A Review of PLP Environmental Baseline Documents: Instream and off-channel habitat distribution and modeling

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EXECUTIVE SUMMARY

The Pebble Limited Partnership (PLP) embarked on a significant effort to characterize the habitat of spawning and juvenile salmon and resident fishes in three streams that would be impacted by mining development (the North Fork Koktuli, South Fork Koktuli, and Upper Talarik Creek) in Bristol Bay, Alaska. Study objectives, methodology, and the resulting data and interpretation are compiled largely into two chapters of the resulting Environmental Baseline Document (Chapter 15, and Appendix E). This report reviews and critiques the information provided based on standards for the scientific peer review process including organization and clarity, repeatability of methods, the degree to which conclusions are supported, and general scientific soundness (ESA 2012).

From 2004-2008, data was collected to describe channel characteristics, hydromorphologic unit types (e.g., pools, riffles, and runs/glides), and special habitat features (e.g., tributaries, springs, seeps, and fish migration barriers) in main stem, tributary, and off-channel habitat types. Habitat data collection methodology relied in part on US Forest Service protocols; however, methods varied over the course of the study. The instream habitat detail and its relationship with changes in flow were estimated using the Physical Habitat Simulation (PHABSIM) model. The instream habitat data is quantitative, while other data is mostly qualitative. In this way, rivers are described as single-thread systems despite the frequent occurrence of wetland complexes, floodplains, beaver ponds, and off-channel habitats throughout the study area. This complexity is not captured in instream habitat classification.

Overall the PHABSIM model developed by PLP suffers from a poor choice of assessment tools for the stated objectives, improper selection of intensive study areas and numerous procedural and technical errors. The presented results suffer from glaring inaccuracies and inappropriate assumptions. The most disturbing are the facts that:

1) Investigation of the direct impact area has been avoided. Only larger water bodies, several miles away from the planned mine, have been assessed.
2) The resolution of physical habitat data collection is inadequate to capture future impacts. Very few transects were measured, sampling strategy was neither rigorous nor systematic and gross extrapolation has been implemented.
3) The biological model is based on very few observations and is lacking data. Inadequate models have not been removed.
4) The modeling results lack validation and verification.

Moreover, the format in which methods and results are reported is cumbersome, making data difficult, if not impossible, to access, understand or analyze. Lack of detail in methodology along with poor presentation and lack of interpretation of results makes research hard to follow, verify, or repeat violating a central tenant of the scientific method (Brown and Guy 2007), and rendering the work incapable of passing a standard peer-review process (ESA 2012).

INTRODUCTION

According to Biology Online, fish habitat is defined as: "The aquatic environment and the immediately surrounding terrestrial environment that, combined, afford the necessary biological and physical support systems required by fish species during various life history stages." The physical portion of habitat serves as the foundation of aquatic ecosystems, shaping the distribution and structure of aquatic communities (Townsend and Hildrew 1994, Poff et al. 1990). Human induced alterations modify the habitat and thereby the distribution of aquatic flora and fauna. Consequently, planning environmental change must include accurate characterization of habitat and the potential for its alteration (Naiman et al. 1995). To characterize future changes, habitat analysis must be quantitative and include spatio-temporal variability of habitat for key aquatic biota potentially undergoing future impacts.

Physical habitat simulation models serve as a tool for such analysis, and originated with the PHABSIM (Physical HABitat SIMulation) model developed in the early 1970's by US Fish and Wildlife Service. This technique has been used for the protection of salmon populations in the western United States for decades. Presently, it is one of many available techniques specializing in microhabitat analysis (Parasiewicz and Dunbar 2001, Tharme 2003). Habitat models of this kind combine a quantitative description of physical patterns with observations of biological response captured by mathematical formulas. Microhabitat analysis defines areas used by aquatic fauna during observation. Though such models are not well suited for analysis of long river stretches and hydraulically complex habitats, they are frequently used in violation of procedural protocols and contrary to intentions of model developers. This misuse has led to heated discussions of model validity (e.g. Gore and Nestler 1988; Williams 1996). Mesoscale approaches, which describe habitat commonly used by aquatic biota during their diurnal cycle, are better suited for quantifying habitat of larger river sections. For fish, those habitats correspond with hydromorphological units, such as pools or runs, which are frequently but, erroneously, equated to mesohabitats. Habitat quantification tools such as USDA Tier 1 and Tier 3 mapping as used by PLP, operate at macro and meso scales, but fail to incorporate biological response analysis, as habitat simulation models do. Recently several mesoscale habitat simulation tools have been developed that build upon both discussed approaches (Borsanyi et al. 2004, Eisner et al. 2005, Parasiewicz 2007 a,b).

Pebble Limited Partnership's Environmental Baseline Document (EBD; PLP 2012) describes the application of habitat simulation model PHABSIM to the potentially affected instream portions of the North Fork Koktuli, South Fork Koktuli, and Upper Talarik Creek. The habitat has been also assessed for in- and off-channel areas of those river sections using modified USDA Tier 1 and Tier 3 methodology. This report reviews and critiques the information provided in the EBD based on standards for the scientific peer review process including organization and clarity, repeatability of methods, the degree to which conclusions are supported, and general scientific soundness (ESA 2012). This review is limited to fish habitat sampling methods, results and interpretation.

METHODS SUMMARY

Methods Presentation

Methods are summarized in Chapter 15 of the EBD (PLP 2012a), and described in full detail in the Consolidated Study Program, Appendix E of the EBD (PLP 2012b).

Study area

The study area stretches for over 380 km of mainstem and tributary habitat in the North Fork Koktuli (NFK), South Fork Koktuli (SFK), and Upper Talarik (UT) and main stem Koktuli River (KR), which are delineated into 18 hydrologic reaches (NFK-A to F, SFK-A to E, UT-A to F, KR). Habitat data were collected in main stem, tributary, and off-channel habitats (Appendix E of EBD Chapter 15). Mesohabitat mapping was conducted in main stem portions of the NFK, SFK, and UT and was followed by microhabitat analysis in selected sections. Stated objectives of habitat data collection are:

- To describe channel morphology and valley form characteristics in main stem and tributary channels
- To characterize riverine habitat types (e.g., pools, riffles, and runs/glides), their distribution throughout the river, as well as the amount of river and stream habitat available for fish
- To document the locations of special habitat features (e.g., tributaries, springs, seeps, and possible barriers to upstream fish migration) that may influence fish distribution and abundance throughout the mine study area
- To characterize the quality and quantity of off-channel habitat within representative off-channel habitat study areas
- To establish the relationship between the fish habitat and surface flows in each of the study streams and selected tributaries

Main stem and tributary habitat surveys

Most main stem and tributary data collection relied on the US Forest Service protocols for aquatic stream habitat data collection (USFS 2001); these included: Modified Tier 1 (information regarding reach scale channel and valley morphology, i.e., discharge, substrate particle size distribution, bankfull width, bankfull depth, bed width, wetted width, and gradient) and modified Tier 3 (information regarding individual habitat types, i.e., beaver pond complexes, backwaters/sloughs, ponds/lakes, cascades, pools, riffles, runs/glides, and wetlands). Some data is quantitative, while other data is qualitative. Methods for several habitat parameters varied (e.g., discharge was estimated using flow meters or floats, gradient was estimated using a stadia rod and auto level or a clinometer, lengths were estimated using hip chains, Kevlar tapes, or laser range finders).

Mesohabitat mapping

"Mesohabitats" are defined as "visually distinct habitat units on a reach-scale" (PLP 2012a). They were mapped using foot surveys in "selected sample areas" in main stems to visually identify runs, riffles, pools and island complexes. These are, however, hydromorphologic units (HMU), not mesohabitats, because mesohabitats consist of more than a morphologic shape of the river. For example, a pool with large amounts of woody debris will offer a different mesohabitat than a pool without woody debris. Main stem reaches that were not foot surveyed were evaluated with remote sensing including 2004 or 2008 digital imagery and/or videography. Data were combined to estimate the total area of each type of habitat type by stream reach, which was used to calculate fish density. Flows during mapping surveys were not specified.

Instream habitat surveys

The PHABSIM method was selected to analyze instream habitat for Chinook salmon, coho salmon, chum salmon, sockeye salmon, Arctic grayling and Dolly Varden within the study areas. The boundary of instream flow study area included 36, 40, 36 and 10 mile reaches on NFK, SFK, UT and KR, respectively (Table 1). Transects were established in reaches NFK-A, NFK-B, NFK-C, NFK 1.190, SFK-A, SFK-B, SFK-C, SFK 1.190, UT-B, UT-C, UT-D, UT-E, UT-F,UT 1.190 and KR (see Figure 15.-12). Within four years of the study 2004, 2005, 2007 and 2008 different numbers of transects were sampled "to capture representative habitat types". A total of 138 transects were surveyed (Table 1). Of those, 117 were used to represent a river length of more than 125 miles (the length of tributary sections was not reported). Hydraulic data were collected in 2005 and 2008 in each transect at three flows corresponding to 20, 50 and 80% exceedance flow (i.e. flows that are exceeded for a given percent of time; hereon referred to as dry, average, and wet flows). Mean column velocity, depth substrate and cover were measured or noted.

Table 1: Number, location and timing of measured transects. Question marks indicate data were either not reported or not clearly stated. Transects are inconsistently distributed.

River	NFK	SFK	UT	KR	UT1.190	NFK1.190	SFK1.190	Total
Length (mi)	36	40	39	10	?	?	?	125
2004	10	10	11	5				36
2005	10	17	15		6			48
2007	1	1	6					8
2008	14	12	11			3	6	46
Total surveyed	35	40	43	5	6	3	6	138
Transects with unusable data	8	3	8	1		1		21
Transects with usable data	27	39	35	4	6	2	6	117

Habitat utilization curves were computed based on fish data collected using snorkel observation and redd counts with subsequent recording of physical attributes in occupied locations. Standard PHABSIM procedures (IFG4, MANSQ and WSP) were used to calculate hydraulic conditions at a range of flows. HABTAV routine was used for calculation of weighted usable areas (WUA). For each transect, three WUA curves were calculated separately based on the roughness coefficients calculated for each flow level (dry, average, and wet). The composite rating curves were then fitted into the curves for each flow. Each transect was associated with an HMU type obtained from earlier surveys. WUA of transects from the same habitat type was averaged, then weighted by the proportion of the river length occupied by each HMU. The rating curves presented a WUA and percent of maximum habitat area for each species life stage. They were used to compute habitat time series using the flow observations in each reach during the study period. The flow time series were divided into wet, average and dry years, and average daily habitat area was calculated for each year type, reach and species life stage.

Off-channel habitat surveys

Off-channel habitat surveys were co-located with main stem habitat survey sites along the main stems of the NFK in 2008, the SFK from 2005-2007, and UT in 2007 (PLP 2012b, Appendix 1). Surveys were conducted where "high concentrations of off-channel habitats were found," although high concentrations are not defined (PLP 2012a). Qualitative habitat data was collected between 2005 and 2007 in SFK and UT, while Tier 3 aquatic habitat survey protocols (USFS 2001) were used to collect off-channel habitat data in the NFK in 2008. The EBD does not provide justification for the varying timing or methodology of off-channel habitat sampling protocols.

REPORTED RESULTS AND DISCUSSION SUMMARY

Data presentation

Habitat data are summarized and interpreted in Chapter 15 of PLP's EBD, and detailed data are summarized in Appendix B, C, D and F of the same chapter (PLP 2012a). Data are presented by section (reach) of each river system and, when collected, tributary data is included within the reach into which the tributary flows. Data in the form of tables, figures, and maps are inconsistent between reaches and frequently lack interpretation or description. Moreover, data that is included are in locked pdf format with hyperlinks to figures available only in the main body of the chapter. Figures and tables are not hyperlinked in the appendices making the reading of the enormous volume very tedious.

Mesohabitat

All three study rivers (NFK, SFK, and UT) are described as single-thread, gravel-bedded channels ranging from straight and high gradient to meandering and low gradient. However, wetland complexes, floodplains, beaver ponds, and off-channel habitats are frequently described. Aerial photographs indicate at least some sections with braided channels. The main stem of the NFK is reported to be dominated by riffle habitat, and the SFK and UT are dominated by riffle and run/glide habitat. Little instream cover, but good quality spawning gravel, is documented in all three study rivers. In all three watersheds, lakes, ponds and beaver ponds proved important to water storage and extended summer runoff.

Groundwater downwelling, or "drying" reaches are described for a tributary of the NFK, and for a middle reach and several tributaries of the SFK. Results suggest the "drying" of the middle reach of the SFK functionally eliminates juvenile habitat from that reach from February through April and results in fish stranding and/or dewatering of incubating eggs. Inter-basin transfer of downwelling water from the SFK to an upwelling area in UT was documented as part of a system of groundwater upwellings throughout UT that stabilize flow and temperature throughout the year.

Instream habitat analysis

The results are presented as an absolute (ft^2/1000ft) and relative habitat area (% of maximum WUA for species) available at different flows as a rating curve for each transect. The Y-axes and X-axes for absolute curves all have varying ranges making comparisons very difficult. Reasons for presenting different flow ranges for different reaches are unclear (for example maximum flow for UT varies between 60 and 800 cubic feet per second, not necessarily increasing downstream--e.g., maximum flow at a lower reach, UT-D, was documented as 400 cfs, while the next reach upstream, UT-E, was 600 cfs and the uppermost reach UT-F was 60cfs). For reaches, only the percent of maximum habitat area for increments of flow (cubic feet per second, cfs) is presented in tabular fashion. Only flows providing 100% and 90% of maximum habitat area are described in the text without describing remaining model results. The absolute value of WUA is reported for studies reaches in acres without reporting reach length even though it is variable (e.g., Figure 102, p 1204).

The habitat time series and habitat duration curves are also presented for study reaches. No summary graphs are offered. The habitat time series are synthesized as an average daily habitat area for dry, average and wet years indicating differences in habitat availability for these events. A series of tables demonstrate the average daily habitat areas for reaches and rivers. Table 73 summarizes those values indicating the largest quantities of habitat for chum salmon (*Oncorhynchus keta*) and Dolly Varden (*Salvelinus malma*), Arctic grayling (*Thymallus arcticus*) and rainbow trout (*Oncorhynchus mykiss*) spawning. It is puzzling that spawning habitat area is larger than the adult foraging habitat.

The discussion states that SFK has the most habitat for spawning Chinook salmon (*Oncorhynchus tshawytscha*), while NFK and UT have more habitat for coho (*Oncorhynchus kisutch*) and chum salmon than for juvenile life stages. According to the time series analysis, most of the anadromous spawning area exists during wet years, while resident salmonid spawning area is maximized during dry years. No difference between years was found for rearing life stages.

Off-Channel habitats

Of the 37 hectares of off-channel habitats (OCH), the mapped majority were beaver ponds (around 90%) with the rest consisting of side channels, percolation channels, pond outlet channels, isolated ponds and alcoves. The proportions of OCH habitat area were consistent among the river channels. With the exception of beaver ponds, the water levels in OCH are strongly affected by river flow. All OCH potentially offer coho salmon spawning and rearing habitat. The relation between the river flow and the OCH surface was established and presented.

DISCUSSION/CRITIQUE

Data Presentation

The format in which results are presented make the EBD difficult to understand, access, analyze, independently interpret, or repeat. Due to the vast size of the chapter regarding fish, the core of the study is unnavigable. All information is in locked pdf format, which makes copying, pasting, or commenting on data impossible. Data are presented for individual stream reaches in variable and inconsistent formats between tables, figures, and maps. Some figures have unreadable axes (see Figure 12 page 3287). Maps frequently lack the explanation of symbols (e.g., red lines in Figure B, Appendix 15.1.B). Individual data points do not include specific dates or locations and cross-referencing among tables, figures, and maps is challenging at best. The units are inconsistent throughout the analysis. Habitat time series curves indicate the year depicted (e.g., Figure 103, Appendix 15.1C). The axes of comparable figures such as rating curves for transects are inconsistent in length and are therefore not easily comparable. The rating curves for transects present habitat area in terms of WUA in ft^2/1000ft, while rating curves generalized for the reach level demonstrate habitat area in acres, without indicating the length of the reaches. Some topics are described with unnecessary detail (e.g., benchmarking cross sections) while other essential information is lacking (e.g., procedure of site or transect location selection). Lack of detail in methodology along with poor presentation of results and lack of interpretation of the results makes research impossible to follow and verify and therefore unrepeatable, violating a central tenant of the scientific method (Brown and Guy 2007), and thus the ability of the EBD to pass any standard peer-review process (ESA 2012).

Mesohabitat mapping

As described earlier, HMUs are considered equivalent to mesohabitats in the EBD. Key information missing in the report includes flows for which habitat was mapped. Several studies indicate that mesohabitats and the size and distribution of HMUs change with varying flow conditions (see www.MesoHABSIM.org for examples), especially at low flows. For example, a riffle at low flow may become a run at higher flows in a time span of hours to days, raising questions regarding HMU characterization.

A review of mesohabitat maps raises doubts about their accuracy. For example, margins of river bends where pools are expected hydraulically, are classified in the maps as runs or sometimes riffles (e.g., Figure B.1-6 or B.15-6). This violates principles of channel hydraulics. Glaring inconsistencies are exemplified on page 35 of the Appendix 15.1C presenting survey results from Tributary UT 1.190, the entirety of which was mapped as riffle habitat. In reality, the transects for the PHABSIM model for this section were surveyed in units classified as runs. This not only brings into question results of HMU mapping, but also demonstrates lack of coordination between teams performing surveys. Apparently, remote sensing classification was never verified on the ground.

Site selection methodology for on-foot-surveys is not described, and thus the representativeness of habitat information is unclear. Some sections were not mapped at all (e.g., NFK-E or SFK-F) or only portions of them were mapped (NFK-E). This fact is disturbing, because these reaches are closest to the area potentially impacted by mining activities.

Methods of data collection varied, in some cases using different instruments to measure the same parameters, and in other cases combining and comparing qualitative to quantitative data with no indication of which data are collected using variable methodologies. Moreover, sites were not sampled in subsequent years of sampling.

Instream habitat analysis

The PHABSIM model applied in the EBD was developed in the early 1970's as a planning instrument for negotiations of in- and out-of-stream water use within the framework of Instream Flow Incremental Methodology (IFIM). This technique was originally designed for applications related to individual water use facilities, particularly the definition of minimum flow requirements. It is neither well designed nor well suited for habitat analysis on long river sections. PHABSIM and other related techniques use high precision measurements of physical conditions to predict flow-related alteration of habitat, together with a habitat suitability criteria for fish. The underlying principle of PHABSIM is to describe these changes by means of a deterministic hydraulic model, an approach originally developed for flood-control engineering. The choice of this hydraulic technique as a backbone of PHABSIM has been crucial to the design and, from a river restoration perspective, the source of model limitations. Although still broadly used, the one-dimensional model strongly simplifies low flow hydraulic conditions, because it assumes steady and gradually varied flow in only one direction (Gordon et. al 1992).

The format of the model algorithm determines the strategy for sampling channel morphology and hydraulics. Stratified sampling (i.e., transects) typically applied for this purpose is relatively crude and does not properly reflect curvilinear distribution of hydro-morphologic parameters (Parasiewicz and Dunbar 2001, Parasiewicz 1996). This limitation is important since deterministic hydraulic models are highly sensitive to changes in riverbed roughness, specifically when applied to low flow conditions. Recently, multidimensional hydraulic models have been used with application of more adequate sampling techniques (e.g. Alfredsen et al. 1997, Lafleur and Leclerc 1997). These methods reduce inaccuracy but still do not resolve the problem of sensitivity to roughness. In more complex systems, or where study objectives require habitat assessment in larger areas, the amount of necessary effort makes the application of such models impractical.

To limit the effort to a feasible level, physical attributes used for model calibration are commonly measured on only a few short sampling reaches and model predictions are then extrapolated to larger segments of rivers and streams. Sometimes this "representative site" design is supported by rapid habitat mapping to weigh the spatial distribution of habitat features. Nevertheless, the accuracy of a river-wide assessment strongly declines during the generalization procedure due to usually high variation of morphology in areas between the sampled sites (Dolloff et. al. 1997). Often extrapolation effects lead to conflicted opinions about the validity of habitat simulation findings caused by the choice of sample-site locations (e.g. Gore and Nestler 1988; Williams 1996). For all these reasons, the physical habitat models are frequently discredited as poorly applicable to larger scale issues and therefore inadequate for system-scale, holistic management.

This issue of large-scale river assessment is central to the study discussed here and begs the question of whether the appropriate model has been chosen to fulfill the objectives of the study. Hundreds of miles of river length was intended to be evaluated using a set of transects. The approach chosen in the EBD is to determine the distribution of HMU types and then subsample them with single independent transects. However, transects were defined *before* the mesolevel survey, hence it cannot be claimed that they were chosen to subsample identified HMUs. From the perspective of the hydraulic model, this is even less accurate than the representative site approach. Considering that HMU classification is not reliable as described above, the entire scheme of data collection is questionable.

Another key issue is that the number of selected transects is not adequate to represent the whole study area, especially in morphologically variable natural channels. Transect locations seem to be selected haphazardly and distances are between 700 and 2000m, which is very poor resolution (Paine et al. 2004). Some sections are sampled more densely then others, for reasons unknown. For example the model for 6 km of KR is based on **four** cross sections. On Tributary NFK 1.190, 8 km are represented by **three** cross sections. Further, in smaller tributaries transects measured at the mouth of the stream were assumed to be valid for the long upstream sections that may have different hydro-morphology. No transects were measured in upstream reaches of NFK and SFK, that are adjacent to the impact area. In fact the reach SFK-E flows through the middle of the ore body, yet the first transect measured is about **ten miles downstream**.

Some of the four habitat types with transects sampled for PHABSIM were under sampled. In several reaches some habitat types are represented by only one cross section. For other units, habitat parameters are simply averaged, without considering the proportion of river length each cross section represented. As mentioned above, the mapped HMUs may be different mesohabitats and every cross section should represent habitats of different length.

Further, pools were not sampled in some reaches (e.g., KR or SFK 190). This is critical because pools have been documented in the off-channel habitat study as the most productive areas of the investigated rivers. Many coho salmon were captured in pools. Another problem results because cross-sections with an unstable riverbed were removed from analysis. Although convenient for analysis and data collection, selectively removing data is erroneous and dangerous as such areas may be the most vulnerable to mining impacts.

Several concerns exist with regard to biological models. The applied habitat suitability criteria are of very poor quality. First of all, univariate habitat utilization curves were constructed and used for analysis. Such criteria neither take into account interactions of investigated physical parameters nor habitat availability. The habitat suitability index is developed for each of the parameters separately and then combined with a prioritized selected formula into composite index. Utilization criteria are based on fish observations only; hence locations that were not occupied at the time of sampling are excluded. Such criteria exclude rare but highly suitable locations (e.g., Morhardt and Hanson 1988).

Furthermore, suitability criteria are based on very few fish observations (see Appendix 15C, Attachment 1). Microhabitat observations are accompanied by high levels of coincidence; in order to find fish in suitable habitat, fish must be present at the time of sampling. Of course, this is often not the case because fish are mobile organisms. More fish observations would alleviate this problem. The only criteria with sufficient fish observations for calculation were for coho salmon, sockeye salmon (except juvenile) and Chinook salmon (except fry). Some spawning observations are clustered in specific locations (e.g., Figure 11, Appendix 15C, Attachment 1), which begs the question whether or not data are spatially auto-correlated. No discussion of this auto correlation is included, however.

Validation of habitat suitability criteria is not described in the report, hence the accuracy of the model cannot be tested or confirmed. The comparison of the number of species with habitat availability for NFK A and NFK B reaches contradicts model predictions which do not correspond with fish distribution. This may be due to the fact that the models only account for the velocity, depth and substrate, neglecting the influence of cover on fish behavior (Parasiewicz and Walker 2007). Therefore, the habitat suitability criteria used in the study are poor. To improve data quality, the models for Arctic grayling, rainbow trout and Dolly Varden should be removed from the report.

Some rating curves indicate computational errors presenting jagged, rapid increases and declines between very small flow increments (i.e., Figure 34, Page 1136). Such results are unreasonable and illogical.

Further, PHABSIM rating curves are extrapolated to flows 2.5 times higher than the highest measured flow and 0.4 times lower than the lowest measured flow. These large extrapolations may be inaccurate because:

a. For higher flows, habitat suitability criteria may not apply since species behavior may differ.

b. For lower flows, extrapolations fail to account for hydraulic conditions which could change dramatically, potentially crossing the threshold to substantial drought in which species may display survival behavior rather than foraging or spawning.

The extrapolations are most likely responsible for the fact that some rating curves show habitat increases at extreme flow levels. For example, Figure 183, Supplement 1, Appendix 15.1 C depicts the WUA for Arctic grayling, Dolly Varden and rainbow trout for transect 05-SFK-RN1. In the figure, Dolly Varden habitat is reported at a minimum at 120 cfs (the highest measured flow), increases slightly from 120-200 cfs, and then increases steeply above 200 cfs. Considering that the accuracy of the extrapolation dramatically declines with flow increase and that the utilization curves are based on sparse data, these are not reliable. The adequacy of the large extrapolations should be demonstrated.

Habitat time series analysis is also unsatisfactory. Only four years of flow records have been considered, which is insufficient. Thirty-year time series are standard in hydrology. Since USGS data are sparsely available, hydrological simulation is preferable. Dividing only four years of data into dry and wet years based on the annual average is not representative of natural variation. The inadequacy of the classification is demonstrated in Figure 11, Appendix 15.1C depicting three flow time series. During the "wet year," flows were lower than average. Only peaks in August increased the average flow rendering its placement in the "wet" category.

The time series are interpreted using average daily habitat area for wet, average and dry years. Because fish communities are influenced more by extreme than average values (Fausch and Blambett 1991, Resh et al. 1988, Trexler et al. 2005), the metric is meaningless. Due to the poor characterization of "wet", "average" and "dry" conditions, the EBD did not document significant differences in habitat availability.

Although duration of total habitat availability is presented in figures (e.g., Figure 14, Appendix 15.1.C), but are neither analyzed nor discussed in the EBD. A "Continuous Duration Under

Threshold" diagram would have more appropriately captured the frequency of habitat-deficit events shaping fish fauna (Capra et al. 1995, Parasiewicz 2007b). More frequent fauna-shaping events such as extended droughts often result from flow alterations associated with mining activities.

Off-channel habitats

Off-channel habitat data is qualitative, documenting the importance of various habitats without quantifying those habitats which is the most important factor in salmonid distribution (e.g., Swales and Levins 1989). Aerial photographs (throughout Appendix B, Chapter 15) indicate side channels and backwaters occur throughout the study region, but were analyzed separately from main channel habitat ignoring the interconnectivity of river floodplains. Except for the few measured transects, the resolution of the OCH study is inadequate for establishment of baseline conditions and thus measurement of future impacts.

Other issues associated with OCH data collection include:

a. Justification for the selection of intensive study areas is not provided.
b. Estimates of active valley OCH area density of OCH in study sites is representative of the entire river's length.
c. Methodology changed in 2008.
d. Beaver ponds are described as the most common habitat, but they are the least characterized habitat.
e. Fish survey results contain conflicting information (e.g., on Page 12, Appendix 15.1D fish density of 100ind/100m^2 for site channels is reported and in the following sentence 15-70ind/m^2 for the same site).

CONCLUSION

The most problematic issue with the study design is the fact that all data was collected in larger water bodies miles away from potential mining activity, thereby rendering data worthless for future impact assessment. Aerial imagery indicates the study area includes a large network of small headwater streams (see Figure B 11-b, Appendix 15.1C). These headwaters would be directly impacted by mining activities which would propagate impacts downstream. Only small portions of this network were qualitatively investigated in the EBD. Solid and modern physical habitat simulation models, at the right scale, should have been applied for the entire study area (e.g. main stem, tributaries and OCH channels).

Consequently, the conclusion that the study provides a "solid framework of information" (Page 62, Appendix 15.1C) is erroneous because the work was not conducted according to scientific and practical standards. The EBD and PHABSIM model results are rife with methodological and technical errors. The data collection strategy, analytical procedures, as well as interpretation are inadequate for an environmental impact assessment. Due to basic errors, the inaccuracy of the PHABSIM model is high and will likely fail validation tests.

REFERENCES

Alfredsen, K., W. Marchand, T. H. Bakken, and A. Harby. 1997. Application and comparison of computer models quantifying impacts of river regulation on fish habitat. In Broch, E., D.K. Lysne, N. Flatabo, and E. Helland-Hansen, eds. 1997. Proceedings of the 3rd international conference hydropower '97 – Trondheim / Norway 30 June – 2 July 1997. A.A. Balkema Publishers, Rotterdam/Brookfield.

Borsanyi P, Alfredsen K, Harby A, Ugedal O, Kraxner K. 2004. A Meso-scale habitat classification method for production modeling of Atlantic Salmon in Norway. *Hydroecologie Appliquee* **14**: 119-138. DOI:10.1051/hydro:2004008.

Brown, M.L. and C.S. Guy. 2007. Science and statistics in fisheries Research. In Guy, C.S. and M.L. Brown (Eds.). Analysis and Interpretation of Freshwater Fisheries Data. American Fisheries Society, Bethesda, Maryland. Pp. 1-30.

Capra H, Breil P, Souchon Y. 1995. A new tool to interpret magnitude and duration of fish habitat variations. *Regulated Rivers: Research and Management*. **10:** 281-289.

Dolloff, C. A., H. E. Jennings, and M. Owen. 1997. A comparison of basinwide and representative reach habitat survey techniques in three southern Appalachian watersheds. *North American Journal of Fishery Management*. **17**:339-347.

Eisner A., Young C., Schneider, M. & Kopecki, I. (2005): MesoCASiMiR - new mapping method and comparison with other current approaches, COST 626, Proceedings from the final meeting in Silkeborg, Denmark, 19-20 May 2005

ESA (Ecological Society of America). 2012. Guidelines for reviewers: Ecology, Ecological Applications, Ecological Monographs. Website: http://esapubs.org/esapubs/reviewers.htm. Accessed 15 April 2012.

Gordon, N.E., T.A. McMahon, and B.L. Finlayson. 1992. Stream hydrology: an introduction for ecologists. John Wiley and Sons, New York.

Gore, J. and J. Nestler. 1988. Instream flow studies in perspective. *Regulated Rivers* **2**: 93-101.

Fausch, K.D., Blamblett R.G. 1991. Disturbance and fish communities in intermittent tributaries of a wester Great Plains River. *Copeia.* **3**. 659-674.

Lafleur, J. & Leclerc, M. 1997. The Fish Habitat Modelling with Two Dimensional Hydraulic Tools: a Worthwhile approach for Setting Minimum Flow Requirements. – Paper Presented at Instream and Environmental Flow Symposium, Houston.

Morhardt, J.E., Hanson, D.F. 1988. Habitat availability considerations in development of habitat suitability criteria. Proceedings of a workshop on the development and evaluation of habitat suitability criteria. Fort Collins, Co. US Fish and Wildlife Service. Biological report 88 (11). 392-403.

Naiman, R. J., J.J. Magnuson, D. M. McKnight, and J. A. Standford eds. 1995. The Freshwater Imperative: a research agenda. Island Press, Washington, DC.

Paine, T.R., Eggers, S.D., Parkinson, D.B. 2004. The Number of Transects Required to Compute a Robust PHABSIM Habitat Index. Hydroécol. Appl. **14**:27-53.

Parasiewicz, P. (1996): Estimation of physical habitat characteristics using automation and geodesic-based sampling. *Regulated Rivers: Research & Management*, **12**, 575-583.

Parasiewicz P. 2001. MesoHABSIM - a concept for application of instream flow models in river restoration planning. *Fisheries* **29** (9): 6-13. DOI: 10.1577/1548-8446(2001)026<0006:M>2.0.CO;2

Parasiewicz P. 2007a. The MesoHABSIM Model Revisited. *River Research and Application* **23** (8):893-903. DOI: 10.1002/rra.1045

Parasiewicz P. 2007b. Developing a reference habitat template and ecological management scenarios using the MesoHABSIM model. *River Research and Application* **23** (8): 924-932. DOI: 10.1002/rra.1044

Parasiewicz P. & M. J. Dunbar (2001): Physical habitat modelling for fish – a developing approach - *Archiv für Hydrobiologie*. Suppl. (Large Rivers Vol. **12**), 135/2-4 p. 239-268

Parasiewicz P. & J. D. Walker (2007): Comparing and testing results of three different micro and meso river habitat models. *River Research and Application* **23** (8): 904-923.

Poff, N.L., Ward, J.V. 1990. The physical habitat template of lotic systems: recovery in the context of historical pattern of spatio-temporal heterogeneity. *Environmental Management.* 14: 629-646.

PLP (Pebble Limited Partnership). 2012a. Chapter 15: Fish and aquatic macroinvertebrates, Bristol Bay drainages. Pebble Limited Partnership Environmental Baseline Document: 2004-2008. Prepared by R2 Resource Consultants, HDR Alaska, Inc., EchoFish, Inter-Fluve, and Pacific Hydrologic, Inc. 6515 pp.

PLP. 2012b. Appendix E: Consolidated study program. Pebble Limited Partnership Environmental Baseline Document: 2004-2008. 603 pp.

PLP. 2012c. Chapter 7: Surface water hydrology, Bristol Bay drainages. Pebble Limited Partnership Environmental Baseline Document: 2004-2008. Prepared by Knight Piésold, Ltd., ABR, Inc., 3 Parameters Plus, Inc., and Bristol Environmental & Engineering Services Corp. 984 pp.

PLP. 2012c. Chapter 7: Surface water hydrology, Bristol Bay drainages. Pebble Limited Partnership Environmental Baseline Document: 2004-2008. Prepared by Knight Piésold, Ltd., ABR, Inc., 3 Parameters Plus, Inc., and Bristol Environmental & Engineering Services Corp. 984 pp.

PLP. 2012d. Chapter 9: Water quality, Bristol Bay drainages. Pebble Limited Partnership Environmental Baseline Document: 2004-2008. Prepared by Schlumberger Water Services, Piteau Associates, SLR Alaska, Bristol Environmental and Engineering Services, HDR Alaska, Inc. 2247 pp.

PLP. 2012e. Chapter 8: Groundwater hydrology, Bristol Bay drainages. Pebble Limited Partnership Environmental Baseline Document: 2004-2008. Prepared by Schlumberger Water Services. 2500 pp.

Resh V.H.,Brown A.H., Covich, A.P.,Gurz, M.E., Li, H.W., Minschall, W.,Reice S.R., Shelon, A.L., Wallace, J.B., Wissmar R.C. 1988.The role of disturbance in stream ecology. *J. N. Am. Benthol. Soc.* **7**(4):433-455.

Swales, S., Levings, C.D. 1989. Role of Off-Channel Ponds in the Life Cycle of Coho Salmon (Oncorhynchus kisutch) and Other Juvenile Salmonids in the Coldwater River, British Columbia. *Canadian Journal of Fisheries and Aquatic Sciences*, 46(2): 232-242, 10.1139/f89-032

Tharme R. E. 2003 A global perspective on environmental flow assessment: emerging trends in the development and application of environmental flow methodologies for rivers. *River Research and Application* s 19 (5-6): 397–441,

Trexler J.C., Loftus W.F., Perry S. 2005. Disturbance frequency and community structure in a twenty-five year intervention study. *Oekologia.* **145** (1): 140-152, DOI: 10.1007/s00442-005-0094-4

Townsend, C.R., Hildrew, A.G. 1994. Species traits in relation to a habitat template for river systems. *Freshwater Biology.* **31**:265-276.

USFS (United States Forest Service). 2001. FSH 2090 Aquatic Habitat Management Handbook, R-10 Amendment 2090.21-2001-1. Chapter 20, Fish and Aquatic Stream Habitat Survey. US Department of Agriculture, US Forest Service.

Williams, J. G. 1996. Lost in space: confidence interval for idealized PHABSIM studies. *Transactions of the American Fisheries Society* **125**: 458-465.