Chuitna Coal Mine baseline monitoring and restoration plan review

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I. Introduction

This is a report from the review of the following documents: 1) "Aquatic Biology: Existing Information for the Chuitna Coal Project", June 18, 2006, prepared by OASIS Environmental Inc., 2) "Chuitna Coal Project 2006 Freshwater Aquatic Biology Study Program" April 4, 2007, prepared by OASIS Environmental Inc., 3) "Chuitna Coal Project – 2007 Freshwater Aquatic Biology Study Program", March 2007, prepared by OASIS Environmental Inc., 4) Chuitna Coal Project Wetland Functional Assessment", March 5, 2008, prepared by HDR Alaska Inc., 5) "Part D7 Fish and Wildlife Protection Plan, Chuitna Coal Project", July 2007, prepared by PacRim Coal, LP, 6) "Chuitna Coal Project Hydrology Component Baseline Report, Historical Data Summary", March 2007, prepared by Riverside Technology Inc., 7) "Winter Freshwater Fish Habitat Baseline Report, Chuitna Coal Project", January 2009, prepared by OASIS Environmental Inc., and 8) "Movement and Abundance of Freshwater Fish in the Chuit River Drainage, Alaska, May through September 2008", February 18, 2009, prepared by LGL Alaska Research Associates, Inc.

This scientific review found critical elements missing from the documents. The failure to address food webs, trophic linkages, interactions among upstream-downstream, stream-riparian, stream-marine, and basin-wide linkages (below and above ground) severely undermines the ability of the mining plans to protect ecosystem function during mining and to restore it post-mining. Further, the lack of consistent, long-term sampling (at least 10 continuous years via consistently applied sampling techniques) does not provide the needed estimate of annual biological variability or range of variability, and therefore does not provide a reference to which post-mining rehabilitation effects can be compared. Finally, recreating the structural complexity and interconnectivity of the below-ground sediment layers in the back-filled mine pit will be impossible, permanently and negatively affecting the natural flowpaths and hyporheic function (including natural upwelling and downwelling) upon which existing biological productivity and biocomplexity depend.

II. General comments

A. Food webs

Noticeably missing from the existing baseline studies and restoration plans in the Chuitna system is an understanding of food webs, trophic processes, and their dynamics. The flow of nutrients, detritus, and prey to and through food webs has been well studied in recent years, and it is clear that food web complexity and productivity is what in part drives fish and other aquatic consumer populations (Polis et al. 2004, Wipfli and Baxter In review).

In baseline studies in the Chuitna system, benthic macroinvertebrates (BMI) and fish were sampled for a few years, independent of each other (i.e., there was no attempt to understand their trophic interactions and their dependence upon and interactions with their environment), but the role that BMI play in supporting fish populations, when and where they are important, and to which fish species and ages classes has been completely overlooked. And BMI are just one small part of the larger food base that supports fish. The science on food webs has progressed markedly over the past several years (Polis et al. 2004), including that from Alaska (Wipfli In press). BMI, along with many other sources of nutrients and prey, are critical to the survival and production of fish, including juvenile salmonids (Wipfli and Baxter In review). Understanding the trophic pathways in the Chuitna system is one of the first steps necessary for restoration planning and monitoring, and these studies and analyses need to be undertaken. Further, sampling of trophic pathways can and should be done for a minimum of 10 years to begin to get an understanding of the spatial, and seasonal and annual variability in prey abundance and prey flow in these food webs.

B. Watershed-scale perspective

Understanding *watershed-wide* processes, linkages, and interactions is also key to understanding what drives ecosystem productivity and ultimately fish populations, and should therefore be a central part of understanding ecosystem function and its restoration in the Chuitna system. Multiple spatially and ecologically distinct but interacting habitats throughout the drainage ultimately drive fish demographics and productivity, within the more limited and confined regions of fish inhabitation in the watershed. In other words, what happens in one part of the drainage can influence other parts of the drainage, e.g., headwater effects on downstream habitats and communities (Vannote et al. 1980, Gomi et al. 2002, Wipfli and Gregovich 2002, Wipfli et al. 2007, Wipfli and Baxter In review). This has been particularly highlighted for some of Alaska's watersheds. Understanding large wood budgets, and nutrient, organic matter, and prey budgets at the watershed scale would help determine the feasibility of restoration plans.

There has been very little, if any, thought or sampling devoted to understanding broader watershed-scale processes and their interactions across time and space in the Chuitna system (e.g., how headwaters affect downstream habitats, or how riparian zones affect the flow of terrestrial invertebrates to fishes). This clearly needs to be undertaken if there is any hope of protecting the Chuitna system during mining operations and restoring the Chuitna system after mining has taken place. As indicated in the above section II. A., this should be accomplished over the course of at least 10 years to get a minimal measure of annual variability.

C. Off-channel-stream linkages

Off-channel habitats such as wetlands, ponds, remnant oxbow channels, etc., can be important rearing, overwintering, and foraging areas for fish (Limm and Marchetti 2009). Understanding the role/function of these off-channel habitats is crucial to understanding broader watershed function. These habitats were not adequately sampled for fish or invertebrates during the baseline sampling, nor was any attention given to foraging ecology of fish and determining what prey are responsible for supporting the various species of fish, and when (e.g., diet analysis), in these habitats. Maintaining the productivity of off-channel systems, and their hydrological connectivity to the larger channels is crucial for the restoration of long-term productivity of the Chuitna system.

Beaver dams are an important component of broader riverine function and productivity. For example, the habitats they create provide key rearing, foraging, and overwintering habitat for fish. The function of beaver pond habitats, and their role in broader watershed productivity, needs to be better understood in the Chuitna system, and more care needs to be given to protecting these habitats, and allowing them to persist at current levels during and after mining operations.

D. Riparian-aquatic linkages

The science on the interactions between streams and their riparian zones has progressed substantially over the years, particularly with our understanding of the flow of food (prey - largely invertebrates) and nutrients between these two habitat types (Richardson et al. In press). Ecologists have long recognized the importance of terrestrial inputs of nutrients, dissolved organic carbon, and plant matter to microbial productivity and invertebrate production in streams (Cummins 1974; Vannote et al. 1980). While these nutrients and energy indirectly feed higher consumers such as salmonid fishes, terrestrial invertebrates that fall into streams are a relatively high quality food source that is directly available to fish. Terrestrial invertebrate subsidies to streams can be substantial during the plant growing season, with annual inputs to forested temperate streams as high as 11×10^3 mg m^{-2} yr^{-1} (see Baxter et al. 2005 for a review), dependent in part on the extent and composition of riparian vegetation (Mason and MacDonald 1982; Edwards and Huryn 1995; Romero et al. 2005). Terrestrial invertebrates can comprise more than half of the energy ingested by stream fishes (Wipfli 1997; Allan et al. 2003) and are often the preferred prey of juvenile salmonids (see reviews by Hunt 1975, Baxter et al. 2005). Wipfli (1997) found that terrestrial prey inputs averaged 10 mg dry mass m^{-2} d^{-1} but at times were as high as 39 mg dry mass m^{-2} d^{-1}, and comprised half or more of the energy intake by salmonids in small streams in southeastern Alaska. In other places, terrestrial invertebrates have been shown to comprise roughly half or more of the annual prey ingested by salmonids (Kawaguchi and Nakano 2001; Nakano and Murakami 2001), with significant consequences for fish growth and abundance (Baxter et al. 2007; Kawaguchi et al. 2003).

Vegetation type (e.g., plant species, coniferous vs. deciduous) and plant community structure affects the amount and type of food supporting salmonid populations (Piccolo and Wipfli 2002, Allan et al. 2003, Richardson et al. In press). Deciduous species such as alder supply more food than many conifers in Alaska (Piccolo and Wipfli 2002, Allan et al. 2003).

Understanding the process of energy flow from streams to riparian habitats, feeding riparian consumers such as birds, and of prey flow from riparian habitats to streams is crucial in the Chuitna system. Knowing how the current plant community affects trophic pathways and food supplies that flow from riparian habitats to streams is essential to more fully understand how this particular trophic process is driving fish populations in the Chuitna system currently. It is also essential to understanding how these processes need to be protected and restored in post-mining reclamation activities, to ultimately restore and sustain fish productivity and other consumers.

E. Headwater-downstream linkages

Ecological linkages between headwater streams and larger-order rivers are better understood today than they were years ago, and a growing body of literature indicates that headwaters are crucial for sustaining the structure, function, productivity and biocomplexity of the downstream ecosystems they flow into (Haigh et al. 1998). Headwater streams provide downstream habitats with a multitude of ecosystem services, including water, nutrients (e.g., nitrogen and phosphorus), food (e.g., organic matter and invertebrate prey for fishes, salamanders, insectivorous birds), and wood which provides structural habitat for biota (Wipfli and Gregovich 2002, Compton et al. 2003, Gregory et al. 2003, Wipfli et al. 2007). They also serve as refugia, spawning habitats, and source areas for biodiversity (Bramblett et al. 2002, Meyer et al. 2007).

Headwater streams affect the ecology and biological integrity of downstream reaches for several reasons. First, headwater habitats encompass the bulk of stream networks and watershed land areas (Naiman 1983a, Benda et al. 2005). Second, they are closely tied spatially to larger streams, entering these waters at numerous contact points (tributary junctions) along channel networks (Leopold et al. 1964). And third, the water draining from headwater streams provides a continual source of essential products (e.g., nutrients, food, wood), which support aquatic and riparian biota (Naiman & Sedell 1979, Naiman 1982, 1983b, Meyer and Wallace 2001, Wipfli and Gregovich 2002). Further, in coastal Alaska and the Pacific Northwest, higher gradient landscapes can often provide fast flowing headwater channels, speeding the delivery process of materials from steep gradient headwater areas to the receiving food webs downstream. Headwater tributary streams, including those that are fishless, are sources of invertebrate prey to predatory fishes in recipient mainstem habitats.

Studies have shown that organic matter and nutrients originating upstream can fuel secondary production in downstream habitats (Vannote et al. 1980; Wallace et al. 1997), but more recent investigations have focused on the transport of invertebrate prey down stream networks, subsidizing downstream fish-bearing food webs via fluvial transport of invertebrates (Wipfli et al. 2007). Wipfli and Gregovich (2002) showed that fishless headwaters may be a year-round source of invertebrates to fish habitats lower in drainages of SE Alaska. They calculated that within a typical southeastern Alaska watershed, subsidies from fishless headwaters (163 mg dry mass of invertebrates $stream^{-1} d^{-1}$; 10.4 g dry mass of detritus $stream^{-1} d^{-1}$) are at levels that could theoretically support 0.2 to 2.0 young-of-the-year coho fry per m^{-2} of stream reach downstream. In addition, Piccolo and Wipfli (2002) reported that headwater subsidies of both invertebrates and leaf litter were strongly mediated by upland forest management and riparian vegetation type. Further, prey from headwater sources appear to be seasonally important at fishless-fish habitat interfaces, as some fish species may seek out these specific habitats during certain times of the year (Bramblett et al. 2002; Bryant et al. 2004), and may partly explain the high fish densities often seen at tributary junctions (Benda et al. 2004).

Recognizing the importance of headwater-downstream linkages and at least attempting to understand the strength of these linkages in the Chuitna system is critical for protecting its short and long-term ecosystem productivity, biodiversity, and complexity throughout the entire watershed.

F. Marine-freshwater linkages

The science on ecosystem linkages between the ocean and fresh water has progressed remarkably over the last decade, and much of this new science has been generated from Alaska. Strong ecological linkages connect marine systems and watersheds via runs of anadromous fishes (e.g., salmon, stickleback), and these linkages have been shown to be essential to the long-term productivity and sustainability of riverine function, nutrient supply and storage, and food web and fish productivity (Wipfli et al. 1998, Gende et al. 2002, Naiman et al. 2002, Wipfli et al. 2004). These linkages still exist naturally and are strong in Alaska because Alaska still supports good runs of salmon, but riverine habitat degradation and loss can severely impact these linkages. In the Pacific Northwest, suppressed salmon runs have led to severe nutrient deficits, leading to reduced freshwater productivity and serious problems with attempts to restore salmon and their ecosystems (Gresh et al. 2000).

Marine inputs from adult salmon returning to freshwater habitats to spawn provide this linkage through providing major energy and nutrient subsidies to freshwater food webs (Krohkin 1967, Krohkin 1975, Mathisen et al. 1988, Elliott 1997; Schmidt et al. 1998; Wipfli et al. 1998; Scheuerell et al. 2005). Salmon range from 2-50 kg each and often return in very high numbers. Returning adult salmon densities can range broadly from a few spawners per stream, to many spawners m^{-2} (> 20 kg m^{-2}) in cases where upstream fish passage is partially or fully blocked. Even very small watersheds can experience large returns of salmon for their size. Following salmon runs, marine carbon, nitrogen, and other nutrients are sequestered at multiple trophic levels in freshwater and terrestrial ecosystems (Kline et al. 1990; Chaloner et al. 2002a; Hicks et al. 2005), and these subsidies dramatically elevate aquatic productivity. The amount of basal trophic levels such as biofilm and invertebrates can increase up to 25 times in Alaska stream systems that receive spawning salmon, and more salmon lead to increased responses, up to a point (Wipfli et al. 1999, 2003). Increases in benthos can be so high simply because Alaska's watersheds, particularly those along the coast, tend to be nutrient limited (mainly by orthophosphate), so any amount of nutrients added, in this case via returning salmon, help sustain ecosystem productivity and function.

Further, aquatic invertebrates colonize and consume salmon carcasses (Piorkowski 1995) and can be found in high densities on and around dead salmon soon after the run (Minakawa and Gara 1999; Chaloner and Wipfli 2002; Claeson et al. 2006). Chaloner et al. (2002b) showed invertebrate growth rates increase in the presence of carcasses in Alaska streams. Through invertebrate prey production these increases are translated to stream-resident salmonids, and young fish also ingest salmon tissue and eggs directly (Bilby et al. 1996). Wipfli et al. (2003) showed that stream-resident salmonids grew faster and larger in southeastern Alaska streams enriched with salmon carcasses and eggs. Similarly, in selected Washington streams, juvenile salmonid growth increased in response to artificially-added salmon carcasses (Bilby et al. 1996; 1998).

Further, salmon runs are important for supplying food webs with omega-3 fatty acids, lipids, proteins, and other macromolecules that are essential for the integrity and health of stream food webs and fish (Heintz et al. 2004, Wipfli et al. 2004, Heintz et al. In review). Juvenile coho salmon rearing in streams with more salmon sequester more energy, put that energy into body reserves that in turn increase their likelihood to survive and eventually return from the ocean to spawn.

No baseline work was done to understand the extent of these ocean-watershed linkages and the marine subsidy effects on the Chuitna system and its food webs. This work needs to be completed for the Chuitna. Like other Alaska systems, the Chuitna likely depends greatly upon the annual returns of salmon, and slumps in returns (from mining impacts for example) could easily lead to long-term and potentially permanent losses of salmon in the system, as a result of long-term nutrient deficits as seen in parts of the Pacific Northwest (Gresh et al. 2000). Simple and somewhat routine measurements of stable isotopes, fatty acid signals, and lipid content of selected BMI and fish, for starters, would tell us a lot about how and to what extent the Chuitna system depends upon the marine system to sustain its health and productivity. This baseline information is important for rehabilitation, as it establishes the degree to which the Chuitna system relies upon marine nutrients (e.g., nitrogen) and energy (i.e., carbon).

G. Physical-chemical-biological interactions

1. Hydrologic flowpaths and linkages. Hydrologic flowpaths that currently exist, which are crucial to biological activity, food web productivity, hyporheic processes and exchange of materials with streams (Stanford and Ward 1993, Stanford et al. 2005, Winter 2007), will be destroyed in the Chuitna system from the coal mining as proposed, and cannot be recreated. And riverine systems also cannot 'repair' such damage. The mosaic of sorted sediment veins and networks (Cardenas et al. 2004, Packman et al. 2006) that have been laid down over thousands of years through natural channel evolution and development along the riverine corridor (including deep below-ground habitats) makes the Chuitna system the fish producer that it is today. Removal of the stream channel and its associated hydrologic system during mining operations will permanently disrupt ground water movement associated with the stream, hyporheic exchange, water chemistry, and stream water temperatures for the life of the stream. This will greatly and irreparably impact the Chuitna food web, its productivity, and could single-handedly destroy the Chuitna system as a viable salmon producer. It will also likely destroy the Chuitna system for other aquatic and riparian species that rely on its intact stream, pond, lake, and wetland habitats.

Also, it is essential that even the smallest tributaries remain hydrologically connected (surface and subsurface) to the larger channels during and after the mining activities. These tributaries are travel corridors and seasonal refugia for aquatic species, including invertebrates and fish, and are key components contributing to the overall health, function, and productivity of the Chuitna system.

2. Contaminants. If increases in flocculants and metal concentrations, and changes in pH occurs, which is often the case during and after mining, loss of in-stream invertebrate production will occur depleting prey resources for fishes (Rosenberg and Resh 1993, Loeb and Spacie 1994). This may be a problem during and long after the mining is completed, and particularly important for the mining void after it is backfilled, as water fills and drains the sediment-filled pit. As in the above point, water chemistry degradation could single-handedly devastate food web integrity, complexity, and productivity, impacting fish for the life of the Chuitna system. Rearing salmonids in freshwater systems in Alaska are often food limited, and any reduction of the natural flow of prey (abundance, species richness, seasonal timing, nutritional value) is expected to affect fish abundance and productivity.

Flocculants can both contaminate stream water, and physically impair aquatic habitats, all but eliminating suitable substrate and a living environment for BMI. The flocculent often covers streambeds, stream gravels and woody debris, eliminating essential habitats and making them inaccessible substrate for BMI. Loss of water quality, even at small increments, has been well documented to devastate BMI species, particularly mayflies, stoneflies, and caddisflies (Loeb and Spacie 1994).

These groups of invertebrates have been shown to be important in the Chuitna system as pointed out in the Chuitna baseline monitoring studies (OASIS 2007, OASIS 2008), and loss of these species may mean a major loss of food resources for fish. Loss of food will mean loss of fish.

3. Annual variability. Noticeably missing from the baseline data collection from the Chuitna system – as alluded to earlier in this document – are estimates of long-term annual variability, including for water chemistry and quality, water temperature, physical characteristics of the stream, streambed and riparian zone, and biological parameters of the drainage. An adequate baseline sampling program should encompass a long enough period of time to: 1) capture the range of natural variability, 2) provide a reliable estimate of the true population mean, and 3) provide a benchmark (target) for rehabilitation efforts. As an example, Adkison and Finney (2003) show how salmon abundance can vary widely over long time periods (e.g., Figs 2 and 4 in their paper -- Salmon "catch" is often used as an index of salmon abundance). Salmon can easily range 10-20x in population size, and their high-low population cycles appear to recur, in this case every 5-10 years, embedded within much longer time scales of nearly 50 yrs. Although the Adkison and Finney (2003) examples represent salmon, they are a good model for other species, and may further provide some expectations about variability in physical and chemical components of natural systems as well. Limited baseline data of only a few years in the Chuitna system does not reflect the range of natural variability, or what the true means are, regarding stream flow, chemistry, and invertebrate and fish densities. In other words, we don't know where, on figures 2 and 4 (Adkison and Finney 2003), the current biological population densities are in relation to the baseline data that has been collected from the Chuitna system (i.e., with invertebrates, fish, etc). Present population densities could be near the low or high range of natural variability, or somewhere in between. Because of the limited baseline data period, it is impossible to say what the true rehabilitation targets and restoration expectations should be for Pac Rim.

The few years that the biological data were collected tells us little about the natural range of variation, which needs to be understood in order to put post-mining restoration effects and monitoring into context. A minimum of 10 contiguous years of chemical, physical, and biological sampling is needed to begin to get an understanding of the bigger picture of annual variability, and how natural variability drives Chuitna biological populations and communities.

H. Fish

1. Homing of adult salmon. Olfactory cues with returning salmon and changes in water chemistry from mining operations during and after mining could be a major issue (Royce and Watson 1987, Groot and Margolis 1991), and has not been at all addressed. Even slight changes in pH or metal concentrations could change the homing behavior and therefore returns of adult salmon to the Chuitna system.

2. Displacement mortality. Moving fish from the mining area to other habitats will be a problem for fish, as their densities will undoubtedly exceed local habitat carrying capacity, causing high mortality in moved fish and even in existing locally-resident fish. Research in Alaska has shown that stream-dwelling salmonids are food limited, so any increase in local fish densities will most certainly result in fish stress and mortality (Wipfli 1997, Wipfli et al. 2003). Competition for food and space is expected to lead to indirect mortality, as well as direct mortality from predators as displaced fish search for new, desirable habitats. There is no evidence in the literature suggesting otherwise. Further, if food is limiting, then the upstream-downstream impacts highlighted in section II. E. are expected to apply here, where impacts in the mined area will affect habitats downstream (Vannote et al. 1980, Gomi et al. 2002, Wipfli and Gregovich 2002, Wipfli et al. 2007) by affected material that gets transported downstream (e.g., food).

3. Demographics and ecology over broader temporal and spatial scales. Also needed are estimates of fish abundance (especially juvenile and spawning adult salmon), distribution, seasonal use of habitats, and fish movement throughout the Chuitna system over a longer time period. A watershed is a highly interconnected complex of aquatic (and terrestrial) habitats, including mainstems, off-channels, beaver ponds, wetlands, and lakes. This collection of habitats serves as refugia, foraging areas, movement corridors, and overwintering habitats throughout different times of the year. Use of all these habitats over broader spatial (watershed) and temporal (10-year) scales will provide a needed, more complete picture of habitat use and variation through time. This will provide a more realistic chance of detecting mining impacts. A few years of inconsistently collected data, as is currently the case, is insufficient. More years of pre-impact data will also improve the robustness of the BACI design proposed by LGL (LGL 2009). While the BACI design may be appropriate if there were sufficient data, four years of pre-impact data is inadequate. And, to improve the BACI approach, both 2002 and 2004 should be used as reference streams (Smith 2002). With that said however, a full BACI assessment should be performed by a statistician familiar with BACI designs.

4. Salmon genetics. A salmon geneticist should be consulted regarding the potential loss of a genetically distinct salmon subpopulation. If the spawning population of salmon present in the Chuitna system is genetically distinct from neighboring populations, this subpopulation may be permanently lost or severely depleted, preventing recolonization of salmon during and after the mining activities.

I. Invasive species

Invasive species continue to spread and impact aquatic ecosystems throughout the globe (Mooney and Hobbs 2000). Invasive species often invade when human traffic enters or increases in a particular place, increasing the likelihood that an animal life stage or plant reproductive part is brought into a given place. Invasives often spread rapidly and displace and impact native species, in both terrestrial and aquatic systems (Mooney and Hobbs 2000). Alaska has been spared many of the problems associated with invasive species because these plants and animals have simply not been introduced in numbers as in the lower 48 states and other places, but there are several invading species that have taken hold in Alaska, especially near population centers such as Anchorage.

There is a substantial risk that one or more invasive species could get introduced and spread in the Chuitna system. Pike are of particular concern, as they can devastate young salmon populations. Precautions need to be taken to prevent introductions and spread, and a clearly articulated plan needs to be in place that describes how invasive species introductions will be prevented, how monitoring for them will be undertaken, and what will be done to eradicate an invasive species if it does get introduced and established.

J. Other

1. Case examples. PacRim must be required to provide examples of a stream that has experienced a mining operation of this nature and scale, which has been successfully restored to its pre-mining ecosystem function, including trophic processes. The local and small-scale rehabilitations that have taken place in other places have had varied levels of success (Palmer review), but nothing has been on the scale of this proposed project. At this point, there is no evidence this rehabilitation effort can be successful, particularly given the scale of this project and the massive and wide-scale disruption of the natural flowpaths in the Chuitna system from the proposed mining activities.

2. Floods. The documents reviewed do not address the risk of a blowout from a large flood event. The <u>entire</u> stream is subject to severe erosion if one of the rehabilitation sites is lost during a large unanticipated flood event, causing that and downstream habitats to unravel. This will not only devastate the physical nature of the downstream portions of stream 2003, but will greatly reduce food web productivity and complexity, leading to high mortality in fish and other riparian and aquatic consumers that rely on aquatic and riparian invertebrates, and will almost certainly impact the river down to salt water. A detailed plan must be in place to deal with such an event.

3. Mine pit void. How will the void left behind from removing 140 vertical feet of coal be filled? How will layers be compacted adequately (not too much, not too little) when the overburden is put back in the mined pit as to not restrict flow and flowpaths, and to avoid slumping? Slumping seems inevitable as replaced sediments settle and conform through time, and this will completely and permanently change the naturally complex hydraulic nature of the Chuitna system, in turn affecting hyporheic exchange, water chemistry and temperature, and therefore riverine food webs, well beyond our lifetimes.

4. Sensitive, rare and endangered species. To ensure accurate identification of all sensitive, rare and endangered species, the existing collections made by PacRim (i.e., invertebrates) should be carefully inspected by taxonomic specialists, and wetland sampling should be greatly expanded (spatially and temporally) for all plant and animal species.

5. Revegetation. How will the fabric used during stream bank rehabilitation allow for natural seeding and germination? How can/will seeds penetrate the fabric?

6. Incomplete stream restoration plan. The *Fish Protection Plan* is terribly vague. The use of language such as "Use of roughness elements such as woody debris jams *will be considered* to manage the post-construction roughness *to some degree*" and "*Design specifications will be developed* for hydraulic and geomorphologic circumstance for each stream type" indicates an incomplete plan. *All* details of the protection plan need to be clearly articulated; it cannot be assumed that issues will be resolved as they are encountered.

7. Stream grades. The post- and pre-mine grades are different in Figure 9 of the *Fish Protection Plan* document. Why, and how will this affect surface and subsurface hydrology, soil, moisture, and vegetation? Among other things, soil moisture plays a key role in the re-establishment and successional development of the riparian vegetation, which in turn controls the biological productivity of stream/riparian systems. Changing the grade will change the natural processes that affect natural chemical and physical patterns, affecting BMI, fish, and other species.

8. Reference reaches. There needs to be more extensive BMI sampling, including above (reference) and below (potentially impacted) the mining reach. Additionally, representative nearby stream systems not influenced by mining or other impacts need to be selected and sampled as reference sites for detecting eventual, potential mining impacts, and for monitoring rehabilitation efforts.

III. Conclusions

The individual studies reviewed for this report provide important biological information about the Chuitna system. My main concerns, however, have to do with critical information that is missing from the baseline reports and the unavoidable impacts to the Chuitna system, which are not addressed in the current plans. My concerns are summarized here.

1) By all accounts it appears it will be impossible to recreate the complex 3D network and interconnected underground channels of variously sorted sediments typically found below and lateral to streams, including streams like 2003. Flowpaths that influence aquatic productivity, and salmon spawning and egg development, which depend upon these hyporheic and groundwater networks, will be severed during the mining process. Recreating these highly complex and sorted networks and flowpaths in a fashion that reconnects them to the natural flowpaths of the intact, surrounding sediment veins will not be possible.

2) Compaction and settling over time of the refilled mined area will change the nature of surface flow in these areas, changing them from what they were previously into something unknown and impossible to predict.

3) Nothing is known about the actual food webs themselves, including what prey are important for the fish, where these prey are produced and delivered to the fishes, and when and where they are important. This needs to be understood in order for mining and reclamation plans to be developed that will maintain existing aquatic productivity.

4) General trophic connectivity throughout the watershed (upstream-downstream connections) is unknown but also needs to be understood for the same reasons as above.

5) The sampling completed to date has been inconsistent and insufficient. Multiple years of consistent sampling is needed to provide critical information on long-term annual variability. I recommend a *minimum* of 10 years of consistent and continuous aquatic biology and fisheries sampling before mining begins, to provide an estimate of the range of variability over a longer time period than the current data provide. This will also provide better statistical power when assessing impacts, including for the proposed BACI design recommended by LGL (LGL 2009).

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