ABANDONED MINE LAND IMPACTS ON TRIBUTARIES IN THE UPPER YAKIMA RIVER WATERSHED, EASTERN CASCADES, WASHINGTON

A Thesis

Presented to

The Graduate Faculty

Central Washington University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

Cultural and Environmental Resource Management

---

by

Scott Kugel

May 2018

CENTRAL WASHINGTON UNIVERSITY

Graduate Studies

We hereby approve the thesis of

Scott Kugel

Candidate for the degree of Master of Science

APPROVED FOR THE GRADUATE FACULTY

_____ _____
Dr. Karl Lillquist, Committee Chair

_____ _____
Dr. Carey Gazis

_____ _____
Dr. Clay Arango

_____ _____
Dean of Graduate Studies

ABSTRACT

ABANDONED MINE LAND IMPACTS ON TRIBUTARIES IN THE UPPER YAKIMA RIVER WATERSHED, EASTERN CASCADES, WASHINGTON

by

Scott Kugel

February 2018

Effluent from abandoned mine lands (AMLs) in several drainages in Washington's Eastern Cascades flows into the Yakima River. Similar sites in Idaho and Colorado are known producers of heavy metals and acid mine drainage. I determined the effects of nine AMLs on water quality in four tributaries to the Yakima River. Archival work was conducted to determine sites that were mined and contained a mill. Each site was characterized by physical features. Water and sediment samples were collected above, at, and below each AML. Samples were analyzed for pH and heavy metal content, and evaluated to determine if the AMLs are sources of pollution as defined by EPA drinking water standards. Results show that mill sites in the Cle Elum and Teanaway River drainages are contributing small amounts of heavy metals to their surrounding environment. Analysis using modified USGS mine waste characterization techniques also shows that these sites are among the most likely to contribute these pollutants to fluvial systems. Additionally, due to local geologic influences, arsenic and lead in water samples were elevated above EPA standards throughout the study area, and the effects of acid mine drainage make these metals more bioavailable. These AMLs contribute to low discharge systems and the effluents from these sites will disproportionally impact them compared to larger downstream systems; however, it the effect they will have on either is

likely limited. These results may be extrapolated to other, similar small-scale, historical mineral processing sites in the region, indicating that they pose less environmental hazard than larger sites.

ACKNOWLEDGEMENTS

Many people deserve thanks for helping and supporting me throughout these past two years. I would like to thank my parents, Peggy and Ken Kugel for always being there for me, supporting me, and being my biggest cheerleaders. I would like to thank Dr. Karl Lillquist, my committee chair and advisor, for reaching out to me, bringing me into the program, and guiding me these past two years; without your help I would not have been able to make it anywhere near this point. I would also like to thank Dr. Carey Gazis for all the technical help and Dr. Clay Arango for being on my committee and helping to steer me. I would also like to thank Ellie Myers, my research assistant, for coming with me into the field, carrying heavy loads and being a huge help to me throughout the process. Dr. Angela Halfpenny, thank you for all the technical help and knowledge that you have given me. It was indispensable.

I would like to also thank Central Washington University Office of Graduate Studies and Research for a Graduate Student Summer Research Fellowship and a Master's Research Fellowship, the Geological Society of America for a Student Research Grant and the Kittitas County Audubon Society for a Kittitas Audubon Scholarship. Each provided essential funding for this research.

Finally, I would like to thank all my beautiful, wonderful friends that I have made here. Who would have thought that a small town in the middle of Washington would be so full of so many truly excellent people.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

Problem

Abandoned hard rock mining (i.e., lode mining) and processing sites, such as adits, mills, arrastras, and tailings piles, are collectively known as abandoned mine lands (AMLs). These features dot the eastern flanks of Washington's Cascades Range (i.e., Eastern Cascades) from the Columbia River north to the US-Canada border. The remnants of past gold, silver, copper, and zinc prospecting, these AMLs mostly date from the latter half of the 19th and the early 20th centuries (Woodhouse et al., 2002). At similar sites around the world, AMLs are known as active sources of pollution that commonly contribute heavy metals and acid mine drainage (AMD) into waterways (Lewin and Macklin, 1987; Nriagu, 1994; Miller, 1997; Malm, 1998; Concas et al., 2006; Donato et al., 2007; Ordóñez et al., 2013; Jacobs and Testa, 2014).

Estimates show that, from 1850 to 1900, more than 68,000 tons of mercury were released into North American environments due to mining and mineral extraction (Nriagu, 1994). Today, the federal government estimates that it spends between $80-85 million each year on the remediation of all types of mining locations (BLM, 2017a). However, only a handful of the over 500,000 known abandoned mine lands in the United States have been fully surveyed for their environmental effects (BLM, 2017b).

The Upper Yakima River Watershed contains many such mines. According to the United States Geological Survey (USGS) Mine Register Data System (MRDS), a compendium of information on mines throughout the US, 372 mines lie within the borders of Kittitas County, WA (USGS, 2018) (Figure 1). Of those, 250 are

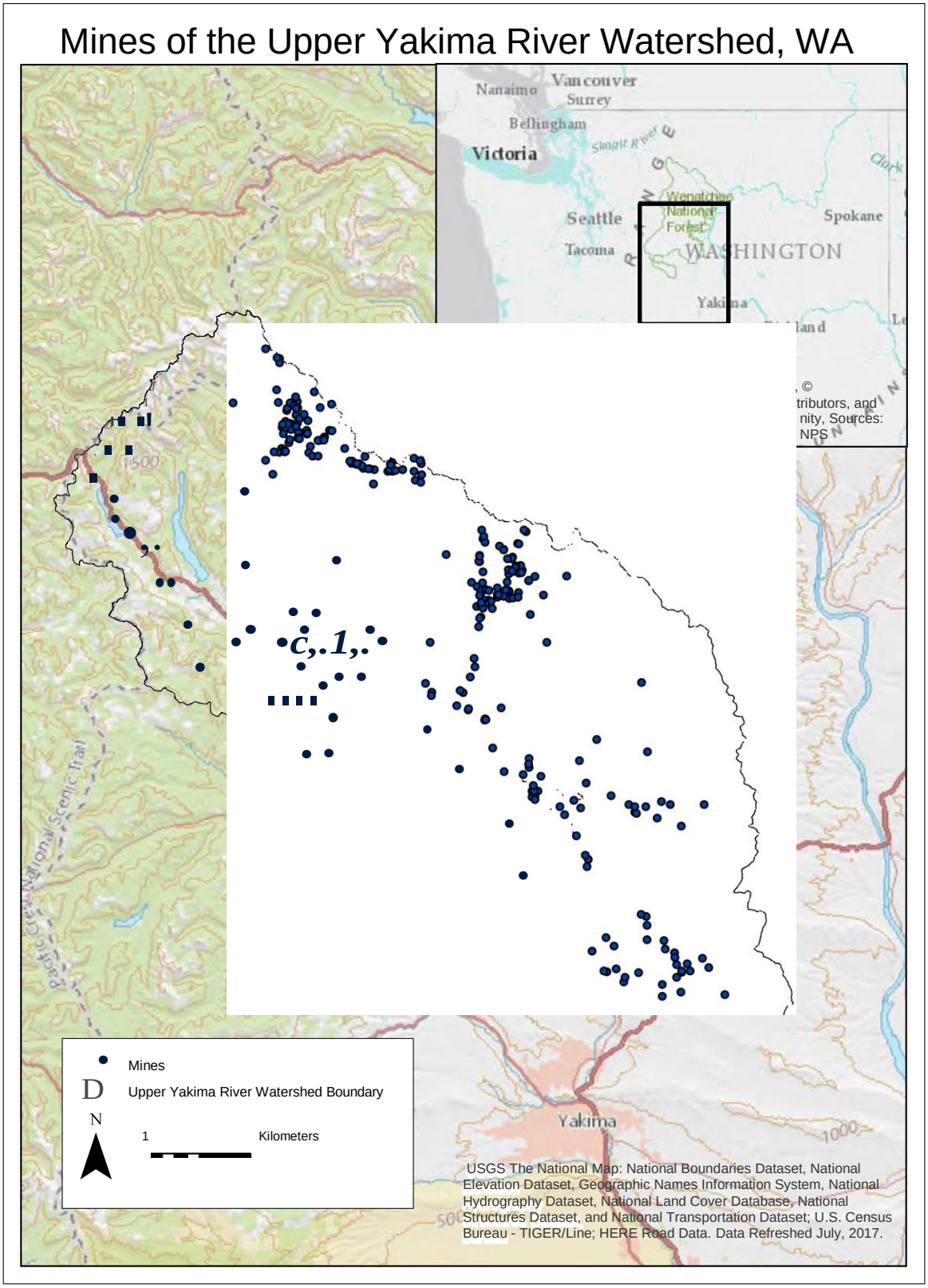


Figure 1: Active and abandoned mines in the Upper Yakima River Watershed. Data from USGS MRDS Database (USGS, 2018).

abandoned mines (USGS, 2018). The Washington Geological Survey has started to collect data on and catalog these AMLs as part of their Inactive and Abandoned Mine Lands Program (Washington Geological Survey, 2018). However, at this point, they are only looking at larger AMLs that produced more than 10,000 tons of ore in their lifespan, had a processing site on location, or had extensive underground workings. As such, they have identified about 60 sites statewide that meet these criteria. None of these sites are within the headwaters of the Yakima River, and only a handful are within the Eastern Cascades.

Serious environmental and health hazards have resulted from the mining and processing of ore in the Pacific Northwest. In Silver Valley, Idaho, these impacts have been particularly profound (Mix, 2016). This area is home to the most productive silver mines in the world and has a history of processing the ores stretching back into the 19th century. This region experienced dramatic deforestation, land degradation, and health and developmental problems such as intellectual impairment and death in children as a direct result of the mining and processing taking place (Mix, 2016).

In my study area, the effluent from AMLs flows into tributaries of the Yakima River, a drainage in the Eastern Cascades and a tributary of the Columbia River. It is home to anadromous fish populations and is used as a source of drinking water in the city of Cle Elum and as a source of irrigation for agriculture throughout the Yakima River Basin (BOR, 2011; 2012). This is problematic because, in humans, prolonged exposure to mercury may cause kidney and heart disease, and may even lead to death (Kerper et al., 1992; Räsänen and Mutanen, 1995). Prolonged exposure to heavy metals may cause nerve damage and thyroid problems (EPA, 2017). In fish, these substances can be lethal

and, in the case of mercury, can bioaccumulate and biomagnify across trophic levels (Neuman et al., 2014). Additionally, the acidification of sediment and water by AMD makes metals more mobile and bioavailable, allowing for easier accumulation in the human body (Neuman et al., 2014).

In the Eastern Cascades, data exists on general water quality of the area. Various state and local agencies run regular tests for inorganic, radioactive, microbiological contaminants, and disinfectant and disinfectant by products on Yakima River water quality as it relates to human safety and fish reproduction. However, very limited work has been done on the impacts of small AMLs on headwater streams of these areas (Leonhard, 2014; McKay et al., 2003).

Purpose

In this thesis, I assessed acid mine drainage and heavy metal pollution from nine small AMLs in the Yakima River Watershed and determined to what degree these features contribute pollution to fluvial systems. I approached this from three perspectives: archival, field, and laboratory. Archival work was conducted to gather general historic information on the AMLs examined in this thesis. Field investigations were used to collect data on each AML. In this phase I: 1) identified and verified nine AMLs within the Mineral Creek, Cle Elum River, and Teanaway River watersheds of the Yakima River; 2) characterized each AML site based on local geology, geomorphology, vegetation presence, and proximity to stream systems; 3) collected sediment samples from each AML site; and 4) collected water samples from the fluvial systems around each AML. In the laboratory, I: 1) prepared the collected samples; 2) analyzed the samples for pH and heavy metals content; and 3) evaluated the data to determine if these

AMLs are sources of pollution as defined by the U.S. Environmental Protection Agency in their National Primary Drinking Water Regulations (NPDWRs) (EPA, 2018). Finally, I made management recommendations to government policy makers and land managers overseeing the areas and disseminated the results to professionals and the public.

Significance

The BOR's Yakima Basin Integrated Water Resource Management Plan is a program funded by Congress to improve water quality and ecosystem health of the Yakima River Watershed for agricultural uses and aquatic life (BOR, 2011). As of 2011, this plan was estimated to cost at least $4 billion, and it involves enhancements designed to increase anadromous fish populations and improve the habitats of other threatened species (BOR, 2011, 2012). If small AMLs are contributing pollution in the form of heavy metals and/or AMD, then this management plan could benefit by considering these sites for remediation. By contributing to the information available on these AMLs, this research will help land managers make more informed decisions on how best to spend tax dollars to manage water quality and anadromous fish populations of the area.

In addition to anadromous fish, the Yakima River is also home to many species of birds and other animals that may be harmed by the output of these AMLs. The northern spotted owl (*Strix occidentalis caurina*), is listed as threatened by the Endangered Species Act, may be vulnerable to AML emissions. It occupies one of the highest trophic levels in the ecosystem, meaning it eats things that eat other things. Due to this, it absorbs the mercury and heavy metals that the other animals have absorbed. This raises the levels of these substances in the organism above background levels in the biomagnification process (Pouilly et al., 2013). This can lead to genetic damage and reproduction problems

in birds including infertility and loss of gender preference in mates (Pastor et al., 2001; Scheuhammer et al., 2007; Fredrick and Jayasena, 2011). All this hampers efforts to protect the spotted owl and promote reproduction in the species.

The Bureau of Land Management has created the Abandoned Mine Lands (AML) program to help manage AMLs on BLM land. They also coordinate with other federal agencies (e.g., the United States Forest Service, USFS) as well as state and local partners (e.g., Washington Department of Natural Resources, WADNR) to enhance water quality and mine safety in the western United States (BLM, 2017a). According to the BLM, AMLs are a danger that is increasing in severity as recreationalists more heavily use the wilderness areas that many AMLs occupy. They threaten people and the environment by releasing unknown pollution into waterways that can be absorbed by aquatic organisms, contributing to the negative legacy of human impact on these areas (BLM, 2017b).

Additionally, this research helps to expand the body of knowledge of mine runoff and waste remediation in the Eastern Cascades, an area that has not been comprehensively studied. By providing more information on what pollutants are produced by AMLs in this area, it will fill this gap. Additionally, because this water is home to anadromous fish species and is used for recreation, human consumption, and agricultural irrigation throughout the Yakima River Basin, this research will help public health officials, irrigation companies, and fisheries managers by informing them of the source of some infrequently monitored contaminants found in the water.

CHAPTER 2

LITERATURE REVIEW

Gold was first discovered in the Eastern Cascades in 1853 when members of George McClellan's expedition to find passes through the Cascades found it in the Yakima River near modern-day Ellensburg (Beckey, 2003). Over the next 50 years, mining would wax and wane throughout the area with miners flocking to the Eastern Cascades in search of riches, only to leave a few years later with very little to show for their efforts (Tozer, 1965; Beckey, 2003). As they created mines, miners also laid the groundwork for the AMLs that might someday pollute the landscape. What follows is a review of literature on the topics of mining in the Eastern Cascades, possible environmental effects of mining, and techniques and methods that have been developed to analyze and describe those effects.

Development of Mineral Deposits

Minerals are naturally occurring, inorganic, usually crystalline, substances of known chemical compositions and atomic structures, and are the core components of all rocks (Klein and Dutrow, 2007). Metal minerals exist in two main types of deposits: hard rock and placer (Healy, 1978). Hard rock, also known as hard rock metals, veins, or lodes, are bodies of a metal within another rock. If the metal is in large, continuous quantities it is often known as free milling. This is opposed to soft rock deposits which are generally made up of coal or salt. During mountain-building events, the component terrains undergo extreme metamorphosis that causes faulting within the rock and squeezes water out of it (Groves et al., 2003). Along with this water, dissolved ions, including metals, also transfer out of the rock (Groves et al., 2003). This water-ion mix is

then pushed to the surface, either through the direct movement of the fluid at faults or through igneous intrusion, where the ions precipitate into existing faults and fractures within the rock creating veins (Healy, 1978; Groves et al., 2003). These precipitates take the form of native minerals such as gold (Au), silver (Ag), copper (Cu), and Iron (Fe), other economically important minerals like galena (PbS), cinnabar (HgS), and Wolframite ($Fe,MnWO_4$), and associated gangue (i.e., unwanted) minerals such as quartz (SiO_2) and pyrite (FeS_2) (Healy, 1978; Groves et al., 2003). Placer deposits are secondary deposits that form when a vein of metal is eroded from surficial bedrock by a fluvial system (Healy, 1978). The placer develops over time as the eroded material collects at a point further down the system as alluvium (Healy, 1978).

In the Upper Yakima River Basin, metal veins are most often found where igneous dikes have intruded into the sedimentary Swauk Formation and the ultramafic Ingalls Tectonic Complex and at fault zones for both (Gualtieri and Simmons, 1964; Tabor et al., 1989; Metzger et al., 2002; Groves et al., 2003). In these locations, the metals are deposited through the previously described tectonic means (Groves et al., 2003). Metals commonly found in the Eastern Cascades include gold, silver, copper, molybdenum, iron, cobalt, lead, and nickel (Huntting, 1956).

Mineral Exploitation

The mining of metals goes back millennia to the Bronze Age where adits and shafts were used to extract gold, copper, tin, and other elements from the ground (Healy, 1978). Documentation exists from over 3,000 years ago of the extensive gold mines of Rameses II in Wadi Alaki in what is now Southeast Egypt and Northeast Sudan (Healy,

1978). The Egyptians, Greeks, and Romans developed many of the basic techniques still used in some form or another today (Healy, 1978).

The First Nation peoples of North America did not mine hard rock minerals (Rickard, 1937). They collected easily accessible placer deposits; however, these mostly consisted of copper, silver, and gold (Rickard, 1937). Early European settlers reported that the native people they encountered had jewelry and knives made of copper; however, these all appear to have been made of copper worked with tools without the use of a forge (Rickard, 1937). Since early settlers relied upon placer deposits as well, it was not until much after the settlement by Europeans that mining and forging processes began to be used in North America (Rickard, 1937; Ruvalcaba et al., 2009).

However, in South America hard rock mining had been occurring for over 500 years (Robins, 2011). Potosí, Bolivia is one of the most important of these locations. Potosi is a city in the Western Cordillera of the Bolivian Andes located at 4090 m. Rising nearly 700 m over the town, one of these mountains is Cerro Rico, which means "rich hill" in Spanish, and is home to the some of the most productive silver mines ever known (Robins, 2011). The first silver mining claim on Cerro Rico was registered in 1545 by Diego de Zenteno (Robins, 2011). It was quickly discovered that a silver deposit of previously unimagined wealth was located within the mountain (Robins, 2011). Within 30 years, it was the West's largest city (Robins, 2011). During the colonial period, Potosí produced 28,660 tons of silver (Robins, 2011).

In 1848, gold was discovered on the banks of the South Fork of the American River in Coloma, California. As word of the riches found at Sutter's Mill in California made its way east, group after group of prospectors started going to the goldfields of

Eastern California. Carson Valley, on the eastern slopes of the Sierra Nevada Mountains, was a popular location for these parties to camp before crossing to the west (Rickard, 1937). In 1849, a small faction of Mormons discovered placer deposits of gold in the valley while waiting for a late season snow to melt; however, these did not prove to be sufficiently economical and the party soon moved on (Rickard, 1937).

It was not until 1851 that this valley, now renamed Gold Valley, started to gain in popularity as a goldfield in its own right (Rickard, 1937). For the next six years, about $16.2 million in gold was collected from the valley's placer deposits. However, it took until 1858 for the source of these placer deposits to be found. One mine in this lode produced almost $500 million over its lifetime. This discovery was the Comstock Lode, one of the largest and earliest hard rock gold and silver discoveries in the United States. This and other similar mines throughout the western territories of the United States mark the beginning of the hard rock mining industry in the country.

In the Eastern Cascades, mining development began in 1874 along Swauk Creek in Kittitas County (Bethune, 1890). Ben Goodwin, a miner from California, discovered placer deposits when he was trying to find his way back to his camp (Bethune, 1890). Though extensive throughout much of the West, placer mining is not the focus of this thesis. Although it can have similar environmental impacts as lode mining, especially in the form of increased sediment lodes throughout a drainage, these effects can often be spread throughout a drainage, are often temporally close to the time of mining, and are hard to pinpoint to a singular site (Langedal, 1997; Miller, 1997; James, 2004).

A few years after the discovery of gold along Swauk Creek, C.P. Culver found placer deposits along Peshastin Creek in Chelan County (Bethune, 1890). Both of these

areas were incredibly profitable, and many miners flooded the area to work them (Bethune, 1890). Lode deposits were not discovered in this area until 1881 when Samuel S. Hawkins, Moses Splaun (sometimes spelled "Splawn"), and A.P. Boyles left the Peshastin Mining District to follow the Upper Cle Elum River in search of new placer claims, the first Euro-Americans to do so (Bethune, 1890; Hodges, 1897; Stancik, 1994). The group turned and followed Camp Creek and went over the southwest flanks of Mount Hawkins to Gallagher Head Lake (then called Lake Ennis) area to discover several hard rock mineral deposits (Bethune, 1890; Hodges, 1897; Stancik, 1994; Woodhouse et al., 2002).

Lode Mining and Mineral Processing

As development of these early American mines began, miners with experience in hard rock mining and processing began to make their way from other parts of the world to the western United States (Rickard, 1937). Up to this point, United States miners had mostly experienced placer mining (Rickard, 1937). Some went to Europe and other notable mining centers around the world to gain the necessary knowledge of lode mining; however, most gained it from experienced foreign miners who had come to work in the U.S. or developed their own techniques (Rickard, 1937). What follows is an overview of the processes used by miners in the Eastern Cascades and across Western North America.

Discovery of Lode Mines

Prospecting of an area for minerals almost always began with the search for placer deposits (Rickard, 1937). If the placer deposit was either already processed or already claimed, miners would begin to look around the general area of the mine for other deposits, be it hard rock or placer (Rickard, 1937). It was often then that someone would

find the signs of a deposit. Searching for minerals often consisted of looking for indications of changing geology such as changes in soils, fauna, or rock colors (Rickard, 1937; Caillaud et al., 2009). These could include exposed primary or secondary minerals, certain vegetation changes, and what is colloquially known as a "yellow boy" (Rickard, 1937; Healy, 1978; Jacobs and Testa, 2014). A yellow boy is produced by similar effects as those that are created by AMD (Jacobs and Testa, 2014). It is an iron hydroxide that precipitates when the highly acidic AMD is diluted by coming in contact with fresh water (Jacobs and Testa, 2014).

Once the yellow boy was located, miners would begin gold panning to locate the vein source. They would start well below the yellow boy and begin panning the gravel of the stream at consistent intervals as they moved up the stream. They would be looking for black sands, which are concentrations of heavier minerals like magnetite and gold in the form of coarse sand and gravel that settle out in the pools of the stream (Woodhouse et al. 2002). If the prospectors were consistently finding gold, they would continue moving up streams until they stopped finding gold, at which point they would know that the hard rock source was near and would begin to look for other signs.

Development of Lode Deposits

Once a lode deposit was located the development could begin. The first action that a miner would take after determining that there could be valuable minerals, would be to stake an unpatented claim with the local mining district or government as directed by the General Mining Act of 1872. This law gave miners the right to prospect and stake a claim on land in the public domain, which is federal land that has not been specifically excluded from this use. An unpatented claim would give miners the exclusive right to

mining on that land. If the miner so wished, they may apply for a patent to that land which would give the miner ownership of the land. This law is still in effect, with the exception of the patenting process, which was halted by congress in 1994 (36 CFR Part 228).

The miner would then begin excavating the ore and following the deposit. This could happen by directly following the ore body or by digging several tunnels to intersect the ore body at different levels (Ritchie and Hooker, 1997). If the miner excavated a tunnel vertically it was known as a shaft or winze. If it was horizontal it was known as an adit or a drift, although a drift does not have to meet with the surface (Ritchie and Hooker, 1997). Generally, if a shaft was excavated this would only be to a certain depth, at which point a drift would be constructed (Ritchie and Hooker, 1997). The surface opening of a tunnel was called a portal (Ritchie and Hooker, 1997). As the miner followed an ore body below the surface, the area that the ore was extracted from was called a stope. The process of removing the ore was called stoping (Ritchie and Hooker, 1997). If the body was exceptionally large and miners must excavate an entire room or if a large zone was excavated as a staging area, this was called a gallery or chamber (Ritchie and Hooker, 1997). If the mine went below the water table, the workings would gradually fill up with water. For mining to proceed the water would either be pumped out of the mine or an adit would be excavated to drain the workings (Rickard, 1937). Over time, this water may become contaminated by the chemicals used in the mining process and by weathered minerals.

To excavate the mines and extract the ore, miners used several tools. A pickaxe would be used to break apart rocks. A gad (occasionally spelled gadd) or pointed metal

bar would be used in conjunction with a sledgehammer to dislodge rocks and drill holes in the rock, similar to how a chisel would be used with a hammer (Ritchie and Hooker, 1997). In the mid 1800s, the mechanical percussion drill was invented (Lynch and Rowland, 2005). The first drills used steam power to bore holes in rocks; however, by the 1880s these drills were switched to compressed air and had significantly shrunk in size from a couple metric tons to about 180 kg (Lynch and Rowland, 2005). By the turn of the 20th century these drills were sufficiently light for one person to operate (Lynch and Rowland, 2005).

Black powder has been used in mining and excavation work since the 17th century (Lynch and Rowland, 2005). However, it was not a preferred method by many miners due to its inherent instability, the lack of a reliable means of safely lighting it, and the large quantities required to effectively use it (Lynch and Rowland, 2005). It was not until after the improvement of the safety fuse by William Bickford in 1831 and the development of the considerably safer TNT and, later, dynamite in the 1860s, that explosives would become relatively safe and common in mines (Lynch and Rowland, 2005). A gad or drill was used to create a hole and the explosive were placed in it (Lynch and Rowland, 2005). Several of these were linked together and detonated as one to loosen large amounts of bedrock at once (Lynch and Rowland, 2005). After the ore was separated from the country rock through these methods, it was then brought to the surface for processing. This could be accomplished through the use of a bucket and pulley system or rails and mine carts.

Ore Processing Techniques

Once ore was extracted from a mine, it was processed to separate the gangue from the minerals. The first step of this process was to pulverize the ore into much smaller pieces. Widely used at smaller mines due to their relative ease of construction and low cost, an arrastra was a small mill built *in situ* that operated in a similar manner as a mill for pulverizing grain (Weaver, 1911; Tozer, 1965). This process migrated north with Mexican miners making their way to the California Goldfields (Rickard, 1937). They were constructed using either stone from the area or cement and could be anywhere from a meter to several meters in diameter (Weaver, 1911; Tozer, 1965). A large stone or a metal ball weighing up to a ton, known as a drag block, was used to roll over the ore, turning it into fine particles (Weaver, 1911; Tozer, 1965; Lynch and Rowland, 2005). These could be powered by animals, water, or humans (Weaver, 1911; Rickard, 1937; Tozer, 1965).

Mills were constructed at larger and more profitable mines where the increased productivity could justify their cost (Weaver, 1911; Tozer, 1965; Lynch and Rowland, 2005). At some locations, stamps weighing as much as half a ton were used to crush the ore and each stamp could process about a third more ore than an arrastra (Weaver, 1911). Some mills had as many as 150 stamps operating at one time (Weaver, 1911; Lynch and Rowland, 2005). Other mills used a jaw-type crusher to pulverize the ore (Lynch and Rowland, 2005). These operated by having a set of jaws that would crush the ore in a masticating-type motion with one jaw moving and one jaw remaining in place (Lynch and Rowland, 2005). Often these would have a flywheel attached to them to provide additional force to the jaws (Lynch and Rowland, 2005). Yet others operated with

tumbling or rolling mills (Lynch and Rowland, 2005). These mills consisted of a drum filled with pebbles, cast-iron or forged steel balls, or metal rods slightly shorter than the length of the mill (Lynch and Rowland, 2005). Ore would be added to the drum and it would then be rotated causing the ore and grinding medium to be lifted up the side of the drum and then dropped to the bottom crushing the ore (Lynch and Rowland, 2005). These mills were often powered by steam engines, but some locations used waterwheels instead (Weaver, 1911; Lynch and Rowland, 2005).

After the ore has been crushed, the most common processing technique of late 19th and early 20th century mines was the "patio method" (Weaver, 1911; Tozer, 1965; Nriagu, 1994; Macklin et al., 2006). This involved the crushing of ore in a mill followed by the extraction of gold or silver using either mercury or a cyanide solution (Weaver, 1911; Tozer, 1965; Macklin et al., 2006). Early on, the crushed ore would be added to a mercury solution because of its affinity to bond with gold and form an amalgam (Tozer, 1965; Nriagu, 1994; Woodhouse et al., 2002; Washborn and Hill, 2003; Lynch and Rowland, 2005; Robins, 2011). The amalgam would then be collected, and the gold and mercury would be separated by distillation (Tozer, 1965; Nriagu, 1994; Woodhouse et al., 2002; Washborn and Hill, 2003). This method would be used for high grade ores that contained coarse-grained minerals (Lynch and Rowland, 2005). It was also not very effective with only about 25% of the mineral recovered (Lynch and Rowland, 2005).

In 1887, John Stewart MacArthur, Dr. Robert Forrest, and Dr. William Forrest developed the MacArthur-Forrest process, that utilized a cyanide solution to dissolve gold, silver, and copper that was suspended in the solution in the form of raw ore (Tozer, 1965; Hunt et al. 1988; Ritchie and Hooker, 1997; Donato et al., 2007; Syed, 2012). The

minerals could then be precipitated from the solution and the solution reused (Tozer, 1965; Hunt et al. 1988; Ritchie and Hooker, 1997; Donato et al., 2007; Syed, 2012). This extremely effective process allowed 90% of the gold and 50% of the silver to be recovered, allowing the processing of finer grained minerals and often the re-processing of tailings to recover more minerals (Tozer, 1965; Hunt et al. 1988; Ritchie and Hooker, 1997; Lynch and Rowland, 2005; Donato et al., 2007; Syed, 2012).

However, the MacArthur-Forrest Process was not suitable for sulfide ores (Lynch and Rowland, 2005). The flotation process was developed in the early 20th century as a solution to this problem (Lynch and Rowland, 2005). This process requires that the ore be crushed very finely and mixed into a slurry (known as "pulp") with water and chemicals in a tank (Lynch and Rowland, 2005). The pulp is then aerated from the bottom of the tank (Lynch and Rowland, 2005). The minerals attach to the bubbles and float to the surface creating a froth at the top of the tank that can then be collected (Lynch and Rowland, 2005). The chemicals used depended on the specific ore that was being processed, were often highly guarded secrets, and generally changed from one mill to the next (Rickard, 1937; Lynch and Rowland, 2005).

These processes were not put in use overnight. Instead, they were developed over periods of time and often had to be reworked for different mineral assemblages (Rickard, 1937). Sometimes, a highly educated professional would help in this process as was the case with Nathaniel Peter Hill who was a professor of chemistry at Brown University before starting the Boston & Colorado Smelting Company (Rickard, 1937).

Once the ore was processed and the minerals extracted, the gangue was discarded in the form of tailings. Modern mines carefully encapsulate the tailings to limit their

interaction with outside systems, but historical mines had no such process. Tailings would often be deposited immediately downhill of a mill, often wherever it was easiest to put them. Nearby canyons or gullies were also popular locations to deposit the tailings as they would be out of the way of mine operations. If tailings are not reworked to extract more minerals from them, they will sit in place, often indefinitely, until acted upon by an outside force such as a stream (Nyssen and Vermeersch, 2010; Martín Duque et al., 2015).

Geomorphic and Hydrologic Impacts of AMLs on Fluvial Systems

Fluvial systems are the main, potential, transportation sources for the pollution examined in this study. They may interact with the mining waste that contains the pollution and redistribute it, having lasting effects on the physical and chemical character of the system. Due to this, it is important to understand the origin of the landforms they interact with and how they are introduced into the systems.

Tailings piles (or heaps) are anthropogenic landforms made up of the waste from mineral processing and are considered a byproduct of the mining industry (Macklin et al., 2006; Nyssen and Vermeersch, 2010). They generally contain the processed gangue (generally very fine grained), wastewater from the mining or processing, and other waste material disposed of by the miners (Macklin et al., 2006; Nyssen and Vermeersch, 2010). Most often, tailings are found very near the processing site as there was little incentive to move them further than necessary (Macklin et al., 2006; Nyssen and Vermeersch, 2010).

Once deposited, tailings may be introduced into streams through several means. Originally, mass wasting would be a major factor; however, the piles stabilize over time and stream erosion becomes the primary method of introduction while also contributing

to mass wasting. The erosion of tailings includes the breaking apart, or disaggregation, of tailings through the processes of undercutting (removing the vertical support of a body), headward erosion (erosion by a stream channel towards its originating location), and incision (erosion of a stream channel vertically into in its bed). All potentially move the particles away from the tailings landforms (Martín Duque et al., 2015). After removal or separation from their landforms, tailings can then easily be carried into fluvial systems by runoff or overbank flooding.

AML Fluvial Process

AMLs may impact ecosystems through physical and chemical means. As physical features, AMLs can drastically impact fluvial systems altering their course. Over time they can begin to physically creep downslope, killing vegetation and destroying habitat as they encompass them (Lewin et al., 1977; Langedal, 1997; Miller, 1997; James, 2004; Wildeman et al., 2007). As a chemical factor in the environment, AMLs may cause severe degradation, damaging or killing flora and fauna and poisoning waterways (Lewin and Macklin, 1987; Nriagu, 1994; Miller, 1997; Malm, 1998; Concas et al., 2006; Donato et al.; 2007; Wildeman et al., 2007; Ordóñez et al., 2013; Jacobs and Testa, 2014).

If a tailings pile is quickly deposited in an incised river valley and blocks off the stream, a valley spur cutoff may form (James, 2004). The deposition may occur at the time of mining or processing or may be due to the natural movement of the system into a pile. The stream must have a sufficiently low flow that it cannot remove the sediment as it is being deposited (James, 2004). This forces the stream to rise up against a meander that is formed by a valley spur. The stream will then incise the spur cutting it off (James, 2004). This process is much quicker than similar natural processes (up to 50 cm a year),

due to the high flow power of the altered stream and the availability of abrasives from the tailings (James, 2004). The erosion may exploit existing weaknesses in the structure of rock, such as vertical bedding, that could also hasten the process (James, 2004). Due to the increased stream gradient caused by the incision, local sediment transport may increase; however, it may be hindered over the whole system as the narrowing of the channel prevents downstream sediment movement (James, 2004).

This type of introduction of tailings falls into a category known as active dispersal, active participation, or active transformation. It is the transportation and deposition of sediment by a fluvial system that produces a lasting change to that system (Lewin and Macklin, 1987; Macklin et al., 2006). This can occur in both stable and unstable stream channels (Lewin and Macklin, 1987; Macklin et al., 2006). In stable streams, a meandering channel may turn into a braided channel with the introduction of large amounts of tailings (Lewin and Macklin, 1987). The stream will form bars in low gradient reaches to store the increased sediment load that will only be moved downstream by flood events (Langedal, 1997). After mining stops, degradation begins to occur. Eventually, a stream may return to a meandering course when the introduced tailings have moved downstream (Lewin et al., 1983; Lewin and Macklin, 1987; Macklin et al., 2006).

Vincent et al. (1999) observed that with active dispersal of braided channels, when large amounts of sediment are introduced, degradation and lateral erosion are the first processes to occur. Aggradation then follows, and the tailings sediments are deposited on top of other sediments (Vincent et al., 1999).

Overbank and floodplain deposits occur in all types of streams during active dispersal as well (Lewin et al., 1977; Lewin and Macklin, 1987). These deposits may contain significant amounts of tailings sediments (Lewin et al., 1977; Langedal, 1997; Miller, 1997). Although finer material is generally always being moved, the larger caliber particles require high discharge events to be transported thus move intermittently, rather than in a continuous stream (Lewin and Macklin, 1987). These large, powerful flood events are required to both place and remove these deposits (Langedal, 1997). Due to this, Langedal (1997) noted that increased channel resistance to vertical or lateral change increases the time that these tailings sediments are present in the system. This is because the channels with higher stability are more prone to overbank deposits that take longer to be moved away (Langedal, 1997). Without it, they are deposited as normal fluvial deposits that are moved more readily by fluvial processes (Langedal, 1997). Once in place, these overbank deposits become new sources of sediments themselves (Lewin et al., 1977).

As tailings age, they are slowly weathered by natural processes. Erosion and mass wasting may cause the pile to spread out. This movement can shift around hardier vegetation such as trees, and smother grasses and small brush (Wildeman et al., 2007). This can result in an area around the downslope edge of the AML without vegetation (Wildeman et al., 2007). The presence of this buffer area has only been associated with the physical movement of the tailings and has not been linked with a chemical process (Wildeman et al., 2007).

Instability and mass wasting are large factors impacting the hydrology of the Upper Cle Elum River and introduce sediment to system (Plum Creek, 1995). Among

these factors are debris flows, avalanches, and landslides. These events occur mostly in the headwaters of streams where the steep sides of cirques create ideal conditions for mass wasting. The transportation of the sediment from these events is controlled by the two main lakes of the drainage, Hyas and Tucquala Lakes, and the low gradient of the middle reach of the river. The lakes provide storage for sediment passing through the area and do not allow further transportation downstream (Plum Creek, 1995). The analysis also found that the middle reach, from below Hyas Lake to the confluence with Paris Creek, has a remarkably low gradient (0.5-4%) which allows for the storage of coarse sediments. However, high flow events can mobilize these sediments (Plum Creek, 1995).

In the Teanaway drainage, the USFS has determined that the north fork of the river is the most at risk of mass wasting due to the glacially altered terrain that comprises most of the area (USFS, 1998). The over-steepened slopes that comprise this portion of the drainage are highly susceptible to shallow rapid debris flows, inner gorge failures, and deep-seated landslides (USFS, 1998, p. 4-15). The findings of this analysis determined that the De Roux Creek and Gallagher Head Lake areas are highly sensitive to mass wasting and have the ability to deliver the sediment downstream, while the area around the Skookum Mine is only moderately sensitive to mass wasting (USFS, 1998).

Acid Mine Drainage

Acid mine drainage (AMD) is a major natural hazard associated with AMLs (Jacobs and Testa, 2014). It is the result of the natural oxidation reaction of iron sulfide minerals with water and oxygen (Jacobs and Testa, 2014). It occurs wherever these minerals are present, such as natural outcrops. However, when mining occurs, and ore is extracted, the crushed-up gangue has a much higher surface area available to oxidize,

dramatically increasing the amount of AMD produced (Jacobs and Testa, 2014). Additionally, the underground workings of AMLs often fill with water, allowing the reaction to occur and concentrating its effects until it overflows due to an input of additional water or it seeps out.

The chemical reaction that produces AMD starts with the exposure of iron sulfide minerals like pyrite (FeS_2) to oxygen and water (Equation 1) (Jacobs and Testa, 2014). The reaction separates the iron from the sulfur in the sulfide and the hydrogen from the oxygen in the water (Jacobs and Testa, 2014). The sulfur and oxygen then combine to create a sulfate (SO_4^{2}) leaving ferrous iron (Fe^{2+}) and proton (H^{+}) ions (Jacobs and Testa, 2014).

1) $FeS_{\$} + 7O_{\$} + 2H_{\$}O \rightarrow 2Fe^{\$+} + 4SO^{\$-}_{-} + 4H^{+}$

The free proton ions created by this process lower the pH of the rest of the water that has not reacted (Jacobs and Testa, 2014). These effects can create streams that are nearly uninhabitable for plant and animal life (Skousen and Jacobs, 2014). Additionally, because AMD increases the number of dissolved solids present in the solution, it can be tested by examining the electrical conductivity, dissolved oxygen, oxidation reaction potential, total dissolved solids, or turbidity of a stream (Skousen and Jacobs, 2014). However, pH is generally used as the major test for AMD because the equipment is available widely and the impacts are easily assessed (Skousen and Jacobs, 2014).

Heavy Metals

"Heavy metal" is an ambiguous term but is often agreed to mean elements with a density greater than 5 g/cm^3, or about five times as dense as water (Tchounwou et al., 2012). Of these metals, arsenic, cadmium, chromium, lead, and mercury are considered to pose the highest threat to human health because they affect multiple organs and are carcinogens. They are used in many forms throughout our world (Tchounwou et al., 2012). Mining and metal production, in particular, is a major point source polluter of these elements. These metals naturally occur in the earth's crust and the processing of the mined rock releases the metals in the form of dust and also allows the metals to leach out of rocks at an increased rate (Tchounwou et al., 2012). The impacts of these elements can have varying effects depending on exposure level, length of exposure, and form to which an organism is exposed (Tchounwou et al., 2012).

Arsenic

Arsenic has been used as an agricultural product and as a component of medicinal compounds for over a century (Tchounwou et al., 2012). Most forms of arsenic, with the exception of arsine (C_5H_5As), are about equal in levels of toxicity (ATSDR, 2007a). Arsine is much more toxic than other forms of arsenic but is extremely uncommon naturally because it is highly volatile (ATSDR, 2007a). Organic arsenic compounds primarily consist of methyl (CH_3) and phenyl (C_6H_5) groups (ATSDR, 2007a). Because the bonds between arsenic and carbon in these molecules is extremely strong, mammalian metabolism cannot generally separate them. Therefore, these arsenic compounds do not commonly impact mammals (ATSDR, 2007a). However, inorganic arsenic compounds do not contain carbon and the arsenic within them can interact with mammal bodies

(ATSDR, 2007a). The main components of inorganic arsenic compounds are monomethylarsonic acid and dimethylarsinic acid (ATSDR, 2007a). These are created by a methylation process of As(V) to As(III) in the liver, which make it more accessible by the body (ATSDR, 2007a).

Oral ingestion is the most common form of arsenic consumption (ATSDR, 2007a). Dermal effects may include irritation and skin lesions (ATSDR, 2007a). Cardiovascular effects may include altered myocardial depolarization, irregular heartbeat, heart disease, and loss of circulation in the extremities (ATSDR, 2007a). Gastrointestinal effects may include severe irritation of the stomach and colon (ATSDR, 2007a). Neurological effects may include confusion, pain in the extremities, seizures, hallucinations, and coma (ATSDR, 2007a).

Cadmium

Cadmium is present throughout much of Earth's crust and is generally found in highest concentrations in sedimentary rocks at about 15 mg/kg (Tchounwou et al., 2012). It is released in many industrial processes, especially mining and mineral processing, is found in high quantities in cigarette smoke, and is released in relatively small amounts from fossil fuel combustion; however, due to the large amount of combustion that takes place, it can be major source (ATSDR, 2012a; Tchounwou et al., 2012; WHO, 1992). It is only present in the environment in an oxidation state of +2.

The most common uptake methods of cadmium are through ingestion and inhalation; however, as inhalation is mostly due to cigarette smoking it will not be discussed in this forum (ATSDR, 2012a). Respiratory effects may include pulmonary fibrosis and emphysema (ATSDR, 2012a). Cardiovascular effects may include heart

attack and peripheral arterial disease (ATSDR, 2012a). Gastrointestinal effects may include stomach and colon irritation and lesions (ATSDR, 2012a). Hematological effects may include anemia (ATSDR, 2012a). Musculoskeletal effects may include softening and weakening of bones, loss of bone density (ATSDR, 2012a). Renal effects may include anuria and kidney failure (ATSDR, 2012a). Neurological effects may include behavioral issues and decreased IQ in children (ATSDR, 2012a). Reproductive effects may include decreased reproductive success (ATSDR, 2012a). Death due to pervasive organ failure may also be an effect of cadmium exposure (ATSDR, 2012a).

Chromium

Chromium holds a distinction amongst this particular group as it is an essential element (i.e., an element necessary for the proper functioning of the body) at lower concentrations but at higher concentrations it can be very harmful (Tchounwou et al., 2012). It is used in the metabolism process (Tchounwou et al., 2012). It is recommended that an average adult ingest 20-45 μg but no more than 72 μg of chromium a day (ATSDR, 2012b).

Chromium is often found in the body in two valence states Cr(VI) and Cr(III) (ATSDR, 2012b). Cr(VI) is more dangerous then Cr(III) because it is more effectively absorbed since it uses a facilitated glucose uptake mechanism to enter the body whereas Cr(III) diffuses across cell membranes (ATSDR, 2012b). The associated impacts of these forms of chromium are different; however, this is mostly just a difference in the magnitude of the effects (ATSDR, 2012b). Respiratory effects may include bronchitis, pneumoconiosis, and pneumonia (ATSDR, 2012b). Gastrointestinal effects may include bleeding and necrosis of the stomach, and colon and abdominal pain (ATSDR, 2012b).

Immunological effects may include increased sensitization to new allergens (ATSDR, 2012b). Hematological effects may include anemia (ATSDR, 2012b). Reproductive effects may include deformation of the male gamete, infertility, and difficulties during gestation and birth (ATSDR, 2012b). Dermal effects may include burns and ulcers (ATSDR, 2012b).

Lead

Lead occurs naturally in the environment; however, over the last 300 years those levels have increased by several orders of magnitude (ATSDR, 2007b). Human exposure most often occurs with inorganic lead compounds as a result of leaded gasoline, corroded lead pipes, or metal mining and associated processing activities, such as the leaching of tailings (ATSDR, 2007b).

Neurodevelopmental effects may include impaired cognitive function, especially in children (ATSDR, 2007b). Cardiovascular and renal effects may include high blood pressure, heart disease, and decreased kidney function (ATSDR, 2007b). Hematological effects may include anemia (ATSDR, 2007b). Musculoskeletal effects may include weakness and cramps of the muscles, joint pain, and osteoporosis (ATSDR, 2007b). Hepatic effects may include significantly decreased liver function (ATSDR, 2007b). Endocrine effects may include altered thyroid, pituitary, and testicular production of hormones (ATSDR, 2007b). Exposure to lead may also significantly depress immunological responses and increase mortality rates (ATSDR, 2007b).

Mercury

Mercury has been used as part of the gold and silver mining process for millennia (Nriagu, 1994). Mercury is generally found in the environment in one of its valence states

(Ullrich et al., 2001). Hg^0, elemental or metallic mercury, is the natural state of mercury when it has not bonded with any other substance and is what miners would have used as part of the amalgamation process. When exposed to certain organic molecules, mostly from decaying organic matter, elemental mercury oxidizes into its most stable form Hg(II) (mercuric mercury) (Ullrich et al., 2001). Mercuric mercury is stable because it bonds with anions that fully fill its electron shell (ATSDR, 1999). Anaerobic microbes may interact with any form of mercury and methylate it into its most dangerous form, methylmercury (ATSDR, 1999; Ullrich et al., 2001). Methylmercury is dangerous due to how it easily bonds with lipids, the fatty acids organisms need to survive, cobalamin (vitamin B12), and proteins (ATSDR, 1999; Ullrich et al., 2001). At moderate pHs (4-9), mercury will precipitate from water as it bonds with sulfides; however, at acidic pHs and where large amounts of organic carbon is present, methylation increases (ATSDR, 1999). Hg(I) is rarely found as it is unstable and will readily disassociate into Hg^0 or Hg(II) (Ullrich et al., 2001).

With the exception of dimethylmercury, mercury rarely volatilizes under normal conditions and can remain as part of a system indefinitely (ATSDR, 1999). The decreased concentration of mercury in natural systems is due to the flux of the element between systems (e.g., mercury precipitate out of solution and is moved downstream by the flow of the water) (ATSDR, 1999).

Depending on exposure level, length of exposure, and the form of mercury that an organism is exposed to, mercury can have many life-altering and lethal effects (ATSDR, 1999). Oral ingestion of mercury is the most common and studied form of exposure (ATSDR, 1999). Respiratory effects may include shortness of breath, pulmonary edema,

fine crackles (a high-pitched crackling sound produced by the lungs during inhalation), and pulmonary hemorrhage (ATSDR, 1999). Cardiovascular effects may include tachycardia, bradycardia, irregular pulse, elevated blood pressure, hyperkalemia, and cardiac arrest (ATSDR, 1999). Renal effects may include renal failure and renal toxicity (ATSDR, 1999). Neurological effects may include tremors, forgetfulness, irritability, fatigue, peripheral neuropathy, vertigo, insomnia, muscular weakness, fretfulness, sleeplessness, weakness, photophobia, hyperactive or hypoactive tendon reflexes, confusion, dysphagia, low brain weight, low brain volume, cerebral abscesses, paresthesia, astereognosis, neuronal degradation, and death (ATSDR, 1999).

Characteristics of Yakima River Water

As part of the National Water Quality Assessment Program, the Yakima Basin has had multiple extensive studies look at its water quality (Morace et al., 1999; Hughes, 2003). These studies found that the inorganic water chemistry of the Yakima River is heavily influenced by the underlying geology of the area, especially in the headwaters of the Yakima River as these rivers and streams have the most direct contact with rock and are the least diluted portions of the river (Morace et al., 1999; Hughes, 2003). Tributaries further down river, such as Wilson Creek, in the Kittitas Basin, are primarily located in Quaternary deposits, which do not impact the water chemistry as drastically (Morace et al., 1999; Hughes, 2003). Antimony, arsenic, chromium, copper, mercury, nickel, selenium, and zinc all have been identified at higher than normal levels in the streambed sediments of the Upper Yakima River Basin as well as in aquatic fauna as compared to the Lower Yakima River Basin (Morace et al., 1999; Hughes, 2003). Of the sites surveyed, the highest concentrations of arsenic found was 5.3 ppb (Morace et al., 1999;

Hughes, 2003) Chromium in the river has been of particular note as it is in the 95th percentile for concentration in Western United States (1,800 ppm) (Morace et al., 1999; Hughes, 2003).

In 2012, ground and surface water samples collected by the USGS in the Upper Yakima River Basin were analyzed for isotopic concentrations as part of a larger study of the area (Hinkle and Ely, 2013). Analyses were run for aluminum, antimony, barium, beryllium, boron, cadmium, chromium, cobalt, copper, lead, lithium, molybdenum, nickel, selenium, silver, strontium, thallium, vanadium, zinc, and uranium. This research found that the chemistry of the water did not exceed water quality standards (Hinkle and Ely, 2013).

AML Sampling Techniques

Hageman (2007) and Smith et al. (2000) created techniques used to sample and test the sediments from AMLs in remote locations. Smith et al. (2000) describes the Mine-Waste Dump Sampling Strategy that is a statistically-based method for quickly taking representative average surface samples from an AML feature. It involves splitting an AML feature into a grid of at least 30 sections and taking equal-sized soil samples from each section (Smith et al., 2000). The technique then mixes the samples together and sifts out the larger particles that are greater than 2 mm, leaving a remaining sample with a total mass of no less than 1 kg (Smith et al., 2000). If moist, samples are air dried and mixed. Larger particles are sifted out, partly due to weight restraints, but also due to the smaller caliber sediments being more readily transportable and containing a larger share of contaminants (Hageman, 2007; Smith et al., 2000).

The USGS Field Leach Test (Hageman, 2007) is a way to use the representative samples collected using Smith et al.'s (2000) technique and analyze them for pH, metals, and sulfates. This involves, in the field, taking representative samples, mixing 50 g with 1,000 g (1 L) of deionized water in a clean and capped container, vigorously agitating it for five minutes, and letting it settle for ten additional minutes (Hageman, 2007). A small portion of the sample (i.e., an aliquot) is removed and preserved for testing (Hageman, 2007). A 60 cc portion of the water is then removed from the settled sample using a syringe and forced through a sterile 0.45 μm filter (Hageman, 2007). An aliquot of the liquid that has been passed through the filter is also taken and preserved for testing (Hageman, 2007). The remaining sample can then either be disposed of in the field or brought back to the laboratory (Hageman, 2007).

The USGS Techniques of Water-Resources Investigations has been published as a way of standardizing water sample collection (2015). This handbook lays out methods that help researchers make decisions on the best way to sample fluvial systems based on the individual physical and biological characteristics of that system (USGS, 2015). It also provides guidance on best practices for sample collection (USGS, 2015).

Skousen and Jacobs (2014) present a way of testing for the presence of AMD in water in the field. One of the main effects of AMD is a drop in pH (Skousen and Jacobs, 2014). By using a handheld meter or test strips that measure pH, it is possible to quickly test for the effects and locate the source of AMD by walking up a stream (Skousen and Jacobs, 2014). As the meter moves closer to the source of AMD the pH of the stream will decrease (Skousen and Jacobs, 2014). When the meter has passed the source of the AMD, the readings should reverse (Skousen and Jacobs, 2014). The investigator may then go

back over the same ground to where the readings are the strongest and search for the source of the AMD (Skousen and Jacobs, 2014).

Wildeman et al. (2007), in conjunction with the USGS, developed the Mine Waste Decision Tree as a way to quickly and easily determine if mining waste in the western United States, such as those found in AMLs, presents a risk to fluvial systems. It uses sediment criteria such as size and stream proximity, biological factors including vegetation presence, geomorphic factors of erosion and mass wasting, and the chemical criteria of dissolved calcium carbonate ($CaCO_3$), pH, and specific conductance to discern the environmental risk of AMLs (Wildeman et al., 2007). It accomplishes this by ranking each factor on a scale from one to five which it then aggregates to make a determination on the ability of the AML to contribute pollutants to the watershed (Wildeman et al., 2007).

AML Analysis Techniques

Agilent Technologies, the maker of the 8900 Triple Quadrupole Inductively Coupled Mass Spectrometer, has published a method for the use of the machine for mercury analysis by Chen et al. (2016). It involves the use of a collected sample in an aqueous state that is then placed in the machine and analyzed to determine ionic concentrations.

The EPA has implemented the NPDWRs as a way to regulate water quality and represent legally enforceable limits. They represent the highest concentration of a substance that water can have without an adverse effect on the human body or aquatic life (Table 1) (EPA, 2018). The EPA divides their standards into two categories: Maximum Containment Levels (MCL), which are the highest amount of the heavy metal that may

Table 1: NPDWRs for select heavy metals (EPA 2018).

	Arsenic	**Cadmium**	**Chromium**	**Lead**	**Mercury**
MCL (ppb)	10	5	100	15	2
MCLG (ppb)	0	5	100	0	2

legally be found in drinking water, and Maximum Containment Level Goals (MCLG), which are the highest amount of the heavy metal that can be found in water without a health risk (EPA, 2018). Sometimes the numbers are different, other times they are the same. For pH, the National Secondary Drinking Water Regulations (NSDWRs) are used. These are non-enforceable guidelines that are either cosmetically or aesthetically undesirable. The NSDWRs for pH are 6.5-8.5 (EPA, 2018).

AML Remediation Techniques

Remediation techniques for AMLs generally fall into three categories: removal of the AML feature; denial of access to the AML; and treatment of the effluent that comes off the AML. The removal of an AML feature involves entirely removing all portions of an AML from the site. This is the most complete way of eliminating the environmental risks posed by AMLs. However, it is also often the most expensive. Due to the remote nature of many AMLs, the amount of material that makes up most AMLs, and the fact that not all AML features can be removed (e.g., adits and portals) this process is often impossible at many sites. This is especially so in wilderness areas such as the Alpine Lakes Wilderness in the Eastern Cascades, where law limits what activities may be performed.

Denial of access is the process of covering an AML in an impermeable barrier so that water, flora, and fauna cannot access it (Johnson and Hallberg, 2005; Donato et al., 2007). This can be accomplished in several ways depending on the nature of the AML. For a deep mine shaft, the flooding of the shaft and then the sealing of all entrances can prevent it from interacting with the outside world (Johnson and Hallberg, 2005). The flooding is a natural process though the sealing can be either natural or anthropogenic. The flooding prevents oxygen from interacting with the rock and waste present in the mine, with the exception of what small amount of dissolved oxygen is present in the water (Johnson and Hallberg, 2005). This dissolved oxygen is quickly used up by chemical reactions (Johnson and Hallberg, 2005). By hermetically sealing the mine, outside oxygen is prevented from replenishing the dissolved oxygen in the water (Johnson and Hallberg, 2005). However, this is costly and only works if all entrances to the mine are known (Johnson and Hallberg, 2005). For tailings piles and similar above ground AMLs, denial of access is possible if the feature is capped with an impermeable layer such as clay (Johnson and Hallberg, 2005). This clay layer will not allow water to pass through and interact with the tailings within (Johnson and Hallberg, 2005). The site may then be covered with soil and planted to act as an erosional buffer (Johnson and Hallberg, 2005). Due to the remote nature of many mines, these processes can often be prohibitively expensive.

The treatment of AML effluent, especially AMD, can be split into two main groups, abiotic and biological remediation, both of which contain active and passive methods (Johnson and Hallberg, 2005). Abiotic methods involve the introduction of a neutralizing agent into the effluent that cancels out the effects of the AMD (Johnson and

Hallberg, 2005). Active methods generally introduce the neutralizing agent on an as-needed basis while passive methods create an environment that the effluent must pass through that contains the neutralizing agent (Johnson and Hallberg, 2005). A popular passive method is creating an anoxic limestone drain, which is essentially a buried mass of limestone that mine effluent is diverted through (Johnson and Hallberg, 2005). Biological methods involve the introduction of bacteria that neutralize the acidity of the water (Johnson and Hallberg, 2005). Additionally, an active method for the remediation of cyanide in tailings piles involves aerating, acidifying, and adding water to the pile to increase the rate of volatilization (Johnson, 2015). They may also be used to detoxify mine effluent containing cyanide (Akcil and Mudder, 2003). Active methods introduce bacteria while passive methods create an environment that the effluent must pass through (Akcil and Mudder, 2003; Johnson and Hallberg, 2005). When constructing an environment for passive remediation, a wetland that is a natural habitat for these bacteria is often built downstream from an AML (Akcil and Mudder, 2003; Johnson and Hallberg, 2005).

Within the Eastern Cascades, these practices have been used at several sites, the most well-known of these being the Holden Mine above Lake Chelan in Chelan County. Mineral production began in the area of the Holden Mine in the late 1800s as a series of copper mines (USFS, 2012). It was not until the 1930s that mining activity began to take off and continued at a high level until 1957. Large amounts of tailings and waste rocks are present at the site. Starting in 1989, the USFS began work to remediate the impacts of this mine. Their efforts included the consolidation of tailings and waste rock from many smaller heaps into several larger ones. They also contained tailings, waste rock, and

effluent by constructing physical barriers around the site and at the portals of the mine. Additionally, they constructed a plant to clean water from the site before discharge into the ecosystem (USFS, 2012).

CHAPTER 3

STUDY AREA

Location of Study Sites

The study area for this research includes three tributaries in the upper Yakima River Basin (Figure 2). These systems, Mineral Creek, Cle Elum River, and Teanaway River, are situated in the Eastern Cascades in the western half of Kittitas County, colloquially known as the "Upper County." All are located in the boundaries of the Okanogan-Wenatchee National Forest.

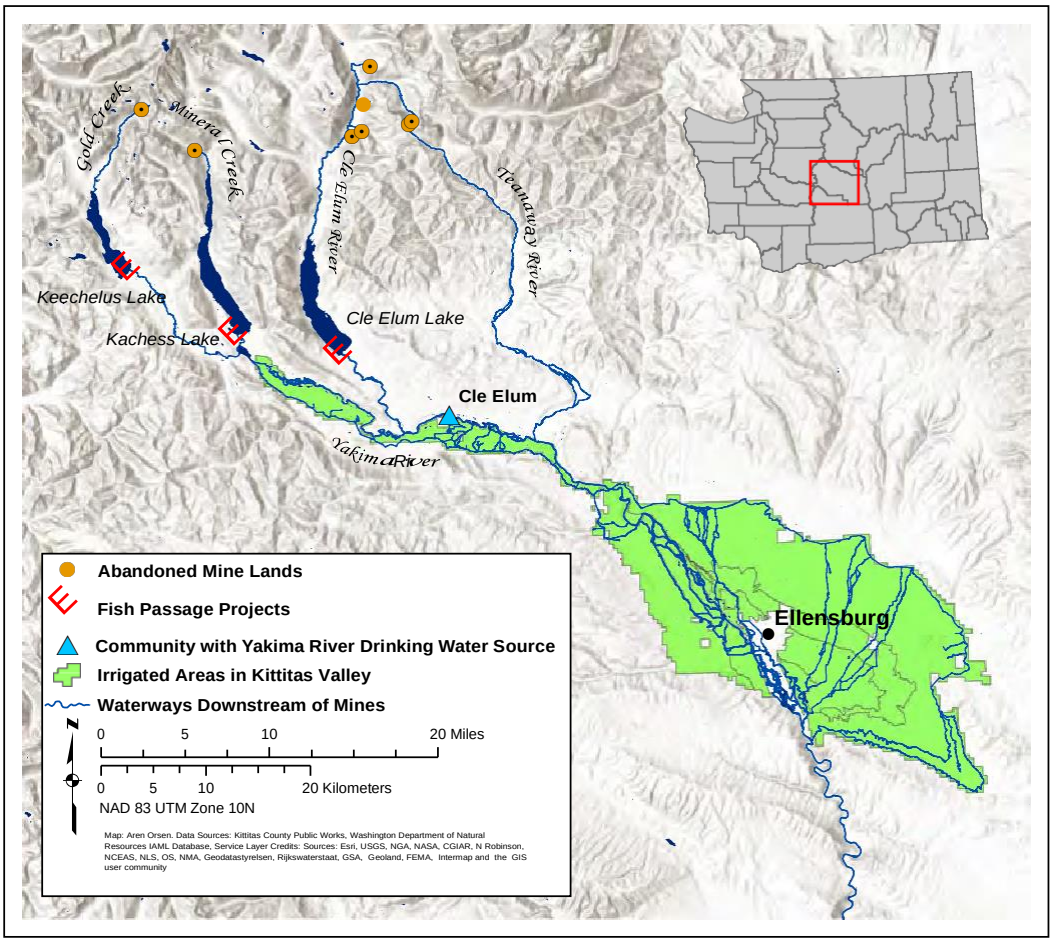


Figure 2: Select AMLs of the Eastern Cascades.

Mineral Creek Drainage

The Mineral Creek drainage begins near the Cascade Crest at Park Lakes and flows in a west-southwest direction to its junction with the Kachess River (Figure 3). The Kachess River Flows into Lake Kachess which then flows into Lake Easton where it connects with the Yakima River. Mineral Creek is bounded by Chikamin Ridge to the north, Box Ridge to the south, and Rampart Ridge to the west. This drainage contains the Mineral Creek claim (47° 25' 27.36" N, 121˚ 15’ 19.43” W) (occasionally erroneously called the Durrwachter Prospect or Liberty Lode). It is located on the north side of the creek near water level about 7.5 km from the Cascade Crest. Also in this area is the Copper Queen Mine which is located on the south side of the creek about 1 km up-stream and 18 m above the creek (Patty, 1921).

Access to the mine is via the Mineral Creek Trail at the end of Forest Service Road #4600. The mill site is located 2.25 km from the trailhead on the north side of the trail, with a total elevation gain of about 150 m. Adits of the mine are shown on the USGS Chikamin Ridge and Pollalie Ridge 7.5-minute quadrangles (Figure 3).

The climate of the area is best characterized by the National Weather Service Stampede Pass climate station (47˚16'59" N, 121˚19'59" W). Located on the Cascade Crest roughly 16 km southwest of the mouth of Mineral Creek, the climate is characterized by warm, dry summers and cold, wet winters (Figure 4). The mean annual temperature of the pass is 5.3º C with a mean annual precipitation of 206.3 cm (WRCC, 2018). The warmest and driest month is August with a mean temperature of 14.7º C and a mean precipitation of 3.1 cm (WRCC, 2018). The coldest month is December with a mean temperature of -2.9º C and the wettest month is November with a mean

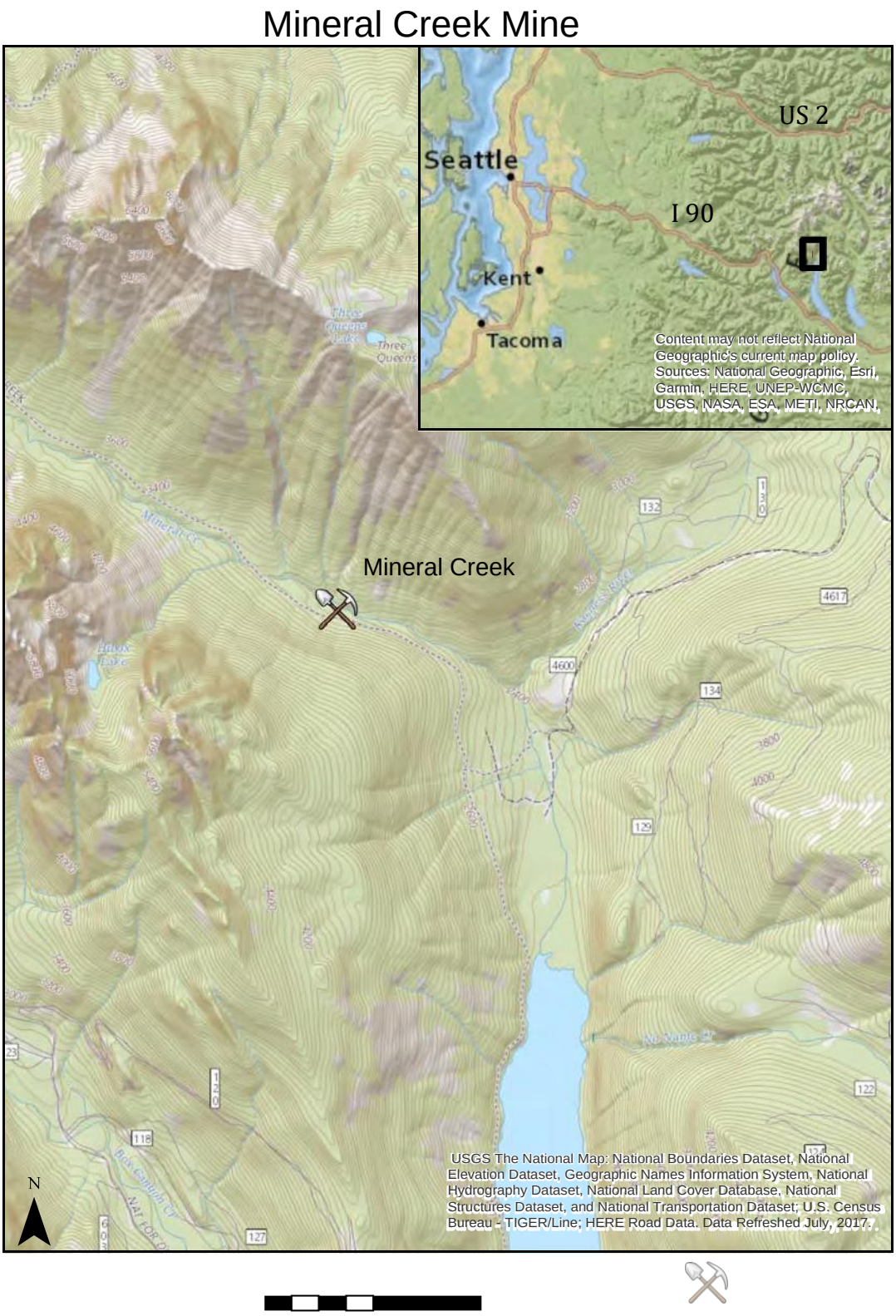


Figure 3: The Mineral Creek claim and the surrounding area. Based on the USGS Chikamin Ridge and Pollalie Ridge 7.5-minute quadrangles.

precipitation of 37.2 cm (Figure 4) (WRCC, 2018). Snow is present from October through June with an average maximum snow depth of 264.2 cm (WRCC, 2018).

Within the Mineral Creek basin, the main geologic components consist of sedimentary and igneous rocks (Figure 5) (Tabor et al., 2000). The Naches Formation is a highly folded and faulted interbedded sedimentary and igneous belt of the Green River-Cabin Creek Block (Tabor et al., 2000). It was deposited from the middle Eocene to the early Oligocene, about 44 Ma to 33.9 Ma, during the third event of the Cascade Orogeny (Tabor et al., 1989; Tabor et al., 2000). It is made up of sandstone, siltstone, and shale with a high content of mica and other silicate minerals and occasionally lesser amounts of quartz (Tabor et al., 2000). About a quarter of the formation is composed of various volcanic interbeds either in the form of flows (rhyolite, andesite, and basalt) or in a

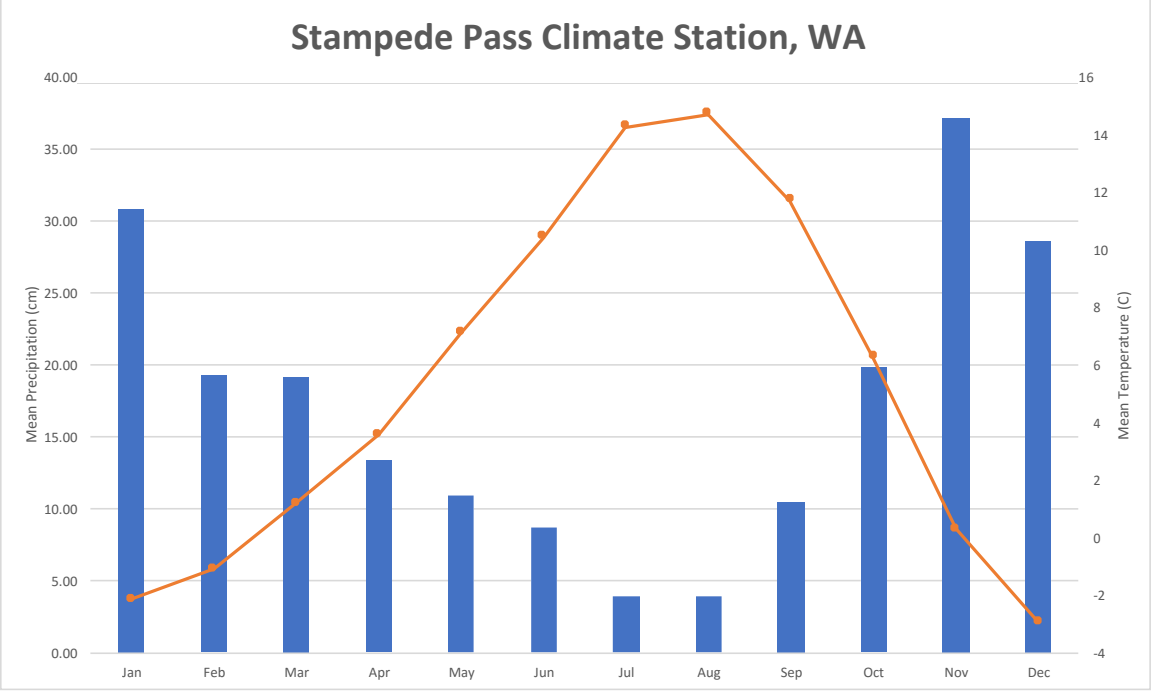


Figure 4: Temperature (line graph) and precipitation (bar graph) recorded at the Stampede Pass climate station, climate normal 1981-2010 (WRCC, 2018).

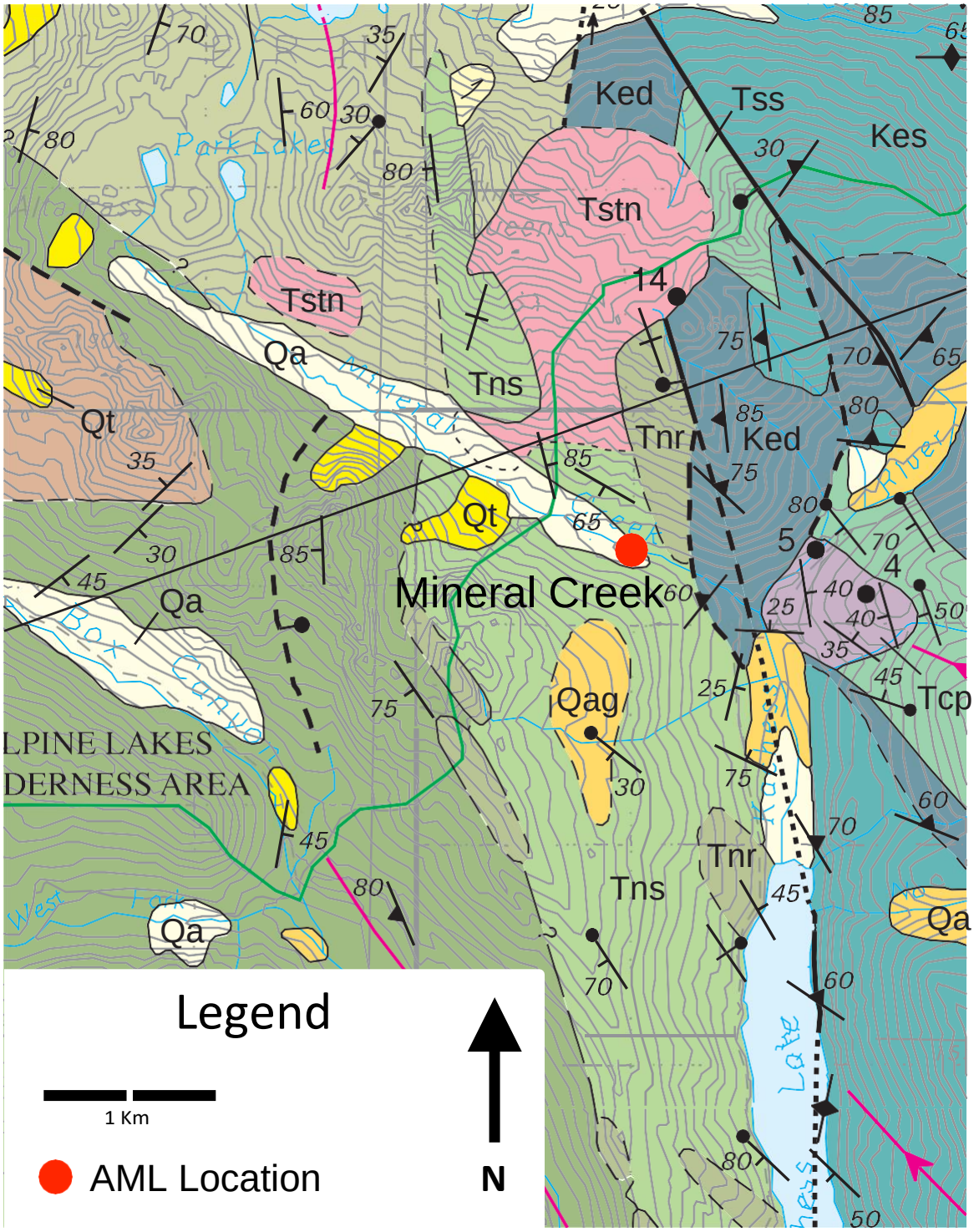


Figure 5: Location of the Mineral Creek AML on the Geologic Map Of The Snoqualmie Pass 30 × 60 Minute Quadrangle, Washington (adapted from Tabor et al., 2000).

breccia (tuff) (Tabor et al., 2000). Occasionally, coal seams may be found in shale portions of the formation (Tabor et al., 2000).

The Snoqualmie Batholith is a Miocene and Oligocene intrusion into the Green River-Cabin Creek Block from about 33.9 Ma to 5.3 Ma, during the fourth stage of the Cascade Orogeny (Tabor et al., 1989; Tabor et al., 2000). This outcrop is characterized as a light-colored granodiorite and tonalite composed primarily of biotite and hornblende (Tabor et al., 2000). In the Mineral Creek area, this specific formation is known for large grained crystals of copper sulfide minerals (Tabor et al., 2000). This formation has been intruded by dacite dikes (Grant, 1969).

The contact between the Snoqualmie Batholith and the Naches Formation creates a narrow mass of sulfide breccia at creek level (Grant, 1969). The breccia consists mostly of a 50:50 mix of pyrite and chalcopyrite ($CuFeS_2$) (Grant, 1969). Also present to lesser extents are free mill gold and silver, molybdenite (MoS_2), and chalcocite (Cu_2S) (Derkey et al., 1990; Grant, 1969). This is exposed for about 140 feet along the creek which is the area that was predominantly mined in the watershed (Grant, 1969). The gangue minerals included pyrite, pyrrhotite ($Fe_{1-x}S$ (x=0 to 0.2)), and quartz (Derkey et al., 1990).

Work began on the Mineral Creek claim in 1917 by Charles and Ernest Durrwachter when they founded the Mineral Creek Copper Company (Huntting, 1956; Woodhouse et al., 2002) (Table 2). A mill was constructed on the south side of the creek in 1920 that could process 22.5 metric tons of ore a day (Patty, 1921; Weed, 1922) (Figure 6). Ore was transported to it by a tram across the river built at the same time (Patty, 1921). The mill consisted of a No. 2 Dodge Crusher, Forester rod mill, Ziegler

Table 2: A quick reference guide to available important information about each mine being examined in this study.

Mine Name	Years Operated	Geologic Units	What Was Mined	How Ore Was Processed
Mineral Creek	1917-1972	Naches Formation, Green River-Cabin Creek Block, Snoqualmie Batholith	Au, Ag, Cu, Mo	Dodge Crusher, Forester Rod Mill, Ziegler Flotation Machine, Wifley Shaker Table
Silver Creek	1937-1956	Ingalls Tectonic Complex	Au, Ag	Mill
Maud O	1889-1930	Ingalls Tectonic Complex	Au, Ag	Five-stamp mill, concentrator
Ida Elmore	1891-1964	Ingalls Tectonic Complex	Au, Ag	Ten-stamp mill, smelter
Gallagher Head Mines	1881-1951	Ingalls Tectonic Complex	Cu, Ag, Au, Co, Cr	1,500 lb stamp mill
Skookum	1902-1981	Swauk Formation/ Ingalls Tectonic Complex	Cu	Cyanide processing plant

Figure 6: Mineral Creek mill as seen from the north looking south. Creek is downslope and to the north. Ellie Myers (left), Scott Kugel (right). A No. 2 Dodge Crusher can be seen above and to the left of Ellie. A Forester rod mill can be seen below and to the right of Scott. August 2017. Photo by Karl Lillquist, August, 2017.

Flotation Machine, and a Wilfley shaker table (Patty, 1921). Ziegler Flotation Machines were capable of processing 70-90 metric tons every full day (Rice, 1918) (Figure 7). In 1920, 18 metric tons of ore, presumably copper bearing, was sent to Tacoma for smelting (Huntting, 1956). In that same year, they made a public offering of their company selling 100,000 shares in Ellensburg for $0.25 each and keeping 600,000 shares for themselves (Weed, 1922).

Work continued on the mine by the Durrwachters until 1926 (Huntting, 1956). At some point prior to 1945, a cabin was built to the southwest of the mill site on the southern bank of the creek (Figure 8) (Panieri, 1945). In 1951, the property was acquired by the Cascade Gold Mining & Milling Company out of Spokane, Washington (Huntting, 1956). Harve H. Phipps of Spokane was the president and Ernest Durrwachter was manager (Purdy, 1952). By 1953, the president of the company had changed to John E. Baldwin of Los Angeles, CA. (Purdy, 1953). Ernest Durrwachter remained as manager (Purdy, 1952). The operations closed in 1953 (Purdy, 1953). The Phelps Dodge Corporation drilled a 1,098 m deep bore hole to explore the potential of further development of the area in 1972 (Thurber et al., 1964). After that, operations appear to have ceased at the site. The main workings of the mine consist of a 15 m deep shaft (now water-filled) that met a 75.6 m drift (Patty, 1921; Huntting, 1956).

Upper Cle Elum River Drainage

The Upper Cle Elum River watershed comprises all streams and rivers that lead into Lake Cle Elum. The drainage is located in the area to the north of the lake and starts just above Hyas Lake near Deception Pass and flows into the northern-most portion of the river. It is bounded to the south by Chikamin Ridge, No Name Ridge, and Red

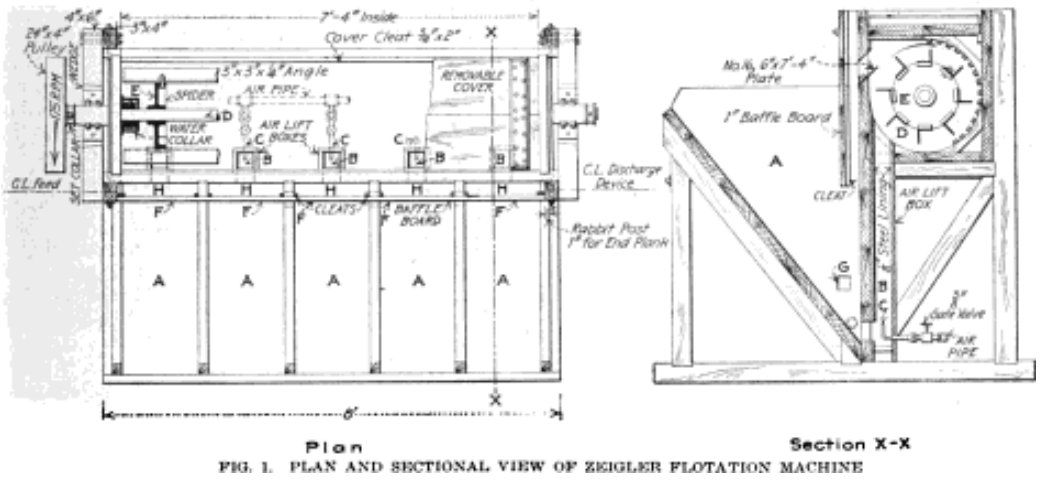


Figure 7: Ziegler Flotation Machine (Rice, 1918).

Figure 8: View down valley (i.e., southeast) of cabin on the Mineral Creek claim in 1945. Mineral Creek is to the left and the Mineral Creek Trail (#1331) to the right. The mill site is about 30 m further down valley and to the left (Panieri, 1945).

Mountain, to the east by Sasse Ridge and the Wenatchee Mountains, and to the west by the Cascade Crest. The Upper Cle Elum River drains into Lake Cle Elum which itself drains into the lower Cle Elum River. This meets with the Yakima River about 3 km upstream of the city of Cle Elum.

This drainage contains the Silver Creek groups of claims (47º 29’ 37.67” N, 121º 1’ 45.38” W), the Maud O (occasionally referred to as the Modog) claim (47°27'27.00" N, 121° 1'49.08"W), and the Ida Elmore (alternatively referred to as the Melade or Hughes-Wayman) claim (47°27'41.93" N, 121° 1'40.41" W) (Derkey et al., 1990) (Figure 9, 10). The Silver Creek group of claims consists of an upper (47° 29' 42.00" N, 121° 2' 24.72" W) and a lower claim (47° 29' 39.48" N, 121° 2' 46.32" W). They are located on Silver Creek about 13 km from the Cascade Crest. The Maud O and Ida Elmore claims are located along Camp Creek about 14.5 km from the Cascade Crest.

Access to the Silver Creek mines is via a derelict road along the Cle Elum River Road (Forest Service Road #4330) near the confluence of Silver Creek and the Upper Cle Elum River. The lower workings are about 0.5 km up the road and the upper working another 0.5 km above with, a total elevation gain of 170 m. Each site is labeled as “Adits” and “Prospect” respectively on the USGS Davis Peak 7.5-minute quadrangle (Figure 9).

The Camp Creek mines can be reached by Forest Service Road #140. The Maud O mine is about 1.3 km up the road from Camp Creek. At this point, a narrow trail on the northeast side of the main road leads to the mine. The Ida Elmore mine can be accessed by continuing on the main road another 1.6 km to a junction with a trail that heads north. This trail continues 0.6 km to the mine with a total gain of 617 m of elevation. The Maud O site is labeled as “Adit” on the USGS 7.5-minute quadrangle of Davis Peak.

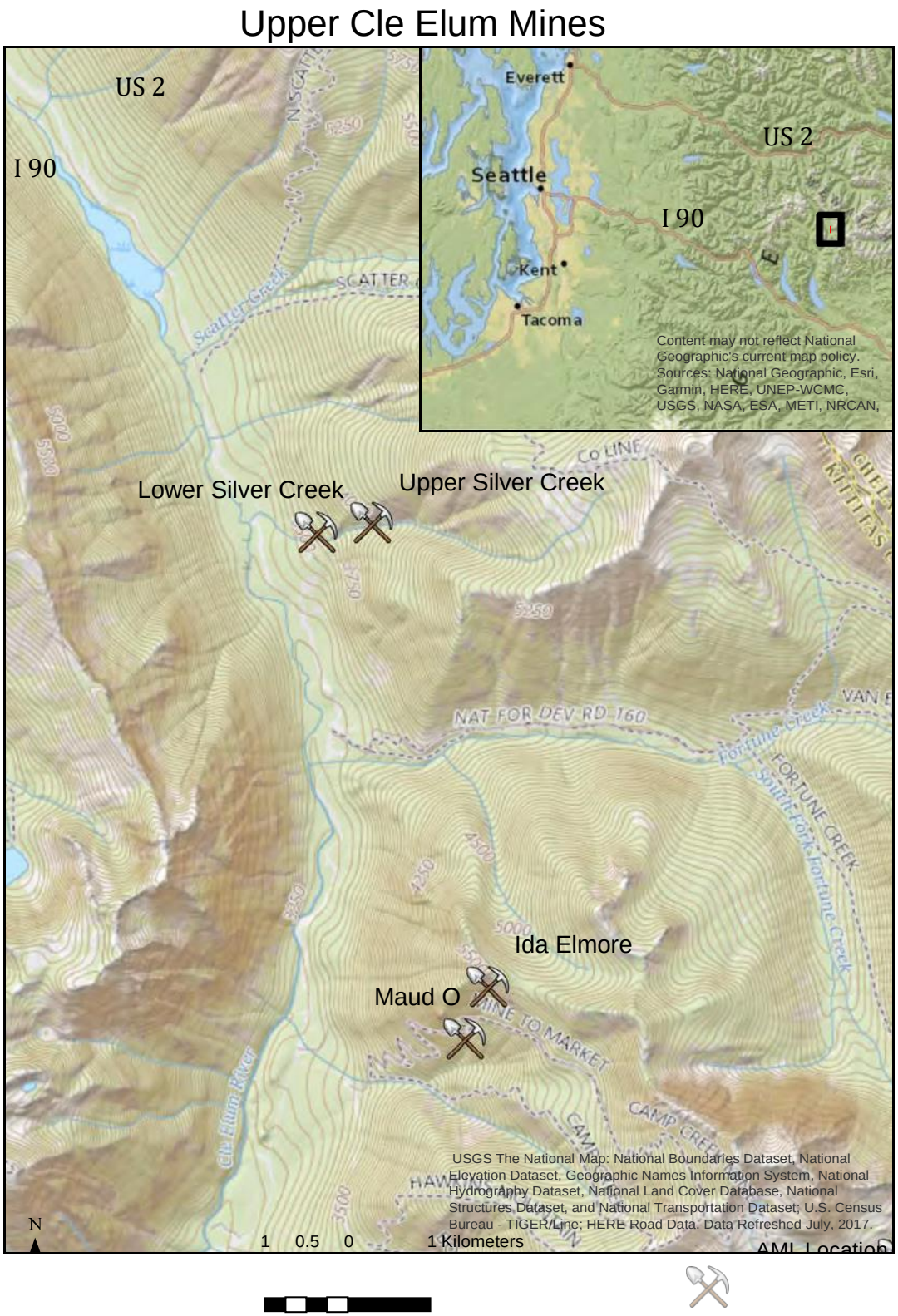


Figure 9: Mines of the Upper Cle Elum River and the surrounding area.

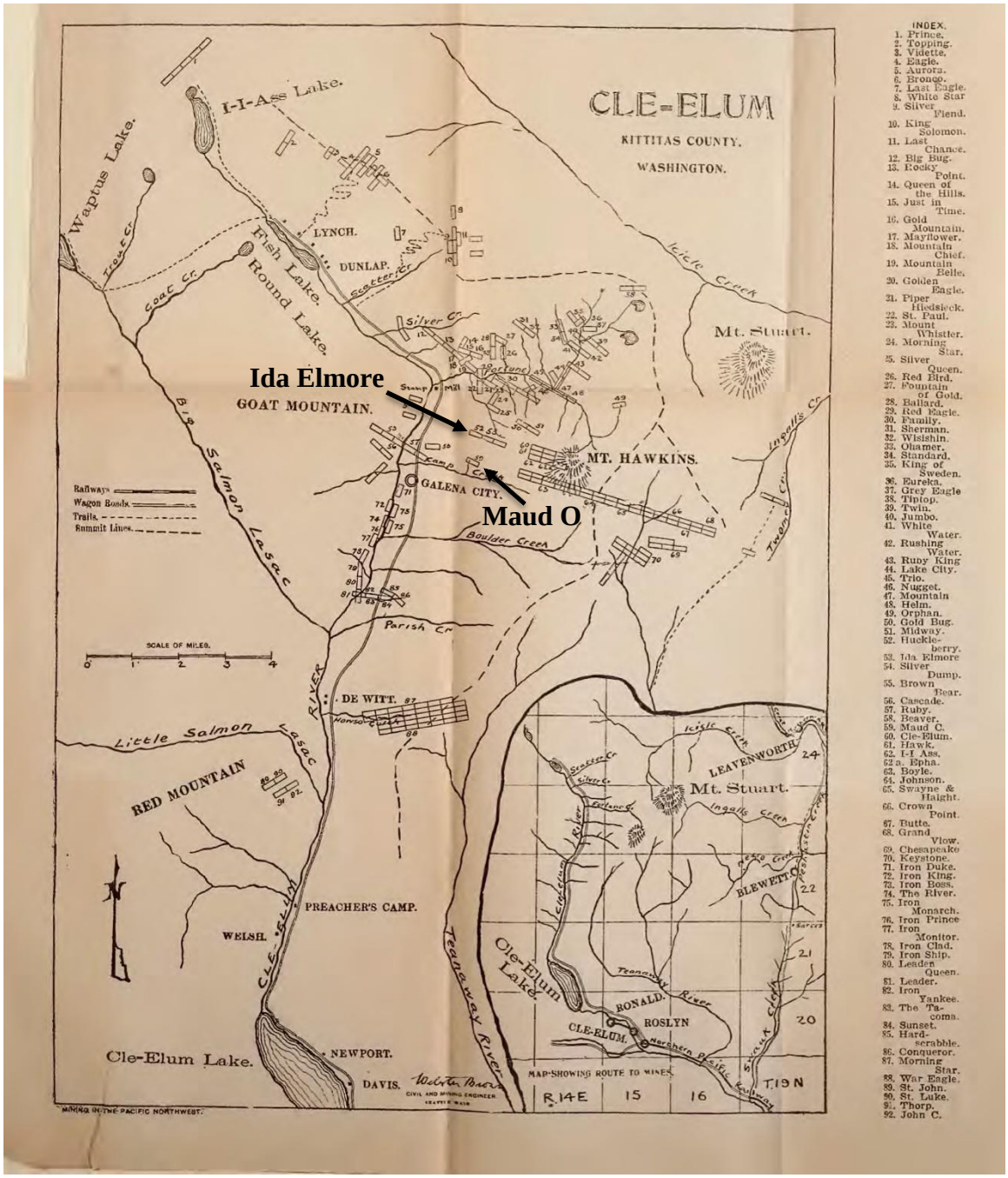


Figure 10: Cle Elum mining district map depicting the Maud O and Ida Elmore claims. Adapted from Hodges (1897, p. 62).

The climate of the area is best characterized by the Natural Resource Conservation Service (NRCS) SNOTEL climate station located at Fish Lake about 3 km north-northwest of the Silver Creek claims on the banks of Tucquala Lake (also known as Fish Lake). Warm, dry summers and cool, wet winters characterize this site. The mean annual temperature is 4.5º C with a mean annual precipitation of 161.8 cm (NRCS, 2018a). The warmest and driest month is July with a mean temperature of 14.4º C and a mean precipitation of 1.8 cm (NRCS, 2018a). The coldest month is December with a mean temperature of -3.1º C and the wettest month is November with a mean precipitation of 28.7 cm (Figure 11) (NRCS, 2018a). Snow is typically present between November and June with an average maximum snow depth of 172.4 cm (NRCS, 2018a).

In the Silver Creek and the Camp Creek drainages, the main geologic component is the Ingalls Tectonic Complex, a late Jurassic to early Cretaceous ophiolite complex

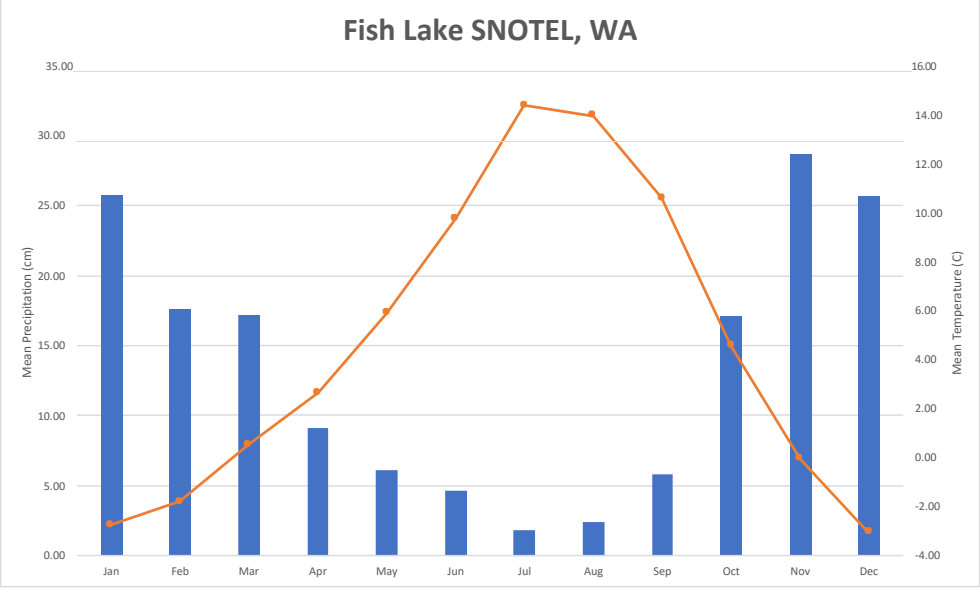


Figure 11: Temperature (line graph) and precipitation (bar graph) recorded at the Fish Lake SNOTEL station, data from period of record (1983-2017) (NRCS, 2018a).

(i.e., a section of oceanic crust that is now in place on a continent above sea level due to uplift) (Tabor et al., 1989; Tabor et al., 2000). It was deposited during the first part of the Cascade Orogeny between 165 Ma to 100 Ma (Tabor et al., 1989; Tabor et al., 2000). The exposed section is unique because, in different portions, it can be either massive (i.e., occurring as a singular homogenous section) or foliated (i.e., occurring with many layers throughout) (Tabor et al., 2000).

The portion of the Ingalls Tectonic Complex in the Silver Creek Drainage mostly consists of ultramafic serpentinite and serpentinized meta-peridotites of the Navaho Divide fault zone (Figure 12) (Tabor et al., 2000; MacDonald et al., 2008). Serpentinite is a metamorphic rock composed of serpentine minerals including antigorite, chrysotile, and lizardite ($Mg_3Si_2O_5(OH)_4$) (Klein and Dutrow, 2007). It is formed at plate boundaries by the metamorphism of igneous rocks prevalent in oceanic crust such as peridotite (Klein and Dutrow, 2007). The serpentinized meta-peridotites are portions of the complex that have not been fully metamorphosed thus retaining some of the traits of the parent material (Tabor et al., 2000; Klein and Dutrow, 2007). This includes the component rocks of dunite and harzburgite (Tabor et al., 2000; Klein and Dutrow, 2007). The main ores sought in production of this area are gold and silver, both free milling and in ores which consisted of a quartz vein about 4.5 m to 6 m wide (Huntting, 1955; Derkey et al., 1990). In the Camp Creek Watershed, the main geologic component also consists of the serpentinite of the Ingalls Tectonic Complex but includes an intrusive section of diabase and gabbro (Huntting, 1955; Tabor et al., 2000). In shear zones in this rock, pyrite, aresenopyrite (FeAsS), chalcopyrite ($CuFeS_2$), and quartz are present (Thurber et al.,

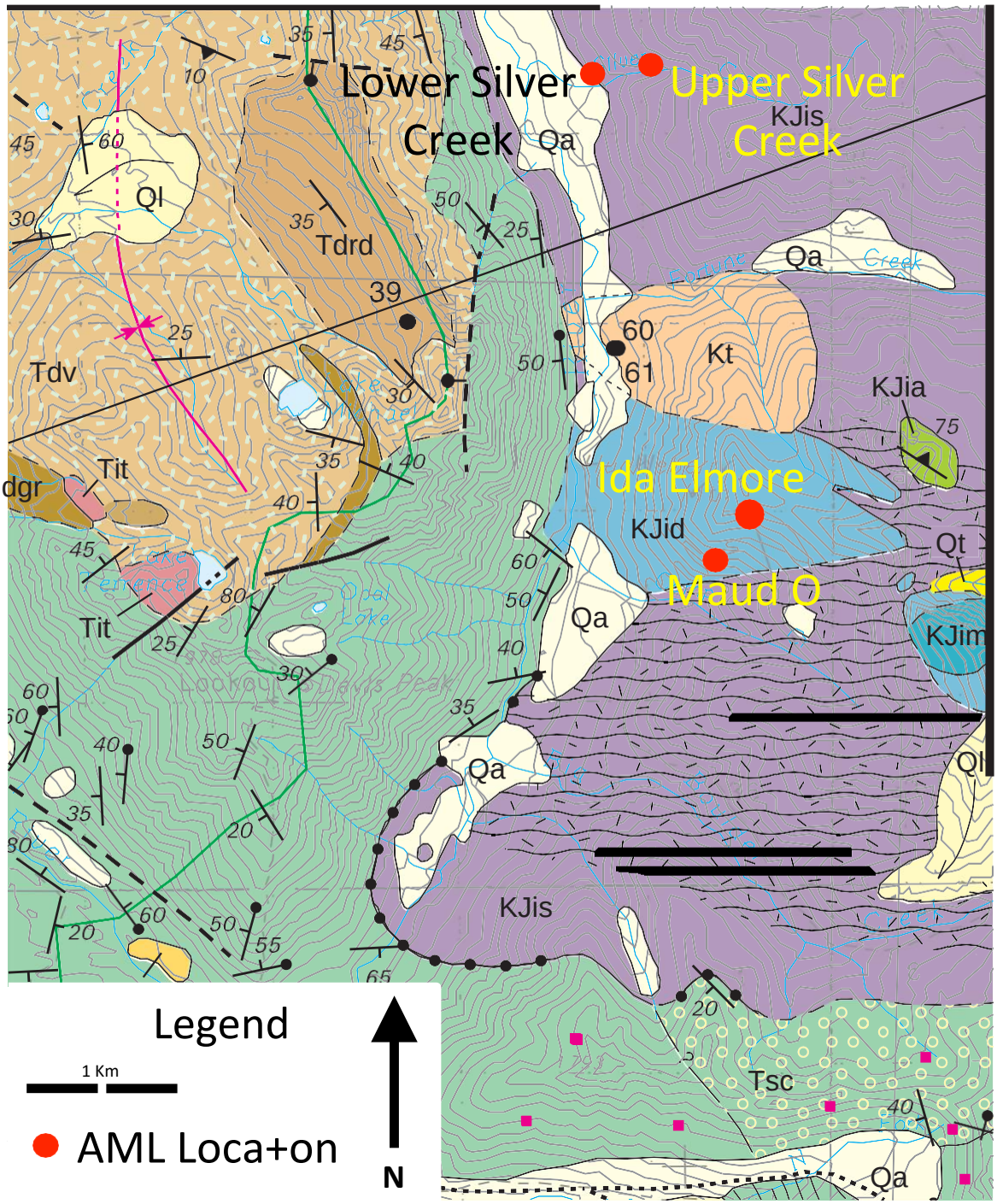


Figure 12: Location of the Silver Creek and Camp Creek AMLs on the Geologic Map Of The Snoqualmie Pass 30 × 60 Minute Quadrangle, Washington (adapted from Tabor et al., 2000).

1964). In the Camp Creek drainage, the main ore bearing units are quartz veins within the serpentinite.

Production began on the mines of the Silver Creek area prior to 1937 (Woodhouse et al., 2002) (Table 2). In 1938, the Silver Creek Mining Company of Tacoma, WA, owned by Guy E. Kelley, was registered as the holder of the claim (State of Washington, 1938; Huntting, 1956; Woodhouse et al., 2002). In 1940, W.A. Hoage took ownership of the company and the mine (Hill and Melrose, 1940). Phil Denny, owner of the Cle Elum Mining Company of Tacoma purchased the claim in 1952 and in 1971 Tom Lloyd gained possession and renamed it the Peter Tu claim (Huntting, 1956; Woodhouse et al., 2002). Between 1937 and 1940, 4500 kg of ore was produced at the mine (Woodhouse et al., 2002). The claim consists of eight separate workings, four at the lower site and four at the upper. By 1956, six of those tunnels were present at the site (Huntting, 1956; Woodhouse et al., 2002). Activity appears to have ceased after this point. A mill and powerhouse were located at the upper site with an ore chute connecting the adit to the processing facility.

A.D. Olmstead, C.O. Swayne, A.W. Haight, E.W. Wilson, and S.W. Sill began work on the Maud O mine in 1889 (Woodhouse et al., 2002) (Table 2). At some point between then and 1898, a five-stamp mill and concentrator were purchased by Swayne and Haight and brought to the mine after being refurbished in Roslyn, Washington (Hodges, 1897; Woodhouse et al., 2002). At a point before July 21, 1897 Joseph B. Wilson gained a stake in the mine (Seattle Post-Intelligencer, 1897). By 1900, the mine had closed but L.F. McConihe was reported to have reopened it (Seattle Post-Intelligencer, 1900c). Around 1930, Anthony Stoves of Galena, Washington had

ownership of the mine (Stancik, 1994). In the summer of 1930, the mine produced 26 metric tons of ore that was shipped to Tacoma for smelting (Stancik, 1994). After this point, there is no evidence of continued work.

Work on the Ida Elmore mine began in 1891 when S.S. Hawkins, James Grieve, and a person only referred to as Dunlap (possibly Keith W. Dunlap) patented the claim (Yakima Herald, 1891; Hodges, 1897; Woodhouse et al., 2002) (Table 2). In 1897, E. Parker was the manager of the mine and oversaw the construction of a stamp mill (Seattle Post-Intelligencer, 1897). In 1898, the Kellog Chemical Process company of Seattle was contracted to mine and process 4.5 to 45 metric tons of ore a day at the mine site (Yakima Herald, 1898). At this point, ownership had expanded as shares in the mine were sold and the major stockholders included S.D. Hawkins, A.D. Wilson, James Grieve, Edward Whitson, Fred Parker, and Keith Dunlap (Yakima Herald, 1898). By 1900, Charles A. Marriner was the acting manager of the mine and a sawmill had been constructed at the site (Seattle Post-Intelligencer, 1900a; Seattle Post-Intelligencer, 1900b). A ten-stamp mill, smelting equipment, and two aerial trams (one 304 m long and the other 1,768 m long) were planned for construction that year as well (Seattle Post-Intelligencer, 1900a; Seattle Post-Intelligencer, 1900b). By 1900, four separate workings were producing ore (Seattle Post-Intelligencer, 1900b; Thurber et al., 1964). Carl Johnson of Ellensburg acquired the mine in 1911 (Ellensburg Dawn, 1911). In 1913, the mine was patented (Torgerson, 1951). From 1949 until 1952, Meleo S. Pechet of Seattle, Washington had control of the mine (Huntting, 1955, 1956; Woodhouse et al., 2002). At this point the mine was known as the Melade Mine (Torgerson, 1951). At some point between 1952 and 1964 the mine was acquired by an unknown party and renamed the Hughes-Wayman

Prospect though it appears that no further work occurred at this location (Thurber et al., 1964).

Teanaway River Drainage

The Teanaway River is a large drainage to the north and northeast of Cle Elum, Washington. It flows generally north to south and meets with the Yakima River about 1 km downstream of the junction of Washington Highways 10 and 970. It is comprised of three main tributaries: the North, Middle, and West Forks. These branches meet near the Teanaway Campground (47° 15' 20.39" N, 120° 53 '34.66" W). The headwaters of the North Fork are between Ingalls Pass and Esmeralda Peak. About 6 km below the headwaters of the North Fork, De Roux Creek converges with the river. De Roux Creek begins at Gallagher Head Lake in a valley between Hawkins Mountain and Esmeralda Peak. The Middle Fork begins to the northwest of Koppen Mountain. The Teanaway drainage is bounded by Cle Elum Ridge to the south, Teanaway Ridge to the east, and Sasse Ridge to the west. The Wenatchee Mountains also delineate the northern border of the watershed.

De Roux Creek contains the Mount Hawkins group of claims. These include the Mount Hawkins (also known as Gallagher Head, Crowe or Skipper) claim (47° 26' 34.30" N, 120° 58' 51.39" W), Dolphin (sometimes referred to as Bonanza) claim (47° 26' 38.93" N, 120° 58' 38.87" W), and West Dolphin Extension (47° 26' 29.01" N, 120° 59' 0.61" W). The names of these three claims at times were extremely fluid and have been used interchangeably. The Middle Fork contains the Skookum claim (47° 24' 33.33" N, 120° 58 '34.95" W) (Figure 13).

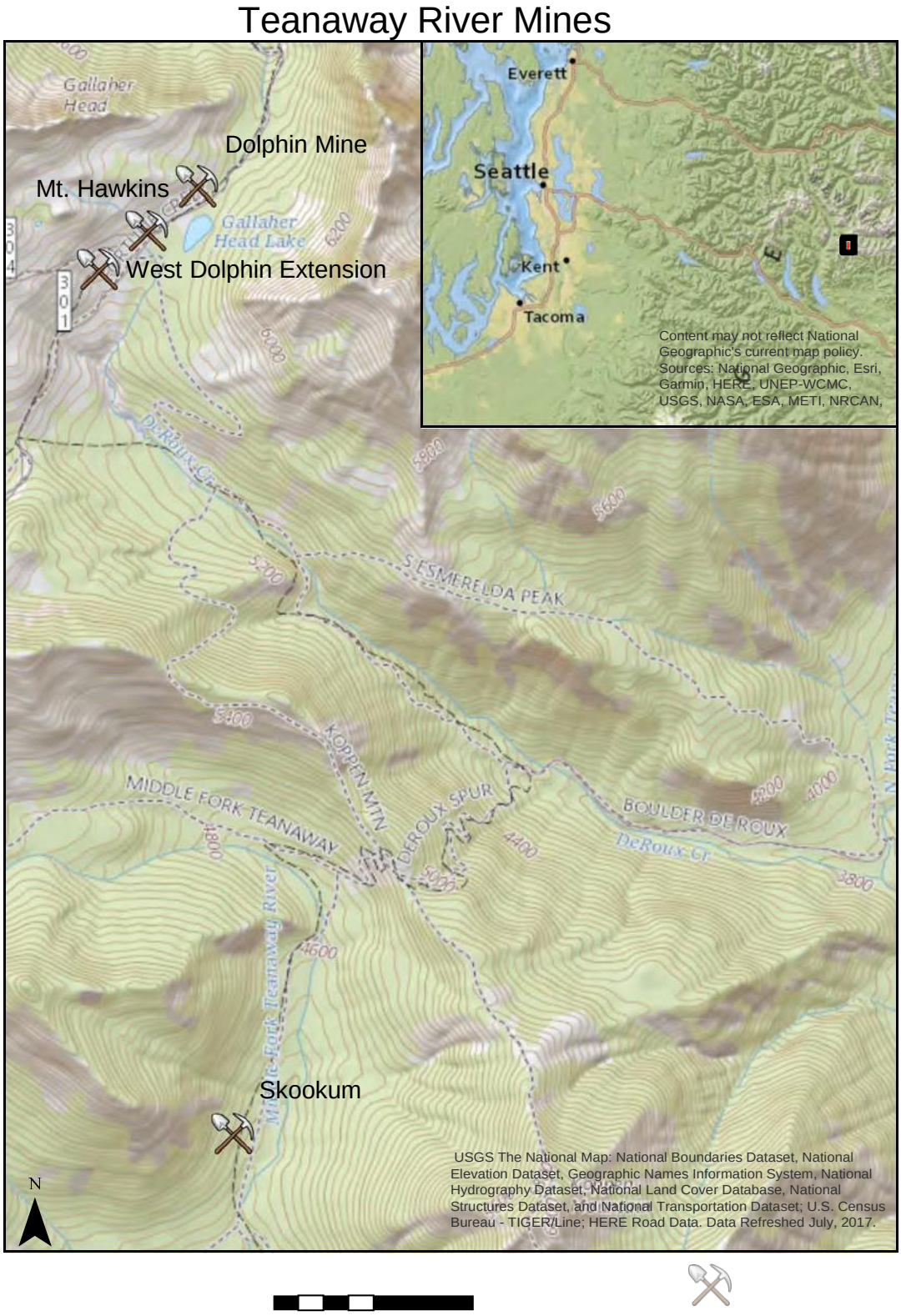


Figure 13: Mines of the Teanaway River and the surrounding area.

Access to the mines in the North Fork is via the De Roux Creek Trail which starts at the De Roux Campground. After about 2 km the trail splits in two. The Mount Hawkins Group of mines can be found after 5 km along the northwestern path, a total gain of 573 m of elevation. Sites are labeled with an "X" and "Adit" "Prospect" on the USGS Mount Stuart 7.5-minute quadrangle (Figure 13). The Skookum mine can be reached by following the southwestern trail 4.5 km, a total gain of 389 m of elevation. It is located on the western side of the trail.

The climate of the area is best characterized by the NRCS SNOTEL climate station located on Sasse Ridge. Warm, dry summers and cool, wet winters characterize this site. The mean annual temperature of the site is 4.8º C with a mean annual precipitation of 148.6 cm (NRCS, 2018b). The warmest month is June with a mean temperature of 10.5º C and the driest month is July with a mean precipitation of 1.3 cm (NRCS, 2018b). The coldest month is December with a mean temperature of -3.7º C and the wettest month is November with a mean precipitation of 26.7 cm (Figure 14) (NRCS, 2018b). Snow is present between October and June with an average maximum snow depth of 184.7 cm (NRCS, 2018b).

The main geologic component of De Roux Creek is the Ingalls Tectonic Complex (Figure 15). In this area, it is in contact with the Esmeralda Peaks unit, a semi-continuous group of gabbro, diabase, and basalt within the Navaho Divide fault zone that partially surrounds the Mount Stuart Batholith. It is from the Late Jurassic, about 161 Ma to 145 Ma (MacDonald et al., 2008). The main minerals being sought in this area include gold, silver, copper, cobalt, and chromium (Derkey et al., 1990). They are found primarily in chalcopyrite, chromite ($FeCr_2O_4$) with pyrite, serpentine, and quartz as the gangue.

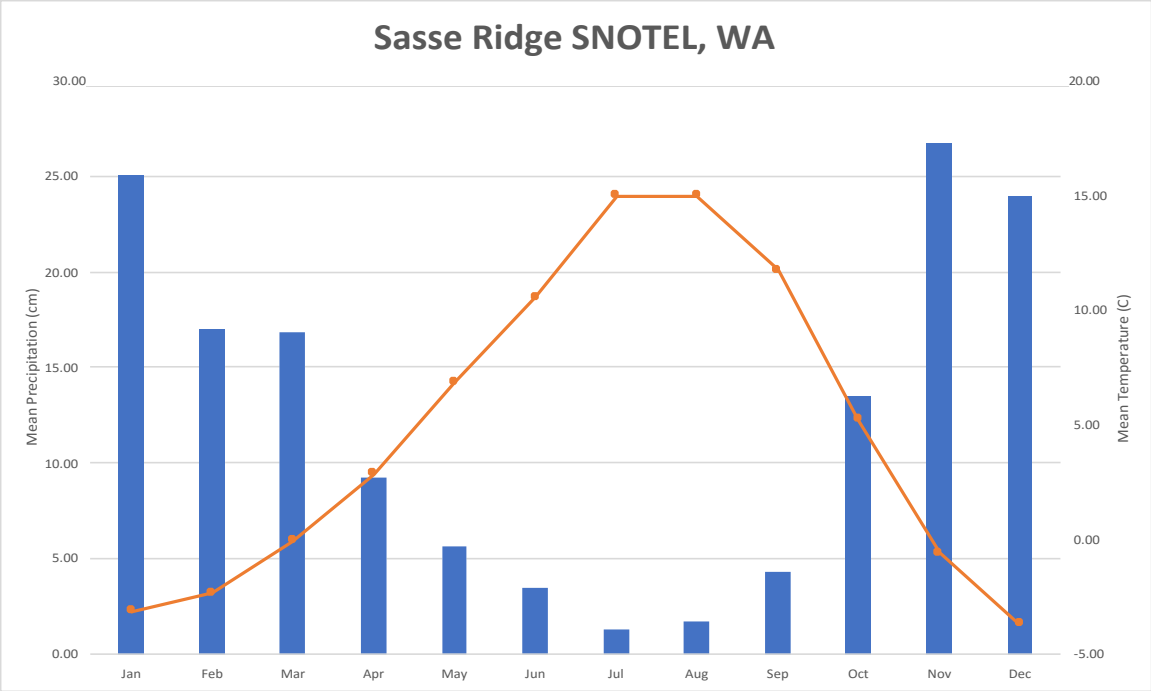


Figure 14: Temperature (line graph) and precipitation (bar graph) recorded at the Sasse Ridge SNOTEL station, data from period of record (1983-2017) (NRCS, 2018b).

Within the Middle Fork of the Teanaway River, the main geologic components are the Swauk Formation and the Ingalls Tectonic Complex (Figure 15) (Miller, 1980; Tabor et al., 1982). The Skookum Mine is located near the contact of these two formations. The Swauk Formation is a Tertiary deposit about 65 Ma to 2.58 Ma. It is comprised of arkosic sandstone and felsic conglomerates. The tailings found at this site appear to be of serpentinite. It is likely that at this location the Swauk somewhat overlies the Ingalls and that the miners tunneled through the Swauk to access the Ingalls. Copper was the primary mineral of this area and was found in the form of native copper, copper oxides, and “copper crystals” (likely chalcopyrite) (Ellensburg Dawn, 1905b; Tabor et al., 1982).

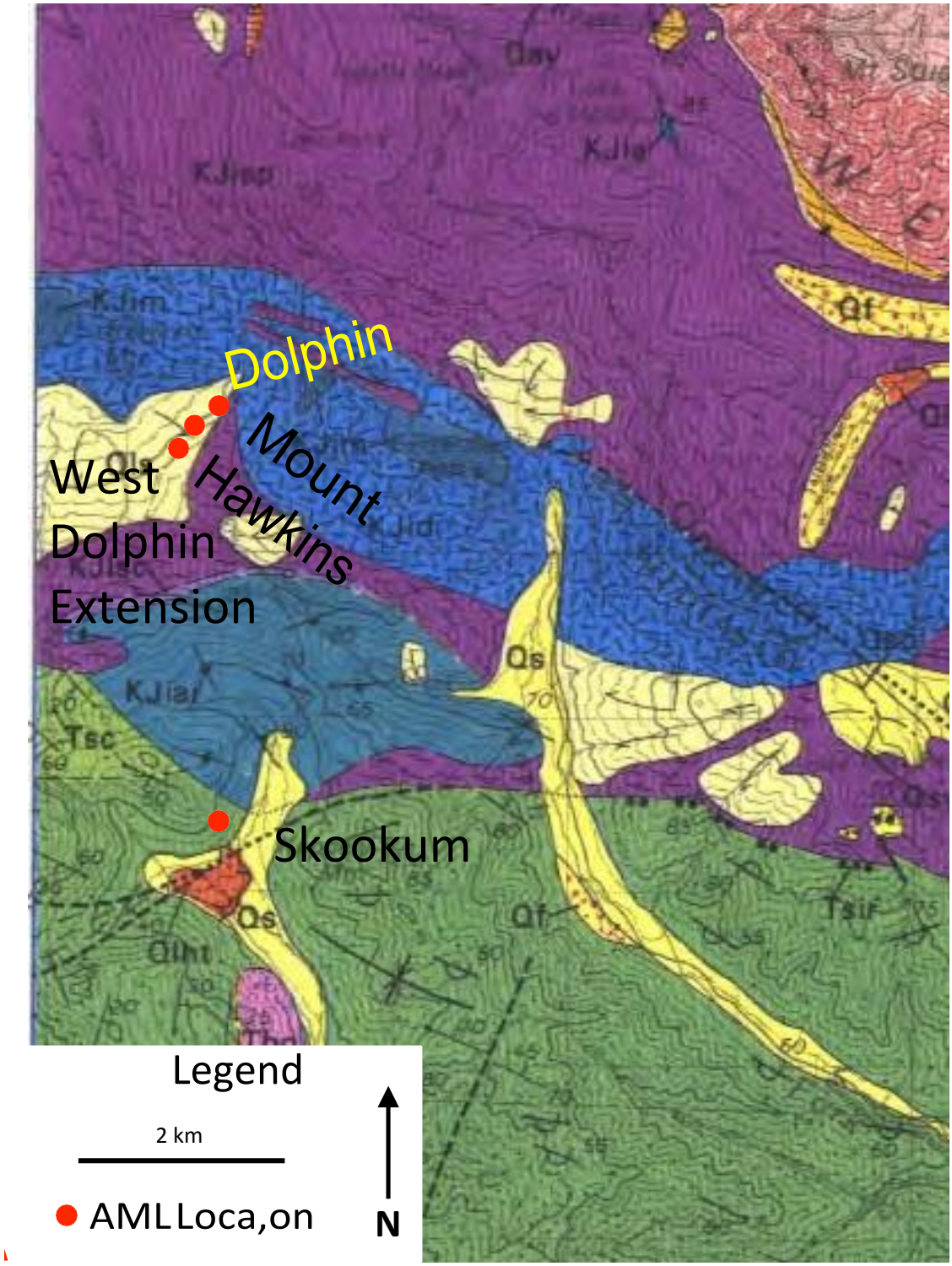


Figure 15: Location of the Teanaway AMLs on the Geologic Map Of The Wenatchee 1:100,000 Quadrangle, Central Washington (adapted from Tabor et al., 1982).

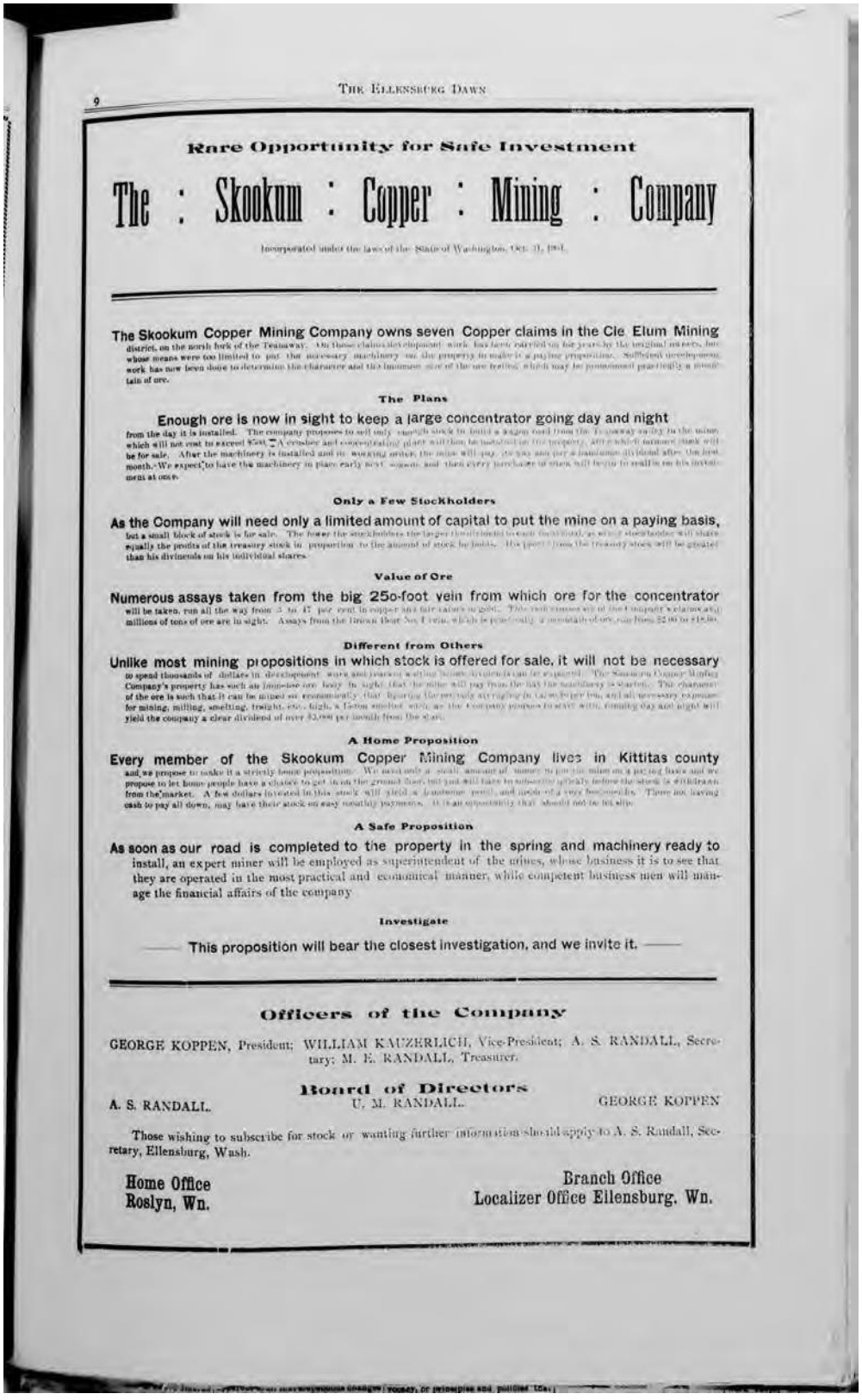
As stated above (p 11), the Mount Hawkins claims were discovered in 1881 by Samuel S. Hawkins, Moses Splaun, and A.P. Boyles. By 1905, five different claims had been built in the area (Gallaher, 1905; Woodhouse et al., 2002) (Table 2). Among them were the Dolphin, West Dolphin Extension, and Mount Hawkins claims. That year, brothers George W. Gallaher and Ed D. Gallaher purchased the property as part of the Gallaher Mining and Development company (Gallaher, 1905; Huntting, 1956). The next year they changed the name of the company to the Gallaher Mining and Milling Company (Stevens, 1907; Huntting, 1956). Around this time, they had a public offering and made $2,000,000 selling at $1 a share (Stevens, 1908). In 1908, the company went into receivership and was purchased by Lee A. Johnson of Sunnyside, Washington for $2,800 (Stevens, 1911; Woodhouse, et al., 2002). He selected George Gallaher as manager (Woodhouse et al., 2002). In 1920, George re-purchased the mine under the Bonanza Mining Company (Huntting, 1956, Woodhouse et al., 2002). In 1951, Phil Denny of Seattle, Washington purchased the property (Huntting, 1956).

At the Mount Hawkins group, a dam was built above the mines to divert water to a Pelton Wheel to power a 1,500-pound (680 kg) stamp mill operated by a group of six men (Woodhouse et al., 2002). In 1905, a wagon road was built from the Cle Elum River up the Camp Creek drainage to the mines following the original path that Hawkins, Splaun, and Boyles took (Gallaher, 1905). This route became known as the Mine-to-Market trail as it went from many mines in the area to the towns of Galena, Ronald, Roslyn, and Cle Elum. It is still accessible as Forest Service Road #4330. In 1905, a shaft house, snowshed, and bunkhouse was built (Gallaher, 1905). By 1907, $15,000 had been spent on the development of the site (Stevens, 1907). Between 1905 and 1907 the

Dolphin mine alone produced 5 tons of ore (Huntting, 1956). Between 1941 and 1945 the Mount Hawkins mine produced 15 tons of ore (Huntting, 1956). After this brief resurgence of production, no further work is evident at the site.

The Skookum Copper Mining Company was organized in 1902 (Stevens, 1911) (Table 2). On October 31, 1904 it was incorporated in the State of Washington (Ellensburg Dawn, 1904). The president was George Koppen, William Kauzeruch was the vice-president, A.S. Randall of Ellensburg, Washington was secretary, A.E. Randall was treasurer, and A.S. Randall, U.M. Randall, and George Koppen made up the board of directors (Ellensburg Dawn, 1904). All company officers and board members were from Kittitas County (Figure 16) (Ellensburg Dawn, 1904). The main company office was located in Roslyn (Ellensburg Dawn, 1904).

1905 was a very active year for the mine. A 25.7 km wagon road from Roslyn to the mine was completed after a year and a half of work (Ellensburg Dawn, 1905a ; Hill Publishing Company, 1909). In the later portion of the year, a fifteen-horsepower engine and compressor (Figure 17), boiler, saw mill (Figure 18), and 90 metric ton cyanide processing plant were purchased for the mine using 30,000 shares of stock sold at $0.25 each (Ellensburg Dawn, 1905b). The plant and engine were placed in an approximately 9 x 24 m building (Ellensburg Dawn, 1905a). A bunkhouse, business office, and dam were also constructed, and an old cabin was converted into a blacksmith shop and tool house around the same time (Ellensburg Dawn, 1905a). A town site known as Koppenville was also platted then, with several small cabins built the following year (Figure 19) (Ellensburg Dawn, 1905a). At this time the mine had 23 separate claims on



Rare Opportunity for Safe Investment

The : Skookum : Copper : Mining : Company

Incorporated under the laws of the State of Washington, Oct. 31, 1903.

The Skookum Copper Mining Company owns seven Copper claims in the Cle Elum Mining district, on the north fork of the Teanaway. On these claims development work has been carried on for years by the original owners, but whose means were too limited to put the necessary machinery on the property to make it a paying proposition. Sufficient development work has now been done to determine the character and the immense size of the ore bodies, which may be pronounced practically a mountain of ore.

The Plans

Enough ore is now in sight to keep a large concentrator going day and night from the day it is installed. The company proposes to sell only enough stock to build a wagon road from the Teanaway valley to the mine, which will not cost to exceed $5000. A crusher and concentrating plant will then be installed on the property, and a limited amount stock will be for sale. After the machinery is installed and in working order, the mine will pay for itself in a few months, and pay a handsome dividend after the first month. We expect to have the machinery in place early next season, and then every purchaser of stock will begin to realize on his investment at once.

Only a Few Stockholders

As the Company will need only a limited amount of capital to put the mine on a paying basis, but a small block of stock is for sale. The fewer the stockholders the larger dividends to each individual, as every stockholder will share equally the profits of the treasury stock in proportion to the amount of stock he holds. His profits from the treasury stock will be greater than his dividends on his individual shares.

Value of Ore

Numerous assays taken from the big 250-foot vein from which ore for the concentrator will be taken, run all the way from 5 to 47 per cent in copper and fair values in gold. This vein crosses all of the Company's claims and millions of tons of ore are in sight. Assays from the Brown Bear No. 1 vein, which is practically a mountain of ore, run from $2.00 to $18.00.

Different from Others

Unlike most mining propositions in which stock is offered for sale, it will not be necessary to spend thousands of dollars in development work and years of waiting before dividends can be expected. The Skookum Copper Mining Company's property has such an immense ore body in sight that the mine will pay from the day the machinery is started. The character of the ore is such that it can be mined so economically that ignoring the ore only as rich as $4.00 per ton, and all necessary expenses for mining, milling, smelting, freight, etc., high, a fifteen stamper mill, as the Company proposes to start with, running day and night will yield the company a clear dividend of over $3,000 per month from the start.

A Home Proposition

Every member of the Skookum Copper Mining Company lives in Kittitas county and we propose to make it a strictly home proposition. We need only a small amount of money to put the mine on a paying basis and we propose to let home people have a chance to get in on the ground floor, but will have to subscribe officially before the stock is withdrawn from the market. A few dollars invested in this stock will yield a handsome profit, and make of a very few comrades. Those not having cash to pay all down, may have their stock on easy monthly payments. It is an opportunity that should not be let slip.

A Safe Proposition

As soon as our road is completed to the property in the spring and machinery ready to install, an expert miner will be employed as superintendent of the mines, whose business it is to see that they are operated in the most practical and economical manner, while competent business men will manage the financial affairs of the company.

Investigate

This proposition will bear the closest investigation, and we invite it.

Officers of the Company

GEORGE KOPPEN, President; WILLIAM KAUZERLICH, Vice-President; A. S. RANDALL, Secretary; M. E. RANDALL, Treasurer.

Board of Directors

A. S. RANDALL. U. M. RANDALL. GEORGE KOPPEN

Those wishing to subscribe for stock or wanting further information should apply to A. S. Randall, Secretary, Ellensburg, Wash.

Home Office
Roslyn, Wn.

Branch Office
Localizer Office Ellensburg, Wn.

Figure 16: Advertisement for the Skookum Copper Mining Company in *The Ellensburg Dawn* (Ellensburg Dawn, 1904).

Figure 17: Compressor of the Skookum Mine (Krueger, 1951a).

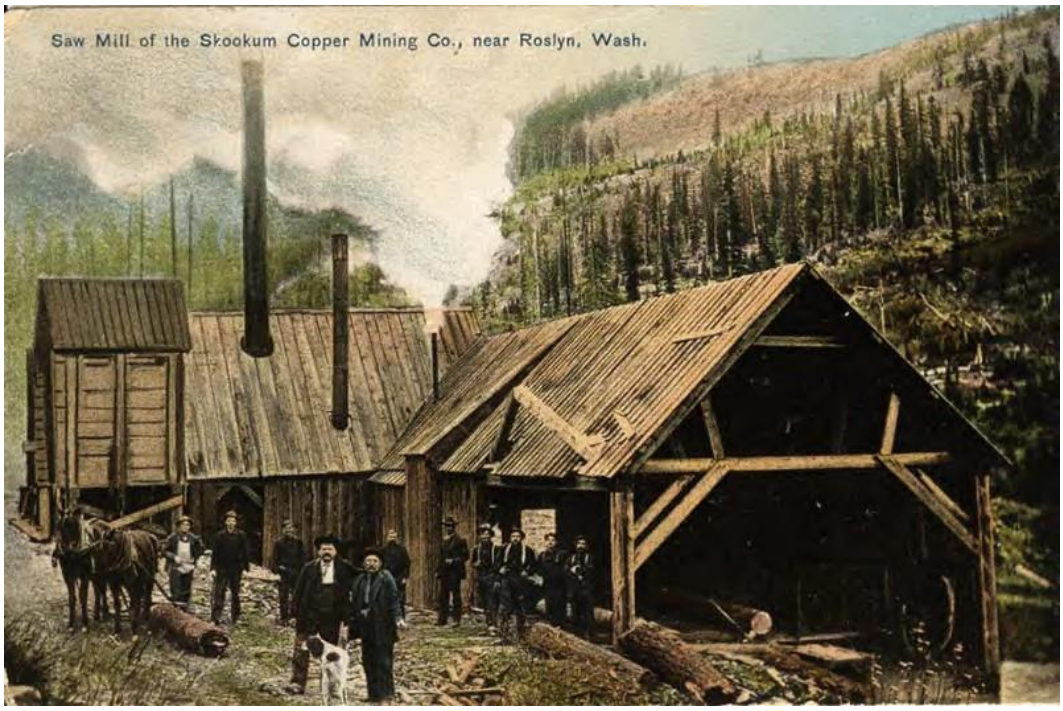


Figure 18: Sawmill of the Skookum Mine (Krueger, 1951b).

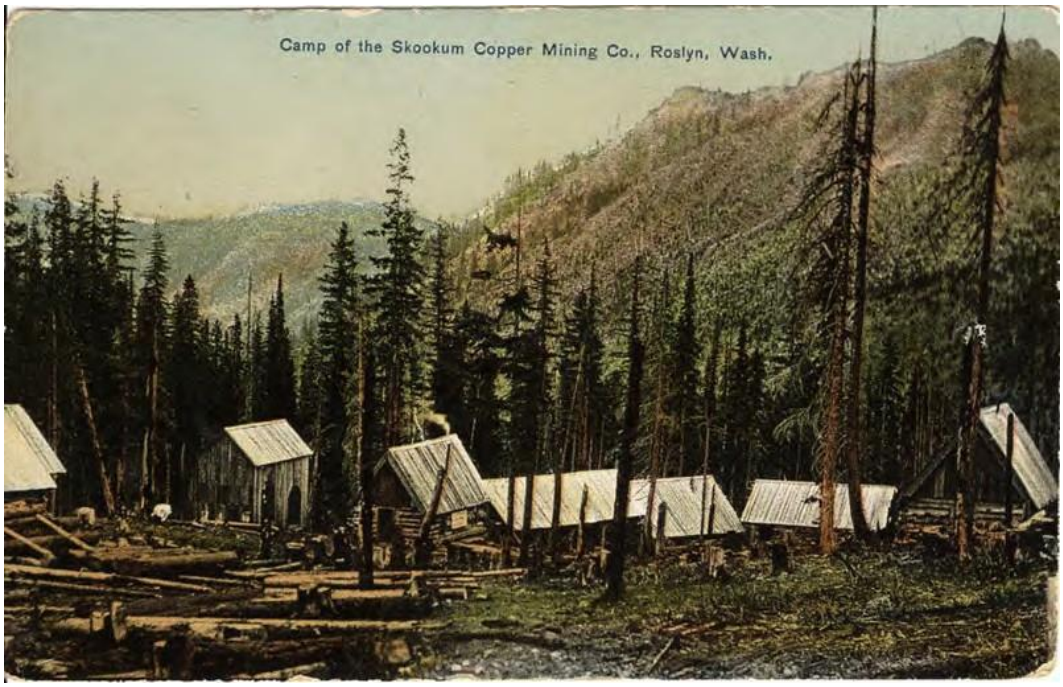


Figure 19: Koppenville at Skookum Mine (Krueger, 1951c).

the site and by late 1905, a shipment of 100 pounds of ore had been sent from the mine (Ellensburg Dawn, 1905a, 1905b).

At 4:00 AM on March 1, 1910 a large avalanche hit the mining camp (The Evening Statesman, 1910). All 17 mine workers escaped but the mine superintendent, Ed L. Simmons, perished (The Evening Statesman, 1910; Woodhouse et al., 2002). The business office, the bunkhouse, the mill, and nine other buildings were all partially or fully destroyed (The Evening Statesman, 1910; Woodhouse et al., 2002). On November 17 of that year, the mine went into receivership with $25,000 in debts (Stevens, 1911). Frank Carpenter was appointed as receiver (Stevens, 1911). By the time of the avalanche, the mine had a 250-ton concentrator plant that had only been installed in January (Hill Publishing Company, 1909; Pullman Herald, 1910; Stevens, 1911). The sawmill was removed from the site sometime between the avalanche and the 1930s, when the USFS

burned the remaining structures to the ground (USFS, 1998). Adolph Elsner Sr., a local miner with several other claims in the area, purchased the mine sometime between 1910 and his death in 1919 (Woodhouse et al., 2002). His son, Adolph Elsner Jr., then owned the mine until 1981 (Woodhouse et al., 2002). There is no indication of any further development of site after 1981.

CHAPTER 4

METHODS AND TECHNIQUES

This research was completed in a three-phase process that created an in-depth understanding of the historic, geographic, and environmental context of each AML. These phases include:

Phase 1 – Archival Investigation

Comprehensive archival research was performed throughout 2017 and winter 2018 using Central Washington University's Brooks Library's Archives and Special Collections, the Library of Congress' Historical American Newspapers Archives, the Roslyn Heritage photograph collection, Washington Department of Natural Resources' (WADNR) Inactive and Abandoned Mine Lands databases, USGS geologic and topographic maps as well as historical folios, Google Earth, existing literature on the AMLs within the study area, and communications with land managers in the USFS. With these resources, I was able to determine three drainages within the Upper Yakima River watershed that contained nine AML sites that were accessible, mined for gold, silver, or copper in sulfide rocks, and had a mill present at the site. I originally intended to sample 12 AML sites; however, I was prevented from visiting three of them when the 2017 Jolly Mountain Fire which caused the USFS to close trails leading to the area.

Phase 2 – Field Investigation

The second phase of this process involved field investigations of each site. Field work was completed between July and October 2017. My research assistant Ellie Myers, an undergraduate student in the Environmental Studies Program at Central Washington University, and I visited each site at least once. On occasion, we were accompanied by

Dr. Karl Lillquist or Noah Driver, another CWU undergraduate student. This phase took place in four steps.

Step 1) AML identification and location verification

Traveling to each AML was accomplished by first locating each site on Google Earth and topographic maps and determining a GPS coordinates. We used these in conjunction with a Garmin eTrex 30x handheld GPS unit and the Gaia GPS iPhone app to navigate to the AML. Once in the general vicinity of the site, we verified the location by searching for the presence of tailings, portals or mining-related artifacts.

Step 2) Site Characterization

Site characterization was accomplished using a modified version of the Mine Waste Decision Tree (Wildeman et al., 2007). The chemical portion of the decision tree was discarded as the USGS analytical methods employed in this research provide more complete insight into the available pollutants at the research sites. The physical portion of the decision tree was modified to include considerations for the geology and geography of the research sites. I added four classes to Wildeman et al.'s (2007) Mine Waste Decision Tree. These consisted of distance to Cascade Crest, which was a way to indicate how much precipitation a site receives, azimuth, which indicates how long snow stays on the site and therefore how much time a site has to experience weathering, surface clast size, which is used to determine the largest clasts present on the AML and therefore is used as an estimate of how thoroughly the tailings were processed and how much surface area is present to interact with water, and Grain Size Estimate, which indicates how homogenous the tailings are.

With this, I then created an "AML Field Data Sheet" to streamline the process and ensure a uniformity of collected data (Appendix A). The data sheet is separated into general site information, AML stability, vegetation on feature, vegetation buffer area, rock weathering, grid samples, sketch of AML, sketch of area/map, and notes/other. A Garmin eTrex 30x GPS unit, Brunton Pocket Transit, 30 m measuring tape, USGS Grain Size Identification Chart, and visual percentage estimation chart were used to survey the site.

General site information. General site information was collected by taking GPS coordinates at a central location of the site and at the northern-, southern-, eastern-, and western-most extent of each location. Azimuth and average slope angle were collected using the Brunton Pocket Transit at a representative location of the site. Size estimates of features were collected using the "Area Calculation" application of the GPS by walking around the boundary of the site. When steep or unstable terrain prohibited the use of this feature, Google Earth was used to create a rough estimate of the area. Volume estimates were collected by measuring average depth of the entire feature from the ground to an average height. This was completed using a measuring tape and multiplying the depth by the area. Surface clast size is a measurement of the largest size clast found on the surface using the USGS Grain Size Identification Chart. Grain size estimate is an average grain size of the sediment of the AML. Crust presence is a determination of the presence of a hard mineral crust layer on the outside of the feature. Thickness is a measurement of how thick that crust layer is.

AML stability. We evaluated whether erosion is taking place on the feature, if so, when and where it occurred, and what the scale of the erosion was. We looked for signs

of gully or rill erosion, mass wasting, and creep on the feature and for fluvial systems eroding the edges of the feature.

Vegetation on feature. This is a measurement of the amount and type of vegetation on the AML. Each feature was divided into quadrants (NW, NE, SW, SE). Within each of these quadrants, we estimated the amount of vegetation using the visual percentage estimation chart and described the vegetation (e.g., grass, shrub, tree) unless more detailed information was available about species.

Vegetation buffer area. We determined whether the feature had moved over time and created a vegetation buffer area. We looked for larger, sturdy vegetation (i.e., trees or woody brush with large stems) near the margins of the feature that had their trunks or stems buried beneath the surface of the feature.

Rock weathering. We determined the extent of weathering on the rock of the tailings. This was based on observations of a weathering rind on the exterior of rocks present on the feature.

Grid samples. We tracked the number of sections within the grid that was created in step three of this phase.

Sketch of AML. We created a large-scale, detailed sketch map of each site including GPS collection points, erosion locations, vegetation locations, sampling grid and locations, and any other pertinent information.

Sketch of area/map. We created a small-scale sketch map that showed the AML in relation to larger area around it. Included were roads, trails, vegetation buffer areas, sampling locations, fluvial features and other pertinent information.

***Notes/other*.** We recorded information that did not fall into the established categories and fields.

Step 3) Sediment Sampling

Sediment samples were collected using the Mine-Waste Dump Sampling Strategies described by Smith et al. (2000). AML features were sampled multiple times and combined to create a representative sample. This was accomplished by extending a 30 m measuring tape across the approximate center of the feature (Figure 20). The length was then divided by 10 to create 10 sections of the AML. Those 10 sections were then divided into three sub-sections. This was most often done with a sub-section in the

Figure 20: Tape measure (center) being used at the Lower Silver Creek site, Upper Cle Elum River to divide tailings pile into sections for sampling as part of the Mine-Waste Dump Sampling Strategy. Photo by Scott Kugel, August 2017.

middle of the feature near the measuring tape and one on either site of the tape. Samples were collected using a folding shovel. A roughly equal size sample was collected from the top 15 cm of each subsection (Figure 21). Large pebbles and cobbles that were

Figure 21: Scott Kugel (left) and Ellie Myers (right) collecting a sediment sample at the Mineral Creek mill site. Photo by Karl Lillquist, August 2017.

obviously larger than 2 mm were separated out of the sample. Samples were placed in sequentially labeled Whirl-pak sampling bags. Additional control samples were collected at a point judged to be outside the influence of the AML. A GPS coordinate was recorded at each of these control locations. The number of samples collected from each site was recorded on the AML Field Data Sheet.

Step 4) Water Sampling

Water sampling was conducted in the manner prescribed in the USGS Techniques of Water-Resources Investigations (2015). Samples were collected from the centroid of stream flow above and below identified AMLs in labeled wide mouth polypropylene bottles. As samples were collected, date, time, GPS coordinates, stream name, and other necessary notes were collected in a "Water Sample Data Sheet" (Appendix B) (Figure 22).

Phase 3 – Laboratory Methods and Data Analysis

The third phase of this process involved four steps: sample preparation, data analysis, data evaluation, and management recommendations. Analysis took place in Central Washington University's Multidisciplinary Instrumentation Lab, in the Science II building. This phase occurred in the fall of 2017 and winter of 2018, and I was assisted by Ellie Myers.

Step 1) Sample Preparation

Sediment samples were prepared using the Mine-Waste Dump Sampling Strategy to generate a homogenized representative sample and the USGS Field Leach Test to generate a leachate (Figure 23) (Hageman, 2007; Smith et al. 2000). Samples were homogenized by rotating and squishing the large sample bag with fingers for ten minutes

so that no samples could be individually identified. After the filtering of the leachate or water sample, 9.8 mL of the leachate was added to a labeled, capped test tube (Figures 24 and 25). The sample was then acidified with 0.2 mL of reagent grade nitric acid to reach a 2% acid ratio. All vials and bottles were acid washed before use in equal parts reagent grade nitric acid and deionized water from a Milli-Q Integral Water Purification System. The items were left in the acid bath for approximately 24 hours.

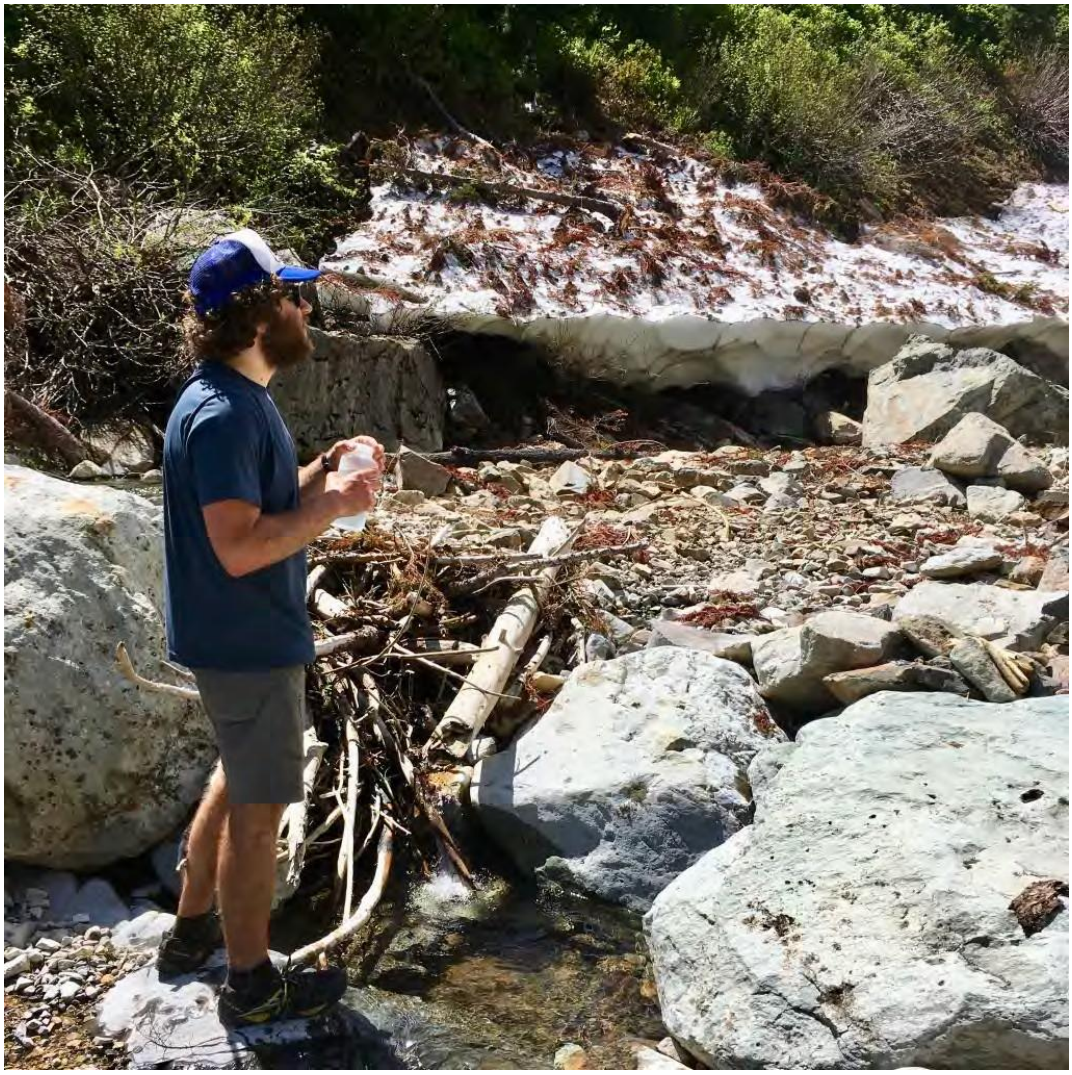


Figure 22: Scott Kugel collecting water sample from Mineral Creek. Photo by Ellie Myers, July 2017.

Figure 23: Samples being sieved to remove the larger than 2 mm fraction. Photo by Scott Kugel, November 2017.

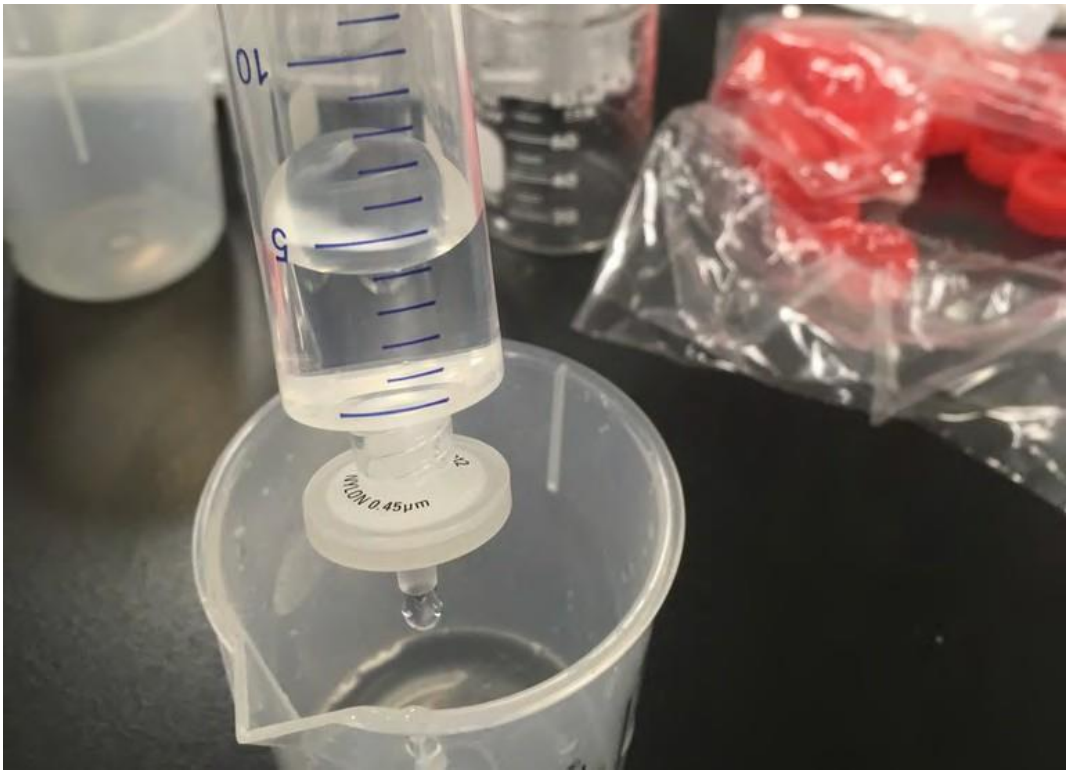


Figure 24: Sample being filtered using a 0.45µm filter. Photo by Scott Kugel, November 2017.

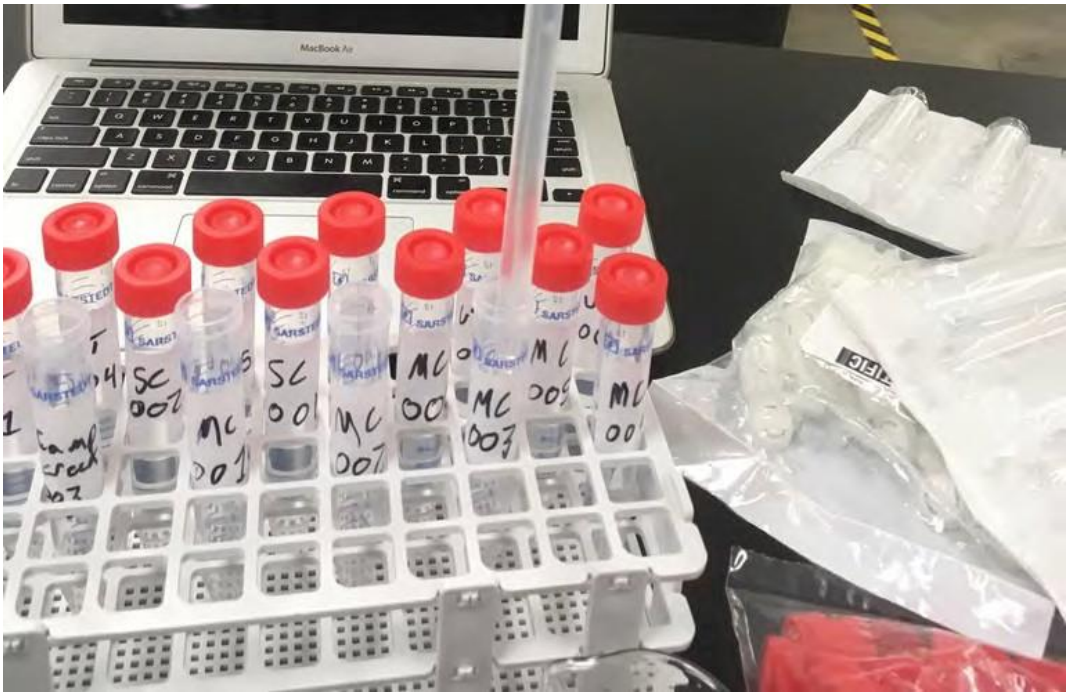


Figure 25: Samples being transferred into labeled test tubes after filtration. Photo by Scott Kugel, November 2017.

Step 2) Sample Analysis

Samples were analyzed using Central Washington University's Geological Science Department's Agilent Technologies 8900 Triple Quadrupole ICP-MS. Standards were created using an "Environmental Standard" (Major Elements - 1000 ppm - Ca, Fe, K, Mg, Na, Minor Elements - 10 ppm - Ag, Al, As, Ba, Be, Cd, Co, Cr, Cu, Mn, Mo, Ni, Pb, Sb, Se, Th, Tl, U, V, Zn), a mercury standard (1000 ppm), and a sulphur standard (1000 ppm). Each standard was diluted using serial dilution. The environmental standard was diluted to 10000/100 ppb (major/trace), 1000/10 ppb, 100/1 ppb, 10/0.1 ppb, 5/0.05 ppb, and 1/0.01 ppb levels. The mercury standard was diluted to 1.0 ppb, 0.5 ppb, 0.1 ppb, 0.05 ppb, and 0.01 ppb. The sulphur standard was diluted to 100 ppb, 50 ppb, 10 ppb, and 1 ppb. In addition, the ICP-MS used an Internal Standard mix of 100 ppm of Bi, Ge, In, ^{6}Li, Lu, Rh, Sc, Tb. Blanks were created using deionized water from a Milli-Q that was placed in an acid washed polypropylene bottles and was acidified to a 2% level using reagent grade nitric acid.

The analysis run was set up with four blanks at the beginning of the run with one of the blanks being a repeat to create a base level for the machine. These were set as a "Calibration Blank" sample type. Each set of standards was then run as a sequence starting with the lowest concentration and ending with the highest. These were set as a "Calibration Standard" sample type. After each standard sequence three blanks were run as a "Sample" sample type to ensure that the machine had fully flushed out the standard. Sample Run One was next in the testing sequence. This consisted of roughly 20 samples that were ran as a "Sample" sample type. These were followed by a Standards Verification Sequence which included two blanks and a mid-tier-concentration standard.

This was repeated for each standard type and was followed by three more blanks. These were all ran as a "Sample" sample type to ensure that the machine did not change its calibration. Following the Standards Verification Sequence, Sample Run Two, a new batch of roughly 20 samples, was run. At the beginning of Sample Run Two, the last sample of Sample Run One was included to ensure consistency of results. This was then followed by another Standards Verification Sequence of the same design as the previous run.

The isotopes of each element that were selected to be tested and the gas modes used were based on suggestions made by an application specialist at Agilent Technologies. The chosen isotopes, which gas mode, and the dwell time (the amount of time the ICP-MS spent collecting information) for each isotope may be found in Table 3. Detection limits were evaluated for all five heavy metals by examining result graphs for each element and visually determining at what minimum concentration the samples are no longer detectable by the equipment (Table 4). A 10% uncertainty is assumed for all elements.

pH readings were collected in the laboratory using a Thermo Scientific Orion pH meter. The meter was calibrated using buffer solutions with a pH of 4, 7, and 10 as recommended by the manufacturer. Water and leachate samples were agitated for five minutes and left to settle for ten additional minutes. At that point the probe for the tester was inserted into the bottle and a reading was taken. The meter was re-calibrated every ten readings.

Each portion of the site characterization process was given an ordinal value adapted from the Mine Waste Decision Tree (Table 5) (Wildeman et al., 2007).

Table 3: Isotopes, gas modes, and dwell times for the ICP-MS used during this research.

	H_2	He	No Gas	Dwell Time [sec]
^{9}Be		X		0.5000
^{23}Na	X			0.5000
^{24}Mg		X		0.5000
^{27}Al		X		1.0000
^{33}S	X	X		0.5000
^{34}S	X	X		0.5000
^{39}K		X		0.5000
^{40}Ca	X			0.5000
^{44}Ca		X		0.5000
^{51}V		X		1.0000
^{52}Cr		X		1.0000
^{55}Mn		X		1.0000
^{56}Fe	X	X		0.5000
^{57}Fe	X			1.0000
^{59}Co		X		1.0000
^{60}Ni		X		1.0000
^{63}Cu		X		1.0000
^{66}Zn		X		1.0000
^{75}As	X	X		1.0000
^{78}Se	X	X		1.0000
^{95}Mo		X		1.0000
^{107}Ag		X		1.0000
^{109}Ag		X		1.0000
^{110}Cd		X		1.0000
^{111}Cd		X		1.0000
^{112}Cd		X		1.0000
^{121}Sb		X		1.0000
^{137}Ba		X		1.0000
^{201}Hg	X	X	X	2.0000
^{202}Hg	X	X	X	2.0000
^{205}Tl		X		1.0000
^{206}Pb		X		1.0000
^{207}Pb		X		1.0000
^{208}Pb		X		1.0000
^{232}Th		X		1.0000
^{238}U		X		1.0000
^{6}Li (ISTD)	X		X	0.1000
^{7}Li (ISTD)	X		X	1.0000
^{45}Sc (ISTD)	X	X	X	0.1000
^{72}Ge (ISTD)	X	X	X	1.0000
^{103}Rh (ISTD)	X	X		1.0000
^{115}In (ISTD)		X		1.0000
^{159}Tb (ISTD)		X		1.0000
^{175}Lu (ISTD)		X		1.0000
^{209}Bi (ISTD)		X		1.0000

Table 4: Calculated limits of detection for the five heavy metals.

	As	Cd	Cr	Pb	Hg
Limit of Detection (ppb)	0.07	0.4	0.01	0.001	0.03

Table 5: Ordinal ranking system used during the site characterization process. Classes added by the author are indicated with an asterisk (adapted from Wildeman et al., 2007).

	0	1	2	3	4	5
Distance to Cascade Crest*	N/A	>20 km	10-20 km	<10 km	N/A	N/A
Azimuth*	N/A	N	S	N/A	N/A	N/A
Slope	N/A	1-15º	15-25º	>25º	N/A	N/A
Size estimate	N/A	<100 m^2	100-200 m^2	200-300 m^2	300-400 m^2	>400 m^2
Volume estimate	N/A	<100 m^3	100-500 m^3	500-2000 m^3	2000-5000 m^3	>5000 m^3
Surface clast size*	Boulders, cobbles, pebbles	Sand, silt, clay	N/A	N/A	N/A	N/A
Grain size estimate*	Boulders, cobbles	Pebbles	Sand	Silt	Clay	N/A
Crust presence	N/A	Yes	No	N/A	N/A	N/A
Thickness	N/A	>3 cm	1-3 cm	< 1 cm	No crust	
Distance to fluvial feature	N/A	>300 m	100-300 m	30-100 m	3-30 m	<3 m
AML stability	None	Sheet wash	Rills less than 15 cm deep	Rills 15–30 cm deep	Gullies more than 30 cm deep	N/A
Active/recent/past	None	Past	Recent	Active	N/A	N/A
Vegetation on feature	N/A	Considerable vegetation present	Some present	Very little present	(No level 4)	No vegetation present
Vegetation buffer area	N/A	No buffer area	(No level 2)	Small buffer	Trees, no underbrush	No vegetation
Rock Weathering	Fresh	(No level 1)	Weathered	Pitted	N/A	N/A

Step 3) Data Evaluation

NPDWRs (Table 1) and NSDWRs standards were used to evaluate element concentration and pH (EPA, 2018). Values above the limits of the NPDWRs pose a significant risk to human and/or animal life. The data collected for mercury by the ICP-MS showed that drift had occurred throughout the run of the machine. I hypothesize that this was caused by an accumulation of mercury in the system that decreased throughout the testing. I corrected for this by normalizing the data against samples, blanks, and standards that were run multiple times during the testing (Figure 26).

Site characterization data was summed to create a total score for each AML. These scores were ranked from highest to lowest. The AML with the highest score had the highest likelihood of its effluent causing harm to a fluvial system.

Phase 4 - Management Recommendations

Management recommendations were based on the results of the data evaluation step. Sites with the highest characterization score, and therefore the highest potential to introduce AML sediment into fluvial systems, and watersheds with the most polluted water were identified. Sites with acidic pH or those that had concentrations of heavy metals exceeding EPA standards and that could be attributed to the impacts of an AML were recommended for remediation. Specific remediation action, if necessary, was suggested based on the site's individual requirements. This information was compiled into a document along with the data collected in this research and was dispersed to all interested parties.

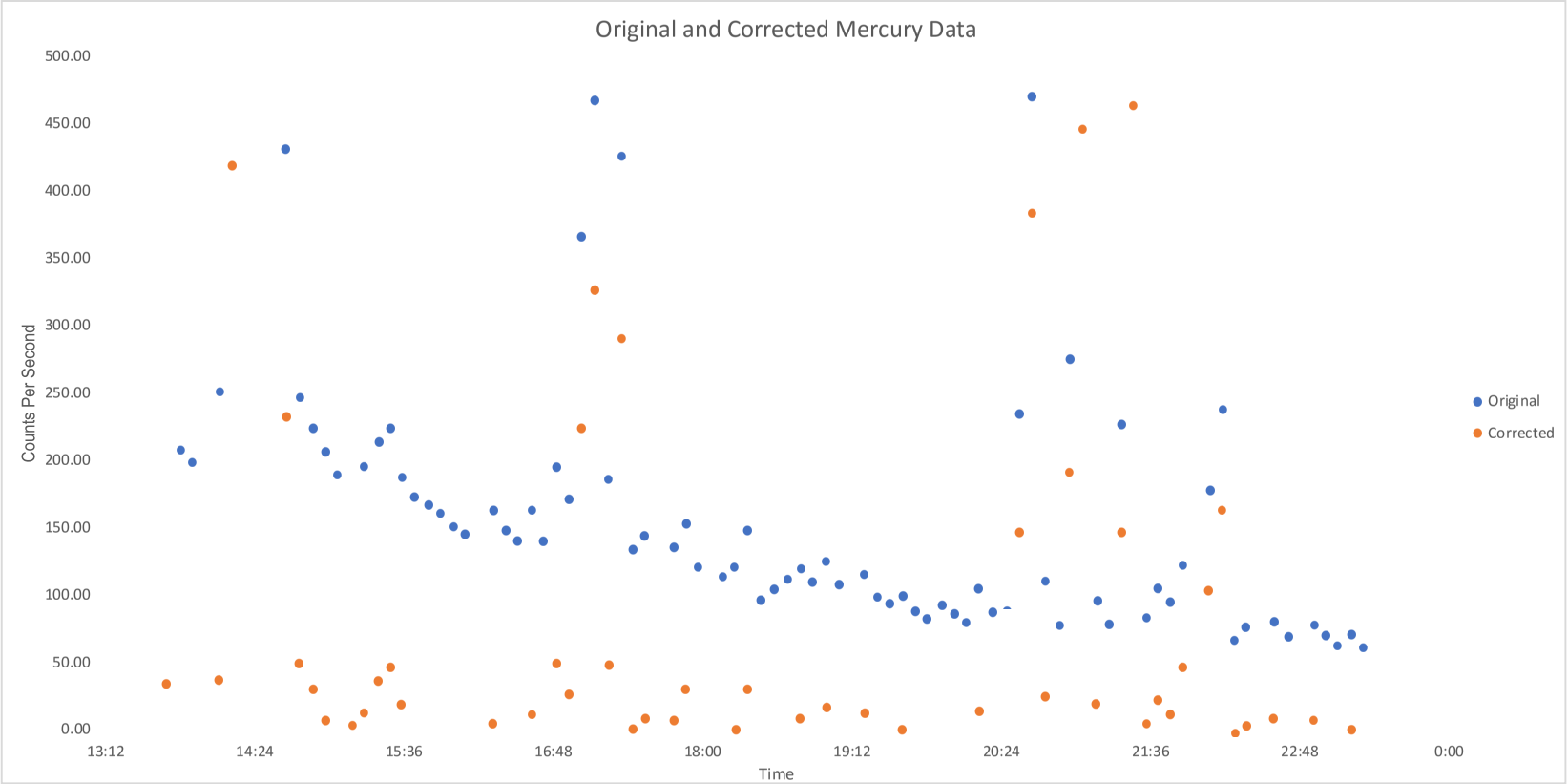


Figure 26: Original and corrected mercury data.

CHAPTER 5

RESULTS AND DISCUSSION

Mineral Creek Drainage

I visited Mineral Creek on July 17th, 2017 and August 16th, 2017 with Ellie Myers and Dr. Karl Lillquist. During the first site visit, water samples from throughout the drainage were collected. Sediment samples and water samples were collected from above, at, and below the site when it was visited a second time. The site is comprised of the extensive remains of a mill and the limited remains of a cabin (Figure 6). No tailings were evident at the location. A small mound that may possibly be tailings was present at the northeastern corner of the site. It did not have classic signs of tailings (i.e., loose aggregate and homogenous grain size) and was covered by soil and plants; however, the location and morphology of the feature was incongruous with the rest of the location (i.e., a small mound in a relatively flat area). The mill site was located on the edge of the canyon containing Mineral Creek. A small tributary to Mineral Creek flows through the western edge of the site before pooling in a muddy area at the northern edge and flowing into the canyon. The cabin remains are located approximately 50 m to the west-southwest (up-valley and up-slope) of the mill site. The cabin site contained what appeared to be the roughhewn foundation and a black smith forge. The remains of the mill contain a No. 2 Dodge Crusher, rod mill, Pelton Wheel, mine carts, wooden water pipes, lead pipes, canvas drive belts, bricks labeled "Clay Elum," roughhewn and more modern dimensional lumber, and various other debris (Figure 6).

Eight water samples and four sediment samples were collected from the drainage (Figure 27). Five water samples were collected above the mine and three from below.

Three of the sediment samples were from the AML site and one was a control sample from nearby in the drainage (Table 6). Due to the lack of tailings at the site, one sediment sample was collected at the top of the site, one sample was collected from the bottom of the site, and one sample was collected from the possible tailings.

All samples contained levels above MCLG standards of lead (0 ppb) but below the MCL (15 ppb). Most also had arsenic within this range (Table 7 and 8, Figure 28). I am not able to attribute either of these to the influence of an AML because of how prevalent they are throughout the watershed. These levels generally occur at about the same level above each AML as they do below them. These concentrations are most likely due to the local geology of the area creating natural background levels of the heavy metals. The rocks of the area may have arsenic and lead within their specific natural geochemistry and are most likely contributing them to the system through natural weathering. Negligible amounts of mercury are present in the samples from this site.

One water sample, MC-2-001, collected directly below the AML site, had cadmium levels elevated above the MCL. Although above the MCL, most of the other water samples collected in the drainage had similarly elevated levels of cadmium; however, they are just below the cadmium MCL of 5 ppb. None of the sediment samples showed heightened levels of cadmium. It is therefore difficult to attribute the elevated concentrations of cadmium to the influence of the AML. It is interesting that the level of cadmium in the water samples is higher than that in the sediment samples because the element should adhere to sediment, settle out, and be visible in the control sediment sample, which should be a fluvial deposit; however, that does not appear to be the case here (WHO, 1992). Further, the sediment samples collected at the AML site, the possible

Mineral Creek Sample Sites

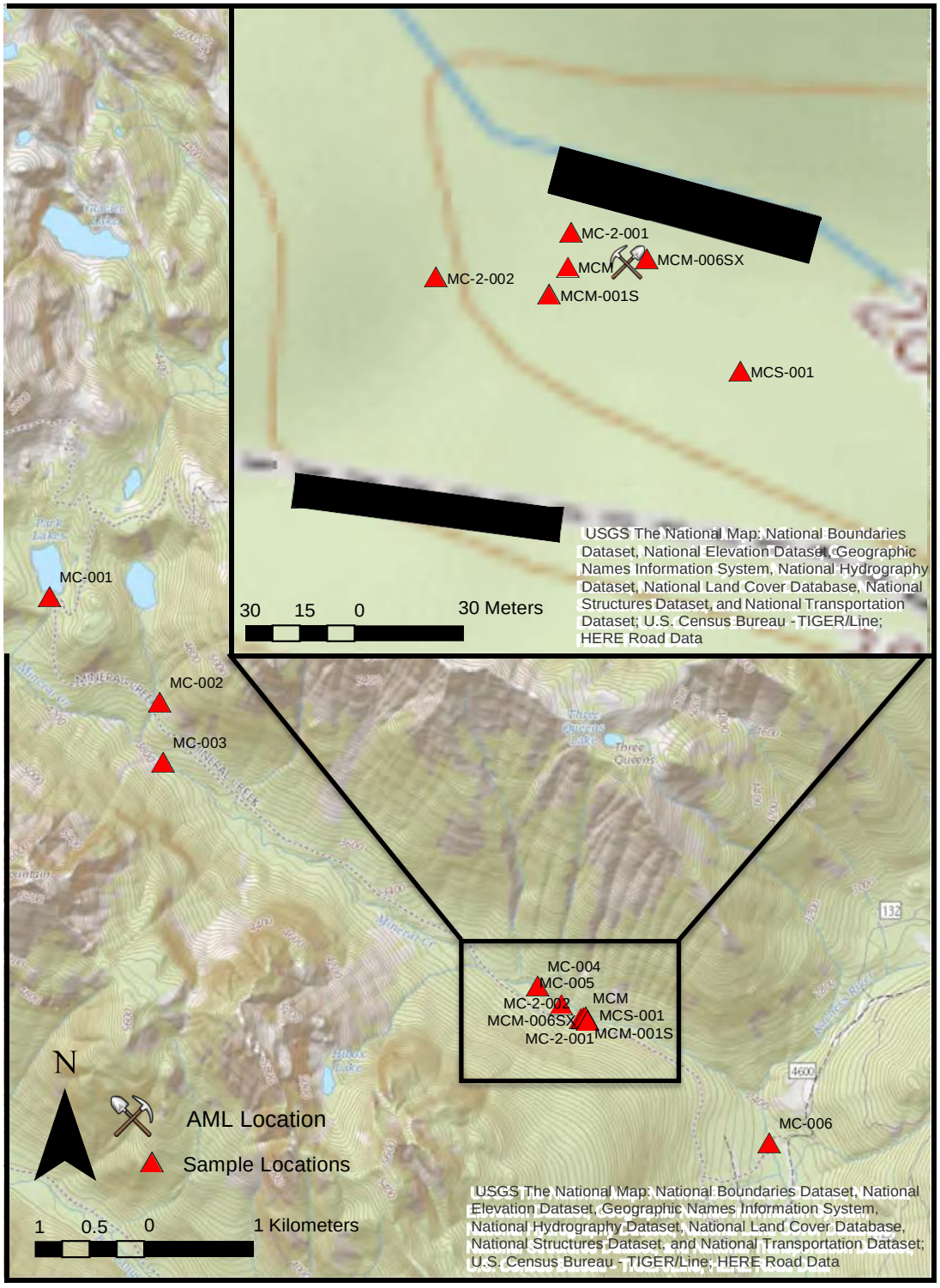


Figure 27: Sample collection sites along Mineral Creek and the surrounding area. Based on the USGS Chikamin Ridge and Pollalie Ridge 7.5-minute quadrangles.

Table 6: Sample name, type, location, and date. Data divided by AML.

Drainage	Sample Name	Sample Type	Site Location	Location Notes	Date
Mineral Creek	MC-001	Water	Mineral Creek	At outlet of northernmost Park Lake	7/17/17
	MC-002	Water	Mineral Creek	Where stream from southern Park Lake is crossed by the trail	7/17/17
	MC-003	Water	Mineral Creek	Two thirds up the drainage, below a snowfield	7/17/17
	MC-004	Water	Mineral Creek	Where trail crosses main channel of Mineral Creek, halfway up drainage	7/17/17
	MC-005	Water	Mineral Creek	Above Mineral Creek Mill, from Mineral Creek	7/17/17
	MC-2-002	Water	Mineral Creek	Above and west of Mineral Creek site from stream that will flow through site	8/16/17
	MCM-001S	Sediment	Mineral Creek	From landing area at top of mill site	8/16/17
	MCM	Sediment	Mineral Creek	From the muddy area at lower end of mill site	8/16/17
	MC-2-001	Water	Mineral Creek	At bottom of Mineral Creek site (north end) from stream that flows through site	8/16/17
	MCM-006SX	Sediment	Mineral Creek	Possible tailing pile	8/16/17
	MC-006	Water	Mineral Creek	Where trail crosses main channel of Mineral Creek at bottom of drainage	7/17/17
	MCS-001	Sediment	Mineral Creek	Control southeast of Mineral Creek Mill	8/16/17
Silver Creek	SC-001	Water	Silver Creek	Above Upper Silver Creek	8/1/17
	SCM	Sediment	Upper Silver Creek	Upper Silver Creek AML	8/1/17
	SC-002	Water	Silver Creek	Below Upper Silver Creek	8/1/17
	LSC	Sediment	Lower Silver Creek	Lower Silver Creek AML	8/1/17
	CE-001	Sediment	Silver Creek	Conrtol northeast of Upper Silver Creek	8/1/17
Camp Creek	IE	Sediment	Ida Elmore	Ida Elmore AML	10/6/17
	CC-002	Water	Camp Creek	Southeast of Ida Elmore where stream crosses trail	10/6/17
	MD	Sediment	Maud O	Maud O AML	10/6/17
	CC-001	Water	Camp Creek	Southwest of Maud O AML	10/6/17
	CC-003	Water	Camp Creek	Below and on south side of bridge that crosses Camp Creek before private property	10/6/17
North Fork	UT-003	Water	Upper Teanaway	Above Mount Hawkins (from open portal)	7/25/17
Teanaway	MTH	Sediment	Mount Hawkins	Mount Hawkins AML	7/25/17
	UT-004	Water	Upper Teanaway	Below Mount Hawkins, also leading out of Gallagher Head Lake	7/25/17
	UTS-002	Sediment	Upper Teanaway	Control west of Mount Hawkins Mine	7/25/17
	UT-005	Water	Upper Teanaway	Above Dolphin	7/25/17
	DM	Sediment	Dolphin	Dolphin AML	7/25/17
	UT-006	Water	Upper Teanaway	Below Dolphin	7/25/17
	UTS-003	Sediment	Upper Teanaway	Control northeast of Dolphin	7/25/17
	UT-001	Water	Upper Teanaway	Above West Dolphin Extension	7/25/17
	WDE	Sediment	West Dolphin Extension	West Dolphin Extension AML	7/25/17
	UT-002	Water	Upper Teanaway	Below West Dolphin Extension	7/25/17
	UTS-001	Sediment	Upper Teanaway	Control east of West Dolphin Extension	7/25/17
Middle Fork	UT-007	Water	Upper Teanaway	Above Skookum	7/26/17
Teanaway	SKM	Sediment	Skookum	Skookum AML	7/26/17
	UT-008	Water	Upper Teanaway	Below Skookum	7/26/17
	UT-008-RUN 2	Water	Upper Teanaway	Below Skookum	7/26/17
	UTS-004	Sediment	Upper Teanaway	Control north of Skookum	7/26/17

Table 7: Heavy metal content in ppb and pH for samples collected from each AML. Levels above MCLG are denoted by yellow cells. Levels above MCL are denoted by orange cells. Purple cells denote samples that have a pH outside of NSDWRs guidelines. Samples are arranged by AML and spatially from the top of the drainage (the top sample of each group) to the bottom of the drainage (the second to last sample of each group). The last sample listed in each group is the control. Water samples are highlighted blue and sediment leachate samples are highlighted brown.

Sample Location	Sample Name	As (ppb)	Cd (ppb)	Cr (ppb)	Pb (ppb)	Hg (ppb)	pH
MCLG		0.00	5.00	100.00	0.00	2.00	
MCL		10.00	5.00	100.00	15.00	2.00	
Mineral Creek	MC-001	0.07	4.46	0.00	0.24	0.00	5.6
Mineral Creek	MC-002	0.00	0.00	0.00	1.37	0.04	5.6
Mineral Creek	MC-003	0.12	4.65	0.06	0.24	0.00	6.4
Mineral Creek	MC-004	0.16	4.41	0.00	0.54	0.00	7.0
Mineral Creek	MC-005	0.16	4.43	0.05	0.13	0.00	6.9
Mineral Creek	MC-2-002	0.12	4.61	0.09	9.38	0.03	7.2
Mineral Creek	MCM-001S	0.08	0.45	0.04	1.31	0.00	5.8
Mineral Creek	MCM	0.00	0.43	0.05	1.25	0.00	5.7
Mineral Creek	MC-2-001	0.08	5.47	0.01	0.77	0.05	7.9
Mineral Creek	MCM-006SX	0.37	0.82	0.00	0.07	0.00	5.4
Mineral Creek	MC-006	0.14	4.26	0.00	0.08	0.00	7.2
Mineral Creek	MCS-001	0.10	0.45	0.00	0.29	0.00	6.1
Silver Creek	SC-001	0.15	4.34	3.72	0.00	0.00	8.1
Silver Creek	SCM	7.33	0.44	1.05	1.12	0.05	7.6
Silver Creek	SC-002	0.67	4.72	3.65	0.28	0.00	8.1
Silver Creek	LSC	6.33	0.48	0.75	4.39	0.07	7.1
Silver Creek	CE-001	0.48	0.74	2.63	1.86	0.00	6.3
Camp Creek	IE	1.34	0.63	0.05	0.22	0.00	4.9
Camp Creek	CC-002	2.16	4.76	1.69	0.00	0.00	7.8
Camp Creek	MD	7.29	0.44	0.97	2.22	0.00	7.0
Camp Creek	CC-001	4.05	4.54	3.48	0.00	0.00	8.0
Camp Creek	CC-003	1.16	4.22	6.92	0.00	0.00	8.2
Mount Hawkins	UT-003	0.08	4.01	1.39	0.26	0.00	7.7
Mount Hawkins	MTH	0.17	0.45	1.43	1.61	0.00	7.3
Mount Hawkins	UT-004	0.16	5.89	1.29	0.73	0.00	7.7
Mount Hawkins	UTS-002	0.08	0.42	1.54	0.08	0.00	6.3
Dolphin	UT-005	0.00	4.30	1.62	0.09	0.00	7.7
Dolphin	DM	0.16	0.44	0.79	0.35	0.00	7.2
Dolphin	UT-006	0.08	4.13	1.92	0.07	0.00	7.7
Dolphin	UTS-003	0.00	0.46	1.27	0.18	0.00	6.0
West Dolphin Extension	UT-001	1.99	4.42	6.62	0.10	0.00	7.8
West Dolphin Extension	WDE	0.17	0.45	0.14	0.32	0.00	7.4
West Dolphin Extension	UT-002	0.21	4.20	1.61	0.39	0.00	7.8
West Dolphin Extension	UTS-001	0.08	0.45	1.85	15.72	0.00	6.1
Skookum	UT-007	0.52	4.40	0.13	0.00	0.00	8.1
Skookum	SKM	0.68	0.57	1.11	0.42	0.06	6.5
Skookum	UT-008	0.19	4.02	0.37	6.32	0.00	7.8
Skookum	UTS-004	0.60	1.04	0.32	0.44	0.00	6.8

Table 8: Heavy metal content in ppb and pH for samples collected from each AML. Levels above MCLG are denoted by yellow cells. Levels above MCL are denoted by orange cells. Purple cells denote samples that have a pH outside of NSDWRs guidelines. Samples are arranged by AML and spatially from the top of the drainage (the top sample of each group) to the bottom of the drainage (the second to last sample of each group). The last sample listed in each group is the control. Water samples are highlighted blue and sediment leachate samples are highlighted brown.

Sample Location	Sample Name	As (ppb)	Cd (ppb)	Cr (ppb)	Pb (ppb)	Hg (ppb)	pH
MCLG		0.00	5.00	100.00	0.00	2.00	
MCL		10.00	5.00	100.00	15.00	2.00	
Mineral Creek	MC-001	0.07	4.46	0.00	0.24	0.00	5.6
Mineral Creek	MC-002	0.00	0.00	0.00	1.37	0.04	5.6
Mineral Creek	MC-003	0.12	4.65	0.06	0.24	0.00	6.4
Mineral Creek	MC-004	0.16	4.41	0.00	0.54	0.00	7.0
Mineral Creek	MC-005	0.16	4.43	0.05	0.13	0.00	6.9
Mineral Creek	MC-2-002	0.12	4.61	0.09	9.38	0.03	7.2
Mineral Creek	MC-2-001	0.08	5.47	0.01	0.77	0.05	7.9
Mineral Creek	MC-006	0.14	4.26	0.00	0.08	0.00	7.2
Silver Creek	SC-001	0.15	4.34	3.72	0.00	0.00	8.1
Silver Creek	SC-002	0.67	4.72	3.65	0.28	0.00	8.1
Camp Creek	CC-002	2.16	4.76	1.69	0.00	0.00	7.8
Camp Creek	CC-001	4.05	4.54	3.48	0.00	0.00	8.0
Camp Creek	CC-003	1.16	4.22	6.92	0.00	0.00	8.2
Mount Hawkins	UT-003	0.08	4.01	1.39	0.26	0.00	7.7
Mount Hawkins	UT-004	0.16	5.89	1.29	0.73	0.00	7.7
Dolphin	UT-005	0.00	4.30	1.62	0.09	0.00	7.7
Dolphin	UT-006	0.08	4.13	1.92	0.07	0.00	7.7
West Dolphin Extension	UT-001	1.99	4.42	6.62	0.10	0.00	7.8
West Dolphin Extension	UT-002	0.21	4.20	1.61	0.39	0.00	7.8
Skookum	UT-007	0.52	4.40	0.13	0.00	0.00	8.1
Skookum	UT-008	0.19	4.02	0.37	6.32	0.00	7.8
Mineral Creek	MCM-001S	0.08	0.45	0.04	1.31	0.00	5.8
Mineral Creek	MCM	0.00	0.43	0.05	1.25	0.00	5.7
Mineral Creek	MCM-006SX	0.37	0.82	0.00	0.07	0.00	5.4
Mineral Creek	MCS-001	0.10	0.45	0.00	0.29	0.00	6.1
Silver Creek	SCM	7.33	0.44	1.05	1.12	0.05	7.6
Silver Creek	LSC	6.33	0.48	0.75	4.39	0.07	7.1
Silver Creek	CE-001	0.48	0.74	2.63	1.86	0.00	6.3
Camp Creek	IE	1.34	0.63	0.05	0.22	0.00	4.9
Camp Creek	MD	7.29	0.44	0.97	2.22	0.00	7.0
Mount Hawkins	MTH	0.17	0.45	1.43	1.61	0.00	7.3
Mount Hawkins	UTS-002	0.08	0.42	1.54	0.08	0.00	6.3
Dolphin	DM	0.16	0.44	0.79	0.35	0.00	7.2
Dolphin	UTS-003	0.00	0.46	1.27	0.18	0.00	6.0
West Dolphin Extension	WDE	0.17	0.45	0.14	0.32	0.00	7.4
West Dolphin Extension	UTS-001	0.08	0.45	1.85	15.72	0.00	6.1
Skookum	SKM	0.68	0.57	1.11	0.42	0.06	6.5
Skookum	UTS-004	0.60	1.04	0.32	0.44	0.00	6.8

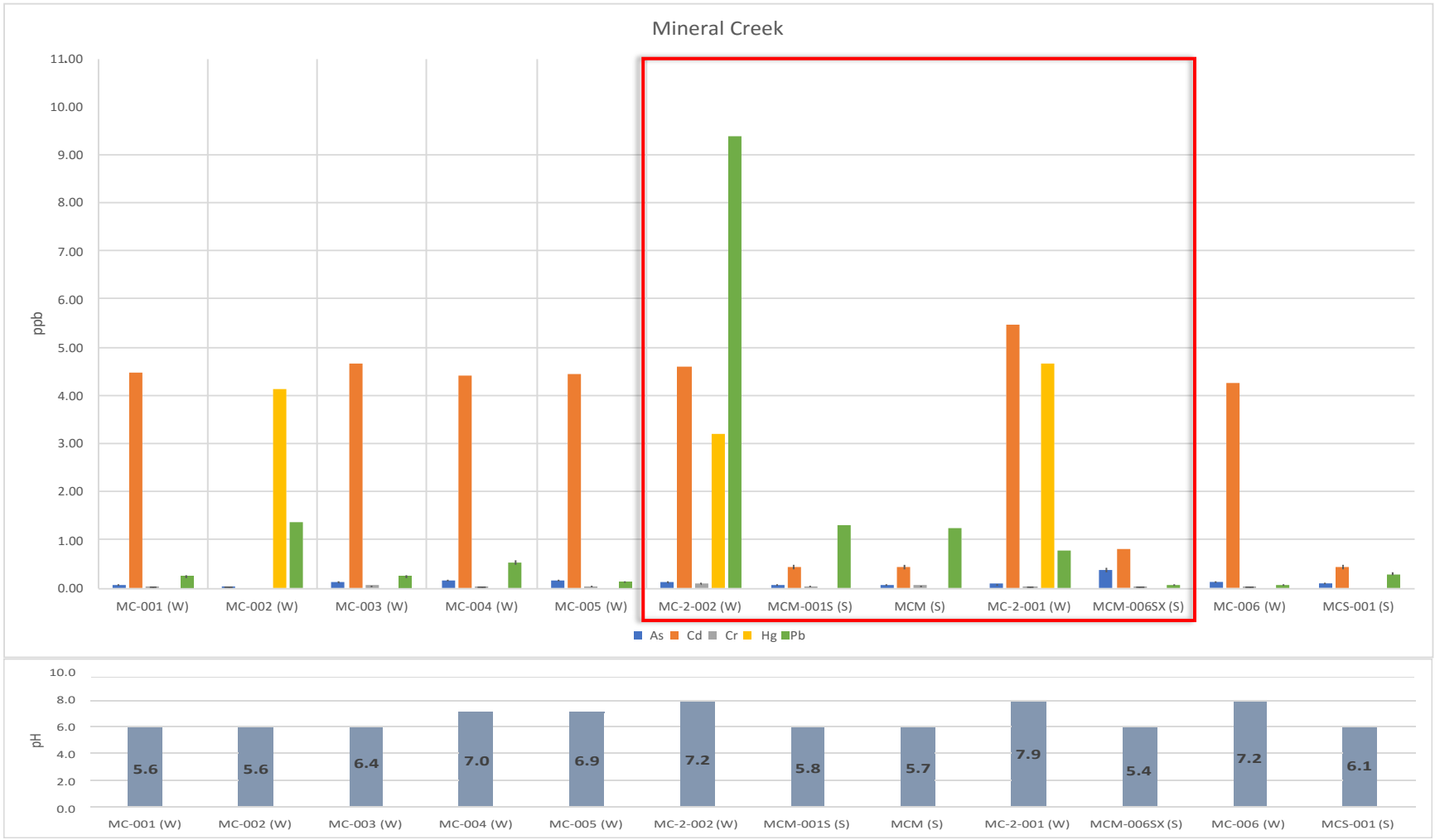


Figure 28: Heavy metal content (above) and pH (below) of samples collected from Mineral Creek. Samples are arranged spatially from the top of the drainage on the left to the bottom of the drainage on the right. The last sample on the right (MCS-001) is the control. Samples collected from the AML site are outlined with a red box. Water samples are denoted with a (W) and sediment with a (S). Mercury data has been multiplied by 100 for readability.

tailings pile, and the control sample have the same elevated levels of cadmium as the rest of the water sample, adding to the mystery.

Curiously, a water sample collected below the cabin and trail but above the AML (MC-2-002) had much higher levels of lead than the surrounding area. As it was collected above the mill site it is unlikely that it was influenced by the AML. This could possibly be of anthropogenic origin, perhaps from the cabin site or trail. During our investigation of the cabin site we did not find any objects or features that could contribute to these heightened levels; however, the site was very overgrown and there may have been some source that we did not see during our visits. Additionally, lead paint may have been used at the site. However, as the levels do not exist in other samples collected, even those less than 100 m downstream, this may be due to contamination of the sample. Further, an adit that was not examined in this research exists roughly 700 m upstream (southwest) of the Mineral Creek AML that may also be the source of this contamination.

The pH of the samples collected in this area are circum-neutral (Table 7 and 8). The water samples collected near the head of this drainage, directly above the AML site, and the leachate from the AML site and from the possible tailings site are all slightly acidic; however, they are not too acidic as to be worrisome although the sample from the possible tailings pile is outside the NSDWRs. Interestingly, the water sample collected directly below the AML site is more basic than those surrounding it. This may be attributable to the impacts of the AML but not to the effects of AMD. Similar effects have been observed in Siberia and Svalbard (Banks et al., 2002). At these locations several factors were put forward as possible reasons for this effect, but two appear to be the most applicable to this location: the neutralization of water by carbonate or alkaline

rocks or groundwater and the lack of contact between water and sulfide minerals. Carbonate rocks could possibly be found in this area. The head of the drainage is less than 10 km from the Snoqualmie Pass where carbonates outcrops can be found (Tabor et al., 2000). It is possible that some of these units may be present in the Mineral Creek drainage. Additionally, because no tailings were found at this AML, the ability for water to interact with sulfides is greatly reduced.

The site characterization data for the Mineral Creek AML (Table 5) shows that it has the lowest score (14) of any examined in this study (Table 9). This is mainly due to the lack of identifiable tailings at the site. As such, it has the least chance of discharging AML contaminants and presents the smallest risk to fluvial systems.

From these data, I am not able to determine that the Mineral Creek AML has any impact on the water quality of Mineral Creek. Elevated concentrations of arsenic and lead were detected throughout the watershed, but it cannot be attributed to the AML and are most likely natural background levels. Additionally, a heightened level of cadmium was detected in a water sample collected directly below the AML; however, these levels are only marginally higher than that of background. Further, the ability of this AML to introduce its contaminants into fluvial systems is lower than all other sites. If the AML does have an impact on the water quality, it appears negligible.

Silver Creek Drainage

Both sites within the Silver Creek Drainage were visited on August 1st, 2017 by Ellie Myers and myself. The upper site is comprised of two separate tailings piles with a trail passing between them (Figure 29). On top of the northern pile are the remains of a

Table 9: Site characterization data and total scores arranged from highest (most pollution potential) to lowest (least pollution potential).

Site Name	Upper Silver Creek	West Dolphin	Maud O	Dolphin	Skookum	Ida Elmore	Lower Silver Creek	Mount Hawkins	Mineral Creek
Distance to Cascade Crest	2	2	2	2	1	2	2	2	3
Azimuth	2	2	2	2	2	2	2	2	1
Slope	3	3	3	2	2	3	3	2	2
Size estimate	5	5	4	5	5	2	4	3	N/A
Volume estimate	4	4	2	4	5	1	3	3	N/A
Surface clast size	1	0	0	0	0	0	1	0	N/A
Grain size estimate	3	3	3	2	3	3	3	2	N/A
Crust presence	1	1	1	1	1	1	2	1	N/A
Thickness	2	3	3	2	3	2	4	2	N/A
Distance to fluvial feature	5	3	5	4	3	5	3	2	5
AML stability	4	3	3	4	3	3	0	3	N/A
Active/recent/past	3	2	3	3	1	3	0	2	N/A
Vegetation on feature	2	3	3	2	2	3	2	3	3
Vegetation buffer area	0	0	0	0	0	0	0	0	N/A
Rock Weathering	2	2	2	2	2	2	0	0	N/A
Total	**39**	**36**	**36**	**35**	**33**	**32**	**29**	**27**	**14**

wooden structure that appears to have entirely collapsed. Above that pile, to its north, are several metal, semicircular chutes or flumes that were most likely used as ore chutes. Throughout the site is various debris as well as several sections of metal rails that may have been used for mine carts.

It appears that considerable deterioration of the ruins at this site has occurred since 1995 when Woodhouse et al. (2002) visited it. In photos found in the book, the wooden structure that we saw was considerably more substantial with what appears to be walls still standing. These are no longer visible. Silver Creek runs directly to the south of the southernmost tailings pile and is actively eroding the site. Roughly 225 m to the west (downstream) of the upper site is the lower site. This site consists of one tailings pile (Figure 20) and one collapsed portal (Figure 30). An old mining road leads to both sites. Although clear enough to follow by foot, the road is impassable by automobile and is denoted as a trail on USGS and USFS maps of the area.

Two water samples and three sediment samples were collected from throughout the drainage (Figure 31). A water sample was collected from above the upper site and from between the upper site and lower site; however, no sample was collected from below the lower site (Table 6). This is due to the fact that the creek had completely disappeared below the site. A defined channel for the stream did exist and is likely filled with water following snowmelt and intense rain events. Two of the sediments samples were for AML sites and one was a control sample collected from within the drainage above the upper site.

All samples contain levels of arsenic above the MCLG but below the MCL, and all samples except the water sample collected from above the upper site contained lead

Figure 29: Tailings at the Upper Silver Creek Site. View roughly east (up valley). Photo by Scott Kugel, August 2018.

Figure 30: Collapsed portal at the Lower Silver Creek AML site. Portal is located to the south of the tailings pile. Photo taken from mining road looking east. Photo by Scott Kugel, August 2018.

above the MCLG but below the MCL (Table 7 and 8, Figure 32). The concentration of arsenic in stream water is elevated below the upper site; however, the increase is too slight to definitively attribute to the AML. The sediment samples collected from the AMLs have much higher levels of arsenic than the water samples or the control sample. This may indicate that the ore body sought in this area has higher levels of arsenic than the surrounding rock.

Silver Creek Sample Sites

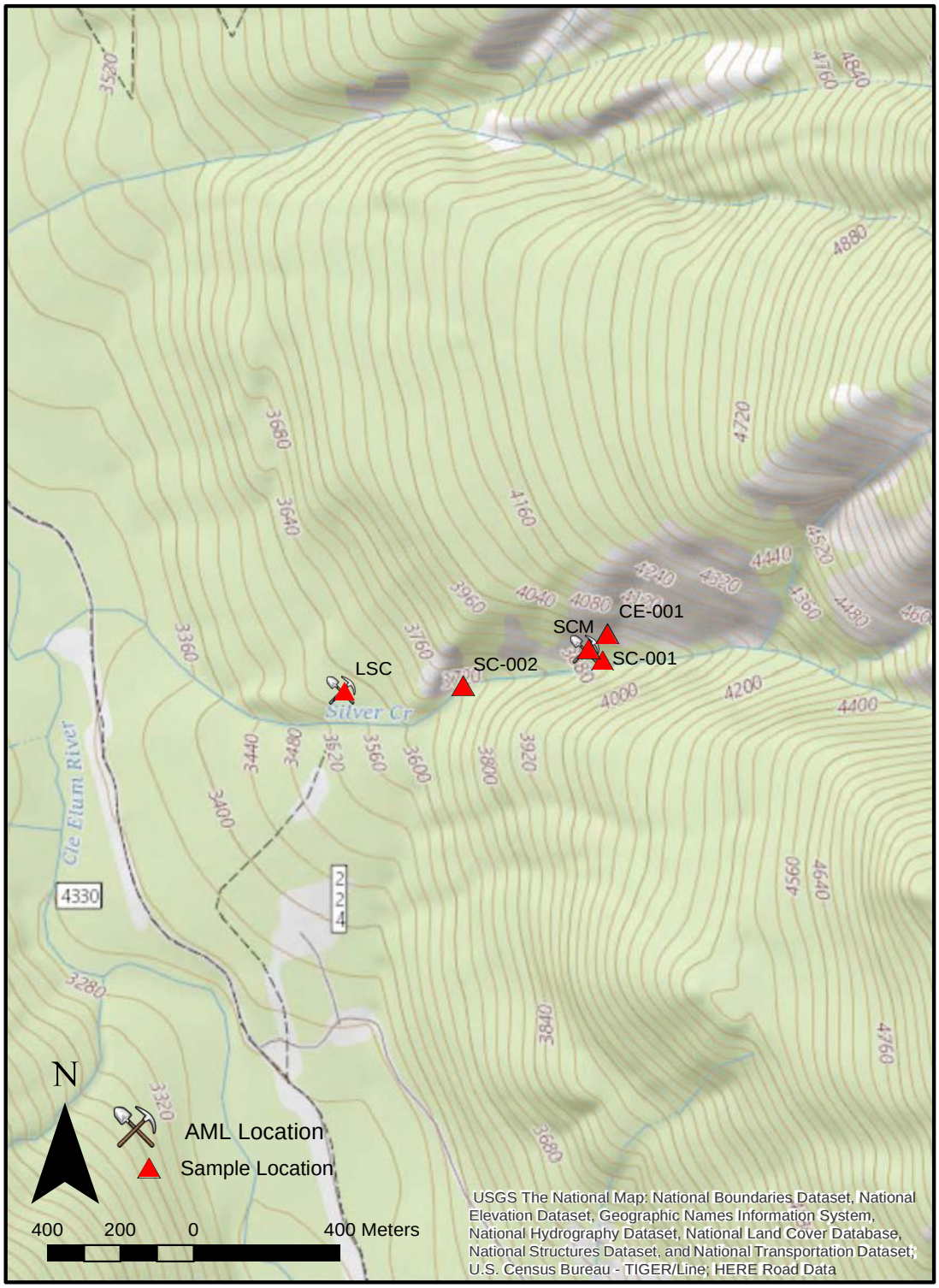


Figure 31: Sample collection sites along Silver Creek and the surrounding area. Based on the USGS Davis Peak 7.5-minute quadrangle.

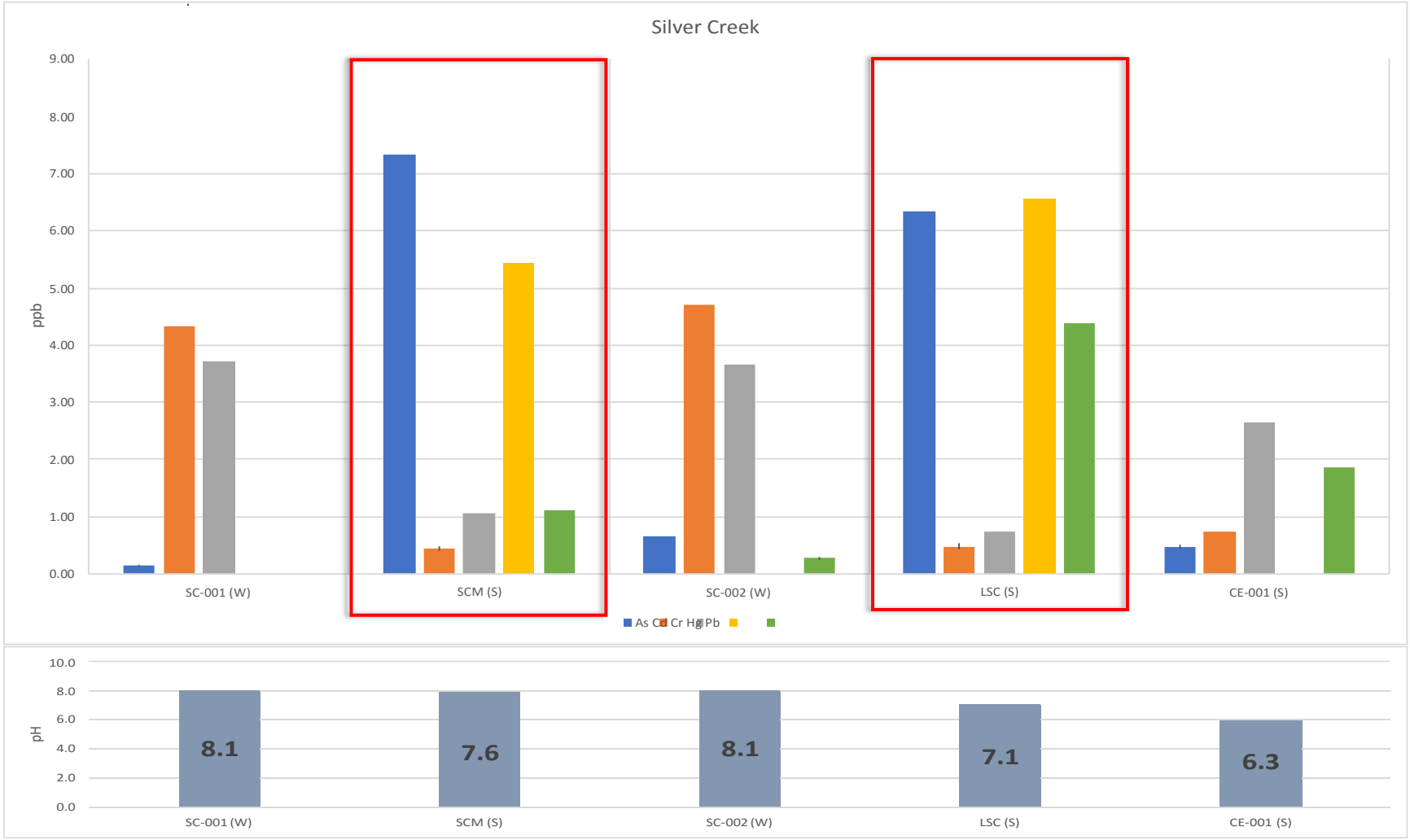


Figure 32: Heavy metal content (above) and pH (below) of the samples collected from Silver Creek. Samples are arranged spatially from the top of the drainage on the left to the bottom of the drainage on the right. The last sample on the right (CE-001) is the control. Samples collected from the AML site are outlined with a red box. Water samples are denoted with a (W) and sediment with a (S). Mercury data has been multiplied by 100 for readability.

Further, like the Mineral Creek area, the cadmium in the water collected here is much higher than that found in the sediment. Both samples are less than 1 ppb below the MCL and MCLG for cadmium. However, unlike the Mineral Creek site, the chromium concentration in both water samples follows the same elevated pattern as the cadmium. Additionally, elevated chromium levels exist in the control sample as well. It is worth noting though that the concentrations of chromium found here are significantly less than the NPDWR standards and have very little to no impact on the environment. Negligible amounts of mercury are present in the samples from this site.

It is also worth considering that the amount of lead in the water rose from 0.00 ppb to 0.28 ppb below the upper site. This is likely due to the influence of the AML because a natural, background geologic influence of lead would likely impact the water over the roughly 2 km of travel from the head of the creek to the sample locations.

The pH of the samples collected from this site are slightly basic but are not harmful to the environment (Table 7 and 8). This is likely due to the chemical characteristics of the local rock. The Ingalls Ophiolite Complex is composed of a significant amount of

ultramafic serpentinite and has calc-alkaline mafic intrusions of basalt and gabbro. Both of these factors have been shown to increase the overall pH of a system (Blank et al., 2009). Notably, the control sample has a much lower pH than the rest of the area. The cause of this is not readily apparent.

The site characterization data collected for the AMLs of the Silver Creek drainage revealed an interesting pattern. The upper site was the highest ranked location with a score of 39 while the lower site was the second lowest ranked site that received scores for

every category with a score of 29 (Table 9). This indicates that the upper site is more likely to impact the water quality of the area than the lower site. However, the disparity in the scores between the two Silver Creek sites is curious due to the similarities of both sites. These sites were operated by the same group, mined for the same ore body, processed using the same equipment, and operated around the same time. Differences in the stability of the AMLs, their level of weathering, and aspect appears to be the cause of the largest portion of the disparity in their scores.

Using these data, I am able to determine that AMLs found along Silver Creek do have an impact upon the water quality of the drainage. Specifically, the upper site is impacting the water of the area, and the lower site is as well, but I am unable to definitively make a determination due to the lack of samples collected below the site. The amount of lead found in the stream appears to be higher than the natural state and in a concentration that is of concern to the EPA. This is supported by the high characterization score of the upper site, which indicates that it has the highest likelihood of all locations to contribute contaminants to the system. However, although arsenic concentrations are also elevated in the area, these levels cannot be attributed to the AML and are likely background concentrations stemming from the natural makeup of the rock.

Camp Creek Drainage

The Ida Elmore and Maud O AML sites within the Camp Creek Drainage were visited on October 6, 2017 by Ellie Myers, Noah Driver, and myself. Both AML sites lie within the same individual drainage that makes up a portion of the Camp Creek drainage. The Ida Elmore AML site consisted of an open portal and a collapsed portal located approximately 90 m to the southeast from the main site. Directly south of the open portal

is a tailings pile that lies on a roughly 40° slope (Figure 33). This pile is unique to all others that were examined in that it is very thin (30 cm at its thickest) and consists of extremely homogenous, fine-grained sediments. The open portal was not entered but observations from the outside indicate that the tunnel is collapsed a few meters from the entrance.

Maud O AML consists of a portal that has been partially sealed by boards, a small open-air shack, the remains of an aerial tram, a tailings pile, and various debris (Figure 34). Small trail-like features have developed laterally across the tailings (Figure 35). These features suggest that the tailings are fairly stable, otherwise the trail would have been covered by the downward movement of sediment in the pile. The portal was not entered, and outside observations were unable to determine its depth. Much of the

Figure 33: Open portal located at the Ida Elmore AML site. Photo taken from trail looking northeast. The tailings pile is located directly behind the photographer. Photo by Scott Kugel, September 2017.

debris located at this site appeared to be from at least the latter half of the 20th century. However, no recent signs of activity were present. An active and posted placer mine is located lower in the drainage, above where the trail crosses Camp Creek.

Two sediment samples and three water samples were collected throughout this drainage (Figure 36). No water sample was collected above the Ida Elmore AML because this site is located very near the top of the Huckleberry Peak and there is no water above it. A water sample was collected from above the Maud O AML site; however, this sample does not come from the same individual drainage that both AML sites are located in (Table 6). This was done because there was no flowing water above the Maud O AML site. The other two water samples were collected from below the Maud O AML site and from where Camp Creek is crossed by the trail near the bottom of the drainage.

Figure 34: Partially sealed portal at the Maud O AML site. Photo taken looking north. The edge of the tailings pile can be seen to the right the portal. Photo by Scott Kugel, September 2017.

Figure 35: Top of tailings pile (red arrow) and trail-like feature (yellow arrow) at the Maud O AML site. Photo taken looking east. Photo by Scott Kugel, September 2017.

Composite sediment samples were collected from the AML sites. No control sample was collected for this area due to errors in the field.

Like the other AML sites, all samples have elevated arsenic levels above the MCLG but below the MCL (Table 7 and 8, Figure 37). This is to be expected as arsenopyrite is present in the area (Thurber et al., 1964). However, unlike other locations, only the two sediment samples contained lead. None of the three water samples contained any detectable amounts of the metal. This indicates that the AML sites are not contributing lead into the water of the area, and possibly are not interacting with the water of the area at all. The presence of lead in the sediment and not the water is likely because the geologic units that were being mined have different concentrations of lead

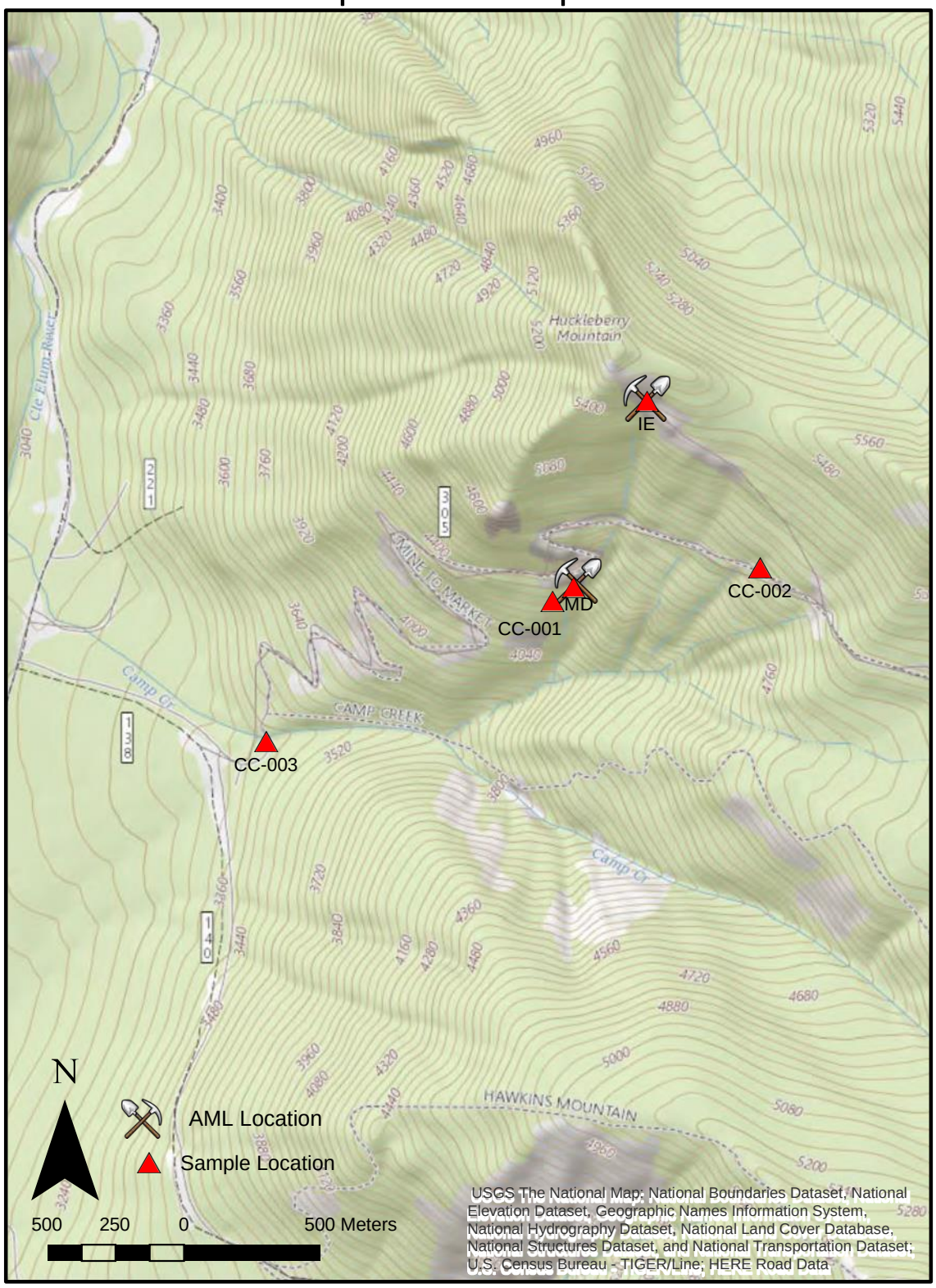


Figure 36: Sample collection sites along Camp Creek and the surrounding area. Based on the USGS Davis Peak 7.5-minute quadrangle.

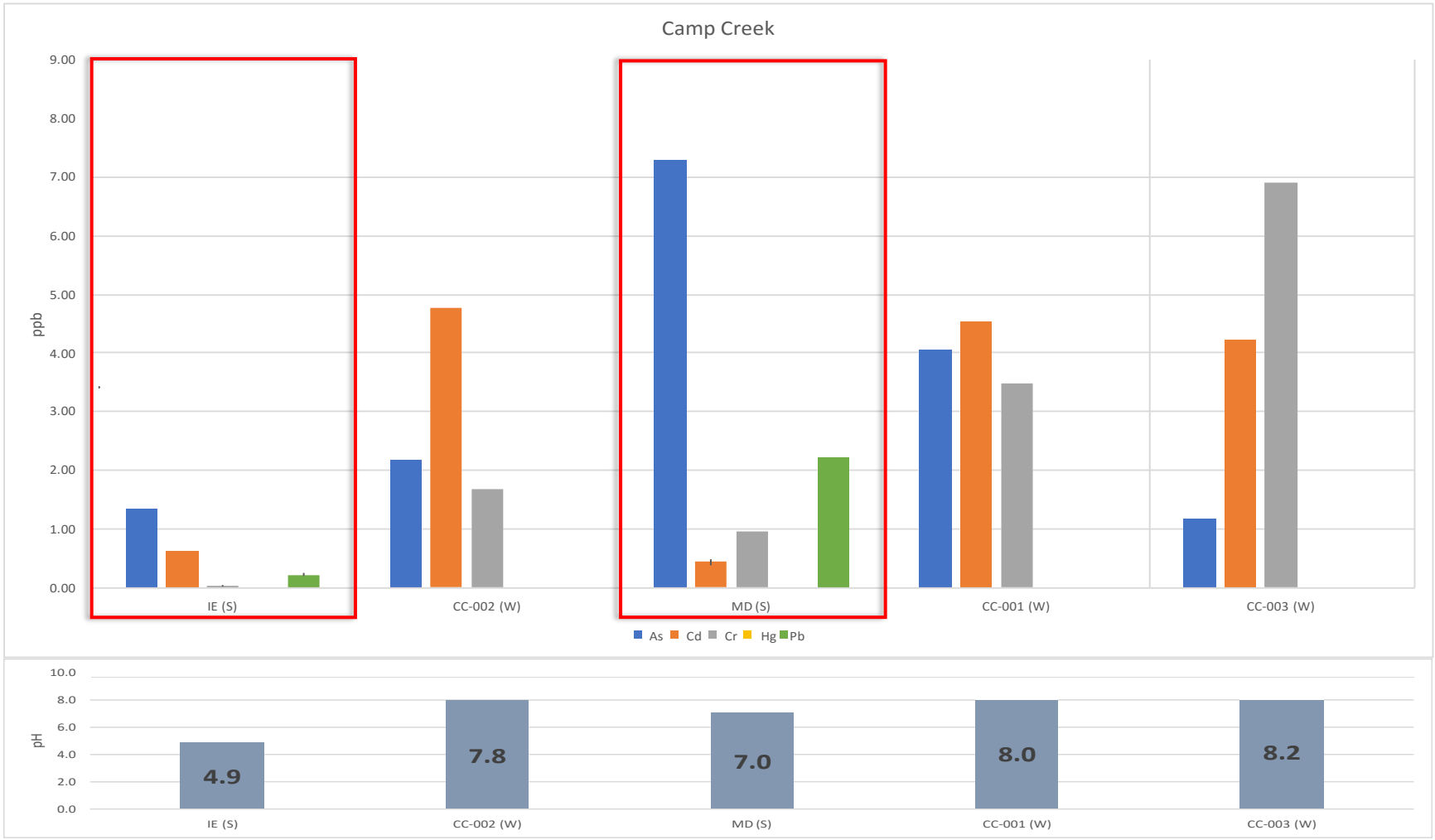


Figure 37: Heavy metal content (above) and pH (below) of the samples collected from Camp Creek. Samples are arranged spatially from the top of the drainage on the left to the bottom of the drainage on the right. Samples collected from the AML site are outlined with a red box. Water samples are denoted with a (W) and sediment with a (S). Mercury data has been multiplied by 100 for readability.

than the surrounding area. I have not found any specific research that indicates the presence of lead minerals in the rocks of this specific area; however, galena is mined with gold and silver in the same rock unit, the Ingalls Complex, in the Peshastin Creek area (Derkey et al., 1990). Further, the abandoned mining town of Galena City, is located near where Camp Creek enters the Upper Cle Elum River (Figure 10). It is likely that the town was named for a mineral that is mined nearby. Additionally, like in the Silver Creek drainage, cadmium and chromium concentrations are elevated in water samples and low in sediment samples. No mercury is present in any sample collected from this site.

The pH of the samples collected in this drainage very widely (Table 7 and 8). The leachate from the Ida Elmore site is acidic and below NSDWRs. It is likely that this is due to the impacts of the processes that causes AMD. However, further down the drainage, the samples become much more basic. This indicates that if the Ida Elmore AML impacts Camp Creek, it is effects are likely minimal, and are neutralized by the geologic effect on pH.

The site characterization data collected for the AMLs along Camp Creek indicate that both sites are in the middle of the grouping in their abilities to contribute sediments to fluvial systems. The Maud O site has the higher score with 36, making it tied for second with the West Dolphin Extension (Table 9). The Ida Elmore site has a score of 32, making it the sixth highest. These scores indicate that they are somewhat likely to contribute their contaminants to the fluvial system, compared to the rest of the sites that were examined.

With these data, I can conclude that the AMLs along Camp Creek are not negatively impacting the water quality of the drainage. Lead concentrations are found

within the sediment samples collected but are not found in the water samples, indicating that the AMLs are not contributing lead to the system. Further, the pH of one sediment sample is low but the pH of the rest are within acceptable limits further signaling that the AMLs have little influence on the water quality of the drainage. The middle of the range characterization score that both of these sites and the Mineral Creek site received, in conjunction with the lack of impacts on water quality, seem to indicate that the lower portion of the characterization score range have little to no impact on water quality in this area.

Teanaway Drainage

Mount Hawkins Mine

The Mount Hawkins AML site was visited on July 25th, 2017 by Ellie Myers and myself. The site is located 150 m to the west of Gallagher Head Lake. The site is comprised of an open portal that is filled with water and a tailings pile directly southeast. The portal is comprised of a winze that is reinforced on all sides with wooden beams (Figure 38). The tailings come directly from the open winze southeast to the edge of the four-wheel drive road/trail.

Two water samples and two sediment samples were collected from the AML site (Figure 39). One water sample was collected directly from the open winze, the other was collected from a small stream that flows out of the southwestern corner of Gallagher Head Lake, the closest water below the site (Table 6). One composite sediment sample was collected from the site and the other is a control.

Similar to other location, concentrations of arsenic and lead occur at this site that are greater than the MCLG but below the MCL (Table 7 and 8, Figure 40). Worth noting

Figure 38: Open portal at the Mount Hawkins AML site. The winze is completely filled with water and a sample was collected from it. Picture is taken looking northeast. Photo by Ellie Myers, July 2017.

is that sediment sample collected from the AML had considerably higher lead levels than the control sample. This could indicate that, similar to samples collected from the Camp Creek area, the ore body that was sought in this location contains more lead than the surrounding surface rock. Additionally, heightened levels of cadmium were found in the water samples of the AML but not in the sediment. Further, the water sample collected below the AML had levels of cadmium above the MCL. This may indicate that the AML is contributing cadmium to the fluvial system. However, like the Mineral Creek drainage, all other water samples collected in this area had elevated cadmium concentrations and this sample was only slightly higher than the rest. Further, because this sample was collected at the outlet of Gallagher Head Lake, it is possibly affected by the Dolphin

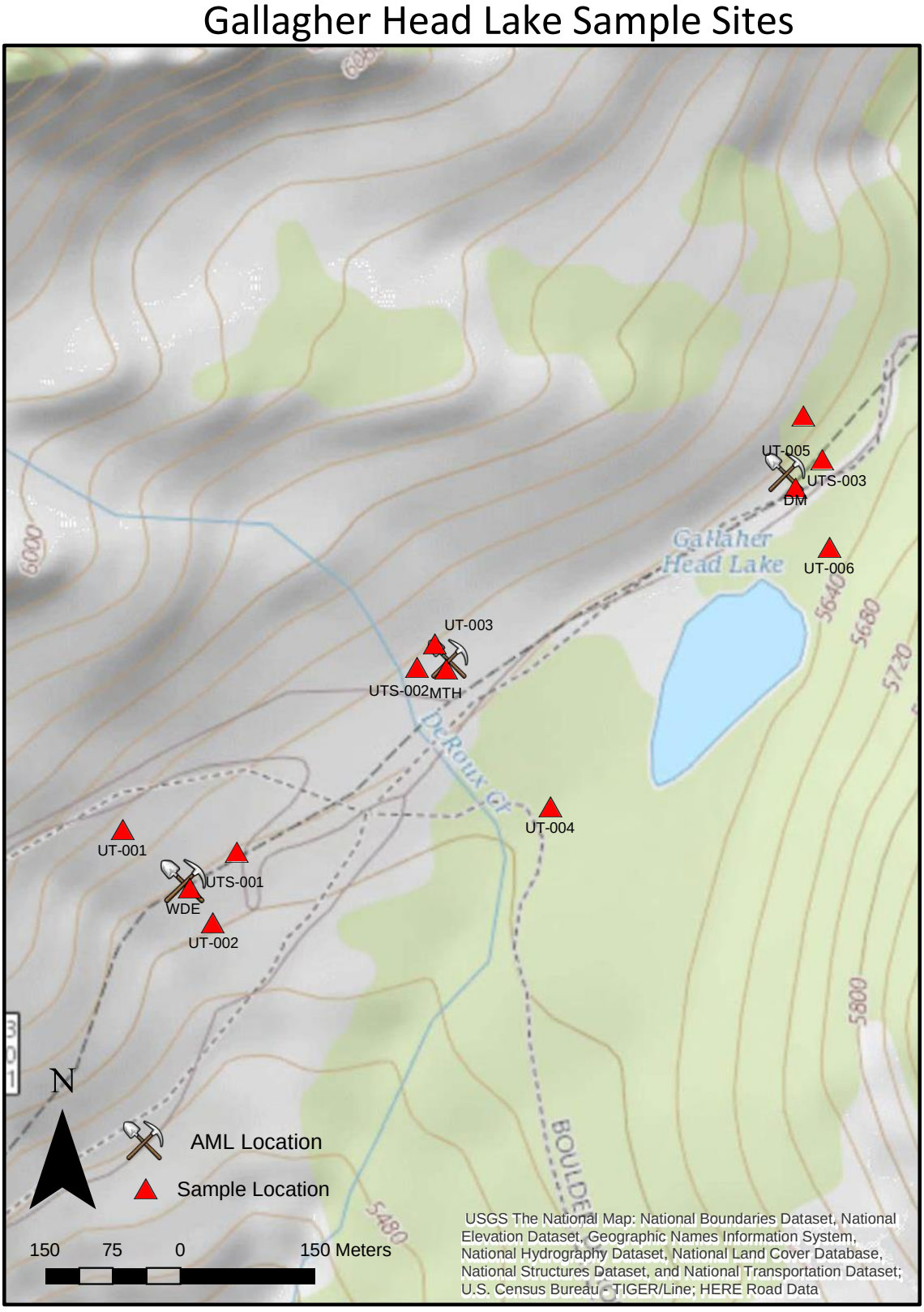


Figure 39: Sample collection sites in the Gallagher Head Lake area.

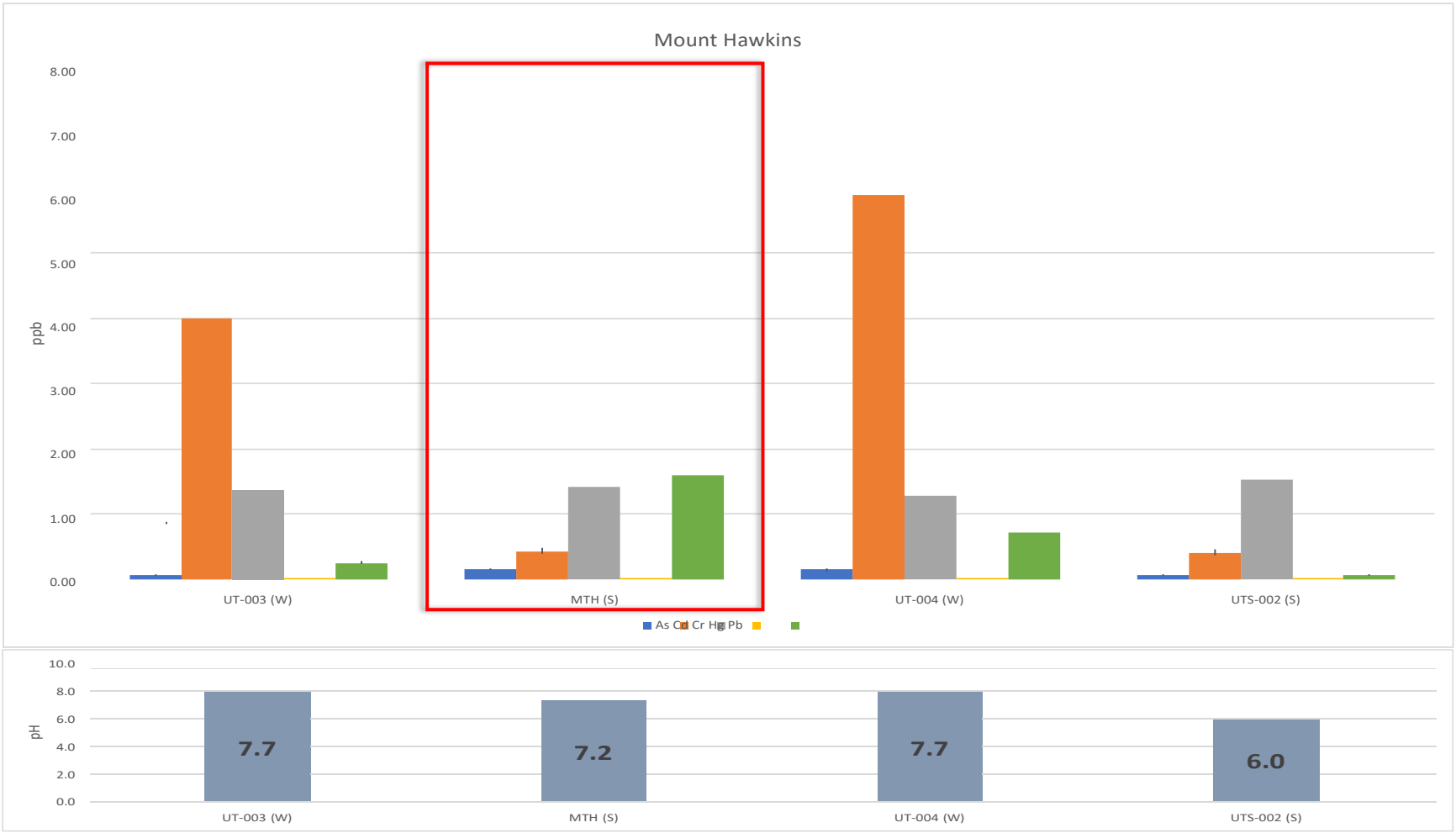


Figure 40: Heavy metal content (above) and pH (below) of the samples collected from the Mount Hawkins AML. Samples are arranged spatially from the top of the drainage on the left to the bottom of the drainage on the right. The farthest right sample (UTS-002) is the control. Samples collected from the AML site are outlined with a red box. Water samples are denoted with a (W) and sediment with a (S). Mercury data has been multiplied by 100 for readability.

AML as well as the rest of the basin that drains into the lake. Due to these impacts, it is likely that this sample is not a good indicator of the impacts of the single AML.

No mercury is present in any sample collected from this site. The pH of the samples collected from this AML are all neutral; however, the control sample is slightly more acidic than the rest (Table 7 and 8). This indicates that impacts of AMD are not present at this location.

The site characterization data collected for the Mount Hawkins AML reveals that this site has low potential to contribute sediments to fluvial systems. It has a score of 27 making it the eighth highest rated and second lowest (Table 9).

Similar to Mineral Creek, based on these data, I am not able to determine that the Mount Hawkins AML has any impact on the water quality of the area. Like at other sites, the elevated levels of arsenic and cadmium found in these samples are likely natural background levels and the AML has little effect on them. Additionally, although the concentration of lead is higher in the AML sediments than in the control, this heightened level does not continue into the water sample collected below the AML. This, and the low characterization scores, further indicate that the site has little to no effect on the water of the area.

Dolphin Mine

I visited the Dolphin AML site on July 25th, 2017 with Ellie Myers. The site consists of one tailings pile about 60 m to the north of Gallagher Head Lake. The site is located directly next to the four-wheel drive road/trail. On the southern and western edges of the tailings are what appear to be the tracks of a four-wheel vehicle (Figure 41).

A second, smaller tailings pile was found about 30 m to the northwest and upslope of this site. However, due to time and equipment restraints, this site was not examined or sampled. It is unclear whether this site is connected to the Dolphin AML or a completely different AML. What may have been a collapsed portal was visible, but it was not possible to determine to any degree of certainty.

The four-wheel vehicle tracks on the AML site are troubling. It was not possible to tell how recent they are or how many vehicles had used them, but they did show that the top layer of the tailings had been disturbed, revealing inner, unweathered portions of the feature that were not previously visible or accessible. The sampling strategy that I employed only collects from the top 15 cm because that is the active layer in the tailings

Figure 41: Dolphin AML site. Ellie Myers in the foreground. Four-wheel vehicle tracks are indicated with an orange arrow. Photo taken looking northwest. Photo by Scott Kugel, July 2017.

that interacts with the atmosphere (Smith et al., 2007). By revealing new layers, new areas of the tailings may begin to be weathered and eroded and brought into the system. Because these new areas have not been weathered before, or at least not as extensively as the outer layer, they may introduce heavy metals and other elements and compounds that had already been weathered on the outer layer into the environment.

Two water samples and two sediment samples were collected from the AML site (Figure 39). One water sample was collected above the AML from a small stream that flows just to the east of the site. This stream continues about 20 meters past the AML to the southeast before turning west and heading into a marshy grasslands area which empties into the northeast corner of Gallagher Head Lake (Table 6). The second sample was collected from the stream as it passed through the marshy area below the AML. One sediment sample was collected from the site and the other is a control.

Like samples collected from other sites, all samples collected from the Dolphin AML had elevated levels of lead above the MCLG but below the MCL (Table 7 and 8, Figure 42). The sediment sample collected from the AML and the water sample below the site have elevated levels of arsenic that were not present above the site. This may indicate that this AML is contributing arsenic to the environment; however, as nearly every other sample collected has similar concentrations of arsenic it is difficult to make this distinction. Additionally, like samples from other areas, cadmium levels in the water are much higher than those found in the sediment samples. No mercury is present in any sample collected from this site. The pH of the samples collected from this AML are all within the neutral range (Table 7 and 8). The control sample is more acidic than the rest. This indicates that impacts of AMD are not present at this location.

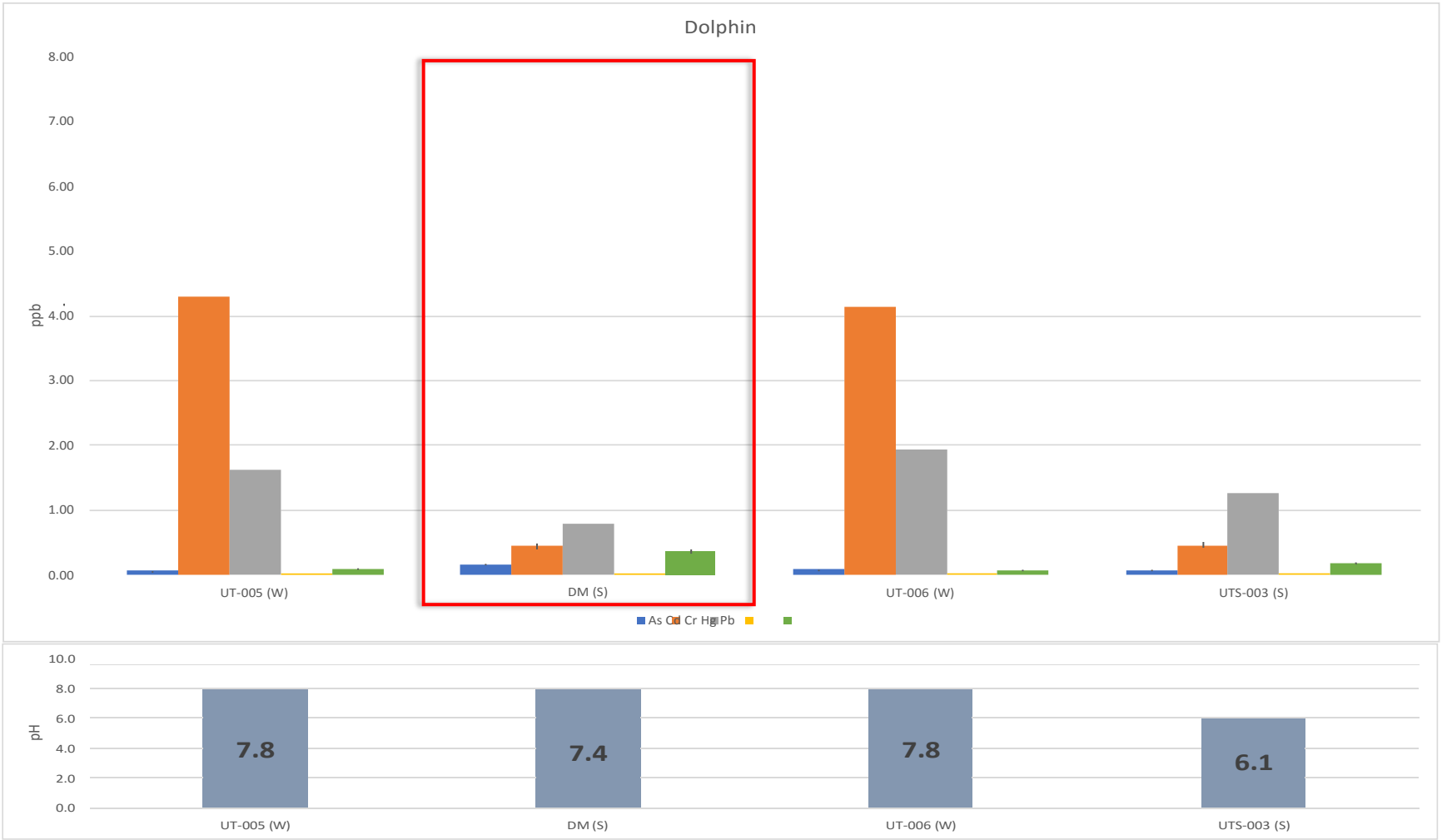


Figure 42: Heavy metal content (above) and pH (below) of the samples collected from the Dolphin AML. Samples are arranged spatially from the top of the drainage on the left to the bottom of the drainage on the right. The farthest right sample (UTS-003) is the control. Samples collected from the AML site are outlined with a red box. Water samples are denoted with a (W) and sediment with a (S). Mercury data has been multiplied by 100 for readability.

The site characterization data collected for the Dolphin AML shows that this site is in the higher portion of the range of abilities to contribute sediments to fluvial systems. With a score of 35, it is the fourth highest rated (Table 9).

From these data, I am not able to determine that the Dolphin AML has any effect on the water quality of the area. None of the indicators of the negative chemical impacts of these features are present at this location. However, its site characterization score places it above most of the other locations examined, indicating that it is more likely to contribute its contaminants to fluvial systems. This is troublesome because of the automobile tracks that are found on the feature. If this site is being used for off-roading, then, as previously stated, newer, potentially less-weathered layers are being exposed which may contribute more contaminants than what was found here. Due to the high characterization score, these contaminants would be more likely to enter fluvial systems of the area.

West Dolphin Extension

The West Dolphin Extension AML site was visited on July 25th, 2017 by Ellie Myers and myself. The site is located about 350 m to the west of Gallagher Head Lake. It consists of a tailings pile that is lobate at the lower, southern end and much narrower at the higher, northern end. A small campfire ring has been constructed atop the pile. A small stream follows the northeastern edge of the tailings and continues into a meadow to the Southeast. Additionally, an orange tinted stream, similar in appearance to those impacted by acid mine drainage, flows from the southeastern tip of the tailings. However, it was unclear if this was caused by upwelling under the tailings or by the small stream

from above. This was the only fluvial system of this type that was observed at any of the sites.

Two water samples and two sediment samples were collected from the AML site (Figure 39). One water sample was collected above the site from a small stream that follows the northeastern side of the site (Table 6). The other water sample was collected from a stream that flows to the west of the site. One sediment sample was collected from the site and the other is a control that was collected near the road to the east of the site.

Like most other samples, many that were collected from this AML have elevated concentrations of arsenic and lead above the MCLG but below the MCL (Table 7 and 8, Figure 43). However, the control sample had levels of lead above the MCL. This concentration can be attributed to the sample location. The nearby road has been in use by overlanding enthusiasts, recreationalists, and miners since 1905 (Gallaher, 1905). It is likely that either the emission of engines using leaded gasoline have polluted this site to this extent or some leaded gasoline or another lead-based automobile fluid, such as a lead-acid battery has been spilled on the site. Also similar to other sites, the cadmium is higher in water samples than in sediment samples. Additionally, the water sample taken above the AML has higher levels of arsenic and chromium than other locations in the area. No mercury is present in any sample collected from this site. The pH of the samples collected from this AML are all within the neutral range (Table 7 and 8). The control sample is the most acidic of those tested at this location. This indicates that impacts of AMD are not present at this location.

This chromium concentration, and those detected throughout the Gallagher Head Lake area are notable in their relatively small concentrations. The mines of this area were

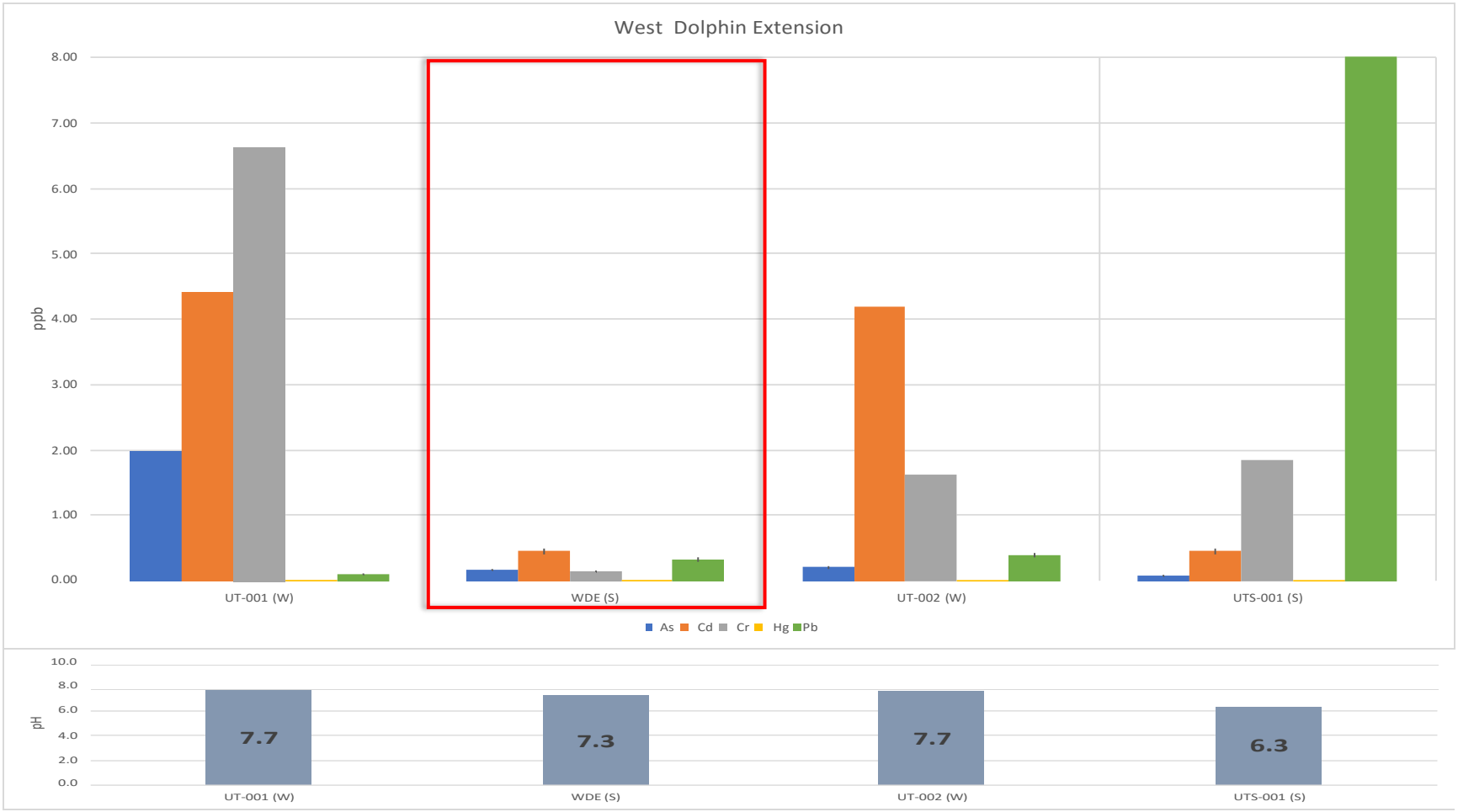


Figure 43: Heavy metal content (above) and pH (below) of the samples collected from the West Dolphin Extension AML. Samples are arranged spatially from the top of the drainage on the left to the bottom of the drainage on the right. The farthest right sample (UTS-001) is the control. Note that the lead concentration in sample UTS-001 is 16 ppb. The graph only extends to 8 ppb to better illustrate the smaller concentrations in other elements. Samples collected from the AML site are outlined with a red box. Water samples are denoted with a (W) and sediment with a (S). Mercury data has been multiplied by 100 for readability.

after chromium, among other metals. It would stand to reason that there would be higher concentrations of chromium in the samples of the area; however, with the exception of the sample collected above the West Dolphin Extension AML, the amounts of chromium identified in these samples are not uniquely high. It is possible that the processing techniques that were employed at these sites were extremely effective but that would not explain why these sites are chemically indiscernible from the surrounding area.

The site characterization data collected for the Dolphin AML shows that this site is tied for the second highest rated site with the Maud O AML with a score of 36 (Table 9). This indicates that it is one of the most likely sites to contribute sediments to fluvial systems.

Like at other Gallagher Head Lake area AML sites, I am not able to determine that the West Dolphin Extension AML has an impact on the water quality of the area. I have also not been able to identify effects of AMD in the samples despite the observations made at the site. If the orange stream was a result of AMD, the impacts of the reaction on the water of the area is very minimal. The site characterization indicates that this site is among the most likely to contribute contaminants to the system, but I have not found that to be the case. The overall elevated levels of arsenic and lead are likely naturally geologic in origin. The extremely high concentration of lead found in the control sample is likely anthropogenic in nature, but it is not caused by the AML.

Skookum

The Skookum AML site was visited on July 26th, 2017 by Ellie Myers and myself. The site is comprised of three tailings piles, the ruins of buildings, and debris from the mining process including rails for mine carts, metal pipes, and unidentifiable

metal scraps. The tailings heaps at this site are the largest of any examined in this study, and the farthest north pile differed in texture and color from the others (Figure 44).

Two water samples and two sediment samples were collected from this AML site (Figure 45). One water sample was collected from the small stream that flows from above the tailings down the southern edge of the piles (Table 6). The other water sample was collected from the same stream below the trail. One composite sediment sample was collected from the site and the other is a control.

Similar to the Silver Creek drainage, all samples have elevated level of arsenic

Figure 44: Contact between northernmost tailings pile (right) and middle tailings pile (left). Photo taken looking west. Photo by Scott Kugel, July 2017.

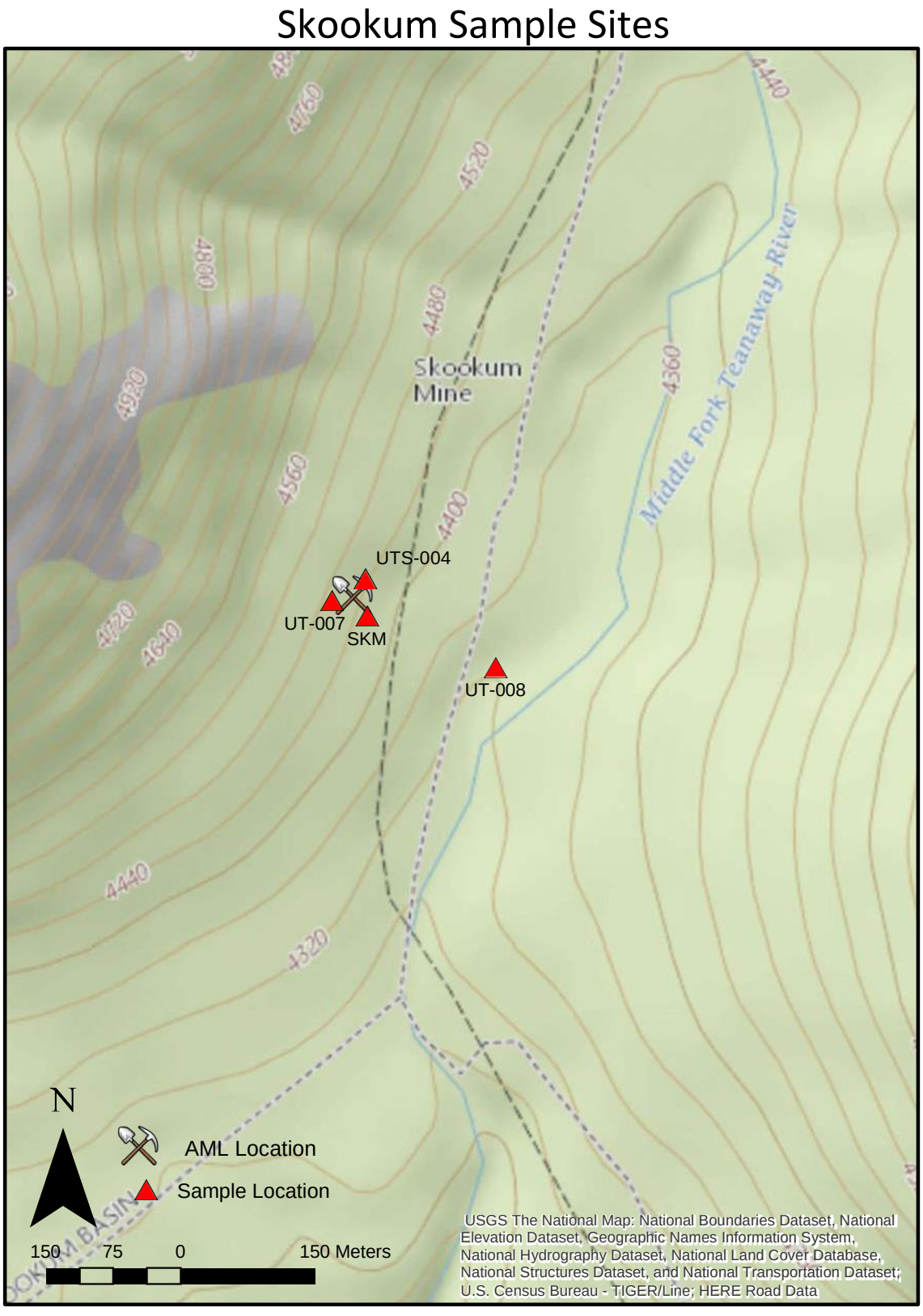


Figure 45: Sample collection sites at the Skookum AML site.

and lead above the MCLG but below the MCL, except for the water sample taken from above the AML Site (Table 7 and 8, Figure 46). Notably, the water sample collected below the AML has much higher lead levels than that of either sediment sample. This indicated that the AML is contributing lead to the fluvial system. Also, as with most water samples collected, the water here exhibited higher concentrations of cadmium than the sediment.

The two different colors and textures present in the tailings piles are peculiar. The northernmost pile has a reddish oxidized hue and is generally finer grained than the pile directly next to it which is much coarser and has a more silver-green color and a metallic luster. I am uncertain of the exact origin of either pile; however, the southern two piles looked to be made of serpentinite, likely from the Ingalls Ophiolite Complex. The northern pile is possibly also serpentinite, although a more weathered presentation of it. This rock may have been removed from a location that was closer to the surface than the rest of the tailings that had experienced weathering and, because of that, was more friable, or it may have been more heavily processed, allowing it to weather quicker. Negligible amounts of mercury are present in the samples from this location.

The pH of the samples collected at this site are all approximately neutral, with the water samples more basic while the sediment leachates are more acidic. This may indicate that the surrounding rock is different than that which was mined and is impacting the chemistry of the water differently than the AML.

The site characterization data collected for the Skookum AML shows that this site is in the middle of all the sites examined in this study with a score of 33, making it the fifth highest rated site despite containing the most tailings of any AML I studied (Table

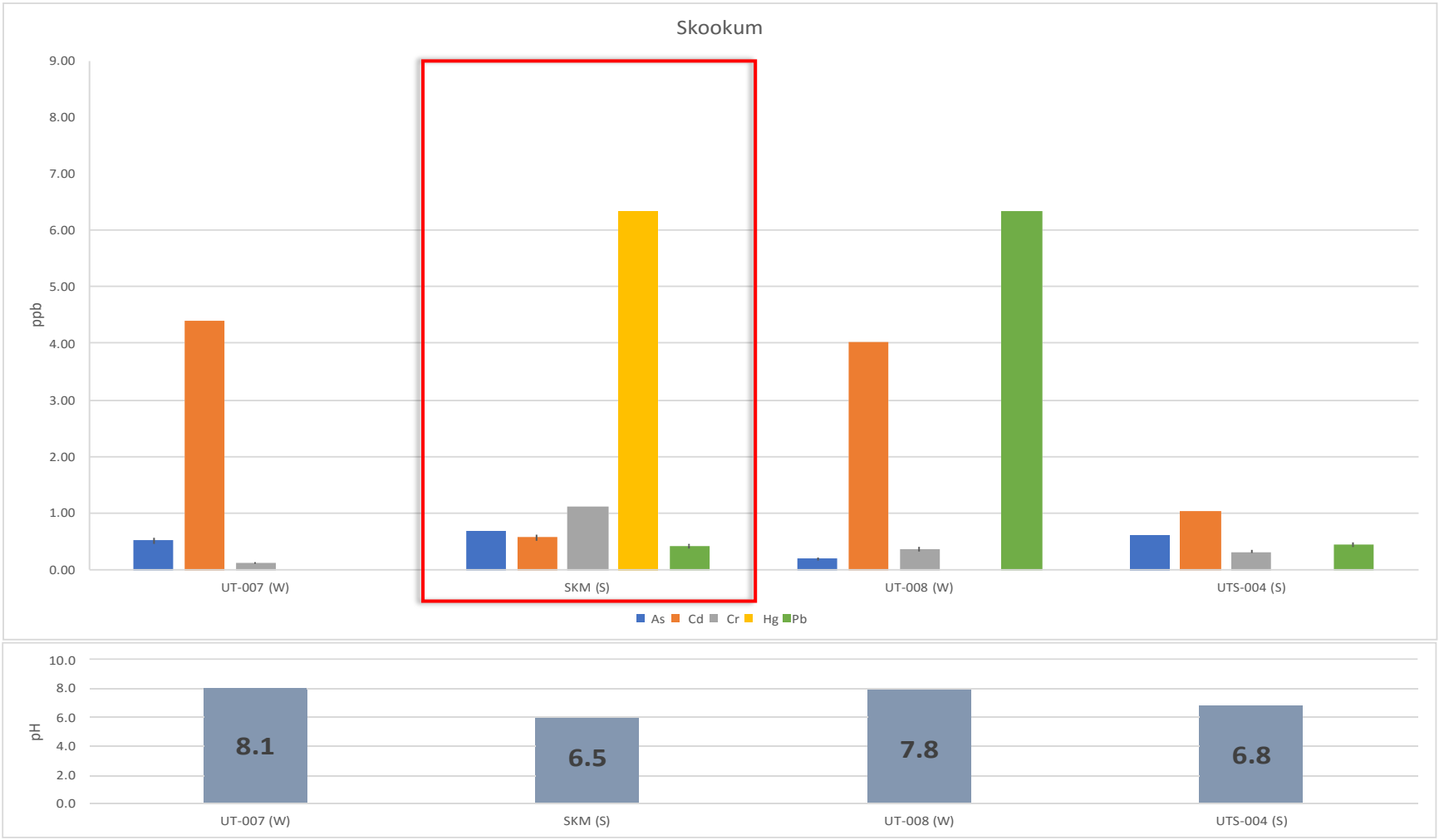


Figure 46: Heavy metal content (above) and pH (below) of the samples collected from the Skookum AML. Samples are arranged spatially from the top of the drainage on the left to the bottom of the drainage on the right. The farthest right sample (UTS-004) is the control. Samples collected from the AML site are outlined with a red box. Water samples are denoted with a (W) and sediment with a (S). Mercury data has been multiplied by 100 for readability.

9). This is because the site is the farthest away from Cascade Crest, is southwest facing, has large surface clasts, is not close to a fluvial system, and is not actively eroding. This indicates that this AML is somewhat likely to contribute contaminants to the fluvial systems.

With these data, I am able to determine that the Skookum AML, similar to the Silver Creek AMLs, does have an impact upon the water quality of the drainage. The concentration of lead found at and below the AML site appears to be greater than the natural, background levels and of a concentration that is of concern to the EPA. Interestingly, the characterization score for this AML ranks it below many other sites that do not appear to be contributing contaminants to their areas. This stands as a reminder that the characterization is only a ranking of probability and not an ultimate deciding factor in contaminant transportation. Conversely, the levels of arsenic found in the area, although higher than EPA standards, cannot be attributed to the AML and are probably the result of the natural chemistry of the rock in the area.

Synthesis

Throughout the study area, samples consistently had high concentrations of arsenic and lead above the MCL. Three sediment samples (Upper and Lower Silver Creek and Maud O) had arsenic concentrations above those found in the National Water Quality Assessment (Morace et al., 1999; Hughes, 2003). Fuhrer et al. (1994) also found elevated concentrations of these metals in sediment samples collected from streambeds of the Upper Yakima River, particularly in the higher order tributaries of the Cle Elum and Teanaway River drainages. They collected samples from Cle Elum River in the Salmon La Sac area, as well as from the north and middle forks of the Teanaway River near the

Teanaway Campground. They attribute the presence of these metals in the system to the influence of the Ingalls Tectonic Complex and the Snoqualmie Batholith. Both of these are present in the rock of the area in the form of galena and arsenopyrite (Thurber et al., 1964; Derkey et al., 1990) However, the concentrations they found were several orders of magnitude greater than those in my samples. This is likely due to their testing of actual stream sediment, while I tested the water of these areas. This difference is therefore understandable because the waters are leaching these metals from the rocks.

Fuhrer et al. (1994) also tested for chromium, cadmium, and mercury in their samples. They found elevated concentrations of chromium and cadmium in the Cle Elum and Teanaway Rivers that were again several orders of magnitude greater than what I observed in my samples. They attributed these levels to the Ingalls Tectonic Complex and the Snoqualmie Batholith, both of which contain these elements in the form of chromite, sphalerite (which can contain cadmium as an impurity in its crystal lattice), coal (found in the Swauk and Roslyn Formations), and cinnabar (Gluskoter and Lindahl, 1973; Derkey et al., 1990; Fuhrer et al., 1994; Tabor et al., 2000; Woodhouse et al., 2002). However, Fuhrer et al. (1994) note a significant connection between the chromium concentrations of the Teanaway drainage and Swauk Formation, a connection that is not evident in my samples.

What is evident in my results are elevated concentrations of cadmium in water samples relative to sediment samples. This is contrary to the literature (e.g., WHO, 1992) on the subject which generally states that the concentrations in sediments should be higher than in the water, as the water should be leaching its heavy metal content from the sediments and rock of the area. I hypothesize that I have observed this in my samples due

to problems with the collection or testing of the samples or because of environmental factors such as extreme weathering of the area. The samples I collected may not adequately represent the surficial geology of the area or they may not interact with or have as much of an impact on water quality as the rock of the area. Additionally, the sediments of the area may have already been extremely weathered and the heavy metal content available for leaching has already been removed.

Mercury was found in two percent of samples collected throughout the entire Yakima River (Fuhrer et al., 1994). Originally the authors had considered anthropogenic mercury as possible sources for what they observed; however, they were only able to attribute one of their samples to an anthropogenic cause and the rest are geologic sources. The negligible amounts of the metal I found in my samples are likely due to the lack of geologic sources above my sample locations.

Additionally, I found evidence of acid mine drainage, at only the Ida Elmore site. Although most samples were circum-neutral, several were slightly alkaline. This may indicate that either the effects of acid mine drainage are not present in most of the AMLs that I studied or the natural buffering effect of the local geology of the area is masking these impacts.

The AMLs that were examined in this study represent a transect of the major geologic units and climate conditions of the area. From the east to the west these sites get wetter and represent a change in geology from sedimentary (Swauk Formation), to metamorphic (Ingalls Tectonic Complex), to igneous rocks (Snoqualmie Batholith). Along with these changes it was expected that the impact of these sites on the water quality of the area would change; however, that does not appear to be the case. Sites like

the West Dolphin Extension and Skookum AMLs which are less than 3.5 km from each other are drastically different in environmental effects. Conversely, the Skookum and Upper Silver Creek AMLs are over 10 km apart and are different climatically and geologically but have similar impacts. I hypothesize that although these factors, especially climate, should matter in the degree to which these effects are felt within the system, the sites examined in this study are too similar in their geology and climate for these impacts to be perceived.

This research also examined various sizes of AMLs. They ranged from the Ida Elmore site which has 60 m^3 of tailings to the Skookum AML that has 11,739 m^3. The four sites that I have identified as being of some management concern (Skookum, Upper Silver Creek, Dolphin, and West Dolphin Extension) also have the four largest tailings heaps, and all have over 1,000 m^3 of tailings. Conversely, the five other sites have very minimal amounts of tailings and I also identified as having little to no associated risks. This suggests that the more tailings that are present at a site, the more problematic it may be. Further, the larger the mining operation, the more environmental complications it likely will cause.

Additionally, the time of year in which these sites were examined likely also impacted this. Samples were collected between July and September, the driest parts of the summer, and these sites may not have had enough water present for their effects on the system to be observable. Fuhrer et al. (1994) noted a similar concern in their testing and hypothesized that samples collected earlier in the season (April-June) may have different results.

CHAPTER 6

CONCLUSION

Summary

The purpose of this study was to determine the impacts of several hard rock AMLs on water quality contributions to the Yakima River from the Mineral Creek, Cle Elum River, and Teanaway River watersheds in the Eastern Cascades. Specifically, I identified nine AMLs within these drainages, characterized each AML based on various physical characteristics, sampled each AML site, and analyzed each site for heavy metal content and pH according to EPA water quality standards.

Thirty-nine samples were collected from throughout my study area, thirty-five of which were found to have levels of arsenic above the maximum containment level. Thirty-four of the samples have concentrations of lead about the maximum containment level and one sample has quantities of lead above the maximum containment level goal. Two samples have cadmium levels above the maximum containment level goal. No samples have elevated concentrations of chromium or mercury above the maximum containment levels. Mercury of any concentration was detected only in five samples. Given their location relative to the AMLs, I attribute the majority of the elevated lead, arsenic, and cadmium to natural geologic sources. The heightened concentrations of the other heavy metals (i.e., mercury and chromium) are likely anthropogenic in origin.

I identified two AMLs, Upper Silver Creek and Skookum, that are contributing heavy metals and are negatively impacting the water quality of the fluvial systems that they occupy. The Upper Silver Creek site also has the highest site characterization score of all locations visited in this study. This indicates that it is the most likely to contribute

its contaminants to its fluvial system. However, Skookum has a middling score, which appears to be congruous with the predictions made by this site assessment. It does not prove it to be a definitive way of determining toxicity on its own. This indicates that although this ranking may be a useful tool in determining broadly which sites may be problematic, it should not be used as an end all be all method in the Eastern Cascade. It may be most useful as a tool to sort sites and determine those that need further study.

Of the other seven AMLs, two are of possible concern regardless of the results of their chemical analyses. The Dolphin AML shows signs of recent use by automobiles in the form of tire ruts in the tailings pile of the site. This is likely causing increased erosion at this site and is probably exposing new depths of the pile to weathering. At the West Dolphin Extension AML, a small stream with the appearance of acid mine drainage emanates from the tailings pile. However, analysis of this water did not reveal chemical characteristics of acid mine drainage. Despite that, the appearance of such a stream indicates that there is additional interaction between the tailings of the AML and water than was witnessed at other sites. This is likely to be problematic even if negative impacts have not been identified in this research.

However, the four AMLs I have identified as troublesome are only locally so. The systems they directly interact with are quite small in relation to the larger systems (i.e., the Yakima River) into which they flow. Due to the dilution that takes place from the influx of water from other areas, the impacts of these AMLs are likely attenuated as the water from these sites travels away from them and mixes with water from other locations. Additionally, these mitigating affects are likely to be seasonally impacted, in that they should be more apparent when more water is in the system during spring runoff because

there is more water available to interact with the feature (Fuhrer et al., 1994). Therefore, although their impacts on the water quality of the area (i.e., concentrations of heavy metals above EPA standards) are locally important, overall, throughout the basin, their effects are minor.

The results of this study may be extrapolated to other similar sites within the Eastern Cascades. I conclude that small, hard rock mining and milling AML sites that operated in the late 19th and early 20th centuries are likely not of major concern to the overall water quality of the Yakima River or its major tributaries.

Management Recommendations

Management recommendations are based on the results of the chemical analysis, site characterizations, and field observations. The data presented in this study could be used by the government entities that administer these sites to form a more detailed and thorough knowledge of the challenges presented by them. In the event that an agency decides it will perform a remediation action at a small AML within the East Cascades, the information presented in this study may be useful for more informed decision-making.

Management recommendations are also tempered by the realities of the General Mining Act of 1872. All AML sites are located within the boundaries of the Okanogan-Wenatchee National Forest; however only eight of them are on USFS property. The Ida Elmore AML is located on a patented mining claim. Due to this, the USFS does not have control of that AML.

The two sites that I have identified as negatively impacting the water quality of their individual fluvial systems, the Upper Silver Creek AML and the Skookum AML, both require further examination and possible remediation action. For the Upper Silver

Creek AML, I recommend remediation techniques that combine the removal of the feature with the denial of access to the site. The southern portion of this site is being directly eroded by Silver Creek. I recommend that the southern tailings pile be either removed from the location or moved to a different part of the site to limit its interaction with the creek. If the tailings are moved on site, I would also recommend that they be covered with an impermeable cap layer to prevent the weathering of the new pile and its erosion. If these options are not feasible, I would recommend that a wetland be constructed downstream of the site as a passive remediation method. This wetland would need to be designed specifically to eliminate the effects of the AML, either by filtering out the heavy metals or by reducing the lead content by the use of bacteria.

However, all of these types of operations are extremely difficult because the AML can only be reached by foot, pack animal, or exceptionally rugged ORV. This limits the heavy equipment that can reach the site to assist in the moving of material at the location and prohibits mass excavation of material. Due to this, the cost of labor for this type of project would be greatly increased. Further, an action of this size would likely require at the very least an environmental assessment under the National Environmental Policy Act (NEPA).

At the Skookum AML, a natural wetland already exist below the site. I recommend that this wetland be modified to remediate the impacts of the AML. However, similar to Upper Silver Creek, this site is remote and any remediation effort would likely be expensive and trigger review through NEPA.

Due to these hurdles, another option exists that may help to clarify the nature of necessary remediation. If no physical remediation can take place at this time, I would

recommend further study of them. In particular, I would recommend that special attention be paid to determining the exact impacts on these sites on the higher order streams that they feed into. For instance, a tracer study may be completed on them, where a known isotope is released into the water at the AML site. The higher order streams would then be sampled, and the water tested for the isotope. Based on the concentration of the isotope, it would be possible to determine how much the AML is influencing the larger system. If the results of this study show that the influence is negligible, then remediation efforts would likely be unnecessary.

Additionally, I recommend the three sites that have open portals, the Maud O, Ida Elmore, and Mount Hawkins AMLs, all be sealed. These present a danger to the public if an unwitting person were to enter one of them. At many other such sites, agencies have covered the entrances with a cage that prevents larger creatures and humans from entering but allows bats and other small animals to come and go as they wish. I suggest that similar or more severe exclusion measures be put in place at these sites. Further, because the USFS does not have authority over the Ida Elmore AML, I recommend that they work with the land owner to limit access to the site.

Additionally, I would recommend that actions be taken to prevent the further deterioration of the Dolphin AML as well as the other two Gallagher Head Lake area AMLs by automobile. This could take the form of excluding users from the site by the construction of a fence or barrier around the tailings or by removing either a portion of the tailings pile or the entire feature so that it is less enticing. It may also manifest itself as an educational campaign to overlanding enthusiasts and other users of the area of the problems involved with using the tailings pile as a terrain obstacle.

Pamphlets, interpretive programs, or similar educational products are in use by the USFS and other agencies to educate the public on topics of interest within their purview. Similar products may be created by these agencies, based on the contents of this study and other work, to educate visitors about the mining history of the area and how it shaped the physical and human geography of the region.

Future Research

Additional research that would examine the local geology's impact on the heavy metal content of the water of the area would be valuable in separating AML impacts from background levels of heavy metals. This could be accomplished through an examination of the geochemical makeup of the specific rocks found in the area, further testing of non-AML impacted sediments within AML containing drainages, and by running chemical analyses on water samples from a stream that does not contain AMLs.

Future efforts could also be spent further expanding and improving the Mine Waste Decision Tree. In this research I added several new classes; however, I kept them on the same scale as the original tree from Wildeman, et al. (2007). I believe that this may impart an amount of error into the characterization score because it does not allow enough levels on the scale. It may weight some of the classes higher than they belong, thus artificially diminishing the importance of some of the classes and increasing the importance of others. If this method is used in the future I would recommend expanding the scale from a 0-5 scale to a 0-10 scale. I believe this would allow for improved accuracy with this system.

In the samples I collected in this study I did not find any significant amounts of mercury. However, I was originally planning to visit a cinnabar mine and mercury

processing facility, the Washington Quicksilver Company/Elsner/Nickelodeon AML, in the Big Boulder Creek drainage but was unable due to the 2017 Jolly Mountain Fire. I believe that this AML has the highest likelihood of containing mercury. Further, there are several AMLs along the Van Epps Trail (Forest Service Road #4W302), a popular four-wheel drive road that follows Fortune Creek. Due to the proximity of these sites to the trail, they require examination to determine if they are being impacted by this trail.

An inventory of the AMLs within the area would be extremely helpful in conducting any future research on this topic. This would result in a database similar in content to Table 2. However, it would need to contain much more information such as location, resources on the history of sites, where to find any previous research, and rough size estimates of tailings. This information could also be invaluable to land managers as a quick resource to check for future projects that may disturb these sites.

Further assessments of AMLs could be improved if streambed sediments were collected in the same locations as water samples. This would add another aspect to the assessment of AMLs by providing information on the input of sediments from the AML into the streams. If the streambed sediments below the AML are significantly different from those above the AML or are significantly similar to the sediment collected from the AML, then it may be possible to determine that the AML has contributed sediments to the system. Additionally, a prioritization of sample collection by the size of tailings present at a site would be beneficial as larger sites appear to have greater impact on their surroundings.

Additionally, if samples could be collected seasonally at the same location, it would greatly improve the accuracy of these results and would allow for the determination of when the max contaminant flux.

Finally, I would recommend that any future research use smaller mercury standards than I did when analyzing their samples using an ICP-MS. The results of my tests show that the 1.0 ppb and 0.5 ppb standards were too high and were not substantial in calculation of the calibration curve and did not represent the amounts of mercury found in my samples. Instead, I would recommend that more standards be created that were lower than 0.01 ppb in order to get more accurate results. Additionally, to help with accuracy and precision of the results, I recommend that only trace element grade chemicals be used throughout the process.

References Cited

Agency for Toxic Substances and Disease Registry (ATSDR). 1999. Toxicological Profile for Mercury. Division of Toxicology and Environmental Medicine/Applied Toxicology Branch, Atlanta, GA.

Agency for Toxic Substances and Disease Registry (ATSDR). 2007a. Toxicological Profile for Arsenic. Division of Toxicology and Environmental Medicine/Applied Toxicology Branch, Atlanta, GA.

Agency for Toxic Substances and Disease Registry (ATSDR). 2007b. Toxicological Profile for Lead. Division of Toxicology and Environmental Medicine/Applied Toxicology Branch, Atlanta, GA.

Agency for Toxic Substances and Disease Registry (ATSDR). 2012a. Toxicological Profile for Cadmium. Division of Toxicology and Environmental Medicine/Applied Toxicology Branch, Atlanta, GA.

Agency for Toxic Substances and Disease Registry (ATSDR). 2012b. Toxicological Profile for Chromium: p. 502.

Akcil, A., and T. Mudder. 2003. Microbial destruction of cyanide wastes in gold mining: process review. *Biotechnology Letters*, 25: 445-450.

Beckey, F.W. 2003. *Range of glaciers: the exploration and survey of the northern Cascade Range*. Portland, OR: Oregon Historical Society Press.

Bethune, G.A. 1890. *Mines and Minerals of Washington: Annual Report of George A. Bethune, First State Geologist.* Olympia, WA: State of Washington.

Blank, J.G., S.J. Green, D. Blake, J.W. Valley, N.T. Kita, A. Treiman, and P.F. Dobson. 2008. An alkaline spring system within the Del Puerto Ophiolite (California, USA): A Mars analog site. *Planetary and Space Science* 57 (5-6): 533-540.

Bureau of Land Management (BLM), U.S. Department of the Interior. 2017a. *Abandoned Mines*. http://abandonedmines.gov/ (Accessed January 12, 2017).

Bureau of Land Management (BLM), U.S. Department of the Interior. 2017b. *Abandoned Mine Lands.* https://www.blm.gov/wo/st/en/prog/more/Abandoned_Mine_Lands.html (Accessed January 23, 2017.)

Bureau of Reclamation (BOR), U.S. Department of the Interior. 2011. Yakima River Basin Study: Proposed Integrated Water Resource Management Plan.

Bureau of Reclamation (BOR), U.S. Department of the Interior. 2012. Yakima River Basin Integrated Water Resource Management Plan Final Programmatic Environmental Impact Statement.

Caillaud, J., D. Proust, S. Philippe, C. Fontaine, and M. Fialin, 2009. Trace metals distribution from a serpentinite weathering at the scales of the weathering profile and its related weathering microsystems and clay minerals. *Geoderma*, 149: 199–208.

Chen, D., M. Jing, and X. Wang. 2016. Determination of Methyl Mercury in Water and Soil by HPLC-ICP-MS, in *Atomic Spectroscopy Solutions for Environmental Applications.* Agilent Technologies.

Concas, A., A. Ardau, A. Cristini, P. Zuddas, and G. Cao. 2006. Mobility of heavy metals from tailings to stream waters in a mining activity contaminated site in a mining activity contaminated site. *Chemosphere* 63: 244–253.

Derkey, R., N. Joseph, and R. Lasmanis. 1990. Metal Mines of Washington - Preliminary Report. Open File Report 90-18: 277, Washington Division of Geology and Earth Resources, Olympia, WA.

Donato, D.B., O. Nichols, H. Possingham, M. Moore, P. Ricci, and B. Noller. 2007. A critical review of the effects of gold cyanide-bearing tailings solutions on wildlife. *Environment International* 33: 974–984.

Ellensburg Dawn. October 31, 1904, *The Skookum Copper Mining Company*. p. 9.

Ellensburg Dawn. September 21, 1905a, *Skookum Mining Company.*

Ellensburg Dawn. September 28, 1905b, *Skookum Has Rich Ore*.

Ellensburg Dawn. October 12, 1911, *Roslyn News*.

Environmental Protection Agency (EPA), United States. 2017. *Table of Regulated Drinking Water Contaminants*. https://www.epa.gov/ground-water-and-drinking-water/table-regulated-drinking-water-contaminants/ (Accessed January 18, 2017).

Environmental Protection Agency (EPA), United States, 2018: *National Primary Drinking Water Regulations*. https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations/ (Accessed February, 2018).

Environmental Protection Agency (EPA), United States, 2018: *Drinking Water Regulations and Contaminants*. https://www.epa.gov/dwregdev/drinking-water-regulations-and-contaminants (Accessed April, 2018).

Fredrick, P., and N. Jayasena. 2011. Altered pairing behaviour and reproductive success in white ibises exposed to environmentally relevant concentrations of methylmercury. Proceedings: *Biological Sciences*, 278: 1713, 1851-1857.

Fuhrer, G., S. McKenzie, J. Rinella, R. Sanzolone, and K. Skach. 1994. Surface-water-quality assessment of the Yakima River Basin in Washington: Analysis of major and minor elements in fine-grained streambed sediments, 1987. Open-File Report 93-30. U.S. Geological Survey, Portland, OR.

Gallaher, G.W. November 11, 1905. *Annual Report*. Yakima Herald: 26.

Gluskoter, H.J., and P.C. Lindahl. 1973. Cadmium: Mode of Occurrence in Illinois Coals. *Science* 181 (4096): 264-266.

Grant, A.R., 1969, Chemical and Physical Controls for Base Metal Deposition in the Cascade Range of Washington. Bulletin 58: 107, Washington Division of Mines and Geology, Olympia, WA.

Groves, D., R. Goldfarb, F. Robert, and C. Hart. 2003. Gold deposits in metamorphic belts: Overview of current understanding, outstanding problems, future research, and exploration significance. *Economic Geology*, 98: 1–29.

Gualtieri, J., and G. Simmons. 1964. Geology of the Alpine Lakes Study Area and Additions, Washington. Bulletin 1542-A, U.S. Geological Survey, Denver, CO.

Hageman, P. 2007. US Geological Survey field leach test for assessing water reactivity and leaching potential of mine wastes, soils, and other geologic and environmental materials. Techniques and Methods 5-D3, U.S. Geological Survey, Reston, VA.

Healy, J. 1978. *Mining and metallurgy in the Greek and Roman world*. London, UK: Thames and Hudson.

Hill, T., and J. Melrose. 1940. Directory of Washington Metallic Mining Properties. Division of Mines and Geology, Olympia, WA.

Hill Publishing Company. 1909. *The Engineering and Mining Journal*: New York, NY, Hill Publishing Company.

Hinkle, S.R., and M. Ely. 2013. Chemical and isotopic data collected from groundwater, surface-water, and atmospheric precipitation sites in Upper Kittitas County, Washington, 2010–12. Data Series Report 751., U.S. Geological Survey, Reston, VA.

Hodges, L. 1897. *Mining in the Pacific Northwest*. Seattle, WA: The Seattle Post-Intelligencer.

Hunt, A., D. Lampshire, and J. Eisele. 1988. Leaching gold-silver ores with sodium cyanide and thiourea under comparable conditions. United States Bureau of Mines, Pittsburgh, PA.

Huntting, M. 1956. Inventory of Washington Minerals: Part II Metallic Minerals: 427.

Jacobs, J., and S. Testa. 2014. Acid Drainage and Sulfide Oxidation: Introduction. In *Acid Mine Drainage, Rock Drainage, and Acid Sulfate Soils: Causes, Assessment, Prediction, Prevention, and Remediation*, ed. J. Jacobs, J. Lehr, S. Testa, 3-8. Hoboken, NJ: John Wiley & Sons, Inc.

James, L. 2004. Tailings Fans and Valley-Spur Cutoffs Created by Hydraulic Mining. *Earth Surface Processes and Landforms* 29 (7): 869–82.

Johnson, D., and K. Hallberg. 2005. Acid mine drainage remediation options: a review. *Science of the Total Environment* 338: 3-14.

Stancik, K. 1994. Searching for Galena, a mining mecca. *Northern Kittitas County Tribune*, May 19, 1994: 6–7.

Kerper, L., N. Ballatori, and T. Clarkson. 1992. Methylmercury transport across the blood-brain barrier by an amino acid carrier. *The American Journal of Physiology* 262: R761.

Klein, C., and B. Dutrow. 2007. *The Manual of Mineral Science*. 23rd ed. John Wiley & Sonns, inc.

Krueger, F. 1915a. Mining – Copper. Photograph. Frederick Krueger Collection. Central Washington University Archives and Special Collections.

Krueger, F. 1915b. Mining – Copper. Photograph. Frederick Krueger Collection. Central Washington University Archives and Special Collections.

Krueger, F. 1915c. Mining – Copper. Photograph. Frederick Krueger Collection. Central Washington University Archives and Special Collections.

Langedal, M. 1997. The Influence of a Large Anthropogenic Sediment Source on the Fluvial Geomorphology of the Knabeåna-Kvina Rivers, Norway. *Geomorphology* 19: 117–32.

Leonhard, J. 2014. 2014 City of Cle Elum Consumer Confidence Report: Water Quality. Cle Elum, Washington.

Lewin, J., B. Davies, and P. Wolfenden. 1977. Interactions between Channel Change and Historic Mining Sediments. *River Channel Changes:* 353–67.

Lewin, J., and M. Macklin, 1987. Metal mining and floodplain sedimentation in Britain. *International Geomorphology Part 1*: 1009–1027.

Lynch, A., and C. Rowland, C. 2005. *The History of Grinding.* Littleton, CO: Society for Mining, Metallurgy, and Exploration.

MacDonald, J., G. Harper, R. Miller, J. Miller, A. Mlinarevic, and C. Schultz. 2008. The Ingalls ophiolite complex, central Cascades, Washington: Geochemistry, tectonic setting, and regional correlations. In *Ophiolites, Arcs, and Batholiths: a Tribute to Cliff Hopson: Geological Society of America Special Paper 438*, ed. J. Wright and J. Shervais. 133–159. Boulder, CO: The Geological Society of America.

Macklin, M., P. Brewer, K. Hudson-Edwards, G. Bird, T. Coulthard, I. Dennis, P. Lechler, J. Miller, and J. Turner. 2006. A geomorphological approach to the management of rivers contaminated by metal mining. *Geomorphology* 79: 423–447.

Malm, O. 1998. Gold mining as a source of mercury exposure in the Brazilian Amazon. *Environmental Research* 77: 73–8.

Martín Duque, J., I. Zapico, R. Oyarzun, J. López García, and P. Cubas. 2015. A descriptive and quantitative approach regarding erosion and development of landforms on abandoned mine tailings: New insights and environmental implications from SE Spain. *Geomorphology* 239: 1–16.

McKay, D. Mac, F. Wolff, and D. Norman. 2003. Statewide Inactive and Abandoned Mine Lands (IAML) Database.

Metzger, E., R. Miller, and G. Harper. 2002. Geochemistry and Tectonic Setting of the Ophiolitic Ingalls Complex, North Cascades, Washington: Implications for Correlations of Jurassic Cordilleran Ophiolites. *The Journal of Geology* 110: 543–560.

Mix, M. 2016. *Leaded: The Poisoning of Idaho's Silver Valley*. Corvallis, OR: Oregon State University Press.

Miller, J. 1997. The role of fluvial geomorphic processes in the dispersal of heavy metals from mine sites. *Journal Geochemical Exploration* 58: 101–118.

Miller, R. 1980. Structure, petrology, and emplacement of the ophilitic Inagalls Complex, north-central Cascades. PhD. diss., University of Washington.

Morace, J., G. Fuhrer, J. Rinella, S. McKenzie, M. Gannett, K. Bramblett, T. Pogue Jr., K. Skach, S. Embrey, T. Cuffney, M. Meador, S. Porter, and M. Gurtz. 1999. Surface-water-quality assessment of the Yakima River Basin in Washington: Overview of major findings, 1987-91. Water-Resources Investigations Report 98–4113. U.S. Geological Survey, Portland, OR.

National Resource Conservation Service (NRCS). 2018a. Fish Lake SNOTEL Site 478:, https://wcc.sc.egov.usda.gov/nwcc/site?sitenum=478 (accessed January 2018).

National Resource Conservation Service (NRCS). 2018b. Sasse Ridge SNOTEL Site 734: https://wcc.sc.egov.usda.gov/nwcc/site?sitenum=734 (accessed January 2018).

Neuman, D., P. Brown, and S. Jennings. 2014. Metals Associated with Acid Rock Drainage and Their Effect on Fish Health and Ecosystems. In *Acid Mine Drainage, Rock Drainage, and Acid Sulfate Soils: Causes, Assessment, Prediction, Prevention, and Remediation*, ed. J. Jacobs, J. Lehr, and S. Testa, 139–169. Hoboken, NJ: John Wiley & Sons, Inc.

Nriagu, J. 1994. Mercury pollution from the past mining of gold and silver in the Americas. *The Science of the Total Environment* 143: 167–181.

Nyssen, J., and D. Vermeersch. 2010. Slope aspect affects geomorphic dynamics of coal mining spoil heaps in Belgium. *Geomorphology* 123: 109–121.

Ordóñez, A., R. Álvarez, and J. Loredo. 2013. Asturian mercury mining district (Spain) and the environment: A review. *Environmental Science and Pollution Research* 20: 7490–7508.

Panieri, P. 1945. Mineral Creek cabin, Kittitas County, Washington, August 1945. Photograph. Roslyn Heritage, Pio Panieri Collection, Roslyn, WA: http://www.washingtonruralheritage.org/cdm/singleitem/collection/roslyn/id/947/rec/1 (accessed April 30, 2018).

Pastor, N., M. Lopez-Lazaro, J. Tella, R. Baos, F. Hiraldo, and F. Corte. 2001. Assessment of genotoxic damage by the comet assay in white storks (*Ciconia ciconia*) after the Doñana Ecological Disaster. *Mutagenisis* 16 (3): 219-223.

Patty, E. 1921. The Metal Mines of Washington. Bulletin No. 23, Washington Geological Survey, Olympia, WA.

Plum Creek Timber Co. 1995. Alps Watershed Analysis.

Pouilly, M., D. Rejas, T. Perez, J. Duprey, C. Molina, C. Hubas, and J. Guimaraes. 2013. Trophic Structure and Mercury Biomagnification in Tropical Fish Assemblages, Itenez River, Bolivia. *PLOS One*, 8 (5): e6054.

Pullman Herald, January, 21, 1910, *Mines and Mining.*

Purdy, C. 1952. Directory of Washington Mining Operations 1952. Information Circular No. 20, Washington Division of Mines and Geology, Olympia, WA.

Purdy, C. 1953. Directory of Washington Mining Operations 1953. Information Circular No. 21, Washington Division of Mines and Geology, Olympia, WA.

Räsänen, L., and M. Mutanen. 1995. Intake of mercury from fish, lipid peroxidation, and the risk of myocardial infarction and coronary, cardiovascular, and any death in eastern Finnish men. *Circulation* 92: 2355.

Rice, C.T. 1918. Flotation in the Coeur d'Alenes. *Engineering and Mining Journal*. 105: 707–716.

Rickard, T. 1937. *A History of American mining*. York, PA: McGraw-Hill Book Company, Inc.

Ritchie, N., and R. Hooker. 1997. An Archaeologist's Guide to Mining Terminology. *Australasian Historical Archaeology* 15: 3–29.

Robins, N. 2011. *Mercury, Mining, and Empire: The Human and Ecological Cost of Colonial Silver Mining in the Andes*. Bloomington, IN, Indiana University Press.

Ruvalcaba Sil, J., G. Peñuelas Guerrero, J. Contreras Vargas, E. Ortiz Díaz, and E. Hernández Vázquez. 2009. Technological and material features of the gold work of Mesoamerica: *ArcheoSciences: revue d'archéometrie*: 289–298.

Scheuhammer, A., M. Meyers, M. Sandheinrich, and M. Murray. 2007. Effects of Environmental Methylmercury on the Health of Wild Birds, Mammals, and Fish. *Ambio* 36 (1): 12-18.

Seattle Post-Intelligencer, July 21, 1897, *Strike on the Maud O. - An English Syndicate Invests*.

Seattle Post-Intelligencer, January 2, 1900a, *Progress Made on the Gold and Copper Mines of Mount Stewart*.

Seattle Post-Intelligencer, January 20, 1900b, *An Ida Elmore Strike*.

Seattle Post-Intelligencer, August 9, 1900c, *Maud O. Mine Reopened*.

Skousen, J., and J. Jacobs. 2014. Stream characterization for acid mine drainage. In *Acid Mine Drainage, Rock Drainage, and Acid Sulfate Soils: Causes, Assessment, Prediction, Prevention, and Remediation*, ed. J. Jacobs, J. Lehr, and S. Testa, 105-118. Hoboken, NJ: John Wiley & Sons, Inc.

Smith, K., C. Ramsey, and P. Hageman. 2000. Sampling strategy for the rapid screening of mine-waste dumps on abandoned mine lands. Open-File Report 00-016, United States Geological Survey, Denver, CO.

Stevens, H. 1907. *The Copper Handbook*. Houghton, MI: Horace J Stevens.

Stevens, H. 1908. *The Copper Handbook: A Manual of the Copper Industry of the World.* Houghton, MI: Horace J Stevens.

Stevens, H. 1911. *The Copper Handbook: A Manual of the Copper Industry of the World*. Houghton, MI: Horace J Stevens.

State of Washington. 1938. Directory of Washington Mines 1938.

Tabor, R., V. Frizzell Jr., D. Booth, and R. Waitt. 2000. Geologic Map of the Snoqualmie Pass 30 x 60 Minute Quadrangle. Map I-2538, United States Geologic Survey, Denver, CO.

Tabor, R., R. Haugerud, E. Brown, R. Babcock, and R. Miller. 1989. Accreted terranes of the North Cascades Range, Washington. Field Trip Guidebook T307, American Geophysical Union, Washington, DC.

Tabor, R., R. Waitt, V. Frizzell Jr., D. Swanson, G. Byerly, and R. Bentley. 1982. Geologic map of the Wenatchee 1:100,000 Quadrangle, Central Washington. Map I-1311, United States Geologic Survey, Denver, CO.

Tchounwou, P., C. Yedjou, A. Patlolla, and D. Sutton. 2014. Heavy Metal Toxicity and the Environment. *National Institute of Health Public Access*: 1–30.

The Evening Statesman, March 4, 1910*, Skookum Mining Company's Camp Wiped Out By Slide*: 2.

Thurber, H., M. Miller, A. McMahan, and F. Federspiel. 1964. Economic Appraisals of the Alpine Lakes Study Area and Additions, Washington. In *Mineral Resources of the Alpine Lakes Study Area and Additions, Chelan, King, and Kittitas Counties, Washington*, p. 85–224. Bulletin 1542, United States Geological Survey, Washington, DC.

Torgerson, R. 1951. Treatment of Gold-Copper Ore from the Melade Gold Mine Cle Elum Washington. Master's thesis. University of Washington.

Tozer, W. 1965. *The history of gold mining in the Swauk, Peshastin, and Cle Elum mining districts of the Wenatchee Mountains, 1853-1899*. Master's Thesis. Washington State University.

Ullrich, S., T. Tanton, and A. Svetlana. 2001. Mercury in the aquatic environment : A review of factors affecting methylation. *Critical Reviews in Environmental Science and Technology* 31 (3): 241-293.

United States Forest Service (USFS). 1998. Teanaway Watershed Analysis.

United States Geological Survey (USGS). 2015. National Field Manual for the Collection of Water-Quality Data. Techniques of Water-Resources Investigations Book 9 Handbook for Water-Resources Investigations, United States Geological Survey, Reston, VA.

United States Geological Survey (USGS). 2018. Mineral Resources Data System: MRDS, http://mrdata.usgs.gov/mrds/ (accessed April 2018).

Vincent, K., S. Church, and D. Fey. 1999. Geomorphological Context of Metal-Laden Sediments in the Animas River Floodplain, Colorado. Presented at U.S. Geological Survey Toxic Substances Hydrology Program Technical Meeting, Charleston, South Carolina, March 8-12.

Washington Geological Survey. 2018. Coal, Metallic and Mineral Resources. https://www.dnr.wa.gov/programs-and-services/geology/energy-mining-and-minerals/coal-metallic-and-mineral-resources#inactive-and-abandoned-mine-lands (accessed January 2018).

Weaver, C. 1911. Geology and ore deposits of the Blewett mining district. Bulletin 6, Washington Geologic Survey, Olympia, Washington.

Weed, W. 1922. *The Mines Handbook; An Enlargement of the Copper Handbook; a manual of the mining industry of North America.* Vol. 15. Tuckahoe, NY: The Mines Handbook Co.

Western Regional Climate Center (WRCC). 2018. Stampede Pass WSCMO, Washington. https://wrcc.dri.edu/cgi-bin/cliMAIN.pl?wastam (accessed January 2018).

World Health Organization (WHO). 1992, Environmental Health Criteria 134; Cadmium. International Programme On Chemical Safety.

Wildeman, T., K. Smith, and J. Ranville. 2007. A Simple Scheme to Determine Potential Aquatic Metal Toxicity from Mining Wastes. *Environmental Forensics* 8: 119–128.

Woodhouse, P., D. Jacobson, G. Cady, and V. Pisoni. 2002. *Discovering Washington's Historic Mines Volume 2: The East Central Cascade Mountains and the Wenatchee Mountains*. Arlington, WA: Oso Publishing Company.

Yakima Herald, February 19, 1891, *Mines of the Cle-Elum District*.

Yakima Herald, July 14, 1898, *Substantial Mining Developments*.

APPENDIXES

Appendix A – AML Field Data Sheet

Site Name: Site Number:

AML Field Data Sheet

Date: _____ Researcher: _____

GPS coordinates:

	Central	North	South	East	West
Latitude					
Longitude					

Azimuth: _____ Elevation: _____ Slope: _____

Location description: _____

_____

_____

_____

Size estimate: _____ Volume estimates: _____

Surface clast size: _____ Grain size estimate: _____

Crust presence: Y / N Thickness: _____

Distance to stream or fluvial feature: _____ Direction: _____

AML Stability

Presence of erosion: Y / N Active / Recent / Past

Where: _____

_____

_____

Description: _____

_____

_____

_____

_____

_____

1 Revised: 7/10/17

Site Name: Site Number:

Vegetation on feature

	NW	NE	SW	SE
% estimates				
Vegetation Type				

Vegetation buffer area

Presence: Y / N Active / Recent / Past

Where: _____

_____

_____

Size Estimate: _____

_____

_____

Description: _____

_____

_____

_____

_____

Rock weathering

Fresh / Weathered / Pitted Presence of weathering rind: Y / N

Grid samples

Grid size: _____

Number of samples collected and homogenized: _____

Total Weight: _____

Site Name: Site Number:

Sketch of AML (include GPS points, erosion, vegetation, sampling grid and locations, etc.)

Site Name: Site Number:

Sketch of area/map (Include vegetation buffer area, sampling locations, fluvial features, etc.)

Site Name: Site Number:

Notes/other: _____

Appendix B – Water Sample Data Sheet

Researcher: _____

Water Sample Data Sheet

Date	Time	Stream Name	Site #	Lat	Long	pH	Conductivity	Temp	Notes

Site Name	**Mineral Creek**	**Upper Silver Creek**	**Lower Silver Creek**	**Maud O**
Distance to Cascade Crest (m)	7.6	12.3	12.1	16
Azimuth	38	225	240	185
Slope	22	45	37	34
Size estimate (m2)	N/A	641.44	319.94	353
Volume estimate (m3)	N/A	3848.64	959.82	176.5
Surface clast size	N/A	Sand, silt, clay	Sand, silt, clay	Boulders, Cobbles
Grain size estimate	N/A	Silt	Silt	Silt
Crust presence	N/A	Yes	No	Yes
Thickness (cm(	N/A	>2	N/A	0.5
Distance to fluvial feature (m)	0	0	40	0
AML stability	N/A	Gullies more than 30 cm de	N/A	Rills 15-30 cm deep
Active/recent/past	N/A	Active	N/A	Active
Vegetation on feature	Very little present	Some	Some	Very little present
Vegetation buffer area	No	No	No	No
Rock Weathering	Weathered	Weathered	Fresh	Weathered

Site Name	**Ida Elmore**	**Mount Hawkins**	**Dolphin**	**West Dolphin**	**Skookum**
Distance to Cascade Crest (m)	16	19.5	19.6	19.5	22.9
Azimuth	195	170	140	160	120
Slope	39	18	5	40	24
Size estimate (m2)	168	268	559.23	436.07	1304.3
Volume estimate (m3)	60	804	1789.536	4709.556	11738.7
Surface clast size	Boulders, Cobble	Pebbles	Pebbles	Pebbles	Pebbles
Grain size estimate	Silt	Sand	Sand	Silt	Silt
Crust presence	Yes	Yes	Yes	Yes	Yes
Thickness (cm(	>1	3	2	< 1	<1
Distance to fluvial feature (m)	0	113.5	8	38.9	50
AML stability	Rills 15-30 cm deep	Rills 15-30 cm deep	Gullies more than 30 cm de	Rills 15-30 cm deep	Rills 15-30 cm deep
Active/recent/past	Active	Recent	Active	Recent	Past
Vegetation on feature	Very little present	Very little present	Some	Very little present	Some
Vegetation buffer area	No	No	No	No	No
Rock Weathering	Weathered	Fresh	Weathered	Weathered	Weathered

Appendix D – Analytical Data

				9 Be [H2]			23 Na [He]			24 Mg [He]			27 Al [He]		
Acq. Date-Time	Type	Level	Sample Name	Conc. [ppb]	Conc. SD	CPS	Conc. [ppb]	Conc. SD	CPS	Conc. [ppb]	Conc. SD	CPS	Conc. [ppb]	Conc. SD	CPS
1/3/18 13:42	CalBlk	1	Blank 1			6.00			76841.30			5769.19			1883.79
1/3/18 13:49	CalBlk	1	Blank 2			5.67			68171.20			8992.89			5726.17
1/3/18 13:55	CalBlk	1	Blank 3			4.00			77009.43			5573.78			3937.89
1/3/18 14:02	CalBlk	1	Blank 1			5.67			64465.74			4710.79			1525.75
1/3/18 14:08	CalStd	8	Hg 0.01 ppb			5.00			75458.29			6783.65			837.02
1/3/18 14:15	CalStd	9	Hg 0.05 ppb			3.33			86435.39			1392.74			284.67
1/3/18 14:21	CalStd	10	Hg 0.1 ppb			2.67			93642.67			3359.74			1130.71
1/3/18 14:27	CalStd	11	Hg 0.5 ppb			4.33			105051.03			4572.75			494.34
1/3/18 14:34	CalStd	12	Hg 1.0 ppb			2.67			105259.25			6844.34			565.68
1/3/18 14:40	Sample		Blank 1			4.33			63040.61			4589.42			1512.75
1/3/18 14:46	Sample		Blank 2			2.00			63952.75			8608.65			5311.01
1/3/18 14:53	Sample		Blank 3			4.00			72806.42			5409.72			3798.85
1/3/18 14:59	CalStd	2	Env 1/0.01 ppb	0.01	0.00	17.33	12.74	0.21	100281.00	0.57	0.07	5550.44	<0.000	0.03	895.03
1/3/18 15:05	CalStd	3	Env 5/0.05 ppb	0.06	0.01	57.33	8.94	0.10	89597.10	3.71	0.05	10172.36	<0.000	0.04	447.68
1/3/18 15:12	CalStd	4	Env 10/0.1 ppb	0.10	0.01	95.67	19.84	0.18	120253.10	10.66	0.15	20390.15	0.41	0.13	1124.71
1/3/18 15:18	CalStd	5	Env 100/1 ppb	1.05	0.06	980.37	113.23	0.80	382888.00	101.93	0.50	154605.83	0.12	0.05	968.03
1/3/18 15:24	CalStd	6	Env 1000/10 ppb	10.15	0.08	9431.48	1035.41	44.76	2976327.83	1053.63	63.86	1554209.25	10.38	0.25	6384.12
1/3/18 15:31	CalStd	7	Env 10000/100 ppb	99.98	0.23	92859.74	9996.32	173.50	28177016.00	9994.62	39.82	14703100.67	99.97	3.12	53682.07
1/3/18 15:36	Sample		Blank 1	0.01	0.00	11.67	0.45	0.43	65742.36	1.10	0.25	6322.10	1.11	0.16	1493.75
1/3/18 15:42	Sample		Blank 2	<0.000	0.00	4.33	<0.000	0.31	62961.65	2.82	0.17	8862.81	8.58	0.22	5436.39
1/3/18 15:48	Sample		Blank 3	<0.000	0.00	5.33	2.70	0.29	72050.50	0.41	0.08	5315.68	5.45	0.10	3783.51
1/3/18 15:55	CalStd	13	S 100/1 ppb	0.00	0.00	8.67	8.47	0.06	88296.23	<0.000	0.02	2130.83	<0.000	0.05	519.68
1/3/18 16:01	CalStd	14	S 1000/10 ppb	0.00	0.00	6.67	1.49	0.24	68649.52	<0.000	0.03	2019.48	<0.000	0.02	627.01
1/3/18 16:07	CalStd	15	S 5000/50 ppb	0.00	0.00	7.33	4.16	0.21	76160.77	<0.000	0.07	4710.13	<0.000	0.09	795.02
1/3/18 16:13	CalStd	16	S 10000/100 ppb	0.00	0.00	8.67	2.94	0.29	72739.11	<0.000	0.05	2470.22	<0.000	0.03	266.67
1/3/18 16:20	Sample		Blank 1	<0.000	0.00	3.67	<0.000	0.02	61028.64	<0.000	0.06	4531.40	1.01	0.16	1442.08
1/3/18 16:26	Sample		Blank 2	<0.000	0.00	2.00	<0.000	0.16	62443.31	2.74	0.05	8738.73	8.28	0.28	5274.99
1/3/18 16:32	Sample		Blank 3	<0.000	0.00	2.33	2.13	0.23	70465.83	0.42	0.11	5327.01	5.37	0.10	3741.84
1/3/18 16:38	Sample		Millq neat	<0.000	0.00	1.33	<0.000	0.22	58186.39	<0.000	0.01	245.33	<0.000	0.02	68.33
1/3/18 16:45	Sample		Nitric HCL Matrix	0.00	0.00	10.00	<0.000	0.07	60830.89	<0.000	0.07	2738.94	<0.000	0.03	524.34
1/3/18 16:51	Sample		SC-002	0.00	0.00	6.00	550.69	12.94	1613165.33	11812.95	257.89	17377195.33	3.66	0.09	2840.96
1/3/18 16:57	Sample		SC-001	<0.000	0.00	3.67	413.19	10.99	1226483.54	10819.67	130.89	15916446.00	1.74	0.14	1822.45
1/3/18 17:03	Sample		MC-2-002	<0.000	0.00	3.67	74778.22	1562.69	210362586.67	210.11	0.39	313710.70	19.91	0.34	11417.66
1/3/18 17:09	Sample		MC-2-001	<0.000	0.00	2.00	74797.82	934.19	210417717.33	191.10	0.79	285750.09	16.28	0.20	9501.23
1/3/18 17:15	Sample		MC-001	0.00	0.00	7.33	322.09	4.69	970266.98	37.07	0.01	59222.16	10.82	0.18	6618.57
1/3/18 17:21	Sample		MC-002	0.00	0.00	8.00	555.49	14.26	1626661.33	84.60	0.59	129125.02	13.12	0.02	7831.19
1/3/18 17:28	Sample		MC-003	<0.000	0.00	5.67	444.96	8.32	1315826.71	72.21	0.41	110905.65	11.32	0.24	6884.03
1/3/18 17:34	Sample		MC-004	<0.000	0.00	3.33	594.10	16.92	1735240.79	125.09	0.60	188678.38	9.16	0.24	5741.51
1/3/18 17:40	Sample		MC-005	<0.000	0.00	3.00	710.40	30.91	2062319.63	117.70	0.77	177799.40	7.23	0.22	4722.46
1/3/18 17:46	Sample		MC-006	<0.000	0.00	2.67	873.81	20.05	2521869.75	283.41	1.65	421500.98	9.40	0.07	5869.90
1/3/18 17:52	Sample		CC-001	<0.000	0.00	1.67	714.90	7.23	2074964.37	7229.29	154.08	10636329.00	1.66	0.06	1781.45
1/3/18 17:58	Sample		CC-002	<0.000	0.00	1.33	1415.71	18.32	4045866.08	4872.19	98.05	7169900.67	0.74	0.01	1296.06
1/3/18 18:05	Sample		CC-003	<0.000	0.00	1.67	753.31	38.82	2182991.25	14823.60	372.14	21804749.33	0.92	0.13	1391.40
1/3/18 18:11	Sample		UT-001	<0.000	0.00	2.67	317.10	2.69	956255.48	9039.86	66.77	13299004.67	2.46	0.13	2206.51
1/3/18 18:17	Sample		UT-002	<0.000	0.00	2.67	395.96	4.70	1178030.33	12864.79	161.43	18924070.00	0.25	0.08	1040.71
1/3/18 18:23	Sample		UT-003	<0.000	0.00	1.67	220.47	1.63	684495.42	5296.24	120.06	7793517.67	2.14	0.11	2037.15
1/3/18 18:29	Sample		UT-004	<0.000	0.00	2.00	406.43	6.49	1207458.54	3920.73	122.17	5770656.33	26.80	0.18	15054.10
1/3/18 18:36	Sample		UT-005	<0.000	0.00	1.00	341.66	4.26	1025310.98	4499.74	64.24	6622160.83	4.55	0.15	3306.73
1/3/18 18:42	Sample		UT-006	<0.000	0.00	2.00	468.70	9.40	1382583.83	4640.43	121.00	6829072.67	13.93	0.19	8261.44
1/3/18 18:48	Sample		UT-007	<0.000	0.00	3.00	1935.73	20.28	5508313.50	2505.61	35.04	3689537.00	1.81	0.18	1859.46
1/3/18 18:54	Sample		UT-008	<0.000	0.00	1.67	1282.88	37.36	3672300.17	2298.76	37.65	3385334.42	7.98	0.23	5121.27
1/3/18 19:00	Sample		Blank 1	<0.000	0.00	3.67	3.24	0.23	73577.01	<0.000	0.12	4697.46	0.70	0.03	1275.06
1/3/18 19:06	Sample		Blank 2	<0.000	0.00	2.33	2.84	0.45	72454.61	2.07	0.10	7760.82	7.11	0.13	4658.11
1/3/18 19:13	Sample		Hg 0.1 ppb	<0.000	0.00	2.33	10.99	0.10	95370.97	<0.000	0.03	3034.33	0.13	0.10	977.70
1/3/18 19:19	Sample		Blank 2	<0.000	0.00	1.33	1.66	0.18	69147.96	2.09	0.03	7782.83	7.16	0.17	4685.79
1/3/18 19:25	Sample		Blank 3	<0.000	0.00	1.67	4.09	0.15	75959.13	0.08	0.02	4833.51	4.37	0.11	3212.70
1/3/18 19:31	Sample		Env 100/1 ppb	0.98	0.03	917.70	102.71	1.46	353325.42	90.24	0.15	137423.96	<0.000	0.05	788.35
1/3/18 19:37	Sample		Blank 1	<0.000	0.00	2.67	0.54	0.42	65987.48	<0.000	0.04	4307.33	0.77	0.13	1311.40
1/3/18 19:44	Sample		Blank 3	<0.000	0.00	1.33	3.06	0.38	73063.75	0.02	0.05	4746.81	4.49	0.09	3276.39
1/3/18 19:50	Sample		S 5000/50 ppb	0.00	0.00	7.00	4.60	0.25	77405.54	<0.000	0.06	4338.67	<0.000	0.05	699.35
1/3/18 19:56	Sample		Blank 1	<0.000	0.00	1.33	<0.000	0.22	63076.79	<0.000	0.01	4176.62	0.63	0.07	1236.72
1/3/18 20:02	Sample		Blank 2	<0.000	0.00	2.33	0.18	0.20	64979.46	2.12	0.09	7821.52	7.04	0.16	4621.10
1/3/18 20:08	Sample		Blank 3	<0.000	0.00	0.67	2.59	0.23	71743.70	0.08	0.09	4828.17	4.56	0.11	3311.39
1/3/18 20:15	Sample		Millq neat	<0.000	0.00	1.33	<0.000	0.09	63004.54	<0.000	0.02	244.00	<0.000	0.00	55.67
1/3/18 20:21	Sample		Nitric HCL Matrix	0.00	0.00	6.33	<0.000	0.32	62775.45	<0.000	0.05	2339.53	<0.000	0.06	451.01
1/3/18 20:27	Sample		UT-008-RUN 2	<0.000	0.00	2.00	1291.81	36.49	3697418.67	2336.59	87.16	3440965.67	8.10	0.18	5181.63
1/3/18 20:33	Sample		DM	<0.000	0.00	2.33	45.69	0.45	192959.52	410.25	1.92	608039.52	17.90	0.17	10353.83
1/3/18 20:39	Sample		SCM	<0.000	0.00	3.33	35.77	1.01	165074.44	707.15	9.48	1044670.83	16.70	0.18	9725.05
1/3/18 20:46	Sample		MCM-001S	<0.000	0.00	2.33	10425.38	130.07	29383665.33	25.66	0.14	42440.16	60.97	0.50	33093.74
1/3/18 20:52	Sample		MCM-006SX	<0.000	0.00	5.33	124.32	0.97	414076.81	234.62	2.11	349750.21	7.82	0.28	5032.91
1/3/18 20:58	Sample		MTH	<0.000	0.00	2.00	45.20	0.29	191590.02	753.20	14.32	1112396.04	17.12	0.43	9942.87
1/3/18 21:04	Sample		SKM	<0.000	0.00	3.00	55.20	0.10	219692.36	225.72	0.63	336665.94	17.49	0.15	10140.34
1/3/18 21:10	Sample		MD	<0.000	0.00	1.00	27.61	0.54	142117.73	388.43	4.51	575952.48	77.91	0.62	42035.71
1/3/18 21:16	Sample		WDE	<0.000	0.00	1.00	25.73	0.61	136813.68	647.79	6.19	957363.19	2.48	0.01	2215.51
1/3/18 21:22	Sample		CE-001	<0.000	0.00	1.33	111.08	0.14	376860.79	1329.25	17.11	1959542.46	36.39	0.35	20117.79
1/3/18 21:28	Sample		LSC	<0.000	0.00	1.33	43.54	0.86	186908.48	659.74	10.67	974948.48	20.12	0.47	11528.75
1/3/18 21:35	Sample		IE	<0.000	0.00	2.67	50.38	0.05	206159.46	756.08	30.14	1116631.04	1.25	0.03	1564.09
1/3/18 21:41	Sample		MCM	<0.000	0.00	4.33	10435.25	397.56	29411415.33	28.34	0.17	46384.58	64.59	0.59	35006.07
1/3/18 21:47	Sample		MCS-001	<0.000	0.00	3.33	66.73	0.61	252134.40	41.24	0.34	65366.74	5.64	0.20	3883.21
1/3/18 21:53	Sample		UTS-001	<0.000	0.00	2.33	108.69	1.75	370120.01	423.88	4.48	628080.71	34.48	0.36	19106.37
1/3/18 21:59	Sample		UTS-002	<0.000	0.00	2.00	73.89	0.75	272257.10	276.48	1.32	411317.40	29.95	0.17	16718.65
1/3/18 22:05	Sample		UTS-003	<0.000	0.00	2.33	83.49	0.22	299251.43	286.13	0.83	425509.42	32.42	0.32	18022.94
1/3/18 22:11	Sample		UTS-004	<0.000	0.00	1.33	312.86	2.88	944325.58	137.46	2.24	206866.45	145.13	0.14	77523.47
1/3/18 22:17	Sample		Blank 1	<0.000	0.00	1.67	<0.000	0.17	59534.01	<0.000	0.05	4147.95	0.70	0.09	1275.73
1/3/18 22:24	Sample		Blank 2	<0.000	0.00	0.00	<0.000	0.09	61227.31	2.17	0.06	7908.24	7.22	0.08	4716.46
1/3/18 22:30	Sample		Hg 0.1 ppb	<0.000	0.00	0.33	7.29	0.07	84953.92	<0.000	0.03	2959.65	0.15	0.07	983.70
1/3/18 22:36	Sample		Blank 2	<0.000	0.00	0.67	<0.000	0.10	59915.28	2.10	0.06	7804.18	7.23	0.31	4722.80
1/3/18 22:42	Sample		Blank 3	<0.000	0.00	2.00	1.21	0.05	67878.45	0.07	0.05	4812.83	4.45	0.14	3257.71
1/3/18 22:48	Sample		Env 100/1 ppb	0.95	0.04	889.03	100.32	0.24	346604.36	91.10	1.24	138684.58	<0.000	0.03	800.35
1/3/18 22:55	Sample		Blank 1	<0.000	0.00	2.67	<0.000	0.11	57850.32	<0.000	0.05	4310.66	0.76	0.03	1306.73
1/3/18 23:01	Sample		Blank 3	<0.000	0.00	1.67	0.93	0.14	67076.61	0.10	0.01	4856.84	4.62	0.22	3343.40
1/3/18 23:07	Sample		S 5000/50 ppb	0.00	0.00	6.33	2.19	0.24	70611.17	<0.000	0.09	4330.00	<0.000	0.04	680.35
1/3/18 23:13	Sample		Blank 1	<0.000	0.00	1.67	<0.000	0.25	57781.40	<0.000	0.05	4138.61	0.71	0.04	1279.39
1/3/18 23:19	Sample		Blank 2	<0.000	0.00	0.33	<0.000	0.09	58469.55	2.19	0.04	7925.57	7.17	0.14	4689.45

	33 S [He]			33 S [H2]			34 S [He]			34 S [H2]			39 K [He]		
Sample Name	Conc. [ppb]	Conc. SD	CPS	Conc. [ppb]	Conc. SD	CPS	Conc. [ppb]	Conc. SD	CPS	Conc. [ppb]	Conc. SD	CPS	Conc. [ppb]	Conc. SD	CPS
Blank 1			23867.77			56043.23			4185.30			68881.23			58328.24
Blank 2			21696.22			53140.55			3771.85			66146.17			58691.81
Blank 3			21801.05			53936.25			3765.18			67659.97			58574.58
Blank 1			21345.68			51848.34			3749.18			65058.27			57241.70
Hg 0.01 ppb			21582.73			53078.29			3788.52			66006.11			62377.15
Hg 0.05 ppb			21178.08			52653.28			3767.84			66416.01			65859.10
Hg 0.1 ppb			22302.52			52785.14			3912.55			67486.57			66821.69
Hg 0.5 ppb			21693.55			52683.45			3808.52			66676.59			71146.40
Hg 1.0 ppb			21558.01			52723.68			3761.84			66065.12			77423.20
Blank 1			20967.11			49454.98			3571.79			62526.21			57104.55
Blank 2			20460.36			48252.09			3663.15			61097.82			58423.31
Blank 3			20964.43			49698.48			3591.80			62513.38			58556.54
Env 1/0.01 ppb			21219.49			50955.71			3710.50			63738.94	3.93	0.36	64296.48
Env 5/0.05 ppb			21397.09			50626.54			3823.19			64018.85	7.84	0.29	71325.41
Env 10/0.1 ppb			20706.72			50087.24			3673.82			63759.59	16.20	0.40	86343.59
Env 100/1 ppb			21390.41			50969.10			3681.83			64663.75	111.51	0.23	257594.73
Env 1000/10 ppb			22541.56			55176.35			3987.24			71016.59	1089.97	32.82	2015553.00
Env 10000/100 ppb			24824.83			58457.75			4151.96			74736.02	9990.88	170.84	18007439.33
Blank 1			24167.63			54412.72			4021.25			69264.55	1.92	0.64	60691.70
Blank 2			22564.27			50425.10			3703.16			64024.23	0.74	0.30	58569.89
Blank 3			21822.42			51733.94			3719.16			65081.13	0.87	0.30	58812.28
S 100/1 ppb	6850.56	150.28	22150.26	916.81	13.58	58374.68	1232.47	72.73	4037.26	1323.02	13.35	70317.10	1.92	0.50	60692.35
S 1000/10 ppb	6968.69	105.42	22532.21	1792.53	14.69	114132.64	1987.59	35.76	6510.86	2150.63	18.12	114303.67	2.12	0.39	61051.28
S 5000/50 ppb	7500.30	40.80	24251.10	5362.21	76.89	341418.27	5467.91	40.33	17911.52	5489.74	21.02	291773.14	4.97	0.43	66170.60
S 10000/100 ppb	8085.48	264.39	26143.19	9731.48	43.37	619615.06	9655.96	139.62	31630.56	9627.84	91.46	511708.18	4.93	0.70	66098.97
Blank 1	6719.63	150.93	21726.94	810.67	14.31	51616.20	1140.65	18.03	3736.50	1229.11	24.56	65325.56	1.10	0.41	59212.65
Blank 2	6658.10	120.70	21527.98	792.25	8.91	50443.84	1122.94	9.00	3678.49	1206.58	22.23	64128.12	1.28	0.53	59536.70
Blank 3	6710.13	118.98	21696.22	824.07	14.80	52469.29	1128.24	48.34	3695.83	1238.39	14.08	65819.18	1.16	0.19	59331.12
Millq neat	7379.06	50.47	23859.10	876.75	22.04	55823.62	1207.43	16.35	3955.23	1324.08	24.80	70373.36	1.83	0.29	60528.32
Nitric HCL Matrix	6916.85	195.98	22364.62	839.43	3.05	53447.74	1175.26	30.86	3849.87	1256.19	10.43	66765.08	0.72	0.14	58537.82
SC-002	5576.15	65.63	18029.66	1021.46	9.40	65037.40	1355.02	44.28	4438.71	1387.16	10.21	73725.93	174.85	1.80	371383.70
SC-001	5445.06	100.44	17605.80	1025.61	3.57	65302.01	1325.50	25.67	4342.02	1380.34	15.51	73363.44	93.17	0.82	224631.04
MC-2-002	6211.87	190.43	20085.15	7800.58	19.26	496672.31	7617.28	146.16	24952.35	7845.47	101.75	416977.67	721.77	23.96	1354016.92
MC-2-001	5894.51	151.78	19059.04	7577.97	49.23	482498.90	7308.62	133.06	23941.23	7674.51	72.14	407891.30	659.29	10.65	1241763.25
MC-001	5062.33	33.10	16368.29	1157.13	10.91	73675.60	1443.78	20.55	4729.47	1505.33	0.55	80006.41	36.66	0.10	123110.57
MC-002	7171.08	55.51	23186.61	2078.36	59.62	132331.62	2129.10	93.73	6974.42	2375.29	34.49	126243.62	108.64	0.26	252424.59
MC-003	5335.44	63.24	17251.35	1549.76	12.88	98674.84	1755.89	6.00	5751.86	1861.21	3.60	98921.29	89.28	0.99	217649.98
MC-004	5365.17	39.24	17347.47	1461.65	14.33	93064.98	1657.96	7.41	5431.06	1755.58	17.26	93306.89	142.94	0.24	314053.04
MC-005	5264.22	62.63	17021.06	1463.96	1.87	93212.12	1677.09	10.34	5493.75	1780.43	15.40	94627.81	193.49	0.19	404875.00
MC-006	5488.82	62.76	17747.30	1630.83	30.47	103837.15	1817.58	12.24	5953.94	1946.59	19.35	103458.72	151.84	1.56	330048.05
CC-001	5734.92	30.78	18543.01	2731.00	11.99	173886.26	2798.65	19.74	9167.69	2959.97	8.56	157318.72	149.58	1.11	325993.32
CC-002	5794.79	19.47	18736.60	2537.28	24.30	161551.84	2612.92	7.47	8559.30	2760.42	15.86	146713.10	188.67	0.65	396223.39
CC-003	5664.31	39.57	18314.71	1572.26	11.82	100107.73	1760.98	27.33	5768.53	1872.24	7.33	99507.46	197.96	1.56	412904.23
UT-001	5457.03	133.11	17644.51	1313.62	15.60	83639.71	1565.53	44.25	5128.28	1642.75	21.04	87310.13	96.22	0.99	230113.84
UT-002	5120.33	96.63	16555.84	1175.53	12.53	74847.24	1396.35	32.93	4574.09	1506.39	14.96	80062.74	158.28	1.04	341622.21
UT-003	5008.86	110.40	16195.41	866.45	13.50	55167.76	1147.57	42.45	3759.17	1203.87	4.52	63984.03	13.76	0.17	81955.09
UT-004	4845.38	139.65	15666.81	927.99	19.91	59086.45	1179.13	13.81	3862.54	1284.97	26.50	68294.57	55.51	0.52	156980.66
UT-005	4854.05	73.08	15694.84	998.38	2.39	63568.00	1243.05	45.48	4071.93	1316.59	23.98	69975.38	40.23	0.42	129516.44
UT-006	4793.15	26.72	15497.95	872.28	8.93	55539.15	1128.64	7.46	3697.16	1178.35	12.87	62627.87	47.25	0.11	142129.41
UT-007	5068.52	71.65	16388.32	1496.03	13.77	95253.81	1648.80	28.63	5401.05	1810.82	6.91	96242.78	174.17	1.49	370171.21
UT-008	5152.33	42.62	16659.29	1281.18	10.24	81574.15	1459.87	11.30	4782.16	1596.40	11.63	84846.96	275.83	2.43	552819.02
Blank 1	6307.67	41.45	20394.93	940.05	4.65	59854.32	1153.89	46.13	3779.85	1348.57	14.64	71674.67	<0.000	0.21	49090.61
Blank 2	6570.33	96.43	21244.19	959.05	14.52	61064.19	1201.11	21.60	3934.56	1383.04	27.17	73506.92	<0.000	0.25	50857.63
Hg 0.1 ppb	6616.80	89.24	21394.43	919.51	7.60	58546.12	1184.02	63.81	3878.54	1348.58	8.64	71675.40	0.46	0.15	58067.13
Blank 2	6596.56	80.26	21328.98	928.20	11.61	59099.78	1208.44	31.33	3958.57	1363.13	7.07	72448.64	<0.000	0.31	51476.60
Blank 3	6652.72	11.87	21510.59	956.84	2.60	60923.00	1200.50	48.66	3932.56	1379.72	6.76	73330.63	<0.000	0.25	51846.65
Env 100/1 ppb	6683.70	37.31	21610.76	954.47	7.54	60772.23	1202.95	53.12	3940.56	1379.99	16.08	73344.59	93.42	0.61	225089.09
Blank 1	6794.18	110.73	21967.98	964.46	9.33	61408.40	1199.69	42.85	3929.89	1391.82	6.17	73973.38	<0.000	0.25	51419.71
Blank 3	6723.36	127.59	21738.98	970.19	11.06	61773.32	1230.43	7.20	4030.59	1396.59	10.47	74227.35	<0.000	0.28	51853.96
S 5000/50 ppb	7359.23	79.64	23794.98	5201.75	59.69	331201.99	4988.24	35.92	16340.25	5286.55	44.17	280973.93	0.65	0.29	58415.92
Blank 1	6714.06	144.80	21708.92	962.15	16.76	61261.05	1199.28	42.42	3928.56	1404.46	18.48	74645.54	<0.000	0.48	51783.06
Blank 2	6614.73	24.83	21387.74	959.02	9.46	61062.15	1212.92	41.60	3973.24	1387.74	9.36	73756.74	<0.000	0.14	52507.08
Blank 3	6690.72	66.14	21633.44	953.72	5.13	60724.70	1224.93	51.40	4012.58	1394.07	9.97	74093.33	<0.000	0.21	52531.17
Millq neat	7167.37	125.06	23174.63	986.18	22.93	62791.30	1263.61	21.68	4139.29	1459.55	13.75	77573.53	<0.000	0.32	54464.61
Nitric HCL Matrix	6907.56	41.82	22334.56	979.04	5.26	62336.45	1253.64	19.57	4106.61	1422.31	3.47	75593.89	<0.000	0.16	52369.23
UT-008-RUN 2	5743.18	125.03	18569.71	1356.63	15.83	86378.32	1575.71	23.82	5161.62	1706.33	19.86	90689.68	289.51	3.94	577400.33
DM	6446.02	66.15	20842.26	1077.48	18.96	68604.48	1328.96	32.46	4353.35	1493.94	22.98	79401.03	380.30	1.03	740505.39
SCM	6546.17	70.38	21166.06	1021.38	14.83	65032.83	1234.50	14.40	4043.92	1439.33	9.96	76498.92	131.51	1.63	293528.42
MCM-001S	7279.92	81.62	23538.55	5805.27	24.85	369628.73	5481.96	16.42	17957.57	5864.02	24.65	311665.57	468.88	1.94	899659.81
MCM-006SX	6613.29	36.41	21383.09	1462.83	30.67	93140.36	1640.04	24.17	5372.37	1858.31	24.04	98766.97	302.48	0.19	600693.52
MTH	6634.14	112.94	21450.52	970.57	17.14	61797.41	1215.37	26.78	3981.24	1408.36	24.60	74852.66	251.63	3.27	509337.78
SKM	6598.21	44.92	21334.33	1026.94	13.03	65386.46	1257.10	13.52	4117.94	1468.18	21.17	78032.06	557.08	1.80	1058121.71
MD	6559.80	128.64	21210.14	930.84	20.06	59267.79	1163.25	4.27	3810.52	1355.03	17.81	72018.49	130.55	0.72	291789.94
WDE	6390.06	91.18	20661.33	927.67	4.62	59065.62	1196.23	21.71	3918.55	1359.67	7.18	72265.01	175.61	0.50	372752.21
CE-001	6429.50	122.13	20788.84	1049.69	5.80	66835.33	1269.52	54.41	4158.62	1458.96	2.79	77542.03	483.58	3.29	926068.21
LSC	6596.56	143.30	21328.99	1028.80	7.38	65504.95	1262.19	37.15	4134.62	1452.54	3.11	77200.72	272.75	3.34	547280.54
IE	6735.33	122.43	21777.68	2636.07	50.32	167842.14	2646.12	37.06	8668.03	2956.80	33.02	157150.44	223.65	1.31	459055.89
MCM	7133.49	90.00	23065.08	5741.36	94.21	365559.28	5416.76	25.59	17743.98	5798.39	32.48	308177.38	459.22	1.85	882303.02
MCS-001	6429.71	63.41	20789.51	1032.21	18.41	65721.97	1282.34	18.81	4200.64	1458.84	20.10	77535.88	492.16	2.56	941482.54
UTS-001	6293.63	50.80	20349.51	974.58	14.74	62052.60	1220.25	24.10	3997.24	1391.37	16.48	73949.81	351.98	1.74	689627.81
UTS-002	6384.70	124.13	20643.98	952.49	6.30	60646.42	1185.24	27.14	3882.54	1357.11	7.30	72128.98	238.81	0.71	486302.37
UTS-003	6359.50	130.82	20562.51	966.48	12.01	61536.96	1211.29	21.52	3967.90	1370.57	21.28	72844.08	579.16	8.03	1097792.46
UTS-004	5980.81	5.62	19338.08	1017.95	19.48	64813.82	1238.98	59.10	4058.60	1393.33	2.65	74053.66	1539.94	27.92	2823989.42
Blank 1	6335.55	110.65	20485.06	908.86	6.78	57867.98	1126.20	11.78	3689.16	1334.57	6.81	70930.83	<0.000	0.09	52147.74
Blank 2	6379.95	101.03	20628.61	907.07	9.59	57754.14	1143.30	15.72	3745.17	1336.47	6.97	71032.06	<0.000	0.16	52299.63
Hg 0.1 ppb	6372.10	44.27	20603.23	889.40	3.89	56628.90	1111.54	5.09	3641.14	1301.42	27.37	69168.80	1.26	0.10	59507.87
Blank 2	6319.86	199.04	20434.32	902.29	18.89	57450.22	1121.11	24.79	3672.49	1324.93	9.32	70418.27	<0.000	0.08	52719.21
Blank 3	6325.64	98.99	20453.01	909.81	9.20	57928.83	1136.99	26.26	3724.50	1330.26	15.50	70701.65	<0.000	0.12	52499.71
Env 100/1 ppb	6497.03	135.95	21007.17	921.38	23.09	58665.34	1178.31	16.62	3859.87	1356.62	16.40	72102.99	95.44	1.74	228716.07
Blank 1	6441.48	77.80	20827.56	926.30	10.96	58978.59	1139.64	34.58	3733.17	1352.29	20.25	71872.41	<0.000	0.26	52051.37
Blank 3	6478.44	113.95	20947.08	932.40	10.01	59366.92	1150.43	56.34	3768.51	1351.23	13.19	71816.02	<0.000	0.15	52333.06
S 5000/50 ppb	7077.52	32.79	22884.11	5105.77	70.06	325090.78	4889.01	127.16	16015.21	5225.03	43.45	277703.96	1.16	0.19	59332.44
Blank 1	6387.17	52.38	20651.98	909.78	22.04	57926.90	1134.95	38.13	3717.83	1335.92	20.76	71002.57	<0.000	0.46	52163.79
Blank 2	6467.91	89.91	20913.03	899.37	17.64	57264.13	1150.02	10.96	3767.18	1310.74	28.01	69664.49	<0.000	0.13	52350.52

	40 Ca [H2]			44 Ca [He]			51 V [He]			52 Cr [He]			55 Mn [He]		
Sample Name	Conc. [ppb]	Conc. SD	CPS	Conc. [ppb]	Conc. SD	CPS	Conc. [ppb]	Conc. SD	CPS	Conc. [ppb]	Conc. SD	CPS	Conc. [ppb]	Conc. SD	CPS
Blank 1			182104.19			2978.32			1591.76			6798.37			3923.90
Blank 2			117224.34			1744.78			1779.12			4360.69			4191.31
Blank 3			191061.86			2040.15			1768.78			3872.55			3471.77
Blank 1			173646.89			1948.81			1509.42			4295.34			3515.45
Hg 0.01 ppb			247551.68			2379.54			1646.43			6641.94			2136.50
Hg 0.05 ppb			291787.98			2451.55			1461.41			3676.49			659.69
Hg 0.1 ppb			473846.65			3430.43			1371.07			4164.30			1694.10
Hg 0.5 ppb			1591495.58			8732.76			1354.73			3855.21			1265.39
Hg 1.0 ppb			2427958.67			12853.97			1561.42			3795.19			1450.08
Blank 1			172164.31			1855.46			1536.09			4463.39			3488.44
Blank 2			114313.47			1555.42			1863.46			4539.75			4116.28
Blank 3			183985.61			1908.80			1835.46			3978.91			3457.44
Env 1/0.01 ppb	38.62	0.14	991804.21	40.68	1.98	6160.71	0.01	0.00	1921.80	<0.000	0.00	4163.96	<0.000	0.00	1087.04
Env 5/0.05 ppb	4.35	0.07	265848.06	4.44	0.89	2408.21	0.06	0.00	3082.01	0.05	0.00	6060.67	<0.000	0.00	1711.11
Env 10/0.1 ppb	17.07	0.11	535343.12	18.08	2.00	3821.20	0.11	0.00	4557.76	0.10	0.00	7748.85	<0.000	0.00	2731.94
Env 100/1 ppb	110.03	4.48	2504473.25	107.87	2.49	13116.89	1.02	0.00	29730.70	1.05	0.00	40861.85	0.88	0.01	19401.69
Env 1000/10 ppb	1008.37	17.25	21534482.67	1015.89	9.55	107131.59	9.90	0.01	274894.90	10.41	0.06	367674.54	10.02	0.04	183888.31
Env 10000/100 ppb	9999.06	157.81	211989701.33	9998.32	131.39	1037146.00	100.01	2.23	2762340.00	99.96	2.10	3492559.33	100.00	4.30	1803412.04
Blank 1	0.53	0.03	184826.14	2.14	1.34	2170.17	0.07	0.01	3330.07	0.02	0.00	4902.54	0.01	0.00	3672.49
Blank 2	<0.000	0.01	115914.75	<0.000	0.27	1631.43	0.02	0.00	1943.14	0.01	0.01	4598.44	0.03	0.01	4051.93
Blank 3	0.53	0.09	184831.68	<0.000	0.55	1880.13	0.01	0.00	1703.77	<0.000	0.00	4190.64	<0.000	0.00	3353.41
S 100/1 ppb	<0.000	0.09	116766.53	<0.000	0.22	1560.09	<0.000	0.00	1477.08	<0.000	0.00	3975.24	<0.000	0.00	574.34
S 1000/10 ppb	<0.000	0.03	118445.35	<0.000	0.59	1552.09	<0.000	0.00	1481.41	<0.000	0.00	3941.57	<0.000	0.00	771.35
S 5000/50 ppb	4.80	0.05	275305.51	4.72	0.71	2437.55	0.00	0.00	1549.09	<0.000	0.00	4115.62	<0.000	0.00	869.36
S 10000/100 ppb	<0.000	0.06	165833.70	<0.000	0.32	1814.79	<0.000	0.00	1453.41	<0.000	0.00	4064.60	<0.000	0.00	754.69
Blank 1	0.11	0.16	175911.91	<0.000	0.32	1832.12	0.00	0.00	1540.75	0.01	0.00	4573.76	<0.000	0.00	3467.77
Blank 2	<0.000	0.06	117277.06	<0.000	0.49	1508.08	0.01	0.00	1911.47	0.01	0.00	4559.42	0.04	0.00	4147.30
Blank 3	0.73	0.09	189076.69	<0.000	0.31	1836.79	0.01	0.00	1840.12	<0.000	0.00	4063.93	<0.000	0.01	3305.73
Millq neat	<0.000	0.02	32871.55	<0.000	0.22	1194.72	<0.000	0.00	210.67	<0.000	0.00	3599.47	<0.000	0.00	344.34
Nitric HCL Matrix	<0.000	0.05	133138.34	<0.000	0.30	1498.08	<0.000	0.00	1423.07	<0.000	0.00	4208.64	<0.000	0.00	1082.71
SC-002	2375.53	45.62	50495958.67	2346.56	29.14	244905.25	0.44	0.02	13586.70	3.65	0.01	131820.34	<0.000	0.00	2368.20
SC-001	2111.31	81.63	44898896.00	2070.94	8.18	216368.00	0.43	0.01	13255.72	3.72	0.02	134169.84	<0.000	0.00	1555.42
MC-2-002	4354.18	72.86	92410869.33	4585.90	52.92	476759.52	0.48	0.00	14855.34	0.09	0.00	7557.41	0.08	0.00	4978.57
MC-2-001	4076.39	33.09	86526346.67	4241.53	28.93	441103.95	0.48	0.01	14848.67	0.01	0.00	4741.15	<0.000	0.00	1456.41
MC-001	336.35	4.73	7298659.17	345.20	2.73	37689.92	0.33	0.01	10638.11	0.01	0.00	4510.07	2.30	0.01	44948.36
MC-002	999.43	47.34	21345224.67	930.57	7.99	98296.99	<0.000	0.00	679.02	<0.000	0.00	3973.24	4.05	0.01	76355.16
MC-003	1405.65	36.25	29950360.67	1375.02	11.74	144313.83	0.37	0.00	11658.60	0.06	0.00	6275.77	0.49	0.00	12290.82
MC-004	2117.48	32.33	45029588.00	2103.55	12.43	219744.28	0.41	0.00	12884.70	0.01	0.00	4565.42	<0.000	0.00	1552.42
MC-005	2130.62	29.44	45307866.67	2065.57	3.39	215812.11	0.41	0.00	12720.88	0.05	0.00	5876.92	<0.000	0.00	1185.05
MC-006	3181.16	97.66	67562176.00	3164.79	39.02	329621.90	0.38	0.01	12037.26	0.01	0.00	4493.07	<0.000	0.00	1028.04
CC-001	16414.95	38.34	347901418.67	15971.12	104.16	1655552.29	0.75	0.01	22152.13	3.48	0.01	125878.44	<0.000	0.00	1064.04
CC-002	9914.13	61.68	210190565.33	9525.39	25.54	988180.13	2.24	0.02	63369.99	1.69	0.01	63261.60	<0.000	0.00	2699.27
CC-003	6042.57	127.66	128177069.33	5914.84	59.80	614354.44	0.51	0.01	15497.05	6.92	0.04	245640.81	<0.000	0.00	744.35
UT-001	2088.02	49.11	44405332.00	2007.36	3.83	209784.53	0.58	0.00	17557.51	6.62	0.03	235262.56	<0.000	0.00	1653.10
UT-002	5115.05	46.70	108528930.67	4858.15	53.40	504947.54	0.36	0.00	11502.13	1.61	0.01	60564.17	<0.000	0.00	1530.75
UT-003	510.22	3.41	10981920.33	478.17	5.97	51456.79	0.40	0.01	12442.62	1.39	0.01	52761.84	<0.000	0.00	1812.45
UT-004	1187.60	29.78	25331215.33	1125.69	8.98	118499.61	0.73	0.00	21708.43	1.29	0.01	49390.04	0.01	0.00	3744.18
UT-005	1645.46	25.09	35030420.00	1588.23	13.19	166389.74	0.54	0.01	16364.05	1.62	0.02	60829.36	<0.000	0.00	1043.71
UT-006	1689.68	37.80	35967198.67	1617.65	3.98	169435.71	0.65	0.01	19472.09	1.92	0.01	71332.52	<0.000	0.00	1750.78
UT-007	18087.33	275.79	383328501.33	19869.19	413.52	2059146.38	0.81	0.01	23733.08	0.13	0.00	8723.76	<0.000	0.00	1129.71
UT-008	15391.45	277.15	326220117.33	15571.06	292.29	1614131.08	1.24	0.02	35711.90	0.37	0.01	17135.99	0.10	0.00	5237.67
Blank 1	0.34	0.06	180826.45	2.43	0.10	2200.84	0.01	0.00	1822.12	<0.000	0.00	3775.19	<0.000	0.01	2961.99
Blank 2	<0.000	0.09	113617.85	<0.000	0.42	1580.76	0.02	0.00	2023.48	<0.000	0.00	4009.92	0.00	0.00	3528.12
Hg 0.1 ppb	13.00	0.14	448942.55	11.59	0.38	3149.03	0.00	0.00	1634.10	<0.000	0.00	3929.89	<0.000	0.00	1340.73
Blank 2	<0.000	0.02	111721.69	<0.000	0.58	1608.76	0.01	0.00	1890.46	<0.000	0.00	3974.24	<0.000	0.00	3496.78
Blank 3	0.15	0.03	176927.32	0.51	0.21	2001.48	0.01	0.00	1809.79	<0.000	0.00	3635.48	<0.000	0.00	2918.98
Env 100/1 ppb	103.80	4.41	2372440.83	95.88	0.77	11876.43	0.89	0.01	26159.80	0.92	0.01	36401.36	0.76	0.01	17234.46
Blank 1	<0.000	0.04	165739.88	<0.000	0.93	1772.12	0.00	0.00	1542.42	<0.000	0.00	4030.59	<0.000	0.00	3022.34
Blank 3	0.21	0.07	178045.16	0.19	0.21	1968.81	0.01	0.00	1790.45	<0.000	0.00	3599.14	<0.000	0.00	2943.65
S 5000/50 ppb	4.18	0.08	262235.78	4.12	0.76	2374.87	0.01	0.00	1683.44	<0.000	0.00	3769.52	<0.000	0.00	729.69
Blank 1	<0.000	0.04	167150.02	<0.000	0.64	1908.80	0.00	0.00	1604.10	<0.000	0.00	4121.95	<0.000	0.00	3026.33
Blank 2	<0.000	0.01	112900.63	<0.000	1.26	1624.76	0.01	0.00	1877.80	<0.000	0.00	4171.63	0.00	0.00	3546.46
Blank 3	0.28	0.04	179553.53	0.12	1.08	1961.47	0.01	0.00	1835.12	<0.000	0.00	3631.81	<0.000	0.00	2910.98
Millq neat	<0.000	0.03	33640.06	<0.000	0.24	1344.73	<0.000	0.00	201.67	<0.000	0.00	3394.42	<0.000	0.00	273.67
Nitric HCL Matrix	<0.000	0.05	128381.12	<0.000	0.27	1660.10	<0.000	0.00	1338.73	<0.000	0.00	3842.87	<0.000	0.00	891.70
UT-008-RUN 2	16013.78	263.47	339403210.67	15933.73	122.25	1651680.79	1.27	0.02	36522.68	0.39	0.01	17770.80	0.10	0.01	5387.39
DM	578.72	6.49	12433018.00	540.15	3.24	57874.72	0.65	0.00	19374.61	0.79	0.01	31868.84	2.28	0.04	44581.18
SCM	565.01	10.87	12142676.67	532.34	9.71	57065.41	0.12	0.00	4856.86	1.05	0.01	41076.50	2.66	0.01	51357.08
MCM-001S	431.34	10.62	9310945.00	424.98	1.18	45950.15	0.19	0.00	6654.27	0.04	0.00	5752.54	2.43	0.03	47225.64
MCM-006SX	300.34	5.93	6535949.33	301.90	1.37	33206.45	0.02	0.00	1936.80	0.00	0.00	4386.37	20.00	0.05	363587.31
MTH	125.12	4.73	2824137.08	114.45	1.98	13798.88	0.18	0.00	6569.90	1.43	0.00	54314.19	6.97	0.03	129046.67
SKM	882.45	10.77	18867028.00	854.09	7.95	90378.77	0.71	0.01	21090.79	1.11	0.01	43190.63	7.83	0.05	144492.62
MD	337.13	7.32	7315351.00	313.97	4.14	34456.17	0.62	0.01	18540.47	0.97	0.01	38049.48	3.12	0.04	59610.30
WDE	501.28	8.84	10792542.67	486.43	3.68	52312.00	0.03	0.00	2365.20	0.14	0.00	9215.08	1.85	0.02	36799.86
CE-001	388.95	4.96	8413035.33	375.89	3.47	40866.93	0.38	0.00	11988.21	2.63	0.03	96152.78	53.96	0.53	974672.21
LSC	787.77	18.23	16861484.00	745.89	7.10	79175.81	0.32	0.00	10356.56	0.75	0.01	30500.41	2.60	0.06	50288.16
IE	399.32	0.20	8632628.67	376.34	2.00	40913.75	0.01	0.00	1834.12	0.05	0.00	5932.95	68.77	0.29	1241285.04
MCM	471.20	8.92	10155408.33	471.89	5.19	50806.42	0.21	0.00	7338.62	0.05	0.00	6110.02	2.62	0.01	50697.31
MCS-001	351.78	12.85	7625511.33	329.18	2.51	36030.84	0.06	0.00	3203.04	<0.000	0.00	3892.22	2.46	0.02	47862.83
UTS-001	124.41	1.83	2809069.67	115.45	2.61	13902.32	0.23	0.00	7950.29	1.85	0.01	68888.17	3.33	0.02	63509.01
UTS-002	70.62	2.13	1669565.21	64.63	1.81	8640.70	0.15	0.00	5560.12	1.54	0.01	58111.62	3.81	0.04	72096.90
UTS-003	202.91	4.43	4471963.17	190.35	4.39	21656.94	0.24	0.00	8155.08	1.27	0.01	48535.03	15.44	0.09	281475.73
UTS-004	1169.63	22.24	24950590.67	1100.12	16.10	115852.07	0.57	0.01	17303.19	0.32	0.01	15548.10	99.35	1.75	1791707.71
Blank 1	<0.000	0.03	171572.13	<0.000	0.31	1738.78	0.01	0.00	1792.45	<0.000	0.00	4150.96	<0.000	0.00	3167.03
Blank 2	<0.000	0.05	115519.46	<0.000	0.36	1451.41	0.02	0.00	2096.16	<0.000	0.00	4220.31	0.00	0.00	3581.47
Hg 0.1 ppb	13.32	0.15	455824.19	10.66	0.25	3052.34	0.01	0.00	1891.13	<0.000	0.01	4043.93	<0.000	0.00	1437.74
Blank 2	<0.000	0.06	116523.05	<0.000	0.51	1475.41	0.02	0.00	2152.83	<0.000	0.00	4258.99	0.00	0.00	3571.46
Blank 3	0.44	0.10	182961.08	<0.000	0.28	1744.11	0.02	0.00	2096.49	<0.000	0.00	3812.53	<0.000	0.00	2921.64
Env 100/1 ppb	109.33	2.09	2489609.00	97.88	1.58	12083.28	0.92	0.02	26861.49	0.94	0.00	36944.81	0.77	0.01	17294.87
Blank 1	<0.000	0.02	172805.39	<0.000	0.44	1738.11	0.01	0.00	1749.78	<0.000	0.00	4267.00	<0.000	0.00	3021.67
Blank 3	0.47	0.09	183695.75	<0.000	1.15	1813.45	0.02	0.00	2069.49	<0.000	0.00	3834.87	<0.000	0.00	2979.99
S 5000/50 ppb	4.33	0.02	265348.74	2.07	0.61	2163.50	0.02	0.00	1945.14	<0.000	0.00	3891.22	<0.000	0.00	697.69
Blank 1	<0.000	0.06	169645.17	<0.000	0.92	1692.10	0.01	0.00	1787.45	<0.000	0.00	4161.30	<0.000	0.00	3023.34
Blank 2	<0.000	0.05	113823.47	<0.000	0.92	1425.41	0.02	0.00	2137.17	<0.000	0.00	4161.63	0.00	0.00	3549.12

	56 Fe [He]			56 Fe [H2]			57 Fe [H2]			59 Co [He]			60 Ni [He]		
Sample Name	Conc. [ppb]	Conc. SD	CPS	Conc. [ppb]	Conc. SD	CPS	Conc. [ppb]	Conc. SD	CPS	Conc. [ppb]	Conc. SD	CPS	Conc. [ppb]	Conc. SD	CPS
Blank 1			384118.40			867245.83			22033.69			475.68			1072.37
Blank 2			599052.15			1484715.00			36679.65			420.34			1143.38
Blank 3			290500.74			705133.88			18073.23			457.68			968.03
Blank 1			342675.84			834101.27			21084.20			339.00			1028.04
Hg 0.01 ppb			362061.89			864938.63			22217.98			381.67			1054.04
Hg 0.05 ppb			27892.99			53857.38			1918.80			95.33			553.68
Hg 0.1 ppb			105405.57			246477.19			6562.91			353.34			1400.41
Hg 0.5 ppb			33134.62			68120.48			2269.52			184.67			755.02
Hg 1.0 ppb			55403.51			121619.51			3551.80			223.67			826.03
Blank 1			341643.50			813621.37			20528.02			326.33			1022.04
Blank 2			596555.34			1468500.63			35509.89			423.01			1152.38
Blank 3			288543.71			676292.85			17155.40			429.34			963.03
Env 1/0.01 ppb	<0.000	0.01	92945.99	<0.000	0.03	207818.44	<0.000	0.08	5633.16	0.01	0.00	809.35	<0.000	0.00	780.02
Env 5/0.05 ppb	<0.000	0.07	153014.63	<0.000	0.03	354833.45	<0.000	0.11	9246.45	0.05	0.00	3652.49	0.04	0.00	1683.44
Env 10/0.1 ppb	<0.000	0.07	304878.33	<0.000	0.02	711392.10	<0.000	0.16	18361.62	0.10	0.00	7260.26	0.10	0.00	2837.63
Env 100/1 ppb	93.31	2.71	3188093.58	89.46	2.51	7525120.33	89.03	0.89	178488.77	1.06	0.01	71097.81	1.08	0.01	21010.76
Env 1000/10 ppb	1045.11	35.08	32211582.00	1017.27	22.41	76915328.00	1062.70	44.25	1899999.42	10.32	0.02	690120.81	10.58	0.06	196879.10
Env 10000/100 ppb	9995.57	224.31	305141333.33	9998.40	90.37	748607189.33	9993.86	106.41	17690870.00	99.97	2.24	6679638.50	99.94	0.13	1851480.00
Blank 1	14.70	2.33	790891.63	8.12	1.41	1441331.96	7.38	0.76	34125.78	0.01	0.00	1179.39	0.01	0.00	1189.05
Blank 2	10.84	0.12	673354.58	11.37	0.63	1684566.42	10.62	0.13	39859.13	0.00	0.00	440.34	0.00	0.00	1058.37
Blank 3	<0.000	0.09	328241.05	<0.000	0.09	762784.81	<0.000	0.14	19498.51	0.00	0.00	449.01	<0.000	0.00	960.03
S 100/1 ppb	<0.000	0.01	53365.48	<0.000	0.02	111707.77	<0.000	0.02	3357.74	<0.000	0.00	91.00	<0.000	0.00	594.34
S 1000/10 ppb	<0.000	0.01	61143.10	<0.000	0.01	135817.96	<0.000	0.03	3867.88	<0.000	0.00	114.00	<0.000	0.00	581.68
S 5000/50 ppb	<0.000	0.02	78313.93	<0.000	0.01	178298.21	<0.000	0.04	4932.89	<0.000	0.00	184.67	<0.000	0.00	883.36
S 10000/100 ppb	<0.000	0.02	33793.16	<0.000	0.01	69576.42	<0.000	0.01	2374.21	<0.000	0.00	148.33	<0.000	0.00	690.02
Blank 1	0.35	0.10	353250.85	0.22	0.10	850874.46	0.38	0.13	21762.58	0.00	0.00	365.34	<0.000	0.00	990.70
Blank 2	8.64	0.21	606144.52	9.55	0.18	1548023.75	8.88	0.34	36783.94	0.00	0.00	402.68	0.00	0.00	1109.04
Blank 3	<0.000	0.10	294475.94	<0.000	0.03	698574.13	<0.000	0.24	17892.99	0.00	0.00	413.34	<0.000	0.00	978.04
Millq neat	<0.000	0.01	9886.90	<0.000	0.00	17231.47	<0.000	0.01	1090.71	<0.000	0.00	35.33	<0.000	0.00	327.67
Nitric HCL Matrix	<0.000	0.07	99331.90	<0.000	0.03	234998.90	<0.000	0.07	6435.51	0.00	0.00	510.01	<0.000	0.00	954.70
SC-002	2.52	0.36	419432.98	1.59	0.06	952660.81	2.13	0.17	24858.48	0.01	0.00	899.70	3.50	0.02	65903.75
SC-001	<0.000	0.05	136011.25	<0.000	0.04	314915.88	<0.000	0.06	9369.20	0.01	0.00	707.69	3.05	0.01	57437.11
MC-2-002	18.28	0.05	900001.54	19.91	0.51	2323313.67	19.67	0.17	55867.43	0.02	0.00	1857.46	0.23	0.00	5302.03
MC-2-001	<0.000	0.04	172130.09	<0.000	0.02	411011.26	<0.000	0.11	12513.04	0.00	0.00	522.01	0.08	0.00	2436.55
MC-001	<0.000	0.01	62088.64	<0.000	0.02	142489.69	<0.000	0.03	4209.98	0.10	0.00	6816.03	0.06	0.01	2195.51
MC-002	<0.000	0.03	65088.54	<0.000	0.02	155065.57	<0.000	0.04	4779.50	0.47	0.01	31451.03	0.37	0.00	7899.61
MC-003	<0.000	0.02	160842.19	<0.000	0.06	381621.62	<0.000	0.11	10931.69	0.11	0.00	7447.02	0.18	0.00	4291.34
MC-004	<0.000	0.04	158287.18	<0.000	0.02	376145.84	<0.000	0.08	10943.70	0.02	0.00	1631.76	0.11	0.00	3154.37
MC-005	<0.000	0.04	142207.42	<0.000	0.02	337426.30	<0.000	0.04	9920.92	0.01	0.00	1235.39	0.13	0.00	3423.76
MC-006	<0.000	0.02	74587.28	<0.000	0.01	171826.90	<0.000	0.05	6083.35	0.01	0.00	730.02	0.10	0.00	2953.65
CC-001	<0.000	0.03	130483.94	<0.000	0.04	315430.03	<0.000	0.08	16086.77	0.00	0.00	575.68	0.65	0.00	13057.22
CC-002	<0.000	0.01	75165.73	<0.000	0.02	175183.00	<0.000	0.10	9375.88	0.01	0.00	735.35	0.16	0.00	4010.92
CC-003	<0.000	0.04	78124.89	<0.000	0.01	182020.26	<0.000	0.08	8099.73	0.00	0.00	514.68	1.79	0.01	34219.33
UT-001	<0.000	0.03	106692.01	<0.000	0.05	253313.30	<0.000	0.08	7823.57	0.01	0.00	846.03	6.31	0.03	117801.67
UT-002	<0.000	0.05	224638.69	<0.000	0.04	549657.63	<0.000	0.12	16491.91	0.02	0.00	1355.73	10.67	0.09	198674.67
UT-003	59.26	1.48	2149812.33	61.52	1.00	5435194.00	58.73	0.63	124926.52	0.01	0.00	1190.72	15.66	0.03	291059.24
UT-004	7.67	0.20	576639.89	9.66	1.03	1556592.79	8.97	0.39	36944.33	0.02	0.00	1553.09	6.94	0.01	129598.07
UT-005	<0.000	0.02	99997.22	<0.000	0.01	239240.02	<0.000	0.06	7233.91	0.01	0.00	1219.72	11.60	0.10	215880.15
UT-006	<0.000	0.01	267086.33	<0.000	0.03	651705.67	<0.000	0.07	17521.86	0.01	0.00	908.36	10.67	0.06	198548.27
UT-007	<0.000	0.03	99899.28	<0.000	0.05	242688.39	<0.000	0.09	14930.80	0.00	0.00	392.68	0.33	0.00	7085.50
UT-008	2.74	0.11	426348.10	3.28	0.12	1079039.46	7.10	0.18	33641.21	0.01	0.00	906.70	1.90	0.01	36215.12
Blank 1	<0.000	0.04	299426.50	<0.000	0.05	757512.25	<0.000	0.10	19240.82	<0.000	0.00	313.67	<0.000	0.00	888.70
Blank 2	5.89	0.09	522160.56	7.07	0.64	1362934.46	7.00	0.09	33469.43	0.00	0.00	363.67	<0.000	0.00	971.03
Hg 0.1 ppb	<0.000	0.03	94170.96	<0.000	0.03	232138.38	<0.000	0.08	6245.43	<0.000	0.00	299.33	0.01	0.00	1230.39
Blank 2	5.98	0.14	525172.13	6.67	0.11	1332738.58	6.92	0.22	33325.76	0.00	0.00	351.67	<0.000	0.00	1018.37
Blank 3	<0.000	0.03	253120.69	<0.000	0.09	630529.04	<0.000	0.14	16240.28	0.00	0.00	389.34	<0.000	0.00	850.36
Env 100/1 ppb	80.48	2.45	2796700.17	82.90	1.54	7034016.33	82.11	0.60	166267.33	0.93	0.01	62804.45	0.94	0.01	18340.60
Blank 1	<0.000	0.07	311498.83	<0.000	0.14	780592.09	<0.000	0.08	19813.63	<0.000	0.00	335.67	<0.000	0.00	885.70
Blank 3	<0.000	0.09	252526.12	<0.000	0.04	635969.10	<0.000	0.10	16234.26	0.00	0.00	382.01	<0.000	0.00	852.36
S 5000/50 ppb	<0.000	0.03	63590.16	<0.000	0.01	151297.31	<0.000	0.05	4407.38	<0.000	0.00	146.00	<0.000	0.00	813.69
Blank 1	<0.000	0.06	304115.56	<0.000	0.05	772403.71	<0.000	0.10	19782.25	<0.000	0.00	297.33	<0.000	0.00	896.70
Blank 2	5.98	0.12	525133.04	8.28	0.59	1453206.29	7.27	0.29	33945.26	<0.000	0.00	337.00	<0.000	0.00	992.70
Blank 3	<0.000	0.08	256486.03	<0.000	0.05	638235.06	<0.000	0.17	16470.55	0.00	0.00	380.68	<0.000	0.00	874.36
Millq neat	<0.000	0.01	7705.50	<0.000	0.00	12294.84	<0.000	0.02	962.70	<0.000	0.00	31.00	<0.000	0.00	354.34
Nitric HCL Matrix	<0.000	0.03	77882.87	<0.000	0.03	189379.08	<0.000	0.08	5315.03	<0.000	0.00	318.00	<0.000	0.00	834.02
UT-008-RUN 2	3.41	0.10	446782.46	4.01	0.10	1133978.17	8.35	0.13	35853.45	0.01	0.00	937.03	1.96	0.03	37243.58
DM	26.07	0.09	1137485.79	30.09	0.64	3084439.75	29.29	0.68	72868.28	0.13	0.00	8971.60	5.84	0.01	109153.25
SCM	102.59	1.01	3470919.92	107.03	1.74	8838691.33	104.47	0.31	205793.96	0.18	0.00	12198.43	3.00	0.01	56567.57
MCM-001S	102.89	3.34	3480236.50	108.48	3.66	8947228.00	105.98	0.71	208458.41	0.13	0.00	9121.04	0.09	0.00	2602.58
MCM-006SX	<0.000	0.08	111328.55	<0.000	0.01	261603.32	<0.000	0.04	7228.58	1.09	0.01	73126.45	7.94	0.05	148048.95
MTH	31.30	0.18	1297194.00	36.96	0.81	3598316.67	35.29	0.36	83476.40	0.51	0.01	34096.67	12.14	0.04	225793.52
SKM	25.61	0.09	1123525.50	31.09	0.68	3159548.17	29.42	0.22	73104.09	0.19	0.00	12984.48	4.21	0.01	78989.29
MD	101.34	3.82	3432940.33	108.81	2.41	8971839.67	105.58	0.74	207756.81	0.23	0.00	15979.64	5.26	0.01	98420.78
WDE	<0.000	0.15	307466.25	<0.000	0.05	771663.04	<0.000	0.10	19760.88	0.05	0.00	3518.79	2.59	0.03	48963.64
CE-001	72.47	2.60	2552566.33	76.38	0.92	6546543.17	73.94	0.29	151812.53	1.10	0.01	73886.19	31.38	0.10	581972.50
LSC	41.19	1.57	1598816.54	45.59	0.76	4243880.58	43.34	0.24	97712.41	0.18	0.00	12597.45	3.79	0.01	71142.15
IE	<0.000	0.05	88084.27	<0.000	0.01	211614.47	<0.000	0.08	6056.01	1.73	0.02	115910.40	28.68	0.12	531993.04
MCM	113.09	2.56	3791155.25	122.72	3.08	10011993.67	118.27	0.42	230199.41	0.13	0.00	9060.33	0.09	0.00	2656.26
MCS-001	<0.000	0.07	110354.16	<0.000	0.03	262704.65	<0.000	0.01	7303.94	0.09	0.00	6040.67	0.04	0.00	1777.78
UTS-001	31.08	0.39	1290434.00	36.37	1.05	3554515.17	34.51	0.10	82095.34	0.16	0.00	10757.89	8.11	0.05	151228.61
UTS-002	21.57	0.12	1000531.52	26.59	0.86	2822668.58	24.33	0.10	64103.31	0.15	0.00	10131.08	4.54	0.03	85099.34
UTS-003	24.10	0.26	1077664.63	29.62	1.08	3049643.83	27.12	0.35	69027.10	0.29	0.00	19467.14	9.57	0.02	178188.81
UTS-004	73.61	0.94	2587361.08	79.79	1.58	6801430.33	77.54	1.18	158182.85	0.12	0.00	8237.14	0.77	0.00	15297.87
Blank 1	<0.000	0.11	309234.30	<0.000	0.05	795386.71	<0.000	0.12	20395.15	<0.000	0.00	328.67	<0.000	0.00	925.37
Blank 2	6.33	0.04	535752.54	8.38	1.15	1460983.42	7.94	0.31	35120.90	0.00	0.00	365.34	<0.000	0.00	992.04
Hg 0.1 ppb	<0.000	0.03	98520.03	<0.000	0.01	243555.12	<0.000	0.05	6579.58	<0.000	0.00	305.67	0.01	0.00	1240.06
Blank 2	6.36	0.16	536765.83	9.01	0.27	1508298.21	8.01	0.03	35240.51	0.00	0.00	356.67	<0.000	0.00	998.71
Blank 3	<0.000	0.04	258958.86	<0.000	0.03	655136.83	<0.000	0.10	16822.97	0.00	0.00	379.34	<0.000	0.00	877.36
Env 100/1 ppb	81.56	2.10	2829593.50	88.69	1.17	7466797.00	84.33	0.20	170189.07	0.93	0.01	62713.72	0.95	0.00	18528.85
Blank 1	<0.000	0.03	313367.35	<0.000	0.08	810882.21	<0.000	0.05	20600.11	<0.000	0.00	335.33	<0.000	0.00	902.70
Blank 3	<0.000	0.03	261674.47	<0.000	0.04	656399.54	<0.000	0.15	16975.17	0.00	0.00	380.68	<0.000	0.00	873.70
S 5000/50 ppb	<0.000	0.03	65270.69	<0.000	0.02	155590.39	<0.000	0.06	4404.71	<0.000	0.00	151.33	<0.000	0.00	824.69
Blank 1	<0.000	0.04	302618.31	<0.000	0.01	785363.77	<0.000	0.10	20134.77	<0.000	0.00	308.67	<0.000	0.00	910.70
Blank 2	6.17	0.08	530702.21	8.61	0.11	1477770.83	7.63	0.21	34568.17	0.00	0.00	339.00	<0.000	0.00	1020.37

	63 Cu [He]			66 Zn [He]			75 As [He]			75 As [H2]			78 Se [He]		
Sample Name	Conc. [ppb]	Conc. SD	CPS	Conc. [ppb]	Conc. SD	CPS	Conc. [ppb]	Conc. SD	CPS	Conc. [ppb]	Conc. SD	CPS	Conc. [ppb]	Conc. SD	CPS
Blank 1			39536.40			28149.23			215.00			6764.69			64.00
Blank 2			34447.32			11698.36			258.33			6284.46			49.00
Blank 3			43842.14			8969.29			166.00			6060.68			39.33
Blank 1			35439.85			9870.57			120.00			5992.99			40.33
Hg 0.01 ppb			2790277.33			109207.04			481.01			6006.00			44.33
Hg 0.05 ppb			3022766.58			11101.86			96.67			5847.26			46.00
Hg 0.1 ppb			281500448.00			280056.40			263.67			5898.95			40.67
Hg 0.5 ppb			1417126.29			19612.75			106.33			5709.87			52.33
Hg 1.0 ppb			266161.43			24650.58			121.00			5743.88			49.00
Blank 1			38133.75			7296.62			143.33			5821.58			51.00
Blank 2			35180.51			6779.69			270.33			5789.91			47.67
Blank 3			44638.38			5416.08			179.67			5876.28			40.33
Env 1/0.01 ppb	0.10	0.00	216380.54	<0.000	0.01	9043.66	0.01	0.00	213.00	<0.000	0.02	5708.20	0.01	0.01	51.33
Env 5/0.05 ppb	9.50	0.03	17186443.33	1.12	0.02	19853.10	0.05	0.00	705.35	<0.000	0.01	5904.62	0.06	0.02	88.00
Env 10/0.1 ppb	6.10	0.09	11048797.67	4.99	0.02	54234.17	0.11	0.00	1303.73	0.03	0.01	6131.72	0.12	0.01	136.67
Env 100/1 ppb	0.10	0.00	215344.46	1.13	0.03	19932.87	1.04	0.02	11342.07	0.95	0.00	10889.04	1.07	0.02	913.70
Env 1000/10 ppb	0.35	0.00	675122.46	9.76	0.12	96587.73	10.38	0.11	111864.00	10.36	0.12	59381.25	10.36	0.07	8522.02
Env 10000/100 ppb	100.96	1.45	182398922.67	100.02	1.48	898351.33	99.96	2.65	1076659.08	99.96	0.52	520985.75	99.96	2.97	81917.21
Blank 1	0.02	0.00	71512.61	<0.000	0.03	6607.94	0.02	0.00	330.34	<0.000	0.02	5865.27	0.05	0.01	77.67
Blank 2	0.00	0.00	39113.17	<0.000	0.03	6072.69	0.01	0.00	267.67	<0.000	0.02	5911.29	0.02	0.01	55.33
Blank 3	0.01	0.00	47522.73	<0.000	0.03	4755.83	0.01	0.00	175.33	<0.000	0.02	5864.94	0.02	0.01	60.33
S 100/1 ppb	3.17	0.01	5761836.17	<0.000	0.02	6355.81	<0.000	0.00	114.00	<0.000	0.02	5718.87	0.02	0.01	53.00
S 1000/10 ppb	5.26	0.02	9533887.00	<0.000	0.03	6504.89	0.00	0.00	125.33	<0.000	0.00	5620.16	0.01	0.01	48.67
S 5000/50 ppb	0.95	0.03	1751102.96	<0.000	0.03	7782.55	0.00	0.00	137.33	<0.000	0.02	5683.19	0.01	0.02	49.00
S 10000/100 ppb	2.82	0.08	5126842.67	0.68	0.04	15913.95	0.00	0.00	129.33	<0.000	0.02	5654.18	0.01	0.01	49.67
Blank 1	0.00	0.00	40592.14	<0.000	0.04	6256.11	0.00	0.00	141.00	<0.000	0.01	5903.62	0.01	0.01	49.00
Blank 2	0.00	0.00	35508.36	<0.000	0.07	7061.18	0.01	0.00	255.33	<0.000	0.02	5914.29	0.01	0.01	50.67
Blank 3	0.01	0.00	44916.29	<0.000	0.01	4560.10	0.00	0.00	167.00	<0.000	0.02	5771.56	0.01	0.00	45.33
Millq neat	<0.000	0.00	5142.97	<0.000	0.01	1883.13	<0.000	0.00	43.33	0.15	0.02	6762.35	0.01	0.01	46.67
Nitric HCL Matrix	0.01	0.00	52205.56	<0.000	0.00	6292.78	0.00	0.00	151.00	0.00	0.01	5997.00	0.01	0.00	50.67
SC-002	8.78	0.11	15901941.33	2.23	0.23	29712.11	0.76	0.00	8257.51	0.58	0.04	8960.29	0.04	0.01	74.00
SC-001	0.14	0.00	284154.34	0.65	0.12	15656.02	0.25	0.01	2781.95	0.06	0.03	6288.12	0.03	0.02	61.00
MC-2-002	592.25	13.93	1069785770.67	53.96	0.35	489242.43	0.12	0.00	1420.08	<0.000	0.01	5766.23	0.04	0.02	74.67
MC-2-001	23.69	0.21	42833240.00	7.85	0.17	79601.77	0.08	0.00	980.70	<0.000	0.02	5552.81	0.02	0.00	58.33
MC-001	8.67	0.22	15688534.33	3.91	0.08	44584.03	0.07	0.01	920.70	<0.000	0.01	5274.36	0.01	0.00	47.00
MC-002	14.69	0.20	26562850.00	11.32	0.02	110396.52	0.02	0.00	288.33	0.07	0.00	6342.15	0.01	0.01	51.67
MC-003	4.01	0.04	7285526.50	5.24	0.10	56405.96	0.12	0.01	1383.41	<0.000	0.01	5424.42	0.01	0.00	51.00
MC-004	3.01	0.10	5471795.67	4.28	0.00	47847.03	0.16	0.00	1804.79	<0.000	0.01	5704.20	0.01	0.00	47.67
MC-005	3.60	0.07	6535176.33	0.40	0.05	13391.24	0.16	0.00	1808.12	<0.000	0.02	5665.18	0.01	0.01	52.33
MC-006	2.45	0.00	4451755.83	0.22	0.05	11822.80	0.14	0.00	1626.43	<0.000	0.03	5573.15	0.02	0.01	56.00
CC-001	0.15	0.00	297800.27	<0.000	0.06	6948.11	4.09	0.03	44180.12	4.00	0.06	26596.37	0.04	0.01	73.67
CC-002	0.15	0.00	300973.00	<0.000	0.05	5998.66	2.29	0.02	24759.23	2.04	0.04	16485.68	0.05	0.02	84.67
CC-003	0.14	0.00	296564.87	<0.000	0.04	6071.02	1.28	0.02	13953.50	1.04	0.01	11350.08	0.04	0.01	71.67
UT-001	1.84	0.00	3353915.33	0.40	0.05	13461.64	1.99	0.01	21515.37	1.73	0.07	14898.85	0.05	0.01	82.33
UT-002	2.96	0.07	5381916.00	2.22	0.03	29583.02	0.21	0.00	2355.20	<0.000	0.02	5797.91	0.04	0.01	76.00
UT-003	20.01	0.10	36172762.67	6.41	0.03	66796.97	0.08	0.00	947.03	<0.000	0.00	5040.94	0.01	0.01	46.00
UT-004	100.92	0.72	182321669.33	3.14	0.04	37735.09	0.16	0.01	1796.12	<0.000	0.02	5447.43	0.02	0.01	55.33
UT-005	1.14	0.01	2100301.92	0.25	0.03	12129.06	0.06	0.00	739.69	<0.000	0.01	4917.89	0.02	0.00	53.00
UT-006	9.95	0.14	18002312.67	<0.000	0.02	8313.53	0.08	0.00	959.04	<0.000	0.01	4926.56	0.03	0.00	63.33
UT-007	0.29	0.00	566457.75	<0.000	0.04	6924.10	0.52	0.01	5715.87	0.29	0.04	7504.41	0.07	0.02	99.00
UT-008	170.64	0.70	308244544.00	69.24	0.40	624978.34	0.19	0.01	2214.52	<0.000	0.01	5646.51	0.08	0.02	103.67
Blank 1	0.03	0.01	93347.07	<0.000	0.00	3936.90	<0.000	0.00	107.67	<0.000	0.01	5211.00	<0.000	0.00	35.67
Blank 2	0.00	0.00	38957.72	<0.000	0.00	3501.12	0.01	0.00	219.33	<0.000	0.02	5337.71	<0.000	0.01	34.00
Hg 0.1 ppb	141.32	1.76	255295568.00	26.25	0.10	243074.63	0.01	0.00	230.67	<0.000	0.01	5202.33	<0.000	0.00	38.67
Blank 2	0.02	0.01	78518.49	<0.000	0.00	3522.12	0.01	0.00	222.00	<0.000	0.01	5230.34	<0.000	0.01	39.33
Blank 3	0.01	0.00	48318.19	<0.000	0.01	2262.52	0.00	0.00	141.67	<0.000	0.01	5180.66	<0.000	0.01	39.67
Env 100/1 ppb	0.09	0.00	192087.72	0.60	0.01	15222.15	0.91	0.01	9940.64	0.74	0.04	9825.89	0.91	0.01	782.02
Blank 1	0.00	0.00	38362.72	<0.000	0.01	3688.17	0.00	0.00	127.67	<0.000	0.01	5273.69	0.00	0.00	43.00
Blank 3	0.00	0.00	43779.94	<0.000	0.01	2203.51	0.00	0.00	130.33	<0.000	0.00	5261.69	0.00	0.00	40.67
S 5000/50 ppb	0.89	0.03	1644656.42	<0.000	0.02	5009.59	<0.000	0.00	116.67	<0.000	0.02	5189.66	<0.000	0.00	34.33
Blank 1	0.00	0.00	38263.77	<0.000	0.01	3633.48	<0.000	0.00	116.67	<0.000	0.02	5406.08	<0.000	0.01	33.00
Blank 2	<0.000	0.00	34534.20	<0.000	0.02	3418.10	0.01	0.00	221.00	<0.000	0.02	5482.11	<0.000	0.01	40.00
Blank 3	0.00	0.00	42952.33	<0.000	0.01	2226.18	0.00	0.00	133.67	<0.000	0.00	5313.71	<0.000	0.01	33.67
Millq neat	<0.000	0.00	6068.68	<0.000	0.01	767.69	<0.000	0.00	26.33	0.03	0.02	6123.05	<0.000	0.01	34.33
Nitric HCL Matrix	0.01	0.00	48342.96	<0.000	0.01	4448.73	<0.000	0.00	85.33	<0.000	0.02	5467.43	<0.000	0.01	40.00
UT-008-RUN 2	175.60	1.17	317210517.33	71.09	0.57	641390.65	0.19	0.01	2191.84	<0.000	0.02	5944.97	0.07	0.02	100.33
DM	15.92	0.17	28797660.67	5.93	0.03	62554.65	0.16	0.01	1811.45	0.01	0.03	6039.68	0.12	0.01	141.00
SCM	22.40	0.28	40494241.33	16.19	0.12	153673.47	7.26	0.03	78324.33	7.40	0.11	44139.33	0.03	0.00	67.33
MCM-001S	17.91	0.12	32383406.00	6.94	0.09	71476.93	0.08	0.00	942.03	<0.000	0.01	5743.88	0.10	0.01	120.67
MCM-006SX	1.16	0.01	2128853.67	1.06	0.02	19259.91	0.37	0.00	4156.64	0.26	0.02	7347.66	0.04	0.01	74.33
MTH	80.73	0.28	145844565.33	5.21	0.04	56117.75	0.17	0.00	1926.14	0.08	0.01	6425.86	0.08	0.01	109.33
SKM	12.53	0.07	22666308.00	6.55	0.07	68030.78	0.68	0.01	7434.04	0.61	0.01	9110.39	0.10	0.01	124.00
MD	90.77	2.15	163980821.33	29.21	0.20	269316.76	7.11	0.09	76677.93	7.48	0.08	44503.86	0.02	0.02	54.33
WDE	16.68	0.08	30166104.67	1.93	0.01	27045.10	0.17	0.00	1899.13	0.06	0.02	6317.14	0.03	0.01	69.00
CE-001	56.65	0.85	102364608.00	6.93	0.03	71412.29	0.50	0.01	5539.47	0.45	0.02	8310.88	0.04	0.00	72.67
LSC	100.00	0.66	180653194.67	36.47	0.24	333843.54	6.18	0.06	66656.28	6.49	0.06	39425.85	0.06	0.01	88.00
IE	4.68	0.08	8482940.50	2.32	0.05	30482.32	1.36	0.03	14774.71	1.31	0.02	12745.65	0.04	0.00	73.33
MCM	23.29	0.45	42104970.67	4.79	0.02	52399.01	0.06	0.00	816.69	<0.000	0.02	5823.25	0.09	0.02	115.33
MCS-001	12.61	0.28	22806683.33	<0.000	0.01	7548.09	0.10	0.00	1224.06	0.00	0.00	5996.99	0.08	0.01	102.33
UTS-001	7.49	0.15	13555834.67	66.28	0.41	598662.29	0.08	0.00	951.03	<0.000	0.02	5850.26	0.03	0.01	61.67
UTS-002	5.96	0.10	10808695.67	<0.000	0.02	7997.34	0.08	0.01	974.37	<0.000	0.02	5845.26	0.03	0.01	67.67
UTS-003	9.24	0.15	16728316.00	1.35	0.02	21838.12	0.07	0.00	862.03	<0.000	0.02	5862.93	0.07	0.01	96.33
UTS-004	9.05	0.07	16382246.67	4.49	0.02	49726.39	0.60	0.01	6634.29	0.49	0.01	8502.33	0.12	0.03	135.33
Blank 1	0.00	0.00	39647.73	<0.000	0.01	3565.80	0.00	0.00	143.00	<0.000	0.01	5536.13	<0.000	0.00	40.33
Blank 2	<0.000	0.00	33764.96	<0.000	0.01	3392.75	0.01	0.00	249.33	<0.000	0.01	5518.79	<0.000	0.01	35.33
Hg 0.1 ppb	147.50	5.02	266455546.67	26.35	0.21	243921.24	0.01	0.00	247.33	<0.000	0.01	5398.74	<0.000	0.01	40.00
Blank 2	0.01	0.00	60821.84	<0.000	0.01	3528.12	0.01	0.00	238.33	<0.000	0.01	5692.53	0.00	0.01	41.67
Blank 3	0.01	0.00	45395.54	<0.000	0.01	2247.19	0.00	0.00	161.00	<0.000	0.01	5505.45	0.01	0.00	45.33
Env 100/1 ppb	0.09	0.00	189657.11	0.61	0.01	15275.21	0.92	0.01	9980.00	0.85	0.03	10370.96	0.92	0.07	792.69
Blank 1	0.00	0.00	36066.48	<0.000	0.02	3661.49	0.00	0.00	135.00	<0.000	0.01	5505.79	<0.000	0.00	34.67
Blank 3	0.00	0.00	41249.11	<0.000	0.01	2180.18	0.00	0.00	155.00	<0.000	0.01	5420.08	0.00	0.01	41.00
S 5000/50 ppb	0.87	0.01	1607760.37	<0.000	0.01	4997.25	0.00	0.00	138.33	<0.000	0.01	5320.38	0.01	0.01	45.67
Blank 1	0.00	0.00	35617.31	<0.000	0.01	3652.49	0.00	0.00	126.67	<0.000	0.01	5528.46	0.01	0.01	45.33
Blank 2	<0.000	0.00	32368.59	<0.000	0.01	3428.77	0.01	0.00	237.67	<0.000	0.00	5429.09	<0.000	0.01	36.67

	78 Se [H2]			95 Mo [He]			107 Ag [He]			109 Ag [He]			110 Cd [He]		
Sample Name	Conc. [ppb]	Conc. SD	CPS	Conc. [ppb]	Conc. SD	CPS	Conc. [ppb]	Conc. SD	CPS	Conc. [ppb]	Conc. SD	CPS	Conc. [ppb]	Conc. SD	CPS
Blank 1			96.00			809.69			825.36			801.36			3014.34
Blank 2			66.00			279.67			519.68			514.34			3842.22
Blank 3			82.67			214.00			365.34			350.67			9878.67
Blank 1			60.33			651.35			672.69			637.35			2609.59
Hg 0.01 ppb			73.33			1791.78			2241.19			2260.19			9375.65
Hg 0.05 ppb			69.33			122.00			327.34			315.33			9459.70
Hg 0.1 ppb			65.33			178.67			704107.11			696783.69			9855.99
Hg 0.5 ppb			62.67			107.33			455.01			442.68			8974.37
Hg 1.0 ppb			53.67			86.33			329.33			353.00			9586.80
Blank 1			47.00			673.69			623.35			623.68			2635.26
Blank 2			56.33			257.33			467.68			477.68			3955.26
Blank 3			62.33			217.67			315.67			324.67			9924.37
Env 1/0.01 ppb	0.01	0.00	136.67	<0.000	0.00	393.01	0.02	0.00	2961.33	0.02	0.00	2959.33	0.49	0.01	9863.00
Env 5/0.05 ppb	0.05	0.00	482.68	0.03	0.00	1596.09	0.07	0.00	8486.71	0.07	0.00	8470.70	0.57	0.00	10992.55
Env 10/0.1 ppb	0.11	0.00	929.36	0.09	0.00	3097.36	0.14	0.00	16827.64	0.14	0.00	16698.16	0.60	0.00	11549.02
Env 100/1 ppb	1.02	0.01	8313.55	1.01	0.01	29782.05	1.10	0.01	128417.13	1.09	0.01	127200.66	1.60	0.02	26216.19
Env 1000/10 ppb	10.38	0.19	83813.50	10.21	0.07	293813.43	10.39	0.07	1212321.25	10.36	0.04	1202087.25	10.88	0.06	163321.83
Env 10000/100 ppb	99.96	0.92	806597.13	99.98	2.49	2871152.33	99.96	1.21	11658341.00	99.96	2.19	11588972.00	99.91	3.19	1478889.46
Blank 1	0.03	0.00	281.67	1.26	0.13	36884.44	0.02	0.00	2636.93	0.02	0.00	2650.60	0.01	0.00	2781.96
Blank 2	0.01	0.00	166.67	0.24	0.00	7612.16	0.00	0.00	813.69	0.00	0.00	785.02	0.09	0.01	3886.57
Blank 3	0.01	0.00	153.67	0.11	0.01	3714.18	<0.000	0.00	568.68	<0.000	0.00	556.34	0.51	0.01	10083.50
S 100/1 ppb	0.01	0.00	152.33	0.06	0.00	2361.87	0.01	0.00	1268.73	0.01	0.00	1229.39	0.50	0.01	10003.10
S 1000/10 ppb	0.01	0.00	133.00	0.03	0.00	1632.10	0.01	0.00	1331.73	0.01	0.00	1328.07	0.51	0.02	10080.16
S 5000/50 ppb	0.01	0.00	125.00	0.02	0.00	1149.05	0.01	0.00	2047.16	0.01	0.00	2059.50	0.51	0.01	10082.83
S 10000/100 ppb	0.00	0.00	100.33	0.01	0.00	980.04	0.01	0.00	1988.48	0.01	0.00	2052.49	0.49	0.02	9845.66
Blank 1	0.00	0.00	96.33	0.04	0.00	1834.79	0.00	0.00	890.03	0.00	0.00	848.03	0.00	0.00	2671.94
Blank 2	0.00	0.00	83.00	0.01	0.00	888.69	<0.000	0.00	576.68	<0.000	0.00	572.34	0.09	0.00	3939.58
Blank 3	0.00	0.00	88.67	0.00	0.00	699.35	<0.000	0.00	406.68	<0.000	0.00	424.34	0.50	0.00	9937.05
Millq neat	<0.000	0.00	39.67	<0.000	0.00	363.00	<0.000	0.00	205.67	<0.000	0.00	215.33	<0.000	0.00	124.33
Nitric HCL Matrix	0.01	0.00	121.33	0.01	0.00	890.36	0.00	0.00	1080.04	0.00	0.00	1055.38	<0.000	0.00	509.68
SC-002	0.04	0.00	377.67	0.08	0.00	2864.30	0.01	0.00	2267.53	0.01	0.00	2278.20	4.71	0.03	72191.24
SC-001	0.03	0.00	308.00	0.03	0.00	1447.75	0.01	0.00	1661.44	0.01	0.00	1667.11	4.30	0.03	66105.71
MC-2-002	0.05	0.00	446.01	2.11	0.02	61357.08	0.41	0.00	48997.34	0.41	0.00	48434.75	4.59	0.02	70389.38
MC-2-001	0.01	0.00	170.00	1.61	0.02	46974.50	0.01	0.00	2158.84	0.01	0.00	2113.50	5.44	0.04	82977.70
MC-001	0.02	0.00	192.33	0.01	0.00	820.36	0.01	0.00	1334.07	0.01	0.00	1353.40	4.43	0.01	68082.04
MC-002	0.00	0.00	84.67	0.16	0.00	5227.02	0.00	0.00	897.03	0.00	0.00	901.36	<0.000	0.00	471.01
MC-003	0.01	0.00	178.33	0.10	0.00	3495.12	0.01	0.00	1482.08	0.01	0.00	1468.42	4.61	0.05	70725.43
MC-004	0.02	0.00	186.00	0.32	0.01	9885.98	0.00	0.00	1140.05	0.00	0.00	1153.39	4.38	0.01	67275.26
MC-005	0.02	0.00	191.00	0.32	0.00	9977.38	0.00	0.00	1039.38	0.00	0.00	1028.71	4.39	0.06	67431.41
MC-006	0.02	0.00	226.67	0.24	0.00	7656.18	0.00	0.00	875.03	0.00	0.00	878.03	4.23	0.02	65086.71
CC-001	0.04	0.00	408.68	0.00	0.00	748.02	0.00	0.00	1227.06	0.00	0.00	1209.39	4.53	0.04	69588.80
CC-002	0.07	0.00	595.01	0.10	0.00	3526.13	0.00	0.00	1100.05	0.00	0.00	1066.71	4.74	0.02	72579.70
CC-003	0.05	0.00	436.34	0.02	0.00	1257.39	0.01	0.00	1315.73	0.01	0.00	1294.73	4.19	0.01	64454.30
UT-001	0.07	0.00	587.68	0.02	0.00	1275.06	0.00	0.00	1210.72	0.00	0.00	1188.05	4.40	0.01	67595.51
UT-002	0.06	0.00	565.68	0.02	0.00	1158.38	0.01	0.00	1648.77	0.01	0.00	1633.44	4.20	0.04	64625.15
UT-003	0.02	0.00	193.33	<0.000	0.00	361.34	0.01	0.00	1511.75	0.01	0.00	1545.42	3.98	0.05	61351.36
UT-004	0.03	0.00	298.33	0.01	0.00	986.04	0.40	0.00	47031.64	0.40	0.00	47119.71	5.85	0.02	89053.48
UT-005	0.02	0.00	236.00	0.01	0.00	876.36	0.01	0.00	2360.87	0.01	0.00	2358.21	4.26	0.02	65605.29
UT-006	0.03	0.00	340.00	0.02	0.00	1150.05	0.02	0.00	2532.58	0.02	0.00	2434.22	4.09	0.02	63045.25
UT-007	0.09	0.00	772.35	0.74	0.00	21899.21	0.00	0.00	1069.38	0.00	0.00	1028.71	4.37	0.02	67192.14
UT-008	0.09	0.00	791.35	0.39	0.00	11753.82	0.43	0.00	50270.75	0.43	0.00	50027.97	4.00	0.03	61728.11
Blank 1	<0.000	0.00	42.67	0.02	0.00	1140.72	0.00	0.00	758.02	0.00	0.00	720.02	<0.000	0.01	2416.56
Blank 2	<0.000	0.00	35.33	<0.000	0.00	421.01	<0.000	0.00	495.01	<0.000	0.00	470.68	0.06	0.01	3458.45
Hg 0.1 ppb	<0.000	0.00	51.33	<0.000	0.00	179.33	5.50	0.05	641968.40	5.51	0.03	639666.12	0.43	0.01	9019.39
Blank 2	<0.000	0.00	31.67	<0.000	0.00	389.01	<0.000	0.00	572.68	<0.000	0.00	587.01	0.06	0.00	3481.46
Blank 3	<0.000	0.00	47.67	<0.000	0.00	289.00	<0.000	0.00	323.00	<0.000	0.00	330.00	0.43	0.01	9022.74
Env 100/1 ppb	0.99	0.00	8067.07	0.90	0.01	26566.63	0.99	0.01	116209.79	0.99	0.01	115054.78	1.43	0.02	23712.81
Blank 1	<0.000	0.00	58.67	0.03	0.00	1543.09	0.00	0.00	693.02	0.00	0.00	675.02	<0.000	0.00	2354.88
Blank 3	0.00	0.00	62.33	<0.000	0.00	414.01	<0.000	0.00	329.00	<0.000	0.00	313.00	0.43	0.01	8957.69
S 5000/50 ppb	<0.000	0.00	54.67	<0.000	0.00	445.68	0.01	0.00	1709.44	0.01	0.00	1752.11	0.43	0.01	8903.65
Blank 1	<0.000	0.00	46.33	0.02	0.00	1154.38	<0.000	0.00	650.69	0.00	0.00	643.68	<0.000	0.00	2389.55
Blank 2	<0.000	0.00	45.33	<0.000	0.00	448.68	<0.000	0.00	463.01	<0.000	0.00	450.01	0.06	0.00	3566.81
Blank 3	<0.000	0.00	51.67	<0.000	0.00	320.33	<0.000	0.00	307.00	<0.000	0.00	302.67	0.43	0.02	9016.40
Millq neat	<0.000	0.00	23.67	<0.000	0.00	80.33	<0.000	0.00	128.00	<0.000	0.00	126.33	<0.000	0.00	120.00
Nitric HCL Matrix	0.00	0.00	65.33	<0.000	0.00	410.68	0.00	0.00	702.69	0.00	0.00	695.35	<0.000	0.00	409.01
UT-008-RUN 2	0.10	0.00	898.03	0.40	0.01	12178.87	0.43	0.00	50842.59	0.43	0.00	51048.16	4.05	0.04	62495.65
DM	0.14	0.00	1188.05	0.05	0.00	1957.14	0.02	0.00	2999.00	0.02	0.00	3011.68	0.43	0.01	8967.37
SCM	0.03	0.00	314.00	0.31	0.00	9650.14	0.09	0.00	11636.42	0.09	0.00	11561.03	0.43	0.00	9006.39
MCM-001S	0.10	0.00	884.36	0.23	0.00	7241.63	0.04	0.00	5518.14	0.04	0.00	5520.82	0.44	0.00	9183.18
MCM-006SX	0.05	0.00	431.01	<0.000	0.00	431.68	0.00	0.00	800.36	0.00	0.00	802.36	0.81	0.01	14573.66
MTH	0.09	0.00	792.02	0.01	0.00	801.69	0.08	0.00	9936.71	0.08	0.00	9781.60	0.44	0.00	9177.51
SKM	0.11	0.00	925.70	0.04	0.00	1863.80	0.02	0.00	2635.59	0.02	0.00	2592.92	0.56	0.01	10905.81
MD	0.01	0.00	144.67	<0.000	0.00	610.01	0.07	0.00	8265.90	0.07	0.00	8353.30	0.42	0.00	8888.64
WDE	0.04	0.00	352.34	<0.000	0.00	152.00	0.01	0.00	1554.76	0.01	0.00	1548.42	0.44	0.00	9173.50
CE-001	0.05	0.00	485.68	0.01	0.00	1081.38	0.16	0.00	18951.16	0.16	0.00	18884.74	0.73	0.01	13434.46
LSC	0.05	0.00	472.34	0.12	0.00	4165.32	0.14	0.00	16867.69	0.14	0.00	16732.86	0.47	0.01	9607.48
IE	0.05	0.00	479.68	<0.000	0.00	183.33	0.01	0.00	1547.76	0.01	0.00	1514.75	0.62	0.01	11761.88
MCM	0.10	0.00	879.03	0.20	0.01	6346.50	0.02	0.00	3532.47	0.03	0.00	3567.15	0.43	0.02	8908.32
MCS-001	0.09	0.00	751.69	0.04	0.00	1693.44	0.04	0.00	5821.27	0.04	0.00	5773.92	0.44	0.00	9096.78
UTS-001	0.05	0.00	442.68	0.03	0.00	1397.41	0.03	0.00	3610.16	0.03	0.00	3676.18	0.44	0.01	9158.49
UTS-002	0.04	0.00	385.01	<0.000	0.00	583.01	0.00	0.00	722.35	0.00	0.00	712.69	0.41	0.01	8733.87
UTS-003	0.08	0.00	714.69	0.01	0.00	947.36	0.01	0.00	1592.76	0.01	0.00	1593.43	0.45	0.00	9243.22
UTS-004	0.13	0.00	1113.38	0.06	0.00	2274.19	0.01	0.00	1507.42	0.01	0.00	1466.08	1.02	0.01	17708.46
Blank 1	<0.000	0.00	41.67	0.02	0.00	1130.05	<0.000	0.00	633.35	0.00	0.00	644.35	<0.000	0.01	2365.88
Blank 2	<0.000	0.00	42.67	<0.000	0.00	398.68	<0.000	0.00	439.34	<0.000	0.00	425.34	0.06	0.01	3474.46
Hg 0.1 ppb	<0.000	0.00	52.33	<0.000	0.00	194.00	5.45	0.03	636786.50	5.41	0.04	627418.33	0.43	0.00	8932.01
Blank 2	<0.000	0.00	38.67	<0.000	0.00	380.01	<0.000	0.00	497.01	<0.000	0.00	488.01	0.06	0.01	3479.79
Blank 3	<0.000	0.00	47.67	<0.000	0.00	310.67	<0.000	0.00	300.00	<0.000	0.00	288.67	0.43	0.01	8942.68
Env 100/1 ppb	1.01	0.01	8172.47	0.89	0.01	26184.22	0.97	0.00	114173.58	0.97	0.00	113448.00	1.42	0.01	23569.56
Blank 1	<0.000	0.00	58.33	0.03	0.00	1501.75	<0.000	0.00	641.35	<0.000	0.00	635.02	<0.000	0.00	2280.53
Blank 3	<0.000	0.00	51.33	<0.000	0.00	405.01	<0.000	0.00	261.67	<0.000	0.00	286.33	0.43	0.00	8978.70
S 5000/50 ppb	<0.000	0.00	47.67	<0.000	0.00	414.68	0.01	0.00	1693.44	0.01	0.00	1693.78	0.42	0.01	8811.26
Blank 1	<0.000	0.00	52.67	0.02	0.00	1113.72	<0.000	0.00	621.68	<0.000	0.00	621.68	<0.000	0.00	2297.87
Blank 2	<0.000	0.00	41.33	<0.000	0.00	433.01	<0.000	0.00	410.34	<0.000	0.00	410.34	0.06	0.00	3498.80

	111 Cd [He]			112 Cd [He]			121 Sb [He]			137 Ba [He]			201 Hg [He]		
Sample Name	Conc. [ppb]	Conc. SD	CPS	Conc. [ppb]	Conc. SD	CPS	Conc. [ppb]	Conc. SD	CPS	Conc. [ppb]	Conc. SD	CPS	Conc. [ppb]	Conc. SD	CPS
Blank 1			2962.33			5709.57			962.70			5813.63	0.02	0.00	260.50
Blank 2			3957.59			7546.48			756.35			1664.11	0.01	0.00	206.83
Blank 3			10142.21			19291.35			777.02			764.35	0.01	0.00	195.83
Blank 1			2546.91			4905.58			700.35			5283.40	0.01	0.00	199.33
Hg 0.01 ppb			9791.61			18630.74			1180.39			10680.70	0.01	0.00	250.33
Hg 0.05 ppb			9912.71			18718.20			699.35			458.01	0.06	0.00	629.35
Hg 0.1 ppb			10193.58			19600.81			934.37			3094.03	0.09	0.00	896.20
Hg 0.5 ppb			9238.22			17843.00			724.35			795.02	0.50	0.01	4584.67
Hg 1.0 ppb			9919.37			19038.66			727.02			955.37	1.26	0.02	11358.29
Blank 1			2673.60			5044.29			680.35			5255.39	0.03	0.00	430.51
Blank 2			3886.57			7551.49			619.35			1628.44	0.01	0.00	245.50
Blank 3			10455.79			19759.03			714.35			805.03	0.01	0.00	223.83
Env 1/0.01 ppb	0.50	0.00	10251.29	0.50	0.01	19500.66	0.01	0.00	1193.05	<0.000	0.00	542.01	0.01	0.00	198.17
Env 5/0.05 ppb	0.57	0.01	11386.55	0.59	0.00	22295.72	0.06	0.00	2900.32	<0.000	0.00	1322.07	0.01	0.00	184.50
Env 10/0.1 ppb	0.62	0.00	12086.83	0.62	0.00	23175.56	0.11	0.00	5062.30	<0.000	0.00	2104.50	0.01	0.00	185.67
Env 100/1 ppb	1.60	0.02	27324.76	1.64	0.01	52954.82	1.07	0.01	42201.73	0.71	0.01	14780.70	0.01	0.00	194.33
Env 1000/10 ppb	10.95	0.03	172109.77	11.07	0.03	329004.31	10.33	0.03	403022.79	10.13	0.10	140137.66	0.01	0.00	212.67
Env 10000/100 ppb	99.90	3.58	1549416.21	99.89	1.15	2928753.50	99.97	4.01	3895718.92	99.99	3.00	1336468.79	0.01	0.00	223.50
Blank 1	0.02	0.00	2802.30	0.02	0.01	5497.14	0.09	0.01	4201.67	0.01	0.00	5444.80	0.01	0.00	187.33
Blank 2	0.10	0.00	4056.62	0.09	0.00	7631.20	0.03	0.00	1709.78	<0.000	0.00	1660.77	0.01	0.00	171.33
Blank 3	0.52	0.02	10592.90	0.52	0.01	20095.55	0.02	0.00	1297.40	<0.000	0.00	809.03	0.00	0.00	166.67
S 100/1 ppb	0.52	0.01	10576.55	0.51	0.00	19880.89	0.01	0.00	1171.39	<0.000	0.00	370.68	0.00	0.00	163.17
S 1000/10 ppb	0.52	0.01	10540.52	0.52	0.01	19989.05	0.01	0.00	1028.38	<0.000	0.00	404.01	0.00	0.00	149.83
S 5000/50 ppb	0.51	0.00	10474.47	0.51	0.01	19948.32	0.01	0.00	989.37	<0.000	0.00	588.35	0.00	0.00	149.50
S 10000/100 ppb	0.50	0.02	10343.03	0.51	0.01	19785.43	0.01	0.00	939.70	<0.000	0.00	653.35	0.00	0.00	147.83
Blank 1	0.01	0.00	2629.26	0.01	0.00	5124.33	0.00	0.00	790.36	0.01	0.01	5393.45	0.00	0.00	162.00
Blank 2	0.09	0.00	3963.26	0.10	0.00	7698.90	0.00	0.00	703.35	<0.000	0.00	1649.44	0.00	0.00	148.17
Blank 3	0.51	0.00	10414.75	0.52	0.01	20038.13	0.00	0.00	714.02	<0.000	0.00	801.36	0.00	0.00	142.00
Millq neat	<0.000	0.00	30.67	<0.000	0.00	66.33	<0.000	0.00	216.33	<0.000	0.00	165.33	0.00	0.00	162.33
Nitric HCL Matrix	<0.000	0.00	362.01	<0.000	0.00	814.36	0.01	0.00	921.36	<0.000	0.01	1112.38	0.00	0.00	139.00
SC-002	4.70	0.02	75268.77	4.74	0.04	143758.51	0.22	0.00	9278.26	0.83	0.01	16266.79	0.01	0.00	195.17
SC-001	4.34	0.03	69733.28	4.39	0.03	133290.83	0.18	0.01	7771.29	0.75	0.01	15249.90	0.01	0.00	170.00
MC-2-002	4.59	0.05	73660.45	4.66	0.03	141404.45	0.17	0.00	7143.60	11.03	0.09	152188.18	0.03	0.00	365.01
MC-2-001	5.46	0.02	87037.38	5.53	0.02	166710.67	0.12	0.01	5534.83	8.51	0.04	118609.44	0.04	0.00	466.51
MC-001	4.46	0.02	71632.73	4.50	0.06	136528.07	0.12	0.00	5217.03	0.80	0.01	15887.32	0.01	0.00	186.00
MC-002	<0.000	0.00	402.01	<0.000	0.00	924.70	0.04	0.00	2152.18	3.60	0.02	53182.69	0.03	0.00	425.18
MC-003	4.65	0.04	74610.03	4.70	0.01	142341.98	0.13	0.01	5921.33	1.08	0.01	19681.15	0.00	0.00	136.50
MC-004	4.40	0.02	70749.34	4.45	0.03	135055.89	0.12	0.00	5440.46	1.48	0.02	25045.66	0.00	0.00	141.00
MC-005	4.43	0.01	71163.88	4.48	0.02	135903.06	0.10	0.00	4687.17	1.49	0.01	25100.10	0.00	0.00	138.83
MC-006	4.25	0.03	68280.46	4.30	0.01	130919.01	0.09	0.00	4358.39	2.00	0.02	31957.70	0.00	0.00	136.00
CC-001	4.52	0.05	72506.47	4.58	0.01	138865.53	0.38	0.01	15593.21	0.60	0.01	13239.37	0.00	0.00	156.83
CC-002	4.75	0.03	76075.96	4.81	0.03	145677.68	0.20	0.00	8343.97	0.05	0.01	5958.69	<0.000	0.00	118.00
CC-003	4.20	0.01	67603.34	4.28	0.01	130327.22	0.12	0.00	5526.49	0.13	0.00	7014.88	<0.000	0.00	117.83
UT-001	4.39	0.02	70539.24	4.47	0.01	135759.20	0.07	0.00	3392.44	0.35	0.01	9967.80	<0.000	0.00	115.50
UT-002	4.19	0.05	67357.75	4.22	0.04	128404.97	0.06	0.00	3052.69	0.96	0.02	18076.50	<0.000	0.00	119.83
UT-003	4.00	0.03	64506.98	4.04	0.02	123288.44	0.05	0.00	2742.29	0.40	0.01	10651.00	0.00	0.00	147.00
UT-004	5.89	0.05	93768.29	5.94	0.04	178838.32	0.06	0.00	3058.69	0.43	0.01	10984.28	<0.000	0.00	97.50
UT-005	4.29	0.05	69011.90	4.35	0.00	132257.87	0.05	0.00	2581.59	0.29	0.02	9118.52	<0.000	0.00	105.67
UT-006	4.13	0.02	66527.97	4.18	0.03	127127.14	0.06	0.00	3075.03	0.44	0.01	11130.41	<0.000	0.00	110.50
UT-007	4.38	0.03	70403.84	4.44	0.02	134950.72	0.17	0.00	7417.75	20.60	0.12	279520.57	<0.000	0.00	119.00
UT-008	4.02	0.01	64798.74	4.05	0.00	123529.66	0.11	0.00	5007.29	15.45	0.01	210948.78	<0.000	0.00	109.00
Blank 1	<0.000	0.00	2401.55	<0.000	0.01	4641.15	<0.000	0.00	440.34	<0.000	0.00	4758.86	0.00	0.00	124.67
Blank 2	0.07	0.00	3595.82	0.07	0.00	6928.48	<0.000	0.00	335.00	<0.000	0.00	1481.08	<0.000	0.00	102.50
Hg 0.1 ppb	0.44	0.01	9428.35	0.44	0.01	17922.10	<0.000	0.00	574.01	<0.000	0.00	2752.62	0.08	0.00	809.19
Blank 2	0.07	0.01	3593.49	0.07	0.00	6937.15	<0.000	0.00	352.67	<0.000	0.00	1496.09	<0.000	0.00	115.33
Blank 3	0.44	0.01	9356.30	0.44	0.00	17921.12	<0.000	0.00	323.67	<0.000	0.00	704.35	<0.000	0.00	95.33
Env 100/1 ppb	1.46	0.03	25133.78	1.47	0.01	47951.15	0.95	0.01	37590.48	0.60	0.01	13324.14	<0.000	0.00	95.33
Blank 1	<0.000	0.00	2338.21	<0.000	0.00	4699.17	<0.000	0.00	476.01	<0.000	0.01	4728.52	<0.000	0.00	99.50
Blank 3	0.45	0.01	9489.73	0.45	0.01	18006.88	<0.000	0.00	364.34	<0.000	0.00	694.35	<0.000	0.00	92.33
S 5000/50 ppb	0.44	0.01	9416.34	0.45	0.01	18034.58	<0.000	0.00	509.01	<0.000	0.00	514.34	<0.000	0.00	83.67
Blank 1	<0.000	0.00	2391.88	<0.000	0.00	4626.81	<0.000	0.00	396.01	<0.000	0.00	4762.20	<0.000	0.00	91.83
Blank 2	0.07	0.01	3654.84	0.07	0.01	6907.47	<0.000	0.00	345.67	<0.000	0.00	1448.75	<0.000	0.00	86.83
Blank 3	0.45	0.01	9481.05	0.45	0.01	18161.10	<0.000	0.00	344.33	<0.000	0.00	710.02	<0.000	0.00	82.50
Millq neat	<0.000	0.00	26.33	<0.000	0.00	61.00	<0.000	0.00	87.00	<0.000	0.00	164.00	<0.000	0.00	104.67
Nitric HCL Matrix	<0.000	0.00	304.00	<0.000	0.00	624.35	<0.000	0.00	523.34	<0.000	0.00	957.70	<0.000	0.00	85.33
UT-008-RUN 2	4.11	0.01	66172.55	4.21	0.01	128083.97	0.13	0.00	5918.33	15.73	0.07	214669.26	<0.000	0.00	88.00
DM	0.44	0.01	9301.93	0.45	0.01	17994.53	0.05	0.00	2541.25	0.08	0.01	6398.90	0.01	0.00	234.17
SCM	0.44	0.01	9421.68	0.45	0.00	18007.22	0.24	0.00	10078.51	1.06	0.01	19335.30	0.04	0.00	468.84
MCM-001S	0.45	0.01	9537.43	0.45	0.01	18187.80	0.08	0.00	3818.22	1.55	0.02	25863.58	<0.000	0.00	109.67
MCM-006SX	0.83	0.01	15424.96	0.82	0.01	28968.26	0.04	0.00	2340.88	0.94	0.02	17863.88	<0.000	0.00	77.83
MTH	0.44	0.01	9390.32	0.45	0.00	18116.36	0.04	0.00	2339.88	<0.000	0.00	3742.20	0.02	0.00	274.00
SKM	0.56	0.01	11272.12	0.58	0.01	21813.25	0.11	0.00	5168.02	8.35	0.02	116387.59	0.05	0.00	528.18
MD	0.44	0.01	9388.99	0.44	0.00	17868.02	0.17	0.00	7196.96	0.24	0.01	8539.13	<0.000	0.00	101.33
WDE	0.46	0.01	9622.82	0.46	0.00	18409.77	0.04	0.00	2406.55	<0.000	0.01	2456.90	<0.000	0.00	80.50
CE-001	0.75	0.02	14115.17	0.75	0.00	26899.92	0.04	0.00	2441.89	0.42	0.01	10880.20	0.01	0.00	226.50
LSC	0.48	0.01	10023.46	0.49	0.01	19270.99	0.62	0.01	24987.31	0.56	0.01	12683.49	0.05	0.00	541.18
IE	0.63	0.01	12303.37	0.64	0.00	23528.85	0.06	0.00	2906.66	0.13	0.00	6971.86	<0.000	0.00	83.17
MCM	0.43	0.01	9269.24	0.44	0.00	17669.09	0.08	0.00	3723.53	0.81	0.01	16055.20	<0.000	0.00	99.67
MCS-001	0.45	0.01	9584.80	0.46	0.01	18227.85	0.04	0.00	2070.16	0.26	0.01	8735.25	<0.000	0.00	87.50
UTS-001	0.45	0.01	9558.44	0.46	0.00	18430.80	0.06	0.00	2878.32	0.15	0.00	7242.34	<0.000	0.00	122.00
UTS-002	0.42	0.01	9028.74	0.43	0.01	17377.38	0.03	0.00	1953.15	0.26	0.01	8701.23	<0.000	0.00	122.00
UTS-003	0.45	0.01	9570.79	0.46	0.00	18484.20	0.02	0.00	1533.09	0.37	0.01	10159.28	0.01	0.00	177.17
UTS-004	1.04	0.02	18612.71	1.07	0.00	36323.98	0.03	0.00	2055.16	7.39	0.11	103685.78	0.01	0.00	236.17
Blank 1	<0.000	0.00	2337.54	<0.000	0.00	4591.46	<0.000	0.00	456.68	<0.000	0.01	4772.87	<0.000	0.00	75.17
Blank 2	0.06	0.00	3491.79	0.07	0.00	6822.09	<0.000	0.00	347.00	<0.000	0.00	1477.75	<0.000	0.00	75.50
Hg 0.1 ppb	0.43	0.00	9235.22	0.44	0.01	17656.08	<0.000	0.00	601.35	<0.000	0.01	2778.96	0.07	0.00	762.85
Blank 2	0.07	0.01	3592.82	0.07	0.00	6846.10	<0.000	0.00	360.67	<0.000	0.01	1451.42	<0.000	0.00	80.17
Blank 3	0.44	0.00	9373.31	0.44	0.01	17907.08	<0.000	0.00	399.68	<0.000	0.00	713.69	<0.000	0.00	68.33
Env 100/1 ppb	1.42	0.01	24506.27	1.44	0.01	47007.80	0.95	0.00	37677.38	0.59	0.02	13180.98	<0.000	0.00	69.67
Blank 1	<0.000	0.00	2383.22	<0.000	0.00	4517.44	<0.000	0.00	470.01	<0.000	0.01	4640.16	<0.000	0.00	77.17
Blank 3	0.44	0.01	9309.94	0.44	0.01	17706.15	<0.000	0.00	400.68	<0.000	0.00	723.02	<0.000	0.00	68.17
S 5000/50 ppb	0.44	0.01	9345.63	0.44	0.01	17762.55	<0.000	0.00	527.34	<0.000	0.00	524.68	<0.000	0.00	63.83
Blank 1	<0.000	0.00	2309.54	<0.000	0.00	4496.43	<0.000	0.00	438.34	<0.000	0.01	4624.49	<0.000	0.00	70.00
Blank 2	0.07	0.01	3553.81	0.06	0.00	6717.04	<0.000	0.00	360.67	<0.000	0.01	1463.41	<0.000	0.00	62.33

	201 Hg [No Gas]			201 Hg [H2]			202 Hg [He]			202 Hg [No Gas]			202 Hg [H2]		
Sample Name	Conc. [ppb]	Conc. SD	CPS	Conc. [ppb]	Conc. SD	CPS	Conc. [ppb]	Conc. SD	CPS	Conc. [ppb]	Conc. SD	CPS	Conc. [ppb]	Conc. SD	CPS
Blank 1	0.01	0.00	93.17	0.01	0.00	211.83	0.01	0.00	575.68	0.01	0.00	216.67	0.01	0.00	470.01
Blank 2	0.01	0.00	89.33	0.01	0.00	188.33	0.01	0.00	483.01	0.01	0.00	190.67	0.01	0.00	439.18
Blank 3	0.01	0.00	76.67	0.01	0.00	177.83	0.01	0.00	432.68	0.01	0.00	187.50	0.01	0.00	416.84
Blank 1	0.01	0.00	78.50	0.01	0.00	180.17	0.01	0.00	464.68	0.01	0.00	191.67	0.01	0.00	425.84
Hg 0.01 ppb	0.01	0.00	99.17	0.01	0.00	214.50	0.01	0.00	541.01	0.01	0.00	227.83	0.01	0.00	484.51
Hg 0.05 ppb	0.06	0.00	273.50	0.06	0.00	602.01	0.06	0.00	1472.25	0.06	0.00	617.18	0.06	0.00	1368.24
Hg 0.1 ppb	0.09	0.00	384.51	0.09	0.00	862.53	0.09	0.00	2041.67	0.09	0.00	858.53	0.09	0.00	1899.64
Hg 0.5 ppb	0.50	0.01	1913.98	0.50	0.00	4302.07	0.50	0.01	10419.65	0.50	0.01	4346.92	0.50	0.00	9715.75
Hg 1.0 ppb	1.25	0.01	4689.54	1.25	0.01	10565.43	1.26	0.02	25732.47	1.23	0.00	10509.89	1.24	0.01	23571.07
Blank 1	0.03	0.00	155.83	0.02	0.00	307.33	0.03	0.00	972.54	0.03	0.00	334.00	0.02	0.00	690.85
Blank 2	0.01	0.00	100.83	0.01	0.00	218.17	0.01	0.00	580.01	0.01	0.00	218.50	0.01	0.00	479.51
Blank 3	0.01	0.00	87.33	0.01	0.00	195.67	0.01	0.00	494.01	0.01	0.00	194.83	0.01	0.00	434.68
Env 1/0.01 ppb	0.01	0.00	83.00	0.01	0.00	174.17	0.01	0.00	443.18	0.01	0.00	176.17	0.01	0.00	400.68
Env 5/0.05 ppb	0.01	0.00	77.67	0.01	0.00	166.17	0.01	0.00	429.84	0.01	0.00	169.83	0.01	0.00	386.34
Env 10/0.1 ppb	0.00	0.00	67.17	0.01	0.00	171.50	0.01	0.00	394.01	0.00	0.00	160.50	0.01	0.00	355.68
Env 100/1 ppb	0.00	0.00	74.83	0.01	0.00	171.00	0.01	0.00	430.84	0.01	0.00	179.00	0.01	0.00	371.34
Env 1000/10 ppb	0.01	0.00	79.00	0.01	0.00	186.17	0.01	0.00	479.18	0.01	0.00	212.00	0.01	0.00	414.01
Env 10000/100 ppb	0.01	0.00	96.50	0.01	0.00	183.83	0.01	0.00	516.51	0.03	0.00	417.01	0.01	0.00	457.01
Blank 1	0.01	0.00	80.00	0.01	0.00	171.00	0.01	0.00	435.84	0.01	0.00	173.17	0.01	0.00	386.01
Blank 2	0.00	0.00	69.67	0.00	0.00	148.33	0.01	0.00	402.18	0.00	0.00	159.33	0.00	0.00	349.34
Blank 3	0.00	0.00	63.00	0.00	0.00	155.67	0.00	0.00	365.01	0.00	0.00	144.33	0.00	0.00	338.34
S 100/1 ppb	0.00	0.00	57.00	0.00	0.00	139.17	0.00	0.00	345.00	0.00	0.00	140.17	0.00	0.00	316.00
S 1000/10 ppb	<0.000	0.00	55.67	0.00	0.00	136.33	0.00	0.00	314.17	0.00	0.00	130.50	0.00	0.00	293.00
S 5000/50 ppb	0.00	0.00	56.83	0.00	0.00	132.50	0.00	0.00	341.83	0.00	0.00	130.83	0.00	0.00	297.50
S 10000/100 ppb	<0.000	0.00	56.33	0.00	0.00	133.83	0.00	0.00	325.50	0.00	0.00	134.83	0.00	0.00	286.33
Blank 1	0.00	0.00	59.33	0.00	0.00	142.83	0.00	0.00	359.17	0.00	0.00	142.83	0.00	0.00	328.33
Blank 2	<0.000	0.00	54.50	0.00	0.00	131.83	0.00	0.00	345.17	<0.000	0.00	119.83	0.00	0.00	302.17
Blank 3	<0.000	0.00	51.17	0.00	0.00	134.83	0.00	0.00	323.67	0.00	0.00	124.33	0.00	0.00	297.00
Millq neat	0.00	0.00	63.83	0.00	0.00	149.33	0.00	0.00	371.18	0.00	0.00	157.17	0.01	0.00	363.67
Nitric HCL Matrix	<0.000	0.00	51.00	<0.000	0.00	115.83	0.00	0.00	315.50	<0.000	0.00	112.67	0.00	0.00	266.17
SC-002	0.00	0.00	72.00	0.01	0.00	169.17	0.01	0.00	435.68	0.01	0.00	174.17	0.01	0.00	395.01
SC-001	0.00	0.00	67.50	0.00	0.00	153.50	0.01	0.00	404.68	0.00	0.00	148.17	0.01	0.00	352.84
MC-2-002	0.05	0.00	224.33	0.05	0.00	549.18	0.32	0.00	6670.44	0.54	0.01	4685.71	0.43	0.01	8417.32
MC-2-001	0.07	0.01	327.33	0.08	0.00	793.03	0.54	0.01	11172.14	0.93	0.02	7921.83	0.74	0.01	14223.04
MC-001	0.01	0.00	76.00	0.00	0.00	155.83	0.01	0.00	477.51	0.01	0.00	192.33	0.01	0.00	428.51
MC-002	0.03	0.00	171.50	0.03	0.00	395.01	0.03	0.00	983.21	0.03	0.00	391.68	0.03	0.00	897.03
MC-003	<0.000	0.00	55.17	0.00	0.00	136.33	0.00	0.00	323.33	0.00	0.00	137.17	0.00	0.00	309.33
MC-004	<0.000	0.00	52.33	0.00	0.00	135.67	0.00	0.00	329.00	0.00	0.00	129.33	0.00	0.00	299.00
MC-005	0.00	0.00	58.67	0.00	0.00	129.67	0.00	0.00	338.67	<0.000	0.00	122.50	0.00	0.00	305.67
MC-006	<0.000	0.00	53.00	0.00	0.00	125.00	0.00	0.00	319.67	0.00	0.00	130.00	0.00	0.00	309.33
CC-001	0.00	0.00	56.83	0.00	0.00	139.33	0.00	0.00	327.17	0.00	0.00	136.67	0.00	0.00	310.67
CC-002	<0.000	0.00	47.17	<0.000	0.00	105.00	0.00	0.00	286.50	<0.000	0.00	113.17	0.00	0.00	259.33
CC-003	<0.000	0.00	45.83	<0.000	0.00	109.33	<0.000	0.00	279.50	<0.000	0.00	117.67	<0.000	0.00	249.83
UT-001	<0.000	0.00	49.67	<0.000	0.00	109.67	<0.000	0.00	273.33	<0.000	0.00	107.00	<0.000	0.00	250.67
UT-002	<0.000	0.00	52.00	0.00	0.00	119.17	<0.000	0.00	274.83	<0.000	0.00	118.00	0.00	0.00	262.17
UT-003	<0.000	0.00	55.00	0.00	0.00	123.00	0.00	0.00	316.83	<0.000	0.00	120.00	0.00	0.00	309.33
UT-004	<0.000	0.00	40.33	<0.000	0.00	85.33	<0.000	0.00	215.00	<0.000	0.00	89.67	<0.000	0.00	214.83
UT-005	<0.000	0.00	50.83	<0.000	0.00	104.00	<0.000	0.00	243.17	<0.000	0.00	106.00	<0.000	0.00	246.33
UT-006	<0.000	0.00	40.33	<0.000	0.00	107.33	<0.000	0.00	265.83	<0.000	0.00	102.67	<0.000	0.00	241.83
UT-007	<0.000	0.00	48.17	<0.000	0.00	106.67	<0.000	0.00	250.33	<0.000	0.00	103.17	<0.000	0.00	252.33
UT-008	<0.000	0.00	41.17	<0.000	0.00	100.17	<0.000	0.00	241.17	<0.000	0.00	100.67	<0.000	0.00	235.50
Blank 1	<0.000	0.00	49.67	<0.000	0.00	102.83	0.00	0.00	286.67	<0.000	0.00	105.00	<0.000	0.00	253.33
Blank 2	<0.000	0.00	41.50	<0.000	0.00	99.33	<0.000	0.00	233.67	<0.000	0.00	98.67	<0.000	0.00	225.33
Hg 0.1 ppb	0.07	0.00	325.33	0.08	0.00	783.02	0.08	0.00	1811.80	0.07	0.00	703.02	0.08	0.00	1739.12
Blank 2	<0.000	0.00	42.50	<0.000	0.00	99.67	<0.000	0.00	260.33	<0.000	0.00	97.67	<0.000	0.00	221.67
Blank 3	<0.000	0.00	37.83	<0.000	0.00	88.17	<0.000	0.00	224.00	<0.000	0.00	85.00	<0.000	0.00	200.67
Env 100/1 ppb	<0.000	0.00	34.83	<0.000	0.00	85.50	<0.000	0.00	215.67	<0.000	0.00	82.50	<0.000	0.00	202.67
Blank 1	<0.000	0.00	38.33	<0.000	0.00	89.50	<0.000	0.00	244.83	<0.000	0.00	100.50	<0.000	0.00	214.83
Blank 3	<0.000	0.00	38.33	<0.000	0.00	77.67	<0.000	0.00	207.17	<0.000	0.00	82.67	<0.000	0.00	188.33
S 5000/50 ppb	<0.000	0.00	32.33	<0.000	0.00	73.17	<0.000	0.00	177.00	<0.000	0.00	67.67	<0.000	0.00	172.67
Blank 1	<0.000	0.00	34.83	<0.000	0.00	89.17	<0.000	0.00	219.17	<0.000	0.00	81.17	<0.000	0.00	199.00
Blank 2	<0.000	0.00	34.50	<0.000	0.00	80.83	<0.000	0.00	191.50	<0.000	0.00	76.00	<0.000	0.00	191.67
Blank 3	<0.000	0.00	33.83	<0.000	0.00	78.33	<0.000	0.00	183.50	<0.000	0.00	74.00	<0.000	0.00	172.83
Millq neat	<0.000	0.00	36.00	<0.000	0.00	101.00	<0.000	0.00	241.67	<0.000	0.00	92.17	<0.000	0.00	232.17
Nitric HCL Matrix	<0.000	0.00	30.00	<0.000	0.00	81.33	<0.000	0.00	185.17	<0.000	0.00	76.67	<0.000	0.00	182.67
UT-008-RUN 2	<0.000	0.00	41.00	<0.000	0.00	82.00	<0.000	0.00	198.17	<0.000	0.00	78.67	<0.000	0.00	180.67
DM	0.01	0.00	94.33	0.01	0.00	225.67	0.01	0.00	544.84	0.01	0.00	204.67	0.01	0.00	514.01
SCM	0.04	0.00	192.17	0.04	0.00	457.18	0.04	0.00	1076.05	0.03	0.00	415.51	0.04	0.00	1021.37
MCM-001S	<0.000	0.00	43.00	<0.000	0.00	97.17	0.00	0.00	321.00	0.00	0.00	151.17	0.00	0.00	335.67
MCM-006SX	<0.000	0.00	29.50	<0.000	0.00	73.67	<0.000	0.00	178.50	<0.000	0.00	66.17	<0.000	0.00	161.33
MTH	0.02	0.00	117.83	0.02	0.00	281.00	0.02	0.00	643.69	0.01	0.00	240.33	0.02	0.00	617.02
SKM	0.04	0.00	205.50	0.04	0.00	492.18	0.05	0.00	1198.06	0.04	0.00	454.51	0.05	0.00	1146.55
MD	<0.000	0.00	39.83	<0.000	0.00	93.17	<0.000	0.00	260.33	<0.000	0.00	92.67	<0.000	0.00	233.33
WDE	<0.000	0.00	32.17	<0.000	0.00	84.67	<0.000	0.00	190.83	<0.000	0.00	76.17	<0.000	0.00	171.33
CE-001	0.01	0.00	85.33	0.01	0.00	209.00	0.01	0.00	500.68	0.01	0.00	206.50	0.01	0.00	491.84
LSC	0.04	0.00	209.67	0.05	0.00	513.01	0.05	0.00	1220.73	0.04	0.00	476.34	0.05	0.00	1196.72
IE	<0.000	0.00	25.67	<0.000	0.00	70.00	<0.000	0.00	184.83	<0.000	0.00	64.00	<0.000	0.00	157.50
MCM	<0.000	0.00	38.33	<0.000	0.00	86.17	0.00	0.00	312.17	0.00	0.00	141.50	0.00	0.00	323.67
MCS-001	<0.000	0.00	32.00	<0.000	0.00	78.83	<0.000	0.00	182.67	<0.000	0.00	74.17	<0.000	0.00	178.50
UTS-001	<0.000	0.00	54.33	0.00	0.00	119.83	0.00	0.00	309.83	<0.000	0.00	122.17	0.00	0.00	296.17
UTS-002	<0.000	0.00	46.67	0.00	0.00	123.17	<0.000	0.00	271.17	<0.000	0.00	100.83	0.00	0.00	257.83
UTS-003	0.00	0.00	73.67	0.01	0.00	169.00	0.01	0.00	394.51	0.00	0.00	155.83	0.01	0.00	388.68
UTS-004	0.01	0.00	93.67	0.01	0.00	215.00	0.01	0.00	543.68	0.01	0.00	212.00	0.01	0.00	527.68
Blank 1	<0.000	0.00	31.83	<0.000	0.00	71.83	<0.000	0.00	169.33	<0.000	0.00	72.67	<0.000	0.00	163.00
Blank 2	<0.000	0.00	24.67	<0.000	0.00	67.33	<0.000	0.00	156.83	<0.000	0.00	61.33	<0.000	0.00	149.00
Hg 0.1 ppb	0.06	0.00	290.00	0.07	0.00	731.35	0.07	0.00	1713.45	0.06	0.00	668.02	0.07	0.00	1648.94
Blank 2	<0.000	0.00	27.50	<0.000	0.00	66.50	<0.000	0.00	177.00	<0.000	0.00	64.17	<0.000	0.00	168.17
Blank 3	<0.000	0.00	27.00	<0.000	0.00	65.00	<0.000	0.00	161.83	<0.000	0.00	60.17	<0.000	0.00	141.33
Env 100/1 ppb	<0.000	0.00	26.00	<0.000	0.00	57.33	<0.000	0.00	152.17	<0.000	0.00	57.50	<0.000	0.00	142.50
Blank 1	<0.000	0.00	27.00	<0.000	0.00	64.50	<0.000	0.00	183.50	<0.000	0.00	66.83	<0.000	0.00	165.33
Blank 3	<0.000	0.00	23.50	<0.000	0.00	62.67	<0.000	0.00	151.33	<0.000	0.00	61.33	<0.000	0.00	137.50
S 5000/50 ppb	<0.000	0.00	23.83	<0.000	0.00	56.17	<0.000	0.00	140.67	<0.000	0.00	50.83	<0.000	0.00	124.67
Blank 1	<0.000	0.00	27.83	<0.000	0.00	73.00	<0.000	0.00	181.17	<0.000	0.00	71.67	<0.000	0.00	163.50
Blank 2	<0.000	0.00	27.33	<0.000	0.00	60.67	<0.000	0.00	159.00	<0.000	0.00	55.67	<0.000	0.00	140.50

	205 Tl [He]			206 Pb [He]			207 Pb [He]			208 Pb [He]			232 Th [He]		
Sample Name	Conc. [ppb]	Conc. SD	CPS	Conc. [ppb]	Conc. SD	CPS	Conc. [ppb]	Conc. SD	CPS	Conc. [ppb]	Conc. SD	CPS	Conc. [ppb]	Conc. SD	CPS
Blank 1			1014.71			6324.26			5620.26			25873.93			3592.19
Blank 2			270.33			4430.12			3820.58			17925.43			3057.71
Blank 3			276.00			2230.87			1873.47			8791.55			4451.14
Blank 1			482.68			5871.04			5180.74			23997.13			3092.72
Hg 0.01 ppb			256.67			310015.95			265257.47			1236322.06			4165.70
Hg 0.05 ppb			246.33			12516.91			10790.98			50149.93			2821.32
Hg 0.1 ppb			266.00			148689.40			127704.62			593670.40			2217.53
Hg 0.5 ppb			251.33			3597.18			3150.40			14467.96			1486.76
Hg 1.0 ppb			278.00			2331.22			1969.15			9343.72			1431.75
Blank 1			516.34			6008.10			5223.42			24285.66			2290.55
Blank 2			284.67			4542.49			3958.29			18358.33			2376.56
Blank 3			273.67			2217.53			1907.48			8919.60			3857.94
Env 1/0.01 ppb	0.01	0.00	4167.69	<0.000	0.00	3399.13	<0.000	0.00	2898.00	<0.000	0.00	13522.21	0.00	0.00	4535.17
Env 5/0.05 ppb	0.06	0.00	18646.51	0.09	0.00	15808.96	0.09	0.00	13505.61	0.09	0.00	63345.04	0.02	0.00	12090.92
Env 10/0.1 ppb	0.11	0.00	36837.63	0.11	0.00	18175.16	0.11	0.00	15542.30	0.11	0.00	73129.35	0.05	0.00	24852.31
Env 100/1 ppb	1.09	0.00	359292.38	1.02	0.00	121644.08	1.04	0.00	103394.52	1.02	0.00	486292.22	0.54	0.03	250317.65
Env 1000/10 ppb	10.53	0.05	3453972.83	10.20	0.05	1169338.84	10.41	0.01	987961.04	10.35	0.04	4727729.04	7.59	0.41	3498761.33
Env 10000/100 ppb	99.95	2.13	32767120.00	99.98	1.38	11407133.33	99.96	0.74	9440139.33	99.97	0.80	45471432.67	100.25	2.82	46174861.33
Blank 1	0.78	0.11	257087.82	0.04	0.01	10478.73	0.04	0.01	9036.94	0.04	0.01	42116.11	4.43	0.41	2042041.50
Blank 2	0.16	0.01	54043.37	<0.000	0.00	5777.00	<0.000	0.00	5019.01	<0.000	0.00	23315.26	1.47	0.05	679112.08
Blank 3	0.09	0.01	28445.03	<0.000	0.00	2967.35	<0.000	0.00	2544.26	<0.000	0.00	11886.57	1.25	0.06	578839.52
S 100/1 ppb	0.06	0.00	18764.09	<0.000	0.00	5155.73	<0.000	0.00	4332.08	<0.000	0.00	20378.88	0.72	0.03	336585.37
S 1000/10 ppb	0.04	0.00	13988.15	<0.000	0.00	4803.25	<0.000	0.00	4243.39	<0.000	0.00	19640.12	0.44	0.01	207659.26
S 5000/50 ppb	0.03	0.00	10995.17	<0.000	0.00	4224.05	<0.000	0.00	3768.90	<0.000	0.00	17260.05	0.31	0.01	147970.89
S 10000/100 ppb	0.03	0.00	9060.63	0.26	0.00	36041.70	0.27	0.00	30587.93	0.26	0.00	142714.93	0.26	0.02	121763.08
Blank 1	0.02	0.00	7452.89	0.01	0.00	6486.68	0.01	0.00	5691.29	0.00	0.00	26014.61	0.09	0.00	46649.90
Blank 2	0.02	0.00	5964.76	<0.000	0.00	4855.61	<0.000	0.00	4201.37	<0.000	0.00	19574.73	0.09	0.00	46287.54
Blank 3	0.01	0.00	5166.41	<0.000	0.00	2484.58	<0.000	0.00	2076.84	<0.000	0.00	9806.52	0.13	0.00	64213.38
Millq neat	0.01	0.00	5148.07	<0.000	0.00	940.70	<0.000	0.00	835.36	<0.000	0.00	3853.24	<0.000	0.00	155.33
Nitric HCL Matrix	0.01	0.00	5286.79	<0.000	0.00	3891.94	<0.000	0.00	3399.46	<0.000	0.00	15670.87	0.05	0.00	27212.27
SC-002	0.07	0.01	22026.16	0.28	0.00	37607.29	0.28	0.00	32040.57	0.28	0.00	149459.25	0.87	0.34	404414.83
SC-001	0.04	0.00	14445.37	<0.000	0.00	3506.82	<0.000	0.00	2953.35	<0.000	0.00	13943.41	0.12	0.01	58404.94
MC-2-002	0.03	0.00	10340.95	9.17	0.03	1051530.87	9.48	0.04	899712.92	9.50	0.16	4343445.13	0.07	0.01	34059.93
MC-2-001	0.03	0.00	8766.75	0.76	0.01	92967.13	0.79	0.00	79436.20	0.76	0.00	370422.92	0.04	0.00	20480.02
MC-001	0.02	0.00	7203.08	0.24	0.00	33187.19	0.25	0.00	28685.11	0.24	0.00	132968.74	0.02	0.00	10866.79
MC-002	0.02	0.00	6465.67	1.35	0.00	159873.96	1.41	0.00	138533.82	1.36	0.01	641851.43	0.01	0.00	5619.29
MC-003	0.01	0.00	5011.01	0.24	0.00	33357.97	0.25	0.00	28332.32	0.24	0.00	132396.19	0.01	0.00	8058.30
MC-004	0.01	0.00	4942.65	0.52	0.00	65568.27	0.55	0.00	57478.47	0.53	0.00	263991.79	0.01	0.00	6647.79
MC-005	0.01	0.00	4232.72	0.13	0.00	20857.66	0.13	0.00	17835.01	0.13	0.00	83185.54	0.01	0.00	5929.76
MC-006	0.01	0.00	3750.90	0.08	0.00	14629.86	0.08	0.00	12619.35	0.08	0.00	58723.03	0.00	0.00	4958.34
CC-001	0.01	0.00	3215.08	<0.000	0.00	4194.37	<0.000	0.00	3547.17	<0.000	0.00	16674.39	0.00	0.00	4655.21
CC-002	0.01	0.00	2621.94	<0.000	0.00	3474.15	<0.000	0.00	2961.02	<0.000	0.00	13682.93	0.00	0.00	3891.62
CC-003	0.01	0.00	2416.24	<0.000	0.00	3933.62	<0.000	0.00	3324.11	<0.000	0.00	15656.54	0.00	0.00	3673.22
UT-001	0.01	0.00	2374.89	0.10	0.00	17091.31	0.10	0.00	14723.31	0.10	0.00	68402.96	0.00	0.00	3464.83
UT-002	0.01	0.00	2148.52	0.39	0.00	50748.08	0.40	0.01	43084.61	0.39	0.00	201201.45	0.00	0.00	3216.76
UT-003	0.00	0.00	2043.17	0.26	0.00	35497.49	0.27	0.00	30677.16	0.26	0.00	142030.24	0.00	0.00	3272.11
UT-004	0.01	0.00	2444.91	0.71	0.00	87315.82	0.75	0.00	75812.46	0.72	0.01	350092.85	0.00	0.00	3902.62
UT-005	0.00	0.00	1957.82	0.09	0.00	16484.83	0.10	0.00	14299.16	0.09	0.00	66086.99	<0.000	0.00	2850.00
UT-006	0.01	0.00	2407.56	0.07	0.00	14092.58	0.07	0.00	12163.90	0.07	0.00	56430.43	0.00	0.00	3180.75
UT-007	0.00	0.00	1633.11	<0.000	0.00	4902.29	<0.000	0.00	4171.03	<0.000	0.00	19589.41	<0.000	0.00	2634.62
UT-008	0.00	0.00	1843.47	6.27	0.02	720751.19	6.45	0.01	614355.81	6.25	0.03	2865482.96	0.00	0.00	5172.42
Blank 1	0.00	0.00	1162.05	0.00	0.00	6123.83	0.00	0.00	5369.48	0.00	0.00	24736.64	0.00	0.00	3333.79
Blank 2	0.00	0.00	487.68	<0.000	0.00	4510.81	<0.000	0.00	3857.59	<0.000	0.00	18011.11	0.00	0.00	3714.56
Hg 0.1 ppb	<0.000	0.00	461.01	1.21	0.01	143329.22	1.24	0.01	122638.77	1.21	0.01	572173.77	0.00	0.00	4909.98
Blank 2	<0.000	0.00	464.34	<0.000	0.00	4552.83	<0.000	0.00	3982.63	<0.000	0.00	18244.56	<0.000	0.00	2949.68
Blank 3	<0.000	0.00	468.34	<0.000	0.00	2175.52	<0.000	0.00	1927.15	<0.000	0.00	8737.86	0.01	0.00	5992.79
Env 100/1 ppb	1.03	0.01	337176.13	0.96	0.00	115059.19	0.97	0.01	96903.01	0.95	0.00	457407.29	0.41	0.03	192903.80
Blank 1	0.01	0.00	2661.62	0.00	0.00	5965.42	0.00	0.00	5255.77	0.00	0.00	24156.20	0.09	0.00	46739.91
Blank 3	0.00	0.00	852.70	<0.000	0.00	2221.86	<0.000	0.00	1904.15	<0.000	0.00	8782.88	0.08	0.00	41602.96
S 5000/50 ppb	0.00	0.00	1052.04	<0.000	0.00	3759.56	<0.000	0.00	3378.46	<0.000	0.00	15297.35	0.05	0.00	26071.81
Blank 1	0.00	0.00	1211.39	<0.000	0.00	5733.98	0.00	0.00	5205.42	<0.000	0.00	23589.44	0.02	0.00	11144.36
Blank 2	0.00	0.00	560.34	<0.000	0.00	4384.43	<0.000	0.00	3775.90	<0.000	0.00	17796.71	0.02	0.00	10425.73
Blank 3	0.00	0.00	502.01	<0.000	0.00	2107.51	<0.000	0.00	1819.13	<0.000	0.00	8606.52	0.03	0.00	14612.30
Millq neat	<0.000	0.00	365.01	<0.000	0.00	789.69	<0.000	0.00	682.35	<0.000	0.00	3123.82	<0.000	0.00	81.33
Nitric HCL Matrix	0.00	0.00	1773.79	<0.000	0.00	3299.77	<0.000	0.00	2894.00	<0.000	0.00	13390.84	0.01	0.00	5680.31
UT-008-RUN 2	0.00	0.00	1710.78	6.21	0.03	713947.50	6.42	0.05	611387.35	6.20	0.04	2844992.48	0.10	0.04	50052.14
DM	0.01	0.00	2577.27	0.35	0.00	45904.15	0.36	0.00	39297.16	0.35	0.00	182519.14	<0.000	0.00	2945.69
SCM	0.00	0.00	1789.13	1.11	0.01	132610.23	1.15	0.00	113601.63	1.11	0.00	529112.46	0.00	0.00	3320.11
MCM-001S	0.01	0.00	2774.98	1.29	0.01	153087.89	1.34	0.00	131229.70	1.29	0.00	611648.73	0.00	0.00	4787.60
MCM-006SX	0.01	0.00	4168.03	0.07	0.00	14356.88	0.07	0.00	12217.96	0.07	0.00	56799.93	<0.000	0.00	1556.77
MTH	0.01	0.00	2847.32	1.61	0.01	189496.75	1.64	0.01	159978.15	1.59	0.01	748224.35	<0.000	0.00	2851.33
SKM	0.00	0.00	1509.42	0.42	0.00	53631.71	0.43	0.00	45438.85	0.42	0.00	213019.99	0.00	0.00	4425.13
MD	0.00	0.00	846.03	2.20	0.02	257054.96	2.26	0.03	218270.33	2.19	0.01	1020277.54	<0.000	0.00	1870.48
WDE	0.00	0.00	1680.11	0.32	0.00	42340.99	0.33	0.00	36128.31	0.32	0.00	169271.45	<0.000	0.00	1812.80
CE-001	0.01	0.00	4946.64	1.85	0.00	216314.08	1.89	0.01	183955.60	1.83	0.00	856461.54	0.00	0.00	3627.54
LSC	0.00	0.00	1973.49	4.37	0.03	504446.17	4.47	0.03	426764.81	4.34	0.01	1995236.94	<0.000	0.00	2539.93
IE	0.01	0.00	4708.55	0.22	0.00	30907.36	0.23	0.00	26679.36	0.22	0.00	123677.53	<0.000	0.00	1408.42
MCM	0.01	0.00	2866.33	1.24	0.01	147699.21	1.27	0.01	125306.25	1.24	0.00	586323.49	0.00	0.00	4299.09
MCS-001	0.01	0.00	2962.02	0.29	0.00	38565.53	0.29	0.00	32942.89	0.28	0.00	153474.98	<0.000	0.00	1632.11
UTS-001	0.01	0.00	2394.90	15.41	0.49	1763290.92	15.67	0.13	1483959.84	16.08	0.41	7332859.84	<0.000	0.00	2411.24
UTS-002	0.01	0.00	2172.52	0.08	0.00	15221.23	0.08	0.00	13086.16	0.08	0.00	60801.81	<0.000	0.00	2326.55
UTS-003	0.01	0.00	4585.51	0.18	0.00	25957.18	0.18	0.00	22278.12	0.17	0.00	103435.29	<0.000	0.00	2951.69
UTS-004	0.00	0.00	1719.45	0.43	0.01	55265.12	0.45	0.00	47590.14	0.44	0.00	222290.71	0.01	0.00	8122.02
Blank 1	0.00	0.00	1007.71	<0.000	0.00	5828.35	<0.000	0.00	5094.04	<0.000	0.00	23614.15	0.00	0.00	3881.28
Blank 2	<0.000	0.00	412.68	<0.000	0.00	4444.12	<0.000	0.00	3802.25	<0.000	0.00	17742.30	0.00	0.00	4303.75
Hg 0.1 ppb	<0.000	0.00	380.34	1.18	0.00	140378.99	1.22	0.00	120141.09	1.18	0.00	558941.94	0.00	0.00	5181.09
Blank 2	<0.000	0.00	412.01	<0.000	0.00	4425.78	<0.000	0.00	3780.57	<0.000	0.00	17778.01	<0.000	0.00	2989.03
Blank 3	<0.000	0.00	409.34	<0.000	0.00	2157.19	<0.000	0.00	1865.47	<0.000	0.00	8636.84	0.01	0.00	6209.56
Env 100/1 ppb	1.00	0.01	329306.35	0.93	0.00	111843.32	0.95	0.00	94897.08	0.93	0.00	444897.74	0.41	0.03	189833.89
Blank 1	0.01	0.00	2562.60	<0.000	0.00	5692.29	<0.000	0.00	4999.00	<0.000	0.00	23061.07	0.09	0.00	45027.59
Blank 3	0.00	0.00	814.69	<0.000	0.00	2111.18	<0.000	0.00	1850.47	<0.000	0.00	8514.81	0.08	0.00	38456.10
S 5000/50 ppb	0.00	0.00	999.37	<0.000	0.00	3742.23	<0.000	0.00	3211.08	<0.000	0.00	14910.83	0.05	0.00	24101.81
Blank 1	0.00	0.00	1098.72	<0.000	0.00	5635.94	<0.000	0.00	4915.97	<0.000	0.00	22821.91	0.02	0.00	10257.93
Blank 2	<0.000	0.00	475.34	<0.000	0.00	4254.06	<0.000	0.00	3658.54	<0.000	0.00	17167.68	0.01	0.00	9836.58

	238 U [He]			6 Li (ISTD) [No Gas]		6 Li (ISTD) [H2]		7 Li (ISTD) [No Gas]		7 Li (ISTD) [H2]		45 Sc (ISTD) [He]	
Sample Name	Conc. [ppb]	Conc. SD	CPS	CPS	CPS RSD	CPS	CPS RSD	CPS	CPS RSD	CPS	CPS RSD	CPS	CPS RSD
Blank 1			300.33	4843542.64	1.57	152364.32	0.33	292923.53	0.21	14751.00	0.66	1611825.34	4.36
Blank 2			97.67	4711850.45	4.50	145990.84	0.64	285028.80	1.27	14129.70	0.85	1427916.79	1.65
Blank 3			139.00	4537232.64	0.74	142870.27	0.38	281690.94	0.48	14010.59	0.23	1435965.67	1.71
Blank 1			301.00	4962259.72	6.43	142993.21	0.84	289744.65	5.11	14145.72	0.22	1445372.04	1.54
Hg 0.01 ppb			458.34	4512883.37	1.44	140520.74	0.36	278645.52	0.51	14042.29	0.68	1421517.50	3.68
Hg 0.05 ppb			37.00	4467642.85	2.46	137494.22	0.74	272581.78	1.41	13600.19	0.82	1451065.67	1.06
Hg 0.1 ppb			52.00	4428918.27	6.30	136960.45	0.56	269770.81	1.37	13546.14	1.27	1429637.08	1.27
Hg 0.5 ppb			57.00	4360014.21	1.80	138365.52	0.69	272227.81	1.56	13730.98	1.31	1459028.42	2.52
Hg 1.0 ppb			49.67	4455496.71	2.24	136038.19	0.50	266589.60	0.41	13369.64	0.80	1489107.13	3.96
Blank 1			293.33	4505967.22	2.42	136844.62	0.49	273081.56	1.19	13504.77	0.76	1432372.08	2.87
Blank 2			116.00	4433233.79	0.54	137448.14	0.82	270501.80	0.63	13588.51	0.97	1477430.63	0.87
Blank 3			140.67	4606937.01	3.07	136239.79	0.53	271976.07	1.21	13527.45	0.56	1446958.66	4.69
Env 1/0.01 ppb	0.01	0.00	4579.85	4514083.68	6.44	136162.18	0.89	269324.74	0.28	13537.80	1.00	1466729.00	2.49
Env 5/0.05 ppb	0.04	0.00	24227.47	4596277.02	1.19	135521.62	0.49	264872.59	0.85	13344.61	0.37	1469413.25	1.13
Env 10/0.1 ppb	0.09	0.00	51626.63	4423516.91	2.20	134888.64	0.28	270861.08	1.00	13330.26	1.25	1420445.63	1.29
Env 100/1 ppb	1.01	0.01	580671.02	4348039.73	1.96	134668.95	0.49	266526.20	1.39	13452.05	1.61	1467911.58	2.15
Env 1000/10 ppb	10.39	0.19	5951385.50	4438063.48	0.87	134191.84	0.35	268413.51	0.77	13385.66	0.71	1441763.50	1.55
Env 10000/100 ppb	99.96	2.11	57282761.33	4419972.95	5.15	132558.38	1.07	263621.94	0.68	13146.76	0.45	1419323.88	6.02
Blank 1	0.06	0.00	35158.94	4552351.08	3.85	137643.33	0.58	269318.47	1.05	13421.35	0.32	1472752.42	1.55
Blank 2	0.01	0.00	5018.69	4368845.04	2.24	135803.41	1.17	267660.41	1.00	13495.76	2.85	1436588.95	0.94
Blank 3	0.00	0.00	2273.88	4364701.19	2.31	134365.44	0.25	266648.57	0.69	13275.22	1.08	1444214.92	0.98
S 100/1 ppb	0.00	0.00	1335.08	4404111.60	4.22	136390.32	0.59	265029.41	1.77	13419.02	1.36	1442953.58	2.64
S 1000/10 ppb	0.00	0.00	888.03	4466213.89	2.33	137676.73	0.53	269543.54	0.84	13575.83	0.13	1454478.63	0.63
S 5000/50 ppb	0.00	0.00	685.02	4475530.56	2.07	136504.35	0.80	269604.36	0.07	13517.11	0.72	1449830.25	3.97
S 10000/100 ppb	0.00	0.00	485.68	4530545.25	2.91	134390.34	0.27	265484.11	0.21	13468.73	0.57	1456142.00	1.09
Blank 1	0.00	0.00	1382.74	4592218.68	2.94	136020.14	0.93	267140.64	1.20	13656.91	1.69	1427977.83	3.20
Blank 2	0.00	0.00	398.68	4518570.56	5.35	137730.88	0.36	270501.20	0.08	13618.87	0.53	1483183.62	0.64
Blank 3	0.00	0.00	363.34	4498508.16	1.27	137043.40	1.09	264894.23	0.50	13424.35	0.42	1483359.25	1.91
Millq neat	<0.000	0.00	45.33	5061143.15	0.72	155923.05	0.41	298089.54	1.01	15016.28	1.60	990429.00	11.99
Nitric HCL Matrix	0.01	0.00	4006.33	4659379.41	5.67	137917.24	0.66	268969.70	1.08	13508.44	1.09	1445162.83	2.55
SC-002	0.00	0.00	1944.82	3987029.63	4.85	123644.42	0.52	250724.19	1.35	12741.40	1.92	1346534.71	1.13
SC-001	0.00	0.00	672.69	4100688.27	4.44	125273.64	1.08	255619.80	0.87	12779.42	0.71	1337590.46	1.48
MC-2-002	0.00	0.00	1224.06	3946933.17	2.16	122944.92	0.90	711195.94	0.22	36449.82	1.18	1259551.08	2.60
MC-2-001	0.00	0.00	407.68	3922012.23	3.41	122295.78	0.49	760571.37	0.65	38776.29	0.81	1279590.00	1.42
MC-001	<0.000	0.00	207.00	4072909.52	3.72	123963.37	0.58	254984.19	0.90	12661.32	0.26	1287234.62	0.89
MC-002	<0.000	0.00	149.00	5225872.73	4.30	151526.92	0.64	294971.89	0.91	14492.07	0.74	1407381.08	4.05
MC-003	0.00	0.00	302.67	4084226.82	6.81	124726.87	0.48	251840.70	0.50	12782.10	0.36	1294728.88	0.94
MC-004	<0.000	0.00	284.33	4046502.44	3.43	124147.05	0.44	251415.93	1.03	12554.89	0.61	1264550.87	3.76
MC-005	0.00	0.00	323.00	3971396.82	6.41	123494.41	0.23	246213.60	1.04	12531.87	1.65	1214737.13	1.85
MC-006	0.00	0.00	363.68	3987200.98	4.28	122297.09	0.63	247267.03	0.76	12302.67	0.87	1210062.21	0.92
CC-001	0.01	0.00	7630.37	3704240.15	6.02	117864.86	0.80	245798.48	0.43	12316.02	0.38	1191583.21	0.94
CC-002	0.00	0.00	2851.00	3887603.17	4.45	117873.26	0.79	249484.92	0.88	12435.46	1.37	1168307.42	1.31
CC-003	0.00	0.00	471.34	3846792.34	3.88	118542.05	0.76	237271.01	0.52	11883.98	1.39	1163531.79	0.87
UT-001	0.00	0.00	305.00	3957964.63	2.40	118868.12	0.44	237888.70	0.55	11845.95	0.48	1150038.00	0.30
UT-002	0.00	0.00	379.34	3742707.55	3.96	117863.16	1.08	234168.45	0.66	11972.05	1.59	1145988.42	0.80
UT-003	<0.000	0.00	261.67	3707812.55	1.57	117437.90	0.65	235605.79	0.44	11890.32	0.30	1170497.50	0.47
UT-004	0.00	0.00	1073.05	3647853.80	7.22	113883.89	1.21	230453.03	0.43	11607.75	0.84	1127097.33	0.28
UT-005	0.00	0.00	313.34	3758997.65	3.02	115822.53	1.18	231334.03	0.77	11635.78	0.33	1139907.29	0.40
UT-006	0.00	0.00	1140.39	3602384.63	1.71	116290.07	1.32	231524.93	1.22	11739.53	1.46	1125343.04	0.58
UT-007	0.11	0.00	60667.38	3657142.03	5.38	113345.78	0.68	241341.20	0.57	12222.60	0.07	1117988.79	0.63
UT-008	0.02	0.00	10352.36	3736220.05	3.22	111300.76	0.57	225999.57	0.56	11168.07	2.27	1086076.50	0.63
Blank 1	0.00	0.00	921.04	4153816.71	3.35	129584.71	0.57	251208.48	0.78	12706.36	0.50	1270514.79	3.09
Blank 2	<0.000	0.00	172.67	4055562.02	2.58	128841.98	0.39	248499.34	0.31	12593.60	2.03	1338607.33	5.03
Hg 0.1 ppb	<0.000	0.00	84.67	3983828.80	4.11	125687.85	0.11	239976.15	0.31	12339.37	0.88	1280137.25	2.55
Blank 2	<0.000	0.00	177.33	3995860.56	2.37	126085.65	0.82	241840.53	1.24	12467.15	1.36	1313260.29	2.55
Blank 3	<0.000	0.00	178.67	3821014.11	4.77	125307.80	0.82	240168.85	0.45	12457.81	0.45	1265895.04	2.86
Env 100/1 ppb	0.95	0.01	544920.38	4051989.63	3.61	125881.22	0.60	239649.97	0.72	12453.14	0.54	1288757.38	1.66
Blank 1	0.00	0.00	1572.77	4065621.82	1.18	128539.36	0.61	240988.95	0.61	12509.19	1.51	1305323.67	4.06
Blank 3	<0.000	0.00	289.33	4126209.31	4.46	126692.69	0.76	238531.85	0.92	12401.09	1.38	1261092.17	3.30
S 5000/50 ppb	<0.000	0.00	265.67	4021467.23	3.36	126935.30	0.60	240281.90	0.84	12536.21	0.87	1292796.87	1.76
Blank 1	0.00	0.00	929.37	4070480.25	4.58	127979.14	0.44	240605.97	0.52	12468.81	0.91	1357859.12	3.74
Blank 2	<0.000	0.00	183.67	4025982.65	4.40	128529.10	0.92	243902.54	0.94	12543.21	0.36	1293727.04	1.65
Blank 3	<0.000	0.00	197.00	3926356.30	1.87	125994.27	0.56	239010.09	0.44	12455.13	0.68	1275478.25	3.44
Millq neat	<0.000	0.00	14.00	4572099.10	3.42	145220.67	0.56	268438.67	1.19	13904.48	0.75	884373.94	12.02
Nitric HCL Matrix	0.00	0.00	1965.83	4278592.54	1.94	129346.81	0.53	243021.56	0.30	12810.45	0.84	1349076.12	1.78
UT-008-RUN 2	0.02	0.00	10333.34	3607443.07	2.74	112139.04	0.94	223366.20	0.98	11420.60	0.56	1150348.17	3.43
DM	0.00	0.00	2058.84	4003376.71	2.29	127343.40	0.25	245260.01	0.08	12639.30	2.00	1330153.58	0.83
SCM	0.00	0.00	2061.51	3986000.67	2.77	127590.07	0.58	246068.29	0.66	12699.02	0.63	1343639.79	5.48
MCM-001S	0.00	0.00	2979.03	4028411.92	5.32	123487.52	0.47	333306.32	0.91	17250.48	0.89	1304043.54	5.33
MCM-006SX	<0.000	0.00	242.00	3976226.61	1.09	125503.59	0.29	244129.52	0.60	12523.20	0.56	1305986.83	4.98
MTH	0.00	0.00	1202.39	3999461.40	5.23	126073.27	0.34	241969.49	0.72	12442.46	1.11	1311960.63	2.23
SKM	0.01	0.00	6125.86	3976941.19	2.82	126053.74	0.34	241514.75	0.38	12557.23	0.75	1346934.33	2.33
MD	0.00	0.00	720.02	3852279.53	1.57	125081.85	0.75	240339.82	1.05	12478.49	0.28	1337810.25	1.82
WDE	<0.000	0.00	122.67	4023239.21	4.29	126620.95	0.27	243306.72	0.84	12592.93	0.67	1351271.46	4.71
CE-001	0.00	0.00	2577.94	4007635.04	1.07	128006.77	0.49	244040.85	1.12	12791.44	1.14	1318806.08	1.12
LSC	0.00	0.00	951.04	4177594.42	7.60	127066.32	0.59	238579.41	0.86	12565.90	1.43	1368248.17	0.62
IE	<0.000	0.00	288.00	3964280.67	0.69	127780.88	1.41	242312.03	0.58	12597.26	1.35	1367582.12	2.06
MCM	0.00	0.00	2951.02	3876600.25	3.40	124644.78	1.46	329594.95	0.60	17098.31	1.67	1312500.58	2.05
MCS-001	0.00	0.00	1021.04	4093429.10	2.58	126525.02	0.89	240392.09	0.70	12626.96	0.39	1348726.13	3.12
UTS-001	0.00	0.00	3078.72	3916867.96	0.42	126495.66	0.26	242511.48	0.48	12516.19	1.33	1327625.79	1.75
UTS-002	0.00	0.00	3148.74	4028269.11	2.06	127337.05	0.49	241161.97	1.25	12586.92	0.80	1307407.29	1.19
UTS-003	0.01	0.00	4598.86	3939302.65	4.60	126462.94	0.20	238678.23	0.87	12490.17	1.60	1335740.59	1.59
UTS-004	0.01	0.00	7097.72	3684720.78	1.11	120882.97	0.70	231473.33	0.44	11940.70	0.71	1273666.92	1.45
Blank 1	0.00	0.00	927.70	3928414.00	1.31	126534.71	0.67	237636.19	0.95	12369.06	1.41	1310112.75	2.14
Blank 2	<0.000	0.00	176.00	3956907.23	2.60	126746.66	0.89	239232.49	0.38	12535.21	0.52	1379439.75	3.36
Hg 0.1 ppb	<0.000	0.00	78.67	3914410.36	6.34	124824.70	0.62	231967.96	1.32	12355.05	0.77	1354969.59	1.52
Blank 2	<0.000	0.00	180.00	4183167.23	2.50	126561.01	0.20	237598.86	0.54	12489.84	0.63	1368138.50	1.85
Blank 3	<0.000	0.00	167.67	3939331.19	1.98	124245.52	0.41	235122.10	0.66	12366.73	2.05	1318374.79	1.60
Env 100/1 ppb	0.93	0.01	531846.58	3800551.51	0.88	125407.76	0.74	233184.47	1.14	12477.49	0.13	1318184.00	0.92
Blank 1	0.00	0.00	1489.76	4051303.69	1.20	126714.33	0.36	236300.83	1.60	12500.51	0.47	1360214.33	4.47
Blank 3	<0.000	0.00	288.67	3903435.98	1.04	126262.80	0.56	234351.20	1.28	12318.69	0.16	1350733.71	2.78
S 5000/50 ppb	<0.000	0.00	280.00	3879029.42	2.81	123753.63	0.87	232470.04	0.86	12198.25	0.85	1357599.54	2.23
Blank 1	0.00	0.00	917.37	3872684.94	1.75	126101.70	0.83	234212.96	0.66	12365.06	0.53	1335161.71	1.23
Blank 2	<0.000	0.00	195.33	3799465.47	2.67	126974.84	0.74	234326.85	0.17	12527.20	1.61	1314364.50	2.30

	45 Sc (ISTD) [No Gas]		45 Sc (ISTD) [H2]		72 Ge (ISTD) [He]		72 Ge (ISTD) [No Gas]		72 Ge (ISTD) [H2]		103 Rh (ISTD) [He]		103 Rh (ISTD) [H2]	
Sample Name	CPS	CPS RSD	CPS	CPS RSD	CPS	CPS RSD	CPS	CPS RSD	CPS	CPS RSD	CPS	CPS RSD	CPS	CPS RSD
Blank 1	17724092.23	4.15	9511534.00	1.42	1338751.04	3.28	4479623.33	0.84	3742098.25	0.36	41509682.67	2.35	4916797.67	1.51
Blank 2	17211660.58	1.69	9145487.67	0.65	1157345.42	0.78	4346598.17	2.07	3632985.00	0.71	38093457.33	2.08	4472218.83	1.26
Blank 3	17401116.41	1.08	9316351.33	0.87	1136284.88	0.39	4405319.83	2.13	3633832.42	2.60	37567838.67	3.11	4414016.33	1.14
Blank 1	18217455.98	8.80	9016767.67	0.68	1141697.54	0.40	4453412.83	7.13	3551137.67	0.76	37744662.67	1.95	4401978.17	2.00
Hg 0.01 ppb	17167325.58	1.02	9210243.67	1.55	1130482.13	0.53	4342029.33	3.35	3530850.33	1.66	37580690.67	2.06	4222503.33	0.54
Hg 0.05 ppb	17448390.58	1.87	9199999.00	0.35	1142103.29	0.44	4393248.33	0.76	3603575.83	2.15	38688292.00	3.87	4269347.83	2.21
Hg 0.1 ppb	17468968.91	0.47	9040254.67	1.31	1104654.96	0.73	4301294.50	0.66	3539822.67	1.98	38028272.00	1.79	4236792.17	1.15
Hg 0.5 ppb	17834174.32	6.90	9011437.67	2.48	1133871.79	0.75	4296629.50	4.32	3561954.25	2.10	37537177.33	1.84	4184451.83	2.40
Hg 1.0 ppb	17432102.66	1.56	9052289.67	0.83	1132706.88	0.32	4314423.83	1.53	3595600.50	1.54	38601429.33	1.64	4213081.92	1.93
Blank 1	17438300.16	3.12	9241975.67	1.33	1153417.83	0.54	4453172.33	4.77	3603276.75	2.07	38737838.67	3.16	4253174.50	1.23
Blank 2	17490460.99	0.77	9045960.00	2.17	1148220.87	0.11	4469716.17	2.48	3627551.83	3.60	39486426.67	4.05	4284003.17	2.47
Blank 3	17926062.23	0.63	8895627.00	3.28	1136575.92	0.28	4345011.17	0.69	3527560.50	0.87	38240813.33	1.21	4244381.33	0.98
Env 1/0.01 ppb	17426223.07	3.00	8919197.33	1.88	1128487.42	0.36	4234300.83	0.88	3518588.17	2.91	39132725.33	1.21	4184033.17	2.71
Env 5/0.05 ppb	17100783.91	3.03	8735757.67	0.76	1115584.96	0.29	4161632.58	3.77	3486138.33	1.08	38659440.00	0.66	4033450.00	1.27
Env 10/0.1 ppb	17481998.91	2.80	9000485.33	0.48	1132244.54	0.62	4427587.00	1.67	3569530.92	1.44	38664858.67	1.38	4196437.83	3.06
Env 100/1 ppb	17332985.16	2.21	8915199.33	2.13	1131154.83	0.15	4307065.83	2.01	3537679.25	0.51	38542176.00	0.79	4080608.67	1.84
Env 1000/10 ppb	17537060.16	4.04	9147653.33	1.83	1139902.04	0.68	4242957.75	2.02	3617482.92	0.93	39884049.33	0.57	4192302.92	3.53
Env 10000/100 ppb	17140192.66	1.35	8934272.00	3.51	1094064.04	3.92	4256520.00	3.70	3609009.08	2.34	35901068.00	6.19	4196961.08	2.24
Blank 1	17110040.16	2.55	9288949.67	2.02	1152618.96	0.85	4215496.58	1.11	3590466.25	2.36	39360544.00	1.27	4281857.08	2.95
Blank 2	17185321.83	3.81	9181967.67	0.96	1145666.71	0.59	4362661.17	1.39	3654917.33	0.25	38829038.67	0.55	4345398.33	4.25
Blank 3	17564550.57	3.19	9161187.67	2.37	1135186.00	0.60	4321926.50	1.06	3548695.25	2.45	39976642.67	2.77	4279711.17	1.75
S 100/1 ppb	17475523.91	1.47	9165518.33	4.75	1138568.17	0.93	4220979.25	2.37	3612946.92	0.75	39579636.00	1.37	4142422.58	2.10
S 1000/10 ppb	17384708.49	0.53	9174138.67	1.47	1115349.54	0.80	4163556.25	1.28	3507173.50	3.80	38527620.00	1.42	4208319.00	1.00
S 5000/50 ppb	17399645.99	1.19	9223152.67	1.55	1124210.29	0.81	4340346.00	1.77	3634181.33	2.48	38660265.33	1.51	4222974.33	0.88
S 10000/100 ppb	17307798.91	2.34	9272458.67	1.88	1139492.96	1.89	4273400.67	1.64	3607214.58	2.86	39389137.33	5.47	4426211.83	2.10
Blank 1	17390946.41	2.24	9220987.33	2.63	1147540.50	1.43	4364248.50	2.55	3608610.25	3.11	39025164.00	1.95	4392975.67	3.03
Blank 2	17593868.90	2.17	9257217.00	1.37	1150725.50	0.30	4444082.67	2.88	3787308.67	0.98	39790888.00	1.65	4350370.67	3.57
Blank 3	17353325.16	0.75	9192753.00	2.63	1138899.59	1.16	4215977.58	1.79	3712788.75	2.19	39916665.33	0.79	4350789.33	0.48
Millq neat	13728322.71	2.62	8500847.17	3.10	1250035.33	1.19	4479094.33	2.03	4055032.25	3.20	38972160.00	2.81	4980024.67	2.48
Nitric HCL Matrix	17020655.58	1.11	9263797.00	2.11	1136977.05	0.28	4243246.25	2.26	3688364.17	1.26	38946301.33	2.28	4385020.00	1.59
SC-002	16480573.92	3.92	8503428.67	0.31	1002975.79	0.52	4001675.17	1.83	3282068.25	3.91	34496950.00	2.39	3535170.08	2.16
SC-001	15986614.76	1.72	8468948.17	3.22	987788.67	0.53	4101516.17	3.21	3135271.50	1.80	34109394.67	1.36	3450849.83	2.03
MC-2-002	15354844.36	4.78	8074626.17	2.42	990660.15	0.49	4064965.50	3.14	3304399.33	0.45	31728514.67	0.45	3248502.08	4.65
MC-2-001	15404383.11	2.13	8233454.17	2.22	996262.44	0.67	3980129.42	0.57	3300312.00	0.61	32093311.33	0.59	3152562.42	2.89
MC-001	16027651.85	2.46	8507385.00	1.53	972374.96	0.15	3986958.58	1.84	3215922.50	1.94	34395020.00	4.08	3396520.67	2.30
MC-002	17984658.48	2.50	9717044.33	3.36	1127678.08	0.29	4431482.33	1.88	3669572.08	0.74	39561726.67	0.87	4765952.83	3.63
MC-003	16051448.51	0.79	8370169.67	2.95	965908.06	0.38	4022162.67	1.43	3224994.50	0.64	34104594.67	2.78	3378567.83	2.99
MC-004	15799542.68	1.62	8084287.33	0.80	963751.85	0.60	3926265.25	1.18	3142150.25	2.65	34500668.00	2.45	3339679.00	2.82
MC-005	15778249.35	2.54	8138049.00	1.05	946851.87	0.67	3990469.50	3.67	3150225.25	2.19	33489942.00	1.61	3329682.00	4.50
MC-006	15647032.68	1.41	7905970.17	1.74	946167.98	0.60	4026539.25	2.85	3182176.67	2.03	33368446.00	2.25	3397044.00	2.51
CC-001	15364934.77	1.28	8095614.50	3.13	923254.96	0.36	3825414.25	1.38	3057910.33	0.96	31755665.33	3.49	3193963.58	2.84
CC-002	14838320.61	1.15	8159245.50	2.50	926407.75	0.27	3796991.25	2.25	2978854.33	2.30	32355864.67	2.58	3131783.17	3.11
CC-003	14766892.28	1.36	7982469.00	1.58	910986.90	0.09	3738125.42	3.43	3026058.58	2.71	31790138.00	3.14	3086979.92	0.23
UT-001	14859772.69	3.10	7881900.17	3.89	910400.96	0.49	3675315.92	1.92	2970829.08	2.74	32315501.33	1.31	3129532.58	0.91
UT-002	14699993.12	1.71	8022613.33	1.20	899777.81	0.48	3795981.25	1.64	3055667.25	1.17	31846190.67	2.53	3079704.58	0.90
UT-003	14796091.45	2.77	8073251.83	1.84	915228.46	0.38	3636745.33	1.20	3074459.17	1.22	32627706.00	1.18	3230863.42	0.15
UT-004	14303244.79	0.40	7687341.83	2.86	854794.44	0.02	3763229.92	4.10	3001833.42	0.63	31117217.33	1.59	3103519.50	5.71
UT-005	14323028.12	2.12	7740978.67	1.23	895067.34	0.37	3612747.00	1.15	2959514.08	1.17	32321386.67	2.41	3089387.58	2.09
UT-006	14680963.95	3.21	7772960.83	0.81	887953.62	0.23	3793480.42	3.21	2920683.92	2.68	31601082.00	1.26	3225943.42	1.17
UT-007	14021146.46	2.05	7762217.00	0.84	870994.67	0.39	3685896.42	2.40	2915749.17	2.13	30380244.67	1.56	2935088.33	2.83
UT-008	14024602.70	2.67	7565618.00	0.95	823120.27	0.54	3595962.42	0.39	2814760.83	0.97	30366462.67	1.90	2963090.42	1.61
Blank 1	15788776.85	2.13	8735300.00	1.28	1017353.13	0.90	3975753.00	1.70	3349709.58	3.86	36111800.00	0.85	3754109.67	2.30
Blank 2	15890993.10	1.83	8533620.33	2.02	1015400.23	1.20	3959786.08	3.51	3376875.58	1.80	35807233.33	2.58	3759605.50	2.05
Hg 0.1 ppb	15952926.84	0.12	8718934.00	1.55	968492.35	0.55	3896447.58	1.89	3420839.92	0.66	35229125.33	1.71	3762641.17	0.61
Blank 2	15860443.52	2.93	8777109.67	2.37	1017377.19	0.99	3976137.67	0.82	3421388.17	2.95	36082846.67	1.18	3775883.25	2.14
Blank 3	15640716.43	1.67	8643226.00	2.37	1024568.54	4.10	3900775.92	1.34	3411269.42	1.82	36092084.00	5.83	3821785.67	2.24
Env 100/1 ppb	15692519.35	1.40	8532121.17	2.76	1014148.54	1.19	3802473.83	3.71	3380065.83	0.55	35524504.00	0.54	3742385.50	1.28
Blank 1	15661413.52	1.48	8647807.00	1.74	1014441.75	0.39	3875911.92	3.05	3394870.17	1.72	35765948.00	0.39	3769288.33	2.60
Blank 3	15560667.27	0.33	8523625.83	2.85	994755.44	0.26	3786555.08	1.76	3308387.08	2.09	34387533.33	0.95	3820791.25	2.20
S 5000/50 ppb	15865647.68	3.72	8805968.67	2.18	995396.52	0.31	3801463.83	1.75	3394620.83	2.85	34884870.67	1.56	3882081.75	1.73
Blank 1	16068928.51	0.76	8920155.00	2.52	1020411.69	0.64	3855953.25	2.06	3433999.25	2.61	36042796.00	1.36	3848112.92	1.19
Blank 2	15868626.85	2.58	8893295.00	3.33	1025171.73	0.93	3931122.67	2.41	3428615.92	1.62	36221529.33	1.12	3988960.75	2.17
Blank 3	15843519.76	0.17	8660924.33	0.67	1002359.42	0.86	4001723.17	1.66	3413512.50	0.39	34569621.33	1.72	3783682.00	3.00
Millq neat	13151256.05	1.96	8222752.00	0.49	1125750.79	0.61	4150042.08	0.47	3895474.75	2.09	35948501.33	3.35	4399675.33	1.48
Nitric HCL Matrix	15694863.10	3.60	9134410.67	2.41	1033710.04	0.84	3943819.25	1.53	3506326.00	4.10	36452238.67	2.88	3976451.42	1.29
UT-008-RUN 2	14664199.36	3.05	7935870.17	0.62	849263.96	0.22	3741876.58	3.12	2928659.33	1.17	31558246.00	4.20	3204483.92	3.37
DM	15917728.93	1.27	8774777.67	1.49	1019876.79	0.33	4064340.25	0.13	3465751.33	1.69	35818332.00	0.83	3853242.33	2.74
SCM	15775627.26	1.38	8824958.00	1.55	1033194.21	3.62	3947426.25	2.66	3522526.00	2.55	35546593.33	1.30	3865123.50	2.16
MCM-001S	15717666.43	0.55	8568559.33	0.91	1009869.06	0.96	4007831.00	3.57	3459321.08	0.96	34359353.33	2.11	3793417.25	3.13
MCM-006SX	15972432.26	1.62	8956593.33	3.05	1004996.85	1.21	4009081.50	1.40	3481054.08	0.82	35419989.33	3.02	3943215.33	2.92
MTH	16315152.67	1.22	8927234.33	0.88	1011659.25	0.39	4053375.08	3.69	3601282.92	2.54	36188650.67	0.70	3983674.42	2.53
SKM	15973107.68	2.50	9185507.33	2.56	1035737.52	0.52	4006147.75	2.69	3523772.17	2.10	36198922.67	1.83	4057631.17	2.34
MD	15993050.59	1.03	8996279.33	1.33	1004400.17	0.76	4003454.50	2.66	3459271.33	1.89	35580657.33	1.53	4012147.50	0.19
WDE	16050891.84	1.73	8952054.00	1.90	1031831.11	0.30	3941943.58	1.37	3516793.67	2.41	35744836.00	1.24	4022353.92	2.15
CE-001	16030711.01	3.05	8847487.00	2.94	1023560.27	0.29	4008408.17	3.21	3536782.08	2.43	35421794.67	0.77	4002255.25	1.55
LSC	15827351.43	2.73	8937437.00	1.44	1010210.92	0.94	3928766.08	2.77	3473178.33	1.19	35334877.33	2.91	4045906.92	1.52
IE	16416058.50	1.90	9198958.00	2.91	1028614.25	1.29	4025385.00	2.04	3574615.25	1.68	36181064.00	1.98	3961586.75	1.91
MCM	15701378.52	0.22	8817170.33	0.74	1020327.48	0.15	3915107.67	3.10	3503983.33	4.50	35500762.67	1.69	3826234.67	1.29
MCS-001	15760888.93	2.42	8772279.33	0.70	1018902.73	0.41	3880096.00	4.88	3468243.58	1.19	36167489.33	3.23	3910293.17	3.26
UTS-001	15910419.34	0.28	9120626.33	1.01	1022874.67	0.51	3895052.92	1.38	3586329.08	0.56	35735908.00	0.44	3829218.08	1.27
UTS-002	16021097.26	2.28	9025721.00	0.39	1019766.25	0.73	3944348.25	1.97	3495958.08	1.45	36055390.67	0.07	3949967.08	3.25
UTS-003	15954516.01	1.86	8996487.67	2.28	1014443.52	0.37	3901112.58	0.16	3504830.67	1.49	35405846.67	1.95	3940964.58	4.03
UTS-004	15452174.35	1.72	8682537.33	0.99	976825.10	1.23	3835561.83	1.86	3344874.42	0.95	33997499.33	1.81	3644404.42	1.35
Blank 1	15857702.27	2.92	9037381.33	0.40	1019029.00	1.31	3883799.17	1.48	3459819.58	1.64	35707933.33	2.06	3923482.92	1.73
Blank 2	16042787.68	0.64	9011396.00	3.96	1026146.77	1.03	4004560.67	5.06	3574366.08	2.10	35412918.67	0.59	3993723.75	1.81
Hg 0.1 ppb	15895720.60	0.90	9144238.67	2.82	999377.33	4.31	3868217.00	1.00	3557866.83	2.51	36516905.33	5.67	3898359.58	3.29
Blank 2	15950701.85	1.16	9097015.00	2.50	1043935.90	3.17	3941606.92	2.44	3614043.50	1.93	36224936.00	3.37	4070088.25	1.79
Blank 3	16112388.93	1.60	9053081.00	1.62	1016542.60	0.82	3973396.33	3.59	3486985.75	2.30	35366721.33	0.27	3999114.75	1.55
Env 100/1 ppb	16084858.51	0.75	9001859.67	1.40	1010552.23	0.46	3921840.67	1.58	3526613.42	2.71	35843004.00	1.36	3948606.25	3.13
Blank 1	16174640.59	0.64	9166684.33	1.42	1025537.35	0.76	4109643.83	1.37	3585830.58	2.22	35419421.33	2.24	3989484.17	2.88
Blank 3	15934612.68	1.26	9264754.67	4.09	1008739.64	1.27	3838928.33	1.19	3504431.92	0.54	35183036.00	2.37	3946198.67	2.38
S 5000/50 ppb	15525906.44	0.77	8968503.00	3.16	989059.85	0.87	3833397.58	2.08	3476667.67	3.34	35324297.33	0.75	3864390.75	2.43
Blank 1	16059235.18	1.32	8972167.67	0.60	1008080.69	0.80	3864465.83	2.14	3506525.42	2.08	35613588.00	2.47	3956980.83	0.49
Blank 2	15888649.35	2.64	8802220.67	1.39	1015994.23	0.74	3906883.75	2.41	3547897.67	1.76	34881154.67	1.41	4027483.17	1.72

	115 In (ISTD) [He]		159 Tb (ISTD) [He]		175 Lu (ISTD) [He]		209 Bi (ISTD) [He]	
Sample Name	CPS	CPS RSD	CPS	CPS RSD	CPS	CPS RSD	CPS	CPS RSD
Blank 1	15202569.67	6.29	65240796.00	2.16	46894114.67	2.82	65710424.00	4.92
Blank 2	13020512.33	1.05	59134534.67	0.91	40900701.33	2.29	55382025.33	1.17
Blank 3	13012622.67	2.84	59228148.00	0.72	41824036.00	1.07	55472118.67	1.41
Blank 1	13129108.67	3.27	59811942.67	1.81	41348346.67	2.37	55107880.00	1.27
Hg 0.01 ppb	12959256.00	3.77	59502806.67	1.90	42643304.00	2.41	56112318.67	0.38
Hg 0.05 ppb	13098918.67	1.58	60732516.00	0.42	43135352.00	2.58	56108932.00	2.88
Hg 0.1 ppb	12788362.33	1.43	59607457.33	1.19	42768792.00	1.78	55602360.00	0.52
Hg 0.5 ppb	12934490.00	2.85	60243574.67	2.91	41654030.67	1.12	55797294.67	2.12
Hg 1.0 ppb	13182968.33	2.10	61337145.33	2.73	43071600.00	1.45	57146990.67	1.61
Blank 1	13543877.67	1.94	59776354.67	1.84	43221736.00	1.52	55954206.67	3.45
Blank 2	13533686.33	1.52	60748537.33	1.83	43514694.67	2.22	56983737.33	1.52
Blank 3	13394188.33	3.05	63080916.00	2.69	43866046.67	0.96	57273421.33	1.50
Env 1/0.01 ppb	13191351.00	1.57	61073410.67	1.48	42923134.67	2.76	57623089.33	1.38
Env 5/0.05 ppb	12945777.33	1.81	60360364.00	1.78	42919853.33	2.19	56716482.67	1.24
Env 10/0.1 ppb	13369368.00	2.60	60315074.67	0.74	42775188.00	1.55	57796562.67	1.73
Env 100/1 ppb	13629023.00	3.89	60761840.00	3.59	43729620.00	2.34	57647638.67	2.76
Env 1000/10 ppb	13351999.00	1.00	61375117.33	1.64	44276661.33	0.89	57139190.67	0.80
Env 10000/100 ppb	12559390.33	5.41	57364153.33	6.85	41003382.67	7.01	53025053.33	4.51
Blank 1	13826544.67	1.12	61620394.67	1.31	43847850.67	1.18	56121872.00	1.06
Blank 2	13379230.00	1.11	62643461.33	3.46	43306798.67	2.66	57461224.00	2.10
Blank 3	13467389.00	1.10	61685408.00	1.22	44889418.67	1.47	58549165.33	3.60
S 100/1 ppb	13609298.33	1.57	61618342.67	2.78	44571352.00	2.89	59031072.00	2.75
S 1000/10 ppb	13460101.67	2.97	61322677.33	1.53	43107652.00	1.81	57414854.67	2.43
S 5000/50 ppb	13547603.33	0.96	62971438.67	0.94	44153538.67	3.14	57183813.33	2.28
S 10000/100 ppb	13384982.67	3.36	61030789.33	2.79	43031460.00	1.81	57087310.67	1.57
Blank 1	14181427.33	2.48	65485126.67	4.88	45927528.00	2.40	58022820.00	2.98
Blank 2	13987137.67	2.37	63248480.00	1.39	45549801.33	2.06	58258334.67	1.10
Blank 3	13445527.33	1.12	61997590.67	1.34	44139369.33	2.89	58813152.00	2.39
Milq neat	13811313.00	8.46	58045556.00	10.76	41645796.00	8.86	26334307.33	1.91
Nitric HCL Matrix	14253751.33	2.63	61976525.33	1.67	43970746.67	1.65	57662936.00	2.24
SC-002	11747714.33	1.74	57752058.67	1.81	42079384.00	1.49	51955314.67	2.04
SC-001	11824860.00	3.15	57630829.33	1.13	40520088.00	0.59	50310549.33	1.78
MC-2-002	11343355.67	3.08	54363577.33	0.51	39404234.67	0.82	48400896.00	1.35
MC-2-001	10938504.00	2.06	54269568.00	2.39	38095105.33	0.68	48283170.67	2.24
MC-001	11560219.00	2.01	58420486.67	2.13	41420273.33	1.36	53752320.00	3.25
MC-002	14145100.67	0.63	64282854.67	2.16	45419704.00	1.11	59125454.67	1.65
MC-003	11584874.67	1.42	57772845.33	1.52	40476552.00	1.24	52271965.33	0.94
MC-004	11469978.00	1.66	56092488.00	1.46	39985714.67	0.69	53500972.00	1.64
MC-005	11527070.00	0.97	55558810.67	1.43	39798896.00	3.05	51931186.67	0.51
MC-006	11343301.00	2.32	55722940.00	0.62	40256788.00	0.63	52033314.67	2.14
CC-001	11009129.67	1.09	55345792.00	1.99	38565153.33	1.79	49672289.33	1.02
CC-002	11321549.00	0.89	56089993.33	1.28	39544402.67	1.89	50121236.00	1.75
CC-003	11046497.00	0.90	54364353.33	3.57	38959118.67	0.43	49962700.00	0.86
UT-001	10892972.33	0.92	54359029.33	1.28	38711082.67	0.35	49640417.33	1.26
UT-002	10699559.67	2.06	53819641.33	2.64	37782737.33	1.23	49077614.67	1.14
UT-003	11002226.00	0.93	53748580.00	0.57	38394338.67	0.08	51101128.00	2.57
UT-004	10668164.33	2.20	52931548.00	2.77	37106288.00	1.21	50164169.33	3.23
UT-005	10888151.00	1.25	53196613.33	1.64	37591712.00	1.10	50057446.67	1.02
UT-006	10865577.00	2.01	53479305.33	1.24	37766206.67	0.89	48976638.67	2.40
UT-007	10599291.67	0.57	51559937.33	2.02	36803080.00	1.68	48448904.00	2.59
UT-008	10652220.00	1.69	52913032.00	1.18	37874994.67	3.40	49448926.67	0.73
Blank 1	12358471.00	1.93	57836917.33	1.55	41300372.00	1.54	53692158.67	0.87
Blank 2	12028244.67	0.06	56864346.67	0.24	40132857.33	1.88	54494889.33	1.72
Hg 0.1 ppb	11971262.00	0.31	56835028.00	2.60	39648066.67	1.80	54788929.33	1.93
Blank 2	12438740.00	1.45	57814637.33	1.44	41285973.33	2.27	55373504.00	1.29
Blank 3	11992301.67	0.66	56462205.33	0.67	40028330.67	0.54	54259681.33	2.58
Env 100/1 ppb	12286256.33	0.81	56563697.33	1.26	39499254.67	1.79	54948494.67	1.85
Blank 1	12042326.00	2.39	56729764.00	1.86	41079918.67	1.91	54252732.00	3.45
Blank 3	12123910.33	0.58	57176252.00	1.56	40015546.67	3.37	54606202.67	3.67
S 5000/50 ppb	12214260.67	3.60	56919722.67	0.95	40120130.67	0.20	54305937.33	1.87
Blank 1	12417974.33	0.54	56288378.67	2.42	39816285.33	2.94	53814053.33	2.42
Blank 2	12421590.33	1.10	57956813.33	0.40	40384176.00	0.99	53777113.33	1.54
Blank 3	12383127.33	2.56	56853428.00	1.91	39487333.33	0.80	54073994.67	3.85
Milq neat	12265709.67	9.43	53885106.67	9.74	39887352.00	9.59	24786713.33	5.47
Nitric HCL Matrix	12373155.00	1.00	57299082.67	0.90	41455518.67	1.70	54811426.67	2.51
UT-008-RUN 2	10983542.00	0.97	52812537.33	2.53	37610426.67	2.74	49741636.00	3.24
DM	12395071.33	0.81	56980309.33	1.44	40642065.33	0.95	54757909.33	1.51
SCM	12064242.67	2.59	55387864.00	0.73	39159765.33	2.93	54659110.67	0.65
MCM-001S	12058105.67	2.15	55391908.00	3.38	39448172.00	2.36	52795408.00	3.60
MCM-006SX	12405810.67	3.32	58152372.00	2.57	41164116.00	2.11	54810516.00	2.53
MTH	12475724.00	2.89	56941505.33	2.76	40842129.33	1.34	56113226.67	0.69
SKM	12497366.33	0.97	57638198.67	2.11	40550669.33	1.84	55602661.33	0.52
MD	12357704.00	1.66	58047720.00	0.65	40969173.33	2.69	55615722.67	2.85
WDE	12407399.33	0.95	57380785.33	1.82	41449817.33	0.58	54985194.67	4.10
CE-001	12507941.33	2.24	58710494.67	0.99	41100364.00	3.77	55033750.67	3.67
LSC	12041285.33	1.81	58399090.67	1.33	41175054.67	0.97	54795274.67	0.34
IE	12314912.00	2.75	57849888.00	0.84	40477069.33	2.45	55129288.00	2.21
MCM	12301324.00	2.94	56287321.33	2.33	40312421.33	2.88	54660560.00	2.33
MCS-001	12471943.67	2.09	57509382.67	1.26	41507812.00	1.66	55988788.00	2.85
UTS-001	12191029.67	2.54	57960420.00	1.77	40323133.33	3.95	55472361.33	0.47
UTS-002	12452711.67	2.55	58159241.33	0.57	40371334.67	4.39	55938481.33	2.23
UTS-003	12145936.33	2.26	56338042.67	2.63	40327970.67	2.19	54437445.33	1.05
UTS-004	11834887.00	3.25	55015318.67	1.41	39062957.33	1.59	54370332.00	2.02
Blank 1	12246259.00	1.99	57990132.00	1.29	40108961.33	1.72	54618053.33	1.01
Blank 2	12330144.00	2.62	57452457.33	4.22	40733748.00	2.03	54812873.33	1.96
Hg 0.1 ppb	12193933.33	3.75	56911686.67	1.65	39664825.33	2.27	53949978.67	2.06
Blank 2	12328719.67	1.43	56696894.67	3.64	40362005.33	4.05	52943486.67	1.31
Blank 3	12411289.67	2.30	56796117.33	1.95	40527865.33	1.38	56139768.00	2.06
Env 100/1 ppb	12160072.33	0.68	56565413.33	0.65	40205882.67	1.32	55161213.33	2.78
Blank 1	12181440.67	0.59	57074481.33	2.78	40055572.00	2.70	53159646.67	2.20
Blank 3	12038161.67	0.99	57209897.33	1.91	40337588.00	1.16	55835814.67	1.61
S 5000/50 ppb	12193057.00	2.42	56620348.00	0.10	39701106.67	2.26	53725114.67	2.18
Blank 1	12036847.33	1.71	56826213.33	0.63	39830396.00	2.45	54358601.33	3.25
Blank 2	12050764.00	0.87	56571288.00	1.88	39920925.33	1.35	54321113.33	1.59