2.0 METHODOLOGY FOR WATER QUALITY EVALUATION

2.1 General

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 1-3** and include:

- Antelope Creek
- Dry Fork Cheyenne River
- Little Powder River
- Upper Belle Fourche River
- Upper Cheyenne River
- Upper Powder River

As stated previously, the assessment focuses on the cumulative impacts to water quality and channel stability with respect to the surface water resources within the study area. In general, the impacts directly relate to the water quantity and quality associated with the discharges from current or projected coal mining activities, CBNG wells or conventional oil and gas wells compared to the water quantity and quality of the receiving drainages. Of particular importance is the amount of production water or discharge that is directly conveyed to the receiving drainages. Based on a review of the data available in the Task 1 and Task 2 reports, it is assumed that the production water discharged directly to the receiving drainages is limited to CBNG wells. In general, the existing data reflects that water production from coal mining activities is largely consumed on site. Water production from conventional oil and gas wells typically requires treatment to meet water quality standards associated with the NPDES permitting requirements.

2.2 Water Quality

Potential impacts to surface water quality associated with proposed CBNG development were evaluated during completion of the Powder River Basin Oil & Gas EIS (BLM, 2003a) and documented in a supporting technical report (Greystone Environmental Consultants, Inc. and ALL Consulting; January 2003). 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. The impact assessment documented in this report utilizes the same water quality parameters and involves a similar evaluation.

2.2.1 Evaluation Criteria

Table 2.2-1 summarizes the most restrictive and least restrictive regulatory standards for EC and SAR applicable to the subwatersheds addressed in the cumulative impact assessment. This information was obtained from several sources including the Wyoming Department of Environmental Quality, Montana Department of Environmental Quality, and South Dakota Legislative Council. The limits presented in **Table 2.2-1** 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 2.2-1 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 Water Quality Rules and Regulations (2006), Montana DEQ Water Quality Standards of Classification (2006), and South Dakota Legislative Council Administrative Rules (2004).

With respect to the information provided in **Table 2.2-1**, the Wyoming Department of Environmental Quality (WDEQ) applies numeric water quality standards for EC and SAR that were adopted for water bodies downstream in South Dakota. Specifically, these standards apply to the Upper Belle Fourche River, Antelope Creek, Upper Cheyenne River, and Dry Fork Cheyenne River. In March of 2003, the Montana Board of Environmental Review adopted numeric standards for EC and SAR for surface water sources. These standards apply to the Little Powder River and Upper Powder River.

2.2.2 Irrigation Suitability Diagram

The Ayers and Westcot (1985) irrigation suitability diagram (also referred to as the "Hanson Diagram"; Hanson, Grattan, Fulton, 1999) was used to compare water quality before and after mixing with discharges from CBNG wells. The diagonal line on the diagram is used as the no-impact threshold for SAR and EC values of the water. Water quality would be expected to cause "no reduction in the rate of infiltration" as a result of dispersion of soils by SAR below and to the right of the irrigation threshold line (Ayers and Westcot, 1985). Alternatively, waters located to the left and above the threshold line for irrigation would be likely to cause slight to moderate reduction in the rate of infiltration (Ayers and Westcot, 1985).

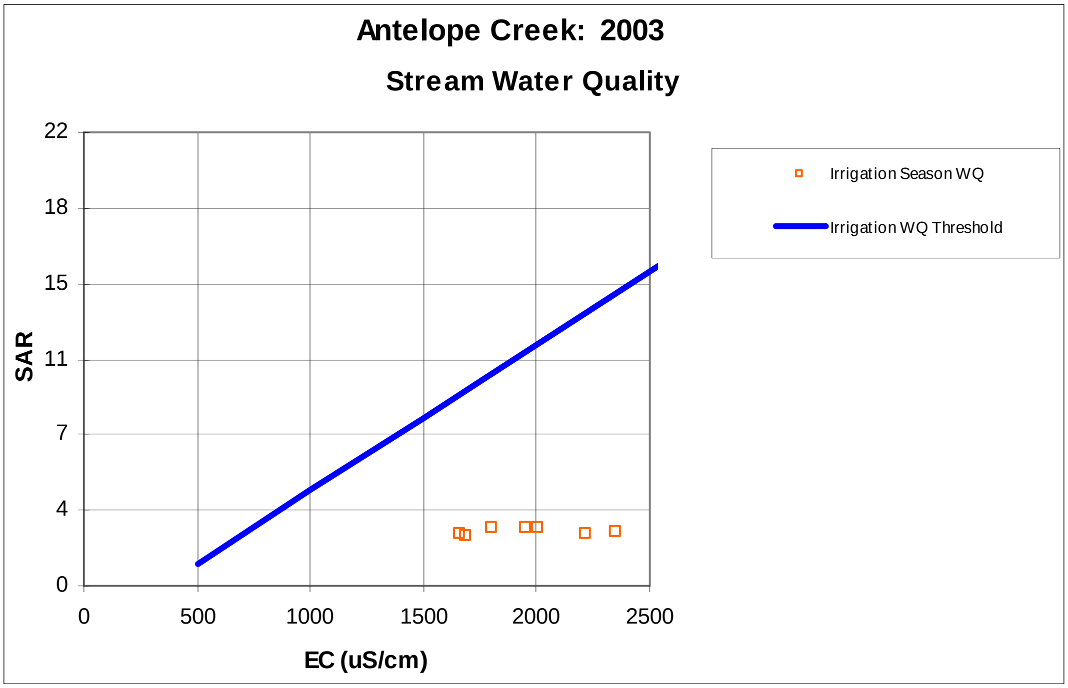
This EC/SAR relationship in the Ayers Westcot irrigation suitability diagram is utilized to determine the effect of irrigation waters on the infiltration capacity of soils. Elevated SAR values may reduce the permeability in clayey soils, consequently reducing the infiltration rate. It should be noted that the significance of the effects associated with a reduction in infiltration rate varies with soil type, and increases on clay and clay-loam soils. In addition, the EC/SAR relationship typically indicates that as salinity increases, the potential impacts of SAR decrease; however this relationship should not be applied without limits. The potential impact of rainfall on sodic soils can cause SAR problems by significantly lowering of the EC with little change in the SAR. An attempt to address this potential problem, along with the inherent variability in soils, is made through the application of an absolute maximum SAR during the analysis.

Figure 2.2-1 illustrates utilization of the Ayers and Westcot irrigation suitability diagram for the existing stream water quality (2003 current conditions) associated with Antelope Creek. As indicated in **Figure 2.2-1**, the existing water quality in Antelope Creek appears to be suitable for irrigation.

2.2.3 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.

Figure 2.2-1



Input parameters to the spreadsheet model are described below.

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

The mixing analysis integrated into the spreadsheet model is described in detail in **Appendix A**; this information was obtained from the technical report prepared by Greystone Environmental Consultants, Inc. and ALL Consulting (January 2003). A summary of the input data used during the impact analysis for surface water quality is presented in **Appendix B**. The results of the spreadsheet modeling are presented in **Appendix C**.

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 data base.
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 the suitability of water for irrigation.

The following assumptions were incorporated into the approach to the water quality modeling. Many of these assumptions are similar to those described in the technical report prepared by Greystone Environmental Consultants, Inc. and ALL Consulting (January 2003) and are included herein:

- Assuming SAR behaves as a single constituent of water, mixed SAR was estimated using a simple flow-weighted mass balance equation. As indicated in Appendix A, this assumption results in an overestimation of SAR and, potentially, of impacts by a factor of 2.
- Impacts to the receiving streams were evaluated for hydrologic conditions associated with relatively dry years as well as normal or average years. The dry year analysis evaluated the maximum likely impacts to surface water quality.
- The model assumed complete mixing. Impacts to surface water quality may be greater than are predicted in the mixing zone near the points of discharge.
- A typical value of channel loss was used in the model. This value would under-predict the impacts to surface water quality if discharge were piped directly to the receiving stream or if the discharge point is very close to the receiving stream.

- Irrigation suitability was evaluated on the basis of the Ayers Westcot Diagram and was determined to be either suitable or unsuitable on the basis of the threshold diagonal line within the diagram. Numeric water quality standards were not utilized to determine irrigation suitability.

2.2.3.1 Stream Flow

Average monthly and annual flows at pertinent gauging stations for the major drainages within each subwatershed were obtained from the Powder/Tongue River Basin Water Plan (HKM Engineering, et al.; 2002a) and the Northeast Wyoming River Basins Water Plan (HKM Engineering, et al.; 2002b). The development of the streamflow data relied on historic streamflow gaging data to the maximum extent possible. The subwatersheds identified in this study, however, are characterized by a scarcity of historic streamflow records. Consequently, it was necessary to develop streamflow data at several locations within the study area. The methodology used to collect the historic records of streamflow, establish a study period, and to extend or fill-in the streamflow data where records are unavailable, has been summarized in the basin plans previously referenced (HKM Engineering, et. al.; 2002a and 2002b). **Appendix D** provides the technical memoranda describing the methodology and results of the surface water hydrology development utilized during this water quality assessment.

The documentation in **Appendix D** provides insight into the availability of existing streamflow data, synthesis of data and selection of the study period. For both basin plans, it was determined that a consistent approach should be utilized to develop streamflow data that reflects water availability at various locations within the watershed. The study period selected for the basin plans extended from 1970 to 1999. This study period contains extended periods of dry years including some of the driest years of record as well as periods of normal and wet hydrologic conditions. This period also has the greatest abundance of recorded streamflow data and ditch diversion data; consequently, less data synthesis was required. Based on the evaluation of the approach and information contained in the technical memoranda, it was determined that the most consistent streamflow data available to support the water quality evaluation was contained in the basin planning reports.

As described in the technical memoranda in **Appendix D**, surface water hydrology data was developed to represent dry year, normal year, and wet year hydrologic conditions. Consequently, the annual streamflows developed in the basin planning effort were ranked and divided into these three hydrologic categories. The years of the study period with non-exceedance probabilities of 20 percent or less (the driest 20 percent) were selected as dry years.

Similarly, the years with exceedance probabilities of 20 percent or less (the wettest 20 percent) were selected as wet years. The remaining 60 percent of the years represent normal years.

The impact analysis was conducted assuming two hydrologic conditions; 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.

2.2.3.2 Stream Water Quality

EC and SAR values for the streams within the study area were identical to the values used in 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). It should be noted that limited data was available to characterize the water quality in the Dry Fork Cheyenne River. Consequently, the data available for the neighboring subwatershed, Antelope Creek, was utilized for the water quality impact analysis.

2.2.3.3 CBNG Well Production Water

Production water from existing and projected CBNG wells was obtained from the Task 2 Report for the Powder River Basin Coal Review (ENSR, October 2005). Sources for this data included, but were not limited to, an oil and gas production and well history database by IHS Energy Services (IHS, 2004) and a data provided by the Wyoming Oil and Gas Conservation Commission (WOGCC, 2004; 2005a; 2005b). This information is summarized in the data tables included in **Appendix B**.

2.2.3.4 CBNG Well Production Water Quality

EC and SAR values for the production water associated with the CBNG wells in the study area were documented in 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). In addition, the Wyoming DEQ/WQD provided pertinent, and more recent water quality data from a Microsoft Access data base relevant to the effluent water quality from CBNG wells in all watersheds with the exception of Antelope Creek and Dry Fork Cheyenne River. The water quality data obtained from both of these sources was reviewed and utilized to describe the water quality associated with the CBNG well production water in this modeling effort. **Appendix B** presents the results of the analysis related to CBNG discharge water quality.

2.2.3.5 Managed Water Loss

The Powder River Basin Oil and Gas EIS (BLM, 2003a) assumed water produced from CBNG wells and managed through containment, land application disposal (LAD) and injection would not have direct effects on quality and quantity of surface water because none of the discharge water would reach drainages in the subwatersheds under these water handling options. The percentage of CBNG well production water managed through these options is referred to as Managed Water Loss (MWL). The percentage of CBNG production water included in the MWL varies between subwatersheds and is presented in **Table 2.2-2**. It should be noted that all CBNG water discharged directly into the drainages may ultimately be consumptively utilized by downstream water users. Based on the profile of water users within the subwatersheds, it is likely that this water will be utilized for irrigation purposes.

Table 2.2-2 Percent of Total Water Production from CBNG Wells per Discharge Method

Subwatershed	Untreated Discharge into Drainages	Passive Treatment	Active Treatment	Infiltration Impoundment	Containment Impoundment	LAD	Injection
Upper Powder River	35	0	10	40	5	5	5
Little Powder River	45	0	0	30	10	10	5
Antelope Creek	55	0	0	35	5	0	5
Upper Cheyenne River	55	0	0	35	5	0	5
Dry Fork Cheyenne River	55	0	0	35	5	0	5
Upper Belle Fourche River	45	0	0	40	5	0	10

Source: ENSR, October 2005

2.2.3.6 Conveyance Loss

Information contained in the Task 1 Report for the Powder River Basin Coal Review (ENSR, 2005) indicated the following:

"Studies conducted by the BLM (2003a) have shown that conveyance losses for direct discharge to drainages are approximately 70 to 90 percent, depending on the time of year. Evaporation losses, which are a large component of conveyance losses, can be 80 percent during the summer months in Wyoming. Thus, most CBNG discharge water either infiltrates or evaporates within a few miles of the discharge outfall and generally is not recorded at USGS stream gauging stations. Impacts to surface water flow and quality are thus limited to within a few miles of the discharge outfall and, as of 2002, have not been recorded by the network of USGS gauging stations."

Conveyance losses will vary by subwatershed as a function of the total CBNG water discharged to the channel, soils, slope of the channel, type of drainage (ephemeral versus perennial), cover/vegetation within the channel, time of year, etc. However, given the variability of these parameters within each subwatershed, a conveyance loss of 70 percent was selected for the water quality assessment and modeling effort. Based on the existing information, this estimate of conveyance loss is considered a conservative value that results in identification of the maximum impact of CBNG water on the water quality of the receiving drainages.