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Impacts of Coal Resource Development on Surface Water Quality in a Multi-jurisdictional Watershed in the Western United States

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Abstract: This study focuses on water quality and quantity impacts from natural resource development on watersheds originating on Crow tribal lands in southeastern Montana. Field research analysis will focus on the surface water quality in three adjacent watersheds. This study will determine impacts to water quality from reclaimed coal mine spoils surface runoff and produced water discharge from coal bed methane wells within the watersheds. A secondary research objective is to determine a baseline assessment of surface water in watersheds prior to proposed mine development, particularly on tribally owned and allotted tracts. Historical data from state agencies will also be compared to data collected within watersheds on tribal lands. Water quality impacts from mining development may be more pronounced than that of coal bed methane as the reclaimed mining sites have demonstrated lasting impacts on the nearby surface water quality in the study area. Historical and current samples have demonstrated increased sodium absorption ratio and sodium levels downstream of a mine site in a tributary to the primary watershed. A sample from a pond in another reclaimed mine site contained the highest sodium adsorption ratio levels of all surface water samples. Coal bed methane development impacts may have been transient in the primary watershed surface water based on sample results. Historical oil and gas development appears to be impacting surface water quality within the southernmost watershed. Analysis has shown the increasing degradation of water quality in watersheds downstream and across the state boundary of Montana into Wyoming where natural resource development has occurred.

Keywords: *water quality, water resources, coal mining, sodium absorption ratio, coal bed methane, tribal land, Powder River Basin*

This study assesses the impact of coal mining and coal bed methane (CBM) development on surface water quality. The headwaters of our study watersheds are located within the boundaries of the Crow Indian Reservation. Part of the motivation for this study is to provide baseline, surface water quality data in advance of potential CBM or other coal mining activities proposed for the area; specifically, the Crow Reservation in Montana, on tracts owned by the tribe and individual tribal members. The sampling area will extend beyond the reservation to include areas with current gas extraction as well as reclaimed coal mines.

Another motive for completing this study is that the impacts on the reservation are understudied in terms of policy and water quality impacts. The watersheds represent a unique regulatory regime as they lie within the jurisdiction of the Crow Tribe and the states of Montana and Wyoming. The policies from each jurisdiction are rarely assessed together in regard to the overall impact on the water management and resulting water quality of the watershed.

The Montana Bureau of Mines and Geology (MBMG) completed a water quality study when coal mines were initially developed in the Tongue River Basin during the 1970s (Hedges et al.

1998). Specific sampling sites were chosen that coincided with sites previously sampled by the MBMG in September 1977 on Youngs Creek and September 1972 on Little Youngs Creek (Hedges et al. 1998) to make a longitudinal assessment and determine if water quality has changed between the mid-1970s and 2016. Tanner Creek data represent samples collected in 1975. Analysis includes comparing the profile of these watersheds to adjacent watersheds that have experienced development.

Site Description and Background

During the time of the MBMG study, several coal mines were being developed east of the reservation boundary including the Decker Company mines in Montana and the Ash Creek Mine to the south in Wyoming (Figure 1). At the time, the Shell Oil Company had developed mine-project plans within the Crow Reservation boundary and submitted a mine permit application (USDOI BIA 1981). Additional data on coal aquifer locations and depths are in the final environmental impact statement of this permit application (USDOI BIA 1981), however, the majority of the surface water data were cited from the MBMG 1977 study. For this study, the Shell Oil plans for mine development were used to estimate the extent of mine development in the Tanner Creek and Youngs Creek watersheds.

The Cloud Peak Energy Company had identified three potential mine coal deposit tracts; Squirrel Creek, Tanner Creek, and Upper Youngs Creek project areas, based on the locations within the watersheds. Each tract lies entirely within the Crow Indian Reservation (Figure 2) and had a separate option to lease. The project area was referred to as the Big Metal Mine. The Department of Interior Bureau of Indian Affairs (BIA) has approved Cloud Peak's Exploration Agreement and Option to Lease Agreement with the tribe. In 2013, the tribe received $2.25 million upon signing the agreements and an additional $1.5 million upon the BIA approval of the agreements. The tribe was to receive approximately $2 million per year for the five-year option period (CPE 2013).

The Navajo Transitional Energy Company had purchased several mines from Cloud Peak Energy Company in 2019 after the company had filed for bankruptcy. Assets purchased from the bankrupt company include the Spring Creek Mine and the mining rights to the Big Metal Mine project. The current status of the Big Metal Mine project or any new exploration and lease agreement is unknown as of the end of 2019.

The coal layers within the basin located in the Tongue River Member of the Fort Union Formation lie shallow enough to the surface for coal strip mining development (Wheaton and Donato 2004). The active coal mines in this region of the Powder River Basin are developed as surface strip mines. The coal beds that were targeted by Cloud Peak and Shell Oil, i.e., those on the Crow Reservation, lie at higher elevations than the other regional mines. These coal beds outcrop throughout the target and study areas among the foothills and alluvial valleys of the study watersheds.

Proposed Coal-Related Development and Geology

Study sites are located in the larger Powder River Basin of Wyoming and Montana, which include both active coal-related fossil fuel extraction activities and undeveloped areas for which water quality can be compared. The coal beds within the Powder River Basin have been developed in this region of Montana and Wyoming. The Powder River Basin has supplied 40 percent of the domestic coal production (USEIA 2017). The active coal developments in Montana within the study area are the Decker and Spring Creek Mines (Figure 1).

The Ash Creek Mine was developed and mined through 1978 within a portion of Little Youngs Creek watershed in Wyoming (Figure 1). The mine was inactive after 1978 and the developed portion of 140 acres was later reclaimed in 1996. The Ash Creek Mine project area was amended to include a larger portion in Wyoming extending south and east to the Ash Creek watershed. The amended project was renamed Youngs Creek Mine and permitted in 2010 by Wyoming agencies including the state of Wyoming Department of Environmental Quality.

Powder River Basin CBM Reserves

A vast amount of CBM reserves are stored in coal seams throughout the Powder River Basin.

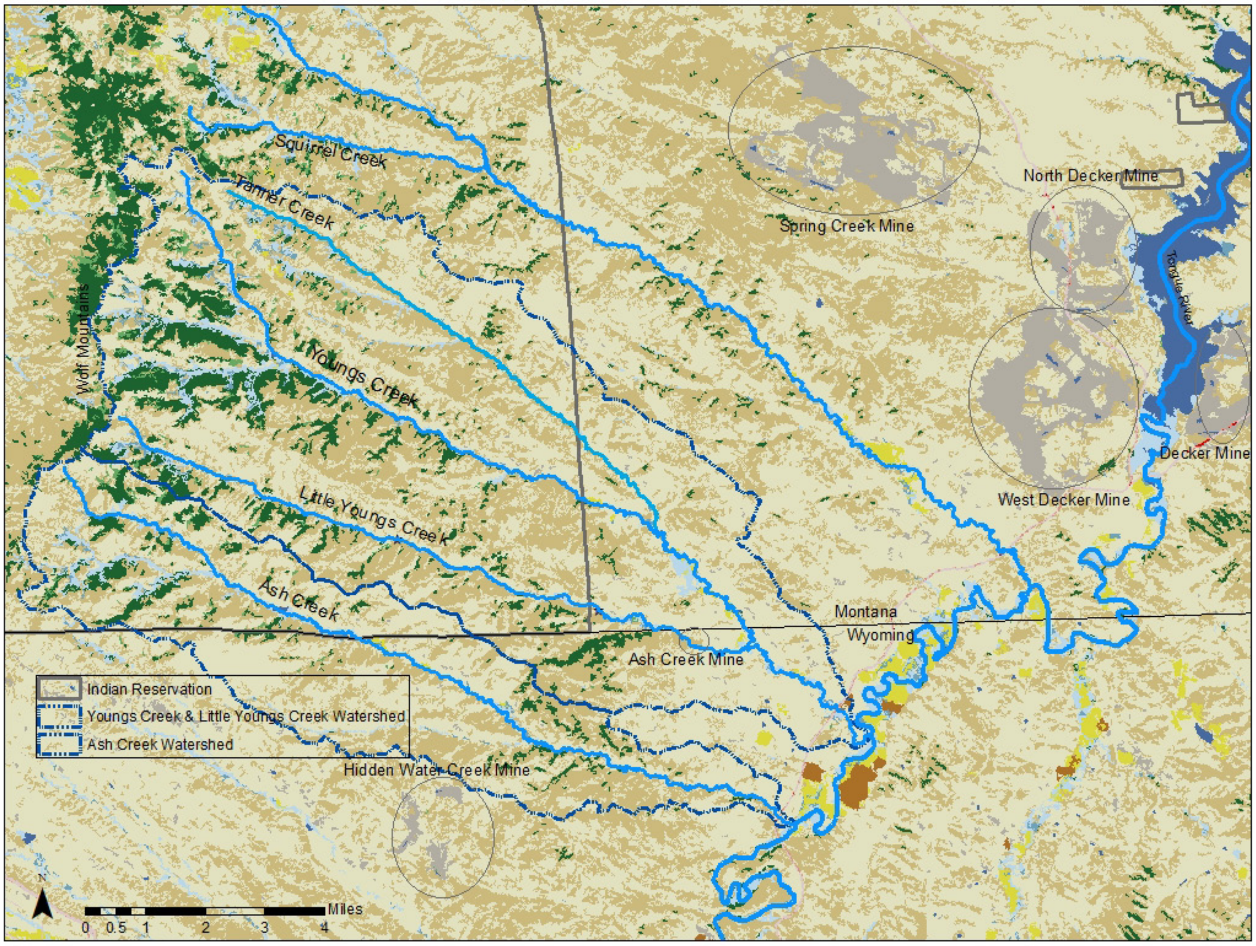

Figure 1. Study area watersheds and mine locations.

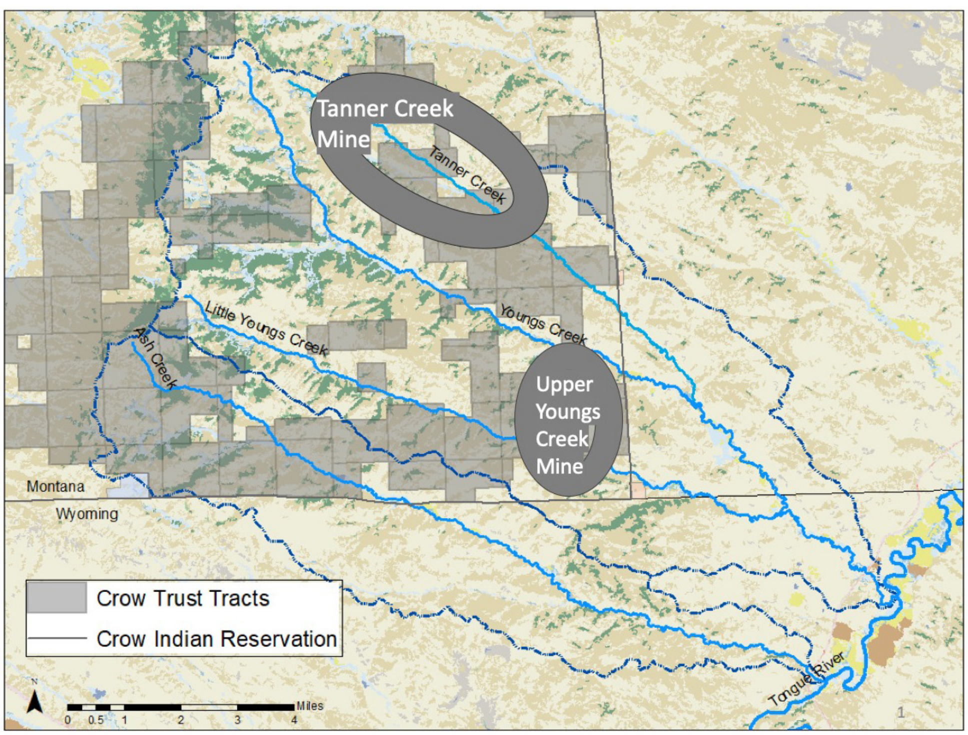

Figure 2. Potential coal mine sites.

Due to the geological setting, fewer reserves are located in Montana coal seams than in Wyoming. The Montana portion of the basin contains an estimated 0.86 trillion cubic feet (TCF) of CBM gas (Wheaton and Donato 2004), while the Wyoming portion of the basin had produced 4.18 TCF through 2010 within the Powder River Basin (USEPA 2010). In Montana, CBM development is limited to 19.3 kilometers (12 miles) north of the state line and between the Wolf Mountains to the west and the Powder River to the east. Active CBM development was located east of the Tongue River Reservoir as of 2017 but had previously extended to the Crow Reservation boundary (MDNRC BOGC 2017).

Background and Relevant BioGeochemical Processes: Coal Seam Aquifer Water Quality

Within the study area, coal bed waters will favor the dominance of the sodium cations. Bicarbonate will be the dominant anion with typical total dissolved solids (TDS) levels ranging from 1000 to 2500 mg/L. Depending on the flow influences present in the coal seam aquifer, levels of TDS will be highly variable. In order to release CBM, the coal seam aquifer is dewatered producing large volumes of produced water. The sodium adsorption ratio (SAR, described later) values of coproduced waters in Montana can be greater than 30. The dominance of sodium-bicarbonate waters associated with CBM coproduced waters is of particular concern in monitoring water quality in the study area.

In the study area, several processes occur in the coal seam, creating conditions for the generation of methane. These include the reduction of sulfate, removal of calcium and magnesium, and the increase in bicarbonate as the dominant anion (Lee 1981). These conditions allow for the biogenic production of methane in coal seams in this portion of the Powder River Basin (Van Voast 2003).

CBM Regulation: Sodium Adsorption Ratio

Coal bed methane produced waters are monitored using SAR as the primary indicator for water quality. SAR limits for the Tongue River are 3 for irrigation season and 5 during the rest of the year (ARM 17.30.670). The SAR of samples collected are calculated from the following equation (U.S. Salinity Lab 1954):

$$\mathrm{SAR} = \frac{\mathrm{Na}}{\sqrt{\frac{(\mathrm{Ca}+\mathrm{Mg})}{2}}}$$

where sodium (Na), calcium (Ca), and magnesium (Mg) are measured in concentrations of milliequivalents per liter.

The U.S. Environmental Protection Agency (EPA) produced an environmental impact report on CBM produced waters, listing the additional contaminants of potassium, sulfate, bicarbonate, fluoride, ammonia, barium, iron, arsenic, and radionuclides (USEPA 2010). However, the agency delisted CBM produced water from the agency regulation in 2014 (USEPA 2014).

Prior to 2010, operators were allowed to discharge produced water from CBM wells directly into stream drainages in Montana and Wyoming (MCA 82-11-175). In 2010, Montana prohibited the direct discharge of CBM produced water into stream drainages. Wyoming has separate produced water standards, and continued permitting direct discharge into stream drainages for beneficial use (USBLM 2003).

The Bureau of Land Management (BLM) considers aquifer waters with levels of TDS less than 10,000 ppm as 'useable water' within federal and tribal land (43 CFR pt. 3160). The EPA considers waters with the same TDS levels to be classified as underground sources of drinking water (USDW). All of the waters in the coal bed aquifers within the study watersheds would be considered USDW and usable sources. This classification as a useable water source may influence the BLM and state agencies regulation of CBM produced waters designated for beneficial use.

Climate and Land Use

The study region is considered semi-arid and receives relatively low levels of precipitation, ranging from 30 to 38 cm (12 to 15 inches) per year. Lands located on the Crow Reservation within the study area are largely uninhabited and primarily used for pasture and grazing lands. There are a few residences on fee lands located along Youngs Creek based on land records (Montana Cadastral 2017), site visits, and personal observation. The land topology is varied with foothills and creek drainages with increasing altitudes upstream to the northwest toward the Wolf Mountains.

Surface Water and Groundwater Quality

Initially, headwaters of a stream would have lower SAR levels, as the dominant cations in surface fed waters are calcium and magnesium (Davis 1984). SAR levels would increase with distance downstream as ground waters contribute increasingly to the stream flow. Groundwater contributing sodium dominated water would increase SAR in stream flows.

Where surface flow from precipitation as snowmelt dominates in the headwaters, TDS concentrations will be lower. Groundwater will contribute to stream flow further downstream thereby increasing TDS concentration (Hedges et al. 1998). TDS concentration will also be lower in streams during high flow rates.

Prior to any energy related development in these watersheds, surface waters were classified as calcium-magnesium bicarbonate type water (Hedges et al. 1998). This is consistent with streams that are surface water fed. Tanner Creek has more highly mineralized waters than Youngs and Little Youngs Creeks (Hedges et al. 1998). Youngs Creek and Little Youngs Creek have TDS concentrations ranging between 200 and 400 milligrams per liter (mg/L) (Hedges et al. 1998). The Tongue River has an average TDS concentration of 440 mg/L (Hedges et al. 1998).

Groundwater quality of the alluvium in Youngs Creek and Tanner Creek at the mouth of each stream represents higher TDS levels than surface water with TDS concentrations of 1500 mg/L (Hedges et al. 1998). By comparison, Little Youngs Creek alluvium contained less than 1000 mg/L TDS. Groundwater primarily contains sulfate anions in each watershed.

Historical SAR levels measured in the Tanner Creek and Youngs Creek watersheds are 0.4 - 0.5 and 0.1 - 1.0, respectively, during low flow periods (Hedges et al. 1998). CBM produced water discharges to surface waters are monitored to limit the resultant SAR level of the Tongue River. Waters with high SAR levels are limited from land application as sodium may damage soil and crops (Hanson et al. 1999). Analysis will focus on the SAR levels of samples as this served as the primary monitoring criteria and limiting factor for produced water discharge in all watersheds.

The primary objectives of the study are to determine impacts to water quality, if any, associated with reclaimed mines and produced water discharge or land application from CBM wells. Although there are potential impacts on groundwater, this study focused on surface waters due to difficulties in sampling groundwater. The study focuses largely on the Tanner Creek, Youngs Creek, Little Youngs Creek, and Ash Creek watersheds, with a few auxiliary sampling points outside of these watersheds. The tributaries draining the developed sites flow directly into the Tongue River.

Methods

Determining Sampling Points

Like previous studies (Hedges et al. 1998), sampling points have been based at locations that were generally accessible from nearby roadways, such as outlets of roadway culverts, stream crossings, and clearings in brush and tree covering. Sampling points were also located at the confluence of tributary streams, and at the mouth of each stream. Sampling points were generally located within roadway right of way areas. Our study was limited to surface water because groundwater was generally not as accessible. Sampling sites were chosen near MBMG 1977 sample sites.

Water samples in Youngs Creek, Little Youngs Creek, and Ash Creek were collected in September 2016. The September sample collection was scheduled to coincide with the 1977 MBMG study during the watershed low flow period. The majority of the Upper Tanner Creek watershed was found to be dry during this sample time with stream flow found at the lowest reach of the creek. There were a few bends in the creek with standing water in the lower most 3.2 km (2 mi) of the creek, above the confluence with Youngs Creek. Two ponds located near the headwaters of Tanner Creek were sampled in the month of June.

The water was sampled during a low flow period in September when runoff would be at minimal levels. The low flow rate would lead to higher expected overall TDS with less flow contribution from surface water that exhibits lower TDS. Youngs Creek was flowing through the entire stream length. Little Youngs Creek and Ash Creek were also flowing in the most upstream sampling sites to the downstream confluence sites.

Several sampling locations were selected based on proximity to prior resource development. Locations nearest the Tongue River Reservoir, immediately outside of the eastern edge of the North Decker Mine area were selected to target waters discharged from the mine site. One location near the reservoir displayed a State of Montana Department of Environmental Quality discharge permit number posted at the site of a discharge point. This point discharged directly into the Tongue River Reservoir through a culvert under Highway 314. Samples were taken from this outfall in April 2016.

Another sampling location was selected at the site of a reclaimed coal mine south of the Ash Creek watershed in the reclaimed Hidden Water Creek Mine in Figure 1. The site was developed with several coal mine pits across the drainage area that flows into the Tongue River south of Ash Creek. There is a pond located in one of the reclaimed pit areas. The standing water was sampled during a period of low flow in September. The pond did not appear to flow into a connecting drainage at the time of low flow.

These sampling locations were accessible in open, unfenced areas where signage is posted regarding the permit designation and reclamation status. The permit and reclamation status can be researched and tied to documentation of land use and water quality data. The samples taken in each watershed are indicated in Figure 3.

Because the area had been previously studied by both the oil and gas industry and the MBMG, there were many, readily accessible auxiliary data. For example, well logs and CBM well production data in Wyoming are available online at the Wyoming Oil and Gas Commission on the State of Wyoming website (WOGCC 2017). Additional data provided by MBMG include CBM well production and associated produced water, as well as locations of CBM infiltration ponds. CBM well production data are available from the Montana Oil and Gas Commission (MDNRC BOGC 2017).

Density of CBM Wells

The CBM wells in Montana and Wyoming were developed in clusters, typically each well targeting different coal bed formations. Wells were co-located and drilled primarily in the Dietz 1-3, Carney, and Monarch formations, and occasionally in the King and Roberts formations. Each well developed in a separate formation produces varying levels of gas and water. Some formations in co-located wells did not produce gas or water. The density of the CBM wells per section is outlined. There were also several dry wells listed in the CBM fields that are not included in this analysis.

Chemical Analysis

Parameters of water quality measured include major cations and anions. Cation and anion measurements detailed the geochemical signature of the stream waters. Water samples were collected at each location by grab sample, then filtered and preserved for analysis. Samples were analyzed at the Cornell University, Department of Biological and Environmental Engineering, Soil and Water laboratory. Anions were analyzed by ion chromatograph. Cations as dissolved metals were analyzed by inductively coupled plasma mass spectrometry. Samples collected in September 2016 were sent to a commercial laboratory in Montana to measure TDS.

Results

The results section focuses on the cation and SAR data, as the criteria were indicators for permitted CBM produced water discharged to stream drainages (ARM 17.30.670). Cation and SAR values for each watershed are listed in Tables 1-3. The density of CBM wells per section or square mile in Montana and Wyoming is shown in Figure 3 and outlined in the supplemental information. All of the wells in this area are listed as capped or inactive as of 2013 (MDNRC BOGC 2017).

Cation Levels/SAR/TDS

A spring above Tanner Creek within the watershed had the lowest total measured concentrations of all water samples and also exhibited the lowest levels of calcium, magnesium,

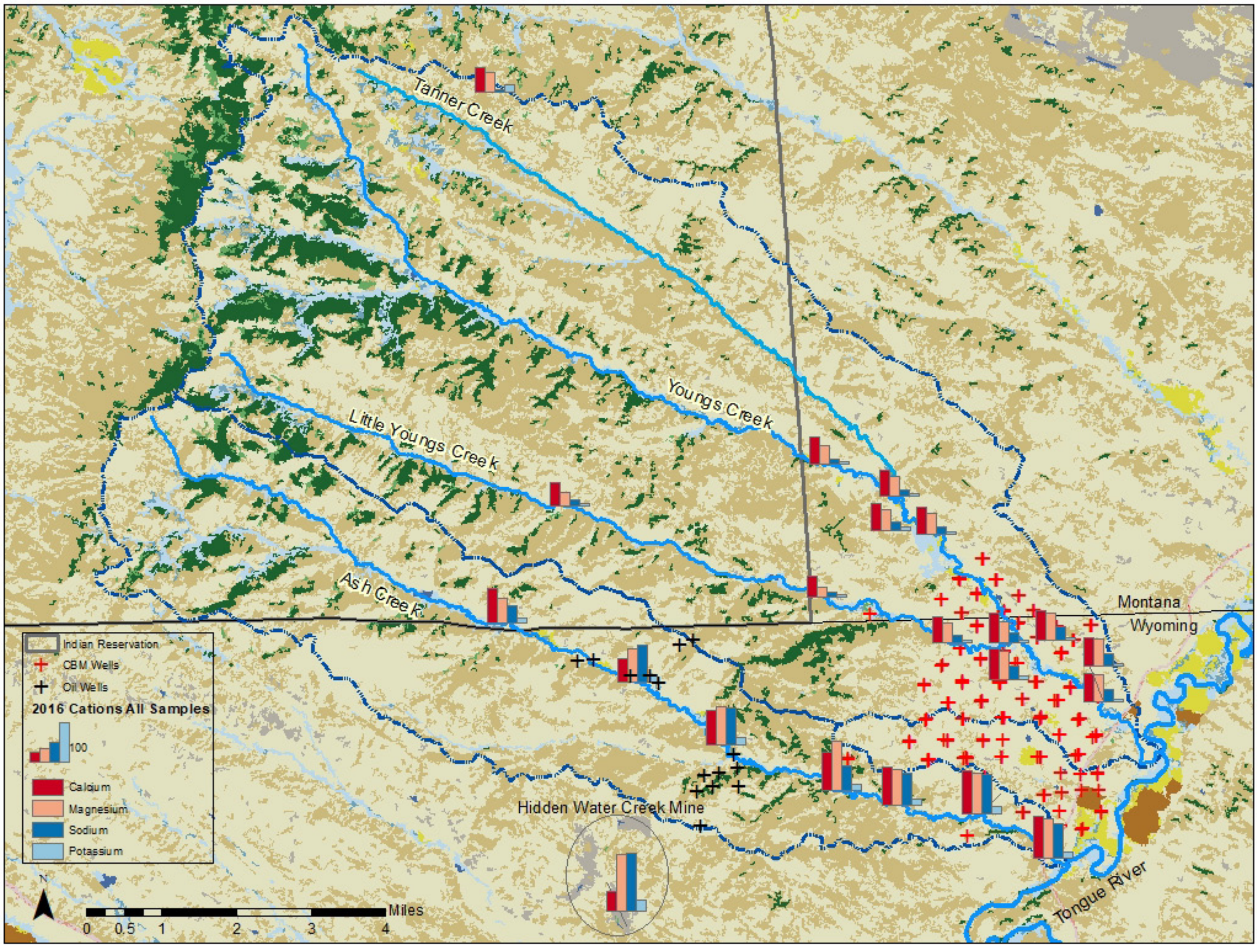

Figure 3. Surface water 2016 cation data with CBM oil wells and mines. The sample concentration value as indicated in the legend is scaled for 100 parts per million.

and sodium. The spring had a slight level of sulfate above 5 mg/L **(**Figure 3). A stock pond in the Tanner Creek watershed did not have sulfate present within the detection limit, and indicated higher levels of calcium, magnesium, potassium, and sodium than the spring pond. The stock pond and the headwaters of Tanner Creek were dry at the time of September sampling, supporting the idea that it is a surface water fed pond.

A pond in the reclaimed mine site of Hidden Water Creek showed elevated levels of sodium and magnesium and moderate levels of calcium. This sample had the highest SAR level of all collected samples, consistent with the presence of sodium, calcium, and magnesium. Measured SAR concentration levels for all samples are indicated in Figure 4.

There were four sampling sites on Youngs Creek that corresponded with the MBMG 1977 sites. On Little Youngs Creek, three sampling sites corresponded with the 1972 and 1977 sites. A paired t-test of sample data compared site-by-site indicates a slight decrease in SAR levels particularly in the Youngs Creek sites at p-value of 0.06 (Table 4).

Discussion

Comparison to MBMG Data: Changes in Land Use and Water Quality Since 1970s Data Collected

Just as the sampling points were generally accessible by roadway or more accessible due to natural features of the stream, these locations were also readily accessible to livestock grazing in adjacent pasturelands. In the summer months, livestock, mainly cattle, were found watering at

Table 1. Youngs Creek, Little Youngs Creek, and Ash Creek water quality results.

	Youngs Creek (n = 7)	Little Youngs Creek (n = 5)	Ash Creek (n = 8)
Sodium	12 - 36 mg/L	12 - 34 mg/L	45 - 105 mg/L
Chloride	2 - 3 mg/L	2 - 3 mg/L	3 - 45 mg/L
Sodium Adsorption Ratio	0.28 - 0.69	0.34 - 0.66	0.49 - 1.84
Magnesium	47 - 74 mg/L	25 - 73 mg/L	52 - 129 mg/L
Potassium	6 - 9 mg/L	5 - 9 mg/L	8 - 21 mg/L
Calcium	70 - 80 mg/L	54 - 80 mg/L	62 - 117 mg/L
Sulfate	0 - 113 mg/L	0 - 105 mg/L	0 mg/L
Date Sampled	9/2016	9/2016	9/2016

Table 2. Reclaimed and developed sites water quality results.

	Hidden Water Creek – Reclaimed (n = 1)	MPDES Outfall North Decker Mine (n = 1)	Tongue River Reservoir (n = 1)
Sodium	154 mg/L	159 mg/L	21 mg/L
Chloride	21 mg/L	20 mg/L	4 mg/L
Sodium Adsorption Ratio	2.47	2.10	0.63
Magnesium	149 mg/L	136 mg/L	26 mg/L
Potassium	29 mg/L	24 mg/L	3 mg/L
Calcium	52 mg/L	209 mg/L	43 mg/L
Sulfate	0	0	0
Date Sampled	9/2016	4/2016	6/2016

Table 3. Tanner Creek Watershed water quality results.

	Tanner Creek Spring (n = 1)	Tanner Creek Pond (n = 1)
Sodium	1.3 mg/L	6 mg/L
Chloride	1.4 mg/L	2.1 mg/L
Sodium Adsorption Ratio	0.08	0.14
Magnesium	5 mg/L	52 mg/L
Potassium	17 mg/L	22 mg/L
Calcium	13 mg/L	67 mg/L
Sulfate	4.6 mg/L	0
Date Sampled	6/2016	6/2016

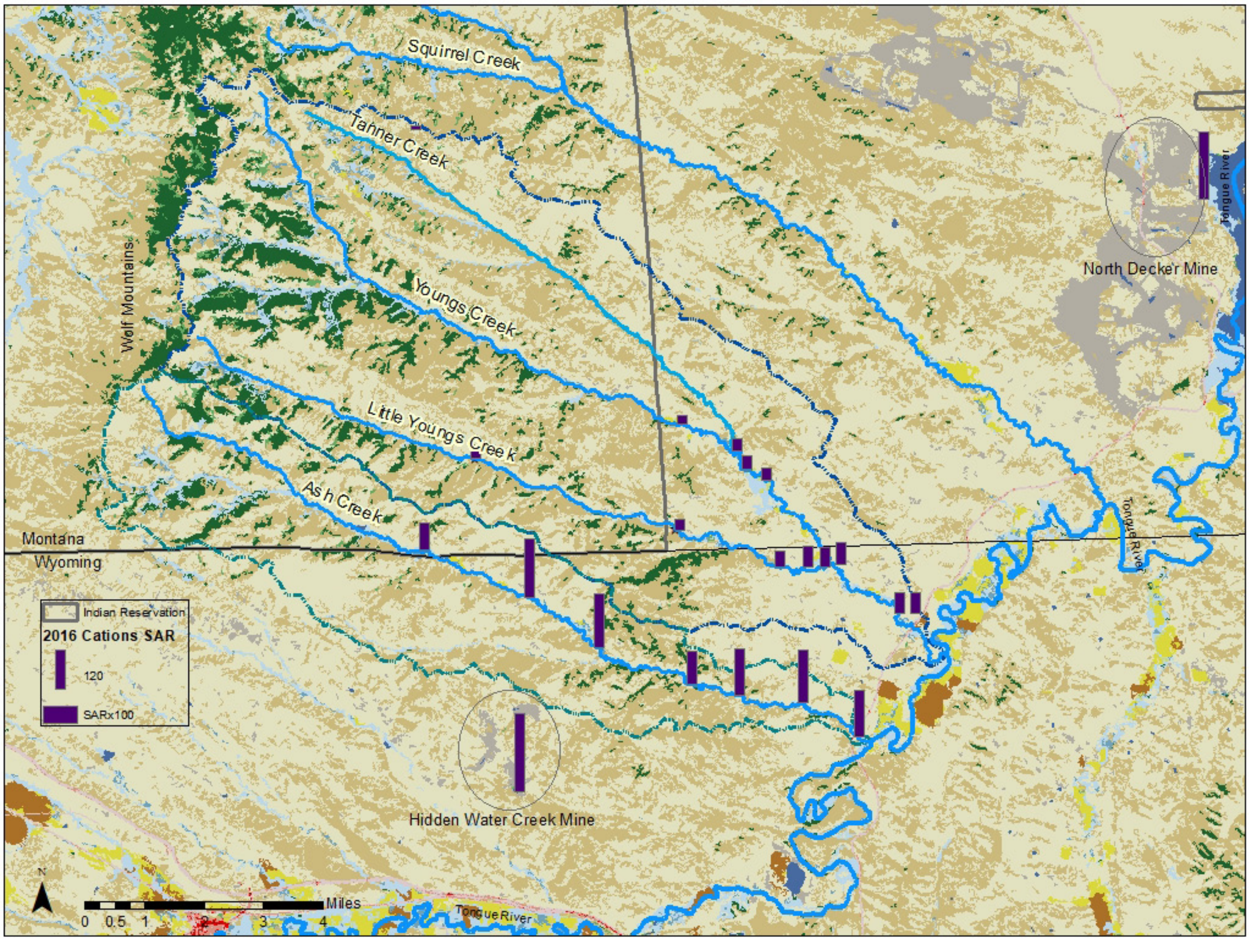

Figure 4. Surface water 2016 data SAR levels.

most sampling locations throughout Tanner and Youngs Creeks.

Cation and SAR levels of Youngs Creek did not differ significantly from initial levels taken in 1977. The land use activities may have changed the Youngs Creek channel in some downstream areas where irrigation canals run throughout the creek fed alluvial valley, based on topographic and aerial maps (Montana Cadastral 2017). These areas are downstream of the confluence of Little Youngs Creek and Youngs Creek and upstream of the mouth of Youngs Creek.

Indications of CBM and Oil and Gas on Water Quality

Water quality impacts from CBM development may be transient. As Youngs Creek experienced the most development with the highest concentration of well density and closest distance to CBM wells, the flow rate of the stream is high enough to resist impacts of produced water. Youngs Creek has a historical average annual flowrate of 0.26 cubic meters per second. The impacts of CBM produced water may have been exhibited at the time of well production but the stream water quality is similar to values recorded in 1977 prior to well development.

Active CBM wells in Wyoming were permitted to discharge produced waters directly into surface water drainages. This water, when not discharged directly into stream channels, is often held on site, in infiltration basins. Water in these basins that does not infiltrate or evaporate is usually channeled through culverts or other overflow structures into adjacent streams. Infiltration ponds for CBM wells were shown to impact groundwater quality (Healy et al. 2008). Depending on the well sites, infiltration of the produced water may have affected the water table directly below the pond site. The produced water would have elevated SAR levels and would raise the SAR levels in the groundwater.

Ash Creek did not experience the same amount of CBM development, however, the watershed has a higher concentration of oil and gas development than the other watersheds in the study area. Contaminant and indicator levels appear to be elevated within the Ash Creek drainage downstream of the Montana border into Wyoming. There are operating oil wells along the creek in addition to several now abandoned CBM wells. The concentration of oil wells along Ash Creek range from one to seven wells per section (WOGCC 2017). The oil and gas wells are located in formations at greater depths than the coal bed seams.

Background and historical data are limited for the Ash Creek watershed due to the location in Wyoming and lying outside of the study area of Montana agencies and databases. The majority of the Ash Creek watershed sampled is within the state of Wyoming. A few USGS data sets from the 1970s may capture effects of the drilling of the oil wells in the watershed (USEPA 2017). Comparatively, the Ash Creek watershed indicates higher levels of chloride, sodium, and SAR indicators than the Youngs Creek watershed.

Mining Impacts

The Ash Creek Mine site was dewatered beginning in 1976, then was reclaimed and dewatering ceased in 1995 (Meredith et al. 2011). The water produced during the dewatering process was likely discharged to infiltration ponds or to nearby streams which would include Little Youngs Creek. The Ash Creek Mine site appears to impact the nearby surface water quality on Little Youngs Creek. A MBMG sample from 1977 taken downstream from the mine site on Little Youngs Creek shows high levels of sodium, sulfate, chloride, and SAR values (Figure 4). The site exhibited the greatest levels of sodium for 1977 data on Youngs Creek and confluence with Little Youngs Creek at 103 mg/L and a SAR level of 2.2. This sample would have been taken during the operational period of the Ash Creek Mine. Samples taken downstream of the reclaimed mine site also show elevated sodium and SAR relative to upstream samples. The mine site has been demonstrated to influence Little Youngs Creek as instream flow is lost within the reclaimed mine site (Hedges et al. 1998). CBM wells were not developed in the Ash Creek Mine site and few

Table 4. Paired t-test for 1977 and 2016 water quality data.

	Difference Mean	SE	df	t-value	p-value
Calcium					
Youngs Creek	9.8 mg/L	2.75	3	3.56	0.0189
Little Youngs Creek	18.9 mg/L	4.63	2	4.07	0.0277
Magnesium					
Youngs Creek	-2.3 mg/L	4.93	3	-0.46	0.3384
Little Youngs Creek	0 mg/L	7.56	2	0	0.5
Sodium					
Youngs Creek	-9.1 mg/L	5.78	3	-1.57	0.1072
Little Youngs Creek	-23.3 mg/L	23.09	2	-1.01	0.2094
Potassium					
Youngs Creek	-0.2 mg/L	0.72	3	-0.23	0.4164
Little Youngs Creek	0.2 mg/L	1.42	2	0.16	0.4438
Sodium Adsorption Ratio					
Youngs Creek	-0.2	0.08	3	-2.12	0.0609
Little Youngs Creek	-0.5	0.51	2	-1.04	0.2038

Note: The mean of difference reported represents 2016 data minus 1977 data values.
SE = standard error; df = degrees of freedom.

wells in the Little Youngs Creek watershed were located upstream of the sampling point at Little Youngs Creek culvert.

Water quality impacts from mining development may be more pronounced than that of CBM due to significant coal seam dewatering and the alteration of the coal bed aquifer during mining development. The reclaimed mine spoils will change the character of the saturated groundwater and surface runoff. As seen with the sample from a pond in the reclaimed area of the former Hidden Water Creek Mine, surface water runoff may have increased SAR. The pond was not connected to a flowing stream, at least not in an obvious way, which would also contribute to the increased level of contaminants found in standing water, i.e., concentration via evaporation. The mine site would be less hydrologically connected to natural groundwater flow paths, therefore, the standing pond water would likely originate from the surface runoff within the site.

The spoils aquifers of reclaimed mines can have higher TDS than adjacent coal aquifers. The spoils aquifers will exhibit higher concentrations of sodium, sulfate, and bicarbonate than the coal aquifers. These elevated concentrations are due to the dissolution of minerals and clays in the spoils aquifers. The ion exchange of the calcium and magnesium ions in favor of the sodium ion within the spoils aquifer also increases the TDS. In the spoils aquifer, the predominant anion will be sulfate (Slagle et al. 1985). TDS levels in spoils aquifers may reach 5,000 mg/L as demonstrated in mined areas in southeastern Montana (Davis 1984).

The sample originating from the North Decker Mine site area also demonstrated an elevated SAR level. The water was likely sourced from dewatering of the coal seam aquifer in an attempt to drawdown the groundwater table. The mine site in the area had not yet been reclaimed and would require continuous dewatering as the nearby Tongue River Reservoir would elevate the groundwater table. The outfall fed directly into the Tongue River Reservoir. Several measurements of the Tongue River Reservoir in this area showed an average SAR level of 0.63. Although the water had elevated SAR levels of 2.1 discharged to the reservoir, it was within SAR permit levels and below the CBM contaminant limit for SAR levels permitted by the Montana Department of Environmental Quality.

Land Area to be Impacted by Mine Development

A significant portion of each watershed within the reservation boundary would be impacted by the proposed Big Metal Mine development project. The entire Tanner Creek watershed would be impacted upstream of the reservation boundary. The Youngs Creek watershed would be altered within the Upper Youngs Creek boundary, a few miles upstream of the reservation boundary detailed in Figure 2. Depending on the extent of the disturbance on the ridge between Tanner Creek and Youngs Creek, the watershed along Youngs Creek would be impacted up past the headwater boundary of Tanner Creek. The greatest disturbance to actual surface land would be most apparent in the Tanner Creek watershed. The Tanner Creek watershed consists of 70 percent tribal lands, the most tribal land ownership of all the watersheds.

The drainage from backfilled mine spoils in the headwater areas would alter the stream flow from current dominance of typical surface fed flows of calcium-bicarbonate to elevated TDS levels with increases in sodium, bicarbonate, and sulfate (Davis and Dodge 1986). This change would be exhibited in surface water runoff. Groundwater changes in the altered watersheds would also be affected by the higher TDS and increased cation concentration. The Tanner Creek watershed would be completely altered throughout nearly the entire stream length upstream from the reservation border. If removed during mining and replaced by spoils, the permeability of the reclaimed watersheds would be affected and would take on the characteristics of the spoils aquifer. The runoff volume from surface water would be expected to increase due to less vegetation and decreased infiltration or percolation of the saturated spoils soil. The topology would also have more uniform slopes with decreased impediments to flow than the natural rugged landscape. This would lead to increased volumes of surface water runoff from the reclaimed watersheds in Tanner Creek and Youngs Creek (USDOI BIA 1981). As mine spoil samples were limited, surface water in reclaimed sites should be further studied to determine resulting water quality.

Conclusion

Reclaimed mining sites may have lasting impacts on the nearby surface water quality in the study area. Historical and current samples have demonstrated higher SAR and sodium levels downstream of the Ash Creek Mine in the Little Youngs Creek watershed. A sample from a pond in the former Big Horn Mine reclaimed site contained the highest SAR level of all surface water samples. CBM development impacts may have been transient in the Youngs Creek surface water based on sample results. Historical oil and gas development appears to be impacting surface water quality within the Ash Creek watershed.

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