	KNOX DUANE	47.3889	-111.1349	MAP	WGS84	BB	19N	05E	20	BCB	CASCADE	WELL	330MDSN	344	4/12/1986	MBMG	7/19/2017 15:23
222833	2309	GUISTI RONALD AND JUDITH	47.38392	-111.14642	MAP	WGS84	BB	19N	05E	19	CAAD	CASCADE	WELL	330MDSN	235	11/26/1979	MBMG	7/19/2017 13:58
222832	205599	MCEWEN LARRY AND MARLENE	47.4052	-111.15371	MAP	WGS84	BB	19N	05E	18	BBD	CASCADE	WELL	330MDSN	216	6/19/2003	MBMG	7/19/2017 11:57
222831	149855	HALKO PATRICK M AND JAMI L	47.406732	-111.164708	NAV-GPS	WGS84	BB	19N	04E	12	DCA	CASCADE	WELL	330MDSN	210	4/7/1995	MBMG	7/19/2017 10:53
222830	276129	GASVODA, JIM	47.1155	-111.1288	MAP	WGS84	BC	16N	05E	29	BBCB	CASCADE	WELL	330MDSN	228.5	5/15/2013	MBMG	7/18/2017 19:00
222768	196148	REDDISH GARY	47.323	-110.931	NAV-GPS	NAD83	BE	18N	06E	14	BDBC	CASCADE	WELL	330MDSN	800	5/13/2002	MBMG	6/22/2017 17:35
222767	31965	BELT COMMUNITY CHURCH	47.4269	-110.9249	NAV-GPS	NAD27	BE	19N	06E	11	ABDB	CASCADE	WELL	330MDSN	250	4/22/1987	MBMG	6/22/2017 14:30
222766	32069	WAREHIME EARL E	47.359654	-110.880956	TRS-SEC	NAD83	BE	19N	07E	31	DCD	CASCADE	WELL	330MDSN	400	4/17/1982	MBMG	6/22/2017 11:01
222763	239236	SMITH, JEFF & CARLA	47.47717	-111.1672	NAV-GPS	NAD83	BB	20N	04E	24	BADA	CASCADE	WELL	330MDSN	342	10/9/2007	MBMG	6/21/2017 10:01
222762	242153	THOMPSON MONTE & LISA	47.478066	-111.16923	TRS-SEC	NAD83	BB	20N	04E	24	BA	CASCADE	WELL	330MDSN	320	11/6/2007	MBMG	6/20/2017 16:11
222761	248664	HUESTIS HARLEY	47.47170278	-111.165525	MAP	WGS84	BB	20N	04E	24	D	CASCADE	WELL	330MDSN	420	12/17/2008	MBMG	6/20/2017 13:00
222760	252467	SHORT, BILL AND LINDA	47.47104351	-111.1616541	SUR-GPS	NAD83	BB	20N	04E	24	DBAD	CASCADE	WELL	330MDSN	482	9/25/2009	MBMG	6/20/2017 11:10
222499	235488	BUMGARNER JAMES	47.4719	-111.1672	NAV-GPS	NAD83	BB	20N	04E	24	CAAA	CASCADE	WELL	330MDSN	330	4/17/2007	MBMG	4/14/2017 16:37
222502	235689	URQHART SCOTT	47.4744	-111.1678	NAV-GPS	NAD83	BB	20N	04E	24	BDAD	CASCADE	WELL	330MDSN	340	4/27/2007	MBMG	4/14/2017 11:35
222496	291365	GOODMAN, RICKEY AND LORI	47.478714	-111.171439	NAV-GPS	NAD83	BB	20N	04E	24	BB	CASCADE	WELL	330MDSN	402	2/24/2017	MBMG	4/13/2017 17:43
222495	261984	OCONNER, TOM AND EMEDORA	47.474527	-111.1672023	SUR-GPS	NAD83	BB	20N	04E	24	ACBC	CASCADE	WELL	330MDSN	420	8/5/2011	MBMG	4/13/2017 15:15
232058	294553	BURGESS, GUY	47.378969	-111.198367	MAP	WGS84		19N	04E	22	DDDD	CASCADE	WELL	330MDSN	740	10/6/2017	MBMG	8/14/2018 16:14
232057	279137	WEBER, CHARLIE	47.485	-111.175278	NAV-GPS	NAD83	BB	20N	04E	13	CB	CASCADE	WELL	330MDSN	410	7/31/2014	MBMG	8/14/2018 10:40
229637	296888	GARY REDDISH GARY REDDISH SHALLOW	47.32311	-110.930838	DIGITALMAP	WGS84	BE	18N	06E	14	BDB	CASCADE	WELL	330MDSN	36		MBMG	5/23/2018 11:05
222765	281405	O'LEARY, JOHN	47.474117	-111.17285	NAV-GPS	NAD83	BB	20N	04E	24	BC	CASCADE	WELL	330MDSN	431	11/4/2014	MBMG	6/21/2017 12:31
222764	279108	GLENN, MEEK, DEBRA, MARTY	47.4735	-111.168583	NAV-GPS	NAD83	BB	20N	04E	24	BDDB	CASCADE	WELL	330MDSN	462	6/9/2014	MBMG	6/21/2017 11:08
243490	214914	AMD 3RD AND LEWIS STREET IN BELT	47.384889	-110.922306	NAV-GPS	NAD83	BE	19N	06E	26	ACAA	CASCADE	MINE DRAINAGE				MBMG	10/22/2019 12:27
238686	214914	AMD 3RD AND LEWIS STREET IN BELT	47.384889	-110.922306	NAV-GPS	NAD83	BE	19N	06E	26	ACAA	CASCADE	MINE DRAINAGE				MBMG	3/26/2019 12:42
234306	214914	AMD 3RD AND LEWIS STREET IN BELT	47.384889	-110.922306	NAV-GPS	NAD83	BE	19N	06E	26	ACAA	CASCADE	MINE DRAINAGE				MBMG	10/8/2018 17:18

sampleid	gwicid	site_name	latitude	longitude	geomethod	datum	basin	township	range	section	tract	county	type	aquifer	total_depth	comp_date	agency	sample_date_time
230871	214914	AMD 3RD AND LEWIS STREET IN BELT	47.384889	-110.922306	NAV-GPS	NAD83	BE	19N	06E	26	ACAA	CASCADE	MINE DRAINAGE				MBMG	7/26/2018 15:12
243489	214915	AMD AT LEWIS COULEE	47.385889	-110.920306	DIGITALMAP	NAD83	BE	19N	06E	26	AACD	CASCADE	MINE DRAINAGE				MBMG	10/22/2019 11:48
239059	214915	AMD AT LEWIS COULEE	47.385889	-110.920306	DIGITALMAP	NAD83	BE	19N	06E	26	AACD	CASCADE	MINE DRAINAGE				MBMG	7/17/2019 9:12
234309	214915	AMD AT LEWIS COULEE	47.385889	-110.920306	DIGITALMAP	NAD83	BE	19N	06E	26	AACD	CASCADE	MINE DRAINAGE				MBMG	10/8/2018 16:31
230870	214915	AMD AT LEWIS COULEE	47.385889	-110.920306	DIGITALMAP	NAD83	BE	19N	06E	26	AACD	CASCADE	MINE DRAINAGE				MBMG	7/26/2018 14:50
243491	200616	ANACONDA MINE DRAIN AT CULVERT	47.381	-110.9292	NAV-GPS	NAD27	BE	19N	06E	26	BDCD	CASCADE	MINE DRAINAGE				MBMG	10/22/2019 12:43
239060	200616	ANACONDA MINE DRAIN AT CULVERT	47.381	-110.9292	NAV-GPS	NAD27	BE	19N	06E	26	BDCD	CASCADE	MINE DRAINAGE				MBMG	7/17/2019 10:24
238687	200616	ANACONDA MINE DRAIN AT CULVERT	47.381	-110.9292	NAV-GPS	NAD27	BE	19N	06E	26	BDCD	CASCADE	MINE DRAINAGE				MBMG	3/26/2019 13:27
234307	200616	ANACONDA MINE DRAIN AT CULVERT	47.381	-110.9292	NAV-GPS	NAD27	BE	19N	06E	26	BDCD	CASCADE	MINE DRAINAGE				MBMG	10/8/2018 17:45
230872	200616	ANACONDA MINE DRAIN AT CULVERT	47.381	-110.9292	NAV-GPS	NAD27	BE	19N	06E	26	BDCD	CASCADE	MINE DRAINAGE				MBMG	7/26/2018 15:30
229536	200616	ANACONDA MINE DRAIN AT CULVERT	47.381	-110.9292	NAV-GPS	NAD27	BE	19N	06E	26	BDCD	CASCADE	MINE DRAINAGE				MBMG	4/3/2018 15:25
226352	200616	ANACONDA MINE DRAIN AT CULVERT	47.381	-110.9292	NAV-GPS	NAD27	BE	19N	06E	26	BDCD	CASCADE	MINE DRAINAGE				MBMG	1/9/2018 14:26
225153	200616	ANACONDA MINE DRAIN AT CULVERT	47.381	-110.9292	NAV-GPS	NAD27	BE	19N	06E	26	BDCD	CASCADE	MINE DRAINAGE				MBMG	10/5/2017 14:52
222813	200616	ANACONDA MINE DRAIN AT CULVERT	47.381	-110.9292	NAV-GPS	NAD27	BE	19N	06E	26	BDCD	CASCADE	MINE DRAINAGE				MBMG	7/13/2017 11:03
222503	200616	ANACONDA MINE DRAIN AT CULVERT	47.381	-110.9292	NAV-GPS	NAD27	BE	19N	06E	26	BDCD	CASCADE	MINE DRAINAGE				MBMG	4/19/2017 8:58
222323	200616	ANACONDA MINE DRAIN AT CULVERT	47.381	-110.9292	NAV-GPS	NAD27	BE	19N	06E	26	BDCD	CASCADE	MINE DRAINAGE				MBMG	1/24/2017 16:29
243492	217524	FRENCH COULEE 4 INCH PVC PIPE AMD	47.3778	-110.9293	NAV-GPS	NAD83	BE	19N	06E	26	CADC	CASCADE	MINE DRAINAGE				MBMG	10/22/2019 13:50
239061	217524	FRENCH COULEE 4 INCH PVC PIPE AMD	47.3778	-110.9293	NAV-GPS	NAD83	BE	19N	06E	26	CADC	CASCADE	MINE DRAINAGE				MBMG	7/17/2019 11:35
238688	217524	FRENCH COULEE 4 INCH PVC PIPE AMD	47.3778	-110.9293	NAV-GPS	NAD83	BE	19N	06E	26	CADC	CASCADE	MINE DRAINAGE				MBMG	3/26/2019 14:10
234308	217524	FRENCH COULEE 4 INCH PVC PIPE AMD	47.3778	-110.9293	NAV-GPS	NAD83	BE	19N	06E	26	CADC	CASCADE	MINE DRAINAGE				MBMG	10/8/2018 18:16
230874	217524	FRENCH COULEE 4 INCH PVC PIPE AMD	47.3778	-110.9293	NAV-GPS	NAD83	BE	19N	06E	26	CADC	CASCADE	MINE DRAINAGE				MBMG	7/26/2018 16:08
229537	217524	FRENCH COULEE 4 INCH PVC PIPE AMD	47.3778	-110.9293	NAV-GPS	NAD83	BE	19N	06E	26	CADC	CASCADE	MINE DRAINAGE				MBMG	4/3/2018 16:44
226353	217524	FRENCH COULEE 4 INCH PVC PIPE AMD	47.3778	-110.9293	NAV-GPS	NAD83	BE	19N	06E	26	CADC	CASCADE	MINE DRAINAGE				MBMG	1/9/2018 15:48
225154	217524	FRENCH COULEE 4 INCH PVC PIPE AMD	47.3778	-110.9293	NAV-GPS	NAD83	BE	19N	06E	26	CADC	CASCADE	MINE DRAINAGE				MBMG	10/5/2017 15:48
222814	217524	FRENCH COULEE 4 INCH PVC PIPE AMD	47.3778	-110.9293	NAV-GPS	NAD83	BE	19N	06E	26	CADC	CASCADE	MINE DRAINAGE				MBMG	7/13/2017 11:54
222504	217524	FRENCH COULEE 4 INCH PVC PIPE AMD	47.3778	-110.9293	NAV-GPS	NAD83	BE	19N	06E	26	CADC	CASCADE	MINE DRAINAGE				MBMG	4/19/2017 10:17
222324	217524	FRENCH COULEE 4 INCH PVC PIPE AMD	47.3778	-110.9293	NAV-GPS	NAD83	BE	19N	06E	26	CADC	CASCADE	MINE DRAINAGE				MBMG	1/24/2017 16:58
229632	291863	GIFFIN SPRING IN #5 COULEE NF-3 USGS 6	47.31408698	-111.186957	MAP	WGS84	BB	18N	04E	14	ACB	CASCADE	MINE DRAINAGE				MBMG	5/22/2018 13:24
222846	291863	GIFFIN SPRING IN #5 COULEE NF-3 USGS 6	47.31408698	-111.186957	MAP	WGS84	BB	18N	04E	14	ACB	CASCADE	MINE DRAINAGE				MBMG	7/20/2017 12:03
229627	291858	KATE'S COULEE OREGON MINE SC-8 USGS 19 KATE'S COULEE SC-8	47.392868	-111.179646	MAP	WGS84	BB	19N	04E	14	DDC	CASCADE	MINE DRAINAGE				MBMG	5/22/2018 10:43
222842	291858	KATE'S COULEE OREGON MINE SC-8 USGS 19 KATE'S COULEE SC-8	47.392868	-111.179646	MAP	WGS84	BB	19N	04E	14	DDC	CASCADE	MINE DRAINAGE				MBMG	7/20/2017 13:42
229628	291861	NELSON MINE AT SAND COULEE SC-12 USGS 20 NELSON MINE SC-12	47.3961619	-111.171901	MAP	WGS84	BB	19N	04E	13	CBC	CASCADE	MINE DRAINAGE				MBMG	5/22/2018 11:17
222844	291861	NELSON MINE AT SAND COULEE SC-12 USGS 20 NELSON MINE SC-12	47.3961619	-111.171901	MAP	WGS84	BB	19N	04E	13	CBC	CASCADE	MINE DRAINAGE				MBMG	7/20/2017 15:04
229626	296887	SC-3 MINE DRAIN WATER AT CULVERT IN PRIVATE ROAD SC-3	47.38855	-111.178844	DIGITALMAP	WGS84	BB	19N	04E	23		CASCADE	MINE DRAINAGE				MBMG	5/22/2018 10:09
229630	291865	COTTONWOOD MINE #2 CW-10 USGS 8 COTTONWOOD MINE #2	47.355057	-111.16451	MAP	WGS84	BB	19N	04E	36		CASCADE	MINE DRAINAGE				MBMG	5/22/2018 12:24
229629	291865	COTTONWOOD MINE #2 CW-10 USGS 8 COTTONWOOD MINE #2	47.355057	-111.16451	MAP	WGS84	BB	19N	04E	36		CASCADE	MINE DRAINAGE				MBMG	5/22/2018 12:04
229631	291859	COTTONWOOD MINE #6 CW-2 USGS 7 COTTONWOOD MINE CW-2	47.336554	-111.151657	MAP	WGS84	BB	18N	05E	6	CCA	CASCADE	MINE DRAINAGE				MBMG	5/22/2018 12:48
222843	291859	COTTONWOOD MINE #6 CW-2 USGS 7 COTTONWOOD MINE CW-2	47.336554	-111.151657	MAP	WGS84	BB	18N	05E	6	CCA	CASCADE	MINE DRAINAGE				MBMG	7/20/2017 11:26
229625	2262	SAND COULEE MINING DISTRICT * NO-NAME CREEK * AS-02 OR 3A	47.388521	-111.17839	MAP	WGS84	BB	19N	04E	23	AADC	CASCADE	MINE DRAINAGE				MBMG	5/22/2018 9:46
229624	2276	MINING COULEE DISCHARGE PIPE * EAST SIDE	47.38555	-111.17736	MAP	WGS84	BB	19N	04E	23	DAAC	CASCADE	MINE DRAINAGE				MBMG	5/22/2018 9:12
222848	2262	SAND COULEE MINING DISTRICT * NO-NAME CREEK * AS-02 OR 3A	47.388521	-111.17839	MAP	WGS84	BB	19N	04E	23	AADC	CASCADE	MINE DRAINAGE				MBMG	7/20/2017 15:22
222845	2276	MINING COULEE DISCHARGE PIPE * EAST SIDE	47.38555	-111.17736	MAP	WGS84	BB	19N	04E	23	DAAC	CASCADE	MINE DRAINAGE				MBMG	7/20/2017 14:13

gwicid	water_temp	lab_name	lab_ph	lab_sc	ca	mg	na	k	fe	mn	sio2	hco3	co3	so4	cl	no3_as_n	f	opo4_as_p	ag	al	as	b	ba	be	br	cd	co	cr
2441	10.4	MBMG	7.32	2158.75	406.4	79.76	14	4.29	0.269 J	1.038	16.78	338.95	0	1061	5.4	0.11	1.42	<0.020 U	<0.500 U	<10.000 U	<0.500 U	86.59	24.8	<0.500 U	117	<0.500 U	3.08	<0.500 U
2174	11.3	MBMG	7.33	595.82	63.73	37.01	12.42	1.87	<0.015 U	<0.002 U	9.67	364.52	0	28.2	4.04	6.01	0.43	<0.020 U	0.280 J	<2.000 U	0.210 J	23.41	276.53	<0.100 U	69	<0.100 U	<0.100 U	0.95
217053	10.8	MBMG	7.45	662.81	55.21	48.19	16.57	4.96	0.329	0.037 J	6.3	442.8	0	23.85	2.6	<0.010 U	1.62	<0.020 U	<0.100 U	<2.000 U	12.95	129.95	88.7	<0.100 U	<10.000 U	<0.100 U	0.200 J	0.95
212233	11	MBMG	7.01	1090.24	79.6	72.26	36.6	5.43	1.807	0.018 J	6.35	493.53	0	190.9	7.52	<0.010 U	0.76	<0.020 U	<0.250 U	<5.000 U	0.670 J	50.73	14.88	<0.250 U	<10.000 U	<0.250 U	<0.250 U	0.530 J
217048	11.2	MBMG	7.23	1121.38	94.66	89.49	12.55	4.34	0.269	0.133	6.78	726.01	0	53.75	6.83	<0.010 U	0.63	<0.020 U	<0.250 U	<5.000 U	1.28	90.51	131.86	<0.250 U	<10.000 U	<0.250 U	4.74	4.49
217056	10.89	MBMG	7.43	697.09	54.33	56.63	12.24	3.8	0.436	0.032 J	6.3	448.27	0	40.3	1.94	0.22	1.25	<0.020 U	<0.100 U	<2.000 U	383.23	110.7	56.44	<0.100 U	<10.000 U	<0.100 U	<0.100 U	1.2
217050	11.28	MBMG	7.49	690.57	45.44	61.04	8.26	1.93	<0.015 U	<0.002 U	7.65	359.32	0	24.77	7.37	18.35	1.04	<0.020 U	<0.100 U	<2.000 U	0.200 J	56.58	120.83	<0.100 U	80	<0.100 U	<0.100 U	1.39
255442	11.4	MBMG	7.41	916.6	93.16	54.17	28.59	3.87	<0.038 U	<0.005 U	12.29	326.65	0	178.6	34.87	9.57	0.68	0.030 J	<0.250 U	<5.000 U	2	55.07	39.7	<0.250 U	<10.000 U	<0.250 U	<0.250 U	<0.250 U
30542	13.8	MBMG	7.77	603.52	62.46	39.24	12.27	1.23	<0.015 U	<0.002 U	8.26	339.2	0	23.41	14.89	10.4	0.31	0.030 J	<0.100 U	<2.000 U	0.250 J	15.76	320.88	<0.100 U	<10.000 U	<0.100 U	<0.100 U	0.270 J
2526	12.7	MBMG	7.57	603.2	84.31	29.22	7.48	1.77	<0.015 U	<0.002 U	9.26	229.45	0	160.8	3.55	0.55	0.37	<0.020 U	<0.100 U	<2.000 U	0.61	30.77	24.72	<0.100 U	<10.000 U	<0.100 U	<0.100 U	0.290 J
279240	10.1	MBMG	7.19	1052.61	65.97	88.4	36.34	5.63	<0.015 U	0.008 J	8.11	617.77	0	87.4	5.24	5.88	0.95	<0.020 U	<0.100 U	<2.000 U	0.310 J	105.49	40.29	<0.100 U	79	<0.100 U	1.07	<0.100 U
277205	8.8	MBMG	7.15	3438.18	217.31	121.76	419.25	8.24	0.728 J	0.329 J	8.19	669.34	0	1212	78.88	<0.050 U	0.85	0.180 J	<1.000 U	<20.000 U	8.1	200.52	6.35	<1.000 U	542	<1.000 U	3.230 J	<1.000 U
164111	11.01	MBMG	7.11	597.94	74.84	25.43	8.62	2.33	0.036 J	0.218	10.59	264.75	0	104.6	3.85	<0.010 U	0.43	<0.020 U	<0.100 U	<2.000 U	0.41	29.47	61.8	<0.100 U	<10.000 U	<0.100 U	0.94	0.66
217052	10.37	MBMG	6.42	859.75	93.52	39.74	8.15	3.6	39.094	0.199	6.43	139	0	353.4	3.97	0.08	0.88	<0.020 U	<0.100 U	48.23	1.33	75.05	26.28	0.290 J	<10.000 U	0.250 J	9.97	0.490 J
223946	11.55	MBMG	7.24	603.65	77.68	27.31	9.92	3.35	<0.015 U	0.116	6.51	304.41	0	95.1	2.56	0.050 J	1.04	<0.020 U	<0.100 U	<2.000 U	<0.100 U	57.97	31.69	<0.100 U	<10.000 U	<0.100 U	0.380 J	0.390 J
215048	11.31	MBMG	6.81	723.19	80.85	38.41	11.16	4.73	0.085	0.094	6.99	320.26	0	146.3	3.26	0.15	0.81	<0.020 U	<0.100 U	<2.000 U	4.06	51.99	21.52	<0.100 U	<10.000 U	<0.100 U	4.24	0.71
152258	9.4	MBMG	7.44	1065.59	93.48	45.94	70.37	11.39	0.769	0.138	8.97	422.02	0	169.2	53.13	0.050 J	1.21	0.050 J	<0.250 U	<5.000 U	9.84	85.82	25.01	<0.250 U	337	<0.250 U	1.7	1.32
146929		MBMG	7.31	828.42	76.5	55.41	15.53	4.6	0.364	0.023 J	9	400.11	0	77.22	12.85	11.24	0.67	0.030 J	<0.250 U	<5.000 U	0.610 J	38.08	117.15	<0.250 U	150	<0.250 U	4.77	1.64
224151	9.69	MBMG			62.38	21.28	2.64	10.18	3.833	0.552	9.73	320.49	0						<0.100 U	2.420 J	4.66	21.74	321.77	<0.100 U		<0.100 U	1.97	0.320 J
224150	11.17	MBMG	5.9	4044.21	635	120.94	13.49	9.12	425.313	3.501	5.96	139.17	0	2530	2.29	0.15	0.84	<0.020 U	<0.500 U	887.89	11.05	457.08	18.63	<0.500 U	<10.000 U	<0.500 U	438.13	<0.500 U
217047	10.77	MBMG	6.89	673.65	61.45	46.28	10.79	3.01	<0.015 U	0.026 J	6.37	237.99	0	128.4	8.33	14.58	0.74	<0.020 U	<0.100 U	3.020 J	0.260 J	45.55	33.44	<0.100 U	<10.000 U	<0.100 U	3.78	0.61
224149	10.84	MBMG	6.81	993.78	124.18	41.2	10.48	3.93	3.655	0.164	6.27	374.59	0	221.6	3.11	<0.010 U	0.45	<0.020 U	<0.100 U	<2.000 U	0.99	50.13	33.09	<0.100 U	<10.000 U	<0.100 U	2.65	1.19
145604	8.3	MBMG	7.5	455.33	64.13	16.08	6.95	1.87	<0.015 U	<0.002 U	7.65	239.41	0	52.69	2.96	0.47	0.21	<0.020 U	<0.100 U	<2.000 U	0.200 J	24.81	47.7	<0.100 U	<10.000 U	<0.100 U	<0.100 U	0.290 J
162423	10	MBMG	7.01	831.5	99.22	45.65	13.58	3.66	<0.015 U	<0.002 U	12.69	467.31	0	85.81	6.53	2.5	0.41	<0.020 U	1.04	<2.000 U	0.290 J	43.22	167.55	<0.100 U	69	<0.100 U	0.210 J	1.49
31992	11.9	MBMG	7.48	637.77	94.13	22.8	7.32	2.4	<0.015 U	<0.002 U	12.04	232.57	0	151.7	5.45	0.74	0.14	<0.020 U	<0.100 U	<2.000 U	0.210 J	22.24	82.6	<0.100 U	<10.000 U	<0.100 U	<0.100 U	<0.100 U
236507		MBMG			401.4	389	169.23	27.18	11.888	2.345										35035.3	15.25	346.3	7.6	<1.000 U		<1.000 U	295.81	<1.000 U
236507	12.6	MBMG	6.32	4188.88	411.67	397.91	165.5	25.56	11.698	2.378	8.27	799.14	0	2246	46.72	<0.050 U	0.58	0.400 J	<1.000 U	158.72	6.99	355.68	4.520 J	<1.000 U	<50.000 U	<1.000 U	306.38	<1.000 U
217046	9.75	MBMG	7.41	671.99	84.64	26.47	4.55	1.59	0.018 J	0.014 J	8.41	251.85	0	156.4	2.36	0.55	0.45	<0.020 U	<0.100 U	<2.000 U	0.340 J	23.58	36.31	<0.100 U	<10.000 U	0.240 J	0.330 J	0.81
149852	13.7	MBMG	7.18	1652	179.85	65.3	86.94	11.39	0.054 J	0.309	25.71	364.5	0	547	50.14	<0.010 U	1.38	<0.020 U	<0.250 U	<5.000 U	1.12	245.65	11.13	<0.250 U	304	<0.250 U	0.660 J	<0.250 U
210668	11.6	MBMG	7.24	1827.98	166.21	89.17	92.15	8.36	<0.038 U	<0.005 U	15.11	477.61	0	473.6	97.88	1.77	0.68	<0.020 U	<0.250 U	<5.000 U	1.55	117.84	18.74	<0.250 U	210	<0.250 U	<0.250 U	0.620 J
32000	12.5	MBMG	7.76	517.34	70.98	21.92	2.12	1.01	<0.015 U	<0.002 U	7.73	198.72	0	120.9	0.9	0.27	0.36	<0.020 U	<0.100 U	<2.000 U	0.46	11.91	34.55	<0.100 U	<10.000 U	<0.100 U	<0.100 U	0.420 J
32009	10.4	MBMG	7.56	687.74	92.99	29.67	3.04	1.23	0.051 J	<0.002 U	8.12	207.54	0	207	1.13	0.33	0.51	<0.020 U	<0.100 U	<2.000 U	0.320 J	19.04	26.67	<0.100 U	<10.000 U	<0.100 U	<0.100 U	0.400 J
141006	12.3	MBMG	7.58	503.35	63.15	27.33	3.32	1.24	<0.015 U	<0.002 U	8.17	190.52	0	126.6	1.1	0.5	0.45	<0.020 U	0.450 J	<2.000 U	0.73	17.3	26.36	<0.100 U	<10.000 U	<0.100 U	<0.100 U	0.88
139022	13	MBMG	7.44	522.21	67.5	24.41	8.63	1.85	0.028 J	<0.002 U	11.15	236.06	0	99.7	4.17	0.5	0.42	<0.020 U	0.430 J	<2.000 U	1.27	34.56	43.54	<0.100 U	<10.000 U	<0.100 U	<0.100 U	0.98
245668	12	MBMG	7.44	512.67	72.97	23.07	2.45	0.92	<0.015 U	<0.002 U	8.27	215.45	0	113.4	1.01	0.49	0.31	<0.020 U	0.61	<2.000 U	0.72	13.79	35.96	<0.100 U	<10.000 U	0.380 J	<0.100 U	0.87
126078	14.8	MBMG	7.08	1191.86	154.29	52.11	26.43	3.72	1.025	0.036 J	11.44	314.82	0	377.3	19.41	<0.010 U	1.02	<0.020 U	0.690 J	<5.000 U	9.46	97.83	10.87	<0.250 U	117	<0.250 U	<0.250 U	0.710 J
31892	16.1	MBMG	7.25	748.46	85.58	30.13	28.48	3.66	<0.015 U	<0.002 U	13.36	257.08	0	175.5	19.25	0.33	0.86	<0.020 U	0.57	<2.000 U	1.75	89.2	22.77	<0.100 U	116	<0.100 U	<0.100 U	0.92
2528	11.9	MBMG	7.6	595.7	80.7	27.68	10.47	1.95	<0.015 U	<0.002 U	10.06	232.5	0	146.3	4.7	0.49	0.5	<0.020 U	<0.100 U	4.160 J	0.95	34.76	26.51	<0.100 U	<10.000 U	<0.100 U	<0.100 U	0.340 J
31939	12.7	MBMG	7.51	943.1	119.63	45.75	14.32	3.2	<0.038 U	<0.005 U	12.17	227.07	0	314	7.51	1.41	0.54	0.040 J	<0.250 U	<5.000 U	2.03	51.31	26.64	<0.250 U	<10.000 U	<0.250 U	<0.250 U	<0.250 U
2309	12.4	MBMG	7.57	537.45	69.86	26.03	9.55	2.11	<0.015 U	<0.002 U	10.85	228.54	0	116.4	4.39	0.82	0.43	0.020 J	<0.100 U	<2.000 U	1.38	36.92	39.69	<0.100 U	<10.000 U	<0.100 U	<0.100 U	0.420 J
205599	13.6	MBMG	7.5	564.27	74.58	26.14	12.03	2.06	<0.015 U	<0.002 U	11.53	239.8	0	122.3	5.79	0.47	0.47	0.030 J	<0.100 U	<2.000 U	1.3	44.48	33.02	<0.100 U	<10.000 U	<0.100 U	<0.100 U	0.390 J
149855	13.4	MBMG	7.2	633.21	84.73	28.02	13.88	2.4	<0.015 U	<0.002 U	12.25	235.76	0	158.7	6.83	0.41	0.57	0.17	0.330 J	4.050 J	6.17	50.09	19.17	<0.100 U	<10.000 U	<0.100 U	<0.100 U	0.430 J
276129	6.8	MBMG	7.49	459.19	77.03	14.87	3.36	0.77	<0.015 U	0.002 J	7.65	300.24	0	4.91	1.22	6.56	0.15	0.060 J	<0.100 U	<2.000 U	0.58	6.43	195.24	<0.100 U	242	<0.100 U	<0.100 U	1.01
196148	9.8	MBMG	7.4	531.93	73.69	25.15	6.05	1.99	0.236	0.021	8.19	310.51	0	43.04	3.46	2.21	0.33	<0.020 U	<0.100 U	<2.000 U	<0.100 U	20.95	68.89	<0.100 U	<10.000 U	<0.100 U	<0.100 U	0.230 J
31965	11.9	MBMG	7.18	1278.94	102.13	89.43	50.46	3.39	<0.038 U	<0.005 U	9.37	478.6	0	291.2	25.56	4.69	0.35	<0.020 U	<0.250 U	<5.000 U	0.690 J	45.28	42.64	<0.250 U	145	<0.250 U	<0.250 U	<0.250 U
32069	9.6	MBMG	6.72	513.33	50.17	36.66	8.1	1.71	4.58	0.248	5.87	256.93	0	80.5	1.72	<0.010 U	0.33	<0.020 U	<0.100 U	<2.000 U	0.330 J	22.34	22.38	<0.100 U	<10.000 U	<0.100 U	0.290 J	0.280 J
239236	14	MBMG	7.48	674.62	84.14	30.59	20.02	3.22	<0.015 U	<0.002 U	11.89	255.13	0	154.5	11.92	0.44	0.6	<0.020 U	<0.100 U	4.960 J	1.5	72.29	24.07	<0.100 U	93	<0.100 U	<0.100 U	0.330 J
242153	13.7	MBMG	7.42	672.64	81.9	29.98	18.96	3.09	<0.015 U	0.008 J	11.8	250.08	0	155.8	11.39	0.42	0.6	<0.020 U	<0.100 U	15.36	0.55	68.61	22.47	<0.100 U	90	<0.100 U	0.64	0.350 J
248664	13.3	MBMG	7.5	615.39	77.83	27.28	14.87	2.68	<0.015 U	<0.002 U	11.73	245.46	0	132.1	8.33	0.4	0.51	<0.020 U	<0.100 U	<2.000 U	1.39	55.36	26.61	<0.100 U	77	<0.100 U	<0.100 U	0.340 J
252467	13.8	MBMG	7.38	581.13	76.64	26.82	12.21	2.42	<0.015 U	<0.002 U	11.14	240.44	0	123.3	6.34	0.44	0.47	<0.020 U	<0.100 U	<2.000 U	1.49	46.34	31.23	<0.100 U	<10.000 U	<0.100 U	<0.100 U	0.350 J
235488	12.7	MBMG	7.21	818.65	101.13	36.7	23.32	3.43	<0.038 U	0.007 J	9.05	254.99	0	226.2	15.64	0.67	0.91	0.070 J	<0.250 U	5.940 J	2.95	71.61	13.98	<0.250 U	112	<0.250 U	<0.250 U	<0.250 U
235689	13.5	MBMG	7.21	934.31	145.96	32.29	17.65	2.92	0.449	0.111 J	13.29	239.36	0	322.3	10.95	0.39	0.74	0.030 J	<0.250 U	7.480 J	2.92	57.21	18.63	<0.250 U	88	<0.250 U	0.860 J	<0.250 U
291365	13.5	MBMG	7.22	697.93	89.19	33.57	20.5	3.25	<0.015 U	0.088	11.03	244.89	0	189.4	12.73	0.45	0.85	0.020 J	<0.100 U	17.17	<0.100 U	66.97	22.79	<0.100 U	202	<0.100 U	7.78	<0.100 U
261984	13.2	MBMG	6.89	1054.6	122.34	69.13	27.18	3.79	<0.038 U	0.362	10.53	256.63	0	406.9	11.99	0.56	1.19	0.030 J	<0.250 U	43.92	0.550 J	69.58	24.87	<0.250 U	104	0.880 J	20.31	<0.250 U
294553	13.8	MBMG	7.41	646.5	72.64	28.46	13.95	2.54	<0.015 U	<0.002 U	11.83	252.93	0	126	7.93	0.77	0.58	<0.020 U	<0.100 U	<2.000 U	1.32	52.75	30.58	<0.100 U	76	<0.100 U	<0.100 U	0.350 J
279137	14.3	MBMG	7.31	665.76	79.57	28.4	16.62	2.77	<0.015 U	<0.002 U	12.42	248.52	0	144.4	10.34	0.45	0.62	<0.020 U	<0.100 U	<2.000 U	1.42	60.45	26.97	<0.100 U	86	<0.100 U	<0.100 U	<0.100 U
296888	8.1	MBMG	7.54	505.85	64.56	22.8	7.1	3.77	<0.015 U	<0.002 U	10.04	284.36	0	33.83	6.46	4.69	0.3	<0.020 U	<0.100 U	<2.000 U	0.230 J	17.6	221.91	<0.100 U	<10.000 U	<0.100 U	<0.100 U	0.350 J
281405	13.5	MBMG	7.39	908.31	117.32	40.49	21.87	3.53	<0.038 U	<0.005 U	8.63	264.28	0	274.4	13.59	0.38	0.74	<0.020 U	<0.250 U	<5.000 U	0.930 J	81.28	12.77	<0.250 U	101	<0.250 U	<0.250 U	0.720 J
279108	13.7	MBMG	7.5	664.18	83.08	30.04	18.65	3.08	<0.015 U	<0.002 U	11.98	252.43	0	149.6	11.16	0.42	0.51	<0.020 U	<0.100 U	<2.000 U	1.3	71.33	24.37	<0.100 U	90	<0.100 U	<0.100 U	0.370 J
214914	8.96	MBMG	2.79	3525	125.62	99.12	21.41	1.510 J	360.228	0.578	71.61	0	0	3415	14.56	<0.050 U	4.57	<0.100 U	<1.000 U	231894.62	<1.000 U	470.9	<1.000 U	14.5	<50.000 U	22.05	559.67	79.85
214914	7.68	MBMG	2.74	4349	162.84	118.03	23.26	1.360 J	521.6	0.745	81.78	0	0	3885	9.86	<0.050 U	5.74	0.240 J	<1.000 U	307800	<1.000 U	462.81	<1.000 U	17.58	<50.000 U	30.14	787.11	99.48
214914	10.06	MBMG	2.71	3902	113.07	86.35	23.17	<0.500 U	324.2	0.477 J	70.3	0	0	3091	14.88	<0.050 U	3.46	<0.100 U	<1.000 U	197750	<1.000 U	360.51	<1.000 U	14.04	<50.000 U	31.37	521.41	87.2

gwicid	water_temp	lab_name	lab_ph	lab_sc	ca	mg	na	k	fe	mn	sio2	hco3	co3	so4	cl	no3_as_n	f	opo4_as_p	ag	al	as	b	ba	be	br	cd	co	cr
214914	19.25	MBMG	2.75	3482	105.8	82.25	23.41	1.49	267.14	0.42	66.6	0	0	2826	16.29	<0.050 U	3.42	<0.100 U	<0.500 U	167565	<0.500 U	135.16	1.060 J	12.9	<50.000 U	23.3	462.07	74.36
214915	9.76	MBMG	3.28	3040	140.89	111.95	20.03	5.15	351.486	0.894	59.4	0	0	3179	19.07	<0.050 U	5.28	<0.100 U	1.710 J	206632.11	<0.500 U	470.3	7.66	14.78	<50.000 U	9.29	506.21	29.9
214915	12.42	MBMG	3.02	3442	160.56	120.21	20.24	4.79	342.84	1.135	78.15	0	0	3199	18.08	<0.050 U	4.31	<0.100 U	5.33	232140.94	<0.500 U	163.73	8.32	18.22	<50.000 U	16.12	562.74	47.5
214915	11.06	MBMG	3.27	3412	139.02	108.73	21.21	5.03	331.495	0.894	55.85	0	0	2855	19.34	<0.050 U	3.85	<0.100 U	<0.500 U	189250	<0.500 U	385.42	7.12	15.4	<50.000 U	11.33	471.67	32.87
214915	13.07	MBMG	3.31	3027	127.55	97.57	18.94	4.61	278.955	1.022	57.53	0	0	2804	19.24	<0.050 U	3.53	<0.100 U	<0.500 U	188275	<0.500 U	157.17	9.23	15.77	<50.000 U	13.67	450.08	43.75
200616	10.02	MBMG	3.03	2666	174.87	78.08	11.73	2.15	197.573	0.478	69.97	0	0	2104	8.76	0.040 J	6.61	<0.020 U	<0.500 U	138135.93	1.840 J	303.25	2.250 J	16.94	<10.000 U	8.12	376.61	38.7
200616	10.05	MBMG	2.89	2703	164.47	77.39	13.31	2.45	193.971	0.475	74.38	0	0	1890	11.22	<0.010 U	1.9	<0.020 U	2.050 J	132957.06	2.02	110.27	1.550 J	16.02	<10.000 U	9.63	398.08	42.25
200616	11.8	MBMG	3.07	2752	166.76	74.93	11.25	2.66	228.545	0.468	72.72	0	0	1950	6.85	0.040 J	5.3	<0.020 U	<0.500 U	148585	2.91	252.41	2.96	14.6	<10.000 U	10.56	398.53	44.79
200616	10.04	MBMG	3.03	2854	169.94	71.61	10.2	2.41	182.433	0.425	66.46	0	0	1810	6.16	<0.010 U	1.54	<0.020 U	<0.500 U	116840	1.700 J	250.22	1.670 J	17.76	<10.000 U	8.67	340.13	35.77
200616	10.03	MBMG	3	2626	147.18	62.14	10.07	1.92	141.78	0.386	66	0	0	1681	7.43	<0.010 U	1.9	<0.020 U	<0.500 U	95085	1.650 J	123.18	1.280 J	15.6	<10.000 U	7.4	307.77	31.23
200616	9.97	MBMG	2.99	7693	159.67	74.67	11.26	2.46	165.95	0.363	64.54	0	0	1844	8.73	<0.010 U	1.77	<0.020 U	<0.250 U	117350	1.53	206.17	1.130 J	8.48	<10.000 U	8.2	307.65	30.53
200616	9.91	MBMG	3.02	2720	175.25	75.67	10.46	2.43	193.21	0.462	66.79	0	0	1859	6.33	<0.010 U	1.71	<0.020 U	4.86	131065	2.67	232.63	19.19	14.48	<10.000 U	8.57	354.17	30.93
200616	10.13	MBMG	3.01	2584	170.93	73.94	11.4	2.68	188.55	0.482	66.9	0	0	1823	6.18	<0.010 U	4.73	<0.020 U	1.300 J	121310	1.910 J	225.83	2.100 J	17.08	<10.000 U	9.25	365.95	31.92
200616	10.1	MBMG	3.04	2022	151.32	66.24	11.2	2.05	141.9	0.361	60.64	0	0	1487	6.59	0.040 J	3.82	<0.020 U	<0.250 U	98465	1.56	100.67	1.190 J	11.14	<10.000 U	5.67	274.85	24.85
200616	9.84	MBMG	3.08	2640	160.81	72.51	9.97	2.23	170.135	0.431	65.65	0	0	1634	7.52	0.05	5.3	0.13	<0.500 U	110670	1.680 J	141.81	1.350 J	10.97	<10.000 U	8.34	339.94	30.28
200616	9.92	MBMG	3.1	2780	161.39	73.18	11.2	2.57	191.15	0.51	65.37	0	0	1752	7.47	<0.010 U	5.98	0.030 J	<0.250 U	112588.34	1.63	166.12	3.41	14.24	<10.000 U	7.78	341.72	32.36
217524	11.05	MBMG	2.68	4429	209.05	98.88	18.48	<0.500 U	578.384	0.634	99.91	0	0	4564	30.15	<0.050 U	8.19	<0.100 U	<1.000 U	337887	<1.000 U	821.93	<1.000 U	31.38	<50.000 U	8.23	268.32	105.87
217524	12.67	MBMG	2.61	3882	147.7	79.94	30.92	0.640 J	424.593	0.421 J	81.33	0	0	3349	45.94	0.47	4.9	0.400 J	2.700 J	226864.05	<1.000 U	107.85	<1.000 U	22.86	<50.000 U	5.63	175.67	71.35
217524	7.32	MBMG	2.73	3996	145.1	65.49	14.06	3.63	396.95	0.410 J	73	0	0	2995	21.74	0.180 J	5.76	<0.100 U	<1.000 U	208100	10.21	373.21	6.77	19.6	<50.000 U	5.99	177.79	58.08
217524	10.21	MBMG	2.87	4253	167.38	78.66	18.05	3.2	530.7	0.480 J	83.01	0	0	3694	27.62	<0.050 U	6.73	<0.100 U	<1.000 U	259350	15.19	523.17	3.780 J	26.88	<50.000 U	6.73	226.74	73.89
217524	12.45	MBMG	2.8	3920	186.36	82.96	26.07	0.870 J	359.95	0.480 J	86.74	0	0	3525	38	0.37	5.87	<0.100 U	<1.000 U	227950	2.730 J	129.5	<1.000 U	23.87	<50.000 U	6.69	196.07	66.74
217524	9.3	MBMG	2.86	3314	173.8	83.96	22.39	3.37	355.485	0.384	75.47	0	0	2695	52.39	<0.010 U	1.7	<0.020 U	<0.500 U	212745	8.36	356.99	4.55	13.43	<10.000 U	5.92	173.08	54.03
217524	9.07	MBMG	2.88	4068	146.04	75.74	14.64	4.12	573.2	0.456 J	84.67	0	0	3777	30.3	<0.050 U	5.94	<0.100 U	<1.000 U	282750	20.35	512.28	4.470 J	22.78	<50.000 U	4.71	207.46	61.84
217524	11.01	MBMG	2.9	3792	151.6	76.03	16.46	4.12	566.75	0.463 J	80.55	0	0	3608	25.89	<0.050 U	5.77	<0.100 U	3.790 J	259800	18.98	490.17	4.530 J	27.38	543	5.23	208.79	64.25
217524	13.93	MBMG	2.61	4013	198.07	89.02	22.31	<0.500 U	341.7	0.467 J	91.69	0	0	3322	35.79	0.26	6.25	<0.100 U	<1.000 U	240250	<1.000 U	171.33	<1.000 U	22.23	<50.000 U	6.89	176.88	70.19
217524	10.97	MBMG	2.84	3850	159.15	79.04	21.38	2.72	414.484	0.443 J	73.39	0	0	3006	43.09	0.39	6.58	0.110 J	<1.000 U	224427.68	13.06	233.27	4.050 J	16.93	<50.000 U	5.88	193.9	60.65
217524	8.52	MBMG	2.93	4370	153.55	78.63	14.86	3.92	622.85	0.463 J	88.46	0	0	3596	30.16	<0.050 U	8.13	<0.100 U	<1.000 U	274059.02	19.5	65.49	4.900 J	22.9	<50.000 U	4.96	225.16	54.68
291863	9.4	MBMG	6.09	1157.39	119.42	45.3	21.39	7.13	67.41	0.469	16.74	128.89	0	548.7	5.64	<0.010 U	1.74	<0.020 U	<0.250 U	661.11	1.18	60.21	13.75	1.54	<10.000 U	<0.250 U	59.56	<0.250 U
291863	9.5	MBMG	6.02	1165.31	122.85	44.42	17.92	6.63	68.17	0.448	15.25	124.63	0	555.4	4.91	<0.010 U	1.5	<0.020 U	<0.250 U	1018.15	1.69	78.51	15.47	2.15	<10.000 U	<0.250 U	87.86	<0.250 U
291858	11.5	MBMG	3.47	3295.37	170.55	135.11	27.65	4.31	283.75	1.098	39.89	0	0	2822	5.37	<0.050 U	6.09	0.480 J	<1.000 U	186550	13.54	104.07	10.62	21.06	<50.000 U	8.03	635.57	26.22
291858	15	MBMG	3.52	3077.23	174.63	138.05	23.62	4.38	266.75	1.251	39.88	0	0	2628	5.34	<0.050 U	5.62	0.160 J	<1.000 U	185350	20.37	189.66	11.59	26.32	<50.000 U	6.59	658.3	22.98
291861	11.9	MBMG	2.7	9041.57	238.47	239.4	34.28	<2.500 U	1406.15	5.374	144.98	0	0	10214	3.640 J	<0.100 U	24.21	0.510 J	<5.000 U	984700	32.03	102.95	<5.000 U	78.76	<100.000 U	106.04	1999.18	254.97
291861	18.5	MBMG	2.72	9859.42	273.52	276.41	20.37	<2.500 U	1733.85	8.561	138.97	0	0	11366	3.870 J	<0.100 U	28.36	0.210 J	<5.000 U	1165600	29.7	299.81	<5.000 U	126.9	<100.000 U	111.75	2394.92	343.16
296887	12.3	MBMG	3	4403.69	219.24	142.9	24.94	3.31	367.4	2.108	66.11	0	0	3820	9.12	0.96	7.46	<0.100 U	<1.000 U	294800	5.98	106.47	13.03	26.54	<50.000 U	32.69	1063.01	77.54
291865	14.1	MBMG	3.3	2786.56	184.25	132.15	20.8	5.09	20.436	0.755	23.71	0	0	2231	36.38	0.3	4.09	<0.100 U	<0.500 U	155895	<0.500 U	177.04	35.96	13.67	<50.000 U	36.31	860.17	7.86
291865	14.1	MBMG	3.22	2838.59	189.39	137.69	21.76	5.31	24.411	0.74	23.91	0	0	3260	36.28	0.29	4.04	0.390 J	<0.500 U	161060	<0.500 U	171.27	35.5	13.77	<50.000 U	35.87	848.58	8.78
291859	11	MBMG	3.03	4986.43	319.37	121.01	14.45	7.72	620.55	1.94	93.01	0	0	4325	2.7	<0.050 U	9.49	<0.100 U	<1.000 U	261000	<1.000 U	190.88	<1.000 U	66.89	<50.000 U	23.55	3189.47	15.08
291859	14.4	MBMG	2.85	5131.14	335.92	128.77	13.85	5.63	625.4	2.271	90.97	0	0	4277	2.7	<0.050 U	9.72	0.110 J	<1.000 U	282750	<1.000 U	275.57	<1.000 U	96.76	<50.000 U	30.56	3945.77	22.35
2262	10.9	MBMG	2.71	4838.78	185.75	135.55	22.4	<0.500 U	394.15	1.628	82.09	0	0	4301	6.76	0.210 J	8.59	<0.100 U	<1.000 U	349200	<1.000 U	159.52	<1.000 U	24.31	<50.000 U	45.04	1175.98	130.93
2276	11.5	MBMG	2.6	7396.29	231.17	203.58	18.86	<0.500 U	799.45	2.545	118.33	0	0	7584	2.030 J	0.250 J	18.8	0.150 J	<1.000 U	759350	2.830 J	205.11	<1.000 U	37.08	316	69.92	2322.7	215.45
2262	10.5	MBMG	2.73	5178.67	190.17	131.93	18.31	<0.500 U	426.9	1.548	78.34	0	0	4254	7.38	<0.050 U	8.59	<0.100 U	<1.000 U	363750	<1.000 U	146.31	<1.000 U	32.07	<50.000 U	43.79	1345.4	100.3
2276	14.9	MBMG	2.58	7179.52	229	199.49	13.65	<0.500 U	828.6	2.137	109.55	0	0	7253	2.180 J	0.28	17.28	<0.100 U	<1.000 U	726000	2.640 J	311.34	<1.000 U	46.57	<50.000 U	77.51	2053.28	219.73

gwicid	cu	hg	li	mo	ni	pb	sb	se	sn	sr	ti	tl	u	v	zn	zr	ce	cs	ga	la	nb	nd	pd	pr	rb	th	w	no2_n_mgl
2441	<2.500 U		<10.0 U	5.19	3.07	<0.300 U	<0.500 U	<0.500 U	<0.500 U	890.88	11.38	<0.500 U	3.35	<0.500 U	37.55	<0.500 U	<0.500 U	<0.500 U	1.350 J	<0.500 U	<0.500 U	<0.500 U	<0.500 U	<0.500 U	<0.500 U	<0.500 U	<0.500 U	<0.010 U
2174	4.13		10.8	1.02	<0.100 U	0.5	<0.100 U	0.96	<0.100 U	293.34	3.02	<0.100 U	3.33	0.410 J	25.83	<0.100 U	<0.100 U	<0.100 U	13.03	<0.100 U	<0.100 U	<0.100 U	0.310 J	<0.100 U	1.9	<0.100 U	<0.100 U	<0.010 U
217053	5.04		60.8	3.95	0.66	<0.060 U	<0.100 U	<0.100 U	<0.100 U	883.34	0.460 J	<0.100 U	<0.100 U	0.250 J	<0.500 U	0.400 J	<0.100 U	<0.100 U	6.13	<0.100 U	<0.100 U	<0.100 U	0.57	<0.100 U	7.13	<0.100 U	<0.100 U	<0.010 U
212233	<1.250 U		64.1	2.49	<0.250 U	<0.150 U	<0.250 U	<0.250 U	<0.250 U	838.23	1.63	<0.250 U	3.1	<0.250 U	44.56	1.050 J	<0.250 U	<0.250 U	0.770 J	<0.250 U	0.690 J	<0.250 U	0.720 J	<0.250 U	7.26	<0.250 U	<0.250 U	<0.010 U
217048	5.25		62.3	6.43	7.49	<0.150 U	<0.250 U	<0.250 U	<0.250 U	869.11	5.97	<0.250 U	26.83	1.68	<1.250 U	1.050 J	3.8	<0.250 U	11.29	<0.250 U	<0.250 U	<0.250 U	1.000 J	<0.250 U	15.14	<0.250 U	0.840 J	<0.010 U
217056	6.68		50.77	113.74	<0.100 U	<0.060 U	0.190 J	<0.100 U	<0.100 U	634.3	0.94	<0.100 U	3.68	0.340 J	<0.500 U	0.380 J	0.280 J	<0.100 U	3.91	<0.100 U	<0.100 U	<0.100 U	0.450 J	<0.100 U	5.97	<0.100 U	0.220 J	<0.010 U
217050	5.88		36.63	2.74	0.340 J	<0.060 U	<0.100 U	2.39	<0.100 U	495.9	0.51	<0.100 U	3.34	0.350 J	<0.500 U	0.56	<0.100 U	<0.100 U	8.43	<0.100 U	<0.100 U	<0.100 U	0.380 J	<0.100 U	3.77	<0.100 U	0.69	<0.010 U
255442	2.390 J		26.8	0.770 J	<0.250 U	<0.150 U	<0.250 U	7.12	<0.250 U	396.07	3.89	<0.250 U	4.06	<0.250 U	9.44	<0.250 U	<0.250 U	<0.250 U	1.43	<0.250 U	<0.250 U	<0.250 U	<0.250 U	<0.250 U	4.45	<0.250 U	<0.250 U	<0.010 U
30542	15.18		5.810 J	0.340 J	<0.100 U	<0.060 U	<0.100 U	0.470 J	<0.100 U	346.58	0.54	<0.100 U	2.17	0.190 J	78.18	0.130 J	<0.100 U	<0.100 U	12.06	<0.100 U	0.270 J	<0.100 U	0.330 J	<0.100 U	2.23	<0.100 U	<0.100 U	<0.010 U
2526	<0.500 U		13.75	1.42	<0.100 U	<0.060 U	<0.100 U	1.02	<0.100 U	1135.84	3.07	<0.100 U	1.63	0.360 J	<0.500 U	<0.100 U	<0.100 U	<0.100 U	0.92	<0.100 U	<0.100 U	<0.100 U	0.66	<0.100 U	1.71	<0.100 U	<0.100 U	<0.010 U
279240	<0.500 U		96.92	2.78	6.25	<0.060 U	<0.100 U	1.07	<0.100 U	1119.59	4.3	<0.100 U	6.69	0.350 J	23.26	0.410 J	<0.100 U	0.280 J	1.61	<0.100 U	0.240 J	<0.100 U	0.66	<0.100 U	7.71	<0.100 U	<0.100 U	0.22
277205	<5.000 U		266.45	6.79	3.620 J	<0.600 U	<1.000 U	<1.000 U	<1.000 U	2880.02	23.04	<1.000 U	12.39	<1.000 U	35.35	<1.000 U	<1.000 U	<1.000 U	<1.000 U	<1.000 U	<1.000 U	<1.000 U	2.190 J	<1.000 U	8.71	<1.000 U	<1.000 U	<0.050 U
164111	<0.500 U		15.04	5.87	<0.100 U	<0.060 U	<0.100 U	<0.100 U	<0.100 U	720.65	2.56	<0.100 U	1.89	0.260 J	7.26	<0.100 U	<0.100 U	<0.100 U	3.13	<0.100 U	<0.100 U	<0.100 U	0.460 J	<0.100 U	2.05	<0.100 U	<0.100 U	<0.010 U
217052	5.91		43.11	3.34	23.07	4.31	<0.100 U	<0.100 U	<0.100 U	768.2	7.14	<0.100 U	<0.100 U	<0.100 U	47.35	<0.100 U	0.89	<0.100 U	1.75	0.64	<0.100 U	0.380 J	0.61	<0.100 U	7.85	<0.100 U	<0.100 U	0.08
223946	6.08		42.13	0.440 J	<0.100 U	<0.060 U	<0.100 U	<0.100 U	<0.100 U	798.67	2.25	<0.100 U	<0.100 U	<0.100 U	55.1	1.31	<0.100 U	<0.100 U	2.23	<0.100 U	<0.100 U	<0.100 U	0.62	<0.100 U	6.05	<0.100 U	0.260 J	<0.010 U
215048	5.97		48.11	7.7	37.3	<0.060 U	0.72	<0.100 U	<0.100 U	763.29	5.38	<0.100 U	6.35	0.92	<0.500 U	<0.100 U	<0.100 U	<0.100 U	1.53	<0.100 U	<0.100 U	<0.100 U	0.480 J	<0.100 U	10.76	<0.100 U	2.62	<0.010 U
152258	<1.250 U		94.79	11.81	3.05	<0.150 U	1.130 J	<0.250 U	<0.250 U	1092.11	2.76	<0.250 U	3.08	<0.250 U	30	0.620 J	<0.250 U	<0.250 U	1.000 J	<0.250 U	0.600 J	<0.250 U	0.840 J	<0.250 U	11.19	<0.250 U	3.47	<0.010 U
146929	2.930 J		20.600 J	22.97	10.82	<0.150 U	<0.250 U	3.59	<0.250 U	380.66	1.42	<0.250 U	5.15	0.800 J	58.4	<0.250 U	<0.250 U	<0.250 U	4.68	<0.250 U	<0.250 U	<0.250 U	<0.250 U	<0.250 U	1.92	<0.250 U	<0.250 U	<0.010 U
224151	6.1		6.290 J	2.32	3.76	<0.060 U	0.420 J	<0.100 U	1.08	349.13	1.04	<0.100 U	0.76	0.75	<0.500 U	1.06	<0.100 U	<0.100 U	22.42	<0.100 U	0.230 J	<0.100 U	0.470 J	<0.100 U	7.72	<0.100 U	0.260 J	
224150	31.11		97.44	1.200 J	812.66	<0.300 U	<0.500 U	<0.500 U	<0.500 U	3262.92	50.47	<0.500 U	<0.500 U	<0.500 U	1776.96	2.51	84.09	<0.500 U	1.320 J	45.51	<0.500 U	47.44	4.32	11.05	15.14	<0.500 U	<0.500 U	0.07
217047	<0.500 U		30.02	0.330 J	15.26	<0.060 U	<0.100 U	0.410 J	<0.100 U	726.35	2.41	0.240 J	0.51	<0.100 U	6.6	0.260 J	<0.100 U	<0.100 U	2.33	<0.100 U	<0.100 U	<0.100 U	0.470 J	<0.100 U	5.62	<0.100 U	0.310 J	0.07
224149	5.79		44.07	0.66	11.17	<0.060 U	0.57	<0.100 U	<0.100 U	762.96	7.47	<0.100 U	<0.100 U	0.58	<0.500 U	<0.100 U	<0.100 U	<0.100 U	2.25	<0.100 U	<0.100 U	<0.100 U	0.55	<0.100 U	7.18	<0.100 U	1.71	<0.010 U
145604	1.050 J		12.3	1.49	<0.100 U	<0.060 U	<0.100 U	<0.100 U	<0.100 U	469.5	0.380 J	<0.100 U	0.93	0.280 J	9.73	0.360 J	<0.100 U	<0.100 U	2.32	<0.100 U	0.320 J	<0.100 U	0.330 J	<0.100 U	0.430 J	<0.100 U	<0.100 U	<0.010 U
162423	2.06		18.35	1.1	<0.100 U	0.37	<0.100 U	0.480 J	<0.100 U	356.1	4.34	<0.100 U	3.37	0.61	8.91	0.430 J	<0.100 U	<0.100 U	7.61	<0.100 U	<0.100 U	<0.100 U	0.350 J	<0.100 U	1.92	<0.100 U	<0.100 U	<0.010 U
31992	4.06		11.56	1.16	<0.100 U	<0.060 U	<0.100 U	0.75	<0.100 U	718.16	6.1	<0.100 U	1.41	<0.100 U	2.85	<0.100 U	<0.100 U	<0.100 U	3.74	<0.100 U	<0.100 U	<0.100 U	0.370 J	<0.100 U	0.83	<0.100 U	<0.100 U	<0.010 U
236507	8.800 J		662.66	<1.000 U	419.36	<0.600 U	<1.000 U	<1.000 U	<1.000 U	11030.38	33	<1.000 U	29.73	28.6	469.74	<1.000 U	10.45	2.680 J	<1.000 U	2.850 J	<1.000 U	10.07	7.58	<1.000 U	51.15	<1.000 U	<1.000 U	
236507	<5.000 U		661.64	<1.000 U	431.26	<0.600 U	<1.000 U	<1.000 U	<1.000 U	10250.01	28.53	<1.000 U	7.06	<1.000 U	407.96	<1.000 U	<1.000 U	2.980 J	<1.000 U	<1.000 U	<1.000 U	<1.000 U	5.68	<1.000 U	48.41	<1.000 U	<1.000 U	<0.050 U
217046	6.05		11.41	2.01	4.08	3.49	0.270 J	0.66	76.16	1457.13	5.63	<0.100 U	1.53	0.310 J	1401.85	0.340 J	<0.100 U	<0.100 U	2.56	<0.100 U	<0.100 U	<0.100 U	0.99	<0.100 U	1.3	<0.100 U	<0.100 U	<0.010 U
149852	<1.250 U		143.45	1.62	<0.250 U	<0.150 U	<0.250 U	<0.250 U	<0.250 U	1141.4	4.89	0.510 J	4.81	<0.250 U	6.44	<0.250 U	<0.250 U	<0.250 U	0.520 J	<0.250 U	<0.250 U	<0.250 U	0.720 J	<0.250 U	6.86	<0.250 U	<0.250 U	<0.010 U
210668	10.76		49.3	1.64	<0.250 U	1.23	<0.250 U	1.55	<0.250 U	1029.38	4.08	<0.250 U	9.69	0.640 J	5.79	<0.250 U	<0.250 U	<0.250 U	0.920 J	<0.250 U	<0.250 U	<0.250 U	0.760 J	<0.250 U	5.7	<0.250 U	<0.250 U	<0.010 U
32000	2.61		<10.0 U	1.37	<0.100 U	<0.060 U	<0.100 U	0.56	<0.100 U	768.98	1.05	<0.100 U	1.91	0.470 J	11.27	<0.100 U	<0.100 U	<0.100 U	1.7	<0.100 U	<0.100 U	<0.100 U	0.480 J	<0.100 U	0.7	<0.100 U	<0.100 U	<0.010 U
32009	1.380 J		<10.0 U	3.35	<0.100 U	<0.060 U	<0.100 U	0.75	<0.100 U	1357.61	1.68	<0.100 U	2.06	0.320 J	193.77	0.480 J	<0.100 U	<0.100 U	1.28	<0.100 U	<0.100 U	<0.100 U	0.85	<0.100 U	0.84	<0.100 U	<0.100 U	<0.010 U
141006	<0.500 U		8.220 J	3.06	<0.100 U	0.070 J	<0.100 U	1.65	<0.100 U	832.06	4.25	<0.100 U	1.52	0.390 J	251.73	<0.100 U	<0.100 U	<0.100 U	1.34	<0.100 U	<0.100 U	<0.100 U	0.65	<0.100 U	0.9	<0.100 U	<0.100 U	<0.010 U
139022	<0.500 U		12.24	1.78	<0.100 U	0.52	<0.100 U	0.66	<0.100 U	727.84	2.36	<0.100 U	1.74	0.72	196.75	<0.100 U	<0.100 U	<0.100 U	2.22	<0.100 U	<0.100 U	<0.100 U	0.57	<0.100 U	1.93	<0.100 U	<0.100 U	<0.010 U
245668	0.890 J		4.980 J	1.36	<0.100 U	3.53	<0.100 U	0.74	<0.100 U	871.12	4.52	<0.100 U	1.2	0.63	458.86	<0.100 U	<0.100 U	<0.100 U	1.74	<0.100 U	<0.100 U	<0.100 U	0.72	<0.100 U	0.67	<0.100 U	<0.100 U	<0.010 U
126078	<1.250 U		51.45	1.98	<0.250 U	<0.150 U	<0.250 U	<0.250 U	<0.250 U	920.21	9.78	<0.250 U	3.94	<0.250 U	67.35	0.600 J	<0.250 U	0.930 J	<0.250 U	<0.250 U	0.550 J	<0.250 U	1.010 J	<0.250 U	8.21	<0.250 U	<0.250 U	<0.010 U
31892	2.47		51.58	1.72	<0.100 U	<0.060 U	<0.100 U	0.65	<0.100 U	1061.81	5.1	<0.100 U	1.53	0.61	36.7	<0.100 U	<0.100 U	1.07	1.11	<0.100 U	<0.100 U	<0.100 U	0.78	<0.100 U	7.81	<0.100 U	<0.100 U	<0.010 U
2528	<0.500 U		16.25	1.37	<0.100 U	0.57	<0.100 U	1.04	<0.100 U	1039.63	3.02	<0.100 U	1.43	0.440 J	8.06	<0.100 U	<0.100 U	<0.100 U	0.94	<0.100 U	<0.100 U	<0.100 U	0.57	<0.100 U	1.92	<0.100 U	<0.100 U	<0.010 U
31939	<1.250 U		30.23	1.000 J	<0.250 U	<0.150 U	<0.250 U	2.04	<0.250 U	720.98	6.68	<0.250 U	2.81	0.550 J	1.490 J	<0.250 U	<0.250 U	<0.250 U	1.010 J	<0.250 U	<0.250 U	<0.250 U	<0.250 U	<0.250 U	3.52	<0.250 U	<0.250 U	<0.010 U
2309	1.090 J		14.92	1.45	<0.100 U	<0.060 U	<0.100 U	1.04	<0.100 U	759.24	2.47	<0.100 U	1.7	0.53	4.24	<0.100 U	<0.100 U	<0.100 U	1.45	<0.100 U	<0.100 U	<0.100 U	0.490 J	<0.100 U	1.78	<0.100 U	<0.100 U	<0.010 U
205599	1.170 J		19.41	1.5	<0.100 U	<0.060 U	<0.100 U	0.95	<0.100 U	787.82	2.66	<0.100 U	1.45	0.53	29.35	0.270 J	<0.100 U	0.290 J	1.25	<0.100 U	0.270 J	<0.100 U	0.51	<0.100 U	2.37	<0.100 U	<0.100 U	<0.010 U
149855	1.430 J		19.04	1.71	<0.100 U	0.280 J	<0.100 U	2.56	<0.100 U	674.95	3.37	0.260 J	1.43	0.470 J	15.83	0.310 J	<0.100 U	0.480 J	0.69	<0.100 U	0.290 J	<0.100 U	0.490 J	<0.100 U	4.36	<0.100 U	<0.100 U	<0.010 U
276129	1.300 J		2.280 J	0.450 J	<0.100 U	0.3	<0.100 U	0.62	2	84.23	<0.100 U	<0.100 U	0.320 J	0.460 J	15.78	<0.100 U	<0.100 U	<0.100 U	6.83	<0.100 U	<0.100 U	<0.100 U	<0.100 U	<0.100 U	0.57	<0.100 U	<0.100 U	<0.010 U
196148	<0.500 U		6.530 J	0.430 J	<0.100 U	<0.060 U	<0.100 U	0.82	<0.100 U	381.3	0.89	<0.100 U	1.03	<0.100 U	279.19	<0.100 U	<0.100 U	<0.100 U	2.78	<0.100 U	<0.100 U	<0.100 U	0.240 J	<0.100 U	1.27	<0.100 U	<0.100 U	<0.010 U
31965	1.280 J		26.54	0.910 J	0.960 J	<0.150 U	<0.250 U	21.12	<0.250 U	532.58	6.23	<0.250 U	10.59	<0.250 U	14.13	<0.250 U	<0.250 U	<0.250 U	1.65	<0.250 U	<0.250 U	<0.250 U	<0.250 U	<0.250 U	3.84	<0.250 U	<0.250 U	<0.010 U
32069	<0.500 U		20.33	0.59	0.59	<0.060 U	<0.100 U	<0.100 U	<0.100 U	239.51	1.72	<0.100 U	<0.100 U	<0.100 U	17.6	0.280 J	<0.100 U	<0.100 U	0.87	<0.100 U	0.260 J	<0.100 U	0.350 J	<0.100 U	2.11	<0.100 U	<0.100 U	<0.010 U
239236	1.320 J		35.4	1.45	<0.100 U	<0.060 U	<0.100 U	0.87	<0.100 U	928.14	3.08	<0.100 U	1.74	0.55	7.44	<0.100 U	<0.100 U	0.64	0.85	<0.100 U	<0.100 U	<0.100 U	0.56	<0.100 U	5.09	<0.100 U	<0.100 U	<0.010 U
242153	1.020 J		33.85	1.41	<0.100 U	0.31	<0.100 U	1.19	<0.100 U	914.57	2.89	<0.100 U	1.47	0.210 J	11.28	0.330 J	<0.100 U	0.63	0.85	<0.100 U	0.290 J	<0.100 U	0.62	<0.100 U	4.87	<0.100 U	<0.100 U	<0.010 U
248664	2.23		26.05	1.29	<0.100 U	<0.060 U	<0.100 U	0.93	<0.100 U	821.63	2.44	<0.100 U	1.47	0.57	15.26	<0.100 U	<0.100 U	0.440 J	1.05	<0.100 U	<0.100 U	<0.100 U	0.440 J	<0.100 U	3.65	<0.100 U	<0.100 U	<0.010 U
252467	9.16		21.26	1.36	<0.100 U	<0.060 U	<0.100 U	0.92	<0.100 U	794.17	2.33	<0.100 U	1.53	0.6	19.75	<0.100 U	<0.100 U	0.360 J	1.21	<0.100 U	<0.100 U	<0.100 U	0.440 J	<0.100 U	2.94	<0.100 U	<0.100 U	<0.010 U
235488	1.480 J		37.7	1.090 J	<0.250 U	0.550 J	<0.250 U	6.38	<0.250 U	724.31	2.47	<0.250 U	2.19	0.790 J	11.12	<0.250 U	<0.250 U	0.580 J	0.650 J	<0.250 U	<0.250 U	<0.250 U	<0.250 U	<0.250 U	7.58	<0.250 U	<0.250 U	<0.010 U
235689	<1.250 U		31.31	2.14	<0.250 U	<0.150 U	<0.250 U	4.45	<0.250 U	861.05	3.86	<0.250 U	2.33	<0.250 U	11.85	<0.250 U	<0.250 U	0.700 J	0.870 J	<0.250 U	<0.250 U	<0.250 U	<0.250 U	<0.250 U	6.63	<0.250 U	<0.250 U	<0.010 U
291365	3.65		40	1.49	24.36	<0.060 U	<0.100 U	0.99	<0.100 U	937.18	2.24	0.210 J	1.53	<0.100 U	46.53	<0.100 U	<0.100 U	0.75	1.11	<0.100 U	<0.100 U	<0.100 U	0.460 J	<0.100 U	6.33	<0.100 U	<0.100 U	<0.010 U
261984	<1.250 U		75	1.090 J	95.32	<0.150 U	<0.250 U	4.04	<0.250 U	1066.05	4.9	<0.250 U	3.45	<0.250 U	133.41	<0.250 U	<0.250 U	0.830 J	1.240 J	<0.250 U	<0.250 U	<0.250 U	0.570 J	<0.250 U	8.14	<0.250 U	<0.250 U	<0.010 U
294553	0.740 J		19.26	1.19	<0.100 U	2.16	<0.100 U	1.22	<0.100 U	786.35	2.15	<0.100 U	1.63	0.390 J	344.56	<0.100 U	<0.100 U	0.390 J	1.15	<0.100 U	<0.100 U	<0.100 U	0.52	<0.100 U	2.91	<0.100 U	<0.100 U	<0.010 U
279137	1.980 J		23.95	1.2	<0.100 U	<0.060 U	<0.100 U	1.06	<0.100 U	850.81	2.78	<0.100 U	1.43	0.390 J	13	<0.100 U	<0.100 U	0.55	1.04	<0.100 U	<0.100 U	<0.100 U	0.64	<0.100 U	3.7	<0.100 U	<0.100 U	<0.010 U
296888	1.450 J		5.470 J	0.370 J	<0.100 U	0.280 J	<0.100 U	0.98	<0.100 U	200.29	0.380 J	<0.100 U	1.32	0.320 J	6.88	<0.100 U	<0.100 U	<0.100 U	9.26	<0.100 U	<0.100 U	<0.100 U	<0.100 U	<0.100 U	1.95	<0.100 U	<0.100 U	<0.010 U
281405	<1.250 U		35.72	0.730 J	<0.250 U	<0.150 U	<0.250 U	1.44	<0.250 U	746.25	5.17	<0.250 U	1.35	0.720 J	19.99	<0.250 U	<0.250 U	<0.250 U	<0.250 U	<0.250 U	<0.250 U	<0.250 U	0.580 J	<0.250 U	5.42	<0.250 U	<0.250 U	<0.010 U
279108	3.23		33.22	1.55	<0.100 U	0.210 J	<0.100 U	0.88	<0.100 U	904.27	2.93	<0.100 U	1.66	0.53	7.54	<0.100 U	<0.100 U	0.6	0.88	<0.100 U	<0.100 U	<0.100 U	0.5	<0.100 U	4.75	<0.100 U	<0.100 U	<0.010 U
214914	90.38		372.41	<1.000 U	1451.85	<0.600 U	<1.000 U	<1.000 U	<1.000 U	1149.58	47.64	<1.000 U	31.93	24.11	4365.27	2.260 J	321.8	<1.000 U	<1.000 U	160.61	<1.000 U	200.1	6.46	48.23	16.93	9.06	<1.000 U	<0.050 U
214914	44.06		492.86	<1.000 U	1859.61	<0.600 U	<1.000 U	5.49	<1.000 U	1497.84	65.25	<1.000 U	40.77	34.69	6373.69	<1.000 U	468.7	<1.000 U	<1.000 U	205.11	<1.000 U	264.43	8.61	63.37	16.38	10.87	<1.000 U	<0.050 U
214914	50.37		306.89	<1.000 U	1191.67	<0.600 U	<1.000 U	<1.000 U	<1.000 U	1018.8	33.31	<1.000 U	35.12	23.25	4213.04	2.300 J	304.84	<1.000 U	<1.000 U	129.79	<1.000 U	182.07	4.620 J	44.03	14.36	12.5	<1.000 U	<0.050 U

gwicid	cu	hg	li	mo	ni	pb	sb	se	sn	sr	ti	tl	u	v	zn	zr	ce	cs	ga	la	nb	nd	pd	pr	rb	th	w	no2_n_mgl
214914	108.13		289.89	<0.500 U	1063.51	<0.300 U	<0.500 U	2.200 J	<0.500 U	938.09	53.77	<0.500 U	31.91	14.19	3669.23	1.430 J	275.1	<0.500 U	1.430 J	117.12	<0.500 U	145.74	3.86	35.62	12.79	8.12	<0.500 U	<0.050 U
214915	67.91		371.54	<0.500 U	1049.1	2.85	<0.500 U	4.07	<0.500 U	1088.36	45.38	1.200 J	16.38	27.5	3087.03	2.440 J	331.6	<0.500 U	1.410 J	137.67	<0.500 U	196.83	7.64	47.94	17.1	4.41	<0.500 U	<0.050 U
214915	194.45		412.42	<0.500 U	1167.85	4.1	<0.500 U	4.3	<0.500 U	1157.54	54.41	1.360 J	26.35	31.66	3678.75	1.140 J	395.54	<0.500 U	2.240 J	179.27	<0.500 U	217.24	7.3	52.3	14.37	11.28	<0.500 U	<0.050 U
214915	46.34		331.11	<0.500 U	911.95	3.51	<0.500 U	3.93	<0.500 U	999.15	26.52	1.190 J	17.56	27.13	3071.47	<0.500 U	318.84	<0.500 U	1.430 J	150.82	<0.500 U	186.86	4.03	49.23	14.63	5.95	<0.500 U	<0.050 U
214915	157.49		335.08	<0.500 U	898.08	3.82	<0.500 U	2.52	<0.500 U	917.8	57.62	1.080 J	22.7	28.89	2939.26	1.820 J	394.46	<0.500 U	1.890 J	167.62	<0.500 U	212.69	4.74	52.36	12.92	11.17	<0.500 U	<0.050 U
200616	44.71		219.6	<0.500 U	959.92	1.410 J	<0.500 U	3.94	<0.500 U	1760.34	30.61	<0.500 U	3.29	23.99	3780.02	1.400 J	223.17	<0.500 U	1.750 J	79.99	<0.500 U	148.7	5.59	32.99	13.78	5.33	<0.500 U	0.08
200616	39.78		218.37	<0.500 U	991.03	1.380 J	<0.500 U	3.74	<0.500 U	1672.38	33.7	<0.500 U	3.61	23.96	4229.78	<0.500 U	225.94	<0.500 U	1.710 J	93.99	<0.500 U	146.86	5.81	32.2	11.74	5.72	<0.500 U	<0.010 U
200616	12.15		233.88	<0.500 U	1021.15	1.74	<0.500 U	4.42	<0.500 U	1727.61	34.38	<0.500 U	3.71	26.88	4527.07	<0.500 U	210.84	<0.500 U	1.990 J	88.95	<0.500 U	132.88	5.74	30.42	12.01	6.29	<0.500 U	<0.010 U
200616	14.58		184.85	<0.500 U	752.32	1.270 J	<0.500 U	3.37	<0.500 U	1731.92	20.71	<0.500 U	3.25	24.16	3829.21	1.480 J	172.07	<0.500 U	1.590 J	69.64	1.240 J	125.08	5.48	29.96	13.23	5.68	<0.500 U	<0.010 U
200616	48.6		169.95	<0.500 U	709.07	<0.300 U	<0.500 U	<0.500 U	<0.500 U	1439.05	42.93	<0.500 U	3.13	18.34	3257.03	<0.500 U	182.2	<0.500 U	1.390 J	74.18	<0.500 U	117.9	4.02	26.09	10	4.73	<0.500 U	<0.010 U
200616	16.56		148.64	<0.250 U	708.4	1.01	<0.250 U	2.89	<0.250 U	1537.14	8.26	0.760 J	3.06	12.74	3668.38	<0.250 U	135.43	<0.250 U	1.28	55.31	<0.250 U	83.84	3.89	18.94	11.67	4.75	<0.250 U	<0.010 U
200616	19.74		182.51	12.53	787	2.22	<0.500 U	5.25	<0.500 U	1691.5	26	1.020 J	2.92	23.93	4010.25	1.620 J	189.2	<0.500 U	2.61	76.87	<0.500 U	119.48	5.45	25.7	12.32	5.74	<0.500 U	<0.010 U
200616	15.34		200.38	<0.500 U	857.99	1.260 J	<0.500 U	3.52	<0.500 U	1819.86	29.54	<0.500 U	3.19	22.14	4205.17	<0.500 U	223.8	<0.500 U	1.600 J	93.37	<0.500 U	144.03	4.82	26.85	12.14	5.86	<0.500 U	<0.010 U
200616	31.48		155.55	<0.250 U	643.58	0.680 J	<0.250 U	2.35	<0.250 U	1381.22	27.98	0.540 J	1.97	11.83	3155.74	<0.250 U	133.1	<0.250 U	0.830 J	49.22	<0.250 U	81.39	4.44	15.9	8.61	2.81	<0.250 U	<0.010 U
200616	13.85		172.99	<0.500 U	776.1	<0.300 U	<0.500 U	4.28	<0.500 U	1684.54	16.5	<0.500 U	3.02	18.17	3748.71	<0.500 U	187.41	<0.500 U	1.460 J	77.71	<0.500 U	107.37	4.27	26.49	13.12	4.8	<0.500 U	<0.010 U
200616	24.91		197.14	0.940 J	750.13	0.99	<0.250 U	3.5	<0.250 U	1661.91	81.05	0.690 J	3.04	17.15	3885.16	<0.250 U	156.26	<0.250 U	<0.250 U	65.31	<0.250 U	107.74	4.24	23.94	10.23	4.15	<0.250 U	<0.010 U
217524	113.81		478.43	<1.000 U	694	<0.600 U	<1.000 U	5.96	<1.000 U	2026.59	57.71	<1.000 U	10.91	19.21	3010.75	2.050 J	399.01	<1.000 U	7.34	170.2	<1.000 U	240.24	7.65	58.44	9.34	18.92	<1.000 U	<0.050 U
217524	98.01		319.02	<1.000 U	477.1	<0.600 U	<1.000 U	5.41	<1.000 U	1320.41	53.8	<1.000 U	8.8	19.71	2093.58	<1.000 U	332.21	<1.000 U	5.81	142.15	<1.000 U	186.63	5.54	44.23	6.98	14.77	<1.000 U	<0.050 U
217524	20.5		353.19	<1.000 U	450.24	3.16	<1.000 U	4.290 J	<1.000 U	1319.01	44.73	<1.000 U	5.92	23.98	2086.66	2.990 J	302.39	<1.000 U	3.900 J	126.61	<1.000 U	175.61	5.66	41.61	13.1	10.67	<1.000 U	<0.050 U
217524	19.950 J		350.6	<1.000 U	526.85	4.48	<1.000 U	4.950 J	<1.000 U	1461.63	37.75	<1.000 U	7.33	40.54	2502.76	<1.000 U	357.73	<1.000 U	4.390 J	148.85	<1.000 U	219.97	5.61	52.45	16.53	13.63	<1.000 U	<0.050 U
217524	105.06		358.79	<1.000 U	515.44	<0.600 U	<1.000 U	<1.000 U	<1.000 U	1657.59	67.84	<1.000 U	6.83	10.77	2454.86	<1.000 U	302.89	<1.000 U	4.310 J	128.08	<1.000 U	167.89	4.850 J	39.85	7.66	11.78	<1.000 U	<0.050 U
217524	19.15		277.82	<0.500 U	422.13	2.15	<0.500 U	3.78	<0.500 U	1490.57	24.54	1.280 J	6.19	14.7	2168.81	1.300 J	247.82	<0.500 U	3.66	103.76	<0.500 U	121.88	4.63	29.21	13.9	11.53	<0.500 U	<0.010 U
217524	14.190 J		356.11	11.6	476.17	3.59	<1.000 U	5.35	<1.000 U	1176.83	51.16	2.060 J	5.87	42.27	2291.74	3.770 J	366.35	<1.000 U	3.730 J	149.62	<1.000 U	207.28	6.93	48.44	17.64	11.93	<1.000 U	<0.050 U
217524	17.400 J		348.82	<1.000 U	496.14	3.98	<1.000 U	4.720 J	<1.000 U	1310.21	58.92	<1.000 U	6.06	44.15	2421.59	<1.000 U	363.84	<1.000 U	3.820 J	145.7	<1.000 U	205.79	5.33	46.38	17.24	11.84	<1.000 U	<0.050 U
217524	126.2		396.25	<1.000 U	518.61	<0.600 U	<1.000 U	4.420 J	<1.000 U	1685.5	70.61	<1.000 U	6.13	4.970 J	2518.35	<1.000 U	250.88	<1.000 U	4.270 J	103.24	<1.000 U	147.38	5.32	30.73	4.560 J	11.3	<1.000 U	<0.050 U
217524	21.45		306.08	<1.000 U	462.7	3.29	<1.000 U	5.55	<1.000 U	1470.03	27.29	<1.000 U	6.58	24.17	2286.29	<1.000 U	304.37	<1.000 U	4.580 J	126.75	<1.000 U	176.73	4.070 J	40.13	14.46	12.61	<1.000 U	<0.050 U
217524	41.44		376.19	<1.000 U	495.37	4.13	<1.000 U	4.900 J	<1.000 U	1333.95	205.11	<1.000 U	6.03	34.5	2440.83	<1.000 U	368.16	<1.000 U	3.460 J	153.16	<1.000 U	196.39	5.29	44.69	16.55	10.39	<1.000 U	<0.050 U
291863	26		65.84	0.580 J	159.98	2.9	<0.250 U	<0.250 U	<0.250 U	306.34	5.55	<0.250 U	<0.250 U	<0.250 U	509.37	1.070 J	9.14	<0.250 U	0.590 J	3.77	<0.250 U	6	0.760 J	1.34	13.25	<0.250 U	<0.250 U	<0.010 U
291863	18.05		72.99	<0.250 U	177.08	3.19	<0.250 U	<0.250 U	<0.250 U	375.31	10.62	<0.250 U	<0.250 U	<0.250 U	645.63	<0.250 U	17.31	<0.250 U	0.860 J	6.83	<0.250 U	11.5	0.690 J	2.48	15.54	<0.250 U	<0.250 U	<0.010 U
291858	131.83		383.11	6.25	1528.1	5.64	<1.000 U	4.920 J	<1.000 U	1199.57	24.66	<1.000 U	19.04	44.71	6113.79	2.110 J	316.76	<1.000 U	<1.000 U	115.84	<1.000 U	200.6	8.21	45.37	12.45	4.760 J	<1.000 U	<0.050 U
291858	97.17		425.58	5.23	1483.04	11.23	<1.000 U	6.09	<1.000 U	1256.06	46.46	<1.000 U	20.8	34.6	6171.85	<1.000 U	348.03	<1.000 U	<1.000 U	130.25	<1.000 U	223.3	8.58	50.41	15.86	2.590 J	<1.000 U	<0.050 U
291861	1314.01		894.89	<5.000 U	4606.32	<3.000 U	<5.000 U	<5.000 U	<5.000 U	1552.07	104.39	<5.000 U	338.67	267.04	16504.63	<5.000 U	1524.68	<5.000 U	35.98	564.34	<5.000 U	887.07	21.160 J	206.61	<5.000 U	95.86	<5.000 U	<0.100 U
291861	1086.45		1116.01	<5.000 U	5290.23	24.51	<5.000 U	23.900 J	<5.000 U	1907.16	198.09	<5.000 U	364.68	406.08	20234.61	<5.000 U	1783.53	<5.000 U	36.81	647.76	<5.000 U	1078.82	28.06	249.15	<5.000 U	108.55	<5.000 U	<0.100 U
296887	228.91		398.48	<1.000 U	2430.12	11.96	<1.000 U	7.66	<1.000 U	1208.13	33.43	2.970 J	45.95	48.2	10392.71	<1.000 U	384.56	<1.000 U	4.220 J	133.13	<1.000 U	260.19	10.59	57.36	8.68	10.48	<1.000 U	<0.050 U
291865	100.16		230.24	<0.500 U	1471.14	1.52	<0.500 U	3.34	<0.500 U	737.95	15.96	<0.500 U	23	<0.500 U	6596.16	<0.500 U	190.57	<0.500 U	2.090 J	76.84	<0.500 U	115.59	3.63	26.6	3.3	8.95	<0.500 U	<0.050 U
291865	106.18		222.17	<0.500 U	1473.64	3.85	<0.500 U	2.86	<0.500 U	712.11	16.41	<0.500 U	22.25	<0.500 U	6584.32	<0.500 U	205.59	<0.500 U	2.280 J	74.26	<0.500 U	132.62	3.83	26.54	3.34	9.78	<0.500 U	<0.050 U
291859	268.91		529.97	<1.000 U	6390.53	2.590 J	<1.000 U	6.82	<1.000 U	1233.07	44.18	3.430 J	8.21	81.06	29540	<1.000 U	611.97	2.270 J	<1.000 U	118.06	<1.000 U	246.54	11.12	52.3	45.7	2.590 J	<1.000 U	<0.050 U
291859	241.33		559.84	<1.000 U	7593.46	7.39	<1.000 U	9.97	<1.000 U	1379.87	63.75	3.390 J	12.37	88.32	36977.06	4.310 J	452.62	2.550 J	2.250 J	145.26	<1.000 U	351.24	14.55	72.18	49.34	4.370 J	<1.000 U	<0.050 U
2262	380.33		472.92	<1.000 U	2912.37	6.55	<1.000 U	8.48	<1.000 U	1145.05	40.19	<1.000 U	53.4	7.68	12713.59	<1.000 U	453.62	<1.000 U	5.06	158.5	<1.000 U	304.43	10.99	67.77	4.870 J	10.34	<1.000 U	<0.050 U
2276	914.13		973.48	<1.000 U	5378.79	13.4	<1.000 U	14.64	<1.000 U	1036.08	92.14	<1.000 U	106.9	55.39	21807.84	2.600 J	633.5	<1.000 U	15.91	255.5	<1.000 U	419.01	21.6	122.48	<1.000 U	33.86	<1.000 U	<0.050 U
2262	240.61		419.79	<1.000 U	2712.88	13.03	<1.000 U	11.96	<1.000 U	1249.27	48.37	<1.000 U	61.42	14.23	14698.37	<1.000 U	487.95	<1.000 U	5.62	167.03	<1.000 U	279.12	12.67	62.65	5.76	13.39	<1.000 U	<0.050 U
2276	822.76		747.17	<1.000 U	4676.75	6.57	<1.000 U	18.58	<1.000 U	1160.77	71.54	<1.000 U	145.7	61.98	23329.71	3.280 J	651.2	<1.000 U	23.33	282.04	<1.000 U	445.06	23.13	131.99	<1.000 U	46.58	<1.000 U	<0.050 U

gwicid	no3_no2_n_mgl	oh_mgl	dissolved_organic_carbon_mgl	dissolved_inorganic_carbon_mgl	total_dissolved_solids_mgl	sum_dissolved_constituents_mgl	hardness_mgl	alkalinity	sar	procedure_type
2441	<0.200 U	0			1756.1931	1928.198	1343.073	278.038	0.1662	DISSOLVED
2174	5.03	0		25.6	342.573	527.77	311.467	299.3624	0.2959	DISSOLVED
217053		0	0.56	88.8	378.6316	603.405	336.2094	363.3358	0.4034	DISSOLVED
212233	<0.200 U	0			645.2548	895.905	496.1834	405.1645	0.7227	DISSOLVED
217048		0	1.38	141.6	627.7905	996.155	604.7069	595.4441	0.23	DISSOLVED
217056		0	0.35	88.1	396.6567	623.967	368.7511	367.4366	0.2719	DISSOLVED
217050		0	0.67	71	352.3333	534.486	364.7043	294.4414	0.1823	DISSOLVED
255442	8.09	0		45.1	578.4227	744.339	455.5842	268.1959	0.5912	DISSOLVED
30542	8.48	0			337.7881	509.793	317.4745	278.038	0.2931	DISSOLVED
2526	0.48	0			410.3379	526.53	330.7916	187.8192	0.1675	DISSOLVED
279240	5.15	0			607.8265	921.393	528.5815	506.8657	0.6813	DISSOLVED
277205	<0.200 U	0			2395.6617	2735.105	1043.7872	548.6944	5.6432	DISSOLVED
164111		0			361.8189	496.277	291.5454	217.3453	0.2294	DISSOLVED
217052		0	1.47	44.9	616.8339	687.361	397.0893	114.0038	0.1747	DISSOLVED
223946		0	13.84	62.3	373.8047	528.051	306.3749	249.332	0.2486	DISSOLVED
215048		0	12.22	79.2	449.9015	612.266	359.978	262.4547	0.2523	DISSOLVED
152258	<0.200 U	0		25.1	661.3318	875.45	422.5086	346.1122	1.4818	DISSOLVED
146929	9.4	0		21	461.0123	663.968	419.0881	328.0684	0.3401	DISSOLVED
224151		0			269.3015	431.666	243.3513	262.4547	0.0837	DISSOLVED
224150		0	7.05	75.7	3817.1089	3887.636	2083.384	114.0038	0.1239	DISSOLVED
217047		0	0.94	58.2	396.9784	517.737	343.9291	195.2007	0.2581	DISSOLVED
224149		0	0.89	86.7	599.1151	789.386	479.6567	307.5641	0.1987	DISSOLVED
145604	0.42	0			270.954	392.22	226.3179	196.0209	0.2025	DISSOLVED
162423	2.26	0		49.7	501.9303	738.881	435.6477	383.0199	0.2919	DISSOLVED
31992	0.71	0			410.7153	528.937	328.8874	191.0998	0.168	DISSOLVED
236507					1035.905	1035.905	2603.4198	0	1.4412	TOTAL RECOVERABLE
236507	<0.200 U	0		132.76	3711.7431	4117.147	2665.7375	655.3166	1.399	DISSOLVED
217046		0	1.95	47.2	410.6559	538.518	320.2966	206.6831	0.1216	DISSOLVED
149852	<0.200 U	0		30.4	1146.959	1332.156	717.8602	299.3624	1.413	DISSOLVED
210668	1.43	0		42.6	1180.865	1423.397	782.0501	392.0417	1.4315	DISSOLVED
32000	4.22	0		19.5	323.9436	424.914	267.4598	163.214	0.0532	DISSOLVED
32009	0.26	0		20.9	446.3171	551.854	354.3177	170.5956	0.0694	DISSOLVED
141006	0.52	0		25.5	325.8207	422.732	270.1758	156.6527	0.0794	DISSOLVED
139022	0.59	0		29.7	335.3632	455.107	269.0191	193.5604	0.2388	DISSOLVED
245668	0.5	0		28.1	327.4103	436.499	277.1622	176.3368	0.0523	DISSOLVED
126078	<0.200 U	0		41.4	800.6394	960.467	599.7469	258.3539	0.462	DISSOLVED
31892	0.39	0		31.6	483.35	613.749	337.7083	210.7839	0.663	DISSOLVED
2528	0.49	0		31	397.1663	515.388	315.4388	191.0998	0.245	DISSOLVED
31939	1.33	0		28.6	630.2027	745.38	487.0231	186.1788	0.276	DISSOLVED
2309	0.82	0		33	352.7019	468.894	281.5799	187.8192	0.2593	DISSOLVED
205599	0.44	0		32.8	372.9756	494.749	293.8185	196.841	0.3046	DISSOLVED
149855	0.37	0		35.8	424.0222	543.766	326.9011	193.5604	0.3369	DISSOLVED
276129	5.8	0		39.5	264.6993	416.916	253.5488	246.0513	0.082	DISSOLVED
196148	1.97	0		38.8	316.321	474.119	287.5213	255.0732	0.154	DISSOLVED
31965	4.03	0		43.7	811.5346	1054.574	623.1125	392.8619	0.8716	DISSOLVED
32069	<0.200 U	0		35.2	317.449	447.848	276.167	210.7839	0.2095	DISSOLVED
239236	0.46	0		33.4	443.3528	572.737	336.006	209.1436	0.4748	DISSOLVED
242153	0.39	0		30.6	437.0587	563.906	327.902	205.0428	0.4566	DISSOLVED
248664	0.4	0		27.6	396.8167	521.127	306.626	200.9419	0.3727	DISSOLVED
252467	0.44	0		26.2	375.7156	497.489	301.7612	196.841	0.3006	DISSOLVED
235488	0.58	0		17.36	542.4568	671.841	403.5788	209.1436	0.4982	DISSOLVED
235689	0.35	0		21.42	663.996	785.262	497.3678	196.0209	0.3512	DISSOLVED
291365	0.39	0		20.47	481.5177	605.828	360.8815	200.9419	0.481	DISSOLVED
261984	0.48	0		25.05	781.248	911.647	590.0221	210.7839	0.4837	DISSOLVED
294553	0.7	0			391.0755	519.445	298.5234	207.5033	0.3526	DISSOLVED
279137	0.41	0			417.6431	543.983	315.5807	204.2226	0.4164	DISSOLVED
296888	3.98	0		27	293.2685	437.367	255.0511	232.9286	0.1907	DISSOLVED
281405	0.38	0		28.9	611.8793	745.83	459.6049	216.5251	0.4465	DISSOLVED
279108	0.42	0		25.2	433.2689	561.131	331.0954	206.6831	0.4544	DISSOLVED
214914		0		13.9	4350.09	4350.09	721.6511	0	0.3401	DISSOLVED
214914		0		14.2	5124.088	5124.088	892.423	0	0.335	DISSOLVED
214914		0		12.4	3927.433	3927.433	637.7524	0	0.3963	DISSOLVED

gwicid	no3_no2_n_mgl	oh_mgl	dissolved_organic_carbon_mgl	dissolved_inorganic_carbon_mgl	total_dissolved_solids_mgl	sum_dissolved_constituents_mgl	hardness_mgl	alkalinity	sar	procedure_type
214914		0			3562.392	3562.392	602.7236	0	0.4076	DISSOLVED
214915		0		25.4	4101.627	4101.627	812.5885	0	0.3053	DISSOLVED
214915		0		28.1	4184.784	4184.784	895.7027	0	0.2908	DISSOLVED
214915		0			3732.117	3732.117	794.6656	0	0.3241	DISSOLVED
214915		0			3605.491	3605.491	720.0905	0	0.3081	DISSOLVED
200616		0		8.04	2796.911	2796.911	758.0277	0	0.1897	DISSOLVED
200616		0		15.1	2565.087	2565.087	729.2188	0	0.2095	DISSOLVED
200616		0		11.5	2672.814	2672.814	724.8116	0	0.1778	DISSOLVED
200616		0		11.5	2440.234	2440.234	719.0869	0	0.1623	DISSOLVED
200616		0			2217.711	2217.711	623.2767	0	0.1743	DISSOLVED
200616		0		15.6	2454.375	2454.375	706.0377	0	0.1801	DISSOLVED
200616				12.9	2525.015	2525.015	749.057	0	0.159	DISSOLVED
200616		0		16.8	2474.4	2474.4	731.1492	0	0.177	DISSOLVED
200616		0			2033.212	2033.212	650.4899	0	0.1877	DISSOLVED
200616		0			2242.753	2242.753	699.9937	0	0.1645	DISSOLVED
200616		0			2387.068	2387.068	704.1997	0	0.1804	DISSOLVED
217524		0		0.11	5947.942	5947.942	928.9879	0	0.257	DISSOLVED
217524		0		1.11	4393.696	4393.696	697.8399	0	0.5106	DISSOLVED
217524		0		11.2	3931.798	3931.798	631.8715	0	0.2423	DISSOLVED
217524		0		11.1	4871.893	4871.893	741.7124	0	0.2876	DISSOLVED
217524		0			4541.83	4541.83	806.8043	0	0.3983	DISSOLVED
217524		0		11.1	3676.693	3676.693	779.558	0	0.3429	DISSOLVED
217524				10.6	4996.822	4996.822	676.4077	0	0.251	DISSOLVED
217524		0		19.7	4797.852	4797.852	691.4847	0	0.2648	DISSOLVED
217524		0			4349.984	4349.984	860.9871	0	0.3262	DISSOLVED
217524		0			4031.925	4031.925	722.7262	0	0.3399	DISSOLVED
217524		0			4872.721	4872.721	707.0554	0	0.2455	DISSOLVED
291863	<0.200 U	0		29.1	898.4628	963.916	484.6465	105.8021	0.4151	DISSOLVED
291863	<0.200 U	0		44.1	900.5284	963.952	489.5892	102.5214	0.354	DISSOLVED
291858	<0.200 U	0		28.2	3688.456	3688.456	981.9761	0	0.3888	DISSOLVED
291858	<0.200 U	0		25.3	3479.299	3479.299	1004.2649	0	0.3295	DISSOLVED
291861	1.53	0		1.3	13308.389	13308.389	1580.83	0	0.3721	DISSOLVED
291861	1.5	0		3.81	15032.851	15032.851	1820.683	0	0.2039	DISSOLVED
296887	1.2	0		1.53	4967.562	4967.562	1135.6187	0	0.3228	DISSOLVED
291865	0.22	0		1.94	2820.991	2820.991	1004.0016	0	0.2884	DISSOLVED
291865	<0.200 U	0		2.5	3870.83	3870.83	1039.6389	0	0.2969	DISSOLVED
291859	0.2	0		15.5	5806.189	5806.189	1295.544	0	0.1693	DISSOLVED
291859	0.35	0		14.3	5812.658	5812.658	1368.8096	0	0.1647	DISSOLVED
2262	0.6	0		2.45	5500.594	5500.594	1021.7415	0	0.2995	DISSOLVED
2276	1.86	0		1.37	9758.822	9758.822	1415.1668	0	0.2198	DISSOLVED
2262	0.47	0		13	5495.789	5495.789	1017.8784	0	0.2455	DISSOLVED
2276	1.81	0		4.96	9403.643	9403.643	1392.9138	0	0.1632	DISSOLVED