Dr. James Gore's Comments on BLM's Draft EIS

Bureau of Land Management
Paul Beels (Project Manager)
1425 Fort Street
Buffalo, Wyoming 82834

Dear Mr. Beels:

With this letter, we are submitting comment on the Draft Environmental Impact Statement and Draft Planning Amendment for the Powder River Basin Oil and Gas Project (WY-070-02-065). We believe that the BLM has done an inadequate job in assessing the potential impacts of return water to the basin during the CBM process. In particular, we are concerned about the potential impacts of these increased lateral flows into the various basins and sub-basins and the potential loss of available physical habitat for various critical aquatic organisms. We are especially concerned that extended periods of reduced habitat availability might result in consequent declines in both density and diversity of macroinvertebrates and fish, as well as the decline in the stability and resilience of the lotic ecosystem, itself. We have performed an initial simulation of habitat losses for target biota and suggest that there will be significant impacts upon available habitat and, ultimately, the potential for loss of these species and/or deterioration of aquatic communities as a result.

Our evaluation group consists of three individuals. Dr. James A. Gore is professor and chair of the Department of Environmental Science and Public Health at Columbus State University. He has been teaching and conducting research on the ecology of regulated flows and aquatic ecosystems for approximately 28 years. As a graduate student in Montana, he conducted his Master's degree work and part of his doctoral work on the Tongue River in Wyoming and Montana and, as a research associate at the University of Wyoming, has had extensive research experience in the Powder River basin, conducting work on the distribution of aquatic insects, suspended sediment distribution, and the impacts of *in situ* uranium recovery, as well as the impacts of regulated flows and the restoration of streams in both the Powder River and Tongue River basins. Dr. Gore's primary area of expertise is in the evaluation of the impacts of altered flows on resident river biota, utilizing both field data and laboratory simulation to evaluate these impacts. As one of the originators of the instream flow incremental methodology, he has had extensive experience in the use of the primary evolution model, the physical habitat simulation (PHABSIM). In 1989, he received a Fulbright Senior Research Fellowship to teach instream flow techniques in universities and to regulatory agencies in southern Africa. In the past, Dr. Gore has also taught instream flow modeling and regulated river management in England (Severn-Trent Water Authority and the National Hydrologic Institute, Oxfordshire), Germany (the University of Karlsruhe), Czech Republic (T.G. Masaryk Institute for Hydrology), and New Zealand (the National Institute of Water and Atmospheric Research). Currently, he serves on the scientific advisory panel for regulated river research for the Australian Water Authority and on the United Nations/UNESCO scientific advisory panel on water resources management, specifically the Ecohydrology Unit, for which he contributed a book chapter on ecohydrologic models for a

UN publication in water resources management. Dr. Gore also serves on the U.S. EPA national advisory board on large river ecology and management and on the advisory council on large river management for the Water Environment Research Federation. We have attached a listing of his primary publications related to instream flow evaluations, for your information. Graduate students, Ms. Tracy Ferring and Mr. Torrey Knight, are currently completing their graduate work and performing PHABSIM analysis as part of a graduate course in advanced instream flow analysis. This letter is a summary of our comments. In providing this comment and the opinions set forth herein, we have relied upon our combined education, training, experience, and observations, and upon scientific reports, treatises, books, and other documents commonly used in our profession, including those specifically referenced.

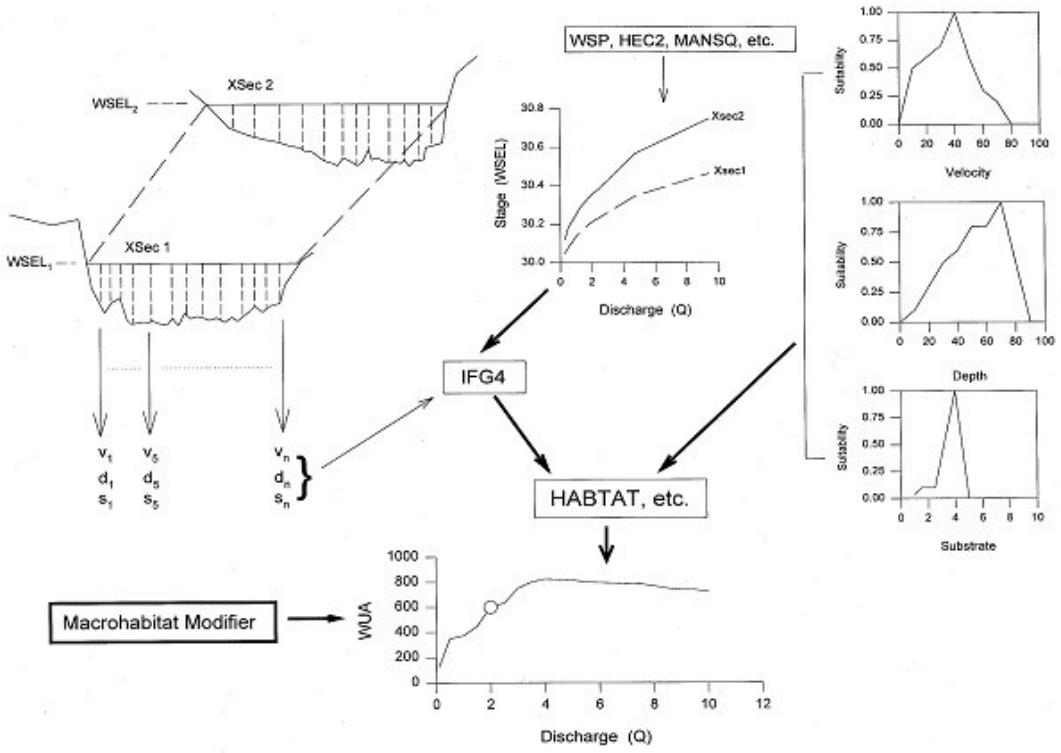
Literature Review

The DEIS in question, on the surface, does not appear to be an instream flow issue. Traditionally, instream flow analysis has been utilized, as a management tool, to reserve *minimum* flows for water withdrawal or diversion permits. These techniques have rarely been used to determine or predict the impacts of the augmentation of flows in a river channel. We suggest that it is too simplistic to assume that the addition of surface flows, even if not flood level flows, can result in the reduction of available habitat and, as a consequence, the reduction in the success of all or a portion of the biotic communities in the system. Although small, there is a body of literature to suggest that the increase in flows can have a detrimental impact on riverine biota, just as the reduction in flows has been demonstrated to do.

In examining the potential impacts of the uprating or upgrading of hydropower turbines in the Cumberland and Tennessee River systems, over 80% of available foraging, spawning, and maintenance habitat were lost to benthic macroinvertebrates, as well as all of the life stages of many fish species (Curtis *et al.* 1987; Gore *et al.* 1989; Nestler *et al.* 1988, and Gore and Hamilton 1996). In all of these cases, the increases in flows sufficiently altered the available hydraulic habitat (combinations of velocity, depth, and substrate) to make those habitat patches unusable for foraging, resting, refuge, or spawning. Although these studies were designed to examine just the impact of increased flows on physical habitat, Moog (1993) determined that even short bursts of increased flows over a long period of time, flushed non-adaptive organisms out of the system, depleted particulate organic matter, and sufficiently altered channel morphology to alter substrate composition by increased sedimentation. The depletion of macroinvertebrates ultimately led to the decline of fish populations, as well. This relatively small body of research does suggest that there is a potential impact from increasing flows to an ecosystem and we believe that the DEIS has failed to address this potential as part of the development of the coal bed methane (CBM) project.

We provide, below, our analysis of some of the river basins in the Powder River Basin oil and gas project and the probable impacts of increasing flows. Although these data are preliminary, our data suggest that BLM and its consultants have not performed an adequate evaluation of potential impacts from increased and sustained higher flows in the streams and

river of the basin. We base this conclusion on our utilization of the Physical Habitat Simulation (PHABSIM0, widely used by the U.S. Geological Survey, the U.S. Fish and Wildlife Service, and the Federal Energy Regulatory Commission for the assessment of altered flows in river ecosystems. The PHABSIM model [the evaluation tool within the Instream Flow Incremental Methodology (IFIM) (Bovee *et al.* 1998)] combines hydrologic records (from gauging stations along the river), direct measurements of conditions at the site, and biological information on the flow-related habitat requirements of various aquatic species. The output of the model is a prediction of the gains and/or losses of habitat with changes in discharge or with a proposed regulated flow regime. PHABSIM and IFIM are widely accepted as a basis for establishing acceptable flows to maintain the integrity of stream and river ecosystems (Stalnaker *et al.* 1995, Bovee *et al.* 1998). The PHABSIM protocol ties hydrologic information (stage/discharge relationships and measured information on velocity, depth, and substrate) at typical stream reaches with biological information (habitat suitability) to predict changes in the amounts and locations of available habitat over a range of discharges. A schematic of the process follows:



discharge at which 15% of the habitat is lost from optimal conditions. In general, instream flow analysts consider a loss of more than 15% habitat, as compared to undisturbed or current conditions, to be a significant impact on that population (Gore and Mead 2002). The analysis is completed with a time-series analysis of a yearly daily hydrograph of the stream to determine which time intervals contain long-duration low-flow periods. These are considered to be "bottlenecks" in the success of the population are management targets. In a similar manner, we have used PHABSIM to analyze the duration and intensity of poor-

habitat-producing high-flow events in selected basins of the Powder River project area.

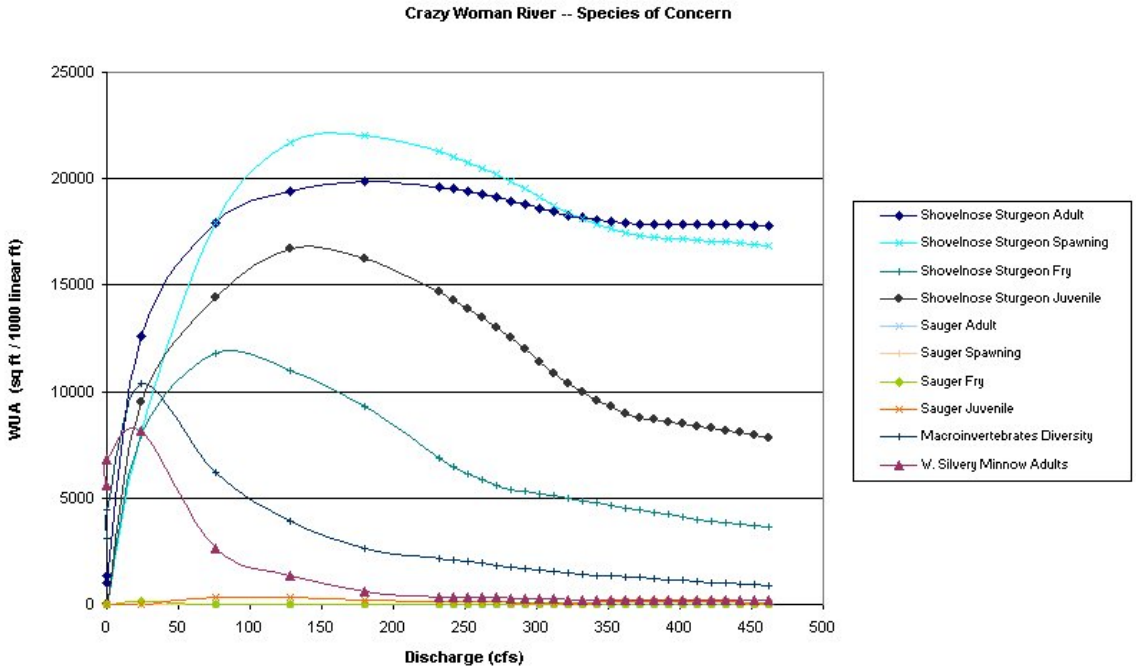
As would be typical of an analysis of impacts of discharge changes upon available habitat, a series of transects across riffles, runs and pools (a typical hydrologic stream unit) should be measured for calibration of the model. Additionally, development of habitat suitability criteria for endemic and unique species, endangered or special concern species, and keystone community species or guilds must be supplied for this evaluation. Since this had not been accomplished for this DEIS or in any previous published work, we chose to use the only available transect data. These data were measured to establish a gauging record and stations (USGS 06316400) at Crazy woman Creek at Upper station, near Arvada, Wyoming, (USGS 06324970) at the Lower Powder River about Dry Creek near Weston, Wyoming, (USGS 06317000) at the Powder River at Arvada, Wyoming, and (USGS 06426500) at the Belle Fourche River below Moorcroft, Wyoming. This single transect is most representative of deep run and pool transects, thus representing only a small portion of available habitat. The data we analyzed then are only representative of impacts to a single type of habitat. However, these are also the habitat types least impacted by flow alterations (Bovee *et al*. 1998; Gore and Mead 2002). Thus, our conclusions should be viewed as an extremely conservative view of the potential impact of increased flows from CBM development in the Powder River basin."

This type of analysis, as a preliminary analysis of potential impacts of altered flow regime, when more extensive field data collections are unavailable, have been accepted by the courts in similar analyses (see: Upper Chattahoochee Riverkeeper vs. Harold Reheis, Director; Environmental Protection Division; Department of Natural Resources (respondent) and Georgia Power Company (intervenor); Case OSAH-DNR-WW-01-74-MM [State of Georgia, Administrative Hearing]).

Habitat evaluations were performed for all life stages of sauger (*Stizostedion canadense*), shovelnose sturgeon (*Staphirhynchus platorynchus*), and adults of the western silvery minnow (*Hybognathus argyritis*). Additionally, habitat conditions to support highest benthic macroinvertebrate diversity were also evaluated. All habitat criteria were provided as standard recommended data by the U.S. Fish and Wildlife Service or the U.S. Geological Survey (Crance 1986, 1987) or modified as appropriate to the biological circumstances (with consultation with the authors), state agencies (Peters *et al.* 1989) or, in the case of macroinvertebrate data, have been previously published and used in habitat evaluations and flow negotiations in the United States (Gore *et al.* 2001).

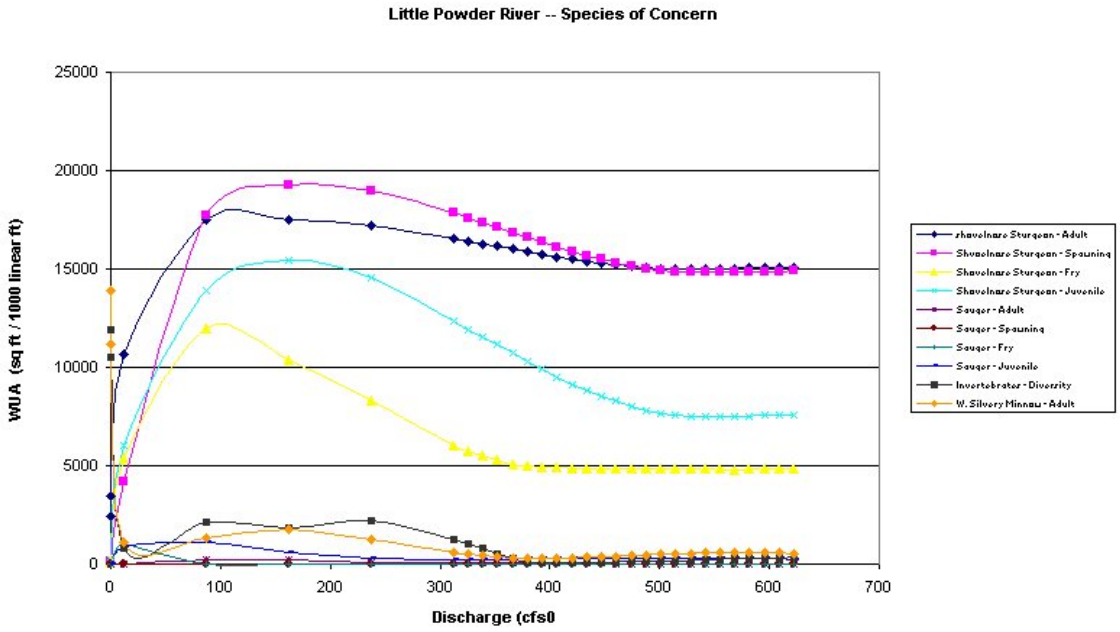
Simulation Results

Crazy Woman Creek



This diagram represents predictions of available habitat over a discharge range of 0 to 462.2 cubic feet per second (cfs). Shovelnose sturgeon adults and spawning requirements lose significant habitat at discharges less than approximately 75 cfs while fry and juveniles stages lose habitat at discharges less than 50 cfs and at discharges greater than 250 cfs. There was no available habitat for sauger adults and spawning at any discharge, while habitat losses occurred for fry and juveniles at discharges less than 40 cfs and more than 175 cfs. The most significant biota to be impacted by flow alterations on Crazy Woman creek were western silvery minnow adults which loses significant habitat at discharges less than 0.05 cfs and greater than 24.5 cfs. Macroinvertebrate community diversity is similarly affected. There are substantive losses of habitat at discharges less than 12 cfs and greater than 50 cfs as well.[Raw data are provided in attachment, Appendix 2

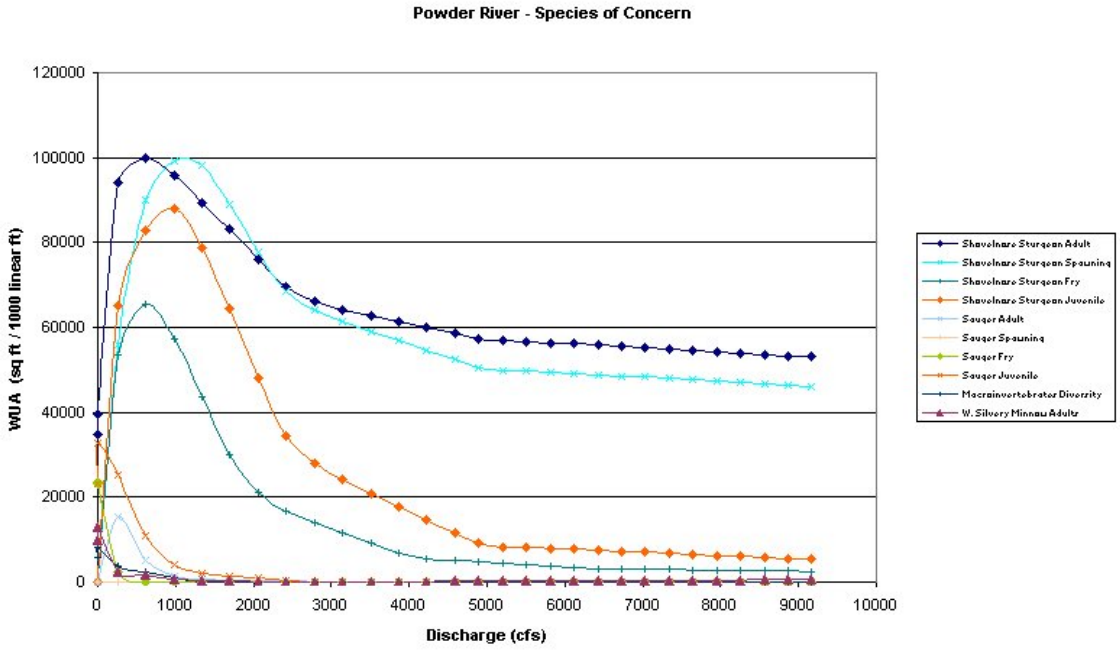
Little Powder River



This diagram represents predictions of available habitat over a discharge range of 0 to 622 cubic feet per second (cfs). Shovelnose sturgeon adults and spawning requirements lose significant habitat at discharges less than approximately 75 cfs while fry and juveniles stages lose habitat at discharges less than 50 cfs and at discharges greater than 162 and 237 cfs, respectively. There was essentially no available habitat for sauger adults and spawning at any discharge, while habitat losses occurred for fry and juveniles at discharges less than 10 cfs and more than 15 cfs for fry and more than 175 cfs for juveniles. The most significant biota to be impacted by flow alterations on the Little Powder River were western silvery minnow adults which loses significant habitat at discharges less than 0.05 cfs and greater than 0.5 cfs. Macroinvertebrate community diversity is similarly affected. Discharges less than 0.2 cfs and greater than 0.5 cfs also result in substantive losses of habitat.

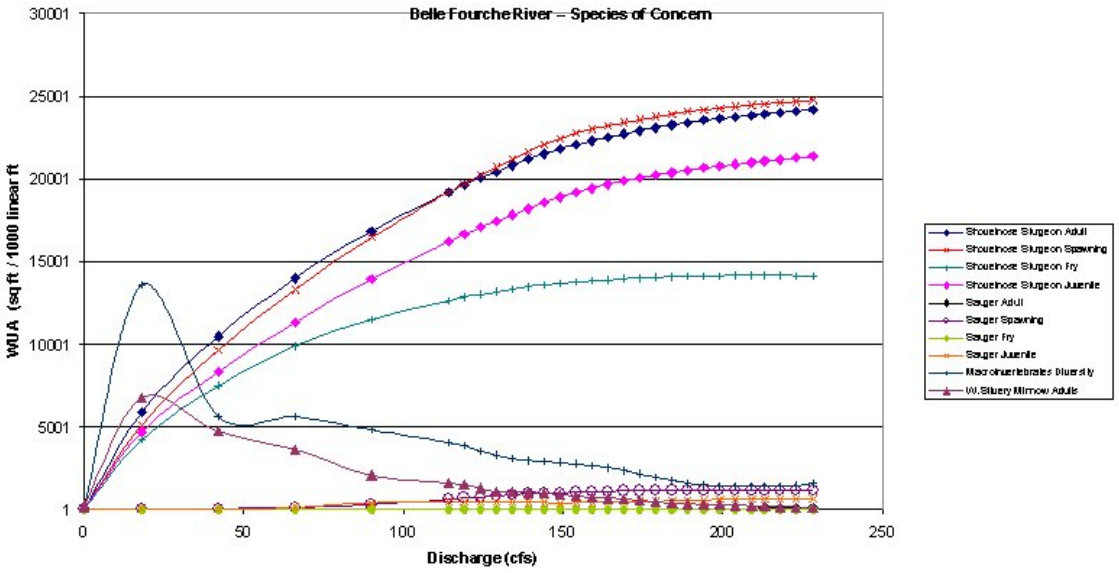
[Raw data are provided in attachment, Appendix 2]

Powder River



This diagram represents predictions of available habitat over a discharge range of 0 to 9172 cubic feet per second (cfs). Shovelnose sturgeon adults and spawning requirements lose significant habitat at discharges less than approximately 75 cfs and greater than 2000 cfs while fry and juveniles stages lose habitat at discharges less than 616 cfs and at discharges greater than 977 and 1338 cfs, respectively. There was essentially no available habitat for sauger spawning while adults lose significant habitat below 200 cfs and at discharges greater than 400 cfs. Habitat losses occurred for fry and juveniles at discharges less than 0.05 cfs and more than 125 cfs. Again, the most significant biota to be impacted by flow alterations on the Powder River were western silvery minnow adults which loses significant habitat at discharges less than 0.05 cfs and greater than 125 cfs. Macroinvertebrate community diversity is similarly affected. At discharges less than 0.05 cfs and greater than 125 cfs, substantive losses of habitat also result.[Raw data are provided in attachment, Appendix 2]

Belle Fourche River



This diagram represents predictions of available habitat over a discharge range of 0 to 228.2 cubic feet per second (cfs). Shovelnose sturgeon adults and spawning requirements were satisfied through the entire range of discharges examined. Indeed, this appears to be one of those instances in which the addition of water would increase available habitat for all life stages. Unfortunately, those same discharge increases would result in the loss of habitat for other target species. There was essentially no available habitat for sauger fry while available habitat for other life stages was minimal. Again, the most significant biota to be impacted by flow alterations on the Belle Fourche River were western silvery minnow adults which loses significant habitat at discharges less than 12 cfs and greater than 30 cfs. Macroinvertebrate community diversity is similarly affected. Discharges less than 16 cfs and greater than 30 cfs also result in substantive losses of habitat.

[Raw data are provided in attachment, Appendix 2]

The first response by any individual examining these graphs is likely to be that such discharges are rarely, exceeded (at either the high or the low end). Thus, it becomes important to understand the duration and intensity of these "poor habitat" periods. That is, the decision-makers must decide what percentage of the time a selected flow is met or exceeded during an average hydrographic and during unusually wet or dry years. This is accomplished through the Habitat Time Series (HTS) component of IFIM (Milhous *et al.* 1990). Such conditions as median habitat value over ten or twenty years of record, the percentage of available habitat if certain magnitudes of flood were attenuated or enhanced, and the duration of low habitat conditions are typical predictions of a HTS evaluation. Obviously this was not accomplished or reported in the DEIS. The DEIS estimates that less than 20% of the water used in the CBM process will ultimately reach surface flows in the local rivers and streams; the remainder of the water either evaporating or returning directly to

groundwater. This seems unlikely at certain times of the year (especially winter months) when evaporative loss and transpirational loss from vegetation will be close to zero [see, for example, Rankl and Lowry 1990, who estimated that more water moves laterally through the alluvium rather than being lost to infiltration]. Rankl and Lowry's work on the Powder River Basin is based on data collected over all months and seasons for several years rather than during the lowest water month, October, when infiltration rates were not typical of the region for the rest of the year and when the single stormwater event that was analyzed would appear to produce the desirable results presented in the DEIS. Indeed, with continuous inputs of water, many ephemeral streams are likely to be transformed into perennial streams. This will result in increases in bank storage and elevation of water tables, slowing infiltration and resulting in even higher lateral flows into the rivers and streams of the basins. This conclusion is supported by at least on current piece of research in the region. Dr. Larry Munn, at the University of Wyoming, has informed us of some recent research being performed in Burger Draw and Sue Draw. In this past year, the draw was still flowing in January and there was very little loss between discharge points and the Powder River. Dr. Quentin Skinner has indicated that the conveyance loss is only a few percent not 80%, as might be predicted by the DEIS.

John Monks, Hydro-Geosciences, who is also providing comment, has provided to us a number of scenarios to examine regarding the duration and intensity of water additions to the various watersheds in the CBM area. His scenarios envision the amount of water that would be added to the system if there were 60%, 40% and 20% of water in the CBM process was not returned to the various basins. These scenarios seem most appropriate, in view of those findings by Rankl and Lowry (1990).

We have used mean daily flow hydrographs for the period of record at each USGS site and added the conveyance scenarios (in percentages) in order to determine what might be the daily losses of habitat, when compared to existing conditions, for the target species of record. Since it does not appear that sauger and shovelnose sturgeon will be heavily impacted, we have focused upon the western silvery minnow and macroinvertebrates. The following tables were created from the raw data and graphics appended to this comment (Appendix 3).

Western Silvery Minnow

Crazy Woman Creek	60% Scenario	40% Scenario	20% Scenario
Annual Habitat Gain/Loss	-2%	-3%	-4%
Total Number of Days of Significant Habitat Loss (>15%)	60	96	133
Duration (days) of Continuous Significant Habitat Loss	14	17	32
Average Habitat Loss During Long-duration Habitat Loss	-21%	-28%	-27%

Little Powder River	60% Scenario	40% Scenario	20% Scenario
Annual Habitat Gain/Loss	-13%	-19%	-13%
Total Number of Days of Significant Habitat Loss (>15%)	97	124	92
Duration (days) of Continuous Significant Habitat Loss	14	20	14
Average Habitat Loss During Long-duration Habitat Loss	-41%	-54%	-43%

Powder River	60% Scenario	40% Scenario	20% Scenario
Annual Habitat Gain/Loss	-6%	-12%	-17%
Total Number of Days of Significant Habitat Loss (>15%)	51	120	188
Duration (days) of Continuous Significant Habitat Loss	33	46	70
Average Habitat Loss During Long-duration Habitat Loss	-23%	-34%	-21%

Belle Fourche River	60% Scenario	40% Scenario	20% Scenario
Annual Habitat Gain/Loss	1%	-1%	-1%
Total Number of Days of Significant Habitat Loss (>15%)	100	134	169
Duration (days) of Continuous Significant Habitat Loss	15	21	71
Average Habitat Loss During			

Under these three scenarios, the western silvery minnow and benthic macroinvertebrates will suffer significant losses of habitat for forage and maintenance during significant portions of the year. Even though there may appear to be a relatively small net loss in habitat over the year, there are significant daily losses of habitat of over 15%. In some cases these habitat losses occur over 33% of the year and as much as 50% of the year. Of greater significance is the duration of some of these habitat-loss periods that last for over two months and may represent losses as high as 45% or more of available habitat. Indeed, there are longer periods of habitat loss broken by single days of adequate habitat. For example, on Crazy Woman Creek, there is on time period of 32 consecutive days of significant habitat loss for western silvery minnow, but one span of 82 days in which 78 days contain significant habitat losses. On the Belle Fourche River, benthic macroinvertebrates suffer the same conditions for 56 consecutive days, broken by a single day in which habitat loss is about 10%. The intervening single day events of adequate habitat likely would result in further losses of individuals of the western silvery minnow or macroinvertebrates as they move into temporarily available habitat and are, on the following day, excluded from these habitats and, perhaps, left without adequate corridors to get to patches of acceptable habitat. Even when these habitat losses occur as additions to predictable flood events, this habitat loss is reflected as inability to access hydraulic refuge, which could result in the flushing of these organisms out of the system. Several studies have indicated that habitat losses like these can be directly correlated with loss in numbers of individuals (i.e., secondary production) and in diversity (Gore 1987;

Gore *et al.* 1998; Nehring and Anderson 1993; Bovee *et al.* 1994). Losses in diversity have the effect of simplifying community structure, making them more susceptible to additional disturbance (natural or anthropogenic) and losses of individuals (especially if fry or juveniles) can result in the creation of population bottlenecks, ultimately leading to the decline and/or extirpation of that population from the basin or similar reaches. Although there are always natural habitat bottlenecks during a water year, these occur quite predictably (spring run-off, for example) and most species are adapted to these predictable periods of reduced spawning and maintenance habitat. Refuge habitat becomes important during these time periods but must be maintained. Habitat loss at intervals other than the usual time periods can result in significant losses to production and population success. This suggests that the proposed operating scenario of continuous additions of water to the rivers in the project area will significantly impact instream communities. At a minimum, BLM must propose alternative operating scenarios in which water will not be conveyed to rivers and streams in the project area during times of potential critical habitat loss. This may mean cessation or reduction of operations during these time periods in order to reduce or eliminate the habitat loss.

These simulations of habitat conditions in the Powder River Basin demonstrate significant losses of habitat for a variety of typical riverine biota during periods of high flow as a result of the proposed CBM project. These habitat losses often have durations of over 30 days and have the potential to result in loss of productivity and diversity of benthic communities and forage fish. Ultimately, these losses, regardless of the availability of adequate habitat for other fish species, will likely result in the loss of fish populations as a result of the loss of the food base. These impacts have not been adequately addressed in the DEIS. These are significant losses to the lotic communities in these rivers and suggests a re-evaluation of the DEIS.

Although this is a preliminary analysis and only represents examination of the hydraulic habitat available for a single transect, the amount of habitat lost or gained in this, the least supportive, habitat type suggests even more significant habitat loss in more productive habitat patches. As in any river system, the greatest proportion of macroinvertebrate production, foraging by adult fish, and nursery support for juveniles and fry are in shallow areas with large amounts of cover, especially snags and undercut banks. Although greater than 25% of the habitat area in a typical reach consists of this habitat type, none of these transects could be evaluated in our analysis of the Powder River Basin. Since instream flow and minimum flow evaluations should focus upon the impacts to those areas <u>first</u> impacted by high flows, that is, riffles and runs, it is more likely than not that the greatest habitat losses are not occurring at the transects we evaluated but <u>instead</u> have yet to be analyzed. Since losses of over 50% of habitat are predicted by PHABSIM in the pool and deep run habitats, losses of comparable habitat in shallower transects will be significantly greater. It is likely that habitat losses under high flows could be well over 75% during prolonged periods of high flow, especially shallow bypass channels and shoals.

A great number of prairie macroinvertebrates and fish are uniquely adapted to the prairie stream environment. None of these species have been adequately studied for life-cycle

habitat or for description of physical habitat requirements. However, since these species have evolved under the influence of a very different hydrograph than that which will be encountered over the next few decades of CBM operation, these species may be the most likely losses from the community.

We suggest that it is imperative that BLM re-evaluate its predictions of the amounts of water that will be conveyed as surficial flow to the streams in the CBM project area and the subsequent impacts of these flows on available habitat for the biota of the rivers and streams in the Powder River Basin. From conversations with our colleagues, who are also providing separate comment, it appears that there has been an inadequate estimate of lateral flows returning to the basin as surface water. As a result, the DEIS improperly predicts no significant impact to biota when our modeling efforts demonstrate the potential for significant habitat losses over the duration of the project. These "bottlenecks" in production and/or population success could lead to the demise of those species in the community and the destabilization of community structure and ecosystem integrity.

We thank you for your time and consideration of our comments. We hope that you will conclude that the DEIS must be re-evaluated and more studies conducted before a definitive conclusion on impacts to riverine ecosystems can be made.

Sincerely,

James A. Gore, PhDProfessor and Chair

Torrey KnightGraduate AssistantTracy FerringGraduate Assistant

Citations:

Bovee, K.D., B.L. Lamb, J.M. Bartholow, J. Taylor, and J. Henriksen. 1989. Stream habitat analysis using the instream flow incremental methodology. U.S. Geological Survey, Biol. Res. Div., Info. Tech. Rpt. USGS/BRD-1998-0004.

Bovee, K. D., T. J. Newcomb, and T. G. Coon, 1994. Relations between habitat variability and population dynamics of bass in the Huron River, Michigan. Biol. Rpt. 21, U. S. Fish Wildl. Serv., Nat. Biol. Survey, Washington, DC.

Crance, J.H. 1986. Habitat suitability models: Shortnose sturgeon. Biological Report 82(10.129) U.S. Fish Wildlife Service, Washington, DC.

Crance, J.H. 1987. Preliminary habitat suitability index curves for sauger. Pp 159-167 in Proc. of the Forty-first Ann. Conf. Southeastern Assoc. Fish and Wildl. Agencies.

Curtis, L.T., J.M. Nestler, and J.L. Martin. 1987. Comparative effects on trout

habitat of hydropower modification with and without reregulation in the Cumberland River below Wolf Creek Dam, Kentucky. *Misc. Paper EL-87-2,* U.S. Army Waterways Experiment Station, Vicksburg, MS.

Gore, J.A., and S.W. Hamilton. 1996. A comparison of flow-related habitat evaluations downstream of low-head weirs on small and large fluvial ecosystems. *Regulated Rivers* 12: 459-469.

Gore, J.A., J.B. Layzer, and J. Mead. 2001. Macroinvertebrate instream flow studies after 20 years: a role in stream and river restoration. *Regulated Rivers* 17: 527-542.

Gore, J.A., and J. Mead. 2002. The Benefits and Dangers of Ecohydrological Models to Water Resource Management Decisions. *In: Ecohydrology: A new Paradigm* United Nations/UNESCO, Geneva and Cambridge University Press.

Layzer, J.B., T.J. Nehus, W. Pennington, J.A. Gore, and J.M. Nestler. 1989. Seasonal variation in the composition of the drift below a peaking hydro-electric project. *Regulated Rivers* 3: 29-34.

Milhous, R.T., J.M. Bartholow, M.A. Updike, and A.R. Moos. 1990. *Reference manual for generation and analysis of habitat time series - Version II*. U.S. Fish and Wildlife Service, Biol. Rpt. 90(16).

Moog, O. 1993. Quantification of daily peak hydropower effects on aquatic fauna and management to minimize environmental impacts. *Regulated Rivers* 8: 5-14.

Nehring, R. B., and R. M. Anderson. 1993. Determination of population-limiting critical salmonid habitats in Colorado streams using the Physical Habitat Simulation system. *Rivers* 4: 1-19.

Nestler, J.M., J.A. Gore, L.T. Curtis, and J.L. Martin. 1988. Prediction of effects on brown and rainbow trout of turbine uprating in the Cumberland River downstream of Wolf Creek Dam, Kentucky. U.S. Army Engineers, Waterways Experiment Station, Misc. Paper EL-88-10.

Peters, E.J., R.S. Holland, M.A. Callam, and D.L. Brunell. 1989. Platte River suitability criteria … habitat utilization, preference and suitability index criteria for fish and aquatic invertebrates in the lower Platte River. Nebraska Tech. Rpt. 17, Nebraska Game Fish Comm., Lincoln.

Rankl, G.L., and M.E. Lowry. 1990. Ground-water flow systems in the Powder River Structural Basin, Wyoming and Montana. U.S. Geol. Surv., Water

Resources Inv. Rpt. 85-4229.

Stalnaker, C., B.L. Lamb, J. Henrikson, K. Bovee, and J. Bartholow. 1995. *The Instream Flow Incremental Methodology. A Primer for IFIM.* Biol. Rpt. 29, National Biological Service, Washington, DC