EXECUTIVE SUMMARY
TASK 3B REPORT
WATER RESOURCES
CUMULATIVE IMPACT ASSESSMENT
WATER QUALITY AND CHANNEL STABILITY

Prepared in support of:

Powder River Basin Coal Review

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EXECUTIVE SUMMARY

The Task 3B component of the PRB Coal Review provides an assessment of the water resources cumulative impact associated with future levels of coal mining, coal mine dewatering, coal bed natural gas (CBNG) groundwater withdrawal and subsequent surface disposal of groundwater, surface disposal of groundwater by coal mines and conventional oil and gas wells. The information contained herein focuses on the cumulative impacts to surface water resources from surface discharge of groundwater by CBNG development and coal mine dewatering. Specifically, impacts related to water quality and channel stability are addressed. The study area and subwatersheds included in the surface water impact assessment are presented in **Figure ES. 1-1**.

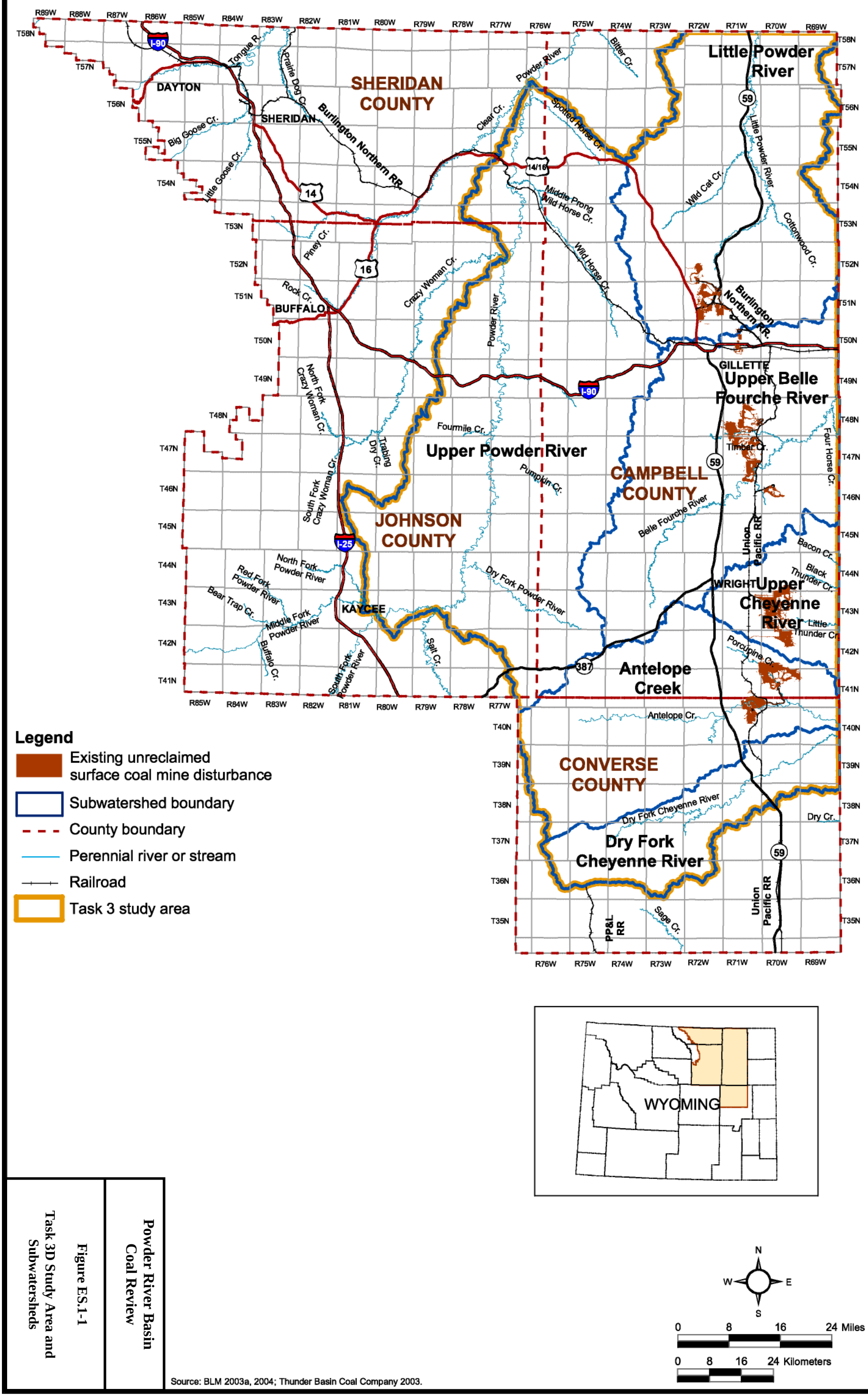
Completion of the work associated with Task 3B relied on information and data provided in the PRB Coal Review Task 1 and Task 2 Reports. The Task 1 Report provides the basis for the resource-specific descriptions of current conditions within the study area. Past and present activities identified in the Task 1 Report are based on the most recent data available at the end of 2003. The Task 2 Report defines the past and present development actions within the study that have contributed to the current environmental and socioeconomic conditions in the PRB study area. The Task 2 Report also defines the Reasonably Foreseeable Development (RFD) scenarios in the Wyoming and Montana PRB for years 2010, 2015, and 2020. The RFD scenarios presented in the Task 2 Report provide the basis for the analysis of potential cumulative impacts to surface water resources in the Task 3 component of the PRB Coal Review.

ES.1 METHODOLOGY FOR WATER QUALITY EVALUATION

The cumulative impact assessment addresses current conditions (2003) and three future RFD scenarios for years 2010, 2015, and 2020. Based on the information developed in support of the assessment and documented in the Task 1B Report (ENSR, 2005a) and Task 2 Report (ENSR, 2005b), the impacts have been addressed on a subwatershed basis. The subwatersheds associated with the work effort are presented in **Figure ES.1-1.**

ES.1.1 Evaluation Parameters

Key water quality parameters for predicting the potential effects of CBNG development focused on the suitability of surface water for irrigated agriculture. Consequently, sodium adsorption ratio, or SAR, and salinity, measured by electrical conductivity or EC, were utilized for the prediction. Most restrictive and least restrictive regulatory standards for EC and SAR applicable to the subwatersheds were developed and utilized in the cumulative impact assessment. The



Source: BLM 2003a, 2004; Thunder Basin Coal Company 2003.

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Figure ES.1-1
Task 3D Study Area and Subwatersheds

limits presented in **Table ES.1-1** were utilized during the comparison of EC and SAR values for resulting mixtures of existing streamflows and discharges from CBNG wells under various flow conditions and RFD projections for the years 2010, 2015 and 2020.

Table ES.1-1 Summary of Proposed Limits for SAR and EC

Subwatershed	Most Restrictive Proposed Limit (MRPL)		Least Restrictive Proposed Limit (LRPL)	
	SAR	EC (µS/cm)	SAR	EC (µS/cm)
Little Powder	5	2,000	9.75	2,500
Powder	5	2,000	9.75	2,500
Belle Fourche	6	2,000	10	2,500
Cheyenne, Antelope Creek	10	2,000	10	2,500

Source: Wyoming DEQ, Montana DEQ, and South Dakota Legislative Council.

The Ayers and Westcot (1985) irrigation suitability diagram was utilized to compare water quality before and after mixing with discharges from CBNG wells.

ES.1.2 Surface Water Quality Model

The surface water model utilized during the completion of the technical report (Greystone Environmental Consultants, Inc. and ALL Consulting; January 2003) in support of the Power River Basin Oil and Gas EIS (BLM, 2003a) was utilized for the cumulative impact assessment. This spreadsheet model employs a steady-state, mass-balance approach to estimate steady-state concentrations of EC and SAR after two or more inflows are mixed.

Input parameters to the spreadsheet model include the items listed below.

- Estimated CBNG Well Production Water (mmgpy)
- CBNG Well Production Water SAR
- CBNG Well Production Water EC (:S/cm)
- Channel Loss (%)
- Subwatershed Streamflow (acre-feet)
- Subwatershed Streamflow SAR
- Subwatershed Streamflow EC (:S/cm)

The operational aspects of the modeling procedure are itemized below.

1. Monthly estimates of CBNG groundwater discharged into the receiving channel are obtained from the data base.
2. The CBNG groundwater discharged to the receiving channel are reduced through conveyance losses to determine an estimate for the CBNG groundwater discharged to the receiving surface water source.
3. Monthly estimates of streamflow for the surface water source are obtained from the database. Two hydrologic conditions were evaluated; a dry year study period and a normal year study period. The dry year analysis was utilized to evaluate the maximum likely impacts to surface water quality, assuming limited flow in the receiving streams.
4. Water quality data (SAR and EC) for both the CBNG groundwater discharge and the receiving drainage are obtained from the data base.
5. A mixing analysis is completed using a simple flow-weighted mass balance equation with the input data associated with CBNG groundwater discharge and water quality data and streamflow and water quality data from the surface water source.
6. Monthly estimates of stream water quality before and after mixing with the CBNG groundwater are determined to support a comparative evaluation of EC and SAR and also plotted on the Ayers-Westcot diagram to ascertain the impact on water for irrigation.

ES.2 IMPACTS TO WATER QUALITY

The projected impacts to water quality from the discharge associated with CBNG development in each subwatershed were graphically evaluated with the data obtained from the surface water modeling results. The graphs depict the projected impact for the current conditions (2003) and each of three future RFD scenarios for years 2010, 2015, and 2020.

As indicated previously, the impacts to water quality on the receiving drainages assumed two hydrologic conditions; dry-year conditions and normal-year conditions. The impact analysis was conducted using monthly flows and comparatively evaluated the water quality parameters (SAR and EC) of the receiving drainage before and after mixing with discharge water generated by the CBNG wells within the watershed. In general, the water discharged from the CBNG wells reflected increased levels of SAR and reduced levels of EC compared to the water quality of the receiving drainages. Impacts to water quality are likely to be maximized during the low flow months; consequently, the comparative evaluation of water quality also focused on the minimum monthly flow associated with the dry-year and normal-year conditions.

The results of the water quality analyses are summarized in **Tables ES.2-1** and **Table ES.2-2**. Several observations can be made regarding the overall effects of mixing CBNG well production water with surface water within the study area. These general observations are discussed in the following paragraphs.

Table ES.2-1 Water Quality Results (Normal Year)

Item	Existing Condition (Before Mixing)	2003 (After Mixing)	2010 (After Mixing)	2015 (After Mixing)	2020 (After Mixing)
Antelope Creek					
EC	> CBNG Discharge	Reduced	Reduced	Reduced	Reduced
SAR	< CBNG Discharge	Increased	Increased	Increased	Increased
Irrigation(1)	Suitable	Suitable	Suitable	Suitable (Except Oct)	Suitable (Except Oct)
MRPL	Exceeds EC (Sept-Feb)	OK	OK	OK	OK
LRPL	OK	OK	OK	OK	OK
Upper Belle Fourche River					
EC	> CBNG Discharge	Reduced	Reduced	Reduced	Reduced
SAR	< CBNG Discharge	Slightly Increased	Slightly Increased	Slightly Increased	Slightly Increased
Irrigation(1)	Suitable	Suitable	Suitable	Suitable	Suitable
MRPL	Exceeds EC (Sept-Jan) Exceeds SAR (Nov-Jan)	Exceeds EC (Jan, Oct, Nov) Exceeds SAR (Aug-Jan)	Exceeds EC (Jan, Oct, Nov) Exceeds SAR (Aug-Jan)	Exceeds EC (Jan, Oct, Nov) Exceeds SAR (Aug-Jan)	Exceeds EC (Oct-Jan) Exceeds SAR (Sept-Jan)
LRPL	Exceeds EC (Nov-Jan)	OK	OK	OK	OK
Upper Cheyenne River					
EC	> CBNG Discharge	Reduced	Reduced	Reduced	Reduced
SAR	≅ CBNG Discharge	Same	Same	Same	Same
Irrigation(1)	Suitable	Suitable	Suitable	Suitable	Suitable
MRPL	Exceeds EC (Except Aug)	Exceeds EC (Except Aug)	Exceeds EC (Except Aug)	Exceeds EC (Except Aug)	Exceeds EC (Except Aug)
LRPL	Exceeds EC (Oct-June)	Exceeds EC (Jan-June, Nov)	Exceeds EC (Jan-June, Nov)	Exceeds EC (Jan-June, Oct, Nov)	Exceeds EC (Jan-June, Oct, Nov)
Upper Powder River					
EC	≅ CBNG Discharge	Slight Decrease	Slight Decrease	Slight Decrease	Slight Decrease
SAR	< CBNG Discharge	Slight Increase	Slight Increase	Slight Increase	Slight Increase
Irrigation(1)	Suitable	Suitable	Suitable	Suitable	Suitable
MRPL	Exceeds EC (July-Apr) Exceeds SAR (July-Apr)	Exceeds EC (July-Apr) Exceeds SAR (July-Apr)	Exceeds EC (July-Apr) Exceeds SAR (Exc. June)	Exceeds EC (July-Apr) Exceeds SAR (Exc. June)	Exceeds EC (July-Apr) Exceeds SAR (All Year)
LRPL	Exceeds EC (July-Dec)	Exceeds EC (July-Dec)	Exceeds EC (July-Dec)	Exceeds EC (July-Dec)	Exceeds EC (July-Dec)
Little Powder River					
EC	> CBNG Discharge	Reduced	Reduced	Reduced	Reduced
SAR	< CBNG Discharge	Slight Increase	Slight Increase	Slight Increase	Slight Increase
Irrigation(1)	Suitable	Suitable	Suitable	Suitable	Suitable
MRPL	Exceeds EC (Except Mar) Exceeds SAR (Except Mar, May)	Exceeds EC (Except Mar, May) Exceeds SAR (Except Mar)	Exceeds EC (Except Mar, May) Exceeds SAR (Except Mar)	Exceeds EC (Except Mar, May) Exceeds SAR (Except Mar)	Exceeds EC (Except Mar, May) Exceeds SAR (Except Mar)
LRPL	Exceeds EC (Aug, Sept, Nov-Jan)	Exceeds EC (Jan, Aug)	Exceeds EC (Jan)	Exceeds EC (Jan)	Exceeds EC (Jan, Aug)
Dry Fork Cheyenne River					
EC	> CBNG Discharge	Same (No CBNG Discharge)	Reduced	Reduced	Reduced
SAR	< CBNG Discharge	Same (No CBNG Discharge)	Slight Increase	Slight Increase	Slight Increase
Irrigation(1)	Suitable	Same (No CBNG Discharge)	Suitable (Except Sept)	Suitable (Except Sept)	Suitable (Except Sept)
MRPL	Exceeds EC (June, Sept-Feb)	Same (No CBNG Discharge)	Exceeds EC (Feb, Nov)	Exceeds EC (Feb)	Exceeds EC (Feb)
LRPL	OK	OK	OK	OK	OK

1. Irrigation results reflect suitability of water for irrigation during the irrigation season

Table ES.2-2 Water Quality Results (Dry Year)

Item	Existing Condition (Before Mixing)	2003 (After Mixing)	2010 (After Mixing)	2015 (After Mixing)	2020 (After Mixing)
Antelope Creek					
EC	> CBNG Discharge	Reduced	Reduced	Reduced	Reduced
SAR	< CBNG Discharge	Increased	Increased	Increased	Increased
Irrigation (1)	Suitable	Suitable (Except June, Aug)	Unsuitable (Except July, Sep)	Unsuitable (Except July, Sep)	Unsuitable (Except July, Sep)
MRPL	Exceeds EC (Sept-Feb)	OK	OK	OK	OK
LRPL	OK	OK	OK	OK	OK
Upper Belle Fourche River					
EC	> CBNG Discharge	Reduced	Reduced	Reduced	Reduced
SAR	< CBNG Discharge	Slightly Increased	Slightly Increased	Slightly Increased	Slightly Increased
Irrigation (1)	Unsuitable (Aug-Oct)	Unsuitable (Aug-Oct)	Unsuitable (Aug-Oct)	Unsuitable (Sep-Oct)	Unsuitable (Oct)
MRPL	Exceeds EC (Sept-Jan) Exceeds SAR (Nov-Jan)	OK Exceeds SAR (Exc. Feb, Mar, May, July)	OK Exceeds SAR (Exc. Feb, Mar, May, July)	OK Exceeds SAR (Exc. Feb, Mar-May, July)	OK Exceeds SAR (Aug-Jan)
LRPL	Exceeds EC (Nov-Jan)	OK	OK	OK	OK
Upper Cheyenne River					
EC	> CBNG Discharge	Reduced	Reduced	Reduced	Reduced
SAR	≅ CBNG Discharge	Slight Increase (July-Sept)	Slight Increase (July-Sept)	Slight Increase (July-Sept)	Slight Increase (July-Sept)
Irrigation (1)	Suitable	Suitable	Suitable	Suitable	Suitable
MRPL	Exceeds EC (Except Aug)	Exceeds EC (Except July, Aug)	Exceeds EC (Except July, Aug)	Exceeds EC (Except July, Aug)	Exceeds EC (Except Aug)
LRPL	Exceeds EC (Oct-June)	Exceeds EC (Jan-June, Oct, Nov)	Exceeds EC (Jan-June, Oct, Nov)	Exceeds EC (Jan-June, Oct, Nov)	Exceeds EC (Oct-June)
Upper Powder River					
EC	≅ CBNG Discharge	Same	Slightly Decreases (Aug, Sept)	Slightly Decreases (Aug, Sept)	Slightly Decreases (Aug, Sept)
SAR	< CBNG Discharge	Slight Increase	Increased	Increased	Increased
Irrigation (1)	Suitable	Suitable	Suitable	Suitable	Suitable
MRPL	Exceeds EC (July-Apr) Exceeds SAR (July-Apr)	Exceeds EC (July-Apr) Exceeds SAR	Exceeds EC (July-Apr) Exceeds SAR	Exceeds EC (July-Apr) Exceeds SAR	Exceeds EC (July-Apr) Exceeds SAR
LRPL	Exceeds EC (July-Dec)	Exceeds EC (July-Dec)	Exceeds EC (July-Dec) Exceeds SAR (Sept)	Exceeds EC (July-Dec) Exceeds SAR (Sept)	Exceeds EC (July-Dec) Exceeds SAR (Sept)
Little Powder River					
EC	> CBNG Discharge	Reduced	Reduced	Reduced	Reduced
SAR	< CBNG Discharge	Increase	Increase	Increase	Increase
Irrigation (1)	Suitable	Suitable (Except Sept-Oct)	Suitable (Except Sept-Oct)	Suitable (Except Sept-Oct)	Suitable (Except Sept-Oct)
MRPL	Exceeds EC (Except Mar) Exceeds SAR (Except Mar, May)	Exceeds EC (Feb, Apr, June, Aug) Exceeds SAR	Exceeds EC (Feb, Apr, June, Aug) Exceeds SAR	Exceeds EC (Feb, Apr, June, Aug) Exceeds SAR	Exceeds EC (Feb, Apr, June, Aug) Exceeds SAR
LRPL	Exceeds EC (Aug, Sep, Nov-Jan)	Exceeds SAR (Sept)	Exceeds SAR (Sept-Jan)	Exceeds SAR (Sept-Jan)	Exceeds SAR (Sept-Nov)
Dry Fork Cheyenne River					
EC	> CBNG Discharge	Same (No CBNG Discharge)	Reduced	Reduced	Reduced
SAR	< CBNG Discharge	Same (No CBNG Discharge)	Increase	Increase	Increase
Irrigation (1)	Suitable	Same (No CBNG Discharge)	Unsuitable (June, Aug-Sep)	Unsuitable (June, Aug-Sep)	Unsuitable (June, Aug-Sep)
MRPL	Exceeds EC (June, Sept-Feb)	Same (No CBNG Discharge)	OK	OK	OK
LRPL	OK	OK	OK	OK	OK

1. Irrigation results reflect suitability of water for irrigation during the irrigation season

ES.2.1 Current Surface Water Quality Conditions

With respect to the Most Restrictive Proposed Limit (MRPL) and the Least Restrictive Proposed Limit (LRPL) for the impact analysis, several of the surface water sources currently exceed the MRPL during many months of the years. Specific observations related to the water quality of the surface water sources are listed below.

- The surface water in the Upper Powder River exceeds the MRPL for both EC and SAR throughout the majority of the year. Levels of SAR are less than the LRPL while EC values generally exceed the LRPL the latter half of the year (July through December).
- The surface water in both Antelope Creek and the Dry Fork Cheyenne River exceeds the MRPL for EC during the low-flow months from September through February. Levels of EC are typically less than the LRPL. The SAR values are relatively low and do not exceed the MRPL.
- The surface water in the Little Powder River exceeds the MRPL for EC and SAR throughout the majority of the year and exceeds the LRPL for EC during the low flow months of August, September and November through January. SAR levels remain below the LRPL throughout the year.
- The surface water in the Upper Cheyenne River exceeds the MRPL for EC for eleven months of the year and exceeds the LRPL nine months of the year. The surface water does not exceed the MRPL for SAR.
- The surface water in the Upper Belle Fourche River exceeds the MRPL for EC during the low-flow months from September through January. Levels of EC are less than the LRPL with the exception of November through January. The SAR values are relatively low but tend to exceed the MRPL from November through January while meeting the LRPL throughout the year.

ES.2.2 Mixed Water Quality Conditions

Specific observations related to the MRPL and LRPL following mixing with CBNG well production water are provided below. The observations are related to the scenario that results in the highest contribution of CBNG well production water to the surface water source thereby maximizing the potential impact associated with the CBNG well production water. These conditions are typically reflected during the dry year; consequently, the observations discussed below reflect dry-year conditions.

- The surface water in the Upper Powder River demonstrates a minimal reduction in EC and a minor increase in SAR. These results reflect the relatively small

contribution of CBNG well production water to the much larger flows in Upper Powder River. EC values continue to exceed the MRPL throughout the majority of the year (July through April) and the LRPL from July through December. SAR values exceed the MRPL throughout the year while meeting the LRPL.

- The surface water in both Antelope Creek and the Dry Fork Cheyenne River reflect a reduction in EC that meets the MRPL throughout the year. Levels of SAR are increased but continue to meet the MRPL. This observation largely reflects the lack of surface water in these streams coupled with the relatively low values for EC and SAR in the CBNG well production water.
- The surface water in the Little Powder River reflects a reduction in EC but continues to exceed the MRPL for four months of the year while meeting the LRPL throughout the year. The SAR values reflect an increase and exceed the MRPL throughout the year, and exceed the LRPL from one (2003) to five (2010, 2015) months of the year.
- The surface water in the Upper Cheyenne River reflects a minor reduction in EC but continues to exceed the MRPL for ten or more months of the year and the LRPL for six or more months of the year. A minimal increase in SAR is realized and the surface water continues to meet the MRPL.
- The surface water in the Upper Belle Fourche River reflects a reduction in EC that meets the MRPL throughout the year. The SAR values reflect a slight increase and tend to exceed the MRPL six or more months of the year while meeting the LRPL throughout the year.

ES.2.3 Observations Related to EC

The EC associated with the surface water sources is typically higher than the EC associated with the CBNG well production water. Consequently, the simple mixing approach utilized during the evaluation results in a reduction or improvement in EC after mixing with CBNG production water. In every instance, the most significant reduction in EC correlates to those scenarios (current conditions or RFD Scenarios) that involve the largest contribution of CBNG water to the receiving stream. This trend is amplified during time periods when surface water flows are reduced in the stream as confirmed by the results of the dry-year analysis. With the exception of the Upper Powder River, this observation was consistent for all surface water sources evaluated during this study. Within the Upper Powder River, the EC associated with the CBNG well production water was the most elevated and similar to the EC of the surface water.

ES.2.4 Observations Related to SAR

The SAR associated with the surface water sources is typically lower than the SAR associated with the CBNG well production water. Similar to the evaluation of EC, the simple mixing

approach utilized during the evaluation will generally result in an increase in SAR after mixing with CBNG production water. The most significant increase in SAR correlates to those scenarios (current conditions or RFD Scenarios) that involve the largest contribution of CBNG water to the receiving stream. This trend is amplified during time periods when surface water flows are reduced in the stream as confirmed by the results of the dry-year analysis. With the exception of Upper Cheyenne River, this observation was consistent for all surface water sources evaluated during this study. Within the Upper Cheyenne River, the SAR associated with the CBNG well production water was similar to the SAR of the surface water.

ES.2.5 Observations Related to Irrigation Suitability

The suitability of the mixed water for irrigation purposes is also related to EC and SAR. The analysis for irrigation suitability relied solely on utilization of the Ayers Westcot Diagram. In general, the water most suitable for irrigation consists of a source with relatively low SAR and relatively high EC. Elevated SAR values may reduce permeability in clayey soils thereby reducing the rate of water infiltration. This relationship in EC and SAR is depicted in the Ayers Westcot Diagram in terms of the suitability of water sources for irrigation purposes. In those instances where the SAR is significantly increased and the EC is moderately low, the water source was considered unsuitable. This observation was specifically noted in the surface water sources associated with Antelope Creek, Dry Fork Cheyenne River, Little Power River and Upper Belle Fourche River. For these streams, the results demonstrated adequate suitability for irrigation during the normal year conditions and unsuitable water sources during a portion, or the entire irrigation season, during the dry-year conditions. These streams also demonstrated a reduced level of EC compared to the Upper Cheyenne River and the Upper Powder River. It should be noted that the unsuitable nature of the water quality in the Dry Fork Cheyenne River is largely attributable to the lack of surface water flow in the river; consequently the increased levels of SAR in the CBNG well production water directly relates to the reduction in the suitability of the water for irrigation purposes. In general, this trend is amplified for all streams during periods when CBNG well production water represents the majority of the flows available for irrigation purposes.

ES.3 IMPACTS TO CHANNEL STABILITY

The cumulative impact assessment includes an evaluation of channel stability with respect to the surface water resources within the study area. In general, the impacts to channel stability largely relate to the water quantity associated with the discharges from current or projected coal mining activities, CBNG wells or conventional oil and gas wells compared to the runoff characteristics

of the receiving drainages. Of particular importance is the amount of production water or discharge that is directly conveyed to the receiving drainages.

Given the limited data available to assess channel stability, quantification of the impacts becomes problematic. To the maximum extent possible, the impact to perennial drainages is addressed on a quantitative basis, at the subwatershed level, using regression equations related to discharge and channel width. To support this evaluation in consideration of the limited data, geomorphic relationships have been utilized to provide a qualitative assessment of the impacts associated with the production of CBNG discharge water. These relationships provided a qualitative assessment of the response of the receiving drainages to an increase in discharge provided by the introduction of CBNG well production water.

ES.3.1 Evaluation of Perennial Streams

Examination of United States Geological Survey (USGS) records for the Belle Fourche River below Moorcroft, Wyoming (USGS Gage 06426500) and the Little Powder River above Dry Creek, near Weston, Wyoming (USGS Gage 06324970) provided the basis of the evaluation of perennial streams. For these two perennial streams, a hydraulic geometry relationship was developed that related channel width as a function of discharge. The hydraulic geometry relationships were developed from all data classified as good (G) by the USGS during the data collection efforts. Using the relationships developed, channel width in the range of the channel forming discharge was computed for the existing condition and for the maximum CBNG well production condition by adding the predicted CBNG discharge to the existing condition discharge **(Table ES.3-1)**. The estimated change in width for the Little Powder River was computed to be less than 0.3%, and was less than 0.2% for the Belle Fourche River. These results suggest that for the larger, perennial streams the effect of the CBNG well production water will be minimal.

Table ES.3-1 Impact of CBNG Production Water on Perennial Streams

Location	Channel Forming Discharge [1] (cfs)	CBNG Discharge		Estimated Width		Potential Impact [Increased Width]	
		(cfs)	(%)	Existing Conditions (ft)	Combined Discharge (ft)	(ft)	(%)
Little Powder River above Dry Creek near Weston, Wyoming (USGS Gage 06324970)	270 to 420	2.2	0.5% to 0.8%	47.3 to 56.3	47.4 to 56.4	0.15 to 0.12	0.3%
Belle Fourche River below Moorcroft, Wyoming (USGS Gage 06426500)	652 to 789	3.9	0.5% to 0.6%	66.9 to 72.1	67.0 to 72.2	0.16 to 0.14	0.2%

[1] Discharge associated with the 1.5 to 2 year recurrence interval.

From a qualitative standpoint, the geomorphic relationships also provide insight into the potential impacts of the CBNG production water on the mean annual discharge events. Applying the geomorphic relationships to the existing data resulted in the following observations:

- An increase in mean annual discharge may result in potential increases in channel width, depth, and meander wavelength while a decrease in channel gradient may occur.
- An increase in mean annual discharge may result in an increase in bed material transport or median particle size of the bed material.

Given the relatively low increase in mean annual discharge, these trends predicted by the geomorphic relationships are considered to be imperceptible.

ES.3.2 Evaluation of Ephemeral Streams

Limited data on streamflows is available for the smaller, ephemeral drainage channels within the study area that may receive discharges from the CBNG wells. Furthermore, the data related to the predicted CBNG well production water is provided on a subwatershed basis. However, it is reasonable to assume that the CBNG well production water will represent a much higher percentage of the mean annual discharges in some of the ephemeral drainages within the study area. Consequently, the impacts to channel stability will be more readily apparent in ephemeral drainages and may be manifested by an increase in channel erosion, headcutting, and incision.

The discharge of CBNG well production water into the ephemeral drainages may initiate or exacerbate erosion within the conveyance channel. Should erosion be initiated, given the relatively minor flow compared to the typical gully section in the typical ephemeral drainage channel, it is anticipated that a small incision may occur. One must also consider that the sustained nature of the CBNB well production water may also generate and support an increase in diversity and density of the vegetation along the channel. The increase in vegetation may tend to prevent channel erosion or partially stabilize existing erosion within the ephemeral drainage channel.

Similar to the perennial stream channels, the geomorphic relationships were utilized to provide insight into the potential impacts of the CBNG production water on the mean annual discharge

events associated with the ephemeral drainages. Applying the geomorphic relationships to the ephemeral drainage systems provided the following observations:

- Given that the relative magnitude of the increase in mean annual discharge is more significant in the ephemeral drainage channel, it is likely that potential increases in channel width and depth will occur along with local reductions in channel slope.
- Again, an increase in mean annual discharge may reduce channel gradient or result in an increase in bed material transport or median particle size of the bed material.

Given the potentially significant increase in mean annual discharge, these trends predicted by the geomorphic relationships are more likely to occur, especially considering that the increases attributable to the CBNG production water are sustained discharges.

Due to the potential for erosion in the ephemeral drainages, it may be prudent to establish a monitoring and management plan on selected drainages prior to the discharge of CBNG production water. Where erosion is evident from the visual inspection and evaluation of the data, methods to mitigate the erosion should be considered. Mitigation measures may include placement of small grade control structures at locations of active erosion and headcutting.

Ephemeral drainage channels that are presently experiencing active headcutting and erosion should be identified. Monitoring of the erosion should be conducted as specified above. Where erosion of the channel is considered significant, mitigation measures should be implemented and the channel stabilized. Mitigation measures identified in the Draft EIS for the Seminoe Road Natural Gas Development Project (BLM, 2005) may be worthy of consideration and include grade control structures, check dams, impact basins, channel reconstruction, and other possible engineered erosion control measures.