Cover photo: Slater Creek within the proposed Brook Mine permit area. Photo taken looking west to the Big Horn Mountains. Photo taken by Matt Kunze, Wyoming Department of Environmental Quality, Land Quality Division, September 24, 2015.
Cumulative Hydrologic Impact Assessment of the Proposed Brook Mine, Upper Tongue River Basin, Wyoming

*Final*

Prepared by

Wyoming Department of Environmental Quality
Land Quality Division
Cheyenne, Wyoming

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WDEQ-CHIA-39
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<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>ac-ft</td>
<td>Acre-feet</td>
</tr>
<tr>
<td>ac-ft/mi²/yr</td>
<td>Acre feet per square mile per year</td>
</tr>
<tr>
<td>ABP</td>
<td>Acid-base potential</td>
</tr>
<tr>
<td>AOC</td>
<td>Approximate original contour</td>
</tr>
<tr>
<td>ASCM</td>
<td>Alternative Sediment Control Measures</td>
</tr>
<tr>
<td>AVF</td>
<td>Alluvial valley floor</td>
</tr>
<tr>
<td>b</td>
<td>Aquifer thickness</td>
</tr>
<tr>
<td>BNSF</td>
<td>Burlington Northern Santa Fe</td>
</tr>
<tr>
<td>°C</td>
<td>Celsius</td>
</tr>
<tr>
<td>CaCO₃</td>
<td>Calcium carbonate</td>
</tr>
<tr>
<td>CBM</td>
<td>Coalbed methane</td>
</tr>
<tr>
<td>CFR</td>
<td>Code of Federal Regulations</td>
</tr>
<tr>
<td>cfs</td>
<td>Cubic feet per second</td>
</tr>
<tr>
<td>CHIA</td>
<td>Cumulative Hydrologic Impact Assessment</td>
</tr>
<tr>
<td>CIA</td>
<td>Cumulative Impact Area</td>
</tr>
<tr>
<td>°F</td>
<td>Fahrenheit</td>
</tr>
<tr>
<td>ft</td>
<td>Feet</td>
</tr>
<tr>
<td>ft²/day</td>
<td>Square feet per day</td>
</tr>
<tr>
<td>GCDB</td>
<td>Geographic Coordinate Database</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographic Information Systems</td>
</tr>
<tr>
<td>gpm</td>
<td>Gallons per minute</td>
</tr>
<tr>
<td>HCO₃</td>
<td>Bicarbonate</td>
</tr>
<tr>
<td>HUC</td>
<td>Hydrologic Unit Code</td>
</tr>
<tr>
<td>K</td>
<td>Hydraulic conductivity</td>
</tr>
<tr>
<td>LiDAR</td>
<td>Light Detection and Ranging</td>
</tr>
<tr>
<td>Max</td>
<td>Maximum</td>
</tr>
<tr>
<td>MCF</td>
<td>Thousand cubic feet</td>
</tr>
<tr>
<td>Mg</td>
<td>Magnesium</td>
</tr>
<tr>
<td>mg/L</td>
<td>Milligrams per liter</td>
</tr>
<tr>
<td>mi²</td>
<td>Square miles</td>
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<tr>
<td>mi/mi²</td>
<td>Miles per square mile</td>
</tr>
<tr>
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<td>Minimum</td>
</tr>
<tr>
<td>N</td>
<td>Nitrogen</td>
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<tr>
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</tr>
<tr>
<td>Na</td>
<td>Sodium</td>
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<td>Description</td>
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</tr>
<tr>
<td>NED</td>
<td>National Elevation Dataset</td>
</tr>
<tr>
<td>NH$_3$</td>
<td>Ammonia</td>
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<td>NHD</td>
<td>National Hydrography Dataset</td>
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<td>Nitrite</td>
</tr>
<tr>
<td>NO$_3$</td>
<td>Nitrate</td>
</tr>
<tr>
<td>NTU</td>
<td>Nephelometric turbidity units</td>
</tr>
<tr>
<td>OSMRE</td>
<td>Office of Surface Mining Reclamation and Enforcement</td>
</tr>
<tr>
<td>PABh</td>
<td>Palustrine aquatic bed-permanently flooded</td>
</tr>
<tr>
<td>PEM</td>
<td>Palustrine emergent</td>
</tr>
<tr>
<td>PEMh</td>
<td>Palustrine emergent-permanently flooded</td>
</tr>
<tr>
<td>PHC</td>
<td>Probable Hydrologic Consequences</td>
</tr>
<tr>
<td>PMT</td>
<td>Post mine topography</td>
</tr>
<tr>
<td>PRB</td>
<td>Powder River Basin</td>
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<tr>
<td>PUB</td>
<td>Palustrine unconsolidated bed</td>
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<tr>
<td>ROS</td>
<td>Regression on order statistics</td>
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<td>Q</td>
<td>Quarter</td>
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<tr>
<td>S</td>
<td>Storage coefficient</td>
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<tr>
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<td>State decision document</td>
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<td>Surface Mining Control and Reclamation Act</td>
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<tr>
<td>SU</td>
<td>Standard units</td>
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<tr>
<td>T</td>
<td>Transmissivity</td>
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<td>TDS</td>
<td>Total dissolved solids</td>
</tr>
<tr>
<td>TFN</td>
<td>Temporary filing number</td>
</tr>
<tr>
<td>TMDL</td>
<td>Total Maximum Daily Load</td>
</tr>
<tr>
<td>TSS</td>
<td>Total suspended solids</td>
</tr>
<tr>
<td>USACE</td>
<td>United States Army Corps of Engineers</td>
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<tr>
<td>USGS</td>
<td>United States Geological Survey</td>
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<td>WDEQ</td>
<td>Wyoming Department of Environmental Quality</td>
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<tr>
<td>WDEQ/AML</td>
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<td>Wyoming Department of Environmental Quality/Water Quality Division</td>
</tr>
<tr>
<td>WOGCC</td>
<td>Wyoming Oil and Gas Conservation Commission</td>
</tr>
<tr>
<td>WS</td>
<td>Wyoming Statute</td>
</tr>
<tr>
<td>WSEO</td>
<td>Wyoming State Engineer's Office</td>
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</table>
WYGISC  Wyoming Geographic Information Science Center
WYPDES  Wyoming Pollutant Discharge Elimination System
yr  Year
**EXECUTIVE SUMMARY**

The Wyoming Environmental Quality Act requires that no coal mining be approved unless the applicant affirmatively demonstrates and the administrator finds in writing that the operation is designed to prevent material damage to the hydrologic balance outside the permit area. Coal mine operations must also not cause material damage to the quantity and quality of water in surface or groundwater systems that supply alluvial valley floors (AVFs) not subject to statutory exclusions. The Wyoming Department of Environmental Quality Land Quality Division (WDEQ/LQD) defines material damage to the hydrologic balance as a significant long-term or permanent adverse change to the hydrologic regime. A cumulative hydrologic impact assessment (CHIA) is used to assess the probable cumulative impacts of all anticipated coal mining in an area to ensure the proposed operation has been designed to prevent material damage to the hydrologic balance outside the permit area.

The permitting action evaluated by this CHIA is the proposed Brook Mine (TFN 6 2/025). The Brook Mine is a new coal mine permit proposed by Brook Mining Co., LLC in the upper Tongue River Basin of Wyoming, approximately six miles south of the Wyoming-Montana border and approximately eight miles northwest of Sheridan. The proposed mine permit would cover 4,548.8 acres, with 1,135.1 of those acres proposed to be disturbed by mining.

The Brook Mine proposes to conduct both highwall and surface coal mining of the Monarch, Upper Carney, Lower Carney, and Carney coal seams of the Fort Union Formation, Tongue River Member. All coal to be mined is held under private ownership. Highwall mining would be the primary mining method, and would consist of initially constructing and mining a trench to create a working area for a continuous miner system. The continuous miner would be remotely operated to mine coal perpendicular to the trench. The coal would be transported from the continuous miner back to the surface by conveyance cars where it would then be stockpiled in the trench for later transport by loaders and trucks. Surface mining would be used in areas of low strip ratios using dozer push methods with loader and truck support, a scraper fleet, or a truck/shovel operation. Additional surface mining will be conducted to expose the highwall for mining by the continuous miner. Mining at the Brook Mine would occur over a 39-year period. Surface mining would occur during the first five years of the operation followed by highwall mining for the remaining mine sequence. Reclamation activities include backfilling the mine pits and trenches, regrading, topsoil placement, revegetation, and monitoring. Contemporaneous reclamation would occur in accordance with the proposed reclamation plan. Major reclamation activities to include grading, topsoil application, reseeding, and facilities demolition/removal would be completed within four years after mining.

This CHIA analyzes the probable hydrologic impacts of the proposed Brook Mine to determine whether the mine operation has been designed to prevent material damage to the hydrologic balance outside the mine permit boundary. The proposed Brook Mine is adjacent to the Big Horn Mine, which holds an active mine permit with the WDEQ/LQD. However, the Big Horn Mine was not explicitly considered in this CHIA since nearly 98 percent of the permit area has been permanently reclaimed and fully bond released, and there are no detectable hydrologic impacts. The probable hydrological effects of the proposed Brook Mine were also determined to not be cumulative with other active coal permits in the upper Tongue River Basin further downstream in...
Wyoming and Montana. Since there are no predicted cumulative effects from other coal mines, the proposed Brook Mine is considered hydrologically isolated and the CHIA has been developed using information from the permit application along with additional outside data sources.

The CHIA delineates a surface and groundwater evaluation area that describes the extent of the analysis area evaluated for the proposed Brook Mine. The surface water evaluation area includes the entire proposed Brook Mine permit area, including portions of Hidden Water Creek, Slater Creek, East Fork Earley Creek, and several other smaller unnamed ephemeral tributaries of the Tongue River or the Tongue River Ditch. The surface water evaluation area was also expanded to include portions of Goose Creek and the Tongue River since these areas are adjacent to the proposed Brook Mine and contain declared AVFs.

The groundwater evaluation area was delineated using the groundwater model predicted five-foot life of mine drawdown contours presented in the Brook Mine permit application for the upper Carney, lower Carney, and Masters coal seams. The Masters seam will not be targeted for mining and the Carney seam is the lowest targeted coal seam. Therefore, the stratum between the Carney and Masters seams is the underburden for the proposed Brook Mine. The Masters seam will be the underlying aquifer evaluated in this CHIA. The groundwater evaluation area encompasses seven geologic units of concern: (1) alluvium, historic mine backfill, and weathered overburden where alluvium and mine backfill are not present, (2) coal overburden, (3) upper Carney coal seam, (4) Carney interburden, (5) lower Carney coal seam, (6) Carney/Masters interburden, and (7) Masters coal. The extent of the model predicted five-foot groundwater drawdown is limited in spatial extent and does not cover the entire proposed Brook Mine permit boundary. The field data collected by the mine indicate that the Carney coal is predominantly dry with limited saturation in the west portion of the proposed permit area. In addition, Carney coal is largely dry to the west of its subcrop into the Tongue River alluvium. To be conservative, the groundwater evaluation area was extended to mimic the surface water evaluation area. Therefore, the extent of groundwater and surface water evaluation areas are the same in this CHIA, and cover approximately 20.5 square miles.

Hydrologic concerns are an expression of problems related to water use and the hydrologic balance that may occur as a result of coal mining. Hydrologic concerns identified and evaluated for surface water include the potential for changes to surface water quality and quantity, which have the potential to affect downstream surface water rights and surface water classes of use. Groundwater level declines or degradation of groundwater quality caused by mining are identified as the primary hydrologic concerns that may affect the existing groundwater uses in the evaluation area. Specific concerns related to the potential for decline of groundwater levels include: (1) reduced yield from existing wells in the evaluation area, (2) alteration of groundwater flow gradients and directions, (3) alterations to the recharge and discharge mechanisms, and (4) ability of the backfill aquifer to store and transmit water and to support the post-mining land use. Specific concerns related to the potential for degradation of groundwater quality include: (1) the effect of groundwater migrating from the backfill aquifer to the undisturbed native aquifers outside the proposed mine permit boundary, (2) the groundwater quality of the backfill aquifer within the proposed permit boundary and its ability to support the post-mining land use, and (3) the effect of the quality of base flow from the backfill aquifer to streams. The backfill aquifer is a new aquifer created by replacing overburden materials into the mined pit and trenches after the coal is removed.
The CHIA evaluates the potential for material damage to the hydrologic balance outside the proposed mine permit area using criteria developed by the WDEQ/LQD. These criteria are based on the identified hydrologic concerns and applicable statutes, rules, and regulations administered by the WDEQ Water Quality Division (WQD) and the Wyoming State Engineer’s Office (WSEO). The potential for material damage is evaluated for surface water quantity and quality and groundwater quantity and quality. For surface water quantity, material damage occurs if the analysis demonstrates that the proposed coal mining will cause a decrease in surface water quantity such that downstream surface water rights will be affected, and the proposed mine has not committed to providing a replacement water source similar in quantity and quality. For surface water quality, material damage occurs if the analysis demonstrates that coal mining will cause a significant long-term or permanent adverse change such that WDEQ/WQD surface water quality standards and classes of use are no longer met. For groundwater quantity, material damage occurs if the analysis demonstrates that the proposed coal mining will cause a decrease in groundwater levels such that groundwater rights will be affected and the proposed mine has not committed to providing a replacement water source similar in quantity and quality. For groundwater quality, material damage to groundwater quality occurs if the analysis demonstrates that the proposed coal mining will cause a long-term change in groundwater quality outside the proposed mine permit boundary that would preclude existing or reasonably foreseeable uses.

Typically, it will take several years to realize the groundwater impacts caused by mining to propagate outside the proposed mine permit boundary because of the relatively slow movement of groundwater. These transient observed groundwater impacts will vary depending on the mining and reclamation methods and sequence, the aquifer of interest, and the distance of the location of interest from the disturbed or reclaimed area. Therefore, the following material damage indicators were identified for groundwater levels and groundwater quality. It is important to note that the material damage indicators are not enforceable but will be used to initiate discussions and alert the mine of possible material damage. The three material damage indicators are: physical characteristics of the backfill aquifer, groundwater level recovery within the backfill aquifer, and groundwater quality of the backfill aquifer within the proposed permit boundary. An additional key distinction between the material damage criteria and material damage indicators is that the identified material damage criteria are applied exclusively to areas outside the proposed mine permit boundary. The material damage indicators can include areas within the proposed mine permit boundary and are not restricted to outside the proposed permit boundary.

**Surface Water Quantity**

Analysis from the CHIA and the information from the Brook Mine permit application indicates that the proposed mining will not cause a significant long-term or permanent adverse change to water quantity such that downstream surface water rights would be affected. The CHIA summarizes the baseline or pre-mining surface water hydrology of several drainages in the surface water evaluation area, including Hidden Water Creek, Slater Creek, Goose Creek, and the Tongue River. The potential for mining to cause measurable changes to surface water quantity is deemed low due to the use of hydrologic control features, the limited extent of surface disturbance, and reclamation practices. Based on the limited amount of acreage affected, there is a low likelihood of detecting changes in water quantity downstream on the Tongue River that would be attributable to the proposed mining.
The Brook Mine proposes to use surface water rights to provide the majority of the mine’s water supply. Water from surface water rights would be supplied using either temporary water haul or purchased from existing surface water rights holders. The Brook Mine would also use water collected in the mine pits from pit inflow and from sedimentation impoundments and flood control reservoirs. Any new surface water rights needed for water supply would be subject to approval by the WSEO under evaluation of the Yellowstone River Compact, which will require that bypass or make-up water be made available. A slight increase in post-mine water retention capacity is also predicted due to the addition of two new permanent post-mine impoundments to support the post-mine land use. The impoundments will be subject to WSEO approval under the Yellowstone River Compact, which will require that bypass or make-up water be made available. The two new impoundments are not expected to affect downstream water rights. In the event that downstream water rights are affected by the mine operation, the Brook Mine permit application commits to providing a replacement water source similar in quantity and quality. Therefore, the proposed Brook Mine is not predicted to cause material damage to surface water quantity outside the permit area. Monitoring of water quantity will continue at several of the surface water monitoring stations at the proposed Brook Mine up until final bond release to evaluate performance standards and reclamation success.

**Surface Water Quality**

The analysis from this CHIA and information in the Brook Mine permit application indicates that the proposed mining will not cause a significant long-term or permanent adverse change such that WDEQ/WQD surface water quality standards and classes of use are no longer met. Surface water quality sample data were analyzed for the baseline or pre-mining period in each of the major drainages within the surface water evaluation area. Infrequent exceedances of WDEQ/WQD surface water quality standards were noted on Hidden Water Creek, Goose Creek, and the Tongue River. It is predicted that occasional exceedances may continue to occur due to natural or non-mining related land use factors. Continued monitoring and comparisons between stations upstream and downstream of mining disturbance will be used to evaluate water quality standard exceedances and material damage potential during the life of the mine.

The use of hydrologic and sediment control features helps to protect surface water quality and limit the potential for material damage. Potential increases in erosion and sediment yield at the proposed Brook Mine will be mitigated through a hydrologic and sediment control plan, which includes the use of alternative sediment control measures (ASCMs) and sediment ponds. Sediment control measures will help disconnect the disturbed areas from the stream network, helping to protect water quality. Other hydrologic control features include flood control reservoirs, temporary diversions, collector and bypass ditches, and culverts. In addition, a 100-foot buffer will be established on either side of Slater Creek within the proposed permit boundary to help protect water quality of Slater Creek flowing within the proposed boundary and downstream water quality on the Tongue River.

Based on the limited amount of acreage affected, there is low likelihood for mining to cause detectable changes in water quality on the Tongue River. Dilution from streamflow generated in the 911 mi² watershed upstream of the proposed mine also helps negate any potential impacts to water quality on the Tongue River.

Reclamation practices at the proposed Brook Mine will help ensure that post-mine surface water quality is similar to pre-mine water quality. Some of the relevant reclamation practices
include: (1) salvaging and replacing topsoil in a manner that prevents compaction, protects erosion, and conserves soil moisture, (2) covering all unsuitable spoils with a minimum of four feet of suitable material prior to replacing topsoil, with the thickness of suitable material increasing to six feet in areas under ephemeral channels and ten feet under intermittent channels, and (3) designing reconstructed landscapes to be erosionally stable, which helps minimize soil loss.

**Groundwater Quantity**

The predicted groundwater effects were compiled and evaluated within the groundwater evaluation area. Although coal mining will have impacts within the proposed permit boundary, based on available data, information presented in the mine permit application, and analysis in this CHIA, the potential for material damage outside the permit boundary to groundwater quantity and quality is limited. The proposed Brook Mine is not expected to significantly change hydrologic conditions such that material damage would occur. Compared to the other aquifer units of interest, mining impacts to groundwater levels in the coal aquifer are more extensive since the coal seams are mined out and the hydraulic conductivity of the coal aquifer is higher than the overburden and underburden units. Away from the mine pits, moving towards the edges of the groundwater evaluation area, coal-mine induced life of mine drawdowns are expected to decrease and will be less than five feet at the edge of the evaluation area.

The proposed Brook Mine developed a three-dimensional MODFLOW groundwater model to predict groundwater level drawdown and associated recovery in the aquifers adjacent to the mining pits. Most of the wells within the model domain are stock or domestic wells and are completed in a geologic strata below the Carney coal that would be mined. The groundwater model predicts a drawdown of greater than zero feet at five wells. The largest model predicted impact seen at any existing well outside of the proposed permit boundary is 3.3 feet. This impact is estimated to be temporary at approximately four years. Model predicted drawdowns at the rest of the four wells are less than two feet. In addition, if the existing wells with water rights are impaired due to coal mining operations, the proposed Brook Mine commits to providing a replacement water source similar in quantity and quality. Because of contemporaneous reclamation, the coal aquifer is expected to be on a recovery trend when mining stops in 39 years. Monitoring of groundwater levels and groundwater quality will continue at the monitor wells at the proposed Brook Mine up until final bond release to evaluate performance standards and reclamation success.

**Groundwater Quality**

The mining impacts on groundwater quality in the undisturbed native coal aquifer outside the proposed Brook Mine permit boundary would depend on the hydrologic connection with the backfill aquifer and on the groundwater quality of the groundwater migrating from the backfill aquifer. The estimated physical characteristics, water level recovery, and water quality of the backfill aquifer were used as material damage indicators to evaluate the backfill aquifer and its effect on groundwater availability within the proposed mine permit boundary and flow to the undisturbed native aquifers. The predicted saturated extent of the backfill aquifer is similar to the observed baseline saturated extent of the coal seams. The Brook Mine predicts that the time period for complete recovery of water levels in the backfill aquifer within the proposed mine permit boundary is about 10 to 20 years. Additionally, viability of the backfill aquifer for beneficial uses could likely be attained prior to full recovery since there would be a rapid initial recovery followed by an asymptotic slower recovery towards the initial static water level. The overall assessment including the groundwater model predictions indicates that the backfill aquifer will likely have
sufficient permeability to yield sufficient quantity of water to meet the proposed post-mining land use of livestock and wildlife.

Analysis in the CHIA and information in the Brook Mine permit application indicates that the potential for the backfill groundwater to migrate to and affect the adjacent undisturbed native aquifers outside the proposed mine permit boundary is minimal and localized. During removal and replacement of the overburden to backfill the mine pits and trenches, appropriate measures are taken to ensure that the water quality of the backfill aquifer will not be degraded such that post-mining land uses cannot be supported. It is generally expected that over time, the backfill aquifer will be flushed by groundwater flowing through the reclaimed material and down gradient to the native undisturbed aquifers. Thus, the water quality in the backfill is expected to support livestock use before the groundwater levels are completely recovered. Based on the predictions from the Brook Mine permit application and the observed data from the adjacent Big Horn Mine, it is expected that the backfill aquifer will be a viable supply source to support the proposed post-mining land use of livestock and wildlife. Therefore, groundwater migrating from the backfill aquifer to the native aquifers outside the mine permit boundary is expected to have a minimal effect and would not affect the ability of the existing wells to supply for their intended use. Overall, evaluation of the three material damage indicators suggest that there is limited potential for the proposed Brook Mine to cause material damage to the native aquifers outside the mine permit boundary.

Alluvial Valley Floors

AVFs have been previously declared by the WDEQ/LQD on Goose Creek and the Tongue River adjacent to and downstream of the proposed Brook Mine. Much of the Tongue River downstream of the Big Horn Mine contains AVFs that are significant to farming. As such, coal mining must not materially damage the quantity or quality of water in surface or underground systems that supply the AVFs. The WDEQ/LQD declared an AVF of 13.11 acres on Slater Creek within the proposed Brook Mine permit boundary. The AVF was deemed not significant to farming since it is on undeveloped rangeland. AVFs on undeveloped rangeland are statutorily excluded from requiring a material damage assessment. The WDEQ/LQD also declared AVFs on Slater Creek and the Tongue River adjacent to the proposed Brook Mine. The WDEQ/LQD determined that a significance to farming test was not required for the adjacent AVFs since they would not be affected.

A material damage assessment was conducted for the AVFs adjacent to the permit area and those declared significant to farming on the Tongue River downstream of the Big Horn Mine by considering the potential for changes in surface water quantity, surface water quality, alluvial water levels, and alluvial water quality. The analysis in the CHIA and information in the Brook Mine permit application indicates that the proposed mining will not cause material damage to the surface water and groundwater hydrology components that support the adjacent and downstream AVFs. The ability for flood irrigation and subirrigation in the adjacent and downstream AVFs is predicted to be maintained throughout the proposed mining and reclamation operation.

Overall Findings

Based on the information presented in the Brook Mine permit application and the analysis completed for this CHIA, the coal mining proposed at the Brook Mine has been designed to prevent material damage to the hydrologic balance outside the proposed mine permit boundary and will
not cause material damage to the quantity or quality of water in surface or groundwater systems that supply AVFs not subject to statutory exclusions.
1. INTRODUCTION

The Wyoming Environmental Quality Act requires that no coal mining be approved unless the applicant affirmatively demonstrates and the administrator finds in writing that the operation is designed to prevent material damage to the hydrologic balance outside the permit area (W.S. § 35-11-406(n)(iii)). Coal mine operations must also not cause material damage to the quantity and quality of water in surface or groundwater systems that supply alluvial valley floors (AVFs) not subject to statutory exclusions (W.S. § 35-11-406(n)(v)).

The Wyoming Department of Environmental Quality Land Quality Division (WDEQ/LQD) defines material damage to the hydrologic balance as a significant long-term or permanent adverse change to the hydrologic regime (WDEQ Land Quality - Coal Rules, Ch. 1, § 2(cf)). A significant long-term or permanent adverse change is defined as changes to the surface or groundwater hydrology that are inalterable conditions contrary to: (1) the Wyoming State Constitution, (2) statutes administered by the Wyoming State Engineer's Office (WSEO), or (3) water quality standards administered by the WDEQ Water Quality Division (WQD) (Wyoming Department of Environmental Quality and Wyoming State Engineer’s Office, 1996). A cumulative hydrologic impact assessment (CHIA) is used to assess the probable cumulative impacts of all anticipated coal mining in an area to ensure the proposed operation has been designed to prevent material damage to the hydrologic balance outside the permit area (WDEQ Land Quality–Coal Rules, Ch. 19, § 2(a)(i)).

The purpose of this CHIA is to evaluate the probable cumulative hydrologic impacts of the proposed Brook Mine. The Brook Mine is a new coal mine permit proposed by Brook Mining Co., LLC. The proposed Brook Mine is located in the upper Tongue River Basin of the west central Powder River Basin (PRB) of Wyoming (Figure 1). The proposed Brook Mine is located east of the Bighorn Mountains in north central Sheridan County, approximately six miles south of the Wyoming-Montana Border and eight miles northwest of Sheridan. The proposed permit boundary is adjacent to Interstate 90 and Wyoming State Highway 345 (Figure 1). The proposed Brook Mine permit would encompass 4,548.8 acres, with approximately 25 percent of the permit acreage proposed to be affected by surface disturbance. The entire proposed permit area is held under private surface ownership (Brook Mine Permit Application, 2020).

The proposed Brook Mine is adjacent to the Big Horn Mine (Figure 1), which holds an active mining permit with the WDEQ/LQD but is no longer mining and has been reclaimed for several years. As discussed in Section 2, the Big Horn Mine was not explicitly considered in this CHIA given its reclamation/bond release status and lack of hydrological impacts. The proposed Brook Mine was also determined to be hydrologically isolated from other active coal permits in the upper Tongue River Basin further downstream in Wyoming and Montana (see Section 2).

The Brook Mine proposes to conduct both highwall and surface coal mining of the Monarch, Upper Carney, Lower Carney, and Carney coal seams of the Fort Union Formation, Tongue River Member (Brook Mine Permit Application, 2020). All coal to be mined is held under private ownership. Highwall mining would be the primary mining method and would consist of initially constructing and mining a trench to create a working area for a continuous miner system. The continuous miner would be remotely operated to mine coal perpendicular to the trench. The coal would be transported from the continuous miner back to the surface by conveyance cars where it would then be stockpiled in the trench for later transport by loaders and trucks. Surface mining would be used in areas of low strip ratios using dozer push methods with loader and truck support,
a scraper fleet, or a truck/shovel operation. Additional surface mining will be conducted to expose the highwall for mining by the continuous miner. Mining at the Brook Mine would occur over a 39-year period. Surface mining would occur during the first five years of the operation followed by highwall mining for the remaining mine sequence. Reclamation activities include backfilling the mine pits and trenches, regrading, topsoil placement, revegetation, and monitoring. Contemporaneous reclamation would occur in accordance with the proposed reclamation plan. Major reclamation activities to include grading, topsoil application, reseeding, and facilities demolition/removal would be completed within four years after mining (Brook Mine Permit Application, 2020).

This CHIA analyzes the proposed Brook Mine to determine whether the operation has been designed to prevent material damage to the hydrologic balance outside the mine permit area. To complete the CHIA and material damage determination, it is necessary to define the area where the proposed mining activities may cause measurable hydrologic changes. Baseline data are summarized to describe the pre-mining hydrologic conditions. Hydrologic concerns are identified and the potential hydrologic impacts are analyzed. The potential impacts are then evaluated against material damage criteria developed by the WDEQ/LQD. These criteria are based on applicable statutes, rules, and regulations administered by the WDEQ Water Quality Division (WQD) and the Wyoming State Engineer’s Office (WSEO) (Wyoming Department of Environmental Quality and Wyoming State Engineer’s Office, 1996). A finding is made regarding the potential for material damage.

The following sub-sections in the Introduction provide a brief overview of the site conditions at and near the proposed Brook Mine, including topography, geology, climate, soils, and vegetation, regional hydrology, current and anticipated mining operations, and oil and gas production. More detailed information on site conditions is available in the Brook Mine Permit Application (2020), available at the WDEQ/LQD office in Cheyenne or Sheridan. The remaining sections of the CHIA are organized as follows:

- **Section 2 – Hydrologic Isolation of the Proposed Brook Mine**
  - Provides the justification for determining that the proposed Brook Mine is hydrologically isolated from existing coal mines in the upper Tongue River Basin, resulting in no potential for cumulative hydrologic impacts.
  - Provides the description of the surface and groundwater evaluation areas and the monitoring networks used for the CHIA.

- **Section 3 – Baseline Hydrologic Conditions**
  - Provides a description of baseline surface water and groundwater quantity and quality in the area of the proposed Brook Mine.
  - Provides a description of alluvial valley floor (AVF) determinations in the area of the proposed Brook Mine.

- **Section 4 – Hydrologic Concerns**
  - Provides the general hydrologic concerns associated with coal mining in the PRB, and more specific hydrologic concerns associated with the mining proposed at the Brook Mine.

- **Section 5 – Material Damage Criteria**
  - Provides material damage criteria for surface water, groundwater, and AVFs.
• **Section 6 – Analysis of Predicted Post-Mine Hydrologic Conditions**
  o Provides the predicted future post-mine conditions in surface water and groundwater quantity and quality in the area of the proposed Brook Mine.

• **Section 7 – Material Damage Potential**
  o Provides the assessment of the potential for the proposed coal mining to cause material damage to surface water and groundwater quantity and quality outside the mine permit area.
  o Provides the assessment of the potential for the proposed coal mining to materially damage the quantity and quality of water that supply AVFs not subject to statutory exclusions.

• **Section 8 – Material Damage Statement of Findings**
  o Provides the overall finding that the proposed coal mining has been designed to prevent material damage to the hydrologic balance outside the mine permit area, and will not materially damage the quantity or quality of water that supply AVFs not subject to statutory exclusions, including signatures noting concurrence by the WDEQ Director and Wyoming State Engineer.

• **References Cited**
  o Provides list of reference materials used to develop the CHIA.

• **Addendum A – Agency Review Comments on CHIA 39**
  o Provides review comments on the CHIA by the Wyoming State Engineer’s Office and the WDEQ Water Quality Division, and responses to comments by the WDEQ/LQD. A comment letter received from the Wyoming Game and Fish Department is also included.
Figure 1. Location of the proposed Brook Mine and existing Big Horn Mine in the upper Tongue River Basin, Wyoming.
1.1 TOPOGRAPHY

The topography of the proposed Brook Mine is comprised of open hills and steep clinker capped buttes and ridges separated by incised drainages that rise from the valley floor of the Tongue River (Brook Mine Permit Application, 2020). Elevations within the proposed permit area range from a low of 3,590 feet at the Tongue River to a high of 4,110 feet in the north central portion of the proposed permit area. Topography of the area has also been affected by historical coal mining. Numerous surficial mine subsidence features from historical underground coal mining were present near the proposed permit area (Dunrud and Osterwald, 1980), but some of these have been reclaimed by the WDEQ Abandoned Mine Lands (AML) Division. The topography of the adjacent Big Horn Mine permit area has been modified by post-mine reclamation, including a permanent 92.5-acre permanent post-mine pit lake impoundment near the Tongue River (Big Horn Mine Permit, 2020). Surface coal mining in the 1940s and 1950s in the headwaters of Hidden Water Creek north of the proposed Brook Mine permit boundary have also been reclaimed as impoundments by the WDEQ/AML (Bureau of Land Management, 2003).

1.2 GEOLOGY

Regional and site specific geologic information for this section was obtained from various regional references and the Brook Mine Permit Application (2020). The proposed Brook Mine used approximately 400 drill holes as part of compilation of geology information in the permit application. The drill holes were either completed by the proposed Brook Mine or other entities. Twelve geologic cross-sections were developed from the logs of these drill holes (Brook Mine Permit Application, 2020).

1.2.1 SURFICIAL GEOLOGY

Surficial geology at the proposed Brook Mine consists of clinker, alluvium, bedrock and glaciated bedrock, and dissected terrace deposits of Quaternary age (Case et al., 1998) (Figure 2). On the eastern edge of the proposed permit area, the surficial geology map also shows mining areas existing at the time the geologic mapping was completed. These areas were at the historic open-pit operations at Big Horn Mine and the headwaters of Hidden Water Creek.

1.2.2 REGIONAL GEOLOGY

The PRB is a structural and sedimentary basin located in northeastern Wyoming and southeastern Montana. The PRB formed as a Laramide foreland basin during latest Cretaceous to early Tertiary time. The basin is asymmetrical with rocks dipping an average of 20-25 degrees along the western margin of the basin and 2-5 degrees along the eastern margin. The basin is approximately 250 miles long by 90 miles wide and contains as much as 23,000 feet of sediment (Denson et al., 1989). The Miles City Arch separates the northernmost PRB in Montana from the Williston Basin in Montana and North Dakota (see Figure 7 in Section 1.4). Paleocene Laramide positive structures representing basement-block uplifts (Curry, 1971; Perry and Flores, 1994) include the Bighorn uplift on the west, the Casper Arch-Laramie Range-Hartville uplift on the south, and the Black Hills uplift on the east (see Figure 7). These ancestral uplifts reflect northeastward migration of Laramide deformation because the uplift on the west (the Bighorn Mountains) is older than that on the east (the Black Hills) (Perry and Flores, 1994).
Figure 2. Surficial geology (500K scale) in the area of the proposed Brook Mine in the upper Tongue River Basin, Wyoming.
1.2.3 STRUCTURAL GEOLOGY

Faulting occurs in many parts of the PRB, especially around the edge of the basin in association with folding. Faulting is more common on the western limb of the basin than on the eastern limb. Vertical displacements can be up to several hundred feet (Brook Mine Permit Application, 2020).

Several northeast-southwest trending faults were identified by Barnum (1983) in and around the proposed Brook Mine permit area. Several low amplitude anticlines, synclines, as well as several en echelon normal faults with traces oriented along the strike direction have been mapped. The displacement of these faults is generally around 50 feet with the proposed permit area (Brook Mine Permit Application, 2020). These faults are depicted on a map in the Brook Mine Permit Application (2020).

1.2.4 REGIONAL STRATIGRAPHY

The stratigraphic development of the PRB is based on the various depositional environments. During the Mississippian and Pennsylvanian periods, shallow seas and broad seaways accompanied by the gentle downwarping of the area brought about the deposition of sandstones, shales, and limestones. In the Mesozoic era, transgressive and regressive seas brought about the interbedding of shaly marine and non-marine strata. During the Laramide Orogeny, the rise of ranges and broad-backed uplifts enclosed the continuing subsiding basin. During this time period, the Northern Great Plains was a vast swamp from which extensive coal beds were later derived. The coal-bearing Fort Union formation was deposited during this time period, with the erosion of Laramie Range supplying the clay and clastic material creating underburden and interburden.

Fort Union strata make up the surface bedrock along the margins of the PRB. These strata are conformably underlain by the Lance Formation (Upper Cretaceous) and conformably (in the basin center) and unconformably (at the basin margins) overlain by the Wasatch Formation (Eocene) (Figure 3). Generalized columnar section representing the tertiary sediments of the PRB giving brief descriptions of ages and thickness is shown in Figure 4. The units that will be discussed in detail include (from oldest to youngest): the Fox Hills, Lance, Fort Union, and Wasatch Formations.
Figure 3. Bedrock geology (500K scale) in the area of the proposed Brook Mine in the upper Tongue River Basin, Wyoming.
Figure 4. Stratigraphic column for geologic units in the Powder River Basin in Wyoming and Montana (Flores and Bader, 1999) (left), and generalized stratigraphic section with coal seams in the area of the proposed Brook Mine, as taken from Figure MP.4-1 from the Brook Mine Permit Application (2020) (right). The Brook Mine proposes to conduct mining of the Monarch, Upper Carney, Lower Carney, and Carney coal seams.
1.2.4.1 FOX HILLS SANDSTONE

The Upper Cretaceous Fox Hills Sandstone is a transitional unit between the older Cretaceous epi-continental sea deposits (Lewis/Pierre marine shale) and the later continental (non-marine) deposits of the uppermost Cretaceous and Tertiary. This unit ranges from approximately 60 to 300 feet thick, and is predominantly comprised of sandstone that coarsens upward, with rare interbedded thin shale units. The Fox Hills was deposited along a retreating, tidally-affected, and wave dominated shoreline. The formation includes depositional facies from lower shoreface up through tidal flat environments. As a result of minor transgressions and regressions of the retreating Cretaceous seaway, the Fox Hills Sandstone inter-finger with the underlying marine Lewis Shale (western Basin) and Pierre Shale (eastern Basin).

1.2.4.2 LANCE FORMATION

The Upper Cretaceous Lance Formation is a fluvial and floodplain deposit composed of brown and gray, nonmarine, lenticular, fine- to medium-grained sandstone, interbedded with sandy siltstone and claystone; thin discontinuous coal deposits are locally present. The Lance Formation ranges in thickness from 500 to 1,000 feet in the northern PRB and increases to 1,600 to 3,000 feet thick in the central PRB (Feathers et al., 1981).

1.2.4.3 FORT UNION FORMATION

The Paleocene Fort Union Formation consists of a thick non-marine sequence of fine to medium grained lenticular sandstone interbedded with siltstone, mudstone, shale, and coal. This formation contains a substantial proportion of the economically important coal found in the PRB. The formation ranges in thickness from 1,100 feet in the eastern part of the Basin to more than 2,500 feet near the western axis of the Basin (Feathers et al., 1981).

The Fort Union Formation consists of three members (from oldest to youngest): the Tullock Member, the Lebo Shale Member, and the Tongue River Member. Subdivision of Fort Union Formation is based on the color, dominant lithology, and thickness variation of the rock units (Mapel, 1958; Tudor, 1975; Denson et al., 1989; Macke and Schumann, 1989). For example, the Tullock and Tongue River Members include abundant weathered, drab yellow and light-gray sandstone beds. The Tongue River Member includes common light-gray to tan mudstone in contrast to the Lebo Member, which contains abundant drab-gray mudstone. The coal beds of the Tullock Member are thin to thick compared to the coal beds of the Tongue River Member, which are mainly thick; the Lebo Member includes very thin and sparse coal beds and carbonaceous mudstone.

Each member of the Fort Union Formation is discussed in detail below.

**Tullock Member:** The Tullock Member is the oldest and lowest of the Tertiary units in the PRB and this member directly overlies the Upper Cretaceous Lance Formation. The Tullock Member is comprised of brown sandstone interbedded with shale and siltstone beds deposited in a fluvial/floodplain/wetland environment (Zelt et al., 1999). An estimated one-third of the sequence is composed of channel sandstones, whereas an estimated two-thirds of the sequence is composed of fine-grained overbank deposits containing thin coal beds. Sediments of the Tullock Member range from approximately 500 feet in the northeastern PRB to 1,440 feet in the southeastern PRB.
**Lebo Shale Member:** The Lebo Shale Member ranges from 500 feet thick in the northwestern PRB to 1,700 feet in the southwestern part of the basin (Law, 1975). The Lebo consists of gray shale interbedded with gray siltstone, claystone, and concretionary sandstone deposited primarily in a lacustrine environment. Fluvial, floodplain, and wetland depositional environments also contributed sediment to this member (Zelt et al., 1999). In the northern PRB, the Lebo shale contains rare beds of gray sandstone as much as 10 feet thick, and in the central PRB, coal beds generally less than two feet thick occur within the Lebo shale and form clinker horizons.

**Tongue River Member:** The youngest and uppermost member of the Fort Union Formation is the Tongue River Member. The Tongue River Member consists of yellow fine- to medium-grained, massive and crossbedded lenticular sandstone, gray to brown mudstone, carbonaceous shale, and abundant coal. These sediments were deposited in channels, as overbank deposits, and as coal beds in fluvial-floodplain-swamp environments (Zelt et al., 1999). The maximum thickness of the Tongue River Member is more than 2,100 feet near the basin axis; however it thins in the eastern part of the basin, and is only 1,000 feet thick north of Gillette. Although coal seams are located throughout the Fort Union Formation, the most continuous coals occur in the upper Fort Union Formation in the Tongue River Member. The lithology directly beneath the Wyodak-Anderson coal in the Tongue River member is usually comprised of carbonaceous claystone and siltstone with thin coal stringers and this few hundred feet thick lithology along with the Lebo Shale is generally referred as the underburden in the PRB. The stratum between the Carney and Masters coal seams is considered the underburden for the proposed Brook Mine.

### 1.2.4.4 WASATCH FORMATION

The Eocene Wasatch Formation, generally referred to as the overburden in the PRB, consists of drab, fine- to coarse-grained, lenticular sandstone interbedded with variegated claystone and shale, and numerous coal deposits. The formation contains coarser-grained sandstone in the southern and southwestern PRB, and conglomeratic sandstone in northwestern PRB. The Wasatch Formation is exposed at the surface throughout most of the PRB, and consequently has the greatest surficial exposure of any geologic formation in the PRB. The Wasatch Formation has a total thickness of more than 2,000 feet in the central PRB and 1,500 feet in the northern part.

The depositional environment of the Eocene Wasatch Formation is presumably similar to that of the Tertiary fluvial-floodplain-swamp environments of the underlying Paleocene Fort Union Formation. The contact between the Fort Union and Wasatch formations is gradational in most of the PRB and is difficult to distinguish either in the field or on geophysical well logs. Locally, a stratigraphic marker bed composed of coquina limestone or conglomeratic sandstone may identify the contact between the Fort Union and Wasatch (Hose, 1955). The top and base contacts of the Wasatch Formations are unconformable, except in the central PRB, where the Wasatch conformably overlies the Fort Union Formation.

The Brook Mine Permit Application (2020) states that the Wasatch Formation has been removed by erosion within the proposed permit area. Uplands east of the proposed permit area contain Wasatch outcrops of similar lithology to the local Fort Union Formation (Brook Mine Permit Application, 2020). The overburden of the Carney coal within the proposed Brook Mine permit area is composed of claystone with intermittent, less continuous, and moderately to well cemented siltstone and sandstone lenses. Extensive clinker remnants occur where the overlying Monarch coal was burned (Brook Mine Permit Application, 2020).
1.2.5 COAL OCCURRENCE

Coal beds in the PRB are not only valuable from an energy standpoint, but also as sources of groundwater for a variety of uses. The primary occurrences of coal in the upper Cretaceous to early Tertiary rocks are found in the Tongue River Member of the Fort Union Formation. Lesser but substantial coal beds are also present in the overlying Wasatch Formation. Tectonism may have played a significant control in accumulation of thick Fort Union coal (Flores, 1981; Ayers and Kaiser, 1984; Kent, 1986). The peat that formed the coal beds was deposited in raised mires and low-lying swamps associated with distal floodplains, at margins of floodplain lakes, and on abandoned fluvial channels and crevasse-splay lacustrine deposits (Flores, 1981; Flores and Ethridge, 1985; Moore, 1986; Flores and Moore, 1994).

The Tongue River Member coal beds are stratigraphically distributed in distinct coal zones. Regionally, the coal zones merge, split, and pinch-out laterally, forming a shingled or overlapping pattern; locally they display a zigzag pattern. The coal beds of the Tongue River Member are exposed in outcrops along the margin of the PRB.

The Wyodak-Anderson coal zone is extensive throughout the PRB, with a thickness that varies greatly. Most of the commercial coal production in the PRB is from the Wyodak-Anderson coal zone in the Upper Tongue River Member of the Fort Union Formation. Laterally, coal beds of these coal zones merge, split, and pinch out. The coal splits into two or more beds that gradually thin or pinch out or interfinger with other clastic rocks. The split coal beds are interbedded with limestone, mudstone, siltstone, and sandstone. Merged coal beds are interbedded with thin carbonaceous shale partings. Local names, such as the Anderson, Canyon, Roland, Smith, and Wyodak are used where the coal seams split. This coal zone in the Wyoming portion of the PRB consists of as many as eleven coal beds including the Werner, Swartz, Smith, Sussex, Big George, Canyon or Monarch, Dietz, Anderson, Badger, and School.

The Wyodak-Anderson coal zone has a maximum net coal thickness of about 280 feet; using coal beds greater than 2.5 feet thick, the entire zone is more than 600 feet thick in the center of the Basin. The total thickness of the coal beds in this zone commonly range from 50 to 150 feet, with individual coal beds averaging 25 feet in thickness and containing clastic interbeds ranging from a few feet to 150 feet thick. These coal beds merge in places into a single bed as much as 200 feet thick. The thickness of a single coal seam in the Wyodak-Anderson coal zone is more than 100 feet near Wright, Wyoming.

The combined thickness of the coal across the proposed Brook Mine is typically less than 30 feet, with thickness increasing from west to east (Figure 5) (Ellis et al., 1999). Coal beds of interest within the proposed mine primarily exist in the Paleocene age Fort Union Formation, Tongue River Member. The Brook Mine proposes to conduct mining of the Monarch, Upper Carney, Lower Carney, and Carney coal seams (Brook Mine Permit Application, 2020) (Figure 4). The Carney seam lies above the Masters seam which together generally mark the bottom of the Tongue River Member of the Fort Union Formation (Figure 4). The Carney seam in the eastern portion of the proposed Brook Mine area ranges from 15 to 20 feet thick and generally becomes thinner to the west. A clay parting cuts the Carney into upper and lower beds generally perpendicular to the dip of the formation in a northwest-southeast trending interface near the center of the proposed permit boundary. The Upper Carney on the western half of the proposed mine area ranges from two to six feet in thickness and generally thins to the west. The Lower Carney ranges from four to 10 feet.
thick across the western half of the proposed permit area, also thins towards the west. The underlying Masters coal seam ranges between four and six feet thick across the proposed permit area with the exception of those areas where the coal has potentially been removed by erosion. The Masters seam will not be mined at the proposed Brook Mine (Brook Mine Permit Application, 2020).

Fragments of the overlying Monarch seam exist within isolated portions of the proposed Brook Mine area. However, a large percentage of the seam was burned or eroded and minable remnants are relatively small and discontinuous. The Dietz coal seams are located above the Monarch seam and were targeted by the adjacent Big Horn Mine. The Dietz seams are not part of the proposed mine plan at the proposed Brook Mine (Brook Mine Permit Application, 2020).
Figure 5. Net thickness of the Wyodak-Anderson coal seam in the area of the proposed Brook Mine in the upper Tongue River Basin, Wyoming (Ellis et al., 1999).
1.3 CLIMATE, SOILS, AND VEGETATION

1.3.1 CLIMATE

The area of the proposed Brook Mine is semiarid with cool dry winters and warm dry summers. Windy conditions exist mostly in the winter months with prevailing winds from the northwest at around eight miles per hour (Brook Mine Permit Application, 2020). Isolated, but often intense, thunderstorms occur during the warmer months and light to moderate snow falls during the colder months. The area receives approximately 15 inches of precipitation annually, with nearly 65 percent of the precipitation occurring during the growing season which extends from April to September (Western Regional Climate Center, 2020a). The potential evapotranspiration rate exceeds precipitation in the area. Average annual pan evaporation for the Sheridan Field Station (Station 488160) near Sheridan is 44.14 inches (Western Regional Climate Center, 2020b).

National Weather Service Cooperative Network station Sheridan County Airport (Station 488155) is located near the proposed Brook Mine. The period of record climate data summary for this station is shown in Table 1. Figure 6 shows the annual precipitation at the station over the 1974 to 2019 period. Evapotranspiration data are not available for the station.

Table 1. Climate data summary for the area of the proposed Brook Mine. Data from Western Regional Climate Center (2020a).

<table>
<thead>
<tr>
<th></th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
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<th>Nov</th>
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<td>38.1</td>
<td>46.3</td>
<td>56.9</td>
<td>66.3</td>
<td>76.2</td>
<td>86.8</td>
<td>85.8</td>
<td>74.1</td>
<td>61.4</td>
<td>45.8</td>
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<tr>
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<td>13.9</td>
<td>21.3</td>
<td>30.7</td>
<td>39.5</td>
<td>47.6</td>
<td>54.0</td>
<td>52.4</td>
<td>42.7</td>
<td>32.2</td>
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<td>31.4</td>
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<tr>
<td><strong>Average Total Precipitation (in.)</strong></td>
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<td>0.67</td>
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<td>1.38</td>
<td>1.26</td>
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<td>0.63</td>
<td>15.25</td>
</tr>
<tr>
<td><strong>Average Total Snow Fall (in.)</strong></td>
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<td>12.33</td>
<td>9.57</td>
<td>1.74</td>
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<td>0.00</td>
<td>1.42</td>
<td>4.40</td>
<td>8.87</td>
<td>10.84</td>
<td>70.67</td>
</tr>
</tbody>
</table>

Figure 6. Annual precipitation at Sheridan County Airport (1974-2019), upper Tongue River Basin, Wyoming.
1.3.2 SOILS

A soil survey was conducted at the proposed Brook Mine for the purposes of characterizing soils for the permit application (Brook Mine Permit Application, 2020). The soil survey found 16 soil map units with 10 dominant soils and four miscellaneous units within the proposed permit area. The dominant soil map unit is the Wibaux-Rock Outcrop Complex, which represents 1,280.1 acres or 28 percent of the proposed permit area. Soils within the proposed permit area are primarily residual. The main soil types are well-drained, but shallow. Deeper soils, varying from well-drained to poorly-drained, are found in drainages. Recommended salvage depths range from 0 inches on rocky outcrops to near 20 inches on reclaimed land. The dominant soil map unit has a recommended topsoil salvage depth of six inches (Brook Mine Permit Application, 2020).

1.3.3 VEGETATION

The flora of the PRB consists of species that are typical of the Northern Great Plains and Rocky Mountain regions. Native vegetation can be classified into dominant vegetation communities whose species composition reflects the amount of moisture available. Upland sagebrush/grassland communities occur on terraces and gently sloping hillsides and are completely dependent on direct precipitation. Upland communities include big sagebrush (*Artemisia tridentata*), blue grama (*Bouteloua gracilis*), needle and thread grass (*Hesperostipa comata*), and prairie june grass (*Koeleria macrantha*). Bottomland communities receive augmented moisture via surface and subsurface sources, and thus demonstrate species with higher water requirements. Dominant species in ephemeral drainages include western wheatgrass (*Agropyron smithii*), Kentucky bluegrass (*Poa pratensis*), and silver sagebrush (*Artemisia cana*). Immediately adjacent to streams, narrow, primarily sub-irrigated mesic communities demonstrate prairie cordgrass (*Spartina pectinata*), chair maker’s rush (*Scirpus americanus*), and common spikerush (*Eleocharis macrostachya*). Lesser communities within the PRB include bunchgrass and cushion plant communities which are found upon steep highly eroded surfaces such as clinker buttes and Wasatch Formation outcrops.

A vegetation survey was conducted in 2013 at the proposed Brook Mine for the purposes of the characterizing vegetation for the permit application (Brook Mine Permit Application, 2020). Eleven vegetation communities, plus two additional categories, reclaimed land and water, were identified. The dominant vegetation communities include upland grassland (21.9 percent of the permit area), big sagebrush shrubland (20.1 percent of the permit area), and scoria grassland (16.0 percent of the permit area). Small areas of agriculture land were also mapped, primarily adjacent to the Tongue River (Brook Mine Permit Application, 2020). Reclamation at the Big Horn Mine has primarily resulted in grassland and mixed shrubland/grassland communities to support the predominant post-mine land use of livestock grazing (Big Horn Mine Permit, 2020).

1.4 REGIONAL HYDROLOGY OF THE POWDER RIVER BASIN

The PRB presents a challenge in hydrologic analysis because the surface water drainage basins and the groundwater basins do not coincide. The aquifers outcrop at the edges of the geological structural basin (Figure 7) and dip toward the center of the basin. Groundwater flow in the coal aquifers is generally from the outcrop toward the center of the structural basin with a
regional flow component to the north. However, most surface water flows to the northeast in five principle drainages: the Tongue River, Powder River, Little Powder River, Belle Fourche River, and the Cheyenne River (Figure 7).

The Tongue and Powder Rivers have their headwaters in the Bighorn Mountains on the western side of the PRB and are generally perennial throughout their entire length. The Little Powder, Belle Fourche, and Cheyenne Rivers originate on the plains and are ephemeral in the upper reaches trending toward intermittent and eventually perennial in the downstream reaches. Most tributaries of the plains river systems are ephemeral or intermittent, flowing in response to precipitation and snowmelt. Infrequent points of groundwater expression may be observed providing small quantities of water in localized areas. Depending on the stream classification assigned by the WDEQ/WQD, surface water in the PRB supports drinking water, aquatic life, recreation, industry, agriculture, and scenic value uses.

Aquifers in the PRB support a variety of uses depending on the specific aquifer unit, location/depth, water availability, and water quality. Supported uses include, but are not limited to, domestic, agricultural, livestock, and industrial uses.
Figure 7. General direction of groundwater flow in the coal aquifer and surface water flow in the major watersheds of the Powder River Basin.
1.5 HISTORICAL AND CURRENT COAL MINING IN THE UPPER TONGUE RIVER BASIN

The area of the proposed Brook Mine contains a long history of coal mining. Numerous underground mines operated in the Sheridan Coal Field beginning in the late 1890s through the early 1950s, including Dietz, Monarch, Acme, and Carneyville (Kleenburn) (Dunrud and Osterwald, 1980). Several underground mines operated within the proposed Brook Mine permit boundary, most notably Carney Mine Number 44 and several Acme mines (Brook Mine Permit Application, 2020). The last underground mine in the area, Monarch, located immediately south of the Tongue River, closed in 1953. Subsidence features such as local depressions, pits, troughs, tension cracks, and compression bulges, have developed on the surface over many of the historical underground mines (Dunrud and Osterwald, 1980). Underground coal fires have also occurred at some of the mines. Some of the subsidence and other features of the historical underground coal mines have been reclaimed by the WDEQ/AML (Bureau of Land Management, 2003).

Surface mining in the area of the proposed Brook Mine started in the 1940s. The Decker Coal Company open-pit strip mined approximately 10 million short tons of coal from several pits in the Hidden Water Creek headwaters immediately north of the proposed Brook Mine from 1944 to 1955 (Wangsness, 1977). The pits were abandoned and became impoundments after filling with water. The WDEQ/AML has conducted reclamation at the site (Bureau of Land Management, 2003), but the pit impoundments remain as permanent features on the landscape.

Operations at the Big Horn Mine started in 1948, with early mining occurring in the valleys of Goose Creek and the Tongue River (Big Horn Mine Permit, 2020). Mining occurred using conventional surface methods such as trucks, scrapers, and shovels. The Big Horn Mine was originally permitted by the State of Wyoming in 1974 under the 1969 Open Pit Cut Reclamation Act. Following the approval of the Wyoming State Program in 1980 under the Federal Surface Mining Control and Reclamation Act (SMCRA) of 1977, the Big Horn Mine received Permit No. 213-T1 from the WDEQ/LQD in August 1981. The permit area initially included 3,467.56 acres, and a subsequent permit renewal in August 1984 increased the permit area to 3,784.31 acres (Big Horn Mine Permit, 2020).

Surface coal mining occurred at the Big Horn Mine until 1999 with reclamation activities occurring concurrently. As a result of successful reclamation, the WDEQ/LQD approved final bond release and termination of jurisdiction of 2,286.04 acres from the permit area in June 2006. The current permit area is 1,385.6 acres. With the exception of 24.15 acres of facilities area, including a shop, loadout area, and rail spur, the remaining mine site has been permanently reclaimed (backfilled, topsoiled, revegetated) and fully bond released under WDEQ/LQD regulations. The Big Horn Mine has no plans to reopen the mine at this time (Big Horn Mine Permit 2019 Annual Report, 2020).

The Brook Mine proposes to conduct both highwall and surface coal mining over a 39-year period. Surface mining would occur during the first five years of the operation followed by highwall mining for the remaining mine sequence. Reclamation activities would occur after coal mining for a period of approximately four years (Brook Mine Permit Application, 2020). Highwall mining would be the primary mining method and would consist of initially constructing and mining a trench to create a working area for a continuous miner system. The continuous miner would be remotely operated to mine coal perpendicular to the trench. The highwall mining method will leave behind
coal pillars and not all the coal will be removed. The pillars left between each mining tunnel are necessary for protection purposes to support the overburden above the coal. The coal would be transported from the continuous miner back to the surface by conveyance cars where it would then be stockpiled in the trench for later transport by loaders and trucks (Brook Mine Permit Application, 2020).

Surface mining would also be used at the Brook Mine in areas of low strip ratios using dozer push methods with loader and truck support, a scraper fleet, or a truck/shovel operation (Brook Mine Permit Application, 2020). Additional surface mining methods would be used to expose the highwall for mining by the continuous miner. Blasting would be used for both overburden and coal to maximize production and minimize loading equipment maintenance. Coal from both highwall and surface mining would be crushed by portable, in-pit crushers. Coal would either be temporarily stored in the pit, at a storage pad, or hauled directly offsite. Other facilities at the mine would include administrative and equipment maintenance facilities. More details of the specific mining process at the proposed Brook Mine is found in the mine plan section of the Brook Mine Permit Application (2020).

1.6 ANTICIPATED COAL MINING IN THE UPPER TONGUE RIVER BASIN

The WDEQ/LQD Coal Rules and Regulations require the WDEQ/LQD to assess the probable cumulative hydrologic impacts of the proposed operation and their interaction with the impacts of all anticipated mining (WDEQ Land Quality–Coal Rules, Ch. 19, § 2(a)(i)). Anticipated mining shall be projected over the life of the operation, and includes all other existing coal mining operations, any proposed coal mining operation for which a permit application has been filed, and all proposed operations required to meet diligent development requirements for leased federal coal where mine development and geological information is available (WDEQ Land Quality–Coal Rules, Ch. 19, § 2(a)(i)).

For the purposes of this CHIA, the mining proposed by the Brook Mine represents the current known extent of planned coal mining in the immediate area. There are no additional areas of anticipated coal mining.

1.7 OIL AND GAS PRODUCTION

A non-coal mine land use in the upper Tongue River Basin that has implications for hydrology and water resources is coalbed methane (CBM) production. CBM production consists of pumping groundwater from the coal aquifer to lower the potentiometric head. This reduces the confining pressure on the methane in the coal allowing the gas to flow and be collected at recovery wells. During the process large quantities of groundwater are removed from the coal aquifer structurally down dip from the coal mines. The water is then discharged to the surface, typically to unlined impoundments, although direct discharge to streams can also occur, potentially causing changes to surface water flow regimes and surface water quality (Healy et al., 2011).

The WDEQ/LQD does not regulate CBM activities. CBM is regulated by various other State agencies including the Wyoming Oil and Gas Conservation Commission (WOGCC) (permitting and reclamation), the WSEO (water rights), and the WDEQ/WQD (discharge permits). The discussion of
CBM in this CHIA is intended to acknowledge and provide a broad overview of the impacts caused by CBM to the hydrologic regime within the area.

Data from the WOGCC indicate that nearly 45,000 CBM wells have been drilled in the Powder River Basin since the early 1980s (Wyoming Oil and Gas Conservation Commission, 2019). The first CBM wells near the proposed Brook Mine in the upper Tongue River Basin produced water in 1999 and gas in 2001. Figure 8 shows the location of 396 CBM wells to the northeast, east, and southeast of the proposed mine. No CBM wells have been drilled within the proposed permit area. The data in Figure 8 also show the status of the CBM wells, as indicated from October 2019 data from the WOGCC. Nearly all of the wells are currently shut in or abandoned and are no longer producing. Data from the WOGCC indicate that gas production from 834 CBM wells in the entire upper Tongue River Basin peaked in 2003 at approximately 17 million thousand cubic feet (MCF), while water production peaked in 2002 at approximately 2,798 acre-feet (ac-ft) (Figure 9). After this peak, production levels declined sharply over time. No production occurred in 2016, 2017, and 2018 (Figure 9) (Wyoming Oil and Gas Conservation Commission, 2019).
Figure 8. Location of historically or actively producing coalbed methane (CBM) wells near the proposed Brook Mine in the Upper Tongue River Basin, Wyoming (Wyoming Oil and Gas Conservation Commission, 2019).
Figure 9. Production of gas and water from CBM wells in the upper Tongue River Basin, 1999 to 2018 (Wyoming Oil and Gas Conservation Commission, 2019).
2. HYDROLOGIC ISOLATION OF THE PROPOSED BROOK MINE

The cumulative impact area (CIA) for a CHIA is defined as "...the area, including the permit area, within which impacts resulting from the proposed operation may interact with the impacts of all anticipated mining on surface- and ground-water systems" (30 C.F.R. § 701.5). The CIA is the area where existing and proposed mining activities may cause measurable hydrologic changes and may cause material damage to surface water and groundwater resources. The CIA depends on the characteristics of the surface and groundwater systems.

As discussed in the sections below, the proposed Brook Mine was determined to be hydrologically isolated from existing coal mining permits in the upper Tongue River Basin, both in Wyoming and Montana. Because of this, the term cumulative impact area does not apply for this CHIA since there are no cumulative hydrologic impacts from multiple coal mines to assess. The CHIA instead delineates a surface and groundwater evaluation area that describes the extent of the analysis area evaluated for the proposed Brook Mine.

As previously discussed in Section 1, the nearest permitted coal mine to the proposed Brook Mine is the Big Horn Mine (WDEQ/LQD Permit 213), located directly to the east (Figure 10). No mining has occurred at the Big Horn Mine since 1999 and 98 percent of the permit area is reclaimed and fully bond released.

The Youngs Creek Mine (WDEQ/LQD Permit 407) also resides in the upper Tongue River Basin, approximately five miles northeast of the proposed Brook Mine (Figure 10). Formerly known as the PSO No. 1 Mine and later the Ash Creek Mine, the mine pit and facilities were developed between 1976 and 1978. The mining operation was suspended from 1980 to 1993, and permanent reclamation seeding of 140 acres of disturbed land occurred in 1996. In 2011, an amendment was approved that added 7,107.65 acres to the permit area and changed the name of the mine to the Youngs Creek Mine. Although permitted to mine coal, no mining has occurred at the Youngs Creek Mine since the amendment was approved in 2011. In May 2018, the WDEQ/LQD approved a revision to the permit to initiate early mine development, with the purpose of opening a pit to supply test burn coal for potential customers. As of December 31, 2019, only minor ground disturbance associated with drilling three industrial water supply wells has taken place at the Youngs Creek Mine (Youngs Creek Mine Permit 2019 Annual Report, 2020).

Three active coal mines (Spring Creek, West Decker, East Decker) near the Tongue River and Tongue River Reservoir in Montana are approximately 14-16 miles northeast of the proposed Brook Mine (Figure 10). As discussed in the sections below, the location of the proposed Brook Mine relative to the Big Horn, Youngs Creek, and Montana mines was evaluated to determine if cumulative effects to surface water and groundwater resources were likely.
Figure 10. Location of the proposed Brook Mine in relation to other permitted coal mines in the upper Tongue River Basin in Wyoming and Montana.
2.1 SURFACE WATER

2.1.1 DELINEATION OF THE SURFACE WATER EVALUATION AREA AND DEMONSTRATION OF HYDROLOGIC ISOLATION OF THE PROPOSED BROOK MINE

The proposed Brook Mine is located within the upper Tongue River drainage basin, a tributary of the Yellowstone River. The proposed Brook Mine drains to three 12-digit Hydrologic Unit Code (HUC) units: Tongue River-Slater Creek, Goose Creek, and Tongue River-Beatty Gulch (Figure 11).

The majority, or 88 percent of the proposed Brook Mine permit area drains to the Tongue River-Slater Creek HUC unit, which includes the drainages of Hidden Water Creek, Slater Creek, East Fork Earley Creek, and several small ephemeral drainages (Figure 11). All of these drainages are direct tributaries to the Tongue River or are intercepted by the Tongue River Ditch, a ditch that provides irrigation water for several hundred acres in the Tongue River valley (Wyoming State Engineer's Office, 2019a). With the exception of a bridge crossing of the Tongue River located in the east part of the proposed permit area, the Tongue River and Tongue River Ditch are located outside of the Brook Mine permit boundary.

The Goose Creek HUC unit contains eight percent of the proposed Brook Mine, located in the southeast part of the proposed permit area (Figure 11). The Goose Creek channel is located outside the proposed permit area with the exception of where the Burlington Northern Santa Fe (BNSF) rail line crosses the channel. No other named streams exist within the portion of the permit area within the Goose Creek HUC unit.

The Tongue River-Beatty Gulch HUC unit includes four percent of the proposed Brook Mine permit area. This area is located in the east portion of the proposed permit area and primarily contains post-mine reclamation completed by the Big Horn Mine (Figure 11).

2.1.1.1 EVALUATION OF THE BIG HORN MINE

As previously discussed, the nearest permitted coal mine to the proposed Brook Mine is the Big Horn Mine (WDEQ/LQD Permit 213) (Figure 10). No mining has occurred at the Big Horn Mine since 1999 and 98 percent of the permit area is reclaimed and fully bond released. On March 14, 2003, the WDEQ/LQD approved Change No. 11 to Term 5 of the permit, which approved groundwater restoration at the mine, releasing the mine from groundwater monitoring requirements (Big Horn Mine Permit, 2020). The mine continues to monitor surface water on the Tongue River, Goose Creek, and the Pit 3 Reservoir, which is an approved permanent post-mining impoundment (see Figure 11). However, the mine may submit a non-significant revision to the WDEQ/LQD to reduce surface water monitoring requirements during the next annual report period (Big Horn Mine Permit 2019 Annual Report, 2020).

Since the Big Horn Mine still monitors surface water, the mine was evaluated for consideration in the surface water evaluation area for the Brook Mine CHIA. The common receiving waterbody and point of accumulation for the proposed Brook Mine and Big Horn Mine is the Tongue River at the location of the Big Horn Mine TR2B80 monitoring station (see Figure 11). In order for the proposed Brook Mine to be considered in the same CIA as the Big Horn Mine, the Big Horn Mine would need to have the potential to cause a measurable change in surface water
quantity or quality at the TR2B80 station on the Tongue River. According to an Office of Surface Mining Reclamation and Enforcement (OSMRE) CHIA guidance document, existing mines that would likely have a measurable cumulative effect on the common receiving stream should be considered as part of the CHIA CIA for any proposed operation (Office of Surface Mining Reclamation and Enforcement, 1985). Therefore, an analysis of surface water quantity and quality data was conducted to determine if the Big Horn Mine is having a measurable impact on the Tongue River.

Data from the Big Horn Mine’s upstream (TR0176) and downstream (TR2B80) monitoring sites on the Tongue River, as well as the Goose Creek tributary (GC00-78) were evaluated. The location of these sites is shown in Figure 11. The dataset evaluated included mean daily flows collected from 2000 to 2018 and water quality samples collected from 2000 to 2019. Mean daily flows were evaluated from April 1 through November 30 in each year since the stations were either not active in the winter months or were affected by ice. The Tongue River stations were missing several days of data in 2001, so this year was not analyzed. In addition, the TR0176 and GC00-78 stations also had several days with no data, particularly after 2005. To supplement streamflow data, data from the closest USGS station were used. For Goose Creek, USGS Station No. 06305700 Goose Creek near Acme, WY data were used. This station is located about 0.3 miles downstream from the GC00-78 station (Figure 11). For the Tongue River upstream of the Big Horn Mine, data were taken from USGS Station No. 06299980 Tongue River at Monarch, WY. This station is located about one mile upstream from the TR0176 station (Figure 11). Over select periods during 2012 to 2018, the Big Horn Mine did not measure flows at the TR2B80 station, but rather estimated flows by adding flows from their upstream stations or the USGS stations on Goose Creek and the Tongue River. All water quality samples used in this evaluation were collected from March 2000 to September 2019 at the stations operated by the Big Horn Mine.

Annual mean daily streamflow from 2000 to 2018 on Goose Creek and the Tongue River upstream and downstream of the Big Horn Mine are presented in Figure 12. On average, the flows were 73 percent higher on the Tongue River below the Big Horn Mine, and much of this increase is due to flows contributing from Goose Creek. The data indicate that the Big Horn Mine has had no discernable impact on flows in the Tongue River over the period the mine has been in reclamation. The TR2B80 station below the Big Horn Mine has a drainage area of approximately 911 mi². The current permit area of the Big Horn Mine is approximately 2.2 mi². Even if the entire permit area was still disturbed, this would only result in 0.24 percent of the watershed area upstream from the gage as being disturbed by coal mining activity. The small area of disturbance relative to the Tongue River watershed area makes it unlikely that changes in surface water quantity would be detectable. Additional analysis of water quantity data from Goose Creek and the Tongue River is provided in Sections 3.1.1.4 and 3.1.1.5.
Figure 11. Location of the surface water evaluation area and active and inactive surface water monitoring stations used to evaluate baseline hydrologic conditions for the CHIA. Further details on the stations are provided in Table 3.
Figure 12. Comparison of annual mean daily streamflow over the April through November period on Goose Creek and the Tongue River above and below the Big Horn Mine, 2000-2018. Year 2001 data for the Tongue River were not analyzed due to the large amount of missing data. Source data includes stations operated by the Big Horn Mine and the USGS.
The WDEQ/WQD has classified Goose Creek and the Tongue River as Class 2AB water (Wyoming Department of Environmental Quality, 2013). Class 2AB waters support game fish populations or spawning and nursery areas at least seasonally. Class 2AB waters are also presumed to have sufficient water quality and quantity to support drinking water supplies. Supported uses include drinking water, game fish, nongame fish, fish consumption, other aquatic life, recreation, wildlife, agriculture, industry, and scenic value (see Table 6 in Section 3.1). The WDEQ/WQD numeric standards for selected constituents on Class 2AB surface waters are presented in Table 7 in Section 3.1.

From March 2000 to September 2019, 79 water quality samples were collected from the Goose Creek and Tongue River stations at the Big Horn Mine. Summary statistics for this dataset are presented in Table 2. The medians in Table 2 for constituents with non-detect concentrations were calculated using methods recommended by Helsel (2005). Non-detect concentrations are defined as concentrations that fall somewhere between zero and the laboratory reporting limit. In this CHIA, for constituents with < 50 percent non-detects, the non-parametric Kaplan-Meier method was used to calculate the median concentration. For constituents with 50-79 percent non-detects, the regression on order statistics (ROS) method was used to calculate the median concentration. For constituents with ≥ 80 percent non-detects, medians were not calculated; rather the proportion of data below the maximum detection limit was reported. Minitab software (Minitab, Inc., 2017) was used to calculate Kaplan-Meier and ROS estimates using macros available from Practical Stats (2012, 2019a, 2019c) and Helsel (2012). A Microsoft Excel spreadsheet using the Kaplan-Meier method (Practical Stats, 2019b) was also used to calculate medians where the sample size was low.

The median total dissolved solids (TDS) concentration at the upstream Tongue River station was 260 mg/l. The median TDS downstream of the Big Horn mine increases to 330 mg/l. The cause for this increase is likely due to inputs from Goose Creek, as the median TDS at this location was 400 mg/l (Table 2).

The 2000-2019 data show that the Class 2AB standards evaluated are infrequently exceeded on both Goose Creek and the Tongue River, both upstream and downstream of the Big Horn Mine. At the TR0176 station upstream of the Big Horn Mine, there was one iron exceedance in 2003 and five water temperature exceedances occurring from 2002 to 2006 (Table 2). On Goose Creek at GC00-78, there was one cadmium exceedance in 2002, one iron exceedance in 2010, and five temperature exceedances occurring from 2002 to 2016 (Table 2). At the TR2B80 station downstream of the Big Horn Mine, there were nine water temperature exceedances occurring from 2002 to 2018 (Table 2).

In 2002, the WDEQ/WQD placed the Tongue River from the Goose Creek confluence downstream to the Montana state line on Wyoming’s Section 303(d) list for impaired water quality due to elevated water temperatures. The source of the elevated temperatures is unknown (Wyoming Department of Environmental Quality, 2018). Another 13.5 mile segment of the Tongue River from Monarch Road upstream to Wolf Creek Road was placed on the 303(d) list in 2010 due to *Escherichia coli* (*E. coli*) exceedances that impair recreation use. This segment of the river is upstream of USGS Station No. 06299980, but adjacent to the proposed Brook Mine. Total Maximum Daily Load (TMDL) development for this segment started in 2015 (Wyoming Department of Environmental Quality, 2018). In 2018, a 4.7 mile segment of the Tongue River from the confluence with Goose Creek upstream to Monarch Road was added to the 303(d) list due to *E. coli* exceedances. The source(s) of *E. coli* is currently unknown, but may be related to spring runoff,
overland flow, and the resuspension of bacteria in streambed sediments (Wyoming Department of Environmental Quality, 2018). The overall evaluation of the 2000-2019 dataset shows that water quality on the Tongue River in the vicinity of the Big Horn Mine is more affected by inputs from Goose Creek and conditions in the upper watershed than by mining activity. Additional analysis of water quality data from Goose Creek and the Tongue River is provided in Sections 3.1.1.4 and 3.1.1.5.

In addition to the above analysis, three other factors support the decision to not include the Big Horn Mine in the surface water evaluation area for the proposed Brook Mine. First, in February 2011, Change No. 1 to Term 7 of the Big Horn Mine permit removed the alternate reclamation plan and associated bonding commitments for the Pit 3 Reservoir, a permanent post-mine impoundment (see Figure 11) (Big Horn Mine Permit, 2020). Under this approval, the Big Horn Mine successfully demonstrated to the WDEQ/LQD that the reservoir has met post-mine water quality and functionality standards, and has not impacted water quantity or quality in the Tongue River. Second, documents related to groundwater restoration demonstrated to WDEQ/LQD’s satisfaction that there have been no mining related impacts on the groundwater-surface water interaction. Third, the mine no longer maintains a Wyoming Pollutant Discharge Elimination System (WYPDES) permit since no discharges to the Tongue River have occurred since May 2000. Regulatory permitted impoundments and alternative sediment control measures (ASCMs) are still used to protect Goose Creek and the Tongue River. Because of these factors and the above analysis, the Big Horn Mine is determined to have no measurable hydrological impacts to the Tongue River and therefore the mine has no relevance for evaluating cumulative surface water hydrologic impacts as part of the Brook Mine CHIA.
Table 2. Surface water quality summary statistics for Goose Creek and the Tongue River above and below the Big Horn Mine, March 2000 to September 2019.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Units</td>
<td>Min</td>
<td>Max</td>
<td>Median</td>
</tr>
<tr>
<td>Aluminum (dissolved)</td>
<td>mg/L</td>
<td>79</td>
<td>&lt;0.1</td>
<td>0.5</td>
</tr>
<tr>
<td>Ammonia as N (dissolved)1</td>
<td>mg/L</td>
<td>75</td>
<td>&lt;0.1</td>
<td>0.5</td>
</tr>
<tr>
<td>Arsenic (dissolved)1</td>
<td>mg/L</td>
<td>79</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>Barium (dissolved)3</td>
<td>mg/L</td>
<td>79</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>Cadmium (dissolved)</td>
<td>mg/L</td>
<td>79</td>
<td>&lt;0.002</td>
<td>&lt;0.002</td>
</tr>
<tr>
<td>Chloride (dissolved)1</td>
<td>mg/L</td>
<td>79</td>
<td>&lt;1</td>
<td>5</td>
</tr>
<tr>
<td>Chromium (dissolved)1</td>
<td>mg/L</td>
<td>79</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Copper (dissolved)</td>
<td>mg/L</td>
<td>79</td>
<td>&lt;0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Dissolved oxygen (field)</td>
<td>mg/L</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Iron (dissolved)</td>
<td>mg/L</td>
<td>79</td>
<td>&lt;0.05</td>
<td>0.32</td>
</tr>
<tr>
<td>Lead (dissolved)</td>
<td>mg/L</td>
<td>79</td>
<td>&lt;0.02</td>
<td>&lt;0.02</td>
</tr>
<tr>
<td>Manganese (dissolved)</td>
<td>mg/L</td>
<td>79</td>
<td>&lt;0.02</td>
<td>0.05</td>
</tr>
<tr>
<td>Mercury (dissolved)2</td>
<td>μg/L</td>
<td>79</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Nickel (dissolved)</td>
<td>mg/L</td>
<td>79</td>
<td>&lt;0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Nitrite plus nitrate as N (dissolved)1</td>
<td>mg/L</td>
<td>79</td>
<td>&lt;0.01</td>
<td>0.28</td>
</tr>
<tr>
<td>pH (field)</td>
<td>S.U.</td>
<td>79</td>
<td>7.10</td>
<td>8.90</td>
</tr>
<tr>
<td>Selenium (dissolved)</td>
<td>mg/L</td>
<td>79</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>Temperature (field)</td>
<td>°C</td>
<td>79</td>
<td>0.1</td>
<td>24.0</td>
</tr>
<tr>
<td>Turbidity</td>
<td>NTU</td>
<td>74</td>
<td>0.1</td>
<td>780</td>
</tr>
<tr>
<td>Zinc (dissolved)</td>
<td>mg/L</td>
<td>79</td>
<td>&lt;0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>Boron (dissolved)</td>
<td>mg/L</td>
<td>79</td>
<td>&lt;0.01</td>
<td>0.1</td>
</tr>
<tr>
<td>Fluoride (dissolved)</td>
<td>mg/L</td>
<td>79</td>
<td>&lt;0.1</td>
<td>0.28</td>
</tr>
<tr>
<td>Sodium (dissolved)</td>
<td>mg/L</td>
<td>79</td>
<td>3</td>
<td>35</td>
</tr>
<tr>
<td>Sulfate (dissolved)</td>
<td>mg/L</td>
<td>79</td>
<td>9</td>
<td>134</td>
</tr>
<tr>
<td>TDS dried at 180 °C</td>
<td>mg/L</td>
<td>79</td>
<td>120</td>
<td>430</td>
</tr>
<tr>
<td>Total suspended solids</td>
<td>mg/L</td>
<td>75</td>
<td>&lt;5</td>
<td>370</td>
</tr>
</tbody>
</table>

Summary statistics for constituents with non-detect values were calculated using methods recommended by Helsel (2005). Concentrations shown in red exceed WD EQ/WQD Class 2A8 surface water quality standards. NA=No numeric standard established. 1) Class 2A8 standard expressed as a total, but only dissolved data were available. 2) Gross macro in Minntah would not calculate a median for unknown reasons.
2.1.1.2 EVALUATION OF THE YOUNGS CREEK MINE

The Youngs Creek Mine (WDEQ/LQD Permit 407) is located approximately five miles northeast of the proposed Brook Mine (Figure 10). The common receiving waterbody and point of accumulation for the proposed Brook Mine and Youngs Creek Mine is the Tongue River at the location of USGS Station No. 06306020, Tongue River below Youngs Creek, near Acme, WY (see Figure 10). In order for the proposed Brook Mine to be considered in the same CIA as the Youngs Creek Mine, the Brook Mine would need to have the potential to cause a measurable change in surface water quality at USGS Station No. 06306020 on the Tongue River. The likelihood of this occurring is very low due to the limited extent of disturbance relative to the Tongue River drainage area upstream from USGS Station No. 06306020. The Youngs Creek Mine is approved to disturb 5,412.51 acres, or approximately 0.8 percent of the 1,027 mi² drainage area upstream of USGS Station No. 06306020 (Youngs Creek Mine Permit, 2020). As of December 31, 2019, only 141 acres or about two percent of the Youngs Creek Mine permit area had been affected by mining disturbance, and this total includes 140 acres that have been permanently reclaimed (Youngs Creek Mine Permit 2019 Annual Report, 2020). If approved, the Brook Mine would have an affected/disturbed area of an additional 1,135.1 acres in the upper Tongue River drainage (Brook Mine Permit Application, 2020). This would result in only approximately 0.2 percent of additional affected area in the drainage area upstream from USGS Station No. 06306020. As discussed later in the CHIA, the Brook Mine is predicted to have minimal effects on surface water quantity due to the limited disturbance area. Due to these factors, potential changes in runoff due to the Brook Mine would likely not be detectable on the Tongue River at USGS Station No. 06306020 and would not be discernable from seasonal variability due to climate. Therefore, the potential for the proposed Brook Mine and Youngs Creek Mine to contribute to cumulative impacts to surface water quantity on the Tongue River is negligible.

The potential for measurable changes in surface water quality on the Tongue River at USGS Station No. 06306020 as a result of the Brook Mine is also low. Sediment control measures at the proposed Brook Mine will help mitigate impacts to water quality within the disturbed area and prevent downstream degradation in water quality. Sediment control measures are discussed in more detail later in the CHIA. In addition, any point source discharges at the mine will be monitored by the WYPDES program with the WDEQ/WQD to ensure water quality is not degraded (Brook Mine Permit Application, 2020). The potential for water quality degradation on the Tongue River is also very low due to the diluting effects of streamflow from the watershed upstream of the point of accumulation. The point of accumulation on the Tongue River at USGS Station No. 06306020 is located approximately 17 miles downstream of the proposed Brook Mine. The long distance from the source of disturbance to the point of accumulation makes it unlikely that water quality impacts would be detectable due to dilution.

2.1.1.3 EVALUATION OF THE MONTANA COAL MINES

Three active coal mines (Spring Creek, West Decker, East Decker) near the Tongue River and Tongue River Reservoir in Montana are approximately 14-16 miles northeast of the proposed Brook Mine (Figure 10). The Montana coal mines are not included in the CHIA for the proposed Brook Mine for the same reasons that the Youngs Creek Mine is not included. There is negligible potential for the proposed Brook Mine and Montana mines to contribute to cumulative surface water quantity impacts due to the distance between the mines and the limited area of disturbance at the proposed Brook Mine. The common receiving waterbody and point of accumulation for the proposed Brook Mine and Montana mines is Tongue River Reservoir (Figure 10). The watershed
area upstream of the reservoir is approximately 1,513 mi², and the affected area at the proposed Brook Mine is 1.77 mi², or 0.12 percent of the watershed area. Any changes in runoff caused by the proposed Brook Mine would likely not be detectable at the reservoir and would not be discernable from seasonal variability due to climate. The potential for measurable change to the surface water quality of the Tongue River Reservoir as a result of the proposed Brook Mine is also low due to sediment control measures, controlled and permitted discharges, the limited area of disturbance, and the diluting effects of streamflow from the Tongue River watershed upstream of the reservoir.

2.1.1.4 DELINEATION OF THE SURFACE WATER EVALUATION AREA FOR THE PROPOSED BROOK MINE

Given the above analysis, the potential impacts of the proposed Brook Mine on the surface water system are limited to the drainages in the immediate vicinity of the permit area and there is no potential for cumulative impacts with other coal mines. The proposed Brook Mine will cause surface disturbance within three 12-digit Hydrologic Unit Code (HUC) units: Tongue River-Slater Creek, Goose Creek, and Tongue River-Beatty Gulch (Figure 11). The majority of the proposed disturbance lies within the Hidden Water Creek and Slater Creek drainages. Several small unnamed ephemeral tributaries to the Tongue River or the Tongue River Ditch will also be disturbed. The surface water evaluation area was created by using a one-half mile buffer around the proposed Brook Mine permit boundary. Although the proposed Brook Mine will not directly disturb any part of the Tongue River or Goose Creek channels, the surface water evaluation area includes these areas since they contain declared alluvial valley floors (AVFs). The area was also extended downstream to include the Big Horn Mine TR2B80 surface water monitoring station on the Tongue River. The surface water evaluation area for the proposed Brook Mine covers approximately 20.5 square miles (mi²) and is shown in Figure 11. Further description of the drainages in the surface water evaluation area is provided in Section 3.1.

It should be noted that the above approach to delineating the surface water evaluation area is different to the approach used by the WDEQ/LQD in past CHIAs. Typically, the entire watershed area above a downstream USGS gaging station has been included in the CIA for a CHIA. Given the size of the Tongue River watershed in Wyoming (~1,450 mi²) relative to the proposed Brook Mine permit area (7.1 mi²), this approach was viewed as unrealistic. The approach of excluding watershed area not impacted by the mining operation is supported by an OSMRE CHIA guidance document (Office of Surface Mining Reclamation and Enforcement, 1985).

2.1.2 DESCRIPTION OF THE MONITORING NETWORK IN THE SURFACE WATER EVALUATION AREA

The surface water monitoring network in the evaluation area is comprised of stations operated by the proposed Brook Mine, the Big Horn Mine, and the USGS. Figure 11 and Table 3 show the location and period of record for all surface water stations used to evaluate baseline hydrologic conditions in the CHIA. Further descriptions of these stations are provided in Section 3.1. Additional discussion on the surface water monitoring stations that would be used at the proposed Brook Mine during the life of the mine operation is provided in Section 7.1.

Additional data have been collected on Goose Creek and the Tongue River in the vicinity of the proposed Brook Mine by the WDEQ/WQD (Wyoming Department of Environmental Quality, 2019a) and Sheridan County Conservation District (SCCD) (Sheridan County Conservation District,
2017a; 2017b). These data sources were not used in the CHIA due to limitations in the number of samples available for a wide range of water quality parameters over a consistent period of time.

Table 3. Surface water stations used to evaluate baseline hydrologic conditions in the surface water evaluation area. Stations in bold are currently active. The location of the stations is shown in Figure 11.

<table>
<thead>
<tr>
<th>Station</th>
<th>Stream Name and Location</th>
<th>Drainage Area (mi²)</th>
<th>Period of Record</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM578409-SW-1 (Brook Mine)</td>
<td>Hidden Water Creek - upstream</td>
<td>6.41¹</td>
<td>9/2013 to 10/2015</td>
</tr>
<tr>
<td>SM578415-SW-1 (Brook Mine)</td>
<td>Hidden Water Creek - downstream</td>
<td>7.57¹</td>
<td>9/2013 to 11/2014</td>
</tr>
<tr>
<td>SM578512-SW-1 (Brook Mine)</td>
<td>Slater Creek – upstream</td>
<td>15.01¹</td>
<td>9/2013 to 10/2015</td>
</tr>
<tr>
<td>SM578418-SW-1 (Brook Mine)</td>
<td>Slater Creek – downstream</td>
<td>16.41¹</td>
<td>9/2013 to 10/2015</td>
</tr>
<tr>
<td>GC00-78     (Big Horn Mine)</td>
<td>Goose Creek</td>
<td>412.95¹</td>
<td>3/2000 to 9/2019</td>
</tr>
<tr>
<td>USGS 06305700</td>
<td>Goose Creek near Acme, WY</td>
<td>413</td>
<td>5/1984 to 10/2007; 6/2015 to 12/2018</td>
</tr>
<tr>
<td>578513-IRR-DITCH (Brook Mine)</td>
<td>Tongue River Ditch</td>
<td>NA³</td>
<td>6/2018 to 7/2018</td>
</tr>
<tr>
<td>578524-TR-1 (Brook Mine)</td>
<td>Tongue River</td>
<td>447¹</td>
<td>4/2018 to 1/2019</td>
</tr>
<tr>
<td>578420-TR-1 (Brook Mine)</td>
<td>Tongue River at the location of USGS 06299980</td>
<td>478</td>
<td>6/2018 to 1/2019</td>
</tr>
<tr>
<td>USGS 06299980¹</td>
<td>Tongue River at Monarch, WY</td>
<td>478</td>
<td>5/2004 to 6/2018</td>
</tr>
<tr>
<td>TR0176      (Big Horn Mine)</td>
<td>Tongue River– upstream permit boundary</td>
<td>479¹</td>
<td>5/1984 to 9/2019</td>
</tr>
<tr>
<td>TR2B80      (Big Horn Mine)</td>
<td>Tongue River– downstream permit boundary</td>
<td>911</td>
<td>5/1984 to 9/2019</td>
</tr>
</tbody>
</table>

¹Drainage area estimated by the WDEQ/LQD.
²The USGS website shows the drainage area as 18.0 mi², but the Brook Mine Permit Application (2020) indicated the entire Slater Creek watershed is 16.44 mi². An independent GIS analysis by the WDEQ/LQD showed the drainage area to be closer to what the Brook Mine Permit Application (2020) estimated, so the value from the permit application was used.
³Drainage area unknown but the ditch upstream of this point extends approximately 5.3 miles upstream to the headgate on the Tongue River.
⁴Streamflow gaging was discontinued on July 1, 2018 but water quality samples are currently collected at the station.

### 2.2 GROUNDWATER

The groundwater evaluation area conceptually includes: (1) areas where aquifers are mined, (2) areas impacted by mine-induced groundwater drawdown, (3) the extent of measurable impacts of groundwater drawdown on the surface water system, and (4) areas where plumes of degraded groundwater may develop and migrate (Office of Surface Mining Reclamation and Enforcement, 1985).

#### 2.2.1 DELINEATION OF THE GROUNDWATER EVALUATION AREA

Analysis of groundwater drawdown resulting from pit dewatering is required as part of the
permitting process to assess the impacts of pit progression and coal removal on the aquifers adjacent to the pits. The Brook Mine Permit Application (2020) developed a three-dimensional MODFLOW model using the Groundwater Vistas pre/post processor. The model is constructed with variable grid spacing and has seven vertical model layers:

- Model layer 1 – Alluvium, historic mine backfill, and weathered overburden where alluvium and mine backfill are not present
- Model layer 2 – Coal overburden
- Model layer 3 – Upper Carney coal seam
- Model layer 4 – Carney interburden
- Model layer 5 – Lower Carney coal seam
- Model layer 6 – Carney/Masters interburden
- Model layer 7 – Masters coal

The groundwater model was calibrated using the baseline data collected by the proposed Brook Mine. Additional information on model parameters, calibration, and operational and reclamation simulations can be found in Addendum MP-3 in the mine plan of the Brook Mine Permit Application (2020). The predicted life of mine five-foot drawdown contours for the upper Carney, lower Carney, and Masters coal seams are shown in Figure 13. The drawdowns observed in the overburden and interburden model layers are relatively of lesser extent than the coal model layers. Mostly, the extent of the model predicted five-foot drawdown is limited within the proposed permit boundary and extends about 0.4 miles south of permit boundary as shown in Figure 13.

As discussed previously in Section 2.1.1.2, the Youngs Creek Mine is located approximately five miles northeast of the proposed Brook Mine. The groundwater CIA delineated in the Youngs Creek CHIA (Wyoming Department of Environmental Quality, 2011) is shown in Figure 13. The distance between the five-foot drawdown contours predicted by the Brook Mine and the Youngs Creek groundwater CIA is about 1.5 miles. Therefore, it is expected that there will be minimal to no discernible overlapping groundwater drawdown impacts between the two mines. In addition, the proposed coal seams for mining at Youngs Creek Mine are different than the Carney coal seam that Brook Mine has in their mine plan. There are four coal seams in the planned mine sequence at the Youngs Creek Mine, and in descending order they are the Roland, Smith, Anderson, and Dietz coals (Youngs Creek Mine Permit, 2020). Because of these factors, the Youngs Creek Mine permit does not need to be considered as part of the proposed Brook Mine CHIA.

The MODFLOW model results provided in the Brook Mine Permit Application (2020) estimate the end of mining drawdown in Year 39. The extent of the model predicted five-foot drawdown is limited in spatial extent and does not cover the entire proposed Brook Mine permit boundary. A composite of the surface water evaluation area and the model predicted five-foot drawdown contours was evaluated. The surface water evaluation area is larger (Figure 11) and encompasses the five-foot groundwater drawdown contours. The Brook Mine Permit Application (2020) has interpreted the Carney coal to be unsaturated in parts of the central and west portions of the proposed permit area while most of the east part of the proposed permit area is either partially saturated or saturated. However, to be conservative, the groundwater evaluation area was extended to mimic the surface water evaluation area. Therefore, in this CHIA the extent of groundwater and surface water evaluation areas are the same as shown in Figure 11. The evaluation area considered for this CHIA is about 20.5 mi².
2.2.1.1 AQUIFERS OF CONCERN

A single groundwater evaluation area will encompass seven geologic units of concern: (1) alluvium, historic mine backfill, and weathered overburden where alluvium and mine backfill are not present, (2) coal overburden, (3) upper Carney coal seam, (4) Carney interburden, (5) lower Carney coal seam, (6) Carney/Masters interburden, and (7) Masters coal. For the purposes of this CHIA, these geologic units are grouped into five aquifer units. The five aquifer units are (1) alluvium, (2) Carney coal, (3) overburden and interburden, (4) Masters coal, and (5) backfill. In addition, the proposed Brook Mine has characterized the geologic unit underlying the Masters coal. The backfill aquifer would only occupy the trenches and surface open pit areas; the underground workings where the highwall miner is used would not be backfilled and would remain as an open cavern. More detailed descriptions of the aquifer units, including aquifer properties, potentiometric surfaces, and groundwater quality, are provided in Section 3.2. Comparing the drawdown predicted by the mine, the drawdown impacts to the alluvial, overburden, and underburden aquifers are less extensive than the drawdown impacts to the coal aquifers and lie within the spatial extent of the coal drawdown impacts. The final groundwater evaluation area (Figure 13) is applicable for all seven geological units of concern.
Figure 13. Maximum five-foot drawdown predicted by the Brook Mine in the upper Carney coal, lower Carney coal, and Masters coal, and location of the groundwater evaluation area.
2.2.2 DESCRIPTION OF THE MONITORING NETWORK IN THE GROUNDWATER EVALUATION AREA

Baseline hydrologic conditions in the groundwater evaluation area were evaluated primarily using data from the monitoring well network established by the proposed Brook Mine (Figure 14). In addition, the Big Horn Mine had 88 discontinued monitoring wells that were constructed in similar units (alluvium, Carney coal, and backfill) to the proposed Brook Mine (Figure 15). The Big Horn Mine monitoring network was initially established in the mid to late 1970s and early 1980s to evaluate baseline hydrologic conditions. For the purposes of this CHIA, the Big Horn Mine monitoring wells were used to provide additional understanding on the hydrogeology near the proposed Brook Mine.

Static groundwater level and groundwater quality data collected at the mines are submitted annually to the WDEQ/LQD and stored and managed in the WDEQ/LQD Hydrology Database. For the purposes of the CHIA, only monitored wells completed and screened within a single geologic unit were evaluated; wells completed in multiple units were not considered. A total of 31 active monitoring wells are located within or adjacent to the proposed Brook Mine permit boundary. Table 4 shows the status (as of December 2019) and number of monitoring wells within each aquifer unit at the two mines. Two Brook Mine wells are not listed in Table 4; one is completed in the Carney burn and one is completed in both the Carney and Masters coal. The location and aquifer unit of the active Brook Mine monitoring wells and discontinued Big Horn Mine monitoring wells are shown in Figure 14 and Figure 15 respectively.

Table 4. Status and number of monitoring wells by aquifer and mine. Well status is current as of December 2019.

<table>
<thead>
<tr>
<th>Aquifer</th>
<th>Mine</th>
<th>Well Status</th>
<th>Number of Monitoring Wells</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alluvial</td>
<td>Brook</td>
<td>Active</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Big Horn</td>
<td>Discontinued</td>
<td>63</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>72</strong></td>
</tr>
<tr>
<td>Overburden</td>
<td>Brook</td>
<td>Active</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Big Horn</td>
<td>Discontinued</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>1</strong></td>
</tr>
<tr>
<td>Carney coal</td>
<td>Brook</td>
<td>Active</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Big Horn</td>
<td>Discontinued</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Big Horn</td>
<td>Discontinued</td>
<td>5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>15</strong></td>
</tr>
<tr>
<td>Masters coal</td>
<td>Brook</td>
<td>Active</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Big Horn</td>
<td>Discontinued</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>9</strong></td>
</tr>
<tr>
<td>Master coal underburden</td>
<td>Brook</td>
<td>Active</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Big Horn</td>
<td>Discontinued</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>1</strong></td>
</tr>
<tr>
<td>Backfill</td>
<td>Brook</td>
<td>Active</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Big Horn</td>
<td>Discontinued</td>
<td>20</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>22</strong></td>
</tr>
<tr>
<td>Grand Total</td>
<td></td>
<td>Active</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Discontinued</td>
<td>89</td>
</tr>
</tbody>
</table>
Figure 14. Location of active monitoring wells in the upper Tongue River Basin. Well status is current as of December 2019.
Figure 15. Location of discontinued monitoring wells in the upper Tongue River Basin. Discontinued wells are mostly located at the Big Horn Mine. Well status is current as of December 2019.
In the alluvial aquifer, 72 monitoring wells were considered to evaluate baseline hydrologic conditions in the groundwater evaluation area (Table 4; Figure 14; Figure 15). As of December 2019, nine wells were active at the proposed Brook Mine while 63 wells at the Big Horn Mine have been discontinued (Table 4). The active alluvial aquifer monitoring wells are located along Slater Creek, the Tongue River, and Goose Creek (Figure 14). Well depths for the active wells range from 16 feet at well 578434-AL-2 on Goose Creek to 35 feet at well 578524-AL-1 on the Tongue River. The median depth for the active alluvial monitoring wells is 22 feet.

One monitoring well was completed in the overburden by the proposed Brook Mine (578513-OVB-1) (Table 4; Figure 14). The Big Horn Mine had no overburden monitoring wells (Table 4). Drilling operations by the proposed Brook Mine found no water elsewhere in the overburden or the interburden. Addendum D5-2 of the Brook Mine Permit Application (2020) contains drilling logs and resistivity logs that demonstrate the majority of the overburden and interburden are dry. The locations of these drill holes can be found on Addendum D5-3, Exhibit 1 (Brook Mine Permit Application, 2020). Exhibit D6.2-4 of the Brook Mine Permit Application (2020) also shows the extent of saturation zones in the overburden within the proposed permit boundary. The exhibit was created using data and interpretation from a total of 31 drill holes and indicates that the majority of the overburden is dry with some pockets of partial saturation.

In the Carney coal seam, 15 monitoring wells were considered to evaluate baseline hydrologic conditions in the groundwater evaluation area (Table 4; Figure 14; Figure 15). As of December 2019, nine wells were active at the proposed Brook Mine. One well has been discontinued at the proposed Brook Mine and five wells have been discontinued at the Big Horn Mine. Well depths for the active Carney coal wells range from 28 feet at well 578420-CRN-PUMP to 153 feet at well 578418-CRN. The median depth for the active Carney coal monitoring wells is 116 feet.

In the Masters coal seam, nine active monitoring wells at the proposed Brook Mine were considered to evaluate baseline hydrologic conditions in the groundwater evaluation area (Table 4; Figure 14). Well depths range from 114 feet at well 578512-MST to 183 feet at well 578418-MST. The median depth for the Masters coal monitoring wells is 140 feet.

Well 578409-UBN is the only Masters coal underburden monitoring well located at a depth of 142 feet (Table 4; Figure 14). Other wells drilled into the Masters coal underburden were dry during drilling by the proposed Brook Mine (Brook Mine Permit Application, 2020). The Big Horn Mine had no Masters coal underburden monitoring wells (Table 4).

In the backfill aquifer at the Big Horn Mine, and a portion of the proposed Brook Mine, 22 monitoring wells were considered to evaluate hydrologic conditions in the groundwater evaluation area (Table 4; Figure 14; Figure 15). Twenty of these wells were installed by the Big Horn Mine to determine post-mine hydrologic conditions. As of December 2019, all of the Big Horn Mine wells were discontinued while the two Brook Mine wells were active (Table 4). Well depths for the active backfill wells are 41 and 108 feet.

Static groundwater levels are monitored at all the active wells within the proposed Brook Mine permit boundary (Figure 14). Groundwater quality is monitored at a subset of wells shown in Figure 14.
3. BASELINE HYDROLOGIC CONDITIONS

Baseline data are collected to characterize pre-mining hydrologic conditions. Baseline data from the surface water and groundwater evaluation areas are reflective of both temporal and spatial variability. Underlying those temporal changes, both aquifers and watersheds have natural spatial variability and can be affected by non-coal mine land use.

3.1 SURFACE WATER

3.1.1 BASELINE WATER QUANTITY AND WATER QUALITY OF INDIVIDUAL DRAINAGES IN THE SURFACE WATER EVALUATION AREA

The baseline water quantity and water quality of individual drainages in the surface water evaluation area are described in the following sections. The primary watersheds potentially affected by the proposed coal mining in the surface water evaluation area include Hidden Water Creek, Slater Creek, East Fork Earley Creek, Goose Creek, and the Tongue River. Mining disturbance is also proposed in seven small unnamed watersheds that are direct tributaries to either the Tongue River or Tongue River Ditch. The level of proposed mining disturbance within these watersheds varies considerably, as discussed below.

3.1.1.1 HIDDEN WATER CREEK

Hidden Water Creek is an ephemeral tributary to the Tongue River with a drainage area of approximately 7.99 mi². The drainage flows in a southeast direction in the east portion of the proposed Brook Mine permit area (Figure 11). Based on USGS 1:24,000 (24K) scale quadrangle maps, the watershed has a relief of 885 feet, contains 25.05 miles of streams, and has a drainage density of 3.14 mi/mi² (Brook Mine Permit Application, 2020). Based on a longitudinal profile created from topography generated from Light Detection and Ranging (LIDAR) data, most of Hidden Water Creek has a channel slope of 1.0 to 1.3 percent, although the lower reaches near the confluence with the Tongue River are steeper at 2.2 to 5.2 percent (Brook Mine Permit Application, 2020). According to the wetlands and aquatic resources inventory completed for the proposed Brook Mine in 2013, less than 0.1 acres of palustrine emergent (PEM) wetlands are associated with Hidden Water Creek within the proposed permit boundary (Brook Mine Permit Application, 2020).

Surface water rights in the Hidden Water Creek watershed are primarily associated with stock and irrigation uses (Wyoming State Engineer’s Office, 2019b). All of the surface water rights in the Hidden Creek watershed are located upstream of the proposed Brook Mine permit boundary. There are also four small unpermitted stock impoundments that exist in the watershed upstream of the proposed Brook Mine (Brook Mine Permit Application, 2020).

The Hidden Water Creek watershed has been historically affected by both underground and surface coal mining. Underground coal mining at the Acme Number One and Acme Number Two mines occurred in the lower part of the drainage near the confluence with the Tongue River (Brook Mine Permit Application, 2020). The Big Horn Mine Permit (2020) describes a berm and diversion channel that were constructed prior to 1927 in lower Hidden Water Creek as part of the Acme No. 1 underground mine. A mine shaft sinkhole had formed in the diversion channel, which then was observed to intercept surface flows (Big Horn Mine Permit, 2020). According to the wetlands and
aquatic resources inventory completed for the proposed Brook Mine in 2013, the berm on Hidden Water Creek still exists (Brook Mine Permit Application, 2020).

Surface coal mining occurred in the Hidden Water Creek headwaters immediately north of the proposed Brook Mine from 1944 to 1955. The Decker Coal Company open-pit strip mined approximately 10 million short tons of coal from several pits in this area (Wangsness, 1977). The pits were abandoned and became impoundments after filling with water. The physical, biological, and chemical characteristics of the pit impoundments have been studied by the USGS (Wangsness, 1977). A sediment yield study of the mine site was also conducted by the USGS (Ringen et al., 1979). The WDEQ/AML has conducted reclamation at the pits (Bureau of Land Management, 2003), but the pit impoundments remain as permanent features and may have an effect on the hydrology of the drainage by holding water and attenuating streamflows. The Big Horn Mine also conducted surface coal mining adjacent to Hidden Water Creek at Pit 4 in the lower part of the drainage near the confluence with the Tongue River. The main channel of Hidden Water Creek was not mined and the valley alluvium was not affected. This area has been reclaimed, fully bond released, and removed from the current Big Horn Mine permit area (Big Horn Mine Permit, 2020).

The proposed Brook Mine would conduct highwall mining within the Hidden Water Creek watershed within the permit area (Brook Mine Permit Application, 2020). Over the course of the mine plan, four trenches would be constructed and mined in the Hidden Water Creek watershed to create a working area for a continuous miner system. Only a small portion of one of the four trenches would be within the watershed. The continuous miner would be remotely operated to mine coal perpendicular to the trench. Other mining disturbance in the watershed would include overburden and topsoil stockpiles, haulroads, sediment ponds, and flood control reservoirs. Three diversions would also be used on Hidden Water Creek to route the stream around the mining disturbance. Further discussion on the possible effects of mining disturbance on Hidden Water Creek, as well as proposed hydrologic and sediment control features, is discussed in Section 7.1.

Surface water quantity and quality has been monitored on Hidden Water Creek by the Big Horn Mine and the proposed Brook Mine. The Big Horn Mine installed a Parshall flume and continuous recorder on Hidden Water Creek (HWC1-79) in 1978 as part of baseline data collection for the Pit 4 area (Table 3, Figure 11) (Big Horn Mine Permit, 2020). The station monitored a drainage area of 7.52 mi² and was discontinued in 1998. In 2013, the proposed Brook Mine installed two stations on Hidden Water Creek: SM578409-SW-1 was installed near the upstream permit boundary and SM578415-SW-1 was installed approximately 1,300 feet downstream of HWC1-79 (Table 3, Figure 11).

Mean daily streamflow data were available in the WDEQ/LQD Hydrology Database for the HWC1-79 station from 1982 to 1998. A hydrograph of the mean daily flows over this period is presented in Figure 16. The maximum mean daily flow over the period was 5.88 cubic feet per second (cfs), recorded in January 1983. The data indicate that streamflow in Hidden Water Creek is primarily due to snowmelt in the late winter or spring. The data also demonstrate the ephemeral nature of the drainage, as no flow was recorded 99.3 percent of the period.
No flow was observed at either Brook Mine monitoring station on Hidden Water Creek from September through October 2013, and from April 2014 to November 2014. Additional station visits were made at the SM578409-SW-1 station in April, June, September, and October of 2015 and no flow was present. The SM578415-SW-1 station was not visited in 2015 due to lack of landowner access permission. The Brook Mine Permit Application (2020) attributed the lack of flow due to existing mine pits and stock reservoirs in the upper Hidden Water Creek drainage and the lack of significant precipitation events.

The Brook Mine Permit Application (2020) presented peak flow and runoff calculations for Hidden Water Creek for storms of varying return intervals using U.S. Army Corps of Engineer’s (USACE) HEC-HMS modelling (U.S. Army Corps of Engineers, 2019) and USGS peak-flow regression equations for the central basins and northern plains region of Wyoming (Miller, 2003). A comparison of estimated peak flows for the 2-year, 10-year, and 100-year event recurrence intervals using the Miller (2003) equations is presented in Table 5 for the primary drainages within the surface water evaluation area. For Hidden Water Creek, peak flow for the 2-year event is estimated at 80 cfs, while the 100-year event is estimated at nearly 1,015 cfs (Table 5).
Table 5. Estimates of peak flows for storms of varying recurrence intervals for the watersheds within and adjacent to the proposed Brook Mine. Estimates calculated using regression equations from Miller (2003) and rounded to the nearest 5 cfs. Note most of the watersheds include contributing area outside the proposed Brook Mine permit boundary.

<table>
<thead>
<tr>
<th>Watershed</th>
<th>Drainage area (mi²)</th>
<th>2-year peak flow (cfs)</th>
<th>10-year peak flow (cfs)</th>
<th>100-year peak flow (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hidden Water Creek</td>
<td>7.99</td>
<td>80</td>
<td>340</td>
<td>1,015</td>
</tr>
<tr>
<td>Slater Creek</td>
<td>16.46</td>
<td>115</td>
<td>470</td>
<td>1,385</td>
</tr>
<tr>
<td>East Fork Earley Creek</td>
<td>1.84</td>
<td>40</td>
<td>175</td>
<td>540</td>
</tr>
<tr>
<td>Goose Creek</td>
<td>414</td>
<td>525</td>
<td>1,980</td>
<td>5,540</td>
</tr>
<tr>
<td>Tongue River</td>
<td>911†</td>
<td>760</td>
<td>2,820</td>
<td>7,775</td>
</tr>
<tr>
<td>TR1</td>
<td>0.24</td>
<td>15</td>
<td>70</td>
<td>225</td>
</tr>
<tr>
<td>TR2</td>
<td>0.52</td>
<td>20</td>
<td>100</td>
<td>315</td>
</tr>
<tr>
<td>TRD1</td>
<td>0.04</td>
<td>5</td>
<td>30</td>
<td>105</td>
</tr>
<tr>
<td>TRD2</td>
<td>0.51</td>
<td>20</td>
<td>100</td>
<td>310</td>
</tr>
<tr>
<td>TRD3</td>
<td>0.59</td>
<td>25</td>
<td>105</td>
<td>330</td>
</tr>
<tr>
<td>TRD4</td>
<td>0.27</td>
<td>15</td>
<td>75</td>
<td>235</td>
</tr>
<tr>
<td>TRD5</td>
<td>0.93</td>
<td>30</td>
<td>130</td>
<td>400</td>
</tr>
</tbody>
</table>

†At Big Horn Mine station TR2B80.

The WDEQ/WQD has classified Hidden Water Creek as Class 3B water (Wyoming Department of Environmental Quality, 2013). Class 3B waters are intermittent or ephemeral streams with sufficient hydrology to normally support and sustain communities of aquatic life including invertebrates, amphibians, or other flora and fauna which inhabit water of the state at some stage of their life cycles. Supported uses include aquatic life other than fish, recreation, wildlife, industry, agriculture, and scenic value (Table 6). Class 3B waters must meet acute and chronic water quality standards for aquatic life other than fish. The WDEQ/WQD numeric standards for selected constituents for Class 3B surface waters are presented in Table 7.

No water quality samples were collected at the two Brook Mine stations on Hidden Water Creek due to lack of streamflow during the monitoring period (Brook Mine Permit Application, 2020). Therefore, data from the Big Horn Mine station (HWC1-79) were used to supplement water quality characterization of Hidden Water Creek. A statistical summary of the nine water quality samples collected at HWC1-79 over the 1979 to 1989 period is presented in Table 8. AqQA software was used to determine water type (RockWare, Inc., 2015). Magnesium sulfate type water was noted in 56 percent of the samples (Figure 23a). TDS ranged from 96 to 3,300 mg/L, with a median of 234 mg/L. Total suspended solids (TSS) ranged from 5 to 3,630 mg/L, with a median of 72 mg/L (Table 8). Dissolved metal concentrations at HWC1-79 were mostly low over the 1979-1989 period, with numerous values below detection limits (Table 8). The maximum concentrations of aluminum (2.0 mg/L) and copper (0.03 mg/L) exceeded WDEQ/WQD Class 3B water quality standards. Aluminum showed two exceedances of Class 3B standards while copper showed one exceedance (Table 8).
Table 6. Wyoming surface water classifications and use, as defined by the WDEQ/WQD (Wyoming Department of Environmental Quality, 2013, WDEQ Water Quality Rules, Ch. 1, § 4).

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
<th>Sub-Class and Description</th>
<th>Uses Supported</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>Outstanding Waters</td>
<td>Class 2A (Drinking water only)</td>
<td>Drinking water, other aquatic life, recreation, wildlife, agriculture, industry, scenic value</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Class 2AB (Fish and drinking water)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Class 2B (Cold and warm water fish only)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Class 2C (Non-game warm water fish only)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Class 2D (Effluent-dependent, fish supporting)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class 2</td>
<td>Fisheries and/or Drinking Water</td>
<td>Class 3A (Isolated waters)</td>
<td>Other aquatic life, recreation, wildlife, agriculture, industry, scenic value</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Class 3B (Intermittent and ephemeral streams)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Class 3C (Perennial streams)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Class 3D (Effluent-dependent waters)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class 3</td>
<td>Aquatic Life Other Than Fish</td>
<td>Class 4A (Canals and ditches)</td>
<td>Recreation, wildlife, agriculture, industry, scenic value</td>
</tr>
<tr>
<td>Class 4</td>
<td>Agricultural, Industry, Recreation and Wildlife (aquatic life uses not attainable)</td>
<td>Class 4B (Intermittent and ephemeral streams)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Class 4C (Isolated waters)</td>
<td></td>
</tr>
</tbody>
</table>
Table 7. Select numeric WDEQ/WQD standards for Class 2AB and Class 3B surface waters in the surface water evaluation area.

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Units</th>
<th>Class 2AB TONGUE RIVER - upstream of Goose Creek</th>
<th>Class 2AB TONGUE RIVER downstream of Goose Creek</th>
<th>Class 2AB GOOSE CREEK</th>
<th>Class 3B HIDDEN WATER CREEK, SLATER CREEK, EAST FORK EARLEY CREEK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum (dissolved)</td>
<td>mg/L</td>
<td>0.75&lt;sup&gt;1&lt;/sup&gt;</td>
<td>0.75&lt;sup&gt;1&lt;/sup&gt;</td>
<td>0.75&lt;sup&gt;1&lt;/sup&gt;</td>
<td>0.75&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td>Ammonia(NH&lt;sub&gt;3&lt;/sub&gt; as N) (total)</td>
<td>mg/L</td>
<td>1.52&lt;sup&gt;2&lt;/sup&gt;</td>
<td>1.29&lt;sup&gt;2&lt;/sup&gt;</td>
<td>1.52&lt;sup&gt;2&lt;/sup&gt;</td>
<td>NA&lt;sup&gt;3&lt;/sup&gt;</td>
</tr>
<tr>
<td>Arsenic</td>
<td>mg/L</td>
<td>0.01&lt;sup&gt;4&lt;/sup&gt;</td>
<td>0.01&lt;sup&gt;4&lt;/sup&gt;</td>
<td>0.01&lt;sup&gt;4&lt;/sup&gt;</td>
<td>0.15&lt;sup&gt;5,12&lt;/sup&gt;</td>
</tr>
<tr>
<td>Barium (total)</td>
<td>mg/L</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>NA</td>
</tr>
<tr>
<td>Cadmium (dissolved)*</td>
<td>mg/L</td>
<td>0.0004&lt;sup&gt;6,12&lt;/sup&gt;</td>
<td>0.0005&lt;sup&gt;6,12&lt;/sup&gt;</td>
<td>0.0005&lt;sup&gt;6,12&lt;/sup&gt;</td>
<td>0.0006&lt;sup&gt;12&lt;/sup&gt;</td>
</tr>
<tr>
<td>Chloride (total)</td>
<td>mg/L</td>
<td>230</td>
<td>230</td>
<td>230</td>
<td>NA</td>
</tr>
<tr>
<td>Chromium(III)*</td>
<td>mg/L</td>
<td>0.13&lt;sup&gt;4&lt;/sup&gt;</td>
<td>0.15&lt;sup&gt;4&lt;/sup&gt;</td>
<td>0.18&lt;sup&gt;4&lt;/sup&gt;</td>
<td>0.23&lt;sup&gt;5,12&lt;/sup&gt;</td>
</tr>
<tr>
<td>Copper (dissolved)*</td>
<td>mg/L</td>
<td>0.017&lt;sup&gt;6,12&lt;/sup&gt;</td>
<td>0.019&lt;sup&gt;6,12&lt;/sup&gt;</td>
<td>0.022&lt;sup&gt;6,12&lt;/sup&gt;</td>
<td>0.029&lt;sup&gt;12&lt;/sup&gt;</td>
</tr>
<tr>
<td>Dissolved oxygen</td>
<td>mg/L</td>
<td>&gt;4&lt;sup&gt;7&lt;/sup&gt;</td>
<td>&gt;4&lt;sup&gt;7&lt;/sup&gt;</td>
<td>&gt;4&lt;sup&gt;7&lt;/sup&gt;</td>
<td>NA&lt;sup&gt;8&lt;/sup&gt;</td>
</tr>
<tr>
<td>Iron (dissolved)</td>
<td>mg/L</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>1</td>
</tr>
<tr>
<td>Lead (dissolved)*</td>
<td>mg/L</td>
<td>0.005&lt;sup&gt;6,12&lt;/sup&gt;</td>
<td>0.007&lt;sup&gt;6,12&lt;/sup&gt;</td>
<td>0.008&lt;sup&gt;6,12&lt;/sup&gt;</td>
<td>0.011&lt;sup&gt;12&lt;/sup&gt;</td>
</tr>
<tr>
<td>Manganese (dissolved)*</td>
<td>mg/L</td>
<td>2.15&lt;sup&gt;9,12&lt;/sup&gt;</td>
<td>2.368&lt;sup&gt;12&lt;/sup&gt;</td>
<td>2.617&lt;sup&gt;12&lt;/sup&gt;</td>
<td>3.105&lt;sup&gt;12&lt;/sup&gt;</td>
</tr>
<tr>
<td>Mercury</td>
<td>μg/L</td>
<td>0.05&lt;sup&gt;4&lt;/sup&gt;</td>
<td>0.05&lt;sup&gt;4&lt;/sup&gt;</td>
<td>0.05&lt;sup&gt;4&lt;/sup&gt;</td>
<td>0.77&lt;sup&gt;5&lt;/sup&gt;</td>
</tr>
<tr>
<td>Nickel*</td>
<td>mg/L</td>
<td>0.095&lt;sup&gt;6,12&lt;/sup&gt;</td>
<td>0.109&lt;sup&gt;6,12&lt;/sup&gt;</td>
<td>0.129&lt;sup&gt;6,12&lt;/sup&gt;</td>
<td>0.16&lt;sup&gt;8,12&lt;/sup&gt;</td>
</tr>
<tr>
<td>Nitrate+Nitrite as N (total)</td>
<td>mg/L</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>NA</td>
</tr>
<tr>
<td>pH</td>
<td></td>
<td>6.5 – 9.0</td>
<td>6.5 – 9.0</td>
<td>6.5 – 9.0</td>
<td>6.5 – 9.0</td>
</tr>
<tr>
<td>Selenium (dissolved)</td>
<td>mg/L</td>
<td>0.0046&lt;sup&gt;6,12&lt;/sup&gt;</td>
<td>0.0046&lt;sup&gt;6,12&lt;/sup&gt;</td>
<td>0.0046&lt;sup&gt;6,12&lt;/sup&gt;</td>
<td>0.0046&lt;sup&gt;12&lt;/sup&gt;</td>
</tr>
<tr>
<td>Temperature</td>
<td>°C</td>
<td>&lt; 20</td>
<td>&lt; 20</td>
<td>&lt; 20</td>
<td>NA&lt;sup&gt;9&lt;/sup&gt;</td>
</tr>
<tr>
<td>Turbidity</td>
<td>NTU</td>
<td>&lt; 10&lt;sup&gt;10,11&lt;/sup&gt;</td>
<td>&lt; 10&lt;sup&gt;10,11&lt;/sup&gt;</td>
<td>&lt; 10&lt;sup&gt;10,11&lt;/sup&gt;</td>
<td>NA</td>
</tr>
<tr>
<td>Zinc (dissolved)*</td>
<td>mg/L</td>
<td>0.217&lt;sup&gt;6,12&lt;/sup&gt;</td>
<td>0.251&lt;sup&gt;6,12&lt;/sup&gt;</td>
<td>0.293&lt;sup&gt;6,12&lt;/sup&gt;</td>
<td>0.382&lt;sup&gt;12&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Table developed from WDEQ/WQD Rules and Regulations, Chapter 1 (Adopted April 24, 2018). Criteria represent concentrations meant to protect both human health and aquatic life uses. Note that the constituents listed are not an exhaustive list of all constituents with standards established by the WDEQ/WQD.

- **Hardness dependent criteria for aquatic life** – based on available sample data, a hardness of 400 mg/L CaCO<sub>3</sub> was used to calculate criteria for Hidden Water Creek and Slater Creek. A hardness of 400 mg/L CaCO<sub>3</sub> was also assumed for East Fork Earley Creek and other ephemeral tributaries. For Goose Creek, a hardness of 292 mg/L CaCO<sub>3</sub> was used based on the median concentration of samples collected at GC00-78 from 2000-2019; for Tongue River upstream of Goose Creek, a hardness of 205 mg/L CaCO<sub>3</sub> was used based on the median concentration of samples collected at TR0176 from 2000-2019; for Tongue River downstream of Goose Creek, a hardness of 243 mg/L CaCO<sub>3</sub> was used based on the median concentration of samples collected at TR2B10 from 2000-2019;

- **Acute aquatic life criterion,** which assumes pH ≥ 7.0 and hardness as CaCO<sub>3</sub> ≥ 50 mg/L; **Criterion Continuous Concentration (CCC)** for fish early life stages present – calculated using median pH and temperature from TR0176, GC00-78, and TR2B10; **Numeric criteria do not apply but concentrations of ammonia attributable to or influenced by human activities shall not be present in concentrations which could result in harmful acute or chronic effects to aquatic life; or which would not fully support existing and designated uses;**

- **Total value;** **Dissolved value;** **Value shown is the aquatic life criterion since the human health value was less stringent or did not apply;** **1-day minimum instantaneous concentration for other life stages – cold water criteria;** **Minimum concentrations do not apply but pollution attributable to the activities of man shall not deplete dissolved oxygen amounts to a level which will result in harmful acute or chronic effects to aquatic life, or which would not fully support existing and designated uses;** **A maximum allowable temperature does not apply, but pollution attributable to the activities of man shall not change ambient water temperatures to levels which result in harmful acute or chronic effects to aquatic life, or which not fully support existing and designated uses;**

- **In all cold water fisheries and/or drinking water supplies, the discharge of substances attributable or influenced by the activities of man shall not be present in quantities which would result in a turbidity increase of 1 NTU;** **Due to the variable nature of turbidity and the difficulty in establishing an ambient turbidity value, turbidity data in this CHIA will not be evaluated against the numeric criterion;** **Chronic value, or four day average concentration for aquatic life;** NA (not applicable).
Table 8. Baseline water quality statistics and number of WDEQ/WQD class of use exceedances for selected constituents on Hidden Water Creek at Big Horn Mine station HWC1-79, 1979-1989.

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Units</th>
<th>Number of samples</th>
<th>Min</th>
<th>Max</th>
<th>Median</th>
<th>Number of exceedances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hidden Water Creek (HWC1-79)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aluminum (dissolved) mg/L</td>
<td>7</td>
<td>&lt;0.1</td>
<td>2.0</td>
<td>.2</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Ammonia as N (dissolved) mg/L</td>
<td>9</td>
<td>&lt;0.01</td>
<td>1.43</td>
<td>0.09</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arsenic (dissolved) mg/L</td>
<td>7</td>
<td>&lt;0.002</td>
<td>&lt;0.005</td>
<td>&lt;100% &lt;0.005</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Barium (dissolved) mg/L</td>
<td>7</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
<td>100% &lt;0.5</td>
<td></td>
<td>NA</td>
</tr>
<tr>
<td>Cadmium (dissolved) mg/L</td>
<td>7</td>
<td>&lt;0.002</td>
<td>&lt;0.005</td>
<td>&lt;100% &lt;0.005</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Chloride (dissolved) mg/L</td>
<td>9</td>
<td>4</td>
<td>29</td>
<td>11</td>
<td></td>
<td>NA</td>
</tr>
<tr>
<td>Chromium (dissolved) mg/L</td>
<td>7</td>
<td>&lt;0.02</td>
<td>&lt;0.02</td>
<td>&lt;100% &lt;0.02</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Copper (dissolved) mg/L</td>
<td>7</td>
<td>&lt;0.01</td>
<td>0.03</td>
<td>0.02</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Dissolved oxygen mg/L</td>
<td>0</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td></td>
<td>NA</td>
</tr>
<tr>
<td>Iron (dissolved) mg/L</td>
<td>7</td>
<td>&lt;0.05</td>
<td>0.62</td>
<td>0.10</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Lead (dissolved) mg/L</td>
<td>7</td>
<td>&lt;0.01</td>
<td>&lt;0.02</td>
<td>&lt;100% &lt;0.02</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Manganese (dissolved) mg/L</td>
<td>7</td>
<td>&lt;0.01</td>
<td>0.09</td>
<td>0.02</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Mercury (dissolved) µg/L</td>
<td>7</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&gt;100% &lt;1</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Nickel (dissolved) mg/L</td>
<td>7</td>
<td>0.01</td>
<td>0.05</td>
<td>0.02</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Nitrite plus nitrate as N (dissolved) mg/L</td>
<td></td>
<td>4</td>
<td>&lt;0.01</td>
<td>0.15</td>
<td>0.11</td>
<td>NA</td>
</tr>
<tr>
<td>pH (field) S.U.</td>
<td>3</td>
<td>6.62</td>
<td>8.60</td>
<td>7.60</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Selenium (dissolved) mg/L</td>
<td>7</td>
<td>&lt;0.002</td>
<td>&lt;0.005</td>
<td>&lt;100% &lt;0.005</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Temperature (field) °C</td>
<td>4</td>
<td>5</td>
<td>20</td>
<td>12.9</td>
<td></td>
<td>NA</td>
</tr>
<tr>
<td>Turbidity NTU</td>
<td>9</td>
<td>2.3</td>
<td>20</td>
<td>30</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Zinc (dissolved) mg/L</td>
<td>7</td>
<td>&lt;0.01</td>
<td>0.05</td>
<td>0.01</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Boron (dissolved) mg/L</td>
<td>9</td>
<td>0.03</td>
<td>1.63</td>
<td>0.40</td>
<td></td>
<td>NA</td>
</tr>
<tr>
<td>Fluoride (dissolved) mg/L</td>
<td>9</td>
<td>&lt;0.1</td>
<td>0.85</td>
<td>0.14</td>
<td></td>
<td>NA</td>
</tr>
<tr>
<td>Sodium (dissolved) mg/L</td>
<td>9</td>
<td>1.4</td>
<td>191</td>
<td>14.5</td>
<td></td>
<td>NA</td>
</tr>
<tr>
<td>Sulfate (dissolved) mg/L</td>
<td>9</td>
<td>&lt;1</td>
<td>1,970</td>
<td>94</td>
<td></td>
<td>NA</td>
</tr>
<tr>
<td>TDS dried at 180 °C mg/L</td>
<td>9</td>
<td>96</td>
<td>3,300</td>
<td>234</td>
<td></td>
<td>NA</td>
</tr>
<tr>
<td>Total suspended solids mg/L</td>
<td>9</td>
<td>5</td>
<td>3,630</td>
<td>72</td>
<td></td>
<td>NA</td>
</tr>
</tbody>
</table>

Medians for constituents with non-detect values were calculated using methods recommended by Helsel (2005). Medians were not calculated for constituents having ≥80% non-detect values. Minimum and maximum concentrations shown in red exceed WDEQ/WQD Class 3B surface water quality standards; NA=no numeric standard established for stream classification.

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### 3.1.1.2 SLATER CREEK

Slater Creek is a tributary to the Tongue River with a drainage area of approximately 16.46 mi². The headwaters of Slater Creek (North Branch Slater Creek and South Branch Slater Creek) reside in Montana. The drainage flows in a southeast direction in the central portion of the proposed Brook Mine permit area (Figure 11). Based on USGS 24K scale quadrangle maps, the watershed has a relief of 1,600 feet, contains 54.72 miles of streams, and has a drainage density of 3.30 mi/mi² (Brook Mine Permit Application, 2020). Based on a longitudinal profile created from topography generated from LIDAR data, most of Slater Creek has a channel slope of less than one percent (Brook Mine Permit Application, 2020). According to the wetlands and aquatic resources inventory completed for the proposed Brook Mine in 2013, 5.2 acres of PEM wetlands are found along Slater Creek within the proposed permit boundary. Additional PEM (1.0 acres) and palustrine unconsolidated bottom (PUB) (1.4 acres) wetlands were found along unnamed...
tributaries to Slater Creek within the proposed permit boundary (Brook Mine Permit Application, 2020).

Surface water rights in the Slater Creek watershed are primarily associated with stock and irrigation uses (Wyoming State Engineer’s Office, 2019b). Upstream of the proposed Brook Mine permit boundary, there are several surface water rights associated with ditches and irrigation of hayfields adjacent to the Slater Creek channel. The WSEO water rights database also indicates that irrigation was attempted along Slater Creek within the proposed Brook Mine permit boundary in the early 1900s, but the attempt apparently failed and the water rights were cancelled (Wyoming State Engineer’s Office, 2019c; Wyoming State Engineer’s Office, 2019d). There are also at least two unpermitted impoundments that exist in the watershed upstream of the proposed Brook Mine (Brook Mine Permit Application, 2020).

The Slater Creek watershed has been less affected by historical underground and surface coal mining than Hidden Water Creek. The Brook Mine Permit Application (2020) shows a small area of underground mining at the Acme Number Three Mine in the lower part of the drainage, approximately 1/4 mile north of what is now Interstate 90. The Conable Prospect Mine is also shown as a point feature in the Slater Creek drainage at Township 57 North, Range 85 West, Section 12 (Taff, 1909; Brook Mine Permit Application, 2020). A permitted sand and gravel mine, the Taylor Quarry (WDEQ/LQD Permit SP0757), also exists in a portion of the lower Slater Creek watershed just north of Interstate 90 (Taylor Mine Permit, 2020).

The proposed Brook Mine would primarily conduct highwall mining within the Slater Creek watershed within the permit area (Brook Mine Permit Application, 2020). Over the course of the mine plan, three trenches would be constructed and mined in the Slater Creek watershed to create a working area for a continuous miner system. The continuous miner would be remotely operated to mine coal perpendicular to the trench. A surface mine covering approximately 25 acres would also occur in the lower portion of the Slater Creek watershed near the existing Taylor Mine. The surface mine would be the first area mined within the first five years of the mine sequence (Brook Mine Permit Application, 2020). Other mining disturbance in the watershed would include overburden and topsoil stockpiles, haulroads, and hydrologic and sediment control measures. Two existing impoundments would be affected by mining, including the removal of one impoundment by the construction of a haulroad. The Slater Creek channel would not be disturbed with the exception of redirecting the channel through a culvert at a proposed haulroad. Further discussion on the possible effects of mining disturbance on Slater Creek, as well as proposed hydrologic and sediment control features, is discussed in Section 7.1.

Surface water quantity and quality has been monitored on Slater Creek by the USGS and the proposed Brook Mine. The USGS installed a peak flow gage on Slater Creek in 1967 near Wyoming State Highway 345 (Station No. 06299900) (Table 3, Figure 11). The station monitored a drainage area of approximately 16.44 mi² and was discontinued in 1981. In 2013, the proposed Brook Mine installed two stations on Slater Creek: SM578512-SW-1 was installed approximately 1,500 feet downstream of the upstream permit boundary and SM578418-SW-1 was installed near the downstream permit boundary, approximately 500 feet upstream from Interstate 90 (Table 3, Figure 11).

Annual peak daily streamflow over the 1967 to 1981 period at USGS Station No. 06299900 are presented in Figure 17. Annual peak daily streamflow ranged from 50 cfs on May 25, 1980 to 1,700 cfs on June 15, 1967. A peak flow of 1,700 cfs would exceed the 100-year event as predicted.
by the peak-flow regression equations of Miller (2003). The 1967 to 1981 data from the gage on Slater Creek indicate that the highest peakflows occur in the spring due to snowmelt.

Figure 17. Annual peak daily streamflow on Slater Creek at USGS Station No. 06299900, 1967 to 1982.

A hydrograph of the mean daily streamflow collected at the two monitoring stations established on Slater Creek by the proposed Brook Mine is presented in Figure 18. Continuous data were collected at both stations in September and October 2013, and from April to November 2014. The maximum mean daily discharge over the period at upper Slater Creek was 5.82 cfs, recorded on May 8, 2014. The maximum mean daily flow at the lower Slater Creek station was 5.61 cfs, also recorded on May 8, 2014 (Figure 18). The data indicate that streamflow in Slater Creek is primarily due to snowmelt in the spring. The Brook Mine Permit Application (2020) also indicates some discharge to Slater Creek occurs from infiltration of precipitation into high perched scoria burn above the stream channel; this water is stored and slowly released to Slater Creek. It appears that this flow may form a shallow water table that provides baseflow to the channel in select locations, and therefore Slater Creek within the proposed Brook Mine permit boundary is best characterized as an intermittent stream. Downstream of the proposed permit boundary at the culvert outlet under Interstate 90, field observations indicated that flows in Slater Creek can be supplemented by discharge from the Tongue River Ditch (Wyoming Department of Environmental Quality, 2015a).

The collected streamflow data also indicate that Slater Creek within the proposed permit boundary may be a losing stream, as more streamflow was recorded at the upper Slater Creek station. For example, a total runoff of 212 ac-ft was recorded at SM578512-SW-1 while 149 ac-ft was recorded downstream at SM578418-SW-1. In addition, no flow was recorded 58.4 percent of the period at SM578512-SW-1, while downstream at SM578418-SW-1, no flow was recorded 70 percent of the period.
Figure 18. Mean daily streamflow on Slater Creek at Brook Mine stations SM578512-SW-1 (upper Slater Creek) and SM578418-SW-1 (lower Slater Creek), September to October 2013 and April to November 2014.

The Brook Mine Permit Application (2020) presented peak flow and runoff calculations for Slater Creek for storms of varying return intervals using USACE HEC-HMS modelling (U.S. Army Corps of Engineers, 2019) and USGS peak-flow regression equations (Miller, 2003). A comparison of estimated peak flows for the 2-year, 10-year, and 100-year event recurrence intervals using the Miller (2003) equations is presented in Table 5 for the primary drainages within the surface water evaluation area. For Slater Creek, peak flow for the 2-year event is estimated at 115 cfs, while the 100-year event is estimated at nearly 1,385 cfs (Table 5).

The WDEQ/WQD has classified Slater Creek as Class 3B water (Wyoming Department of Environmental Quality, 2013). The WDEQ/WQD numeric standards for selected constituents for Class 3B surface waters are presented in Table 7.

The Brook Mine Permit Application (2020) indicates that the two sampling stations on Slater Creek were visited six times from September 2013 to September 2014 to collect water quality samples. However, due to either lack of flow or insufficient flow, only one water quality sample was collected at each of the stations during this period. Additional water quality samples were collected in 2015 at both stations. A summary of the water quality data collected in 2014 and 2015 at the stations is presented in Table 9. Magnesium sulfate was the water type noted for all the samples collected (RockWare, Inc., 2015) (Figure 23b; Figure 23c). At SM578512-SW-1 on upper Slater Creek, TDS ranged from 1,220 to 5,200 mg/L. TDS at on lower Slater Creek ranged from 1,560 to 3,990 mg/L (Table 9). Dissolved metals at both stations were low with nearly all values below detection limits. There were no exceedences of WDEQ/WQD Class 3B water quality standards at either station (Table 9).
Table 9. Baseline water quality data and number of WDEQ/WQD class of use exceedances for selected constituents on Slater Creek at the proposed Brook Mine, 2014 and 2015.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Number of samples</td>
<td>Min</td>
</tr>
<tr>
<td>Aluminum (dissolved)</td>
<td>mg/L</td>
<td>2</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Ammonia as N (dissolved)</td>
<td>mg/L</td>
<td>2</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Arsenic (dissolved)</td>
<td>mg/L</td>
<td>2</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>Barium (dissolved)</td>
<td>mg/L</td>
<td>2</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Cadmium (dissolved)</td>
<td>mg/L</td>
<td>2</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Chloride (dissolved)</td>
<td>mg/L</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Chromium (dissolved)</td>
<td>mg/L</td>
<td>2</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Copper (dissolved)</td>
<td>mg/L</td>
<td>2</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Iron (dissolved)</td>
<td>mg/L</td>
<td>2</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Lead (dissolved)</td>
<td>mg/L</td>
<td>2</td>
<td>&lt;0.02</td>
</tr>
<tr>
<td>Manganese (dissolved)</td>
<td>mg/L</td>
<td>2</td>
<td>0.08</td>
</tr>
<tr>
<td>Mercury (dissolved)</td>
<td>µg/L</td>
<td>2</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Nickel (dissolved)</td>
<td>mg/L</td>
<td>2</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Nitrite plus nitrate as N (dissolved)</td>
<td>mg/L</td>
<td>2</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>pH (field)</td>
<td>S.U.</td>
<td>2</td>
<td>8.04</td>
</tr>
<tr>
<td>Selenium (dissolved)</td>
<td>mg/L</td>
<td>2</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>Temperature (field)</td>
<td>ºC</td>
<td>2</td>
<td>12.9</td>
</tr>
<tr>
<td>Turbidity</td>
<td>NTU</td>
<td>2</td>
<td>8.3</td>
</tr>
<tr>
<td>Zinc (dissolved)</td>
<td>mg/L</td>
<td>2</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Boron (dissolved)</td>
<td>mg/L</td>
<td>2</td>
<td>0.1</td>
</tr>
<tr>
<td>Fluoride (dissolved)</td>
<td>mg/L</td>
<td>2</td>
<td>0.5</td>
</tr>
<tr>
<td>Sodium (dissolved)</td>
<td>mg/L</td>
<td>2</td>
<td>112</td>
</tr>
<tr>
<td>Sulfate (dissolved)</td>
<td>mg/L</td>
<td>2</td>
<td>550</td>
</tr>
<tr>
<td>TDS dried at 180 ºC</td>
<td>mg/L</td>
<td>2</td>
<td>1,220</td>
</tr>
<tr>
<td>Total suspended solids</td>
<td>mg/L</td>
<td>2</td>
<td>8</td>
</tr>
</tbody>
</table>

Summary statistics for constituents with non-detect values were calculated using methods recommended by Helsel (2005). Medians were not calculated for constituents having ≥80% non-detect values. Medians were not calculated for station SM578512-SW-1 since only two samples were collected. Concentrations shown in red exceed WDEQ/WQD Class 3B surface water quality standards. NA=no numeric standard established.
3.1.1.3 EAST FORK EARLEY CREEK

East Fork Earley Creek is a tributary to the Tongue River with a drainage area of 1.84 mi². Although East Fork Earley Creek is considered a tributary of the Tongue River, aerial imagery and the USGS 24K scale quadrangle map indicates that the lower portion of the drainage was historically intercepted by the Tongue River Ditch prior to directly entering the Tongue River. Construction of Interstate 90 further modified the lower portion of the drainage. The Brook Mine Permit Application (2020) states that no culvert or other type of conveyance structure exists for East Fork Earley Creek under Interstate 90. The Brook Mine Permit Application (2020) indicates that historical surface and underground coal mining has not occurred within the East Fork Earley Creek watershed.

East Fork Earley Creek flows in a southeast direction across a very small part of the west portion of the proposed Brook Mine permit area (Figure 11). Within the proposed permit boundary, the main channel flows through approximately 950 feet of two different sections, and the watershed contributing area occupies approximately 98 acres. Based on USGS 24K scale quadrangle maps, the watershed has a relief of 520 feet, contains 4.81 miles of streams, and has a drainage density of 2.61 mi/mi² (Brook Mine Permit Application, 2020). Based on a longitudinal profile created from topography generated from LIDAR data, most of East Fork Earley Creek has a channel slope ranging from 0.9 to 1.5 percent (Brook Mine Permit Application, 2020). According to the wetlands and aquatic resources inventory completed for the proposed Brook Mine in 2013, there are no wetlands along East Fork Earley Creek within the proposed permit boundary (Brook Mine Permit Application, 2020).

Surface water rights in the East Fork Earley Creek watershed are primarily associated with stock and irrigation uses (Wyoming State Engineer’s Office, 2019b). Within the proposed Brook Mine permit boundary, there is a point of diversion for two surface water rights (ditches) on East Fork Earley Creek. The ditches appropriated 1.74 cfs for irrigation of 127 acres adjacent to lower East Fork Earley Creek (Wyoming State Engineer’s Office, 2019e; Wyoming State Engineer’s Office, 2019f). All of the other surface water rights in the East Fork Earley Creek watershed are located upstream of the proposed Brook Mine permit boundary. There is also at least one unpermitted impoundment in the watershed outside of the proposed Brook Mine permit boundary (Brook Mine Permit Application, 2020).

The proposed Brook Mine would conduct highwall mining within only a very small portion of the East Fork Earley Creek watershed within the permit area (Brook Mine Permit Application, 2020). Minimal direct surface disturbance would occur in the watershed, only resulting from topsoil stockpiles located near the watershed divide. The East Fork Earley Creek channel would not be disturbed. Further discussion on the possible effects of mining disturbance on East Fork Earley Creek, as well as proposed hydrologic and sediment control features, is discussed in Section 7.1.

Due to the minimal direct surface disturbance planned in the watershed, the proposed Brook Mine did not establish a surface water monitoring station on East Fork Earley Creek. The Brook Mine Permit Application (2020) presented peak flow and runoff calculations for East Fork Earley Creek for storms of varying return intervals using USACE HEC-HMS modelling (U.S. Army Corps of Engineers, 2019). A comparison of estimated peak flows for the 2-year, 10-year, and 100-year event recurrence intervals using the Miller (2003) equations is presented in Table 5 for the primary drainages within the surface water evaluation area. For East Fork Earley Creek, peak flow for the 2-year event is estimated at 40 cfs, while the 100-year event is estimated at nearly 540 cfs (Table 5).
3.1.1.4 GOOSE CREEK

Goose Creek is a perennial tributary to the Tongue River near the southeast portion of the proposed Brook Mine permit area (Figure 11). The Goose Creek watershed drains approximately 414 mi². The Goose Creek watershed is comprised of three primary drainages: Big Goose Creek, Little Goose Creek, and Goose Creek. The headwaters of Big Goose Creek, the largest tributary to Goose Creek, is in the Big Horn Mountains southwest of Sheridan at an elevation of approximately 11,760 feet (SWCA Environmental Consultants, 2010).

As discussed in Section 2.1.1.1, the Goose Creek HUC unit contains eight percent of the proposed Brook Mine permit area (Figure 11). The Goose Creek channel is located outside the proposed permit area with the exception of where the BNSF rail line crosses the channel. No other named streams exist within the portion of the permit area within the Goose Creek HUC unit. According to the wetlands and aquatic resources inventory completed for the proposed Brook Mine in 2013, approximately 0.4 acres of PEM wetlands are found along two unnamed tributaries to Goose Creek within the proposed permit boundary (Brook Mine Permit Application, 2020).

Surface water rights on Goose Creek adjacent to the proposed Brook Mine are primarily associated with irrigation uses (Wyoming State Engineer’s Office, 2019b; Brook Mine Permit Application, 2020). There is also at least one unpermitted impoundment that exists on a tributary to Goose Creek adjacent to the proposed Brook Mine permit boundary (Brook Mine Permit Application, 2020).

Goose Creek near the confluence with the Tongue River has been historically affected by both underground and surface coal mining. Underground mining at the Hotchkiss Number Two Mine and Dietz Number Five and Eight Mine occurred in the lower part of the drainage (Brook Mine Permit Application, 2020). Surface coal mining has occurred within and adjacent to Goose Creek, including at the reclaimed Plachek Pit from which Goose Creek has flowed through since 1962 (Vinikour, 1980). The WDEQ/AML has contracted reclamation work on Goose Creek at the Plachek Pit (RESPEC, 2019). The Big Horn Mine also conducted surface coal mining adjacent to Goose Creek at Pit 1 in the lower part of the drainage. This area has been reclaimed, fully bond released, and removed from the current Big Horn Mine permit area (Big Horn Mine Permit, 2020).

The proposed Brook Mine would not conduct mining adjacent to Goose Creek (Brook Mine Permit Application, 2020). An area within the Goose Creek watershed and within the existing Big Horn Mine permit boundary may receive surficial disturbance for other operational mine needs. Other mining disturbance in the watershed would include a topsoil stockpile and sediment control features. The Goose Creek channel would not be directly disturbed. Further discussion on the possible effects of mining disturbance on Goose Creek, as well as proposed hydrologic and sediment control features, is discussed in Section 7.1.

Surface water quantity and quality has been monitored on Goose Creek by the USGS, the Big Horn Mine, and the proposed Brook Mine. The USGS installed a station on Goose Creek – Station No. 06305700 Goose Creek near Acme, WY in 1983 near Wyoming State Highway 339 (Table 3, Figure 11). Streamflow was continuously monitored at the station from 1984 to 2007. Streamflow monitoring resumed at the station in June 2015. Water quality samples were collected at the station from 1983 to 2008. The Big Horn Mine has monitored Goose Creek at station GC00-78 since 1978; GC00-78 is located approximately 0.3 miles upstream from the USGS station (Table 3, Figure 11). The USGS and Big Horn Mine stations monitor approximately 413 mi², or nearly the entire
Goose Creek watershed. The Brook Mine also sampled water quality on Goose Creek in 2015 and 2016 and presented the data in the mine permit application. However, the data from this site (station 578434-GC-1) are not presented in the CHIA since a longer period of record is available from the Big Horn Mine station on Goose Creek. More information on the Brook Mine monitoring sites is provided in Section 7.1.

Annual mean daily streamflow from the April to November period over 2000 to 2018 on Goose Creek was presented in Section 2.1.1.1 in Figure 12. Data for the graph were taken from both GC00-78 and USGS Station No. 06305700. Annual mean daily flows over this period ranged from a low of 41 cfs in 2001 to a high of 414 cfs in 2011. A comparison of the annual mean daily flows to precipitation received at the Sheridan County Airport indicates that flows are correlated to precipitation ($R^2=0.44$, $p=0.002$). For example, the high flows recorded in 2011 occurred when precipitation was 18.75 inches, which was the second highest over the 2000 to 2018 period at the Sheridan County Airport (Western Regional Climate Center, 2020a).

Additional analysis of streamflow data from USGS Station No. 06305700 and GC00-78 was conducted for the 1984 to 2018 period to further characterize the hydrology of Goose Creek. Data from May 1984 to October 2007 and June 2015 to December 2018 were taken from the USGS station while data from November 2007 to June 2015 were taken from the Big Horn Mine station. Over the 1984-2018 period, the average daily flow was 170.99 cfs, resulting in an average annual runoff of 123,574 ac-ft, and a unit-area annual runoff of 299.2 ac-ft/mi²/yr. Mean daily flows for the period range from a low of three cfs on August 24, 2001 to a high of 3,040 cfs on June 17, 1995 (Figure 19). A flow duration curve for the period is shown in Figure 20. A flow of 85 cfs was equaled or exceeded 50 percent of the time (Figure 20). On a monthly basis, the majority of streamflow occurred in June due to snowmelt (Figure 21). The lowest flow occurred in August, likely due to high evapotranspiration rates, lack of recharge, and withdrawals for irrigation use (Big Horn Mine Permit, 2020).
Figure 19. Mean daily streamflow at Goose Creek near the proposed Brook Mine, May 1984 to December 2018. Data are taken from USGS Station No. 06245900 and Big Horn Mine station GC00-78. Gaps indicate periods when data were not available.
A comparison of estimated peak flows for the 2-year, 10-year, and 100-year event recurrence intervals using USGS peak-flow regression equations (Miller, 2003) is presented in Table 5 for the primary drainages within the surface water evaluation area. For Goose Creek, peak flow for the 2-year event is estimated at 525 cfs, while the 100-year event is estimated at nearly 5,540 cfs (Table 5). The maximum instantaneous peak daily discharge at USGS Station No. 06305700 over the 1984 to 2007 and 2015-2018 periods was 3,430 cfs, occurring June 8, 2007. This flow corresponds to between a 25-year and 50-year event as predicted by the equations of Miller (2003).

The WDEQ/WQD has classified Goose Creek as Class 2AB water (Wyoming Department of Environmental Quality, 2013). Class 2AB waters support game fish populations or spawning and nursery areas at least seasonally. Class 2AB waters are also presumed to have sufficient water.
quality and quantity to support drinking water supplies. Supported uses include drinking water, game fish, nongame fish, fish consumption, other aquatic life, recreation, wildlife, agriculture, industry, and scenic value (Table 6). The WDEQ/WQD numeric standards for selected constituents for Class 2AB surface waters are presented in Table 7.

Water quality in Goose Creek is affected by land uses in the watershed upstream of the proposed Brook Mine. In 2000, Goose Creek was placed on Wyoming’s Section 303(d) list for impaired water quality due to fecal coliform (Wyoming Department of Environmental Quality, 2018). In 2006, the same segment of Goose Creek was placed on the 303(d) list for impaired water quality due to habitat alterations and sediment (Wyoming Department of Environmental Quality, 2018). In 2010, a TMDL was prepared for Goose Creek to address the water quality impairment (SWCA Environmental Consultants, 2010).

A statistical summary of 79 water quality samples collected at Big Horn Mine station GC00-78 for the March 2000 to September 2019 time period was presented in Table 2 in Section 2.1.1.1. Magnesium bicarbonate was the dominant water type noted in 69.6 percent of the samples (Figure 23d) (Rockware Inc., 2015). TDS ranged from 100 to 580 mg/L, with a median of 400 mg/L. TSS ranged from <5 to 86 mg/L, with a median of 6 mg/L (Table 2). Dissolved metal concentrations were mostly low over the 2000-2019 period, with numerous values below detection limits. The maximum concentrations of cadmium (0.006 mg/L in 2002), iron (0.35 mg/L in 2010), and water temperature (23 degrees Celsius in 2006) exceeded WDEQ/WQD Class 2AB water quality standards. Cadmium and iron showed one exceedance each and temperature showed five exceedances occurring from 2002 to 2016 (Table 2). The overall data indicate that Goose Creek infrequently exceeds water quality standards, although it is important to note that bacteria data such as fecal coliform and E. coli were not collected at the GC00-78 station and not evaluated in this CHIA. The 2010 TMDL for Goose Creek identifies several possible E. coli sources that contribute to water quality impairment including septic systems, livestock, wildlife, domestic animals, municipal stormwater outfalls, and wastewater treatment plants (SWCA Environmental Consultants, 2010).

3.1.1.5 TONGUE RIVER

The Tongue River is a perennial stream that has its headwaters in the Big Horn Mountains east of Sheridan. The Tongue River flows through northern Wyoming and southeastern Montana before joining the Yellowstone River at Miles City, Montana. The Tongue River flows in an east to northeast direction in the vicinity of the proposed Brook Mine (Figure 11). With the exception of a bridge crossing located in the east part of the proposed permit area, the Tongue River is located outside of the Brook Mine permit boundary. The Tongue River drains 911 mi² upstream of the Big Horn Mine TR2B80 surface water monitoring station (Figure 11).

Surface water rights on the Tongue River adjacent to the proposed Brook Mine are primarily associated with irrigation uses (Wyoming State Engineer’s Office, 2019b; Brook Mine Permit Application, 2020). There are numerous irrigated hayfields located in the Tongue River valley, particularly upstream of the Interstate 90 crossing.

The Tongue River adjacent to the proposed Brook Mine has been historically affected by both underground and surface coal mining. Underground mining occurred at several mines, including the Acme Number One, Acme Number Two, Carney Number Forty-Four, Model, March Number Five, Old Monarch, and Kooi Number Forty-Six mines (Brook Mine Permit Application, 2020). Some of the subsidence and other features of the historical underground coal mines have been reclaimed by the WDEQ/AML (Bureau of Land Management, 2003). Surface coal mining has
occurred within and adjacent to the Tongue River. The Big Horn Mine relocated a portion of the Tongue River during 1973, 1977, and 1978 (Big Horn Mine Permit, 2020). The mine later reconstructed a 2,500 foot reach of the river, and in 2011, the project received an OSMRE Excellence in Surface Coal Mining Reclamation National Award (Office of Surface Mining Reclamation and Enforcement, 2011).

The proposed Brook Mine would conduct highwall and limited surface mining in several smaller watersheds that drain to either the Tongue River or Tongue River Ditch, but the Tongue River and its adjacent floodplain would not be disturbed (Brook Mine Permit Application, 2020). Further discussion on the possible effects of mining disturbance on the Tongue River, as well as proposed hydrologic and sediment control features, is discussed in Section 7.1.

Surface water quantity and quality has been monitored on the Tongue River by the USGS, the Big Horn Mine, and the proposed Brook Mine. The USGS operates a station on the Tongue River upstream from Interstate 90 (Station No. 06299980 – Tongue River at Monarch, WY) (Table 3, Figure 11). Streamflow was continuously monitored at the station from May 2004 until July 1, 2018. Water quality samples have been collected at the station from 1974 to 1983, and from 2004 to present. The Big Horn Mine has monitored the Tongue River upstream of the mine at station TR0176 since 1976; TR0176 is located approximately one mile downstream from the USGS Station No. 06299980 (Table 3, Figure 11). The Big Horn Mine has also monitored the Tongue River downstream of the mine at station TR2B80 since 1980 (Table 3, Figure 11). The proposed Brook Mine collected water quality samples at two locations on the Tongue River: one at the location of USGS Station No. 06299980 and one approximately 3.7 miles further upstream (Table 3, Figure 11). The proposed Brook Mine also collected water quality samples from a site within the Tongue River Ditch (Table 3, Figure 11). The two Tongue River sampling locations and the ditch sampling location are located south of the proposed permit boundary (Figure 11).

Annual mean daily streamflow from the April to November period over 2000 and 2002 to 2018 at the upstream and downstream Tongue River stations was presented in Section 2.1.1.1 in Figure 12. Data for the graph were taken from both TR0176 and USGS Station No. 06299980 for characterizing flows on the Tongue River upstream of the Goose Creek confluence and the Big Horn Mine, while data from TR2B80 were used for characterizing flows on the Tongue River downstream of the Goose Creek confluence and the Big Horn Mine. For the upstream Tongue River, annual mean daily flows over the 2000 and 2002 to 2018 period ranged from a low of 99 cfs in 2004 to a high of 577 cfs in 2011. For the downstream Tongue River, annual mean daily flows over the period ranged from a low of 150 cfs in 2004 to a high of 1,000 cfs in 2011. A comparison of the annual mean daily flows to precipitation received at the Sheridan County Airport indicates that flows are correlated to precipitation (R²=0.39 and p=0.005 for Tongue River upstream; R²=0.42 and p=0.004 for Tongue River downstream). For example, the high flows recorded in 2011 occurred when precipitation was 18.75 inches, which was the second highest over the 2000 to 2018 period at the Sheridan County Airport (Western Regional Climate Center, 2020a).

Additional analysis of streamflow data from the Tongue River upstream and downstream of Goose Creek was conducted for the 1984 to 2018 period to further characterize the hydrology of the Tongue River. There were some periods that data were not available for the Big Horn Mine stations in the WDEQ/LQD Hydrology Database, including 1989 to 1995, and part of 1997 to 2000. In addition, the winter months had no data for some of the period due to ice or the stations being shut down. Furthermore, over select periods during 2012 to 2018, the Big Horn Mine did not
measure flows at the TR2B80 station, but rather estimated flows by adding flows from their upstream stations or the USGS stations on Goose Creek and the Tongue River.

At the upstream Tongue River, mean daily flows for the period range from a low of 10 cfs on December 8, 2013 to a high of 3,560 cfs on May 29, 2018 (Figure 22a). At the downstream Tongue River, mean daily flows for the period range from a low of six cfs to a high of 6,480 cfs on May 29, 2018 (Figure 22b). Similar to Goose Creek, on a monthly basis, the annual peak streamflow typically occurred in May or June due to snowmelt. Given the number of missing days between stations, flow duration curves were not constructed.

A comparison of estimated peak flows for the 2-year, 10-year, and 100-year event recurrence intervals using USGS peak-flow regression equations (Miller, 2003) equations is presented in Table 5 for the primary drainages within the surface water evaluation area. For the Tongue River at TR2B80, peak flow for the 2-year event is estimated at 760 cfs, while the 100-year event is estimated at nearly 7,775 cfs (Table 5). The maximum mean daily discharge at TR2B80 over the periods shown in Figure 22b was 6,480 cfs. This flow corresponds to between a 50-year and 100-year event as predicted by the equations of Miller (2003). For comparison, the maximum instantaneous daily discharge recorded at a station active since 1961 on the Tongue River at the Wyoming-Montana state line was 17,500 cfs on May 19, 1978. This flow was greater than a 100-year event and occurred during a large storm event that resulted in widespread flooding across northeastern Wyoming and southeastern Montana (Parrett et al., 1984).
Figure 22. Mean daily discharge on the Tongue River: (a) upstream of the Big Horn Mine and Goose Creek confluence, and (b) downstream of the Big Horn Mine and Goose Creek confluence, 1984 to 2018. Gaps indicate periods when data were not available.
The WDEQ/WQD has classified the Tongue River as Class 2AB water (Wyoming Department of Environmental Quality, 2013). The WDEQ/WQD numeric standards for selected constituents for Class 2AB surface waters are presented in Table 7. Slightly different numeric standards for dissolved metals exist on the Tongue River upstream and downstream of Goose Creek due to differences in hardness between sites.

Water quality in the Tongue River is affected by land uses in the watershed upstream of the proposed Brook Mine. Goose Creek also is suspected to affect water quality in the Tongue River (Wyoming Department of Environmental Quality, 2018). In 2002, the WDEQ/WQD placed the Tongue River from the Goose Creek confluence downstream to the Montana state line on Wyoming’s Section 303(d) list for impaired water quality due to elevated water temperatures (Wyoming Department of Environmental Quality, 2018). The reasons for the higher temperatures are unknown. Another 13.5 mile segment of the Tongue River from Monarch Road upstream to Wolf Creek Road was placed on the 303(d) list in 2010 due to *E. coli* exceedances that impair recreation use. This segment of the river is upstream of USGS Station No. 06299980, but adjacent to the proposed Brook Mine. TMDL development for this segment started in 2015 (Wyoming Department of Environmental Quality, 2018). In 2018, a 4.7 mile segment of the Tongue River from the confluence with Goose Creek upstream to Monarch Road was added to the 303(d) list due to *E. coli* exceedances. The source(s) of *E. coli* is currently unknown, but may be related to spring runoff, overland flow, and the resuspension of bacteria in streambed sediments (Wyoming Department of Environmental Quality, 2018).

A statistical summary of 79 water quality samples collected at Big Horn Mine stations TR0176 and TR2B80 for the March 2000 to September 2019 time period was presented in Table 2 in Section 2.1.1.1. Calcium bicarbonate was the dominant water type noted in 94.9 percent of the samples at TR0176 (Figure 23e) (Rockware Inc., 2015). The dominant water type at TR2B80 was also calcium bicarbonate, noted in 81.0 percent of the samples (Figure 23f). Magnesium-bicarbonate water was more prevalent at the downstream station than the upstream station (19.0 percent of the samples versus 5.1 percent), owing to inputs from Goose Creek.

TDS at TR0176 over the 2000 to 2019 period ranged from 120 to 430 mg/L, with a median of 260 mg/L (Table 2). TDS at TR2B80 was slightly higher, ranging from 110 to 500 mg/L, with a median of 330 mg/L. TSS at TR0176 ranged from <5 to 370 mg/L, with a median of 6 mg/L. TSS at TR2B80 ranged from <5 to 82 mg/L, with a median of 8 mg/L. Dissolved metal concentrations at both stations were low over the 2000-2019 period, with numerous values below detection limits. At TR0176, the maximum concentrations of iron (0.32 mg/L in 2003) and water temperature (24 degrees Celsius in 2006) exceeded WDEQ/WQD Class 2AB water quality standards. Iron showed one exceedance and temperature showed five exceedances occurring from 2002 to 2006 (Table 2). Downstream at TR2B80, there were nine temperature exceedances occurring from 2002 to 2018 (Table 2). The overall data show that water temperature is the primary concern for the Tongue River upstream and downstream of the Big Horn Mine and Goose Creek tributary.

Summary statistics for the water quality data collected by the proposed Brook Mine on the Tongue River and the Tongue River Ditch are presented in Table 10. Five samples were collected from 2nd Quarter (Q) 2018 through 1st Q 2019 at station 578524-TR-1, located approximately 3.7 upstream of the location of USGS Station No. 06299980. Four samples were collected from 2nd Q 2018 through 1st Q 2019 at station 578420-TR-1 at the location of USGS Station No. 06299980. Two samples were collected in 2nd Q 2018 and 3rd Q 2018 from the Tongue River Ditch south of the proposed permit boundary; additional samples were attempted to be collected in 4th Q 2018 and 1st
Q 2019 but the ditch was either dry or frozen (Brook Mine Permit Application, 2020). Calcium bicarbonate-type water was noted at each sample at each of the three sites (Figure 24) (Rockware Inc., 2015), which is consistent with the dominant water type noted at the TR0176 station at the Big Horn Mine upstream of the Goose Creek confluence. TDS at 578524-TR-1 ranged from 140 to 380 mg/L, with a median of 270 mg/L (Table 10). TDS at 578420-TR-1 was slightly lower, ranging from 170 to 290 mg/L with a median of 245 mg/L (Table 10). TDS in the Tongue River Ditch was similar at 150 and 210 mg/L (Table 10). Dissolved metal concentrations at each site were nearly all below detection limits. The only water quality exceedances noted at the three sites was for water temperature (Table 10), which is consistent with the data history at the Big Horn Mine sites and the WDEQ/WQD 303(d) listing for temperature on the Tongue River in this location.
Table 10. Surface water quality summary statistics for sites established by the Brook Mine on the Tongue River and Tongue River Ditch, 2018 to 2019.

<table>
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<tr>
<th>Constituent</th>
<th>Units</th>
<th>Number of samples</th>
<th>Min</th>
<th>Max</th>
<th>Median</th>
<th>Number of exceedances</th>
<th>Min</th>
<th>Max</th>
<th>Median</th>
<th>Number of samples</th>
<th>Min</th>
<th>Max</th>
<th>Median</th>
<th>Number of samples</th>
<th>Min</th>
<th>Max</th>
<th>Median</th>
<th>Number of exceedances</th>
</tr>
</thead>
<tbody>
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<td>Aluminum (dissolved)</td>
<td>mg/L</td>
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<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>0.01</td>
<td>100% &lt;0.1</td>
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<td>&lt;0.1</td>
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<td>4</td>
<td>&lt;0.1</td>
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<td>&lt;0.1 &lt;100% &lt;0.1</td>
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<td>0.01</td>
<td>100% &lt;0.1</td>
<td>2</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
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<td>0</td>
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<td>&lt;0.005</td>
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<tr>
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<td>100% &lt;0.001</td>
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<tr>
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<td>100% &lt;0.01</td>
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<td>4</td>
<td>&lt;0.01</td>
<td>&lt;0.01 &lt;100% &lt;0.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrite plus nitrate N (dissolved)</td>
<td>mg/L</td>
<td>5</td>
<td>&lt;0.1</td>
<td>0.2</td>
<td>0.1</td>
<td>88% &lt;0.1</td>
<td>2</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>---</td>
<td>0</td>
<td>4</td>
<td>&lt;0.1</td>
<td>0.2 &lt;100% &lt;0.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH (field)</td>
<td>S.U.</td>
<td>5</td>
<td>7.97</td>
<td>8.69</td>
<td>8.63</td>
<td>0</td>
<td>2</td>
<td>8.69</td>
<td>8.89</td>
<td>---</td>
<td>0</td>
<td>4</td>
<td>8.14</td>
<td>8.60 &lt;8.31 &lt;100%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Selenium (dissolved)</td>
<td>mg/L</td>
<td>5</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
<td>0.005</td>
<td>100% &lt;0.005</td>
<td>2</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
<td>---</td>
<td>0</td>
<td>4</td>
<td>&lt;0.005</td>
<td>&lt;0.005 &lt;100% &lt;0.005</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature (field)</td>
<td>°C</td>
<td>5</td>
<td>1.4</td>
<td>21.0</td>
<td>9.4</td>
<td>1</td>
<td>2</td>
<td>22.6</td>
<td>23.7</td>
<td>---</td>
<td>2</td>
<td>4</td>
<td>1.4</td>
<td>20.7 &lt;9.6 &lt;100%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turbidity</td>
<td>NTU</td>
<td>5</td>
<td>1.2</td>
<td>15.1</td>
<td>6.9</td>
<td>NA</td>
<td>2</td>
<td>22.8</td>
<td>24.1</td>
<td>---</td>
<td>NA</td>
<td>4</td>
<td>1.2</td>
<td>9.9 &lt;4.7 &lt;100%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zinc (dissolved)</td>
<td>mg/L</td>
<td>5</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>0.01</td>
<td>100% &lt;0.01</td>
<td>2</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>---</td>
<td>0</td>
<td>4</td>
<td>&lt;0.01</td>
<td>&lt;0.01 &lt;100% &lt;0.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boron (dissolved)</td>
<td>mg/L</td>
<td>5</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>0.1</td>
<td>100% &lt;0.1</td>
<td>NA</td>
<td>2</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>---</td>
<td>NA</td>
<td>4</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>&lt;100% &lt;0.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fluoride (dissolved)</td>
<td>mg/L</td>
<td>5</td>
<td>&lt;0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>---</td>
<td>NA</td>
<td>2</td>
<td>0.1</td>
<td>0.1</td>
<td>---</td>
<td>NA</td>
<td>4</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1 &lt;100% &lt;0.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sodium (dissolved)</td>
<td>mg/L</td>
<td>5</td>
<td>5</td>
<td>28</td>
<td>31</td>
<td>NA</td>
<td>2</td>
<td>7</td>
<td>8</td>
<td>---</td>
<td>NA</td>
<td>4</td>
<td>7</td>
<td>16 &lt;10.5 &lt;100%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfate (dissolved)</td>
<td>mg/L</td>
<td>5</td>
<td>15</td>
<td>115</td>
<td>47</td>
<td>NA</td>
<td>2</td>
<td>22</td>
<td>27</td>
<td>---</td>
<td>NA</td>
<td>4</td>
<td>26</td>
<td>58 &lt;39.5 &lt;100%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TDS dried at 180 °C</td>
<td>mg/L</td>
<td>5</td>
<td>140</td>
<td>380</td>
<td>270</td>
<td>NA</td>
<td>2</td>
<td>150</td>
<td>210</td>
<td>---</td>
<td>NA</td>
<td>4</td>
<td>170</td>
<td>290 &lt;245 &lt;100%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total suspended solids</td>
<td>mg/L</td>
<td>5</td>
<td>&lt;5</td>
<td>29</td>
<td>8</td>
<td>NA</td>
<td>2</td>
<td>38</td>
<td>103</td>
<td>---</td>
<td>NA</td>
<td>4</td>
<td>&lt;5</td>
<td>18 &lt;5 &lt;100% &lt;100%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Summary statistics for constituents with non-detect values were calculated using methods recommended by Helzel (2005). Concentrations shown in red exceed WDEQ/WQO Class 2A8 surface water quality standards. NA= no numeric standard established.

*Class 2A8 standard expressed as a total, but only dissolved data were available.
Figure 23. Piper diagrams for surface water monitoring stations in the surface water evaluation area: (a) Hidden Water Creek at Big Horn Mine station HWC1-79 (1979-1989), (b) upper Slater Creek at Brook Mine station SMS78512-SW-1 (2014-2015), (c) lower Slater Creek at Brook Mine station SMS78418-SW-1 (2014-2015), (d) Goose Creek at Big Horn Mine station GC00-78 (2000-2019), (e) upper Tongue River at Big Horn Mine station TR0176 (2000-2019), and (f) lower Tongue River at Big Horn Mine station TR2B80 (2000-2019). Each symbol represents a sample collected. The piper diagram in (g) provides a legend to assist in interpreting water types.
Figure 24. Piper diagrams for surface water monitoring stations in the surface water evaluation area: (a) Tongue River at Brook Mine Station 578524-TR-1 (2018-2019), (b) Tongue River Ditch at Brook Mine station 578513-IRR-DITCH (2018), and (c) Tongue River at Brook Mine Station 578420-TR-1 (2018-2019). Each symbol represents a sample collected. The piper diagram in (d) provides a legend to assist in interpreting water types.
3.1.1.6 **UNNAMED TRIBUTARIES TO THE TONGUE RIVER AND TONGUE RIVER DITCH**

The Brook Mine Permit Application (2020) identifies seven small, relatively steep watersheds that reside in the proposed permit area and that would receive varying levels of mining disturbance. All of these watersheds are direct ephemeral tributaries to either the Tongue River or Tongue River Ditch (Figure 11). The drainages are unnamed on USGS 24K scale quadrangle maps but the Brook Mine Permit Application (2020) has added a naming convention for the purposes of baseline characterization. A description of these watersheds is provided below.

### 3.1.1.6.1 TR1

TR1 is an ephemeral tributary to the Tongue River with a drainage area of approximately 0.24 mi². The drainage flows in a southeast direction in the southeast portion of the proposed Brook Mine permit area (Figure 11). Based on USGS 24K scale quadrangle maps, the watershed has a relief of 300 feet, contains 0.73 miles of streams, and has a drainage density of 3.00 mi/mi² (Brook Mine Permit Application, 2020). Based on a longitudinal profile created from topography generated from LIDAR data, the TR1 channel has a slope of 5.6 to 10.2 percent (Brook Mine Permit Application, 2020). According to the wetlands and aquatic resources inventory completed for the proposed Brook Mine in 2013, there are no wetlands associated with TR1 within the proposed permit boundary (Brook Mine Permit Application, 2020). There are no surface water rights in the TR1 watershed. Historical underground coal mining at the Carney Mine Number Forty-Four occurred beneath nearly the entire TR1 watershed (Brook Mine Permit Application, 2020).

The proposed Brook Mine would not cause any mining-related disturbance within the TR1 watershed. Although most of the watershed is located within the proposed permit boundary, the entire area would be outside of the proposed affected area (Brook Mine Permit Application, 2020).

The Brook Mine Permit Application (2020) presented peak flow and runoff calculations for TR1 for storms of varying return intervals using USACE HEC-HMS modelling (U.S. Army Corps of Engineers, 2019). A comparison of estimated peak flows for the 2-year, 10-year, and 100-year event recurrence intervals using the Miller (2003) equations is presented in Table 5 for the primary drainages within the surface water evaluation area. For TR1, peak flow for the 2-year event is estimated at 15 cfs, while the 100-year event is estimated at nearly 225 cfs (Table 5).

### 3.1.1.6.2 TR2

TR2 is an ephemeral tributary to the Tongue River with a drainage area of approximately 0.52 mi². The drainage flows in a southeast direction in the east portion of the proposed Brook Mine permit area (Figure 11). Approximately the lower half of the watershed is located on state land and is outside of the proposed permit boundary. Based on USGS 24K scale quadrangle maps, the watershed has a relief of 460 feet, contains 1.59 miles of streams, and has a drainage density of 3.05 mi/mi² (Brook Mine Permit Application, 2020). Based on a longitudinal profile created from topography generated from LIDAR data, the TR2 channel has a slope of 3.0 to 5.3 percent (Brook Mine Permit Application, 2020). According to the wetlands and aquatic resources inventory completed for the proposed Brook Mine in 2013, there are no wetlands associated with TR2 within the proposed permit boundary (Brook Mine Permit Application, 2020). There are no surface water rights in the TR2 watershed. Historical underground coal mining at the Carney Mine Number Forty-Four occurred beneath much of the lower TR2 watershed (Brook Mine Permit Application, 2020).
The proposed Brook Mine would primarily conduct highwall mining within the headwaters of the TR2 watershed within the permit area (Brook Mine Permit Application, 2020). Over the course of the mine plan, one trench would be constructed and mined in the headwaters of the TR2 watershed to create a working area for a continuous miner system. The continuous miner would be remotely operated to mine coal perpendicular to the trench. The main channel of the TR2 drainage would not be disturbed. Other mining disturbance in the watershed would include an overburden stockpile, a haulroad, and hydrologic and sediment control measures (Brook Mine Permit Application, 2020).

The Brook Mine Permit Application (2020) presented peak flow and runoff calculations for TR2 for storms of varying return intervals using USACE HEC-HMS modelling (U.S. Army Corps of Engineers, 2019). A comparison of estimated peak flows for the 2-year, 10-year, and 100-year event recurrence intervals using the Miller (2003) equations is presented in Table 5 for the primary drainages within the surface water evaluation area. For TR2, peak flow for the 2-year event is estimated at 20 cfs, while the 100-year event is estimated at nearly 315 cfs (Table 5).

3.1.1.6.3 TRD1

TRD1 is an ephemeral tributary to the Tongue River Ditch with a drainage area of approximately 0.04 mi². The drainage flows in a south direction in the southcentral portion of the proposed Brook Mine permit area (Figure 11). Based on USGS 24K scale quadrangle maps, the watershed has a relief of 260 feet, contains 0.31 miles of streams, and has a drainage density of 7.97 mi/mi² (Brook Mine Permit Application, 2020). Based on a longitudinal profile created from topography generated from LIDAR data, the primary TRD1 channel has a slope of 5.2 to 15.4 percent (Brook Mine Permit Application, 2020). According to the wetlands and aquatic resources inventory completed for the proposed Brook Mine in 2013, there are no wetlands associated with TRD1 within the proposed permit boundary (Brook Mine Permit Application, 2020). There are no surface water rights in the TRD1 watershed. The TRD1 watershed has not been affected by previous surface or underground coal mining (Brook Mine Permit Application, 2020).

The proposed Brook Mine would conduct highwall mining within the TRD1 watershed within the permit area (Brook Mine Permit Application, 2020). Over the course of the mine plan, one trench would be constructed and mined in the watershed to create a working area for a continuous miner system. The continuous miner would be remotely operated to mine coal perpendicular to the trench. A portion of the main channel of the TRD1 drainage would also be disturbed. Other mining disturbance in the watershed would include hydrologic and sediment control measures (Brook Mine Permit Application, 2020).

The Brook Mine Permit Application (2020) presented peak flow and runoff calculations for TRD1 for storms of varying return intervals using USACE HEC-HMS modelling (U.S. Army Corps of Engineers, 2019). A comparison of estimated peak flows for the 2-year, 10-year, and 100-year event recurrence intervals using the Miller (2003) equations is presented in Table 5 for the primary drainages within the surface water evaluation area. For TRD1, peak flow for the 2-year event is estimated at five cfs, while the 100-year event is estimated at nearly 105 cfs (Table 5).

3.1.1.6.4 TRD2

TRD2 is an ephemeral tributary to the Tongue River Ditch with a drainage area of approximately 0.51 mi². The drainage flows in a south direction in the east central portion of the proposed Brook Mine permit area (Figure 11). Based on USGS 24K scale quadrangle maps, the watershed has a relief of 435 feet, contains 1.44 miles of streams, and has a drainage density of 2.81
mi/mi² (Brook Mine Permit Application, 2020). Based on a longitudinal profile created from topography generated from LIDAR data, the TRD2 channel has a slope of 3.0 to 5.3 percent (Brook Mine Permit Application, 2020). According to the wetlands and aquatic resources inventory completed for the proposed Brook Mine in 2013, there are no wetlands associated with TRD2 within the proposed permit boundary (Brook Mine Permit Application, 2020). There are no surface water rights in the TRD2 watershed. Historical underground coal mining at the Carney Mine Number Forty-Four occurred beneath much of the lower TRD2 watershed (Brook Mine Permit Application, 2020).

The proposed Brook Mine would conduct highwall mining within the TRD2 watershed within the permit area (Brook Mine Permit Application, 2020). Over the course of the mine plan, one trench would be constructed and mined in the watershed to create a working area for a continuous miner system. The continuous miner would be remotely operated to mine coal perpendicular to the trench. Other mining disturbance in the watershed would include an overburden stockpile, a sediment pond, and other hydrologic and sediment control measures. A portion of the main channel of the TRD2 drainage would also be disturbed (Brook Mine Permit Application, 2020).

The Brook Mine Permit Application (2020) presented peak flow and runoff calculations for TRD2 for storms of varying return intervals using USACE HEC-HMS modelling (U.S. Army Corps of Engineers, 2019). A comparison of estimated peak flows for the 2-year, 10-year, and 100-year event recurrence intervals using the Miller (2003) equations is presented in Table 5 for the primary drainages within the surface water evaluation area. For TRD2, peak flow for the 2-year event is estimated at 20 cfs, while the 100-year event is estimated at nearly 310 cfs (Table 5).

3.1.1.6.5 TRD3

TRD3 is an ephemeral tributary to the Tongue River Ditch with a drainage area of approximately 0.59 mi². The drainage flows in a south direction in the central portion of the proposed Brook Mine permit area (Figure 11). Based on USGS 24K scale quadrangle maps, the watershed has a relief of 445 feet, contains 2.27 miles of streams, and has a drainage density of 3.84 mi/mi² (Brook Mine Permit Application, 2020). Based on a longitudinal profile created from topography generated from LIDAR data, the TRD3 channel has a slope of 3.2 to 4.2 percent (Brook Mine Permit Application, 2020). According to the wetlands and aquatic resources inventory completed for the proposed Brook Mine in 2013, there are no wetlands associated with TRD3 within the proposed permit boundary (Brook Mine Permit Application, 2020). There are no surface water rights in the TRD3 watershed. Historical underground coal mining at the Carney Mine Number Forty-Four occurred beneath much of the lower TRD3 watershed (Brook Mine Permit Application, 2020).

The proposed Brook Mine would conduct highwall mining within the TRD3 watershed within the permit area (Brook Mine Permit Application, 2020). Over the course of the mine plan, one trench would be constructed and mined in the watershed to create a working area for a continuous miner system. The continuous miner would be remotely operated to mine coal perpendicular to the trench. Other mining disturbance in the watershed would include topsoil stockpiles, a haulroad, flood control reservoirs, and other hydrologic and sediment control measures. A portion of the main channel of the TRD3 drainage would also be disturbed (Brook Mine Permit Application, 2020).
The Brook Mine Permit Application (2020) presented peak flow and runoff calculations for TRD3 for storms of varying return intervals using USACE HEC-HMS modelling (U.S. Army Corps of Engineers, 2019). A comparison of estimated peak flows for the 2-year, 10-year, and 100-year event recurrence intervals using the Miller (2003) equations is presented in Table 5 for the primary drainages within the surface water evaluation area. For TRD3, peak flow for the 2-year event is estimated at 25 cfs, while the 100-year event is estimated at nearly 330 cfs (Table 5).

### 3.1.1.6.6 TRD4

TRD4 is an ephemeral tributary to the Tongue River Ditch with a drainage area of approximately 0.27 mi². The drainage flows in a south direction in the west central portion of the proposed Brook Mine permit area (Figure 11). Based on USGS 24K scale quadrangle maps, the watershed has a relief of 230 feet, contains 0.5 miles of streams, and has a drainage density of 1.85 mi/mi² (Brook Mine Permit Application, 2020). Based on a longitudinal profile created from topography generated from LIDAR data, the TRD4 channel has a slope of 1.5 to 2.4 percent (Brook Mine Permit Application, 2020).

According to the wetlands and aquatic resources inventory completed for the proposed Brook Mine in 2013, 0.4 acres of PEM wetlands, 1.1 acres of palustrine aquatic bed-permanently flooded (PABh) wetlands, and 0.4 acres of PEM-permanently flooded (PEMh) wetlands are found along TRD4 within the proposed permit boundary (Brook Mine Permit Application, 2020). There is one surface water right in the TRD4 watershed for a stock reservoir, and one unpermitted reservoir. The TRD4 watershed has not been affected by previous surface or underground coal mining (Brook Mine Permit Application, 2020).

The proposed Brook Mine would conduct highwall mining within the TRD4 watershed within the permit area (Brook Mine Permit Application, 2020). Over the course of the mine plan, one trench would be constructed and mined in the watershed to create a working area for a continuous miner system. The continuous miner would be remotely operated to mine coal perpendicular to the trench. Other mining disturbance in the watershed would include a haulroad and hydrologic and sediment control measures. A portion of the main channel of the TRD4 drainage would also be disturbed (Brook Mine Permit Application, 2020).

The Brook Mine Permit Application (2020) presented peak flow and runoff calculations for TRD4 for storms of varying return intervals using USACE HEC-HMS modelling (U.S. Army Corps of Engineers, 2019). A comparison of estimated peak flows for the 2-year, 10-year, and 100-year event recurrence intervals using the Miller (2003) equations is presented in Table 5 for the primary drainages within the surface water evaluation area. For TRD4, peak flow for the 2-year event is estimated at 15 cfs, while the 100-year event is estimated at nearly 235 cfs (Table 5).

### 3.1.1.6.7 TRD5

TRD5 is an ephemeral tributary to the Tongue River Ditch with a drainage area of approximately 0.93 mi². The drainage flows in a southeast direction in the west portion of the proposed Brook Mine permit area (Figure 11). Based on USGS 24K scale quadrangle maps, the watershed has a relief of 300 feet, contains 2.86 miles of streams, and has a drainage density of 3.08 mi/mi² (Brook Mine Permit Application, 2020). Based on a longitudinal profile created from topography generated from LIDAR data, the TRD5 channel has a slope of 1.3 to 4.7 percent (Brook Mine Permit Application, 2020).

According to the wetlands and aquatic resources inventory completed for the proposed Brook Mine in 2013, 0.6 acres of PEM wetlands, 4.3 acres of PABh wetlands, and 1.0 acres of PEMh
wetlands are found along TRD5 within the proposed permit boundary (Brook Mine Permit Application, 2020). There are three surface water rights for stock reservoirs in the TRD5 watershed within the proposed permit boundary. Historical surface coal mining at the Masters, Riverside, and Black Mountain mines occurred in a portion of the lower TRD5 watershed (Brook Mine Permit Application, 2020).

The proposed Brook Mine would conduct highwall mining within the TRD5 watershed within the permit area (Brook Mine Permit Application, 2020). Over the course of the mine plan, five trenches would be constructed and mined in the watershed to create a working area for a continuous miner system. The continuous miner would be remotely operated to mine coal perpendicular to the trench. Other mining disturbance in the watershed would include topsoil and overburden stockpiles, a haulroad, and hydrologic and sediment control measures. Much of the main channel of the TRD5 drainage would also be disturbed (Brook Mine Permit Application, 2020).

The Brook Mine Permit Application (2020) presented peak flow and runoff calculations for TRD5 for storms of varying return intervals using USACE HEC-HMS modelling (U.S. Army Corps of Engineers, 2019). A comparison of estimated peak flows for the 2-year, 10-year, and 100-year event recurrence intervals using the Miller (2003) equations is presented in Table 5 for the primary drainages within the surface water evaluation area. For TRD5, peak flow for the 2-year event is estimated at 30 cfs, while the 100-year event is estimated at nearly 400 cfs (Table 5).

3.2 GROUNDWATER

3.2.1 DESCRIPTION OF AQUIFERS AND AQUIFER PROPERTIES

The following sub-section will provide a description of the aquifers of concern in the groundwater evaluation area as well as key aquifer properties such as hydraulic conductivity, transmissivity, storage coefficients, and other key characteristics. Some of the basic definitions that will be used in this section are discussed below.

Unconfined and confined are the two basic types of aquifers. An aquifer is considered unconfined if water only partially fills the aquifer materials and water freely rises and declines along the unsaturated/saturated zone boundary. These unconfined aquifers are often referred to as water-table aquifers. A confined aquifer is generally defined when water completely fills the aquifer materials and is overlain by a confining bed. A common term for a confined aquifer is an artesian aquifer. The water level from a well that permits water solely from a confined aquifer to enter the well will be above the structural top of the confined aquifer but not necessarily above the land surface. In addition to unconfined and confined aquifers, there is also perched groundwater where groundwater is sitting on top of a low permeable layer.

Hydraulic conductivity (K) is dependent on the aquifer properties and is a measure of the ease with which a geologic medium transmits water; higher K materials transmit water more easily than lower K materials. The unit used for K in this CHIA is feet per day (feet/day). Transmissivity (T) is hydraulic conductivity (K) multiplied by aquifer thickness (b); the unit used for T in this CHIA is feet$^2$/day. The storage coefficient (S) of an aquifer is the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in potentiometric head. Storage coefficient is presented as a unitless parameter in this CHIA. The magnitude of the
storage coefficient indicates whether the aquifer is unconfined or confined. Confined aquifers are typically indicated by storage coefficients less than 0.001 (Freeze and Cherry, 1979).

The proposed Brook Mine and the Big Horn Mine have conducted numerous pump and slug tests to characterize the hydraulic properties of the aquifers of concern within the evaluation area. Summary statistics of hydraulic conductivity and storage coefficient grouped by aquifer unit and by mine are presented in Table 11. A boxplot comparing the hydraulic conductivity values by aquifer unit is presented in Figure 25. In a few cases, the Big Horn Mine analyzed the aquifer test results using multiple analytical techniques and therefore analysis of a single aquifer test might result in multiple hydraulic conductivity or storage coefficients. For the purposes of this CHIA, multiple analyses or tests reported at a single well were averaged to represent the aquifer properties at that location. The aquifer tests at the mines focused on determining the horizontal hydraulic conductivity and no tests reported the vertical hydraulic conductivity of the aquifers of concern. Therefore, use of the term hydraulic conductivity in this CHIA refers to the horizontal hydraulic conductivity.

![Figure 25. Boxplots comparing the hydraulic conductivity of the aquifers of interest at and near the proposed Brook Mine.](image-url)

<table>
<thead>
<tr>
<th>Aquifer Unit</th>
<th>hydraulic conductivity (ft/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alluvial - Slater Creek (n=3)</td>
<td>11.6</td>
</tr>
<tr>
<td>Alluvial - Goose Creek (n=3)</td>
<td>12.5</td>
</tr>
<tr>
<td>Alluvial - Tongue River (n=18)</td>
<td>254</td>
</tr>
<tr>
<td>Camey Coal (n=7)</td>
<td>0.06</td>
</tr>
<tr>
<td>Masters Coal (n=7)</td>
<td>0.18</td>
</tr>
<tr>
<td>Backfill (n=8)</td>
<td>1.1</td>
</tr>
</tbody>
</table>

Figure 25. Boxplots comparing the hydraulic conductivity of the aquifers of interest at and near the proposed Brook Mine.
### Table 11. Summary statistics of hydraulic conductivity and storage coefficients by aquifer and mine.

<table>
<thead>
<tr>
<th>Aquifer unit</th>
<th>Mine</th>
<th>Hydraulic conductivity (feet/day)</th>
<th>Storage coefficient (unitless)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Number of wells tested</td>
<td>Minimum</td>
</tr>
<tr>
<td>Alluvial – Slater Creek</td>
<td>Brook</td>
<td>3</td>
<td>0.23</td>
</tr>
<tr>
<td></td>
<td>Big Horn</td>
<td>0</td>
<td>--</td>
</tr>
<tr>
<td><strong>Total for mines</strong></td>
<td></td>
<td>3</td>
<td><strong>0.23</strong></td>
</tr>
<tr>
<td>Alluvial – Goose Creek</td>
<td>Brook</td>
<td>3</td>
<td>6.7</td>
</tr>
<tr>
<td></td>
<td>Big Horn</td>
<td>0</td>
<td>--</td>
</tr>
<tr>
<td><strong>Total for mines</strong></td>
<td></td>
<td>3</td>
<td><strong>6.7</strong></td>
</tr>
<tr>
<td>Alluvial – Tongue River</td>
<td>Brook</td>
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3.2.1.1 CLINKER AQUIFER

Natural burning of the coal seams over the past three million years created extreme heat and produced pyrometamorphic rocks from the overlying claystones, siltstones, and sandstones named clinker or scoria (Heffern and Coats, 1996). The characteristic red color, which has resulted in the nickname “red dog”, arises from oxidization of the iron in the sediments. Clinker is able to store large amounts of rainfall and snowmelt, protect it from evaporation, and discharge the water to springs, streams, and aquifers (Heffern et al., 1996). Some physically continuous clinker may not be continuous hydrologically. An example would be at the former Jacobs Ranch Mine in the southern PRB (now part of the Black Thunder Mine) where inflow occurred from some clinker areas along Burning Coal Draw but not in other areas (Black Thunder Mine Permit, 2020).

The surficial extent of clinker remnants at the proposed Brook Mine are shown in Figure 2. Based on the geophysical logs presented in Addendum D5-2-2 of the Brook Mine Permit Application (2020), the clinker zones are typically limited to less than five feet of depth and are typically dry. These clinker zones have the potential to recharge underlying aquifers. The recharge rate of the clinker may exceed the flow rate into the aquifer units below. Under those conditions, water in the clinker at some localities may discharge as springs and seeps at the interface with units adjacent to the clinker. The analysis by the proposed Brook Mine has determined that the clinker does not have extensive, laterally connected, saturated zones of groundwater (Brook Mine Permit Application, 2020). Therefore, no groundwater monitor wells are located in the clinker within the groundwater evaluation area and no aquifer tests were conducted. There will be limited discussion in this CHIA about the groundwater impacts to the clinker.

3.2.1.2 ALLUVIAL AQUIFER

The proposed Brook Mine drilled three alluvial wells (Figure 14) along Slater Creek and six boreholes perpendicular to the Slater Creek channel to assist with the characterizing the alluvial aquifer. The alluvial transects are presented on Exhibit D11.3-2 of the Brook Mine Permit Application (2020). Quaternary fill in the Slater Creek valley floor averages approximately 20 feet in thickness.

Three boreholes were also constructed along Hidden Water Creek, which are included in Addendum D11-3 of the Brook Mine Permit Application (2020). The locations of these boreholes are shown on Exhibit D11.3-1 of the Brook Mine Permit Application (2020). These boreholes show that the Hidden Water Creek valley fill is predominantly angular scoria in a colluvial, silty matrix. In addition, the two boreholes (HW-BH-1 and HW-BH-2) located in the channel bottom show that bedrock is shallow at a depth of three feet. The third borehole (HW-BH-3) was taken on a terrace approximately eight feet above the channel bottom. This borehole also had scoria in a silty matrix. These findings are similar to those found in Appendix D6, pages D6-157 to D6-158 of the Big Horn Mine Permit (2020).

The proposed Brook Mine drilled three alluvial wells (Figure 14) along Tongue River to characterize the Tongue River alluvium and three alluvial wells along Goose Creek (Figure 14) to characterize the Goose Creek alluvium. The Tongue River and Goose Creek are large perennial streams having broad, actively degrading channels and well-defined terraces. Stream-laid deposits (alluvium), fan deposits, and contiguous deposits of colluvium and slope wash, all of Holocene age, cover broad, flat areas of the Tongue River valley floor. Alluvial material associated with the Tongue River is regionally understood to be medium to coarse, rounded sands and gravels. Recent exploration drilling through the Tongue River alluvial material near the proposed mine area
demonstrates local alluvial composition is similar to regional findings (Brook Mine Permit Application, 2020).

The proposed Brook Mine conducted seven slug tests in the alluvial aquifer (Figure 26; Table 11). Three tests were conducted at wells on Slater Creek, one test was conducted at a well on the Tongue River, and three tests were conducted at wells on Goose Creek. Hydraulic conductivity on Slater Creek ranged from 0.23 to 39.3 feet/day (Table 11). Hydraulic conductivity on Goose Creek ranged from 6.7 to 28.9 feet/day (Table 11). Hydraulic conductivity on the Tongue River was 19.0 feet/day (Table 11). The Big Horn Mine conducted 17 aquifer tests in the Tongue River alluvium (Figure 26; Table 11). Hydraulic conductivity ranged from 177.9 to 2,451 feet/day, with a median of 314 feet/day (Table 11). The Tongue River had the highest hydraulic conductivity among all the aquifer units evaluated (Figure 25).
Figure 26. Alluvial aquifer test sites and observed hydraulic conductivity values at the proposed Brook Mine and Big Horn Mine.
3.2.1.3 CARNEY COAL

The Carney coal in the eastern portion of the proposed Brook Mine area ranges from 15-20 feet thick and generally becomes thinner to the west as depicted on cross-sections in the Brook Mine Permit Application (2020). The overburden material above the Carney coal seam increases to the southeast following the general dip of the coal seam. A clay parting cuts the Carney into upper and lower beds generally perpendicular to the dip of the formation in a northwest-southeast trending interface near the center of the proposed permit boundary as depicted on the Carney isopach maps. The Upper Carney on the western half of the proposed mine area ranges from two to six feet in thickness and generally thins to the west. The Lower Carney ranges from four to 10 feet thick across the western half of the permit area, and also thins towards the west (Brook Mine Permit Application, 2020).

The Big Horn Mine did not conduct any aquifer tests in the Carney coal. The Big Horn Mine Groundwater Restoration Demonstration noted that the Carney coal seam was not physically or hydraulically affected by the Big Horn Mine since it lies approximately 100 feet below the Monarch coal. The hydrograph for the Carney well BH465 shows no effect from mining of the Monarch coal seam by the Big Horn Mine (Big Horn Mine Permit, 2020).

The proposed Brook Mine conducted three pump tests and four slug tests in the Carney coal (Figure 27). An additional slug test was conducted at Carney coal well 578409 CRN-1 to compare the results from a pump test at the same well. Both tests indicated a hydraulic conductivity of 0.31 feet per day. The transmissivity from the pump test is 5.6 ft²/day and the storage coefficient is 0.00036 (Brook Mine Permit Application, 2020) (Table 11). Hydraulic conductivity from the seven tests ranged from 0.01 to 1.5 feet/day with a median of 0.31 feet/day (Table 11; Figure 25). The slug test results from 578409 CRN-1 are not presented in Table 11, Figure 25, or Figure 28. The aquifer pumping tests conducted in June 2018 to evaluate the potential communication between the Tongue River alluvium and the Carney Coal indicate that confining claystone intervals are a hydrologic barrier between the coal seam and the Tongue River alluvium (Brook Mine Permit Application, 2020).

3.2.1.4 OVERBURDEN AND INTERBURDEN

The majority of the Carney overburden within the proposed Brook Mine permit area is composed of claystone. Siltstone and sandstone lenses are also present. The thickness of Carney overburden increases in the southeast corner of the proposed permit area. In review of electric logs in Addendum D5-2 of the Brook Mine Permit Application (2020), the proposed Brook Mine noted that the overburden is mostly dry. Areas of saturation are generally shallow, less than 30 feet below the ground surface, and generally occur near streams within the proposed permit area (Brook Mine Permit Application, 2020).

The interburden between the Carney and Masters coal seams is predominately claystone with thin, discontinuous sandstone and siltstone lenses in some areas; however, it is generally understood to be an aquitard (Brook Mine Permit Application, 2020). The interburden ranges in thickness from less than one foot on the eastern boundary of the proposed permit area, to over 50 feet on the north-central portion of the proposed permit area and averages 24 feet thick. One monitoring well was completed in the overburden and no wells were completed in the interburden as little or no water was found in these units during drilling (Brook Mine Permit Application, 2020). Based on a review of the Big Horn Mine Permit (2020), the Big Horn Mine did not install any wells in the overburden.
Lab permeability tests were conducted by the proposed Brook Mine for the confining intervals above and below the coal seams. A total of eight permeability tests were conducted by the proposed Brook Mine on three core samples. The results indicate that the overburden and underburden units are comprised of predominantly clay with low hydraulic conductivity (Brook Mine Permit Application, 2020). The permeability of the Carney overburden and Carney interburden are at least three orders of magnitude lower than the hydraulic conductivity of the coal seams.
Figure 27. Carney coal aquifer test sites and observed hydraulic conductivity and storativity values.
3.2.1.5 MASTERS COAL

The Masters coal seam ranges between four and six feet thick across the proposed Brook Mine permit area with the exception of those areas where the coal has potentially been removed by erosion as depicted on the geologic cross-sections in Addendum D5-3 of the Brook Mine Permit Application (2020). The total material thickness above the Masters seam including the combination of overburden, the Carney coal, and the interburden generally tends to increase as the Masters seam dips toward the southeast portion of the proposed permit area. The total material thickness above the Masters seam is at a minimum in the northwest portion of the proposed permit area in lowland areas where the Masters coal seam outcrops (Brook Mine Permit Application, 2020).

The proposed Brook Mine conducted one pump test and six slug tests in the Masters coal (Figure 28). An additional slug test was conducted at Masters coal well 578409 MST-1 to compare the results from a pump test at the same well. These tests indicated a hydraulic conductivity of 0.54 and 0.51 feet per day, respectively. The transmissivity from the pump test was 3.2 ft²/day and the storage coefficient was 0.00025 (Brook Mine Permit Application, 2020) (Table 11). Hydraulic conductivity for the seven tests ranged from 0.02 to 55.7 feet/day with a median of 0.54 feet/day (Table 11; Figure 25). The slug test results from 578409 MST-1 are not presented in Table 11, Figure 25, or Figure 28.

The Big Horn Mine did not conduct aquifer tests in the Masters coal. The results from Carney coal and Masters coal at the proposed Brook Mine are comparable with measured coal aquifer properties for other coal seams in the vicinity. The Big Horn Mine reported transmissivities ranging from 0.13-100 ft²/day and a storage coefficient of 1.4x10⁻⁴ for the Monarch coal (Bighorn Mine Permit, 2020). Similarly, in the Dietz 3 seam, the Big Horn Mine reported transmissivities ranging from 0.26-93 ft²/day and a storage coefficient of 1.4x10⁻⁴. The aquifer test results from the Youngs Creek Mine (Youngs Creek Mine Permit, 2020) in Sheridan County indicate average transmissivity (with an outlier thrown out) of about three ft²/day. A detailed comparison of the Brook Mine tests against all the available hydraulic conductivities from Wyoming coal mines is presented in Table D6.2-22 of the Brook Mine Permit Application (2020).

3.2.1.6 MASTERS COAL UNDERBURDEN

The underburden below the Masters coal seam is largely characterized as a thick claystone containing thin coal stringers with interbedded siltstone. From the bottom of the Masters coal seam to the top of the Wall coal seam, underburden thicknesses range from 550-600 feet. The claystone and siltstone are dry and incapable of producing greater than 0.5 gallons per minute (gpm). Addendum D5-2 of the Brook Mine Permit Application (2020) contains the geophysical log and electric log for drill hole R13-026 that describes the underburden. One underburden well was evaluated during the testing since the other wells drilled into the underburden were dry during drilling (Brook Mine Permit Application, 2020).
Figure 28. Masters coal aquifer test sites and observed hydraulic conductivity and storativity values.
3.2.1.7 BACKFILL

The backfill aquifer is a new aquifer created by replacing overburden materials into the mined pit and trenches after the coal is removed. Within the areas where the highwall miner is used for mining, an open cavern would remain. Unless the mined out areas collapse, the backfill aquifer is essentially an open cavern. By the end of mining activities, all spoil material would be backfilled into trenches or other surface mining excavation areas.

The backfill at the Big Horn Mine is typical of large open pit surface mines, where backfill was placed into all areas where coal was mined. The backfill aquifer at the proposed Brook Mine will be limited to the small surface pit and the trenches excavated for the highwall miner. Given the proximity of the Big Horn Mine to the proposed Brook Mine, data from backfill wells at the Big Horn Mine are discussed in this CHIA.

The proposed Brook Mine attempted to conduct two slug tests at the Big Horn Mine backfill and both tests failed due to the high hydraulic conductivities encountered at the site (Brook Mine Permit Application, 2020). The locations of the eight aquifer tests conducted by Big Horn Mine in the backfill are shown in Figure 29. These aquifer tests conducted by the Big Horn Mine indicate a hydraulic conductivity range of 0.11 feet per day to 158.2 feet per day with a median of 3.1 feet per day (Table 11; Figure 25).
Figure 29. Backfill aquifer test sites and observed hydraulic conductivity and storativity values at the Big Horn Mine.
3.2.2 BASELINE TIME PERIODS FOR GROUNDWATER LEVELS AND GROUNDWATER QUALITY

The data collected by the proposed Brook Mine was used as the primary source of groundwater level and water quality data for baseline characterization. The proposed Brook Mine initially collected baseline groundwater data from October 2013 through July 2014. Additional wells were sampled for baseline from 3Q 2015 through 2Q 2016, and from 1Q 2018 through 4Q 2019. As noted in Section 2.1.1.1, the nearest permitted coal mine to the proposed Brook Mine is the Big Horn Mine (WDEQ/LQD Permit 213). No mining has occurred at the Big Horn Mine since 1999 and 98 percent of the permit area is reclaimed and fully bond released. On March 14, 2003, the WDEQ/LQD approved Change No. 11 to Term 5 of the permit, which approved groundwater restoration at the mine, releasing the mine from groundwater monitoring requirements (Big Horn Mine Permit, 2020). There are no active monitoring wells in the Big Horn Mine permit area besides those completed by the proposed Brook Mine. The available information from the Big Horn Mine permit was used in the baseline characterization. In addition, geologic cross sections and hydrogeologic information provided in the Big Horn Mine permit were used qualitatively in the groundwater baseline characterization.

3.2.3 GROUNDWATER LEVELS

When groundwater level measurements are collected for a specific aquifer and a specific time period, they can be contoured to generate a groundwater potentiometric surface map. Water level measurements obtained from an unconfined aquifer represents the water table surface, and water levels obtained from a confined aquifer represent the potentiometric surface. Groundwater flows in the direction of decreasing head. The rate of groundwater flow is dependent on the magnitude of the hydraulic gradient (defined as the change in head per unit distance), effective porosity, and the hydraulic conductivity of the aquifer. The maps presented in this section show the groundwater levels by aquifer units of interest and hydrographs of select monitoring wells.

3.2.3.1 ALLUVIAL AQUIFER

Exhibit D6.2-8 of the Brook Mine Permit Application (2020) shows the extent of saturation zones in the Slater Creek alluvium within the proposed permit boundary. The exhibit was created using data and interpretation from the three alluvial monitoring wells in Slater Creek. The entire Slater Creek alluvium is interpreted as partially saturated (Brook Mine Permit Application, 2020).

Nine wells were used to generate the water level map shown in Figure 30. Three wells are on Slater Creek, three wells are on the Tongue River, and three wells are on Goose Creek. Potentiometric surfaces were not contoured for the alluvial water level data due to the limited and discontinuous nature of the alluvial sediments. The general direction of groundwater flow in the alluvial aquifer follows the topography towards the downstream or down valley direction. Groundwater gradients appear to mimic the elevation gradient of the alluvial valleys, as groundwater levels decrease in the downstream direction (Figure 30). The water levels shown in Figure 30 are median water levels during the baseline period. The baseline period varied at each well depending on the period of data collection at each well.

The depth to groundwater at the alluvial wells varied between three to 27 feet. Hydrograph insets for the baseline period are shown on Figure 30 for alluvial wells 578512-AL on Slater Creek, 578420-AL-1 on the Tongue River, and 578433-AL-1 on Goose Creek. The date range of water level
measurements varied at each well. The hydrographs for 578512-AL and 578433-AL-1 show little change in water levels, while 578420-AL-1 showed a slight decline of 2.5 feet over the June 2018 to January 2019 period (Figure 30). The two groundwater level measurements at 578415-AL-1 collected during the third and fourth quarter of 2019 show a variability of less than one foot.

Longer term trends in alluvial water levels from wells on Goose Creek and the Tongue River at the Big Horn Mine are shown in Figure 31. Three wells were selected to illustrate the seasonal changes in water levels over a 21-22 year time period. Well BH403 on Goose Creek showed a fluctuation of around one to two feet over the course of a year, while well BH397 on the Tongue River showed slightly higher fluctuations of up to four to six feet (Figure 31). Additional interannual variability in the alluvial water levels may be due to changes in streamflow as well as climate and precipitation during drought and wet years.

### 3.2.3.2 Carney Coal

Ten Carney coal wells were used to generate the water level map shown in Figure 32. The water levels shown in the map are median water levels during the baseline period. Potentiometric surface interpretation by the proposed Brook Mine is shown on Exhibit D6.2-2 of the Brook Mine Permit Application (2020). The general direction of groundwater flow in the Carney coal is generally northwest to southeast. The groundwater gradient in the Carney coal ranges approximately from 0.02 to 0.008. Estimated range of groundwater velocity is between 1 to 2.5 feet per year. The Carney coal is generally unconfined in the proposed permit area due to substantial outcropping, faulting, limited recharge sources, and past CBM development. The Carney coal is largely dry to the north and west of its subcrop into the Tongue River alluvium (Exhibit D6.2-3, Brook Mine Permit Application, 2020).

Sources of recharge for the Carney coal include: clinker that is in communication with the coal seam, historic surface mine pits (where the Carney seam was mined) north of the proposed Brook Mine permit area, regions where the Carney seam subcrops into either Slater Creek or Tongue River alluvial material, and infiltration from precipitation on the Monarch burn stratigraphically higher than the Carney seam (Brook Mine Permit Application, 2020).

Exhibit D6.2-5 of the Brook Mine Permit Application (2020) shows the extent of saturation zones in the Carney coal within the proposed permit boundary. The exhibit was created using data and interpretation from a total of 37 drill holes. Dry zones are interpreted to exist in parts of the central and west portions of the proposed permit area while most of the east part of the proposed permit area is interpreted as either partially saturated or saturated (Brook Mine Permit Application, 2020).

The depth to groundwater at the 10 Carney coal wells varied between eight to 147 feet. The highest median water level was observed at well 578510-CRN located in the northwest corner of the proposed permit boundary (Figure 32). The lowest median water level was observed at well 578409-CRN located near Hidden Water Creek (Figure 32). Hydrograph insets for the baseline period are shown on Figure 32 for wells 578511-CRN, 578409-CRN, and 578418-CRN. At each of these wells, four water level measurements were taken in 2013-2014 and one measurement was taken in either 2018 or 2019. The hydrographs for these wells show that there was little to no seasonal variability to the water levels in the Carney coal wells during the baseline period.
Figure 30. Baseline groundwater levels and select hydrographs for wells in the alluvial aquifer at and near the proposed Brook Mine.
Figure 31. Historical alluvial water levels on select wells on Goose Creek and the Tongue River at the Big Horn Mine.
Figure 32. Baseline groundwater levels and select hydrographs for wells in the Carney coal aquifer at and near the proposed Brook Mine.
3.2.3.3 MASTERS COAL

Nine wells were used to generate the water level map shown in Figure 33. The water levels shown in the map are median water levels during the baseline period. Potentiometric surface interpretation by the proposed Brook Mine is shown on Exhibit D6.2-3 in the Brook Mine Permit Application (2020). The general direction of groundwater flow in the Masters coal is generally northwest to southeast. The direction of groundwater flow in the coal seam generally follows the geologic dip. The groundwater gradient in the Masters coal ranges approximately from 0.02 to 0.009. Estimated range of groundwater velocity is between two to four feet per year. The Masters coal is generally confined in the proposed permit area, although some areas of the mine are unconfined near surface outcrops and in stratigraphic highs (Brook Mine Permit Application, 2020). Sources of recharge for the Masters coal include infiltration from overlying strata, communication with river alluvium, and seam outcrops west of the proposed Brook Mine permit area (Brook Mine Permit Application, 2020).

Exhibit D6.2-6 of the Brook Mine Permit Application (2020) shows the extent of saturation zones in the Masters coal within the proposed permit boundary. The exhibit was created using data and interpretation from a total of 37 drill holes. Dry zones are interpreted to exist in parts of the central and west portions of the proposed permit area but the majority of the proposed permit area is interpreted as either partially saturated or saturated (Brook Mine Permit Application, 2020).

The depth to groundwater at the nine Masters coal wells varied between 96 to 185 feet. The highest median water level was observed in well 578510-MST located in the northwest corner of the proposed permit boundary. The lowest median water level was observed at well 578409-MST located near Hidden Water Creek. Hydrograph insets for the baseline period are shown on Figure 33 for wells 578511-MST, 578513-MST, and 578408-MST. At each of these wells, four water level measurements were taken in 2013-2014 and one measurement was taken in 2018. Water levels at well 578511-MST changed little over time although the well was dry in March 2014. Water levels at 578408-MST increased about six feet from December 2013 to May 2014. In January 2018 the water level at this well nearly matched the level from the first measurement in October 2013. At well 578513-MST, the water level in January 2018 was about 2.6 feet higher than the level measured in May 2014. In general, the observed vertical hydraulic gradient is from Carney coal to Masters coal. However, the low permeability of the interburden indicates that there might be limited interaction between the two coal seams.

3.2.3.4 MASTERS COAL UNDERBURDEN

The Masters coal underburden is directly beneath the Masters coal seam. The proposed Brook Mine noted that the underburden in general is dry (Brook Mine Permit Application, 2020). There is one Masters coal underburden monitor well (578409-UBN; Figure 14). The median water level from five measurements taken at 578409-UBN over the October 2013 to March 2019 period is 3,601.8 feet. Water levels at the well varied by about two feet over the baseline period.
Figure 33. Baseline groundwater levels and select hydrographs for wells in the Masters coal aquifer at the proposed Brook Mine.
3.2.3.5 BACKFILL

Exhibit D6.2-7 of the Brook Mine Permit Application (2020) shows the extent of saturation zones in the backfill within the proposed permit boundary. The exhibit was created using data and interpretation from a total of two drill holes and information from the Big Horn Mine Permit (2020). Partial saturation was interpreted to occur in the majority of the Big Horn Mine backfill within the proposed Brook Mine permit boundary (Brook Mine Permit Application, 2020).

Groundwater level data were collected at two wells located in the backfill reclaimed by the Big Horn Mine (578415-SPL-1 and 578415-SPL-2) (Figure 34). Four water level measurements were collected at these wells over the June 2018 to January 2019 period. At 578415-SPL-1, water levels decreased by 2.35 feet over the period. At 578415-SPL-2, water levels decreased by 6.5 feet from June 4 to July 11, 2018 (Figure 34). This backfill well is located close to the Tongue River and the decrease was likely due to the stage lowering on the Tongue River. For example, the mean daily flow for the Tongue River at USGS Station No. 06306300 Tongue River at State Line near Decker, Montana decreased from 2,170 to 329 cfs over this time period.

Longer term trends in backfill water levels from wells in reclaimed areas at the Big Horn Mine are shown in Figure 35. Three wells were selected to illustrate the trends in water level recovery of the backfill over approximately 20 years. Additional discussion on the backfill recovery is provided in the Big Horn Mine Groundwater Restoration Document (Big Horn Mine Permit, 2020). Well BH655 showed approximately 30 feet in water level recovery from 1981 to 1999; from 1999 through 2001 water levels stabilized. At well BH657 water levels were more variable during the post-mining period. At the end of monitoring in 2001, water levels recovered by about 12 feet over a 20 year period. At well BH823, water levels recovered from 1984 until the early 1990s and then fluctuated by about 10 feet. Starting in around 1996, water levels sharply rose until stabilizing in 1998 through 2001 (Figure 35).
Figure 34. Baseline groundwater levels and select hydrographs for wells in the backfill aquifer at the proposed Brook Mine.
Figure 35. Historical water levels at select wells in the backfill aquifer at the Big Horn Mine.
3.2.4 GROUNDWATER QUALITY

Groundwater quality varies both between and within aquifers in the groundwater evaluation area. The variation between aquifers is probably due to the differences in aquifer materials as well as geochemical and biochemical changes along the flow paths of the groundwater. Within aquifers the variability is partially due to the proximity of a given sampling location to recharge/discharge zones and structural features. Water quality of selected constituents is compared throughout this CHIA to groundwater quality standards established by the WDEQ/WQD (Table 12) (WDEQ Water Quality Rules, Ch. 8, § 5). It is important to note that the WDEQ/WQD is responsible for, and has the sole authority to classify groundwaters of the State (WDEQ Water Quality Rules, Ch. 8, § 4). The comparisons of the water quality parameters against the WDEQ/WQD groundwater standards in the CHIA should not be interpreted as an attempt to classify the aquifers.

Table 12. Selected WDEQ/WQD groundwater quality class of use standards.

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<tr>
<td>Zinc</td>
<td>5.0</td>
<td>2.0</td>
<td>25.0</td>
</tr>
<tr>
<td>pH</td>
<td>6.5-8.5 s.u.</td>
<td>4.5-9.0 s.u.</td>
<td>6.5-8.5 s.u.</td>
</tr>
</tbody>
</table>

From WDEQ Water Quality Rules, Ch. 8, § 5. Values in milligrams per liter unless otherwise indicated. Note that the constituents listed are not an exhaustive list of all constituents with standards established by WDEQ/WQD.

The WDEQ Land Quality Coal Rules, Chapter 4, Section 2(w), state that “The operator shall conduct all operations in such a manner as to minimize disturbance of the hydrologic balance within the permit and adjacent areas, to prevent material damage to the hydrologic balance outside the permit area, to assure the protection or replacement of water rights, and to support approved postmining land uses in accordance with the terms and conditions of the approved permit and the performance standards of this Chapter.” The post-mining land use of the proposed Brook Mine permit area is mostly livestock grazing but also includes recreational and industrial land uses.
(Brook Mine Permit Application, 2020). The predominant post-mining land use in reclaimed areas is livestock grazing and recreation. Therefore, groundwater quality in this CHIA is evaluated primarily by comparing data against the WDEQ/LQD Class III livestock groundwater quality standards (Table 12) (WDEQ Water Quality Rules, Ch. 8, § 5).

As noted in Section 3.2.2, the proposed Brook Mine collected baseline groundwater data from October 2013 through July 2014, September 2015 to May 2016, and January 2018 to November 2019. WDEQ/LQD Guideline No. 8 (Hydrology) provides a list of recommended parameters to be monitored by coal mines (Wyoming Department of Environmental Quality, 2015b). For all the aquifers of concern, statistical analyses were conducted on a subset of parameters selected from the parameters listed in WDEQ/LQD Guideline No. 8 and a comparison was made against the WDEQ/LQD Class III livestock standards.

One of the key parameters of interest in this CHIA is TDS, a measure of the combined content of all dissolved inorganic and organic substances in groundwater. The dissolved solids include carbonate, bicarbonate, chloride, sulfate, phosphate, nitrate, calcium, magnesium, sodium organic ions, and other ions. The use of the term TDS in the CHIA refers to TDS dried at 180° Celsius (C). For the major aquifer units evaluated in this CHIA, maps were created to show the baseline TDS concentrations by well location in order to provide a spatial representation of groundwater quality in each aquifer. The statistical analyses and discussions presented in this section are limited to these spatial extents and should not be extrapolated to other areas that do not have monitor wells. Similar to surface water quality analyses (Section 3.1.1), the medians for constituents with non-detect concentrations were calculated using methods recommended by Helsel (2005).

### 3.2.4.1 ALLUVIAL AQUIFER

Groundwater quality data were collected from nine alluvial wells shown in Figure 36. Three wells are on Slater Creek, three wells are on the Tongue River, and three wells are on Goose Creek. The minimum TDS was observed at well 578434-AL-2 near Goose Creek and the maximum TDS was observed at 578512-AL located near Slater Creek (Figure 36). There are both spatial variability between wells and temporal variability within a well (Figure 36). The TDS varied between 250 to 1,330 mg/L along Goose Creek. In the three alluvial wells near Tongue River, the TDS varied between 530 to 2,190 mg/L. The higher TDS was observed at well 578415-AL-1 that is completed in the reconstructed Tongue River alluvium. The native alluvium at this location was disturbed and reconstructed by the Big Horn Mine. The TDS along the Slater Creek alluvial wells varied between 760 to 5,650 mg/L.

A comparison of baseline water quality summary statistics for select parameters with the WDEQ/WQD Class III livestock standards is shown in Table 13. Class III exceedances were observed for sulfate (one well), TDS (one well), and field pH (one well). The sulfate and TDS exceedances were from one well on Slater Creek. The TDS ranged from 250 to 5,650 mg/L with a median of 1,260 mg/L (Table 13). The water quality of the alluvial aquifer generally exhibited the highest TDS concentrations among the aquifers of concern in the groundwater evaluation area.

Figure 37 shows the spatial distribution of alluvial wells and their corresponding baseline water quality type. A water quality type analysis (piper diagram) indicated that the baseline water type in the alluvial aquifer included magnesium sulfate for two wells on Slater Creek and one well on the Tongue River, sodium sulfate for one well on Slater Creek, magnesium bicarbonate for the
three wells on Goose Creek and the upstream well on the Tongue River, and calcium bicarbonate for the other well on the Tongue River (Figure 37; Figure 48a).

The available historic water quality data was reviewed from Big Horn Mine Permit (2020). Sixty three alluvial wells are shown in Figure 38. Out of the 63 wells, seven wells had TDS data. The TDS at these wells varied between 234 to 3,142 mg/L. All the available TDS measurements were less than 5,000 mg/L and met the Class III livestock standard for TDS. Figure 39 shows the water quality type of seven wells. Five of the seven wells are of calcium bicarbonate type and the remaining two wells are of magnesium bicarbonate type.

Table 13. Baseline water quality statistics for selected constituents in the alluvial aquifer at and near the proposed Brook Mine.

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Units</th>
<th>Class III Livestock Standard</th>
<th>Number of Wells Sampled</th>
<th>Number of Samples</th>
<th>Min</th>
<th>Max</th>
<th>Median</th>
<th>Number of Samples with Class III Exceedances</th>
<th>Number of Wells with Class III Exceedances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>mg/L</td>
<td>5.0</td>
<td>9</td>
<td>41</td>
<td>&lt;0.1</td>
<td>0.5</td>
<td>93% &lt;0.1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ammonia as N</td>
<td>mg/L</td>
<td>---</td>
<td>9</td>
<td>41</td>
<td>&lt;0.1</td>
<td>1.7</td>
<td>0.1</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Arsenic</td>
<td>mg/L</td>
<td>0.2</td>
<td>9</td>
<td>41</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
<td>100% &lt;0.005</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Barium</td>
<td>mg/L</td>
<td>---</td>
<td>9</td>
<td>41</td>
<td>&lt;0.1</td>
<td>0.2</td>
<td>93% &lt;0.1</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Boron</td>
<td>mg/L</td>
<td>5.0</td>
<td>9</td>
<td>41</td>
<td>&lt;0.1</td>
<td>0.5</td>
<td>0.3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cadmium</td>
<td>mg/L</td>
<td>0.05</td>
<td>9</td>
<td>41</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>100% &lt;0.001</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Chloride</td>
<td>mg/L</td>
<td>2,000</td>
<td>9</td>
<td>41</td>
<td>3</td>
<td>24</td>
<td>11</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Chromium</td>
<td>mg/L</td>
<td>0.05</td>
<td>9</td>
<td>41</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>100% &lt;0.01</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Copper</td>
<td>mg/L</td>
<td>0.5</td>
<td>9</td>
<td>41</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>100% &lt;0.01</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Fluoride</td>
<td>mg/L</td>
<td>---</td>
<td>9</td>
<td>41</td>
<td>0.2</td>
<td>1.2</td>
<td>0.7</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Iron</td>
<td>mg/L</td>
<td>---</td>
<td>9</td>
<td>41</td>
<td>&lt;0.05</td>
<td>6.65</td>
<td>0.7</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Lead</td>
<td>mg/L</td>
<td>0.1</td>
<td>9</td>
<td>41</td>
<td>&lt;0.02</td>
<td>&lt;0.02</td>
<td>100% &lt;0.02</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Manganese</td>
<td>mg/L</td>
<td>---</td>
<td>9</td>
<td>41</td>
<td>&lt;0.02</td>
<td>2.28</td>
<td>0.33</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Mercury</td>
<td>mg/L</td>
<td>0.00005</td>
<td>9</td>
<td>41</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>100% &lt;0.001</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Nickel</td>
<td>mg/L</td>
<td>---</td>
<td>9</td>
<td>41</td>
<td>&lt;0.01</td>
<td>0.01</td>
<td>93% &lt;0.01</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Nitrite+nitrate as N</td>
<td>mg/L</td>
<td>100</td>
<td>9</td>
<td>41</td>
<td>&lt;0.1</td>
<td>1.4</td>
<td>85% &lt;0.1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Selenium</td>
<td>mg/L</td>
<td>0.05</td>
<td>9</td>
<td>41</td>
<td>&lt;0.005</td>
<td>0.006</td>
<td>98% &lt;0.005</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sulfate</td>
<td>mg/L</td>
<td>3,000</td>
<td>9</td>
<td>41</td>
<td>41</td>
<td>3,240</td>
<td>422</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>TDS dried at 180°C</td>
<td>mg/L</td>
<td>5,000</td>
<td>9</td>
<td>41</td>
<td>250</td>
<td>5,650</td>
<td>1,260</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Zinc</td>
<td>mg/L</td>
<td>25.0</td>
<td>9</td>
<td>41</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>100% &lt;0.01</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>pH (field)</td>
<td>S.U.</td>
<td>6.5-8.5</td>
<td>9</td>
<td>41</td>
<td>7.00</td>
<td>8.72</td>
<td>7.52</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Bicarbonate</td>
<td>mg/L</td>
<td>---</td>
<td>9</td>
<td>41</td>
<td>203</td>
<td>956</td>
<td>770</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Calcium</td>
<td>mg/L</td>
<td>---</td>
<td>9</td>
<td>41</td>
<td>26</td>
<td>369</td>
<td>114</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Magnesium</td>
<td>mg/L</td>
<td>---</td>
<td>9</td>
<td>41</td>
<td>22</td>
<td>490</td>
<td>148</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Potassium</td>
<td>mg/L</td>
<td>---</td>
<td>9</td>
<td>41</td>
<td>1</td>
<td>33</td>
<td>7</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Sodium</td>
<td>mg/L</td>
<td>---</td>
<td>9</td>
<td>41</td>
<td>13</td>
<td>501</td>
<td>114</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>

Medians for constituents with non-detect values were calculated using methods recommended by Helsel (2005). Medians were not calculated for constituents having ≥ 80% non-detect values. Minimum and maximum concentrations shown in red exceed WDEQ/WQD Class III groundwater quality standards.
Figure 36. Baseline TDS concentrations and select time-series plots for wells in the alluvial aquifer at and near the proposed Brook Mine.
Figure 37. Baseline water quality type for wells in the alluvial aquifer at and near the proposed Brook Mine.
Figure 38. Historical TDS concentrations and select time-series plots for wells in the alluvial aquifer at the Big Horn Mine.
Figure 39. Historical water quality type for wells in the alluvial aquifer at the Big Horn Mine.
3.2.4.2 CARNEY COAL

Groundwater quality data were collected at six Carney coal wells (578408-CRN, 578409-CRN-OB, 578417-CRN, 578511-CRN, 578524-CRN-PUMP, and 578420-CRN-PUMP) shown in Figure 40. The minimum TDS was observed at well 578420-CRN-PUMP and the maximum TDS was observed at 578511-CRN located between Slater Creek and East Fork Earley Creek (Figure 40). There are both spatial variability between wells and temporal variability within a well (Figure 40). Baseline water quality statistics for select parameters were compiled and compared against the WDEQ/WQD Class III livestock standards (Table 14). No Class III exceedances were observed at any of the Carney coal wells. The TDS ranged from 640 to 3,150 mg/L with a median of 1,430 mg/L (Table 14).

A water quality type analysis (piper diagram) indicated that the baseline water type in Carney coal varied between magnesium sulfate, sodium sulfate, and sodium bicarbonate (Figure 41 and Figure 48b). This variability is attributed to the strike and dip of the coal, the presence of several faults, the location of coal recharge areas next to outcrops, and the transitioning of the coal aquifers from confined to unconfined within the proposed permit area (Brook Mine Permit Application, 2020).

3.2.4.3 MASTERS COAL

Groundwater quality data were collected at four Masters coal wells (578408-MST, 578409-MST, 578511-MST, and 578513-MST) shown in Figure 42. The minimum TDS was observed at well 578409-MST and the maximum TDS was observed at 578513-MST (Figure 42). There are both spatial variability between wells and temporal variability within a well (Figure 42). Baseline water quality statistics for select parameters were compiled and compared against the WDEQ/WQD Class III livestock standards (Table 15). No Class III exceedances were observed at any of the Masters coal wells. The TDS ranged from 1,430 to 3,370 mg/L with a median of 1,670 mg/L (Table 15).

A water quality type analysis (piper diagram) indicated that the baseline water type in the Masters coal varied between magnesium sulfate, sodium bicarbonate, and sodium sulfate (Figure 43 and Figure 48c).

3.2.4.4 MASTERS COAL UNDERBURDEN

Groundwater quality data were collected from one Masters coal underburden well shown in Figure 14 (578409-UBN). A comparison of baseline water quality summary statistics for select parameters with the WDEQ/WQD Class III livestock standards is shown in Table 16. Class III exceedances were observed only for field pH. The TDS ranged from 2,760 to 2,860 mg/L with a median of 2,825 mg/L (Table 16). A water quality type analysis (piper diagram) indicated that the baseline water type in the Masters coal underburden is sodium sulfate (Figure 48d).
Table 14. Baseline water quality statistics for selected constituents in the Carney coal aquifer at and near the proposed Brook Mine.

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Units</th>
<th>Class III Livestock Standard</th>
<th>Number of Wells Sampled</th>
<th>Number of Samples</th>
<th>Min</th>
<th>Max</th>
<th>Median</th>
<th>Number of Samples with Class III Exceedances</th>
<th>Number of Wells with Class III Exceedances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>mg/L</td>
<td>5.0</td>
<td>6</td>
<td>22</td>
<td>&lt;0.1</td>
<td>0.9</td>
<td>0.1</td>
<td>82% &lt;0.1</td>
<td>0</td>
</tr>
<tr>
<td>Ammonia as N</td>
<td>mg/L</td>
<td>--</td>
<td>6</td>
<td>22</td>
<td>&lt;0.1</td>
<td>7.6</td>
<td>2.7</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Arsenic</td>
<td>mg/L</td>
<td>0.2</td>
<td>6</td>
<td>22</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
<td>100% &lt;0.005</td>
<td>0</td>
</tr>
<tr>
<td>Barium</td>
<td>mg/L</td>
<td>--</td>
<td>6</td>
<td>22</td>
<td>&lt;0.1</td>
<td>0.2</td>
<td>0.2</td>
<td>86% &lt;0.1</td>
<td>--</td>
</tr>
<tr>
<td>Boron</td>
<td>mg/L</td>
<td>5.0</td>
<td>6</td>
<td>22</td>
<td>&lt;0.1</td>
<td>0.5</td>
<td>0.2</td>
<td>--</td>
<td>0</td>
</tr>
<tr>
<td>Cadmium</td>
<td>mg/L</td>
<td>0.05</td>
<td>6</td>
<td>22</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.9</td>
<td>100% &lt;0.001</td>
<td>0</td>
</tr>
<tr>
<td>Chloride</td>
<td>mg/L</td>
<td>2,000</td>
<td>6</td>
<td>22</td>
<td>&lt;0.01</td>
<td>0.27</td>
<td>8</td>
<td>--</td>
<td>0</td>
</tr>
<tr>
<td>Chromium</td>
<td>mg/L</td>
<td>0.05</td>
<td>6</td>
<td>22</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>100% &lt;0.01</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td>mg/L</td>
<td>0.5</td>
<td>6</td>
<td>22</td>
<td>&lt;0.01</td>
<td>0.02</td>
<td>0.26</td>
<td>--</td>
<td>0</td>
</tr>
<tr>
<td>Fluoride</td>
<td>mg/L</td>
<td>--</td>
<td>6</td>
<td>22</td>
<td>&lt;0.05</td>
<td>0.6</td>
<td>0.9</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Iron</td>
<td>mg/L</td>
<td>--</td>
<td>6</td>
<td>22</td>
<td>&lt;0.02</td>
<td>0.22</td>
<td>0.3</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Lead</td>
<td>mg/L</td>
<td>0.1</td>
<td>6</td>
<td>22</td>
<td>&lt;0.02</td>
<td>&lt;0.02</td>
<td>100% &lt;0.02</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Manganese</td>
<td>mg/L</td>
<td>--</td>
<td>6</td>
<td>22</td>
<td>&lt;0.02</td>
<td>0.64</td>
<td>0.26</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Mercury</td>
<td>mg/L</td>
<td>0.00005</td>
<td>6</td>
<td>22</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>100% &lt;0.001</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Nickel</td>
<td>mg/L</td>
<td>--</td>
<td>6</td>
<td>22</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>100% &lt;0.01</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Nitrite+nitrate as N</td>
<td>mg/L</td>
<td>100</td>
<td>6</td>
<td>22</td>
<td>&lt;0.1</td>
<td>7.9</td>
<td>82% &lt;0.1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Selenium</td>
<td>mg/L</td>
<td>0.05</td>
<td>6</td>
<td>22</td>
<td>&lt;0.005</td>
<td>0.038</td>
<td>91% &lt;0.005</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Sulfate</td>
<td>mg/L</td>
<td>3,000</td>
<td>6</td>
<td>22</td>
<td>33</td>
<td>1,340</td>
<td>646</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>TDS dried at 180°C</td>
<td>mg/L</td>
<td>5,000</td>
<td>6</td>
<td>22</td>
<td>640</td>
<td>3,150</td>
<td>1,430</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Zinc</td>
<td>mg/L</td>
<td>25.0</td>
<td>6</td>
<td>22</td>
<td>&lt;0.01</td>
<td>0.07</td>
<td>91% &lt;0.01</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>pH (field)</td>
<td>S.U.</td>
<td>6.5-8.5</td>
<td>6</td>
<td>22</td>
<td>6.88</td>
<td>8.33</td>
<td>7.67</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Bicarbonate</td>
<td>mg/L</td>
<td>--</td>
<td>6</td>
<td>22</td>
<td>440</td>
<td>1,000</td>
<td>614</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Calcium</td>
<td>mg/L</td>
<td>--</td>
<td>6</td>
<td>22</td>
<td>8</td>
<td>177</td>
<td>77</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Magnesium</td>
<td>mg/L</td>
<td>--</td>
<td>6</td>
<td>22</td>
<td>8</td>
<td>240</td>
<td>86</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Potassium</td>
<td>mg/L</td>
<td>--</td>
<td>6</td>
<td>22</td>
<td>9</td>
<td>30</td>
<td>19</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Sodium</td>
<td>mg/L</td>
<td>--</td>
<td>6</td>
<td>22</td>
<td>79</td>
<td>690</td>
<td>231</td>
<td>--</td>
<td></td>
</tr>
</tbody>
</table>

Medians for constituents with non-detect values were calculated using methods recommended by Helsel (2005). Medians were not calculated for constituents having ≥ 80% non-detect values. Minimum and maximum concentrations shown in red exceed WDEQ/WQD Class III groundwater quality standards.
Figure 40. Baseline TDS concentrations and select time-series plots for wells in the Carney coal aquifer at and near the proposed Brook Mine.
Figure 41. Baseline water quality type for wells in the Carney coal aquifer at and near the proposed Brook Mine.
Table 15. Baseline water quality statistics for selected constituents in the Masters coal aquifer at the proposed Brook Mine.

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Units</th>
<th>Class III Livestock Standard</th>
<th>Number of Wells Sampled</th>
<th>Number of Samples</th>
<th>Min</th>
<th>Max</th>
<th>Median</th>
<th>Number of Samples with Class III Exceedances</th>
<th>Number of Wells with Class III Exceedances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>mg/L</td>
<td>5.0</td>
<td>4</td>
<td>14</td>
<td>&lt;0.1</td>
<td>0.8</td>
<td>0.8</td>
<td>86% &lt;0.1</td>
<td>0</td>
</tr>
<tr>
<td>Ammonia as N</td>
<td>mg/L</td>
<td>...</td>
<td>4</td>
<td>14</td>
<td>2.0</td>
<td>10.6</td>
<td>4.8</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Arsenic</td>
<td>mg/L</td>
<td>0.2</td>
<td>4</td>
<td>14</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
<td>100% &lt;0.005</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Barium</td>
<td>mg/L</td>
<td>...</td>
<td>4</td>
<td>14</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>100% &lt;0.1</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Boron</td>
<td>mg/L</td>
<td>5.0</td>
<td>4</td>
<td>14</td>
<td>0.1</td>
<td>0.4</td>
<td>0.3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cadmium</td>
<td>mg/L</td>
<td>0.05</td>
<td>4</td>
<td>14</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>100% &lt;0.001</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Chloride</td>
<td>mg/L</td>
<td>2,000</td>
<td>4</td>
<td>14</td>
<td>7</td>
<td>30</td>
<td>9.5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Chromium</td>
<td>mg/L</td>
<td>0.05</td>
<td>4</td>
<td>14</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>100% &lt;0.01</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Copper</td>
<td>mg/L</td>
<td>0.5</td>
<td>4</td>
<td>14</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>100% &lt;0.01</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Fluoride</td>
<td>mg/L</td>
<td>...</td>
<td>4</td>
<td>14</td>
<td>0.5</td>
<td>1.5</td>
<td>0.65</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Iron</td>
<td>mg/L</td>
<td>...</td>
<td>4</td>
<td>14</td>
<td>&lt;0.05</td>
<td>0.68</td>
<td>0.37</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Lead</td>
<td>mg/L</td>
<td>0.1</td>
<td>4</td>
<td>14</td>
<td>&lt;0.02</td>
<td>&lt;0.02</td>
<td>100% &lt;0.02</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Manganese</td>
<td>mg/L</td>
<td>...</td>
<td>4</td>
<td>14</td>
<td>0.05</td>
<td>0.92</td>
<td>0.12</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Mercury</td>
<td>mg/L</td>
<td>0.00005</td>
<td>4</td>
<td>14</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>100% &lt;0.001</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Nickel</td>
<td>mg/L</td>
<td>...</td>
<td>4</td>
<td>14</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>100% &lt;0.01</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Nitrite+nitrate as N</td>
<td>mg/L</td>
<td>100</td>
<td>4</td>
<td>14</td>
<td>&lt;0.1</td>
<td>8.0</td>
<td>0.01</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Selenium</td>
<td>mg/L</td>
<td>0.05</td>
<td>4</td>
<td>14</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
<td>100% &lt;0.005</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sulfate</td>
<td>mg/L</td>
<td>3,000</td>
<td>4</td>
<td>14</td>
<td>449</td>
<td>1,780</td>
<td>813</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>TDS dried at 180°C</td>
<td>mg/L</td>
<td>5,000</td>
<td>4</td>
<td>14</td>
<td>1,430</td>
<td>3,370</td>
<td>1,670</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Zinc</td>
<td>mg/L</td>
<td>25.0</td>
<td>4</td>
<td>14</td>
<td>&lt;0.01</td>
<td>0.02</td>
<td>86% &lt;0.01</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>pH (field)</td>
<td>S.U.</td>
<td>6.5-8.5</td>
<td>4</td>
<td>14</td>
<td>6.53</td>
<td>8.57</td>
<td>7.45</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Bicarbonate</td>
<td>mg/L</td>
<td>...</td>
<td>4</td>
<td>14</td>
<td>540</td>
<td>1,470</td>
<td>737</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Calcium</td>
<td>mg/L</td>
<td>...</td>
<td>4</td>
<td>14</td>
<td>15</td>
<td>129</td>
<td>115</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Magnesium</td>
<td>mg/L</td>
<td>...</td>
<td>4</td>
<td>14</td>
<td>12</td>
<td>184</td>
<td>165</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Potassium</td>
<td>mg/L</td>
<td>...</td>
<td>4</td>
<td>14</td>
<td>14</td>
<td>34</td>
<td>29</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Sodium</td>
<td>mg/L</td>
<td>...</td>
<td>4</td>
<td>14</td>
<td>101</td>
<td>793</td>
<td>500</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>

Medians for constituents with non-detect values were calculated using methods recommended by Helsel (2005). Medians were not calculated for constituents having ≥ 80% non-detect values. Minimum and maximum concentrations shown in red exceed WDEQ/WQD Class III groundwater quality standards.
Figure 42. Baseline TDS concentrations and select time-series plots for wells in the Masters coal aquifer at the proposed Brook Mine.
Figure 43. Baseline water quality type for wells in the Masters coal aquifer at the proposed Brook Mine.
Table 16. Baseline water quality statistics for selected constituents in the Masters coal underburden aquifer at the proposed Brook Mine.

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Units</th>
<th>Class III Livestock Standard</th>
<th>Number of Wells Sampled</th>
<th>Number of Samples</th>
<th>Min</th>
<th>Max</th>
<th>Median</th>
<th>Number of Samples with Class III Exceedances</th>
<th>Number of Wells with Class III Exceedances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>mg/L</td>
<td>5.0</td>
<td>1</td>
<td>4</td>
<td>&lt;0.1</td>
<td>0.2</td>
<td>NA</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ammonia as N</td>
<td>mg/L</td>
<td>--</td>
<td>1</td>
<td>4</td>
<td>&lt;0.1</td>
<td>2.2</td>
<td>1.7</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Arsenic</td>
<td>mg/L</td>
<td>0.2</td>
<td>1</td>
<td>4</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
<td>100% &lt;0.005</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Barium</td>
<td>mg/L</td>
<td>--</td>
<td>1</td>
<td>4</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>100% &lt;0.1</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Boron</td>
<td>mg/L</td>
<td>5.0</td>
<td>1</td>
<td>4</td>
<td>0.2</td>
<td>0.5</td>
<td>0.3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cadmium</td>
<td>mg/L</td>
<td>0.05</td>
<td>1</td>
<td>4</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>100% &lt;0.001</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Chloride</td>
<td>mg/L</td>
<td>2,000</td>
<td>1</td>
<td>4</td>
<td>28</td>
<td>34</td>
<td>31</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Chromium</td>
<td>mg/L</td>
<td>0.05</td>
<td>1</td>
<td>4</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>100% &lt;0.01</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Copper</td>
<td>mg/L</td>
<td>0.5</td>
<td>1</td>
<td>4</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>100% &lt;0.01</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Fluoride</td>
<td>mg/L</td>
<td>--</td>
<td>1</td>
<td>4</td>
<td>1.0</td>
<td>1.1</td>
<td>1.0</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Iron</td>
<td>mg/L</td>
<td>--</td>
<td>1</td>
<td>4</td>
<td>&lt;0.05</td>
<td>0.3</td>
<td>NA</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Lead</td>
<td>mg/L</td>
<td>0.1</td>
<td>1</td>
<td>4</td>
<td>&lt;0.02</td>
<td>&lt;0.02</td>
<td>100% &lt;0.02</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Manganese</td>
<td>mg/L</td>
<td>--</td>
<td>1</td>
<td>4</td>
<td>0.04</td>
<td>0.41</td>
<td>0.26</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Mercury</td>
<td>mg/L</td>
<td>0.00005</td>
<td>1</td>
<td>4</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>100% &lt;0.001</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Nickel</td>
<td>mg/L</td>
<td>--</td>
<td>1</td>
<td>4</td>
<td>&lt;0.01</td>
<td>0.03</td>
<td>NA</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Nitrite+nitrate as N</td>
<td>mg/L</td>
<td>100</td>
<td>1</td>
<td>4</td>
<td>3.2</td>
<td>13.6</td>
<td>6.2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Selenium</td>
<td>mg/L</td>
<td>0.05</td>
<td>1</td>
<td>4</td>
<td>0.005</td>
<td>0.012</td>
<td>0.008</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sulfate</td>
<td>mg/L</td>
<td>3,000</td>
<td>1</td>
<td>4</td>
<td>1,530</td>
<td>1,620</td>
<td>1,580</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>TDS dried at 180°C</td>
<td>mg/L</td>
<td>5,000</td>
<td>1</td>
<td>4</td>
<td>2,760</td>
<td>2,860</td>
<td>2,825</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Zinc</td>
<td>mg/L</td>
<td>25.0</td>
<td>1</td>
<td>4</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>100% &lt;0.01</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>pH (field)</td>
<td>S.U.</td>
<td>6.5-8.5</td>
<td>1</td>
<td>4</td>
<td>7.76</td>
<td>8.74</td>
<td>7.92</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Bicarbonate</td>
<td>mg/L</td>
<td>--</td>
<td>1</td>
<td>4</td>
<td>505</td>
<td>569</td>
<td>557</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Calcium</td>
<td>mg/L</td>
<td>--</td>
<td>1</td>
<td>4</td>
<td>67</td>
<td>85</td>
<td>75</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Magnesium</td>
<td>mg/L</td>
<td>--</td>
<td>1</td>
<td>4</td>
<td>50</td>
<td>75</td>
<td>61</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Potassium</td>
<td>mg/L</td>
<td>--</td>
<td>1</td>
<td>4</td>
<td>12</td>
<td>35</td>
<td>15</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Sodium</td>
<td>mg/L</td>
<td>--</td>
<td>1</td>
<td>4</td>
<td>707</td>
<td>801</td>
<td>778</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>

Medians for constituents with non-detect values were calculated using methods recommended by Helsel (2005). Medians were not calculated for constituents having ≥ 80% non-detect values. Minimum and maximum concentrations shown in red exceed WDEQ/WQD Class III groundwater quality standards. NA: sample size was too low for regression on order statistics (ROS) method to calculate a median.
3.2.4.5 BACKFILL

The proposed Brook Mine collected groundwater quality data at two wells located in the backfill reclaimed by the Big Horn Mine (578415-SPL-1 and 578415-SPL-2) (Figure 44). TDS concentrations were approximately three times higher at 578415-SPL-1, owing to much higher concentrations of calcium, magnesium, and sulfate. 578415-SPL-2 is closer to the recharge source of the Tongue River, which may explain the lower concentration of ions. Baseline water quality statistics for select parameters were compiled and compared against WDEQ/WQD Class III livestock standards (Table 17). No exceedances were observed at either of the wells. The TDS ranged from 1,160 to 4,800 mg/L with a median of 2,600 mg/L (Table 17).

A water quality type analysis (piper diagram) indicated that the baseline water type in the backfill was variable between the two wells. One well showed magnesium sulfate type water and the other well showed sodium sulfate type water (Figure 45 and Figure 48e).

The available historic water quality data was reviewed from Big Horn Mine permit (2020). Twenty backfills wells are shown in Figure 46. Out of the 20 wells, eleven wells had TDS data. The TDS at these wells varied between 50 to 6,440 mg/L. The mean TDS at nine wells met the Class III livestock standard. Figure 47 shows the water quality type of eleven backfill wells. Eight of the eleven wells are of magnesium sulfate type, two wells were of sodium bicarbonate type, and the remaining one well was of calcium bicarbonate type.
### Table 17. Baseline water quality statistics for selected constituents in the backfill aquifer at the proposed Brook Mine.

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Units</th>
<th>Class III Livestock Standard</th>
<th>Number of Wells Sampled</th>
<th>Number of Samples</th>
<th>Min</th>
<th>Max</th>
<th>Median</th>
<th>Number of Samples with Class III Exceedances</th>
<th>Number of Wells with Class III Exceedances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>mg/L</td>
<td>5.0</td>
<td>2</td>
<td>8</td>
<td>&lt;0.1</td>
<td>0.3</td>
<td>0.3</td>
<td>88% &lt;0.1</td>
<td>0</td>
</tr>
<tr>
<td>Ammonia as N</td>
<td>mg/L</td>
<td></td>
<td>2</td>
<td>8</td>
<td>4.2</td>
<td>8.5</td>
<td>5.6</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Arsenic</td>
<td>mg/L</td>
<td>0.2</td>
<td>2</td>
<td>8</td>
<td>&lt;0.005</td>
<td>&lt;0.005</td>
<td>0.005</td>
<td>100% &lt;0.005</td>
<td>0</td>
</tr>
<tr>
<td>Barium</td>
<td>mg/L</td>
<td></td>
<td>2</td>
<td>8</td>
<td>&lt;0.1</td>
<td>0.3</td>
<td>0.2</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Boron</td>
<td>mg/L</td>
<td></td>
<td>2</td>
<td>8</td>
<td>&lt;0.1</td>
<td>0.1</td>
<td>NA</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Cadmium</td>
<td>mg/L</td>
<td>0.05</td>
<td>2</td>
<td>8</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.001</td>
<td>100% &lt;0.001</td>
<td>0</td>
</tr>
<tr>
<td>Chloride</td>
<td>mg/L</td>
<td>2,000</td>
<td>2</td>
<td>8</td>
<td>15</td>
<td>26</td>
<td>16.5</td>
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<tr>
<td>Chromium</td>
<td>mg/L</td>
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<td>2</td>
<td>8</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>100% &lt;0.01</td>
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</tr>
<tr>
<td>Copper</td>
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<td>2</td>
<td>8</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>100% &lt;0.01</td>
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</tr>
<tr>
<td>Fluoride</td>
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<td></td>
<td>2</td>
<td>8</td>
<td>0.4</td>
<td>1.5</td>
<td>0.95</td>
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<tr>
<td>Iron</td>
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<td>8</td>
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<td>2.43</td>
<td>0.1</td>
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<tr>
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<td>8</td>
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<tr>
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<td>1.0</td>
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<td>Mercury</td>
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<td>&lt;0.005</td>
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<tr>
<td>Sulfate</td>
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<td>2</td>
<td>8</td>
<td>2</td>
<td>2,510</td>
<td>1,113</td>
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<tr>
<td>TDS dried at 180°C</td>
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<td>2</td>
<td>8</td>
<td>1,160</td>
<td>4,800</td>
<td>2,600</td>
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<td>100% &lt;0.01</td>
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<td>2</td>
<td>8</td>
<td>6.71</td>
<td>7.93</td>
<td>7.25</td>
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<tr>
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<td>1,150</td>
<td>1,350</td>
<td>1,240</td>
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<td>349</td>
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<td>Sodium</td>
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<td>8</td>
<td>307</td>
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<td>420</td>
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</table>

Medians for constituents with non-detect values were calculated using methods recommended by Helsel (2005). Medians were not calculated for constituents having ≥ 80% non-detect values. Minimum and maximum concentrations shown in red exceed WDEQ/WQD Class III groundwater quality standards. NA1 regression on order statistics (ROS) method would not calculate a median.
Figure 44. Baseline TDS concentrations and select time-series plots for wells in the backfill aquifer at the proposed Brook Mine.
Figure 45. Baseline water quality type for wells in the backfill aquifer at the proposed Brook Mine.
Figure 46. Historical TDS concentrations and select time-series plots for wells in the backfill aquifer at the Big Horn Mine.
Figure 47. Historical water quality type for wells in the backfill aquifer at the Big Horn Mine.
Figure 48. Piper diagrams for baseline conditions at each aquifer at the proposed Brook Mine: (a) alluvial, (b) Carney coal, (c) Masters coal, (d) Masters underburden, and (e) backfill. Plotting positions are based on the median concentrations at each well. The piper diagram in (f) provides a legend to assist in interpreting water types.
3.3 ALLUVIAL VALLEY FLOORS

The Wyoming Environmental Quality Act defines alluvial valley floors (AVFs) as “the unconsolidated stream laid deposits holding streams where water availability is sufficient for subirrigation or flood agricultural activities but does not include upland areas which are generally overlain by a thin veneer of colluvial deposits composed chiefly of debris from sheet erosion, deposits by unconfined runoff or slope wash, together with talus, other mass movement accumulation and windblown deposits” (W.S. § 35-11-103(e)(xviii)). Coal mining operations may not interrupt, discontinue, or preclude farming on AVFs that are irrigated or naturally subirrigated, provided that the AVF is not subject to statutory exclusions (W.S. § 35-11-406(n)(v)). Statutory exclusions for AVFs include: (1) AVFs on undeveloped rangelands which are not significant to farming, (2) AVFs on lands as to which the Administrator finds that if farming will be interrupted, discontinued, or precluded, it is of such small acreage as to be of negligible impact to the farm’s agriculture production, and (3) AVFs part of surface coal operations that produced coal in commercial quantities prior to August 3, 1977. Significance to farming is determined by calculating the percent farm production loss as a result of disturbing the AVF. A loss greater than 10 percent is considered to exceed a negligible impact to both small and large Wyoming farming operations, and thus mining of the AVF is prohibited (Wyoming Department of Environmental Quality, 2000). If a farm’s total production is less than 5,000 animal units or their equivalent, Chapter 3 of the LQD Rules and Regulations provides an equation to estimate the negligible impact percentage (WDEQ Land Quality-Coal Rules, Ch. 3, § 2(f)). Coal mining also must not materially damage the quantity or quality of water in surface or underground systems that supply AVFs not subject to statutory exclusions (W.S. § 35-11-406(n)(v)(B)). This includes AVFs adjacent to the permit area.

AVFs in Wyoming can be mined provided that either: (1) the AVF is not significant to farming or is on undeveloped rangeland, or (2) the mine produced coal in commercial quantities prior to the effective date of SMCRA (August 3, 1977). However, in each of these cases the mine must restore the essential hydrological functions of the AVF after mining. Essential hydrologic functions are defined as “those conditions of surface and groundwater hydrology that support or enhance subirrigation or flood irrigation agricultural activities” (WDEQ Land Quality–Coal Rules, Ch. 1, § 2(at)). If the AVFs are located outside of affected lands, the essential hydrologic functions still must be preserved.

AVF investigations are typically interdisciplinary, involving an analysis of surface water quantity and quality, alluvial aquifer water levels and quality, vegetation, soils, geomorphology, and surficial geology. Categories of WDEQ/LQD AVF determinations include:

- **AVF – Significant to Farming**: The AVF is significant to farming and cannot be mined. Mining must not materially damage the quantity or quality of water in surface or underground systems that supply the AVF.

- **AVF – Not Significant to Farming**: The AVF is not significant to farming and can be mined provided that the essential hydrologic functions are restored after mining. If the AVF is not mined, the essential hydrologic functions still must be preserved.

- **AVF – Grandfathered**: The area is an AVF, but significance to farming test is not required since the mine produced coal in commercial quantities prior to the effective date of SMCRA (August 3, 1977). The AVF can be mined provided that the
essential hydrologic functions are restored after mining. If the AVF is not mined, the essential hydrologic functions still must be preserved.

- **AVF – No Significance to Farming Test Required**: The area is an AVF, but it was determined that a significance to farming test was not required since the AVF would not be affected. The essential hydrologic functions still must be preserved. Mining must not materially damage the quantity or quality of water in surface or underground systems that supply the AVF if statutory exclusions do not apply.

- **Not an AVF**: The area does not meet the definition of an AVF. The area can be mined.

A description of the AVF determinations at and near the surface water evaluation area is presented below.

### 3.3.1 PREVIOUSLY DECLARED ALLUVIAL VALLEY FLOORS

Several prior AVF determinations have been issued by the WDEQ/LQD for areas adjacent to and downstream of the proposed Brook Mine. Most of the past determinations were made for the Tongue River. These determinations were completed in the early to mid-1980s for several permitted or proposed mining operations, including the Big Horn Mine, the Whitney Mine, the Welch No. 1 Mine, and the Carter Tongue Property. Additional determinations were made for the Tongue River for proposed operations further downstream, but these will not be discussed here. Some of the AVF determinations on the Tongue River overlap, and in some cases, conflict with each other with respect to significance to farming. More recently, AVF determinations were made in 2011 at the Youngs Creek Mine for several tributaries to the Tongue River. **Figure 49** shows the extent of the previous AVF determinations. A chronological description of the AVF determinations follows below.

The WDEQ/LQD issued AVF determinations for the Big Horn Mine on August 21, 1981 in Finding No. 11 of the Term 1 (T-1) of the State Decision Document (SDD) (Big Horn Mine Permit, 2020). The SDD references two Exhibits in the Big Horn Mine Permit (2020) that describe the extent of the AVFs that encompass the area of the Tongue River and Goose Creek. The SDD states that the extent of AVFs included all lands within the zero (0) alluvial isopach shown on Exhibit D11-7. The SDD also states that the AVFs remaining undisturbed by the mining operation were delineated by Exhibit D11-10 – *Potential Subirrigated Areas*.

Upon inspection of both Exhibits in the Big Horn Mine permit, the zero alluvial isopach map (Exhibit D11-7) includes several areas that had been mined through prior to the AVF study. As discussed in previous sections of this CHIA, historical mining occurred in lower Goose Creek and parts of the Tongue River, and post-mine reclamation altered the original channel locations. The Big Horn Mine Permit (2020) states that the alluvial isopach in the central part of the mine area was completely inferred since the alluvium in this area was removed during previous mining. Some of the areas within the zero alluvial isopach map are now in uplands that are not located in the valley floor adjacent to the channel and have no potential for subirrigation or flood irrigation activities. Therefore, Exhibit D11-10 – *Potential Subirrigated Areas* is a more accurate representation of the AVF extent on the Tongue River and Goose Creek at the Big Horn Mine. The extent of this AVF is shown in **Figure 49**, and is also shown in Exhibit D11.6-1 of the Brook Mine Permit Application (2020).
Since the Big Horn Mine produced coal in commercial quantities prior to the effective date of SMCRA (August 3, 1977), no significance to farming test was required for the AVFs declared in the T-1 SDD. However, to the extent possible, the mine was required to restore and preserve the essential hydrologic functions of the AVFs. The T-1 SDD identifies the essential hydrologic functions of the AVFs as: (1) availability of surface waters of suitable quality and quantity for flood irrigation, (2) adequate soil, slope, and land-form conditions to permit flood irrigation activities, and (3) ability to transport groundwaters of suitable quality and quantity to support subirrigation of certain areas (Big Horn Mine Permit, 2020).

On May 3, 1983, the WDEQ/LQD issued an AVF determination for the Whitney Mine (TFN 14/294) (Wyoming Department of Environmental Quality, 1983). The determination included two areas on the Tongue River downstream of the Big Horn Mine: Whitney West (516.1 acres) and Whitney East (851.4 acres) (Figure 49). Both AVF areas were determined to be significant to farming. It is noted that the AVF deemed significant to farming overlaps with the Big Horn Mine East Extension AVF that was later declared not significant to farming (see below). The AVF declared for the Whitney Mine also overlaps with the AVF declared at the Welch No. 1 Mine and the Carter Tongue Property (see below). The Whitney Mine was never developed and the permit application was terminated.

The August 1, 1984 T-2 SDD for the Big Horn Mine states that “no other drainages are of significant size or lack the stream laid deposits necessary to be an Alluvial Valley Floor within the renewal and/or amendment areas” (Big Horn Mine Permit, 2020). It is implied from this statement that Hidden Water Creek is not an AVF. Appendix D-6 of the Big Horn Mine Permit (2020) describes the AVF investigation for Hidden Water Creek. The study concluded that although Hidden Water Creek contains unconsolidated streamlaid deposits, the stream is not an AVF due to the lack of subirrigation and extremely low potential for flood irrigation (Big Horn Mine Permit, 2020).

On May 1, 1985, the WDEQ/LQD issued an AVF determination for the Carter Tongue Property (TFN 14/371) (Wyoming Department of Environmental Quality, 1985a). The determination included a section of the Tongue River (Figure 49). The AVF on the Tongue River was determined to be significant to farming. It is noted that the AVF overlaps with the AVF that was previously declared for the Whitney Mine also overlaps with the AVF declared at the Welch No. 1 Mine (see below). The Carter Tongue Property was never developed.

On June 17, 1985, the WDEQ/LQD issued an AVF determination for the Sheridan Enterprises Welch Ranch Property (TFN 16/384) (Wyoming Department of Environmental Quality, 1985b). The property later became the Welch No. 1 Mine permit (WDEQ/LQD Permit 497). The permit was issued in 1979, but the mine was never developed and the permit was terminated in 2015. The determination included a section of the Tongue River, and the AVF was determined to be significant to farming (Figure 49). It is noted that the AVF overlaps with the AVF that was previously declared for the Whitney Mine and the T-1 AVF mapped on the Tongue River for the Big Horn Mine (Figure 49).

On September 17, 1985 the WDEQ/LQD issued an AVF determination for the East Extension (TFN 15/398) at the Big Horn Mine (Wyoming Department of Environmental Quality, 1985c). The determination included two areas on the Tongue River adjacent to and downstream of the Big Horn Mine permit area: an AVF significant to farming was found for 254.3 acres, and an AVF not significant to farming was found for 431 acres (Figure 49). It is noted that some of the AVF
deemed not significant to farming overlaps with the Whitney Mine AVF that was previously declared significant to farming. The AVF declared for the East Extension also overlaps with part of the T-1 AVF mapped on the Tongue River for the Big Horn Mine (Figure 49).

The WDEQ/LQD issued AVF determinations for the Youngs Creek Mine in March 2011 (Youngs Creek Mine Permit, 2020). AVFs were declared on Ash Creek, Little Youngs Creek, and Youngs Creek. The Little Youngs Creek and Youngs Creek AVFs were found to be not significant to farming (Figure 49). The Ash Creek AVF would not be affected by mining and therefore no significance to farming test was required (Figure 49). For the AVFs on the Tongue River near the Youngs Creek Mine, the WDEQ/LQD and the Youngs Creek Mine agreed that the previous determinations on extent and farming significance were appropriate and new determinations were not warranted (Youngs Creek Mine Permit, 2020).

In summary, much of the Tongue River downstream of the Big Horn Mine contains AVFs that the WDEQ/LQD has previously declared to be significant to farming. As such, these AVFs cannot be mined and coal mining also must not materially damage the quantity or quality of water in surface or underground systems that supply the AVFs.
Figure 49. Extent of declared alluvial valley floors (AVFs) at and adjacent to the proposed Brook Mine in the upper Tongue River Basin, Wyoming.
3.3.2 ALLUVIAL VALLEY FLOORS DECLARED FOR THE PROPOSED BROOK MINE

The Brook Mine Permit Application (2020) evaluated the potential for AVF characteristics on several streams within and adjacent to the proposed mine permit boundary. Within the proposed permit boundary, Hidden Water Creek, Slater Creek, and East Fork Earley Creek were evaluated. All of these streams contain some extent of unconsolidated streamlaid deposits. Hidden Water Creek and East Fork Earley Creek were not identified as AVFs due to the lack of subirrigation and surface water sufficient for subirrigation or flood irrigation activities (Brook Mine Permit Application, 2020). As stated previously, the Big Horn Mine Permit (2020) also contends that Hidden Water Creek is not an AVF.

Based on a September 2015 site visit, on February 24, 2016 the WDEQ/LQD declared an AVF of 13.11 acres on Slater Creek within the proposed Brook Mine permit boundary (Figure 49) (Wyoming Department of Environmental Quality, 2016a; Wyoming Department of Environmental Quality, 2016b). The AVF occupies Slater Creek and adjacent lands from the point of the upstream proposed Brook Mine permit boundary downstream approximately 1,600 feet (Figure 49). The reach contains unconsolidated streamlaid deposits, characterized by a relatively wide valley bottom and a channel that is not incised. Subirrigation and/or natural flood irrigation is of sufficient extent for flood irrigation agricultural activities. The AVF was deemed not significant to farming since the lands are undeveloped rangeland. Therefore this AVF is statutorily excluded from the requirements of W.S. § 35-11-406(n)(v)(A) and (B).

The WDEQ/LQD determined that the remainder of Slater Creek within the proposed Brook Mine permit boundary is not an AVF given the channel is deeply incised into bedrock (Wyoming Department of Environmental Quality, 2016b). A historical attempt was made to irrigate lands adjacent to the channel in this location, but the attempt apparently failed as evidenced by cancellation of the water rights in 1905 (Wyoming State Engineer’s Office, 2019c; Wyoming State Engineer’s Office, 2019d). No other known attempts have been made to irrigate the lands along this portion of Slater Creek.

On January 10, 2020, the WDEQ/LQD determined that portions of Slater Creek immediately upstream of the proposed Brook Mine permit boundary and the Tongue River south of the proposed permit boundary are AVFs (Figure 49). The determination did not identify any potential for mining activities to interrupt, discontinue, or preclude agricultural activities on lands identified as AVFs. Since these AVFs would not be affected by mining it was determined that a significance to farming test was not required (Wyoming Department of Environmental Quality, 2020). The CHIA conducts the material damage assessment required by W.S. § 35-11-406(n)(v)(B) for these adjacent AVFs since they are not subject to statutory exclusions.
4. HYDROLOGIC CONCERNS

The objective of this CHIA is to determine the probable hydrologic impacts of the proposed Brook Mine within the delineated evaluation area and to determine if the operation has been designed to prevent material damage to the hydrologic balance outside the proposed permit area. Probable impacts to the quantity and quality of surface water and groundwater are addressed. The following discussion in this section identifies the general hydrologic concerns that are associated with coal mining in the PRB of Wyoming, as well as more specific concerns that may be associated with the proposed Brook Mine. Hydrologic concerns are an expression of problems related to water use and the hydrologic balance that may occur as a result of coal mining (Office of Surface Mining Reclamation and Enforcement, 1985).

4.1 SURFACE WATER

4.1.1 SURFACE WATER USE

The identification of surface water hydrologic concerns is integral to the existing surface water uses within the surface water evaluation area. Surface water rights were obtained from the WSEO and evaluated according to their permitted beneficial use. Only surface water rights with a status of complete, incomplete, fully adjudicated, or unadjudicated were considered. As discussed in Section 3.1 for the individual drainages and as shown in Figure 50, many of the surface water rights in the surface water evaluation area are for stock and irrigation uses (Brook Mine Permit Application, 2020; Wyoming State Engineer’s Office, 2019b). For example, within the surface water evaluation area, there are a total of 52 surface water rights, and 48 percent of these water rights are for irrigation use (Figure 50). Approximately 29 percent of the surface water rights are for stock use. Other surface water rights are appropriated for domestic, fish propagation, industrial, municipal, reservoir supply, steam, wetlands, wildlife, and temporary use (Figure 50). The use for two surface water rights is unlisted.

The Brook Mine Permit Application (2020) contains a table and a map of the surface water rights inside and within three miles of the proposed permit boundary. The surface features that support these water rights include reservoirs and ditches. The Tongue River and many of its tributaries in the area have a long history of irrigation of hayfields adjacent to the channels, as many of the water rights have been held since the early 1900s. Areas of active irrigation include the Tongue River, and on Slater Creek upstream of the proposed Brook Mine permit boundary. Surface water rights for irrigation also exist on Hidden Water Creek, East Fork Earlcy Creek, and lower Goose Creek. There are also several nearby unpermitted impoundments outside the proposed Brook Mine permit boundary and one unpermitted impoundment inside the proposed Brook Mine permit boundary (Brook Mine Permit Application, 2020). The unpermitted impoundment inside the permit boundary is on private land not owned by the proposed Brook Mine and is outside the disturbance footprint of the proposed Brook Mine.
Figure 50. Location of WSEO-permitted surface water rights by use within the surface water evaluation area.
The State of Wyoming has agreed to several river compacts and court decrees that address the allocation of surface water flows out of Wyoming (W.S. §41-12-101, -201, -301, -401, -501, -601, and -701). The proposed Brook Mine lies within the Tongue River Basin, which is part of the Yellowstone River Compact of 1950 (Wyoming State Engineer’s Office, 2006). The Compact deals with the diversion of water from four primary tributaries to the Yellowstone River, including the Clarks Fork, Big Horn, Tongue, and Powder rivers. The following rules apply to all tributaries: (1) existing water rights as of January 1, 1950 maintain their status quo, (2) no water may be diverted from the Yellowstone River Basin without consent from all States, and (3) existing and future domestic and stock water uses, including stock water reservoirs not exceeding 20 acre-feet in capacity, are exempted from the provisions of the Compact. The unappropriated flow of each tributary after needs for supplemental supply for existing rights are met is allocated to Wyoming and Montana on a percentage basis. For the unappropriated flow in the Tongue River, Wyoming is allotted 40 percent and Montana is allotted 60 percent (Wyoming State Engineer’s Office, 2006).

### 4.1.2 HYDROLOGIC CONCERNS

#### 4.1.2.1 WATER QUANTITY

**During Mining**

Surface water runoff is affected by climate, geomorphology, topography, soil characteristics, vegetation, and land use. Mining has the potential to affect all of these factors except climate.

*Increased Runoff:* Runoff can increase during mining if mines are dewatering aquifers and discharging the water into ponds or stream channels. However, the potential for increased runoff is limited in coal mining areas of Wyoming since much of the dewatering water and water intercepted by the mine pit is used for dust suppression. At the proposed Brook Mine, all water intercepted by the pits is expected to be used for dust suppression or will be routed to sediment ponds (Brook Mine Permit Application, 2020).

Runoff can also increase during mining due to an increase in impervious surfaces that decrease infiltration rates. These include the presence of unpaved access or haul roads and infrastructure associated with mine facilities. Since coal mines progress with contemporaneous reclamation, the entire permit area is not completely disturbed at any one time. This practice serves to lessen the impact of mining on runoff. The proposed Brook Mine will cause less surface disturbance than a typical open-pit strip coal mine because of the primary mining method of highwall mining. The highwall mining operation will open trenches from which the highwall continuous miner will extract coal from underneath the undisturbed overburden. This will result in a smaller disturbance footprint than traditional open-pit surface mining and will lessen the effects of the mining activity on runoff. Most of the mining trenches at the proposed Brook Mine will also be oriented parallel to major drainages which will help to lessen the impact on through-drainage runoff.

*Decreased Runoff:* Runoff from areas upstream of a mine is either captured by flood control reservoirs or the mine pit or routed around the active mining and reclaimed areas. This capture or diversion effectively isolates the mine area from contributing flow downstream. At the proposed Brook Mine, water from the mine area will be captured by flood control reservoirs, sediment ponds, or the mine trenches. The mine also proposes to use surface water rights to account for approximately 88 percent of the mine’s water supply requirements (Brook Mine Permit...
Water from surface water rights would be supplied using either temporary water haul or purchased from existing surface water rights holders. The Brook Mine would also use water collected in the mine pits from pit inflow and from sedimentation impoundments and flood control reservoirs. All new water rights will be subject to WSEO approval and would be evaluated for compliance with the Yellowstone River Compact, which will require that bypass or make-up water be made available. Hidden Water Creek will be diverted around the active mining operation while flows in Slater Creek will be unobstructed (Brook Mine Permit Application, 2020).

Sediment control is required for all areas disturbed by mining activities. Runoff from disturbed areas is required to pass through some type of treatment structure. These can range from simple rock check dams to large settling ponds. All sediment ponds greater than two ac-ft are required to be permitted individually with the WSEO. The WSEO will issue a single WSEO permit for a number of small sediment ponds whose individual capacity is equal to or less than two ac-ft as long as the cumulative capacity of all ponds in this category does not exceed 19.8 ac-ft per individual permit (Wyoming Department of Environmental Quality, 2003).

Water collected by sediment ponds is often used by coal mines for dust control, equipment wash down, or livestock and wildlife use, rather than being released once WYPDES standards are met. Evaporation and seepage may result in additional surface water losses. Subsurface contributions to streamflow may also be temporarily disconnected as a result of disruptions to the local aquifer during overburden and coal excavation. The cumulative effect of these activities may cause a reduction in runoff volumes and peak flows. However, these actions are often necessary to protect downstream water quality.

Subsidence is a potential hydrologic concern associated with underground longwall mining. The impacts of subsidence on surface water can range from no discernable impact to ponding, capture, and retention of runoff. The formation of subsidence-induced cracks and depressions near surface water features can lead to complete or partial loss of water due to leakage to the underlying strata (Bhattacharya and Singh, 1985). Changes in the surface slope of streams can also affect channel hydraulics.

The Brook Mine Permit Application (2020) predicts that the mine design is not prone to the development of either trough or sinkhole subsidence. This is due in part to: (1) substantial pillars being left which are designed to carry the overburden load without failing, (2) pillars designed with a minimum 1:1 width:height ratio to avoid lower strength narrow pillars, (3) pillars designed based on the reduced coal strength of the Carney seam, (4) narrow entry widths of 11.5 feet to provide more stability, (5) the absence of intersections and crosscuts, which increases stability, and (6) an extraction ratio of 39%, which results in lower average pillar stresses and lower potential for pillar degradation and associated roof weakening. Nonetheless, the permit application includes a subsidence monitoring program to detect elevation changes that might be caused due to subsidence. Subsidence features will be reclaimed if they are not self-healing or if the subsidence causes material damage or reduces the value of the reasonable foreseeable uses of the surface lands. The Brook Mine will continue to perform reclamation on subsidence up until final bond release is approved (Brook Mine Permit Application, 2020). Further discussion on the commitments to monitor and mitigate subsidence is provided in Section 6.1.1 and Section 7.1.1 of the CHIA.
4.1.2.1.2 Post-Mining

**Increased Runoff:** Surface mine reclamation has the potential to change runoff volumes and peak flows. The proposed Brook Mine will cause less surface disturbance than a typical open-pit strip coal mine because of the primary mining method of highwall mining. This will result in a smaller disturbance footprint than traditional open-pit surface mining and will lessen the effects of reclamation on runoff.

Most coal mines use a combination of direct topsoil placement and topsoil stockpiles. The proposed Brook Mine will primarily use topsoil stockpiles but will also direct haul topsoil when possible (Brook Mine Permit Application, 2020). If topsoil salvaged for site reclamation is stockpiled for long periods of time, it can lack structure when it is reapplied over the reclaimed surface. Soils with diminished structure have lower infiltration rates when compared to native soils, which may result in increased runoff.

Several studies have shown that after reclamation, infiltration rates increase over time as root and soil structure develops. Rainfall simulation experiments conducted from 1979-1983 at the Belle Ayr Mine found that over time, reclaimed areas develop an infiltration-runoff response that closely reflects that of undisturbed areas (Belle Ayr Mine Permit, 2020). Schafer et al., (1979) examined soil genesis on mine spoils that ranged in age from 1 to 50 years at a surface coal mine in the PRB near Colstrip, Montana. The results showed that between four and six years were required for water use patterns in mine spoil to become similar to native soils. The study found no difference between infiltration rates on mine spoil and undisturbed soils. The study also illustrated the effects that different machinery and methods of soil placement can have on soils; dozers and draglines resulted in un-compacted soils while scrapers caused compacted zones (Schafer et al., 1979). Use of scrapers to replace topsoil has also been noted to cause compaction in early coal mining in the Wyoming PRB. More recently, Reynolds and Reddy (2012) compared infiltration rates between native sites and reclamation that was 10-15 years old and 20-25 years old at two coal mines in the PRB of Wyoming. The study found that infiltration rates on 20-25 year old reclamation was similar to native sites, and significant differences were found between infiltration rates on 10-15 year old reclamation and both 20-25 year old reclamation and native sites (Reynolds and Reddy, 2012).

Vegetation plays an important role in runoff generation. Early in the reclamation phase there is the potential for increased runoff due to reduced interception losses and limited root structure. Additionally, the thickness and extent of litter during the early stages of reclamation is less than pre-mine conditions, which may result in increased runoff.

**Decreased Runoff:** Following backfilling of a mine pit, there is the potential for some differential settling to occur, resulting in the creation of small depressions. Because of their small size, any decrease in drainage area is generally considered negligible. This may not be the case if larger features such as sediment ponds are not reclaimed but rather left behind as permanent post-mine impoundments. Justification to leave these features is associated with maintaining or enhancing the post-mining land use or replacement of a pre-mine feature. If there is an increase in the number of post-mine features compared to what existed pre-mine, there could be a reduction in runoff volume due to a net increase in storage capacity. All features that have the potential to capture and detain runoff generally require WSEO approval of appropriated water rights. At the proposed Brook Mine, nine permanent post-mine impoundments are proposed to replace the depressions and stockponds disturbed by the mining operation (Brook Mine Permit Application, 2020). Two of the impoundments will be new impoundments. Although the detailed designs of the
two new post-mine impoundments will not be submitted until the permit term of construction, the impoundments will result in a net increase in water storage capacity within the proposed permit boundary. Further discussion on the permanent post-mine impoundments at the proposed Brook Mine is provided in Section 6.1.1 and Section 7.1.1 of the CHIA.

A decrease in runoff may also occur due to differential settling in reconstructed stream channels. Stream channel reconstruction at some PRB mines involves using an impermeable layer such as clay to prevent streamflow losses to backfill material, which is then overlaid with a material that will sustain the properties and function of the pre-mine alluvium. In areas of settling, depressions or pools may be develop within the channel. Evidence of evaporation has been noted at the edges of these pools, indicating loss of water in the alluvial system due to evaporation.

After reclamation, most reconstructed drainage basins have comparable drainage areas to the pre-mining drainage area although individual sub-basins may vary somewhat from the pre-mining configuration. A change in contributing drainage area at the sub-basin scale may result in a change in runoff volumes for individual sub-basins. However, changes in sub-basin contributing areas should be compensated for at a larger watershed scale, resulting in little or no change in total contributing drainage area. This implies that runoff volumes after mining should be similar to pre-mining since the total contributing drainage area has not changed. Further discussion on the post-mine drainage basin characteristics at the proposed Brook Mine is provided in Section 6.1.1 and Section 7.1.1 of the CHIA.

Runoff may also decrease in the reclamation period due to increased infiltration and reduced overland flow resulting from an increase in vegetative cover. Anecdotal evidence from coal mines in the PRB suggests that groundcover, particularly litter, tends to be much higher post-mine than pre-mine. This increase is due in part to a reduction in grazing. In addition, exotics and annuals such as cheat grass can rapidly invade a reclamation site and result in an increase in cover. Higher ground cover generally results in increased interception, increased infiltration, and slowed overland flow velocities, which translates to less runoff. The implication is that the resumption of grazing practices to pre-mine levels would help offset any decrease in runoff following reclamation.

Wetlands are replaced on a one-to-one area basis as regulatory statutes require. While the final placement of wetlands may not always reflect the locations of the original features, they are designed to function as hydrologic features that will preserve the hydrologic balance and support the post-mining land use. Further discussion on the wetlands and wetland restoration at the proposed Brook Mine is provided in Section 6.1.1 of the CHIA.

### 4.1.2.2 WATER QUALITY

#### 4.1.2.2.1 During Mining

**Degraded Quality:** The removal of vegetation and topsoil exposes overburden and can result in increased erosion potential. Runoff from disturbed areas may contain increased concentrations of sediments or other constituents which may degrade water quality. Erosion can also increase during mining due to an increase in impervious surfaces that decrease infiltration rates. These include the presence of unpaved access or haul roads and infrastructure associated with mine facilities. The proposed Brook Mine will cause less surface disturbance than a typical open-pit strip coal mine because of the primary mining method of highwall mining. The highwall mining operation will open trenches from which the highwall continuous miner will extract coal from underneath the undisturbed overburden. This will result in a smaller disturbance footprint than
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Traditional open-pit surface mining and will lessen the effects of the mining activity on water quality.

All surface water runoff from disturbed areas is required to pass through a sediment pond or ASCM and meet specific water quality criteria prior to discharge. The proper design of diversion ditches and culvert crossings will ensure that downstream water quality impacts are mitigated.

Selenium is a naturally occurring element that is essential to humans and animals. Selenium has been identified as a constituent of concern in backfill groundwater quality at coal mines in the PRB of Wyoming (Martin et al., 1988; Dreher and Finkelman, 1992; Reddy et al., 1995). Oxidization of overburden materials brought to the surface during mining may decrease the stability of the selenium containing sulfides and organic matter, increasing dissolved selenium concentrations in backfill (Naftz and Rice, 1989; Reddy et al., 1995). Murphree (2005) also suggested that high selenium concentrations in backfill can occur due to oxidation of organic matter and sulfides from native alluvium used for stream reclamation. Studies in British Columbia (McDonald and Strosher, 1998), Alberta (Casey and Siwik, 2000), and West Virginia (Lemly, 2008) have shown elevated selenium in surface water downstream of coal mines. The concern for aquatic environments is that selenium can bioaccumulate in food chains and potentially be toxic for aquatic life (Lemly, 2008). In the PRB of Wyoming, several drainages upstream of the coal mines show periodic exceedances of selenium, and pre-mining data from streams downstream of the mines show exceedances, indicating selenium may exceed standards in some areas under natural or pre-mine conditions (Wyoming Department of Environmental Quality, 2019b). Selenium has not been identified has a constituent of concern at the Big Horn Mine or the proposed Brook Mine.

Improved Quality: All surface water leaving areas affected by mining is treated and released after WYPDES regulations are met. Water which has passed through these treatment facilities typically has a much lower TSS concentration than water in native/undisturbed drainages.

4.1.2.2.2 Post-Mining

Changes in various landscape characteristics, such as vegetation, hillslope profile, channel morphology, and soils, have the potential to affect post-mining surface water quality.

Degraded Quality: A decrease in vegetation density and/or infiltration rates can result in increased runoff and ultimately the transport of additional sediment to reclaimed channels. Increased erosion and sedimentation can develop if stream channels are designed improperly. For example, if the reclaimed gradient is too steep, incision or other forms of channel adjustment may occur, resulting in erosion of the channel bed and/or banks. Conversely, if the gradient is not sufficiently steep to transport the sediment load through the system, sediment is deposited, which increases channel gradient and ultimately results in channel incision as the channel attempts to find a slope that balances sediment load and discharge. These adjustments in channel morphology have the potential to result in temporary increases in sediment load.

Improved Quality: Surface water quality has the potential to be improved because of permit commitments by the mining companies to cover all unsuitable material with a minimum of four feet of material. The burial depth is generally increased to eight feet under major drainages. Therefore, the potential to expose problematic material is reduced. As part of the Stream Channel Verification in the Phase 1 Bond release process, the WDEQ/LQD verifies that an operator has sampled the material beneath stream channels and floodplains to ensure water quality will not be impaired (Wyoming Department of Environmental Quality, 2019c).
Reclaimed hillslope profiles are generally concave up, similar to what can be expected of a mature landscape. This profile shape tends to reduce the sediment loading of stream channels because a substantial portion of the sediment is deposited at the toe of the slope.

Prior to the release of bond for any mined area, the WDEQ/LQD requires the operator to demonstrate that the reclaimed land exhibits sufficient surficial stability and development of post-mining vegetation to show that runoff does not need to pass through a sediment pond or an ASCM. Final bond release requires that the post-mining vegetation cover meets or exceeds pre-mining conditions. If post-mining vegetation cover meets bond release requirements, it is assumed that interception losses and protection of the soil surface closely resembles pre-mining conditions. An increase in vegetative cover following reclamation will increase infiltration and slow overland flow velocities. This will help trap and filter sediment before entering stream channels, helping to improve water quality.

Toy (1989) studied sheetwash erosion of natural and reclaimed hillslopes at the Dave Johnston Mine near Glenrock, Wyoming. The study concluded that the difference in sheetwash erosion between native and reclaimed slopes was virtually non-detectible. The Big Horn Mine performed a series of plot studies on reclaimed and native lands between 1982 and 1996. The Big Horn Mine concluded that sediment yield from reclaimed lands was less than that from native lands (Big Horn Mine Permit, 2020).

4.2 GROUNDWATER

The identification of groundwater hydrologic concerns is integral to the existing and foreseeable groundwater uses within the groundwater evaluation area. An inventory of existing groundwater uses within the groundwater evaluation area is discussed below.

4.2.1 GROUNDWATER USE

As of January 2020, there are 44 valid groundwater rights in the groundwater evaluation area (Figure 51). These groundwater rights were obtained from the WSEO (Wyoming State Engineer's Office, 2019b) and evaluated according to their permitted beneficial use. Groundwater rights permitted for monitoring were not considered since the impacts from the coal mine operations do not affect the intended use of these water rights.

The majority, or 70 percent of the WSEO-permitted groundwater rights in the groundwater evaluation area are for domestic use or a combined domestic/stock use (Figure 51). The domestic wells are located in the Tongue River valley outside the proposed Brook Mine permit boundary. There are nine groundwater rights in the evaluation area permitted specifically for stock use, and one groundwater right for irrigation/stock use (Figure 51). Identification of the aquifer in which groundwater rights in the groundwater evaluation area are completed in is not readily available from the WSEO database. Based on a review of the completion information available in the WSEO records, the proposed Brook Mine has inferred the completion of wells that may be potentially impacted. The Brook Mine groundwater model predictions were used to identify the list of wells that may be potentially impacted by the mining operations (Brook Mine Permit Application, 2020). Well depths are available for 43 of the permitted groundwater rights in the WSEO database; well depths range from 7 to 540 feet. The Brook Mine Permit Application (2020) also contains a table
and a map of the groundwater rights inside and within three miles of the proposed permit boundary.
Figure 51. Location of WSEO-permitted groundwater rights by use within the groundwater evaluation area. Water rights used for monitoring are not shown.
4.2.2 HYDROLOGIC CONCERNS

Groundwater level declines or degradation of groundwater quality caused by mining may affect the existing groundwater uses in the groundwater evaluation area. In the areas where groundwater will be migrating from the backfill aquifer to the native undisturbed aquifers outside the permit boundary, the groundwater quality is dependent on the backfill aquifer groundwater quality, which in turn, is dependent on the physical characteristics of the backfill aquifer.

In general, there is a significant time lapse for the groundwater impacts caused by mining to propagate outside the mine permit boundary. The timing of these impacts will vary spatially depending on the proximity of a well to mining operations, the aquifer in which the well was completed, the depth to water, and the yield and quality required from the well to maintain its intended purpose. The two primary hydrologic concerns, the decline of groundwater levels and degradation of groundwater quality, are discussed in the sub-sections below.

4.2.2.1 DECLINE OF GROUNDWATER LEVELS

Coal mining operations at the proposed Brook Mine will lower the groundwater levels to some extent in all the aquifers of concern within the groundwater evaluation area. This lowering of water levels can manifest as several different types of impacts on the water use and the hydrologic balance, including:

(1) Reduced yield from existing wells in the groundwater evaluation area:

Groundwater elevations in the wells located within and adjacent to a mine permit boundary may be lowered by de-watering, pit inflow, and mine facility wells completed in the deeper aquifers. The changes in depth to water and the potentiometric surface could potentially decrease groundwater available to wells with existing water rights (Figure 50). The magnitude of the decrease in the water level is generally a log-normal function of distance, thus the amount of drawdown of the water levels decreases with distance from the mine pits. The water level drawdowns, however, are additive where they intersect, which commonly happens when mines are in close proximity. The drawdowns are also being affected by other activities, including CBM dewatering, water for conventional oil and gas development, municipal development, and pumping from private wells for households and livestock use.

(2) Alteration of groundwater flow gradients and directions:

The removal of coal and the dewatering of the overburden and coal aquifers result in a change in groundwater flow directions. In some instances flow direction is reversed. When the backfill aquifer is saturated to the pre-mining groundwater levels, the groundwater gradients should return to the pre-mining condition. Until that time, the trenches, pits, and the backfill aquifer act as groundwater sinks that will have an impact on the hydrologic balance of the aquifer system. At the proposed Brook Mine, mining will not alter the hydrologic function of faults since the highwall mining panels will generally end at the faults and the mining sequence has been designed to avoid faults. Therefore, the hydrologic function of the faults will remain intact.
(3) Alterations to the recharge and discharge mechanisms:

The impacts of coal mining might alter the existing recharge and discharge mechanisms resulting in a change to the hydrologic balance. For example, in some areas of the PRB, groundwater from the coal and overburden aquifers contribute to stream baseflow by discharging to the alluvium or directly to streams. Lowering the groundwater potentiometric surface will decrease the amount of groundwater available to discharge. If the decreased quantity is large, there is the potential to affect surface water flow rates, possibly affecting downstream water rights. In addition, there might be changes in the interaction between the backfill and the reclaimed and native aquifers. At the proposed Brook Mine, there will be limited changes in infiltration because a large portion of the overburden will remain undisturbed due to the highwall mining method.

(4) Backfill aquifer properties:

As new trenches are developed, overburden will be hauled to preceding trenches behind the continuing highwall mining activity. Some stockpiling of overburden outside of the trenches will be required until highwall mining has been completed and the trench has been completely abandoned by highwall mining operations. By the end of mining activities, all spoil material will be backfilled into trenches or other surface mining excavation areas. Subsidence and hydraulic interconnection (including fracturing) of the undisturbed native aquifers with the trenches and pits will change the hydraulic properties and the groundwater flow regime in the vicinity of the trenches and pits.

The backfill aquifer is predicted to saturate over time. Although the lithologic materials in the backfill aquifer will be the same as the overburden, the bedding and arrangement of materials will be different. The differences between the reclaimed and pre-mine aquifer characteristics may alter the groundwater flow regime. The ability of the backfill aquifer to store and transmit water will determine how productive the backfill aquifer will be to support the post-mining land use. Hydraulic conductivity, porosity, storage coefficient, and infiltration rate are the key indicators to assess the ability of the backfill aquifer to support the post-mining land use and also to maintain the pre-mining hydrologic balance.

4.2.2.2 DEGRADATION OF GROUNDWATER QUALITY

Groundwater flowing through the backfill aquifer may have higher concentrations of dissolved constituents because more fresh mineral surfaces are exposed for chemical reaction in the backfill than in the undisturbed sediments. Initial conditions in the backfill include a more oxidized environment when compared to the undisturbed conditions. This increase in exposed mineral surfaces and difference in oxidation state may cause an increase in TDS and other constituents in groundwater.

The identified concerns related to the degradation of groundwater quality include:

(1) The effect of groundwater migrating from the backfill aquifer to the undisturbed native aquifers outside the mine permit boundary.
(2) The groundwater quality of the backfill aquifer within the mine permit boundary and its ability to support the approved post-mining land use. This includes the vertical migration of groundwater that might be caused by subsidence and aquifer interconnection.

(3) The effect of the quality of base flow from the backfill aquifer to the streams.

The first two identified concerns can be evaluated by comparing the existing and expected groundwater quality of the backfill aquifer against the WDEQ/WQD groundwater standards. The third concern can be evaluated against the surface water standards using surface water quality monitoring data.

4.3 ALLUVIAL VALLEY FLOORS

WDEQ/LQD Coal Rules and Regulations require that all potential AVFs be identified prior to mining. The WDEQ/LQD makes final determinations on the extent of AVFs and farming significance using information submitted by the coal mines. Operators are required to submit monitoring plans to ensure that: (1) mining will not materially damage the quantity and quality of water in surface or groundwater systems that supply AVFs not subject to statutory exclusions, (2) the essential hydrologic functions of all AVFs are maintained, and (3) the essential hydrologic functions of AVFs approved to be mined are successfully reestablished after mining (WDEQ Land Quality-Coal Rules, Ch. 5, § 3(b)).

The previously declared AVFs on the Tongue River downstream of the Big Horn Mine are the only AVFs determined to be significant to farming near the CHIA area (see Section 3.3).

Several of the surface water and groundwater hydrologic concerns previously identified in this section also apply to AVFs. These concerns have the potential to affect the essential hydrologic functions of the AVF, which in turn can reduce the capability of the AVF to support subirrigation or flood irrigation activities. With respect to AVFs, these hydrologic concerns are primarily related to changes in surface water quantity, changes in surface water quality, water level changes in the alluvial aquifer, and changes in alluvial water quality. For the purposes of this CHIA, these concerns are applied only to AVFs not subject to statutory exclusions, including the adjacent AVFs on the Tongue River and Slater Creek, as well as the Tongue River AVFs downstream of the proposed Big Horn Mine that have declared significant to farming.

4.3.1 CHANGES IN SURFACE WATER QUANTITY

With respect to surface water quantity, the primary concern in a semi-arid environment is decreased surface water flow to AVFs, although increased water quantity may also be a concern. Decreased runoff may reduce natural flood irrigation of vegetation in AVFs, as well as the capability for artificial flood irrigation. This may result in a reduction in the amount of flood irrigable land in AVFs. An increase in water quantity may change vegetation composition in AVFs.

4.3.2 CHANGES IN SURFACE WATER QUALITY

Degradation of surface water quality may affect soils and vegetation in AVFs. In particular, increases in TDS may increase salinity which can affect soils and growth of certain plant species.
4.3.3 WATER LEVEL CHANGES IN THE ALLUVIAL AQUIFER

Water level changes in the alluvial aquifer may be caused by: (1) disturbance or removal of the alluvium or other aquifers that show hydrologic connection to the alluvial aquifer, (2) mine dewatering, or (3) activities that reduce surface water flow to the alluvium such as stream diversions and impoundments. Decreases in alluvial water levels may potentially reduce the amount of subirrigated land in AVFs. The loss of diurnal fluctuations in alluvial water levels may also affect subirrigated vegetation in AVFs. Mining activities may also increase water levels in some cases, and this may affect vegetation composition in AVFs.

4.3.4 CHANGES IN ALLUVIAL WATER QUALITY

The water quality of the alluvial aquifer in many streams of the PRB is poorer compared to deeper aquifers. Despite the poorer water quality in the alluvial aquifer, any increases in TDS concentrations over pre-mine conditions may have the potential to increase salinity and affect soils and vegetation in AVFs. A reduction in surface water quantity can also cause less flushing of salts through the alluvial aquifer.
5. MATERIAL DAMAGE CRITERIA

The objective of this section is to develop appropriate material damage criteria for surface water, groundwater, and alluvial valley floors.

The Wyoming Environmental Quality Act requires that no coal mining be approved unless the applicant affirmatively demonstrates and the administrator finds in writing that the operation is designed to prevent material damage to the hydrologic balance outside of the permit area (W.S. § 35-11-406(n)(iii)). The WDEQ/LQD defines material damage to the hydrologic balance as a significant long-term or permanent adverse change to the hydrologic regime (WDEQ Land Quality–Coal Rules, Ch. 1, § 2(cf)). A significant long-term or permanent adverse change is defined as changes to the surface or groundwater hydrology that are inalterable conditions contrary to the Wyoming State Constitution, or of statutes administered by the WSEO, or water quality standards administered by the WDEQ/WQD (Wyoming Department of Environmental Quality and Wyoming State Engineer’s Office, 1996). An evaluation of the available monitoring data and information in the mining permits is used to indicate when material damage to the hydrologic balance may have occurred as a result of coal mining. The material damage criteria for surface water and groundwater are described in more detail below.

5.1 SURFACE WATER

The material damage criteria for surface water are examined for water quantity and water quality. Since no during or post-mining data are available yet for the proposed Brook Mine, the material damage criteria for this CHIA are developed from qualitative predictive measures.

5.1.1 WATER QUANTITY

Surface water quantity is evaluated to predict if coal mining will cause material damage to downstream surface water rights. The available surface water quantity data are evaluated for the baseline period in each of the major drainages within the surface water evaluation area. Specific data elements evaluated include mean daily flows, peak flows, flow duration, monthly flows, and annual runoff volumes.

No during or post-mining water quantity data are available yet for the proposed Brook Mine. Therefore, the material damage assessment for this CHIA is more qualitative in nature and considers factors such as use of hydrologic control features, extent of surface disturbance, extent of surface water use, extent and capacity of water retention features, the proximity of downstream water rights, and changes to post-mine drainage basins. Material damage to surface water quantity is predicted to occur if the analysis demonstrates that the proposed coal mining will cause a decrease in surface water quantity such that downstream surface water rights will be affected, and the proposed mine has not committed to providing a replacement water source similar in quantity and quality.

5.1.2 WATER QUALITY

Except where authorized by permit, it is prohibited to cause, threaten, or allow discharge of pollution into waters of the state (W.S. § 35-11-301(a)(i)). Pollution is defined as contamination or other alteration of the physical, chemical, or biological properties of waters of the State which
creates a nuisance or renders waters harmful, detrimental or injurious to public health, safety or welfare, to domestic commercial, industrial agricultural, recreational, or other legitimate beneficial uses, or to livestock, wildlife or aquatic life, or degrades the water for its intended use, or adversely affects the environment (W.S. § 35-11-103(c)(i)).

Material damage to surface water quality is evaluated using WDEQ/WQD Rules and Regulations to determine if coal mining will cause a significant long-term or permanent adverse change such that WDEQ/WQD surface water quality standards and classes of use are no longer met. The WDEQ/WQD has classified surface waters according to their use or potential use (Wyoming Department of Environmental Quality, 2013). Each surface water classification has a set of numeric criteria established to meet the defined use (Wyoming Department of Environmental Quality, 2018c).

No during or post-mining water quality sample data are available yet for the proposed Brook Mine. Therefore, the material damage assessment for this CHIA is more qualitative and predictive in nature. Material damage to surface water quality is predicted to occur if the analysis indicates that the proposed Brook Mine will cause a significant long-term or permanent adverse change such that WDEQ/WQD surface water quality standards and classes of use are no longer met.

All streams evaluated in this CHIA are either Class 2AB(ww) or Class 3B streams and must meet WDEQ/WQD water quality standards for aquatic life other than fish. WDEQ/WQD Rules and Regulations require that numeric standards for aquatic life other than fish will not be exceeded more than once every three years (WDEQ Water Quality Rules, Ch. 1, § 21(b)). According to methods established by Wyoming’s Methods for Determining Surface Water Quality Condition, if representative data show that at least one aquatic life other than fish criterion is exceeded for at least two separate years in a three-year period, than uses are not fully supported (Wyoming Department of Environmental Quality, 2017). Class 2AB streams such as Goose Creek and the Tongue River have additional protected uses such as drinking water, game fish, non-game fish, and fish consumption. As such, additional criteria exist for the human health consumption of fish and drinking water. According to the WDEQ/WQD, the uses of drinking water and fish consumption are fully supported when there are no exceedances of any related criterion within at least two separate years of any three year period (Wyoming Department of Environmental Quality, 2017).

The available surface water quality data are analyzed for the baseline period in each of the major drainages within the surface water evaluation area. Summary statistics, including the minimum, maximum, and median concentrations are compiled. The frequency of WDEQ/WQD water quality standard exceedances is examined. Discussion of possible changes caused by the proposed mining is included.

5.2 GROUNDWATER

The identified material damage criteria in this CHIA for groundwater are related to:

1. Protection of Water Uses: Protection of existing and reasonably foreseeable water uses within the groundwater evaluation area, and
2. Existing Groundwater Quality Standards: The CHIA material damage criteria considers and incorporates the WDEQ/WQD approved groundwater quality standards as part of the impact assessment.
It should be noted that material damage indicators which are not enforceable, but act as an early potential sign of possible material damage in the future are identified in this CHIA. The intent of identifying a material damage indicator is to alert the coal mines and the WDEQ/LQD of potential water resource impacts of concern so the coal mine may take appropriate actions to prevent material damage. Continuous monitoring and evaluation of these material damage indicators are required so that measures may be taken to prevent an exceedance of material damage criteria, which would result in a finding that material damage to the hydrologic balance outside the permit area had occurred.

An additional key distinction between the material damage criteria and material damage indicators is that the identified material damage criteria are applied exclusively to areas outside the coal mine permit boundary. The material damage indicators can include areas within the coal mine permit boundary and are not restricted to outside the permit boundary.

5.2.1 MATERIAL DAMAGE CRITERIA

Material damage to groundwater would be expected if (1) the CHIA demonstrated that coal mining will cause an irretrievable loss of the groundwater resource to support existing or reasonably foreseeable uses outside of the coal mine permit boundary, and (2) the mine did not commit to providing a replacement water source similar in quantity and quality. The material damage criterion is examined for water quantity and water quality and is presented below.

5.2.1.1 GROUNDWATER QUANTITY

Material damage to groundwater quantity occurs if the analysis demonstrates that the proposed coal mining will cause a decrease in groundwater levels such that groundwater rights within the groundwater analysis area will be affected and the proposed mine has not committed to providing a replacement water source similar in quantity and quality.

Baseline groundwater levels and estimated drawdowns caused by the proposed Brook Mine are evaluated to predict if coal mining will cause adverse impacts to existing water rights within the groundwater analysis area. The simulated groundwater level data are evaluated for during-mining periods. The assessment considers factors such as the extent of drawdown caused by mine dewatering, depth of the well with the associated water right, proximity of the well to the mine, aquifer in which the well is located, and local hydrogeology.

5.2.1.2 GROUNDWATER QUALITY

Material damage to groundwater quality occurs if the analysis demonstrates that the proposed coal mining will cause a long-term change in groundwater quality outside the proposed mine permit boundary that would preclude existing or reasonably foreseeable uses.

The estimated during-mining and post-mining groundwater quality data are evaluated against applicable WDEQ/WQD groundwater quality standards. The potential for material damage is assessed by evaluating the effect of groundwater migrating from the backfill aquifer or other coal mining affected aquifers within the proposed permit boundary to the undisturbed native aquifers outside the proposed permit boundary.
5.2.2 MATERIAL DAMAGE INDICATORS

Typically, it will take several years to realize the groundwater impacts caused by mining to propagate outside the proposed mine permit boundary because of the relatively slow movement of groundwater. These transient observed groundwater impacts will vary depending on the mining and reclamation methods and sequence, the aquifer of interest, and the distance of the location of interest from the disturbed or reclaimed area. Therefore, the following material damage indicators were identified for groundwater levels and groundwater quality. It is important to note that the following indicators are not enforceable but will be used to initiate discussions and alert the mine of possible material damage.

It is critical to assess how physical characteristics, recovery rates, and the groundwater quality of the backfill aquifer will affect groundwater availability within the coal mine permit boundary and flow through the backfill aquifer to the undisturbed native aquifers. The backfill aquifer is a critical component of the hydrologic balance. The material damage indicators are:

(1) Comparison of physical characteristics of the backfill aquifer to the pre-mining baseline conditions.

- The ability of the backfill aquifer to store and transmit water will determine the ability of the backfill aquifer to support the post-mining land use. The physical characteristics of the estimated backfill aquifer are compared to the pre-mining baseline conditions to determine the magnitude of changes in hydraulic properties. Estimated hydraulic conductivities and storage coefficients of the backfill aquifers are examined to determine if these changes would affect the availability of groundwater on the adjacent native aquifers outside the proposed mine permit boundary.

(2) Evaluation of groundwater level recovery in the backfill aquifer.

- The groundwater level recovery rates will be estimated based on the model predictions provided in the Brook Mine Permit Application (2020). These data will be evaluated to determine if the backfill aquifer could act as a viable supply source to support the post-mining land use of livestock and wildlife. In addition, the recovery rate of the backfill aquifer will be used as an indicator to evaluate the impacts on the adjacent native aquifers outside the proposed mine permit boundary.

(3) The groundwater quality of the backfill aquifer within the proposed permit boundary and its ability to support the post-mining land use of livestock and wildlife.

- The predictions presented in the Brook Mine Permit Application (2020) on post-mining groundwater quality of the backfill aquifer will be used to determine if the backfill groundwater quality can meet the WDEQ/WQD Class III livestock groundwater quality standards. The effect of backfill groundwater migrating to the adjacent undisturbed native aquifers outside the proposed permit boundary will be an indicator of the probable impact on the existing water uses outside the proposed permit boundary.
### 5.3 ALLUVIAL VALLEY FLOORS

The Wyoming Environmental Quality Act requires that no surface mining be approved unless the operation will not materially damage the quantity and quality of water in surface or groundwater systems that supply alluvial valley floors not subject to statutory exclusions (W.S. § 35-11-406(n)(v)(B)). Material damage with respect to AVFs is defined by WDEQ/LQD Coal Rules and Regulations as "changes in the quality or quantity of the water supply to any portion of an alluvial valley floor where such changes are caused by coal mining and reclamation operations and result in changes that significantly decrease the capability of the alluvial valley floor to support subirrigation or flood irrigation activities" (WDEQ Land Quality–Coal Rules, Ch. 1, § 2(cg)). Only AVFs on developed lands not subject to statutory exclusions necessitate material damage findings by the regulatory authority (W.S. § 35-11-406(n)(v)).

The previously declared AVFs on the Tongue River downstream of the Big Horn Mine are the only AVFs determined to be significant to farming near the CHIA area (see Section 3.3). The WDEQ/LQD also declared AVFs adjacent to the Brook Mine permit area on the Tongue River and Slater Creek. The CHIA will conduct a material damage assessment for these AVFs by considering the potential for changes in surface water quantity, surface water quality, alluvial water levels, and alluvial water quality. A material damage assessment will not be conducted for AVFs that are on undeveloped rangeland which is not significant to farming.
6. ANALYSIS OF PREDICTED POST-MINE HYDROLOGIC CONDITIONS

The following sections discuss predicted post-mine hydrologic conditions and predicted post-mine impacts to surface water, groundwater, and alluvial valley floors not subject to statutory exclusions. Post-mining impacts are qualitatively discussed since mining has not occurred yet at the proposed Brook Mine.

6.1 SURFACE WATER

6.1.1 POST-MINING WATER QUANTITY AND WATER QUALITY IN THE SURFACE WATER EVALUATION AREA

The overall reclamation objective at the proposed Brook Mine is to restore the land to the post-mining land use which is mostly livestock grazing but also includes recreational and industrial land uses (Brook Mine Permit Application, 2020). With respect to surface water quantity and quality, the goals are to minimize disturbance to the hydrologic balance inside the permit boundary, not cause material damage to the hydrologic balance outside the permit boundary, protect or replace water rights, and to support approved post-mining land uses. Proper reclamation will ensure that no material damage occurs to surface water quantity and quality as a result of mining.

Since no mining has occurred yet at the proposed Brook Mine, there are no during-mining surface water quantity or quality data available to compare against pre-mining data. Thus, a prediction concerning post-mining water quantity and quality is based on a qualitative analysis.

The proposed Brook Mine is classified as an approximate original contour (AOC) mine (Brook Mine Permit Application, 2020), which means that there is sufficient spoil available to construct a post-mine topography (PMT) that is similar to pre-mine conditions. The PMT was developed through a mass balance model of the volume of material required to complete reclamation of the mine pits with the total spoil available for reclamation. The PMT was then adjusted to be similar to the pre-mine landscape by blending the reclaimed contours with the native topography (Brook Mine Permit Application, 2020). The modelled post-mining slopes within the proposed permit boundary show minimal changes to the pre-mining values. For example, the average post-mining slope is predicted to decrease only slightly from 13.5 to 13.4 percent, while the maximum post-mining slope would be identical at 69.5 percent (Brook Mine Permit Application, 2020).

At the proposed Brook Mine, post-mining drainage basin characteristics such as drainage area, channel length, basin relief, valley slope, drainage density, and stream sinuosity are designed to be similar to the pre-mining condition (Brook Mine Permit Application, 2020). Due to the limited extent of surface disturbance associated with the primary mining method of highwall mining, there are very minor predicted changes in post-mining drainage basin characteristics. Only three of the minor drainage basins on the proposed permit area will have changes in post-mining drainage area: TRD1 will decrease 5.1 acres or 5.2 percent; TRD5 will increase 2.5 acres or 0.42 percent; SCSUB5, a tributary to Slater Creek, will increase 5.2 acres or 6.4 percent. The Brook Mine Permit Application (2020) also predicts that based on modeled PMT, the Slater Creek drainage will decrease 10 acres.
or 0.09 percent. Given the minimal predicted changes in post-mine geomorphic conditions, the post-mining surface water quantity and quality in the surface water evaluation area should be similar to pre-mine conditions.

The Brook Mine Permit Application (2020) used the USACE HEC-HMS runoff model to predict post-mine peak flows and runoff volumes for the drainages within the proposed permit boundary for storms of varying recurrence intervals. The results showed that the predicted post-mining peak flows and runoff volumes were less than one percent different than the pre-mining values (Brook Mine Permit Application, 2020). The minimal change in post-mining modelled runoff is attributable to slight changes in runoff curve numbers and the minimal change in post-mine drainage area within the watersheds of the proposed permit area.

Pre-mine geomorphic characteristics were used in conjunction with post-mine flood estimates to design reconstructed stream channels at the proposed Brook Mine (Brook Mine Permit Application, 2020). Runoff modeling was used to evaluate hydraulic suitability and predict post-mine flows in reconstructed channels for varying recurrence intervals. The reclaimed topography at the proposed Brook Mine includes the reconstruction of Hidden Water Creek and Slater Creek and their tributaries, along with several of the ephemeral channels that are direct tributaries to either the Tongue River or the Tongue River Ditch (TRD1, TRD2, TRD3, TRD4, TRD5) (Brook Mine Permit Application, 2020). The extent and timing of stream channel reconstruction varies considerably; the locations of reconstruction are shown in Exhibit RP.8-1 and the longitudinal channel profiles are shown in Exhibit RP.8-2 of the Brook Mine Permit Application (2020). Slater Creek will not be mined through but will have approximately 750 feet of reconstruction due to disturbance associated with redirecting the channel through a culvert at a proposed haulroad (Brook Mine Permit Application, 2020).

The WDEQ/LQD requires that permanent reclaimed channels and associated floodplains be designed to pass, in a non-erosive manner, the 100-year, 6-hour precipitation event (WDEQ Land Quality-Coal Rules, Ch. 4, § (e)(v)(H)). Some bed and bank erosion is likely to occur; but the channel slope and cross-sectional dimensions should not change substantially during the design runoff event. Post-mine channels are generally wider and often flow at shallower gradients than corresponding pre-mine channels. This design results in greater cross-sectional area providing flow resistance and lower velocities while enhancing erosional stability.

The Brook Mine Permit Application (2020) predicts that the mine design is not prone to the development of subsidence following highwall mining. Nonetheless, the permit application includes a subsidence monitoring program to detect elevation changes that might be caused due to subsidence. Subsidence features will be reclaimed if they are not self-healing or if the subsidence causes material damage or reduces the value of the reasonable foreseeable uses of the surface lands. The Brook Mine will continue to perform reclamation on subsidence up until final bond release is approved (Brook Mine Permit Application, 2020). Therefore, it is expected that subsidence features will not have implications for post-mining surface water quantity and quality.

Permanent post-mining impoundments fall in two categories: small impoundments that are generally used as stockponds and major impoundments. Stockponds are defined by the WDEQ/LQD as impoundments that have a capacity of less than 20 ac-ft and a dam height of less than 20 feet. A major impoundment is an impoundment that provides a storage capacity of greater than 20 ac-ft and/or has an embankment height greater than 20 feet (Wyoming Department of Environmental Quality, 2019f). Both small and major impoundments must have a designed
spillway to provide through drainage, and WSEO approval must be obtained for a water right. The WSEO requires structures whose capacity exceeds 50 ac-ft and whose embankment exceeds 20 feet in height to have safety of dam inspections. Depending on the size and number of impoundments that remain after reclamation, there may be some decrease in water yield due to increased evaporative losses. However, permanent post-mine impoundments are beneficial in that they support the post-mine land use of livestock and wildlife. In many cases these permanent impoundments replace pre-mine impoundments.

At the proposed Brook Mine, a total of nine permanent post-mine impoundments are planned to replace the stockponds disturbed by mining (Brook Mine Permit Application, 2020). Two of the impoundments are new impoundments while the remaining seven impoundments are replacements for pre-mining features. The impoundments are expected to support the post-mining land use of stock watering, and will also provide wildlife habitat, wetland mitigation, and potential recreational use opportunities. The specific designs for the two new permanent post-mine impoundments are conceptual; detailed designs will be submitted during the permit term of construction. The total post-mine capacity of the two new impoundments is expected to be 35.45 ac-ft (Brook Mine Permit Application, 2020). As a result of the two new permanent post-mine impoundments, there will be a net increase in water storage capacity compared to pre-mining conditions. The impoundments will be subject to WSEO approval and as such would be evaluated for compliance with the Yellowstone River Compact, which will require that bypass or make-up water be made available.

All of the permanent impoundments at the proposed Brook Mine will be monitored for reservoir stage and water quality on a quarterly basis up until bond release (Brook Mine Permit Application, 2020). Further details on this monitoring are provided in Section 7.1. Water quality from post-mine permanent impoundments will be evaluated using procedures recommended by WDEQ/LQD Guideline No. 17 (Wyoming Department of Environmental Quality, 2019f).

All disturbed wetlands at the proposed Brook Mine are required to be replaced on a one-to-one area basis per regulatory statutes. The proposed Brook Mine completed a wetlands and aquatic resources inventory within the permit boundary in 2013 (Brook Mine Permit Application, 2020). A jurisdictional determination by the USACE was requested in May 2015, but at the time of developing the CHIA, the determination had not been issued yet. The proposed Brook Mine will directly disturb 5.6 acres of wetlands and indirectly disturb an additional 5.0 acres of wetlands. The wetland mitigation plan will use drainage wetlands along stream channels and impoundment wetlands to replace wetland acreage disturbed by mining (Brook Mine Permit Application, 2020). Since the post-mining wetlands are small in volume and mostly replace existing features, they are not expected to affect the hydrologic balance of any of the reclaimed drainages.

The potential for acid drainage to occur after reclamation at the proposed Brook Mine is expected to be minimal. Pre-mine overburden core samples demonstrated little concerns with acid-base potential (ABP), which is used by the WDEQ/LQD to indicate acid-forming potential. The minimum ABP value for four of the 18 cores did exceed the criteria of &lt; -5 tons CaCO₃/1000 tons set by WDEQ/LQD Guideline No. 1 (Wyoming Department of Environmental Quality, 1984). An ABP result of less than -5 tons CaCO₃/1000 tons indicates there is an acid-forming potential for both the surface (potential root zone) and aquifer restoration. However, the average values, which are more representative of what will exist after the materials are mixed during reclamation, were all greater than -5 tons CaCO₃/1000 tons (Brook Mine Permit Application, 2020). The lowest average ABP value from one of the holes was 16.9. The Brook Mine Permit Application (2020) commits to use
prudent handling and mixing of any zones of concern to meet the criteria set by LQD Guideline No. 1.

Prior to replacing topsoil and contouring, the proposed Brook Mine has committed to cover unsuitable spoil with a minimum of four feet of suitable material (Brook Mine Permit Application, 2020). In the vicinity of minor (ephemeral) reclaimed channels, this commitment is increased to six feet, while the commitment is increased to ten feet under major (intermittent) channels. Construction of permanent post-mine impoundments will have similar commitments for suitability (Brook Mine Permit Application, 2020). These commitments should provide an adequate rooting zone and minimize impairment concerning vegetation reestablishment. The increased burial depth within minor and major drainages, and permanent impoundments, should assist in reducing the amount of unwanted salts or trace elements being wicked to the surface during dry periods and into surface water during runoff events.

Vegetative cover will be slightly lower during the early stages of reclamation when compared to the pre-mine environment. To obtain final bond release, vegetative cover for each community type must be equal to or exceed pre-mine conditions. If post-mining vegetation cover meets these requirements, it is assumed that the level of soil surface protection closely resemble pre-mining conditions. Prior to the release of bond for any mined area, the WDEQ/LQD requires that the unit of permanently reclaimed land exhibit sufficient surficial stability and sufficient development of its post-mining vegetation. These conditions are used to demonstrate that drainage from the reclaimed unit does not need to pass through a sediment pond or ASCM structure. Post-mining surface water quality in the drainages within the proposed permit boundary is expected to meet surface water quality class-of-use standards.

The above analysis indicates that the differences between pre-mine and post-mine topography, drainage basin characteristics, and vegetation cover will be minimal following reclamation at the proposed Brook Mine. This suggests that runoff from the permit area at the end of the bond release period will be similar in quantity and quality compared to the pre-mine condition. However, there will be a slight increase in water retention capacity (35.45 ac-ft) due to the addition of two new permanent post-mine impoundments to support the post-mine land use. The impoundments will be subject to WSEO approval under the Yellowstone River Compact, which will require that bypass or make-up water be made available, and should not affect downstream water rights. Sediment yield is expected to be lower post-mine compared to pre-mine, and this would be consistent with results from other Wyoming coal mines that have shown that sediment yield from reclaimed lands is usually less than yields from adjacent native lands. Post-mine water quality from the drainages on the proposed permit area is not expected to be degraded and is expected to meet WDEQ/WQD standards for class of use. Monitoring of water quantity and quality will continue at the surface water monitoring stations at the proposed Brook Mine up until final bond release to evaluate performance standards and reclamation success (see Table 18 and Figure 52 in Section 7.1).

### 6.2 GROUNDWATER

The proposed coal mining operations by the Brook Mine within the groundwater evaluation area are estimated to occur over a 39-year period beginning in approximately year 2020. Contemporaneous reclamation activities would continue during mining and major reclamation activities to include grading, topsoil application, reseeding, and facilities demolition/removal would
be completed within four years after mining (Brook Mine Permit Application, 2020). At the completion of reclamation: (1) all the mined pits and trenches will be backfilled and reclaimed, (2) the portions of the backfill aquifer that were contemporaneously reclaimed during mining will be under a transient groundwater level recovery, and (3) a structural contact between the backfill aquifer and the undisturbed native aquifers would be established and this contact would be static over time.

Since no mining has occurred yet at the proposed Brook Mine, there are no during-mining groundwater quantity or quality data available to compare against pre-mining data. The estimates of predicted groundwater levels and groundwater quality discussed in this section are primarily based on the predictions presented in the Brook Mine Permit Application (2020).

### 6.2.1 ALLUVIAL AQUIFER

The groundwater modeling and analyses presented in the Brook Mine Permit Application (2020) indicate that no significant long-term permanent changes in groundwater levels and groundwater quality are expected to the alluvial aquifer. This estimation is based on:

1. The baseline conditions indicate that the general direction of groundwater flow in the alluvial aquifer follows the topography towards the downstream or down valley direction. Therefore, the effects of mining are expected to be minimal on the upstream undisturbed alluvial aquifers outside the proposed mine permit boundary.

2. The alluvium of Goose Creek and the Tongue River will not be physically disturbed.

3. The surface disturbances to the Slater Creek channel are limited. The only anticipated direct disturbance to the Slater Creek channel is in Section 13, T57N, R85W, where the channel will be redirected to flow through a culvert under a proposed haul road. However, these changes will be temporary. A 100-foot buffer boundary of the Slater Creek channel will be marked prior to disturbance. This buffer zone will minimize impacts to the Slater Creek alluvium.

4. There are multiple claystone intervals between the Carney coal and the surface. The confining claystone intervals provide a barrier from mining activities significantly affecting the alluvial aquifer within the proposed mine permit boundary.

5. Lab permeability tests were conducted by the proposed Brook Mine for the confining units above and below the coal seams. The lab results indicate that the overburden and underburden units are comprised of predominantly clay with low hydraulic conductivity. The hydraulic conductivity of the Carney overburden and Carney interburden is at least three orders of magnitude lower than the hydraulic conductivity of the coal seams. In addition, the aquifer pumping tests conducted by the proposed Brook Mine to evaluate the potential communication between the Tongue River alluvium and the Carney Coal indicate that confining claystone intervals are a hydrologic barrier between the coal seam and the Tongue River alluvium.

6. The mining-induced drawdown simulated by the groundwater model is less than 0.1 feet in the Tongue River alluvium. Maximum impacts are expected to occur in areas...
where the overburden is thin (near coal seam subcrops) and the impacts are of short duration. The data from Big Horn Mine station TR0176 and USGS Station No. 06299980 indicate that the Tongue River annual mean daily flows over the 2002 to 2018 period ranged from a low of 99 cfs in 2004 to a high of 577 cfs in 2011. The groundwater model has estimated that the maximum pit inflows during mining is about 0.056 cfs. Compared to the Tongue River low flow of 99 cfs, the estimated pit flows are 0.06 percent of the flows in the Tongue River. The estimated amount of groundwater pumped by Brook Mine is minimal compared to the water budget of the hydrologic system that includes Tongue River. Increased infiltration into the groundwater system and associated streamflow losses from the Tongue River because of these impacts are therefore expected to be minimal (Brook Mine Permit Application, 2020).

7. The Slater Creek, Tongue River, and Goose Creek alluvium will be monitored regularly by the proposed Brook Mine. During mining and reclamation operations, color infrared aerial photography will be obtained annually and analyzed as an indicator to ensure appropriate corrective measures are taken, if needed.

6.2.2  CARNEY COAL

The groundwater modeling and analyses presented in the Brook Mine Permit Application (2020) indicate that no significant long-term permanent changes in groundwater levels and groundwater quality are expected to the Carney coal seam. It is expected that the impacts of mining would be more extensive on the coal aquifer than the other aquifers of interest as the coal seams would mostly be mined out and the hydraulic conductivity of the coal aquifer is higher than the overburden and underburden aquifers. However, the impacts on groundwater levels and groundwater quality are expected to be minimal and the coal aquifer would be able to support livestock use. This estimation is based on:

1. Predicted drawdowns in the Carney coal seam are mainly within the proposed permit area but may extend one-half to one mile from the mine pit in a few areas (Figure 13). The drawdowns shown in Figure 13 are not associated with a specific point in time and represent the maximum predicted drawdowns during mining. The field data collected by the mine indicate that the Carney coal is predominantly dry with limited saturation in the western portions of the proposed permit area. These predictions are consistent with the expected groundwater impacts while mining occurs in areas where Carney coal is dry.

2. Most of the wells within the CIA are stock or domestic wells with intermittent pumping. The groundwater model estimates a predicted drawdown of greater than zero feet at five wells. The largest model predicted impact seen at any existing well outside of the proposed Brook Mine permit boundary is 3.3 feet. This impact is estimated to be temporary (approximately four years). Model predicted drawdowns at the rest of the wells are less than two feet (Brook Mine Permit Application, 2020).

3. A recovery to a residual drawdown of less than five feet is predicted by the groundwater model in the Upper Carney and the Lower Carney coal seams within five years from cessation of mining. Most of the estimated recovery occurs within the first five years as
recovery versus time follows an exponential curve (Brook Mine Permit Application, 2020).

6.2.3 MASTERS COAL

The groundwater modeling and analyses presented in the Brook Mine Permit Application (2020) indicate that no significant long-term permanent changes in groundwater levels and groundwater quality are expected to the Masters coal seam. This estimation is based on:

1. Masters seam will not be mined and the Carney seam is the lowest targeted coal seam. Therefore, the stratum between the Carney and Masters seams is the underburden for the proposed Brook Mine. Based on the low permeability of the underburden between the Carney and Masters coal seams, the drawdown impacts on Masters coal seam is expected to be less than the impact on Carney coal seam.

2. Predicted drawdowns in the Masters coal seam are mainly within the permit area but may extend one-half to one mile from the mine pit in a few areas (Figure 13). The drawdowns shown in Figure 13 are not associated with a specific point in time and represent the maximum predicted drawdowns during mining.

3. Most of the wells within the model domain are stock or domestic wells with intermittent pumping.

4. A recovery to a residual drawdown of less than five feet is predicted by the groundwater model in the Masters coal seams within five years from cessation of mining. Most of the estimated recovery occurs within the first five years as recovery versus time follows an exponential curve.

6.2.4 UNDERBURDEN

The stratum between the Carney and Masters seams is the underburden for the proposed Brook Mine. During mining, the underburden aquifer that is in close proximity to the mine pits will be impacted in various ways, including some fragmentation, drawdown due to the influences of the pit dewatering, and exposure of the aquifer materials for a limited time to the atmosphere, and direct precipitation events. During the initial stages of backfill aquifer resaturation, there is expected to be some upward groundwater flow from the underburden to the backfill aquifer.

Outside the mined out areas, the aquifers overlying the underburden aquifer would remain structurally undisturbed. In addition, the relatively lower hydraulic conductivity of the underburden aquifer supports that coal mining would have limited hydrologic effects on the underburden groundwater system and these effects will be declining with increasing distance from the proposed Brook Mine permit boundary.

6.2.5 BACKFILL AQUIFER

The backfill aquifer is a new aquifer created by replacing overburden materials into the mined pit and trenches after the coal is removed. Within the areas where the highwall miner is used for mining, an open cavern would remain. Unless the mined out areas collapse, the backfill aquifer is essentially an open cavern. By the end of mining activities, all spoil material would be
backfilled into trenches or other surface mining excavation areas. The effects of possible subsidence on groundwater and the hydrologic system are minimal during mining operations as the area where subsidence would be most likely to occur would be dewatered during the operation. Once mining operations are completed, any subsidence that occurs would have a minimal, temporary impact on groundwater quality before stabilizing after a number of pore volumes passes through the material. Alterations to recharge rates are expected to be minimal (Brook Mine Permit Application, 2020).

During mining operations, an overburden sampling program will be used to identify the presence of unsuitable material. The sampling program will include one drill hole sample taken every 40 acres (16 sample locations per square mile) within areas where surface operations will cause removal of overburden down to the level of the coal seam to determine if mining operations will encounter unsuitable materials when overburden are excavated. If an area of unsuitable material is encountered during this sampling program, then additional holes will be drilled to delineate the zone of unsuitable material. Should any strata be considered unsuitable based upon the criteria, overburden stripping and backfilling operations will then be scheduled so that the identified unsuitable strata are not placed: (1) in the uppermost four feet (rooting zone) of the final backfill thickness; (2) within six feet of the spoil surface beneath ephemeral channels; and (3) within ten feet of the spoil surface beneath permanent impoundments or major (intermittent) channels and their 100-year floodplains (Brook Mine Permit Application, 2020). Therefore, the groundwater quality effects are expected to be minimal.

The backfill aquifer will be limited in extent within the mined areas inside the proposed Brook Mine permit boundary. The amount of area replaced with backfill would be significantly less than a typical open pit coal mine, so the potential impact from a backfill aquifer replacing a coal aquifer would be less than a typical open pit mine. From the material damage evaluation perspective, the area of interest is outside of the permit areas (W.S. § 35-11-406(n)(iii)). Outside the proposed Brook Mine permit boundary, the backfill aquifer will not be present and the native existing aquifers will remain structurally undisturbed. Groundwater modeling indicates that the effects of mining in these native aquifers are smaller than the effects observed at mined areas that were backfilled. Therefore, it is reasonable to expect that the recovery of these native aquifers outside the permit boundaries would be relatively faster than the backfill aquifer, and the existing wells in these native aquifers would remain viable to support the existing land use.

### 6.3 ALLUVIAL VALLEY FLOORS

As discussed in Section 3.3, the only AVFs that are not subject to statutory exclusions are on the Tongue River and Slater Creek adjacent to the proposed Brook Mine, as well as on the Tongue River downstream of the Big Horn Mine (Figure 49). For the purposes of this CHIA, predicted post-mining hydrologic conditions are only discussed for these AVFs.

There are no predicted post-mine impacts to the AVFs adjacent to the proposed Brook Mine or downstream of the Big Horn Mine. Post-mine hydrologic conditions in these AVFs are predicted to remain unchanged from pre-mining and during-mining conditions for the reasons discussed in Sections 6.1 and 6.2. Reclamation operations at the proposed Brook Mine are not predicted to result in changes that significantly decrease the capability of the downstream AVFs to support subirrigation or flood irrigation activities. Section 7.3 conducts a material damage assessment for
these AVFs by considering the potential for changes in surface water quantity, surface water quality, alluvial water levels, and alluvial water quality.
7. MATERIAL DAMAGE POTENTIAL

The potential for material damage to the hydrologic balance outside the proposed Brook Mine permit area was evaluated. This evaluation focused on surface water quantity and quality, groundwater quantity and quality, and alluvial valley floors not subject to statutory exclusions.

7.1 SURFACE WATER

7.1.1 WATER QUANTITY

Surface water quantity will be evaluated to determine if coal mining at the proposed Brook Mine will cause impacts to downstream surface water rights. The available surface water quantity data were evaluated for the baseline period in each of the major drainages within the surface water evaluation area (see Section 3.1). Specific data elements evaluated included mean daily flows, peak flows, flow duration, and monthly, seasonal, and annual runoff volumes. The following factors were also evaluated to assess the potential of the proposed Brook Mine to cause material damage to surface water quantity: use of hydrologic control features, extent of surface disturbance, extent of surface water use, extent and capacity of water retention features, the proximity of downstream water rights, and changes to post-mine drainage basins. Material damage to surface water quantity is presumed to occur if the analysis demonstrates that coal mining will cause a decrease in surface water quantity such that downstream surface water rights will be affected, and the mine has not committed to providing a replacement water source similar in quantity and quality.

The proposed Brook Mine established surface water quantity monitoring stations on Hidden Water Creek and Slater Creek within the proposed permit boundary; no station was established on East Fork Earley Creek due to the minimal surface disturbance in the watershed (Brook Mine Permit Application, 2020). On Hidden Water Creek, no streamflow was observed during the baseline monitoring period, demonstrating the ephemeral flow regime of the drainage (see Section 3.1.1.1). Historical streamflow data from a Big Horn Mine station on Hidden Water Creek (HWC1-79) also demonstrate that flows are ephemeral and result primarily due to snowmelt in the late winter or spring. Flows in Hidden Water Creek may also be affected by reclaimed mine pits and other small impoundments in the watershed upstream of the proposed Brook Mine.

On Slater Creek within the proposed Brook Mine permit boundary, streamflow monitoring demonstrated that flows are primarily due to snowmelt in the spring (see Section 3.1.1.2). The Brook Mine Permit Application (2020) also indicates some discharge to Slater Creek occurs from infiltration of precipitation into high perched scoria burn above the stream channel; this water is stored and slowly released to Slater Creek. It appears that this flow may form a shallow water table that provides baseflow to the channel in select locations, and therefore Slater Creek within the proposed permit area is best characterized as an intermittent stream. The proposed Brook Mine will use a 100-foot buffer around Slater Creek to protect the channel; the only disturbance of the main channel will occur where the channel is redirected through a culvert at a proposed haulroad (Brook Mine Permit Application, 2020). Continued monitoring and comparisons between the Hidden Water Creek and Slater Creek stations upstream and downstream of mining disturbance will be used to evaluate water quantity and material damage potential in the future.

Streamflow data were also analyzed on Goose Creek and the Tongue River adjacent to the proposed Brook Mine (see Sections 2.1.1.1, 3.1.1.4, and 3.1.1.5). On Goose Creek, streamflow is
perennial and the majority of flow occurs in June due to snowmelt. It is predicted that the proposed Brook Mine will not affect streamflows in Goose Creek since the channel will remain undisturbed. No mining is proposed adjacent to the channel; only surficial disturbance of portions of the contributing area is proposed based on mine operational needs.

On the Tongue River, annual mean daily streamflow was analyzed from 2000 to 2018 for stations upstream (USGS Station No. 06299980 or Big Horn Mine station TR0176) and downstream (Big Horn Mine station TR2B80) of the Big Horn Mine. On average flows were 73 percent higher on the Tongue River below the Big Horn Mine, and much of this increase is due to flows contributing from Goose Creek. It is predicted that the proposed Brook Mine will not cause detectable changes in streamflow on the Tongue River since the main channel will remain undisturbed and the amount of surface disturbance at the mine would be minimal compared to the large contributing area of the Tongue River and Goose Creek watersheds upstream of the mine.

Hydrologic control features at the proposed Brook Mine will serve to both sustain surface water flows through the permit boundary and help protect downstream areas from flooding and water quality degradation. These features include flood control reservoirs, temporary diversions, collector and bypass ditches, and culverts (Brook Mine Permit Application, 2020). These features will be designed such that they prevent erosion and help route and convey runoff away from disturbed areas. Four small (≤4.54 ac-ft) flood control reservoirs are proposed in the first five years of mining to help contain runoff from disturbed areas. Each flood control reservoir will contain an emergency spillway to safely discharge the peak flow from a 25-year, 6-hour precipitation event (Brook Mine Permit Application, 2020). As appropriate, all hydrologic control structures will be permitted with the WSEO and will be subject to the limitations of the permits.

The proposed Brook Mine will use three temporary diversions on Hidden Water Creek to route streamflows around mining disturbance (Brook Mine Permit Application, 2020). The mine will also establish a 100-foot buffer on either side of Slater Creek within the proposed permit boundary. The buffer has been displayed on a map within the permit application and will also be marked in the field prior to commencing surface disturbance. The buffer will help sustain streamflows in Slater Creek within the proposed boundary so that downstream water quantity is unaffected. Assuming the hydrologic control features are properly designed, constructed, and maintained, the proposed Brook Mine is not predicted to cause material damage to downstream surface water quantity.

The proposed Brook Mine will cause less surface disturbance than a typical open-pit strip coal mine because of the primary mining method of highwall mining. The highwall mining operation will open trenches from which the highwall continuous miner will extract coal from underneath the undisturbed overburden. This will result in a smaller disturbance footprint than traditional open-pit surface mining. Within the proposed permit area, the Brook Mine will be directly disturbing 1,135.1 acres over the 39-year life of the mine, or approximately nine percent of the surface water evaluation area. The entire disturbance area would not be disturbed at once due to the planned mining sequence and the practice of contemporaneous reclamation. Based on the limited amount of acreage affected relative to the size of the surface water evaluation area, there is a low probability for mining to cause detectable changes in water quantity on the Tongue River. Runoff and streamflow from the 911 mi² watershed upstream of the mouth of the surface water evaluation area also helps negate any potential impacts to water quantity on the Tongue River. As discussed previously, the proposed Brook Mine does not anticipate that subsidence will occur.
following mining, but a subsidence monitoring and mitigation plan has been proposed to address subsidence if it does occur.

The Brook Mine Permit Application (2020) estimated the volume of water that would be required for specific uses at the mine and the probable sources of the water. The total volume of water estimated to be used at the mine is 304,200 gallons per day (gpd), or nearly 111 million gallons per year. This value may vary year to year based on climatic conditions and specific mine needs. The water at the proposed mine would be used for such uses as potable water, dust control, truck wash, and the highwall miner. The sources of water include: trucking potable water/reverse osmosis (6.9 percent of total), pit inflows (3.0 percent of total), sediment/flood control reservoirs (2.3 percent of total), and surface water rights (87.7 percent of total). At this time the proposed Brook Mine does not propose to drill a water supply well to use groundwater for mine water supply needs (Brook Mine Permit Application, 2020). Water from surface water rights would be supplied using either temporary water haul or purchased from existing surface water rights holders. The Brook Mine would also use water collected in the mine pits from pit inflow and from sedimentation impoundments and flood control reservoirs. Any new surface water rights needing to be obtained for mine water supply needs would be subject to WSEO approval under evaluation of the Yellowstone River Compact, which will require that bypass or make-up water be made available.

As discussed previously, the proposed Brook Mine will be constructing several hydrologic and sediment control features that have the potential to capture and retain surface water within the proposed permit boundary. These features include flood control reservoirs, diversions, sediment ponds, and alternative sediment control measures (ASCMs). These features will be installed at varying times throughout the life of the mine depending on the term of the permit and the mine sequence. Sediment ponds and ASCMs proposed to be used are described in more detail in Section 7.1.2. In addition to these features, surface water has the potential to be captured in the mining trenches associated with highwall mining. The mine also proposes to construct a wastewater impoundment, although the complete design details of the impoundment have not been determined yet (Brook Mine Permit Application, 2020).

It is reasonable to expect some amount of short-term reduction in water yield in the surface water evaluation area due to water retention in the hydrologic and sediment control features, but many of these features are necessary to protect downstream water quality. There are some considerations that may reduce the potential reduction in water quantity. First, the water retention features and mining trenches will not be constructed at the same time and many of the features will be contemporaneous reclaimed as the mine progresses, lessening the magnitude of water retention at any given point in time. Second, mining will temporarily remove seven of the pre-mining stockponds on the proposed permit boundary (total capacity of 44.47 ac-ft) (Brook Mine Permit Application, 2020). The additional water retention capacity of the flood control reservoirs and sediment ponds proposed by the mine will therefore be somewhat offset by the removal of the water holding capacity of the pre-mining stockponds. Any increase in water retention capacity by the hydrologic and sediment control features is not expected to be sufficient to impact downstream water rights. In the event that a non-mine water right is impacted by mining activities, the law and permits require water supply to be replaced by a source suitable in quantity and quality. Therefore, the proposed mining is not predicted to cause material damage to surface water rights downstream of the mine.

A total of nine permanent post-mine impoundments are planned to replace the stockponds disturbed by mining (Brook Mine Permit Application, 2020). Two of the impoundments are new
impoundments while the remaining seven impoundments are replacements for pre-mining features. The impoundments are expected to support the post-mining land use of stock watering, and will also provide wildlife habitat, wetland mitigation, and potential recreational use. The total post-mining capacity of the two new impoundments is expected to be 35.45 ac-ft (Brook Mine Permit Application, 2020). The two new impoundments will be located in the TRD4 drainage, an ephemeral tributary to the Tongue River Ditch (see Figure 11). As a result of the two new permanent post-mine impoundments, there will be a net increase in water storage capacity compared to pre-mining conditions. The impoundments will be subject to WSEO approval and as such would be evaluated for compliance with the Yellowstone River Compact, which will require that bypass or make-up water be made available. The new impoundments are not expected to impact downstream surface water rights. In the event that a non-mine water right is impacted by mining activities, the law and permits require water supply to be replaced by a source suitable in quantity and quality. Because of this, the new impoundments are not expected to cause material damage to the hydrologic balance outside the proposed mine permit boundary.

The Brook Mine Permit Application (2020) has identified all surface water rights within the proposed permit area and within a three mile radius of the proposed permit area, and the CHIA displays the surface water rights within the surface water evaluation area in Figure 50. Many of the surface water rights immediately downstream of the proposed Brook Mine on the Tongue River are for ditches associated with irrigation use. Given the analysis in this CHIA, it is unlikely the proposed Brook Mine would affect surface water flows sufficient to impair the water rights on the Tongue River downstream of the proposed mine. In the event that a water right is determined to be impacted by mining, the Brook Mine Permit Application (2020) contains a commitment to replace all water rights affected by mining.

Following coal removal, drainages at the proposed Brook Mine will be reconstructed to AOC. Pre-mine drainage basin characteristics have been characterized to ensure appropriate reconstruction and function in the PMT. Post-mine drainage basin characteristics such as drainage area, channel length, basin relief, valley slope, drainage density, and stream sinuosity are designed to be similar to the pre-mining condition (Brook Mine Permit Application, 2020). Due to the limited extent of surface disturbance associated with the primary mining method of highwall mining, there are very minor predicted changes in post-mining drainage basin characteristics. Given the minimal predicted changes in post-mine geomorphic conditions, there should be little change in runoff potential and post-mining surface water quantity in the surface water evaluation area should be similar to pre-mine conditions. The Brook Mine Permit Application (2020) used runoff modelling to predict post-mine peak flows and runoff volumes for the drainages within the proposed permit boundary for storms of varying recurrence intervals. The results showed that the predicted post-mining peak flows and runoff volumes were less than one percent different than the pre-mining values.

In summary, the analysis from this CHIA and information in the Brook Mine Permit Application (2020) indicates that the proposed mining will not cause a significant long-term or permanent adverse change to water quantity such that downstream surface water rights would be affected. The Brook Mine proposes to use surface water rights to account for the majority of the mine’s water supply needs. Any new surface water rights needing to be obtained for mine water supply needs would be subject to WSEO approval under evaluation of the Yellowstone River Compact, which will require that bypass or make-up water be made available. A slight increase in post-mine water retention capacity (35.45 ac-ft) is also predicted due to the addition of two new permanent post-mine impoundments to support the post-mine land use. The impoundments will
be subject to WSEO approval under the Yellowstone River Compact, which will require that bypass or make-up water be made available, and should not affect downstream water rights. In the event that downstream water rights are affected by the mine operation, the Brook Mine Permit Application (2020) has committed to providing a replacement water source similar in quantity and quality. Surface water right replacement may include establishing new impoundments, development of diversions of existing water rights, or establishing a system of pipelines for stock tanks (Brook Mine Permit Application, 2020). Therefore, there is no potential for the proposed Brook Mine to cause material damage to surface water quantity outside the permit area.

Monitoring of water quantity will continue at the surface water monitoring stations at the proposed Brook Mine up until final bond release to evaluate performance standards and reclamation success (see Table 18, Figure 52).

7.1.2 WATER QUALITY

Surface water quality will be evaluated to determine if coal mining at the proposed Brook Mine will cause impacts to surface water quality downstream of the proposed mine permit boundary. The available surface water quality data were evaluated for the baseline period in each of the major drainages within the surface water evaluation area (see Section 3.1.1). Summary statistics were compiled, and water quality differences between stations were discussed. The frequency of water quality standard exceedances was also examined. In addition to that analysis, the following will evaluate factors at the proposed Brook Mine that relate to the evaluation of material damage potential to surface water quality, including: use of hydrologic and sediment control measures, extent of surface disturbance, and reclamation practices. Material damage to surface water quality is presumed to occur if the analysis demonstrates that coal mining will cause a significant long-term or permanent adverse change such that WDEQ/WQD surface water quality standards and classes of use are no longer met.

The proposed Brook Mine established surface water quality monitoring stations on Hidden Water Creek and Slater Creek within the proposed permit boundary; no station was established on East Fork Earley Creek due to the minimal surface disturbance in the watershed (Brook Mine Permit Application, 2020). On Hidden Water Creek, no water quality samples were collected at the two Brook Mine stations due to lack of streamflow during the monitoring period. Therefore, data from the discontinued Big Horn Mine station (HWC1-79) were used to supplement water quality characterization of Hidden Water Creek (see Section 3.1.1). From 1979 to 1989, nine samples were collected at HWC1-79, showing infrequent exceedances of WDEQ/WQD Class 3B water quality standards. On Slater Creek within the proposed Brook Mine permit boundary, two water quality samples were collected at the upstream station and three samples were collected at the downstream station during the baseline period of data collection. There were no exceedances of WDEQ/WQD Class 3B water quality standards at either station (see Section 3.1.1.2). It is expected that during and post-mining water quality on Hidden Water Creek and Slater Creek will continue to support WDEQ/WQD Class 3B standards, although occasional exceedances may occur due to natural or non-mining factors. Continued monitoring and comparisons between stations upstream and downstream of mining disturbance will be used to evaluate water quality standard exceedances and material damage potential in the future. All existing reservoirs and stockponds that will be disturbed will also be sampled for water quality on a quarterly basis (see Table 18, Figure 52) (Brook Mine Permit Application, 2020).
Water quality data were also analyzed on Goose Creek and the Tongue River adjacent to the proposed Brook Mine (see Sections 3.1.1.4 and 3.1.1.5). On Goose Creek, 79 samples collected at Big Horn Mine station GC00-78 for the March 2000 to September 2019 period showed one exceedance each of cadmium and iron, and five temperature exceedances. The overall data indicate that Goose Creek infrequently exceeds water quality standards, although it is important to note that bacteria data such as fecal coliform and E. coli were not collected at the GC00-78 station. In 2000, Goose Creek was placed on Wyoming’s Section 303(d) list for impaired water quality due to fecal coliform (Wyoming Department of Environmental Quality, 2018). In 2006, the same segment of Goose Creek was placed on the 303(d) list for impaired water quality due to habitat alterations and sediment (Wyoming Department of Environmental Quality, 2018). The 2010 TMDL for Goose Creek identifies several possible E. coli sources that contribute to water quality impairment including septic systems, livestock, wildlife, domestic animals, municipal stormwater outfalls, and wastewater treatment plants (SWCA Environmental Consultants, 2010). It is predicted that the proposed Brook Mine will not affect water quality in Goose Creek since the channel will remain undisturbed and sediment control will be used on disturbed contributing areas. Water quality on lower Goose Creek will continue to be affected by land uses in the watershed upstream of the proposed Brook Mine.

On the Tongue River, water quality is also affected by land uses in the watershed upstream of the proposed Brook Mine. The Goose Creek tributary also is suspected to affect water quality in the Tongue River (Wyoming Department of Environmental Quality, 2018). In 2002, the WDEQ/WQD placed the Tongue River from the Goose Creek confluence downstream to the Montana state line on Wyoming's Section 303(d) list for impaired water quality due to elevated water temperatures (Wyoming Department of Environmental Quality, 2018). The reasons for the higher temperatures are unknown. Another 13.5 mile segment of the Tongue River from Monarch Road upstream to Wolf Creek Road was placed on the 303(d) list in 2010 due to E. coli exceedances that impair recreation use (Wyoming Department of Environmental Quality, 2018). In 2018, a 4.7 mile segment of the Tongue River from the confluence with Goose Creek upstream to Monarch Road was added to the 303(d) list due to E. coli exceedances (Wyoming Department of Environmental Quality, 2018).

Seventy nine water quality samples were evaluated from the Tongue River at Big Horn Mine stations TR0176 and TR2B80 for the March 2000 to September 2019 time period. At TR0176, the maximum concentrations of iron and water temperature exceeded WDEQ/WQD Class 2AB water quality standards. Downstream at TR2B80, there were nine temperature exceedances occurring from 2002 to 2018 (Table 2).

The proposed Brook Mine collected water quality samples on the Tongue River and the Tongue River Ditch in 2018 and 2019. The only water quality exceedances noted at the three sites was for water temperature (Table 10), which is consistent with the data history at the Big Horn Mine sites and the WDEQ/WQD 303(d) listing for temperature on the Tongue River in this location. The overall data from the Big Horn Mine and proposed Brook Mine Tongue River data show that water temperature is the primary concern for the Tongue River upstream and downstream of the Big Horn Mine and Goose Creek tributary. Since the proposed Brook Mine will not be directly disturbing either the Tongue River or Goose Creek channels, the proposed mining should have no effect on water temperature in the Tongue River.

Potential increases in erosion and sediment yield during mining at the proposed Brook Mine will be mitigated through a hydrologic and sediment control plan, which includes the use of
alternative sediment control measures (ASCMs) and sediment ponds (Brook Mine Permit Application, 2020). Sediment control measures will help disconnect the disturbed areas from the stream network, helping to protect water quality.

The proposed Brook Mine will use ASCMs across the disturbed area to slow overland flow and filter sediment, helping to protect downstream water quality. ASCMs to be used would include surface roughening, diversion ditches, check dams, silt fences, straw wattles, earthen berms, sediment traps, sediment basins, seeding, and erosion control blankets (Brook Mine Permit Application, 2020). For ASCMs with a contributing drainage area greater than 30 acres, specific design details have been provided in the Brook Mine Permit Application (2020). As recommended by WDEQ/LQD Guideline No. 15 (Wyoming Department of Environmental Quality, 2004), the proposed Brook Mine will not use ASCMs as the primary sediment control within a 0.5 mile buffer to all Class 2 streams, including the Tongue River and Goose Creek. Within the 0.5 mile buffer to these streams, more traditional sediment control such as sediment ponds and the mining trenches will be used. For ASCMs that are outside the 0.5 mile buffer and drain to larger receiving streams such as Slater Creek, Goose Creek, or the Tongue River, the Brook Mine Permit Application (2020) has committed to monitoring stream channel cross sections or having upstream and downstream sediment yield monitoring stations to ensure ASCMs are functioning properly (Brook Mine Permit Application, 2020). The proposed Brook Mine has also committed to routine inspection and maintenance of all ASCMs to ensure effectiveness. When property designed, constructed, and maintained, the ASCMs should be as effective as sediment ponds in controlling erosion and protecting downstream water quality. Nearly 30 years of monitoring at the Jim Bridger Mine in southwest Wyoming has shown there is no substantial difference between the sediment yields from undisturbed watersheds and disturbed watersheds that use ASCMs as the primary sediment control, implying that ASCMs are effective in reducing sediment loads from drainages disturbed by surface mining activities (Jim Bridger Mine Permit, 2020; Wyoming Department of Environmental Quality, 2019d).

The Brook Mine will use one sediment pond in the first five years of mining to further control erosion and protect downstream water quality (Brook Mine Permit Application, 2020). Additional sediment ponds are proposed for later years of mining; designs for these ponds are either in the Brook Mine Permit Application (2020) or will be submitted in a subsequent term of the permit. Six of the ponds proposed at this time are located within the 0.5 mile buffer to Goose Creek and the Tongue River. The sediment ponds will be total-containment impoundments without spillways; the ponds will be designed to contain the 10-year, 24-hour precipitation event and will be maintained with a minimum of one year's available sediment storage capacity. The proposed Brook Mine has committed to routine inspection and maintenance of all sediment ponds to ensure effectiveness. The mining trenches at the proposed Brook Mine will also provide sediment control. In the event that it is necessary to discharge from the sediment ponds or mining trenches, the point source discharges will monitored by the WYPDES program with the WDEQ/WQD to ensure water quality is not degraded (Brook Mine Permit Application, 2020).

Other hydrologic control features at the proposed Brook Mine will also serve to help protect downstream water quality. These other features include flood control reservoirs, temporary diversions, collector and bypass ditches, and culverts. These features will be designed such that they prevent erosion and help route and convey runoff away from disturbed areas. The proposed Brook Mine has committed to routine inspection and maintenance of all culverts to ensure proper function. In the event that it is necessary to discharge from the flood control reservoirs, the point
source discharges will monitored by the WYPDES program with the WDEQ/WQD to ensure water quality is not degraded (Brook Mine Permit Application, 2020).

Based on the above discussion, and assuming sediment control measures and hydrologic control features are properly designed, constructed, and maintained, the proposed Brook Mine is not predicted to cause material damage to downstream surface water quality. In addition to sediment control measures, the proposed Brook Mine will establish a 100-foot buffer on either side of Slater Creek within the proposed permit boundary (Brook Mine Permit Application, 2020). The buffer has been displayed on a map within the permit application and will also be marked in the field prior to commencing surface disturbance. The buffer will help protect water quality of Slater Creek flowing within the proposed boundary, and will therefore help protect downstream water quality on the Tongue River.

Within the proposed permit area, the Brook Mine will be directly disturbing 1,135.1 acres over the 39-year life of the mine, or approximately nine percent of the surface water evaluation area. As discussed previously, the proposed Brook Mine does not anticipate that subsidence will occur following mining, but a subsidence monitoring and mitigation plan has been proposed to address subsidence if it does occur. Although 1,135.1 acres are proposed to be disturbed by the proposed mine, the entire area would not be disturbed at once due to the planned mining sequence and the practice of contemporaneous reclamation. Based on the limited amount of acreage affected relative to the size of the surface water evaluation area, there is a low probability for mining to cause detectable changes in water quality on the Tongue River. Dilution from streamflow generated in the 911 mi² watershed upstream of the mouth of the surface water evaluation area also helps negate any potential impacts to water quality on the Tongue River. Water quality on the Tongue River downstream of the proposed mine will continue to be more affected by conditions in the watershed upstream of the proposed Brook Mine and also the Goose Creek tributary.

The potential for acid drainage to occur during mining and after reclamation at the proposed Brook Mine is expected to be minimal. Pre-mine overburden core samples demonstrated little concerns with ABP, which is used by the WDEQ/LQD to indicate acid-forming potential. The minimum ABP value for four of the 18 cores did exceed the criteria of <5 tons CaCO₃/1000 tons set by WDEQ/LQD Guideline No. 1 (Wyoming Department of Environmental Quality, 1984). An ABP result of less than -5 tons CaCO₃/1000 tons indicates there is an acid-forming potential for both the surface (potential root zone) and aquifer restoration. However, the average ABP values, which are more representative of what will exist after the materials are mixed during reclamation, were all greater than -5 tons CaCO₃/1000 tons (Brook Mine Permit Application, 2020). The lowest average ABP value from one of the holes was 16.9. The Brook Mine Permit Application (2020) commits to use prudent handling and mixing of any zones of concern to meet the criteria set by LQD Guideline No. 1.

Reclamation practices at the proposed Brook Mine will help ensure that the post-mine surface water quality is similar to the pre-mine water quality. Some of the relevant reclamation practices include: (1) salvaging and replacing topsoil in a manner that prevents compaction, protects erosion, and conserves soil moisture, (2) covering all unsuitable spoils with a minimum of four feet of suitable material prior to replacing topsoil, with the thickness of suitable material increasing to six feet in areas under ephemeral channels and ten feet under intermittent channels, and (3) designing reconstructed landscapes to be erosionally stable, which will help minimize soil loss. WDEQ/LQD Phase 2 Bond Release requirements include demonstration of adequate surficial stability to ensure conditions on reclaimed lands will not: (1) preclude achievement of post-mining
land uses, (2) preclude establishment of vegetative cover, and (3) cause or contribute to a violation of water quality standards (Wyoming Department of Environmental Quality, 2019e). These conditions are used to demonstrate that drainage from the reclaimed unit does not need to pass through a sediment pond or ASCM structure.

As discussed in Section 6.1.1, there are minimal changes predicted in post-mine geomorphic conditions at the proposed Brook Mine. Similar post-mine geomorphic conditions will help ensure that post-mine surface water quality will be similar to pre-mine conditions. Furthermore, the two proposed permanent post-mine impoundments at the Brook Mine will be designed to meet the water quality criteria associated with the designated land use (Brook Mine Permit Application, 2020).

In summary, during and post-mine water quality from the drainages on the proposed Brook Mine permit area is not expected to be degraded by the mining operation. Water quality is expected to meet WDEQ/WQD standards for class of use, although periodic exceedances of dissolved metal criteria for aquatic life may occur due to other non-mining related factors, as noted during the baseline monitoring period on some of the streams. Water quality on Goose Creek and the Tongue River should also not be degraded by the proposed mining and will continue to be affected by non-mining land use factors. The analysis from this CHIA and information in the Brook Mine Permit Application (2020) indicates that the proposed mining will not cause a significant long-term or permanent adverse change such that WDEQ/WQD surface water quality standards and classes of use are no longer met. Therefore, the proposed Brook Mine is not predicted to cause material damage to surface water quality outside the permit area. Monitoring of water quality will continue at the surface water monitoring stations and reservoirs at the proposed Brook Mine up until final bond release to evaluate performance standards and reclamation success (see Table 18, Figure 52) (Brook Mine Permit Application, 2020). Surface water monitoring by the Big Horn Mine and the USGS on Goose Creek and the Tongue River in the vicinity of the proposed Brook Mine is also expected to continue (see Table 18, Figure 52).
### Table 18. Operational surface water monitoring stations at the proposed Brook Mine and other active stations on Goose Creek and the Tongue River operated by the Big Horn Mine and the USGS. The location of the stations is shown in Figure 52.

<table>
<thead>
<tr>
<th>Entity</th>
<th>Station Name/Number</th>
<th>Stream/Reservoir Name and Location</th>
<th>Type and Frequency of Measurement</th>
<th>Source</th>
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<tr>
<td>Brook Mine</td>
<td>SM570409-SW-1</td>
<td>Hidden Water Creek – upstream</td>
<td>CS, Q</td>
<td>TFN 6 2/025: Mine Plan Table MP.7-1</td>
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<td>Slater Creek – downstream</td>
<td>CS, QM</td>
<td>TFN 6 2/025: Mine Plan Table MP.7-1</td>
</tr>
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<td>Brook Mine</td>
<td>578514-TR-1</td>
<td>Tongue River – upstream</td>
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<td>TFN 6 2/025: Mine Plan Table MP.7-1</td>
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<td>Brook Mine</td>
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<td>Tongue River at Highway 33H</td>
<td>L, Q</td>
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<tr>
<td>Brook Mine</td>
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<td>Tongue River at USGS 062999B0</td>
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<td>Tongue River near Acme, WY</td>
<td>L, Q</td>
<td>USGS: <a href="https://waterdata.usgs.gov/nwis">https://waterdata.usgs.gov/nwis</a></td>
</tr>
</tbody>
</table>

**Note:**
- **CS:** Continuous streamflow measurements from approximately April 30 through October 1 or first hard freeze.
- **Q:** Quarterly water quality sample for WDEQ/LQD Guideline No. 8 parameters (dominant ions, select dissolved metals, and nutrients) (Wyoming Department of Environmental Quality, 2015b).
- **QM:** Monthly water quality sample for WDEQ/LQD Guideline No. 8 parameters (dominant ions, select dissolved metals, and nutrients) (Wyoming Department of Environmental Quality, 2015b).
- **A:** Alternate streamflow measurement site for Station 578524-TR-1.
- **I:** Instantaneous streamflow measurement at the time of water quality sampling.
- **C:** Continuous streamflow measurements throughout the year.
- **T:** April, June, and September water quality sample for WDEQ/LQD Guideline No. 8 parameters (dominant ions, select dissolved metals, and nutrients) (Wyoming Department of Environmental Quality, 2015b).
- **L:** Biannual water quality sample for reduced parameter list.
- **M:** Monthly water quality sample for dominant ions and select dissolved metals.
- **¹**: Flow measurement taken at USGS 06305700.
- **º**: Funded by the USGS Groundwater and Streamflow Information Program as Federal Priority Streamgage.
- **²**: Partner funding provided by the WDEQ/WQD WYPDES Program.
- **³**: Partner funding provided by the WDEQ/LQD.
Figure 52. Operational surface water monitoring stations at the proposed Brook Mine and other active stations at and near Goose Creek and the Tongue River operated by the Big Horn Mine and the USGS.
7.2 GROUNDWATER

The potential for the proposed Brook Mine to cause material damage to groundwater in the aquifers of interest outside the proposed mine permit boundary was evaluated in this CHIA. The analyses for this evaluation included:

1. Delineation of the horizontal and vertical extents of the groundwater evaluation area (Section 2.2).
2. Baseline data characterization of the pre-mining hydrologic conditions (Section 3.2).
3. Predicted future hydrologic conditions and predicted hydrologic impacts (Section 6.2).

Groundwater hydrologic concerns within the groundwater evaluation area were identified in Section 4.2 and the material damage criteria and material damage indicators were defined in Section 5.2. The approach used to evaluate the material damage criteria and material damage indicators was to use the information provided in the Brook Mine Permit Application (2020) and to evaluate the potential for any additional impacts that may cause material damage outside the proposed mine permit boundary.

7.2.1 MATERIAL DAMAGE INDICATORS

Contemporaneous reclamation at other coal mines in Wyoming has provided the opportunity to identify three material damage indicators that are related to the contemporaneously reclaimed backfill aquifer within the proposed mine permit boundary. A summary of the material damage indicators is presented below.

7.2.1.1 PHYSICAL CHARACTERISTICS OF THE BACKFILL AQUIFER

The Brook Mine Permit Application (2020) proposes to install backfill monitoring wells across the proposed permit area. Continued monitoring of the backfill aquifer will be needed and additional analyses will be required as more data become available. Based on the estimates presented in the Brook Mine Permit Application (2020), the backfill aquifer will have sufficient permeability for groundwater flow. The backfill aquifer will also have sufficient permeability to yield sufficient quantities of water to meet the proposed post-mining land use of livestock and wildlife.

7.2.1.2 GROUNDWATER LEVEL RECOVERY IN THE BACKFILL AQUIFER

The Brook Mine Permit Application (2020) estimates that the time period for the impacted aquifers to achieve steady state conditions is about five to 10 years. From the material damage evaluation perspective, the area of interest is outside of the permit areas (W.S. § 35-11-406(n)(iii)). It is important to note that these recovery time periods are for mostly for the areas within the proposed mine permit boundary where the material damage assessment is not applicable. Therefore, it is more reasonable to evaluate the groundwater level recovery in the backfill aquifer as a material damage indicator than as a material damage criterion.

Viability of the backfill aquifers for the proposed post mining use would likely be attained before the 10 years of full recovery estimate. The recovery rate at a specific location in the backfill
The Brook Mine Permit Application (2020) proposes to install backfill monitoring wells across the proposed permit area. Continued monitoring of the backfill aquifer will be needed and additional analyses will be required as more data become available. The Brook Mine Permit Application (2020) also commits to using single-well or multi-well aquifer pump tests to determine the hydraulic properties of the backfill aquifer. In addition, infiltration tests will be used to determine infiltration rates on reclaimed areas. Based on the model predictions, it is expected that the backfill aquifer will be a viable supply source to support the proposed post-mining land use of livestock and wildlife.

7.2.1.3 GROUNDWATER QUALITY IN THE BACKFILL AQUIFER

The analyses from Brook Mine Permit Application (2020) indicate that the potential for the backfill groundwater to migrate to and affect the adjacent undisturbed native aquifers outside the proposed mine permit boundary would be minimal and localized. Some of the significant items of note are:

- During removal and replacement of the overburden to backfill the mine pits and trenches appropriate measures are taken to ensure that the water quality of the reclaimed backfill aquifer will not be degraded such that post-mining land uses cannot be supported.

- It is generally expected that over time, the backfill aquifer will be flushed by groundwater flowing through the reclaimed material and down gradient to the southeast. Thus, the water quality in the backfill is expected to improve over time.

- The data from the backfill aquifer need to be continuously evaluated.

On March 14, 2003, the WDEQ/LQD approved Change No. 11 to Term 5 of the Big Horn Mine permit, which approved groundwater restoration at the mine, releasing the mine from groundwater monitoring requirements (Big Horn Mine Permit, 2020). Based on the predictions from the Brook Mine Permit Application (2020) and the observed data from the Big Horn Mine, it is expected that the backfill aquifer will be a viable supply source to support the proposed post-mining land use of livestock and wildlife. Therefore, groundwater migrating from the backfill aquifer to the native aquifers outside the mine permit boundary is expected to have a minimal effect and would not affect the ability of the existing wells to supply for their intended use. The three material damage indicators suggest that there is limited potential for the proposed mining operation to cause material damage to the native aquifers outside the proposed mine permit boundary.

7.2.2 MATERIAL DAMAGE CRITERIA

The material damage criteria are examined for groundwater quantity and quality. The finding that the proposed mining operations at the Brook Mine are designed to prevent material damage to the hydrologic balance outside the permit areas is supported by the evaluation conducted in this CHIA and is summarized in Table 19 for the aquifers of interest within the evaluation area. Potential impact mitigation strategies are also presented in Table 19. As noted in
Section 2, the proposed Brook Mine is hydrologically isolated and there are no cumulative groundwater hydrologic impacts with other coal mines outside the permit boundary. Therefore, there is no potential for cumulative hydrologic impacts in the evaluation area.

Impacts to water supplies are addressed on an individual basis either by the WSEO interference process or by W.S. § 35-11-415(b)(xii) and W.S. § 35-11-416 (b) which requires, within the constraints of the law, replacement of a water supply that has been affected by surface coal mine operations. The Brook Mine Permit Application (2020) has committed to this requirement.

The predicted groundwater effects were evaluated within the groundwater evaluation area. Although coal mining will have impacts, based on available data, information presented in the mine permit application, and analysis in this CHIA, material damage to groundwater quantity and groundwater quality outside the proposed mine permit boundary is not expected.
Table 19. Summary of groundwater material damage analyses in the CHIA and potential impact mitigation strategies.

<table>
<thead>
<tr>
<th>Aquifer</th>
<th>Sections in the CHIA with Relevant Analyses</th>
<th>Primary Reasons for No Material Damage Finding</th>
<th>Impact Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alluvial</td>
<td>3.2.3.1, 3.2.4.1, 6.2.1</td>
<td>As shown for baseline and current conditions, the general direction of groundwater flow in the alluvial aquifer currently follows the topography towards the downstream or down valley direction. Therefore, the effects of mining are expected to be minimal on the upstream undisturbed alluvial aquifer outside the proposed Brook Mine permit boundary to the west.</td>
<td>The alluvium of Goose Creek and the Tongue River will not be physically disturbed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>There are multiple claystone intervals between the Carney coal and the surface. The confining claystone intervals provide a barrier from mining activities significantly affecting the alluvial aquifer in the vicinity of the proposed Brook Mine permit boundary. There is minimal hydrologic connection between the Tongue River alluvium and Carney coal. Lab permeability tests were conducted by the proposed Brook Mine for the confining units above and below the coal seams. The lab results indicate that the overburden and underburden units are comprised of predominantly clay with low hydraulic conductivity. The hydraulic conductivity of the Carney overburden and Carney interburden is at least three orders of magnitude lower than the hydraulic conductivity of the coal seams. In addition, the aquifer pumping tests conducted by the proposed Brook Mine to evaluate the potential communication between the Tongue River alluvium and the Carney Coal indicate that confining claystone intervals are a hydrologic barrier between the coal seam and the Tongue River alluvium. The mining-induced drawdown simulated by the groundwater model is less than 0.1 feet in the Tongue River alluvium. Maximum impacts are expected to occur in areas where the overburden is thin (near coal seam subcrops) and the impacts are of short duration. The data from Big Horn Mine station T90376 and USGS Station No. 06299948 indicates that the Tongue River annual mean daily flows over the 2002 to 2018 period ranged from a low of 99 cfs in 2004 to a high of 577 cfs in 2011. The groundwater model has estimated that the maximum pit inflows during mining is about 0.056 cfs. Compared to the Tongue River low flow of 99 cfs, the estimated pit flows are 0.06 percent of the flows in the Tongue River. The estimated amount of groundwater pumped by Brook Mine is minimal compared to the water budget of the hydrologic system that includes Tongue River.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Based on the proposed mine plan, hydrogeologic properties of the alluvium, interburden and coal seams and the groundwater model predictions, the effects of any groundwater level drawdowns caused by mining to the Tongue River alluvium will be minimal.</td>
<td></td>
</tr>
<tr>
<td>Carney coal</td>
<td>3.2.3.2, 3.2.4.2, 6.2.2</td>
<td>Most of the wells within the groundwater evaluation area are stock or domestic wells with intermittent pumping. The groundwater model estimates a predicted drawdown of greater than zero feet at five wells. The largest model predicted impact seen at any existing well outside of the proposed Brook Mine permit boundary is 3.3 feet. This impact is estimated to be temporary (approximately four years). Model predicted drawdowns at the rest of the wells are less than two feet. The field data collected by the mine indicate that the Carney coal is predominantly dry with limited saturation in the western portions of the proposed permit area. These predictions are consistent with the expected groundwater impacts while mining occurs in areas where Carney coal is dry. A recovery to a residual drawdown of less than five feet is predicted by the groundwater model in the Upper Carney and the Lower Carney coal seams within 15 years from cessation of mining. Most of the estimated recovery occurs within the first five years as recovery versus time follows an exponential curve. The magnitude of the decrease in the potentiometric surface is a lognormal relation to time and space, the drawdowns outside the proposed permit boundary in the native coal aquifers are expected to be less than the drawdowns adjacent to the coal mine pits. The impacts on groundwater levels and groundwater quality in the undisturbed native aquifers outside the proposed mine permit boundary are expected to be minimal and less than the impacts observed inside the proposed permit boundary.</td>
<td>Contemporaneous reclamation</td>
</tr>
<tr>
<td>Masters coal</td>
<td>3.2.3.3, 3.2.4.3, 6.2.3</td>
<td>From the material damage evaluation perspective, the area of interest is outside of the permit areas (W.S. § 35-11-406(3)(ii)). Masters coal seam will remain structurally undisturbed and will not be mined by Brook Mine. The predicted drawdowns in the Masters coal seam are mainly within the proposed permit area but may extend one-half to one mile from the mine pit in few areas. In addition, the magnitude of the decrease in the potentiometric surface is a lognormal relation to time and space, and the drawdowns outside the permit boundary in the native coal aquifers are expected to be less than the drawdowns adjacent to the coal mine pits. A recovery to a residual drawdown of less than five feet is predicted by the groundwater model in the Masters coal seam within five years from cessation of mining. Most of the estimated recovery occurs within the first five years as recovery versus time follows an exponential curve. The impacts on groundwater levels and groundwater quality in the undisturbed native aquifers outside the proposed mine permit boundary would depend on the hydrologic connection with the backfill aquifer and on the groundwater quality of the groundwater migrating from the backfill aquifer. The backfill aquifer water quality is expected to meet the WDEQ/WQD standards for livestock use. On a regional scale, the groundwater migrating from the backfill aquifer is not expected to significantly affect the groundwater quality of the coal aquifer outside the proposed mine permit boundary.</td>
<td>Contemporaneous reclamation</td>
</tr>
<tr>
<td>Underburden</td>
<td>6.2.4</td>
<td>Outside the mined out areas, the aquifers overlying the underburden aquifer would remain structurally undisturbed. In addition, the relatively lower hydraulic conductivity of the underburden aquifer supports that coal mining would have limited effects on the underburden groundwater system and these effects will be declining with increasing distance from the proposed mine permit boundary.</td>
<td>Contemporaneous reclamation</td>
</tr>
</tbody>
</table>
7.3 ALLUVIAL VALLEY FLOORS

As discussed in Section 3.3, the only AVFs that have been determined to be not subject to statutory exclusions are on the Tongue River and Slater Creek adjacent to the proposed Brook Mine, as well as on the Tongue River downstream of the Big Horn Mine (Figure 49). Because these AVFs are not subject to statutory exclusions, the CHIA will conduct a material damage assessment for these AVFs by considering the potential for changes in surface water quantity, surface water quality, alluvial water levels, and alluvial water quality. The other AVFs at the proposed Brook Mine are on undeveloped rangeland which is not significant to farming. For these AVFs, the CHIA does not conduct a material damage assessment.

7.3.1 SURFACE WATER QUANTITY

The proposed Brook Mine is not predicted to cause material damage to the AVFs that are adjacent to the permit boundary or the downstream AVFs on the Tongue River that are significant to farming. The analysis from this CHIA and information in the Brook Mine Permit Application (2020) indicates that the proposed mining will not cause material damage to the hydrologic components that support the AVFs. The AVFs would not be physically disturbed and physical use would not be limited by fencing or access. As discussed in Section 3.3, in January 2020 the WDEQ/LQD determined that the adjacent AVFs would not be affected by the proposed Brook Mine and there was no potential for mining activities to interrupt, discontinue, or preclude agricultural activities.

The proposed Brook Mine will have no effect on surface water quantity in the adjacent AVF on Slater Creek since this AVF is upstream of all proposed disturbance. Due in part to the limited disturbance area associated with the proposed highwall mining method, the proposed Brook Mine is not predicted to cause detectable changes in streamflow on Goose Creek and the Tongue River. Flood irrigation potential of the downstream AVFs should be maintained throughout the proposed mining operation. Runoff and streamflow generated from the watershed upstream of the AVFs will continue to supply surface water to support the AVFs on the Tongue River adjacent to the permit area and those downstream of the Big Horn Mine. Furthermore, the proposed Brook Mine does not propose to remove or affect the surface irrigation systems that supply water to the adjacent AVFs.

As discussed in Section 7.1.1, the proposed mining is not expected to cause reductions in water quantity sufficient to impact water rights adjacent to or downstream of the permit boundary, including those associated with irrigation of the adjacent or downstream AVFs. In the event that a non-mine water right is impacted by mining activities, the law and permits require water supply to be replaced by a source suitable in quantity and quality. Any new surface water rights needing to be obtained for water supply at the proposed Brook Mine would be subject to WSEO approval under evaluation of the Yellowstone River Compact, which will require that bypass or make-up water be made available. A slight increase in post-mine water retention capacity (35.45 ac-ft) is also predicted due to the addition of two new permanent post-mine impoundments to support the post-mine land use. The impoundments will be subject to WSEO approval under the Yellowstone River Compact, which will require that bypass or make-up water be made available. The new impoundments are not expected to affect downstream water rights. In the event that downstream water rights are affected by the mine operation, the Brook Mine Permit Application (2020) has committed to providing a replacement water source similar in quantity and quality. Therefore, any
downstream surface water rights that support irrigation of the adjacent or downstream AVFs will be protected and the potential for material damage to the AVFs is negligible.

7.3.2 SURFACE WATER QUALITY

The analysis from this CHIA and information in the Brook Mine Permit Application (2020) indicates that the proposed mining will not cause material damage to water quality of the Tongue River, which support the downstream AVFs. The proposed Brook Mine will have no effect on surface water quality in the adjacent AVF on Slater Creek since this AVF is upstream of all proposed disturbance. As discussed in Section 7.1.2, during-mining and post-mine water quality from the drainages on the proposed Brook Mine permit area is not expected to be degraded by the mining operation. Sediment control measures will help disconnect the disturbed areas from the stream network, helping to protect downstream water quality. Water quality on Goose Creek and the Tongue River should not be degraded by the proposed mining and will continue to be affected by non-mining land use factors. The analysis from this CHIA and information in the Brook Mine Permit Application (2020) indicates that the proposed mining will not cause a significant long-term or permanent adverse change such that WDEQ/WQD surface water quality standards and classes of use are no longer met. Therefore, the proposed Brook Mine is not predicted to cause material damage to surface water quality on the Tongue River AVFs adjacent to the proposed Brook Mine and downstream of the Big Horn Mine.

7.3.3 ALLUVIAL WATER LEVELS

As discussed in Section 6.2.1, the proposed Brook Mine is not expected to cause significant long-term permanent changes in groundwater levels in the alluvial aquifer of the Tongue River. The mining-induced drawdown simulated by the groundwater model in the Brook Mine Permit Application (2020) is less than 0.1 feet in the Tongue River alluvium. Maximum drawdowns are expected to occur in areas where the overburden is thin near coal seam subcrops, and the drawdowns are of short duration. The estimated amount of groundwater pumped by Brook Mine is minimal compared to the water budget of the hydrologic system that includes Tongue River (Table 19). Therefore, increased infiltration into the groundwater system and associated streamflow losses from the Tongue River are expected to be marginal (Brook Mine Permit Application, 2020). It is assumed that if groundwater level drawdowns in Tongue River alluvium directly adjacent to the proposed Brook Mine are minimal, there should also be no drawdowns in the Tongue River AVFs downstream of the Big Horn Mine. Therefore, subirrigation of the adjacent and downstream AVFs should be maintained throughout the proposed mining operation. The proposed Brook Mine would have no effect on alluvial water levels in the adjacent AVF on Slater Creek since this AVF is upstream of all proposed disturbance. This interpretation is consistent with the groundwater model predictions that showed no discernible drawdowns in the vicinity of this AVF.

The Brook Mine Permit Application (2020) has committed to monitoring the declared AVFs on the Tongue River adjacent to the permit boundary by monitoring aerial color infrared imagery, alluvial wells, and surface water. This monitoring will be used to evaluate the essential hydrologic functions and subirrigation extent of the AVFs on Slater Creek, Goose Creek, and the Tongue River adjacent to the proposed mine permit boundary. It is assumed that monitoring data from the adjacent AVFs will also provide a surrogate of the hydrologic conditions that exist in the AVFs on the Tongue River further downstream.
7.3.4 ALLUVIAL WATER QUALITY

Assuming the proposed Brook Mine will not affect surface water quality in the Tongue River and that mining will cause minimal drawdowns in the alluvium of the Tongue River, the proposed Brook Mine should have no effect on alluvial water quality in the adjacent area and downstream Tongue River AVFs. As discussed in Section 7.3.3, the monitoring of the three alluvial wells in the Tongue River adjacent to the proposed Brook Mine will also provide insight into possible alluvial water quality changes at the AVFs downstream of the proposed mine. The proposed Brook Mine will have no effect on alluvial water quality in the adjacent AVF on Slater Creek since this AVF is upstream of all proposed disturbance.
8. MATERIAL DAMAGE STATEMENT OF FINDINGS

Based on the information in the Brook Mine Permit Application (TFN 6 2/025) and the analysis in this cumulative hydrologic impact assessment (CHIA), the WDEQ/LQD has determined that the mining proposed by the Brook Mine has been designed to prevent material damage to the hydrologic balance outside the proposed mine permit area. The proposed operation will also not materially damage the quantity or quality of water in surface or underground water systems that supply alluvial valley floors (AVFs) not subject to statutory exclusions.

Todd Parfitt  
Director  
Wyoming Department of Environmental Quality  

Greg Lanhing  
Wyoming State Engineer  
Wyoming State Engineer's Office  

Date  
7/1/2020  

Date  
7/2/20
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ADDENDUM A: AGENCY REVIEW COMMENTS ON CHIA-39

The following contains the agency review comments on CHIA-39 for the proposed Brook Mine. The Wyoming State Engineer’s Office reviews the surface and groundwater quantity aspects of the CHIA and the Wyoming Department of Environmental Quality Water Quality Division reviews the surface and groundwater quality aspects of the CHIA.

The CHIA was reviewed by the agencies during the public notice and comment period for the permit application. Reviews and concurrence on the CHIA findings were initially received from the agencies in April 2020. During this time, a review letter was also received from the Wyoming Game and Fish Department, which is included below. Based on public comments on the draft CHIA and internal review, the CHIA was revised for agency review and a second concurrence was received in June and July 2020. The concurrence letters from the second review are included below along with associated comments received during both the first and second reviews. A copy of the WDEQ/LQD responses to applicable comments received during the first agency review is included below. It was determined that a WDEQ/LQD response was not needed for the comments receiving during the second review.
July 1, 2020

Mr. Alan Edwards, Deputy Director  
Wyoming Department of Environmental Quality  
200 W. 17th St.  
Cheyenne, WY 82002


Dear Mr. Edwards:

The Watershed Protection Program and Groundwater Pollution Control Program of the Water Quality Division have reviewed the Department of Environmental Quality, Land Quality Division’s Revised Draft Cumulative Hydrologic Impact Assessment of the Proposed Brook Mine, Upper Tongue River Basin, Wyoming (TFN 6 2/025) (CHIA #39).

Based on our review of the data and analysis presented in the draft CHIA, both Programs are in agreement with the conclusions of the draft CHIA that the proposed operation has been designed to prevent material damage to the hydrologic balance outside the permit area and the proposed operation will not materially damage the quantity or quality of water in surface or underground water systems that supply alluvial valley floors (AVFs) not subject to statutory exclusions.

Sincerely,

Kevin Frederick  
Administrator, Water Quality Division

Attachments: Staff Reviews

cc: David Waterstreet, WQD Cheyenne  
Lily Barkau, WQD Cheyenne  
Muthu Kuchanur, LQD Cheyenne  
Matt Kunze, LQD Cheyenne  
Jeremy Zumberge, WQD Sheridan  
Nicole Twing, WQD Cheyenne
Kevin Frederick <kevin.frederick@wyo.gov>

CHIA #39
1 message

Nicole Twing <nicole.twing@wyo.gov>  Tue, Jun 30, 2020 at 9:02 PM
To: Kevin Frederick <kevin.frederick@wyo.gov>, Lily Barkau <lily.barkau@wyo.gov>

Kevin and Lily

I have taken a look at the revisions to the Revised CHIA #39 for the proposed Brook Mine near Sheridan, WY.

Based on the information provided in the revisions, I would agree with the conclusion that there would not be material impacts to the alluvial valley aquifers adjacent to the permit boundaries. Any potential impacts are expected to be minor (<5 ft) and short term duration. There is a proposed 100 ft buffer between any mining disturbance and Slater Creek (except for a mine road). In addition, there will be upstream and downstream monitoring conducted to assess for potential impacts to flows in the river. In addition, due to confining layers between the Carney Coal and the AVF, there is expected to be little impact to the overlying alluvium in the valley floors outside of the permit area.

Let me know if you need additional information or have any questions.

Thanks

Nicole Twing, P.G.
Groundwater Pollution Control Program
Geology Supervisor
Wyoming Dept of Environmental Quality
(307) 777-8275
nicole.twing@wyo.gov

Wyoming Department of Environmental Quality
200 W 17th Street, Suite 400
Cheyenne, WY 82002

E-Mail to and from me, in connection with the transaction of public business, is subject to the Wyoming Public Records Act and may be disclosed to third parties.
MEMORANDUM

To: Kevin Frederick, Administrator, WQD
Through: Lily Barkau, Groundwater Section Manager
From: Nicole Twing, P.G., Geology Supervisor, Groundwater Section
Date: March 27, 2020
Subject: WQD, GPC Review of Draft Cumulative Hydrologic Impact Assessment of Coal Mining associated with the Brook Mine, Upper Tongue River Basin, Wyoming

I have reviewed the above-mentioned document and have the following comments:

1. The Brook Mine is a new coal mine permit proposed by Brook Mining Co., LLC in the upper Tongue River Basin of Wyoming, approximately six miles south of the Wyoming-Montana border and approximately eight miles northwest of Sheridan. The proposed mine permit would cover 4,548.8 acres, with 1,135.1 of those acres proposed to be disturbed by mining. The groundwater cumulative impact area (CIA) is the area encompassed by the modeled five (5) foot drawdown contour. The 5-foot groundwater drawdown is limited in extent and does not cover the entire proposed permit boundary. To be conservative, the groundwater impact evaluation was extended to mimic the surface water evaluation area. The evaluation area covered approximately 20.5 square-feet.

   Largest groundwater elevation drawdowns modeled outside of the permitted mine boundary were within the Carney coal, and were estimated at 3.3 feet, with recovery within 15 years after mining cessation, with the majority of the recovery happening in the first 5 years.

2. Based upon the data and assumptions presented in CHIA #39, the proposed Brook Mine will not result in material damage to aquifer yields.

3. Based upon the data and assumptions presented in CHIA #39 the potential for material damage to shallow groundwater quality as a result of the Brook Mine appears to be limited.

END OF MEMO
MEMORANDUM

TO: Kevin Frederick
FROM: Jeremy ZumBerge
DATE: July 1, 2020


This CHIA evaluates the probable hydrologic impacts of the proposed Brook Mine. The Brook Mine is a new coal permit, proposed by Brook Mining, LLC, within the upper Tongue River Basin of Wyoming, approximately eight miles northwest of Sheridan. Mining primarily will be by highwall mining methods, with a small amount of surface strip mining also proposed. The permit would encompass 4549 acres, with up to 1135 acres to be affected by mining.

Based on the information and assumptions presented, the proposed development of the Brook Mine likely will not cause material damage to surface water quality in Tongue River outside the permit boundary. Segments of Slater Creek, Hidden Water Creek, and Goose Creek potentially affected by mining are contained within the permit area thus, I believe, material damage evaluations are not applicable.

Brook Mine will establish a 100ft buffer around Slater Creek which should help protect water quality in Slater Creek, and therefore also the Tongue River downstream of Slater Creek.

There is a very small amount of pre-mining surface water quality data on Slater Creek and Hidden Water Creek. Two recent samples were collected from Slater Creek and no new samples were collected from Hidden Water Creek, although Bighorn Mine collected data from Hidden Water Creek in the 1980s. Additional sampling effort could be targeted toward collecting pre-mining water quality data from both streams during periods when streamflow occurs. The combination of better pre-mining water quality data and paired upstream and downstream during-mining data will best enable LQD and Brook Mine to evaluate impacts of mining on water quality of these streams.

I have no new comments or concerns resulting from revisions to the CHIA that occurred between the April and July 2020 draft versions of the document.

JZ:

CC: David Waterstreet, WQD Cheyenne
MEMORANDUM

TO: Kevin Frederick
FROM: Jeremy ZumBerge
DATE: April 1, 2020


This CHIA evaluates the probable hydrologic impacts of the proposed Brook Mine. The Brook Mine is a new coal permit, proposed by Brook Mining, LLC, within the upper Tongue River Basin of Wyoming, approximately eight miles northwest of Sheridan. Mining primarily will be by highwall mining methods, with a small amount of surface strip mining also proposed. The permit would encompass 4549 acres, with up to 1135 acres to be affected by mining.

Based on the information and assumptions presented, the proposed development of the Brook Mine likely will not cause material damage to surface water quality in Tongue River outside the permit boundary. Segments of Slater Creek, Hidden Water Creek, and Goose Creek potentially affected by mining are contained within the permit area thus, I believe, material damage evaluations are not applicable.

Brook Mine will establish a 100ft buffer around Slater Creek which should help protect water quality in Slater Creek, and therefore also the Tongue River downstream of Slater Creek.

There is a very small amount of pre-mining surface water quality data on Slater Creek and Hidden Water Creek. Two recent samples were collected from Slater Creek and no new samples were collected from Hidden Water Creek, although Bighorn Mine collected data from Hidden Water Creek in the 1980s. Additional sampling effort could be targeted toward collecting pre-mining water quality data from both streams during periods when streamflow occurs. The combination of better pre-mining water quality data and paired upstream and downstream during-mining data will best enable LQD and Brook Mine to evaluate impacts of mining on water quality of these streams.

JZ:

CC: David Waterstreet, WQD Cheyenne
MEMORANDUM

TO: Kevin Frederick, Administrator, WQD

CC: David Waterstreet, Program Manager, Watershed Protection, WQD
    Jeremy Zumberge, Natural Resources Program Supervisor, Watershed Protection, WQD
    Nicole Twing, Geology Supervisor, Groundwater Section, WQD
    Lilly Barkau, Groundwater Section Manager, WQD
    Alan Edwards, Deputy Director, WDEQ
    Mark Rogaczewski, District 3 Supervisor, LQD
    Bj Kristiansen, Natural Resources Program Principal, LQD
    CHIA-39 File

FROM: Matt Kunze, Natural Resources Program Supervisor, LQD
      Muthu Kuchanur, Natural Resources Program Manager, LQD

DATE: June 1, 2020

SUBJECT: Response to Comments on Draft Cumulative Hydrologic Impact Assessment (CHIA) for the Proposed Brook Mine (TFN 6 2/025), CHIA #39

On April 2, 2020, the WDEQ/LQD received comments from the WQD on the draft CHIA prepared for the proposed Brook Mine (TFN 6 2/025), CHIA-39. The review stated that the WQD is in agreement with the conclusions of the CHIA regarding material damage and provided review memorandums for surface and groundwater. The WDEQ/LQD appreciates the review of the CHIA and offers the following response to one of the surface water comments. Please note it was determined that a response was not necessary for the groundwater review.

WDEQ Comment 1 (Surface Water): There is a very small amount of pre-mining surface water quality data on Slater Creek and Hidden Water Creek. Two recent samples were collected from Slater Creek and no new samples were collected from Hidden Water Creek, although Bighorn Mine collected data from Hidden Water Creek in the 1980s. Additional sampling effort could be targeted toward collecting premining water quality data from both streams during periods when streamflow occurs. The combination of better pre-mining water quality data and paired upstream and downstream during-mining data will best enable LQD and Brook Mine to evaluate impacts of mining on water quality of these streams.
WDEQ/LQD Response: As agreed to by the proposed Brook Mine and the LQD, baseline surface water data were collected for one year (September 2013 to September 2014) to characterize the surface water system. Monitoring was not conducted during the winter months (November-March). Very little streamflow occurred during the period on Slater Creek and no flow was observed on Hidden Water Creek so little water quality data were collected. To help strengthen the baseline characterization of Hidden Water Creek, the LQD requested that the historical sample data collected by the Big Horn Mine on Hidden Water Creek be incorporated into the permit application. The supplemental permit application also added additional water quality data from 2015 for Slater Creek and verification that attempts were made to sample one of the stations on Hidden Water Creek, but the channel was dry. The other station on Hidden Water Creek could not be visited due to lack of surface ownership permission but it was also likely dry. The LQD determined that the available surface water quality data from both streams was adequate to support the material damage findings of the CHIA.

Upon approval of the permit, the Brook Mine would be required to begin the operational monitoring plan, which would include quarterly surface water sampling on Hidden Water Creek and Slater Creek, as well as stock reservoirs and other monitoring sites on Goose Creek, the Tongue River, and the Tongue River Ditch. The stations will be sampled at the same time, allowing for upstream-downstream and between drainage comparisons. The data will be continuously evaluated and reviewed by the LQD in the mine’s annual report. Monitoring will continue throughout the life of the mine and throughout reclamation up until bond release.
June 30, 2020

Mr. Alan Edwards, Deputy Director
Wyoming Department of Environmental Quality
200 W. 17th St.
Cheyenne, WY 82002


Dear Mr. Edwards:

The Ground Water Division and Surface Water Division of the State Engineer’s Office have reviewed the Department of Environmental Quality, Land Quality Division’s Revised Draft Cumulative Hydrologic Impact Assessment of the Proposed Brook Mine, Upper Tongue River Basin, Wyoming (TFN 6 2/025) (CHIA #39).

Based on our review of the data and analysis presented in the draft CHIA, both Divisions are in agreement with the conclusions of the draft CHIA that the proposed operation has been designed to prevent material damage to the hydrologic balance outside the permit area, and the proposed operation will not materially damage the quantity or quality of water in surface or underground water systems that supply alluvial valley floors (AVFs) not subject to statutory exclusions.

Sincerely,

Lisa Lindemann
Administrator, SEO Ground Water Division

Attachments: Staff Reviews

cc: Greg Lanning, State Engineer
Nathan Graves, Administrator, SEO Surface Water Division
Jeremy Manley, SEO Ground Water Division
Muthu Kuchanur, LQD Cheyenne
Matt Kunze, LQD Cheyenne
To: Lisa Lindemann, Administrator, Ground Water Division  
From: Jeremy Manley, Natural Resources Program Principal, Ground Water Division  
CC:  
Date: April 10, 2020  

The State Engineer’s Office (SEO) again thanks WDEQ for providing the opportunity for our agency to review this document. The review indicates, overall, that SEO is in general agreement with the conclusions of this document. Upon finalization please submit the document to the State Engineer for concurrence.

SEO Ground Water Division staff reviewed the pre-decisional Draft document and pertinent sections of the updated Application to Mine under TFN 6 2/05.

It is noted that previous comments provided by Wyoming State Engineer’s Office staff in the Interstate Streams Division, Surface Water Division, and Ground Water Division for the December 2016 CHIA Document have been incorporated, we appreciate the authors for the inclusion of those comments.

No further comments or request are being supplied for by the Ground Water Division as part of this review.

Minor edits for grammar or spelling will be forwarded under separate cover.
Jeremy Manley <jeremy.manley@wyo.gov>

To: Matthew Kunze <matthew.kunze@wyo.gov>

Matt,

See response, below, for SW for the CHIA review.

Jeremy Manley

Wyoming State Engineer's Office
Ground Water Division
122 West 25th Street
1st Floor East
Cheyenne, Wyoming 82002
307-777-7730
jeremy.manley@wyo.gov

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------------- Forwarded message -----------
From: Nathan Graves <nathan.graves@wyo.gov>
Date: Mon, Apr 13, 2020 at 11:25 AM
Subject: Re: Brooks Mine CHIA Review Comments
To: Jeremy Manley <jeremy.manley@wyo.gov>, Jason Feltner <jason.feltner@wyo.gov>

Jeremy,

I reviewed this last week again and it mentions that the proposed mining operations will be downstream of permitted SW rights. No problems that I see.

Nathan Graves, P.E.
Surface Water Administrator

Wyoming State Engineer's Office
122 W. 25th Street
Herscher Building
Cheyenne, Wyoming 82002
Phone (307) 777-3500
Email - nathan.graves@wyo.gov

On Mon, Apr 13, 2020 at 11:21 AM Jeremy Manley <jeremy.manley@wyo.gov> wrote:
Jason and Nathan,

Did you all have a chance to a chance to finish a review and offer comments if any? WDEQ has requested our compiled comments by close of business today.
On Thu, Apr 2, 2020 at 4:45 PM Jeremy Manley <jeremy.manley@wyo.gov> wrote: 

Jason and Nathan,

Does SW have any comments for the revised Brooks Mine CHIA document? I am working on the GW Division Comments and would be happy to incorporate comments from SW.

Jeremy Manley

Wyoming State Engineer's Office
Ground Water Division
122 West 25th Street
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March 25, 2020

WER 13896.006
Wyoming Department of Environmental Quality
Land Quality Division
Pre-decisional Draft
Cumulative Hydrologic Impact Assessment of the
Proposed Brook Mine
Sheridan County

Kyle Wendtland, Administrator
Land Quality Division
Wyoming Department of Environmental Quality
200 W. 17th Street, Suite 10
Cheyenne, WY 82002

Dear Mr. Wendtland,

The staff of the Wyoming Game and Fish Department (Department) has reviewed the Pre-decisional Draft of the Cumulative Hydrologic Impact Assessment (CHIA) of the Proposed Brook Mine located in Sheridan County. We offer the following comments for your consideration.

Slater, Early, and Hidden Water Creeks are ephemeral/intermittent losing streams that receive most of their flow from upstream of the proposed mine. Goose Creek and the Tongue River are snowmelt driven systems, which do not rely on aquifer recharge from the proposed mine area. We agree with the CHIA that mining activity should not result in material damage to these surface waters.

Thank you for the opportunity to comment. If you have any questions or concerns please contact Mark Conrad, Habitat Protection Biologist, at 307-777-4509.

Sincerely,

[Signature]

Amanda Withroder

"Conserving Wildlife - Serving People"
Habitat Protection Supervisor

AW/me

cc: U.S. Fish and Wildlife Service
Paul Mavrakis, Wyoming Game and Fish Department
Matt Kunze, Wyoming Department of Environmental Quality
Chris Wichmann, Wyoming Department of Agriculture