J. David Allan, Ph.D Comments on BLM's Draft EIS

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Draft Environmental Impact Statement and Draft Planning Amendment for the Powder River Basin Oil and Gas Project

Introduction

To evaluate the impacts of coal bed Methane (CBM) Mining on the ecology of the Powder River Ecosystem, including its tributaries and many ephemeral streams, it is critical to understand the basic principles of stream ecosystem composition, structure and function. Streams and rivers are intimately connected to the landscapes they drain and the valleys through which they flow (Hynes 1970; Allan, Erickson and Fay 1997). Non-point source pollution is recognized today as the most serious family of threats to the health of the Nation's freshwaters (Carpenter et al. 1999; Karr, Allan and Benke 2000; EPA 1996). Human activities within watersheds alter flow pathways, increase sediment yield, contribute contaminants, and damage native riparian vegetation, all with well-established adverse impacts on river ecology. In order to ask, how well does the Wyoming DEIS identify the central threats of CBM development to aquatic ecosystems, we must first examine basic principles of ecosystem structure and function as applied to the Powder River watershed. Because headwater streams are likely to be most influenced by onsite activities and the surplus water resulting from CBM mining, it is important to understand their role in river ecosystems.

Streams and rivers exist within networks, and are characterized by a high degree of connectivity. What happens in one place has consequences for stream condition in another place. The Horton stream order classification system helps to clarify this point (Allan 1995). The smallest, permanently flowing tributaries of a drainage are termed first-order; the union of two first-order streams creates a second-order stream, and so on. In any drainage basin, the majority of its stream miles are in first-order streams, with progressively fewer miles of second, third, and higher orders. Thus the mainstem of a river is fed by a vast network of small streams, which together constitute its headwaters. Each headwater stream drains a small area, and is intimately tied to the landscape. Nor are ephemeral streams unimportant, particularly in arid landscapes. While these streams flow only during wet periods, they carry organic matter, nutrients and sediments into first-order streams, and may exert an influence over a considerable distance.

The river continuum concept (RCC, Vannote et al. 1980, Minshall et al. 1985) is a mature and well-accepted body of knowledge based on the longitudinal changes that occurs in any river system, and the upstream-downstream connectivity imposed by streamflow and the movements of organisms. Headwater streams (1st- through 3rd-order) are biologically productive, and export energy downstream. The energy supply to any stream or river can be categorized according to its source. Autochthonous production occurs within the stream channel, and typically is due to algae, including diatoms, green algae, and Cyanobacteria ("blue-green algae"). Allochthonous production occurs outside the stream, and typically is due to riparian vegetation (leaves, fruits, etc) that falls or blows into stream channels and is subjected to microbial breakdown, producing a protein-rich organic matrix. In arid-land and grassland streams, both sources of energy can be high (Minshall 1978, Fisher and Gray 1983). Minimal shading allows high algal production, while both herbaceous and woody riparian vegetation can provide high inputs of organic matter. Significant amounts of this biological production is exported downstream, often episodically during high flow events. Ephemeral streams of the Powder River ecosystem likely function similarly to desert streams of Arizona, accumulating biomass during periods of low or no flow, and exporting to downstream reaches during high flows (Fisher et al. 1982).

Very recent work is further establishing the often intricate connections between aquatic and terrestrial ecosystems. Instream biological production can provide important food subsidies to terrestrial consumers, such as bats and birds (Power et al. in press), while terrestrial invertebrate inputs can augment the energy available to aquatic food webs (Allan et al. 2002).

Human impacts on river ecosystems

Human activities alter river ecosystems in many ways, through changes to natural physical, chemical and biological processes (Allan and Flecker 1993, Cushing and Allan 2001, chapter 22). Contaminants have direct physiological effects, both non-lethal and lethal, and these effects may ramify through food webs to other members of the biological community. Structural changes to river channels, including channel straightening, levees, and dams, alter flow regimes and connectivity, both upstream-downstream and lateral. Invasive species, often favored by various human impacts, can dramatically affect native species. Activities throughout watersheds, collectively termed nonpoint pollution and often quantified by land-use measures such as percent agricultural land, percent impervious surface, road density, etc., increasingly are emerging as a central concern in watershed management. According to US Environmental Protection Agency (1996), the most common pollutant to streams nationwide was sediment, which was a contributing factor for 50% of impaired streams. Ultimately, of course, streams and rivers suffer from the cumulative impact of all of these stressors (Wickham et al. 1999), but often one or a few stressors overwhelm all others.

Land-use activities near the stream, i.e., within the riparian, are of special concern because they can directly affect stream ecosystems in multiple ways (Gregory et al. 1991). Changes to riparian vegetation affect allochthonous energy inputs, as well as having consequences for native vegetation and the many animals that use riparian ecosystems. An undisturbed riparian zone ensures that harmful activities occur well away from stream banks, and can trap sediments and nutrients that might otherwise enter the stream channel. Large trees are a source of wood that serves as habitat for organisms (Benke et al. 1985) and helps to maintain riffle-pool heterogeneity within the channel, thus increasing the variety of habitat.

The Powder River Ecosystem is likely to be impacted by CBM mining in several ways. Contaminated water, high in salts and other minerals, can harm instream biota and riparian vegetation. The very high SAR (sodium adsorption ratio) of well water can affect soil stability, influencing both runoff and erosion. Altered flows from surface release of well water will negatively impact thermal and flow regimes, and likely contribute to bank erosion and changes in riparian vegetation. Land-use impacts from mining operations, infrastructure development, and altered vegetation can have many indirect impacts on stream ecosystems. Collectively these impacts pose serious risks to the biota and the ecological intergity of one of the last, relatively intact examples of Great Plains fluvial ecosystems.

The Powder River ecosystem

The Powder River, and other rivers of central Wyoming including the Little Powder, Cheyenne, Belle Fourche and Tongue, flow north into eastern Montana, joining the highly valued Yellowstone River. The Powder is a healthy remnant of the many, once unspoiled rivers of this semi-arid region of the Great Plains.

There is scant published information on the Powder River ecosystem, but Hubert (1993) provides a valuable account. The following account draws upon Hubert's article and the expert knowledge of aquatic scientists who have studied the Powder and surrounding rivers, as well as studies of prairie and arid-land streams conducted elsewhere in the West. The scarcity of published information indicates the need for further investigations relevant to the proposed CBM mining.

The main river is a low-gradient shallow, highly braided system that meanders through a substantial flood plain. Most of its drainage is high plains, and is typified by highly erodible sedimentary material and an extreme climate. The Powder is characterized by very high turbidity and conductivity, highly fluctuating flows, and an unstable sand bottom in most reaches. The fish fauna is largely a warm water fauna, and the invertebrates include a number of unusual taxa of Ephemeroptera. With a length of 800 km including the South Fork, its longest fork, and undammed except for an upper tributary, the Powder now uniquely maintains habitat conditions and a fauna that must once have been widespread.

Rivers of this region, in their natural state, are typified by extremes. Temperatures range from 0 to > 30 C, river flows show a spring snowmelt signature but are highly variable throughout summer months due to thunderstorms, and can be very low during prolonged dry periods. In dry years, the Powder River upstream from Clear Creek ceases its flow (Hubert 1993). Sediment loads are naturally high, and the substrate is sandy and shifting in many locations. The river is naturally turbid and saline due to the highly erodible sedimentary material in its basin. Total dissolved solids (TDS) can reach 3,500 mg/L and specific conductance can exceed 2000 uS/cm.

Cottonwood trees (*Populus* spp), willow (*Salix* spp) sage (*Artemesia* spp) and herbaceous vegetation line most of the stream banks, and the riparian zone is especially well developed along many of the tributaries. Particularly during summer, when dry episodes are punctuated by thunderstorms and rapidly rising streamflows in ephemeral and headwater streams, large amounts of prairie-derived organic matter and debris is flushed into stream channels. According to Rehwinkle et al. (1978, cited in Hubert 1993), the tributaries are believed to be higher in biological productivity than the main Powder River, which is consistent with much ecological theory regarding the role of headwaters in exporting energy to downstream reaches.

The Powder River and its four tributaries support 25 native fish species (and 32 total), a substantial number of taxa in the comparatively species-poor West. The native fauna is tolerant of and adapted to the widely fluctuating range of temperatures, salinities, temperatures and discharges, and thus likely to be vulnerable to environmental impacts that would reduce or eliminate this natural variability. The fishes of intermittent tributaries of aridland rivers have various adaptations that allow them to persist in an environment of harsh physical and chemical conditions (Fausch and Bramblett 1991). Many of the non-native taxa in this system are salmonids, introduced into the uppermost coldwater tributaries, and until now unable to effectively colonize the lower river system. Likely changes to the natural conditions of the Powder (discussed in detail below) are likely to favor the non-native taxa, dealing an additional blow to native fishes. Large fishes such as the channel catfish (*Ictalurus punctatus*) and shovelnose sturgeon (*Scaphirhynchus platorynchus*) are highly migratory, moving between the Powder and the Yellowstone, while others move into tributaries to spawn (Hubert 1993, Smith and Hubert 1989). Thus the ecological integrity and inter-connectedness of the river system is critical to the persistence of the native community.

Although less well described, the invertebrate community also includes a unique and restricted fauna. According to Dan Gustafson of Montana State University, who has collected extensively throughout this region, the Ephemeroptera fauna of the Powder River includes a number of unusual taxa, including *Analetris eximia*, *Raptoheptagenia cruentata*, *Ametropus albrighti*, and *Homoeoneuria alleni*. These once would have been found in the sister rivers, including the Bighorn, Tongue, Green and Saskatchewan Rivers. Large mainstem dams have altered these systems, however, by trapping sediments and converting them into clearwater systems. Only the Powder remains without a major mainstem dam, and continues to have high sediment loads and support an invertebrate fauna that now can be found in few other locations.

To close the description of the Powder River it is useful to quote from the conclusion of Hubert's (1993) report: "The fish community of the Powder River is unique… and.. probably represents the kind of community that was found in free-flowing Great Plains rivers." Although less documented, it seems highly likely that the invertebrate fauna likewise is constitutes a unique remnant community. Similar rivers have been altered throughout this region, and so there is a special responsibility to ensure that CBM development in this region does not eliminate a critical remnant on a once vast and unspoiled ecosystem.

Potential impacts of CBM mining on the Powder River Ecosystem

The potential impacts of CBM mining on the Powder River Ecosystem, detailed below, are based on the expectation that large amounts of groundwater will enter surface and shallow sub-surface drainage pathways. According to the Wyoming DEIS, the primary means of water disposal is direct surface discharge. This flow is likely to alter key ecosystem functions within the stream and within the riparian zone, as described below. It is further anticipated that this water will be of lesser water quality that surface water, with likely adverse affects on riparian vegetation and stream biota. In addition, infrastructure to support CBM mining, including roads and site footprints, are expected to contribute to environmental impacts. This analysis includes impacts to ephemeral and headwater streams as well as the main river. It should be very strongly emphasized that important impacts are highly likely to occur under certain conditions, and that average conditions do not adequately represent expected risk. Specifically, impacts are likely to be greatest during times of low flow, in ephemeral and small perennial streams, and during times of initial well production, when the greatest quantities of water are expected to be released.

Under the assumption that substantial quantities of well water will reach stream channels, CBM mining activities have a very high probability of altering natural thermal regimes. Groundwater will cause winter warming, perhaps resulting in winter surface flows in what would otherwise be frozen-over or dry streams, and substantial summer cooling. These effects are similar to those caused by deep-release reservoirs on large rivers, where bottom water is at near-constant 4 C, causing winter warming and summer cooling. Altered thermal conditions was responsible for the elimination of the majority of aquatic invertebrate taxa for a distance of at least 30 km on the Saskatchewan River (Lehmkuhl 1974), because many taxa produced over-wintering eggs that required a period of freezing followed by warming in order to hatch.

Under the same assumption, flow regimes also are likely to be altered, a topic treated in detail by another reviewer. However, it is important to note that the constant input of groundwater has a high probability of making river flow more constant, and a very high probability of converting an unknown number of ephemeral streams to perennial streams of constant flow. The natural cycle of accumulation and export of autochthonous and allochthonous organic matter will be altered, with unknown consequences.

A more constant flow regime poses threats to riparian and stream channel vegetation. While the extent of flow regulation brought about by well discharges may not be as extreme as those caused by large mainstem dams, some lessons learned from the effects of regulated flows on riparian vegetation deserve consideration. Cottonwoods are the dominant riparian trees throughout this region. They comprise a unique riparian ecosystem that is of great value to mammalian and avian biota. They are the main source of wood to the channel, thus likely provide valuable snag habitat to invertebrates and fish, as well as create channel heterogeneity. Their leaves and other plant products are a source of coarse particulate organic matter and thus an important allochthonous energy source to stream food webs. More constant stream flows tend to result in the displacement of riparian vegetation, adapted to flow variability, by upland plants that cannot tolerate frequent inundation. In many areas of the arid west, the non-native saltcedar invades the riparian following human actions that make streamflows more constant. Saltcedar is established in the region, and so poses a threat to the riparian zone of the Powder and other rivers of the region.

Discharge from CBM wells is likely to travel through riparian zones via surface water flows or shallow sub-surface flows, also affecting riparian vegetation. These effects may harm or promote plant growth, depending on the quality of mined water. Damage to riparian vegetation due to direct toxicity will have adverse effects similar to those described in the preceding paragraph. If mine water is of sufficient quality to promote herbaceous vegetation near stream channels, this potentially will attract grazing livestock, which brings risks of streambank degradation. Seepage and wet areas may be colonized by non-native plants, such as Purple Loosestrife and Hoary Cress, both of which are present in the region. Finally, drawdown of aquifers can result in lower streamflows due to groundwater decline, and this can seriously alter vegetation patterns (Stromberg et al. 1996). The fact that these are conflicting and uncertain scenarios points to the need for further investigation.

The turbidity of streamwater may increase or decrease as a result of CBM mining. A substantial and constant supply of clear groundwater will reduce turbidity, whereas any sediment mobilized by road and site construction, as well as any long-term reduction in vegetation cover due to site activities, will increase sediment loading into the system. Because these are off-setting activities of uncertain magnitude, the direction of change is difficult to predict. While it often is assumed that turbidity negatively impacts streams, and in most instances of anthropogenic disturbance this is true, reductions of turbidity in naturally turbid prairie streams, which has been observed due to reservoir trapping of sediments, can have adverse effects. Rabeni and Smale (1995) note that increased water clarity in some plains streams has allowed non-native piscivores to be especially successful, to the detriment of native taxa. Gustafson (personal communication) attributes the uniqueness of the Ephemeroptera fauna of the Powder River to the absence of a mainstem dam that would convert a sediment-rich system to a clearwater system. While it is speculative to suggest that augmented groundwater flow to the Powder could have a similar effect, the possibility should not be discounted.

The addition of substantial quantities of water of poor quality has a very high probability of resulting in both lethal and non-lethal effects. Without specific knowledge of the amount and quality of added water, it is difficult to forecast impacts, which are treated in detail by another reviewer. It should be noted that surface waters in the Powder River Ecosystem already reflect the high mineral content of the land and high evaporative rates of the region, resulting in Specific Conductance values as high as 2000 uS/cm. While most scientists would agree that the fauna is adapted to this extreme, there is no reason to believe that the fauna can readily tolerate significantly higher mineral content of the water. This situation may be analogous to the temperature tolerances of fishes, which seems to reach a maximum near 40 C, and so the fishes that occupy very warm waters have the least, not the most, capacity to withstand further warming (Matthews and Zimmerman 1990). The Montana DEIS (US BLM 2002) expresses concern that the assimilative capacity of rivers may be so reduced by Wyoming discharges that no Montana CBM water could be released, clearly suggesting a threshold is near.

Construction of wells requires road access and well-related infrastructure. These activities have a very high probability of disturbing surface soils and creating erosion. In addition, drilling and pumping machinery is expected to produce contaminants. In the absence of a well-managed containment program these are likely to enter stream channels along with surface runoff, with expected harmful effects on stream biota.

Construction of infiltration basins, irrigation when suitable, and use of lined and unlined containment ponds are described by the DEIS as possible alternatives to surface water discharge. All these options likely are preferable to direct discharge into receiving stream channels, and also provide the opportunity to treat water and manage discharge releases. However, there is a very high probability that standing water bodies will develop their own biota, and since such water bodies are unnatural in this area, there is a high probability that they will develop a non-native fauna, which can then colonize surrounding habitat. There is a very high probability that these standing water bodies will attract migratory waterfowl. In California and elsewhere, standing water of high toxicity has been harmful to such species. Failure of the dam or impoundment walls of holding basins poses a risk of catastrophic harm to affected surface waters, and represents the extreme end of the possible impacts of well water.

Depending upon the magnitude and timing of well water releases, and the influence of high SAR on soil stability, and possible changes in riparian vegetation integrity, CBM discharges could cause significant bank erosion in tributaries or possibly in the main Powder River. While the Powder is a naturally dynamic system characterized by high sediment loads, the possibility of significant degradation in river habitat, brought about by augmented flows and bank erosion, should not be discounted.

<u>Summary Evaluation and Recommendations</u>

The Powder River Ecosystem supports many unique elements of ecosystem function and biological diversity associated with its physical setting, and its status as one of the remaining river systems without mainstem dams, and with a low level of human impact. Coal bed methane mining has the potential to severely disrupt the ecosystem and harm its biota, both within the riparian zone and within the stream itself. The interconnectedness of rivers with their landscapes renders any river ecosystem vulnerable to numerous threats from human activities. It is difficult to imagine that the development of 50,000+ wells throughout the basin will be harmless.

Two central arguments that are well-supported by ecological theory and practice must be re-emphasized here. First, environmental impacts are often not well captured by average conditions, but by particular conditions. The effects of CBM discharge are likely to be more severe in ephemeral and smaller perennial streams, during times of low flow, and early in the CBM extraction when well water releases are greatest. Second, ecosystems are naturally variable, and few illustrate this principle more dramatically than the Powder. Characterized by extremes of temperature, flow, salinity, and sediment transport, and unaltered by large mainstem dams, it retains a unique native fauna because it retains the conditions under which that fauna historically has flourished. Altering those conditions is highly likely to significantly damage the ecological integrity of a largely intact Great Plains river, a surviving remnant of a once vast and widespread ecosystem.

While the environmental impacts have some degree of uncertainty associated with them, much of that uncertainty is due to lack of critical information about the immediate impacts of CBM mining. Many of the environmental impacts identified by this reviewer carry a very high probability of occurring, if assumptions about water discharges are approximately correct. Key elements of the ecosystem likely to be impacted include the thermal, flow, and sediment regimes, riparian vegetation structure, and land-water linkages that depend on an intact riparian zone.

Many specific recommendations follow from the above analysis. Grouped into the two broadest recommendations, this reviewer urges the following:

1. The DEIS lacks critical information about the basic ecology of the Powder River Ecosystem, and it lacks critical information about the amount and quality of water that will be discharged onto the land and into surface drainages. A more thorough study should be conducted as part of the DEIS.

2. In order to evaluate impacts on the Powder River Ecosystem, monitoring both pre- and post mining development is essential. This monitoring should examine key aspects of the physical, chemical, and biological condition of the riparian ecosystem and the river ecosystem. At present the possible impacts of CBM mining are extrapolated from a relatively modest level of current activity. If CBM mining is significantly ramped up, it should be accompanied by a serious and well-developed plan of adaptive monitoring that will allow responsible agencies to assess the extent of impacts as they potentially develop, and adapt regulations accordingly.

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