

# **ATTACHMENT D**



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22 May 2013

Mr. Bruce Jenkins  
Northern Dynasty Minerals, Inc.  
15th Floor - 1040 W. Georgia St.  
Vancouver, BC CANADA V6E 4H1

Re: Review of EPA's stance on fish habitat mitigation in BBWA-2

Dear Bruce,

Pursuant to your request Randy Bailey of Bailey Environmental and I have reviewed the second draft of the EPA's Bristol Bay Watershed Analysis that focuses on their idea of a large mine development in the Bristol Bay Watershed, with special attention to their position that mitigation for fish habitat impacts is not possible. Attached, please find a report documenting our findings.

We find that the EPA position is not based in an accurate understanding of biological resources, especially salmon, in the streams surrounding their hypothetical mine development, greatly overestimates the likely mitigation obligation associated with their mine scenario, ignores the abundant opportunities for appropriate mitigation measures within the streams associated with their mine scenario, ignores the most important and beneficial off-site opportunities within larger adjacent watersheds (especially the Kvichak watershed), and utterly disregards the vast body of knowledge related to salmonid habitat rehabilitation, mitigation and enhancement and three-quarters of a century of successful track records for appropriate mitigation measures.

We find the EPA position on mitigation for their mine scenario completely untenable and scientifically unsupportable. We hope you find the attached report informative. If you have any questions on this or other related matters, please do not hesitate to contact us.

Sincerely,

J.W. Buell, Ph.D.  
President, Buell & Associates, Inc.

*Randy Bailey*

Randy E. Bailey,  
Principal, Bailey Environmental

AN EVALUATION OF EPA'S BRISTOL BAY WATERSHED ASSESSMENT 2013 2<sup>nd</sup>  
DRAFT ASSERTIONS REGARDING FISH HABITAT MITIGATION MEASURES  
EFFICACY AND APPLICABILITY

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May 22, 2013

## Table of Contents

	Page
<b>About the Authors</b> .....	<b>2</b>
<b>Executive Summary</b> .....	<b>3</b>
<b>1. Introduction</b> .....	<b>6</b>
<b>2. U.S. Environmental Protection Agency’s Assumptions and Conclusions Regarding Fish Habitat Mitigation Potential</b> .....	<b>9</b>
<b>3. Review of the Scientific Literature with Respect to Fish Habitat Mitigation Techniques</b> .....	<b>17</b>
<b>4. Review of the Documented Efficacy of Selected Fish Habitat Mitigation Techniques</b> .....	<b>67</b>
<b>5. Identification of Fish Habitat Mitigation Techniques and their Applicability to Pebble Deposit Area Watersheds</b> .....	<b>70</b>
<b>6. Identification of Fish Habitat Mitigation Opportunities at Off-Site Locations</b>	<b>74</b>
<b>7. Relevant Examples of Large, Successful Fish Habitat Mitigation Programs in the U.S.</b> .....	<b>76</b>
<b>8. Conclusions</b> .....	<b>78</b>
<b>9. References</b> .....	<b>81</b>

## About the Authors

The authors of this report have extensive professional experience and training in aquatic habitat mitigation techniques. They are familiar with the scientific literature and have participated in numerous evaluations of the applicability and efficacy of fish habitat improvement programs.

**Randy Bailey** is a fisheries biologist with more than 37 years experience dealing with anadromous salmonids in the Western United States. He served as a Forest Service Forest Fishery Biologist whose duties included designing and installing fish habitat improvements for anadromous fish. He also served as Regional Fisheries Biologist for the California Region of the Forest Service and served as a regional technical expert for the U.S. Forest Service on their fish habitat improvement program and as a national oversight committee member of the Forest Service's fish habitat research program. Bailey served as Chief of the U.S. Fish and Wildlife Service's Fisheries Resources Division in Anchorage, AK for nine years. As a consultant he has been involved in numerous habitat and ecosystem restoration programs including writing several documents, co-developing with author Buell and one other a \$5 billion ecosystem restoration program for the Central Valley of California. In addition, Bailey served on a select evaluation committee that reviewed the first \$500 million of a restoration program funded by the Cal/Fed Bay Delta Program. He has worked as a senior fish biologist on the Pebble Project since 2007.

**James W. Buell, Ph.D.** is an aquatic biologist specializing in salmonid fishes with over 38 years' experience as a consultant, over 35 of which have been as President of his own company. He received his Bachelor's degree in Biology at Occidental College (1966) and his Ph.D. in comparative physiology at the University of Oregon (1973).

Dr. Buell has extensive experience with large projects, including many mining projects, in Alaska, British Columbia, the Pacific Northwest and California. He has worked on 21 major mining, stream restoration, environmental studies, stream habitat enhancement evaluations. He is a co-author with Randy Bailey on a \$5 billion ecosystem restoration plan for the Central Valley of California. He has extensive experience with stream and watershed analysis, including habitat enhancement and remediation, and has worked extensively with engineers, geologists, hydrologists, wetlands scientists, resource economists and other professionals over the course of his career. He has served as special consultant to the State of Oregon, including eight years on the Oregon Fish Screening Task Force (one year as Chair), the US Army Corps of Engineers, Fisheries and Oceans, Environment Canada and Alaska Department of Fish and Game. Dr. Buell has been a consultant to owners of the Pebble prospect, first Cominco Alaska (1991-1994) and later NDM/PLP (2004-2012).

Dr. Buell has spent a great deal of time in the watersheds surrounding the Pebble prospect and in many watersheds in the region, especially around Iliamna Lake. He has a unique understanding of the aquatic resources from both local and regional perspectives. In addition, he has a deep understanding of the support functions provided by aquatic habitats in the area with respect to local anadromous and resident fish populations.

## Executive Summary

A review was conducted of the United States Environmental Protection Agency (EPA) Bristol Bay Watershed Assessment (BBWA2) incorporating a large hard rock mine northeast of Iliamna, Alaska. Review emphasis was placed on the EPA's position that fish habitat impacts associated with their hypothetical mine development could not be successfully mitigated. This report presents the findings of that review.

EPA failed to use readily available scientific data and information to develop their ecological characterization for anadromous fishes in the three watersheds surrounding the Pebble deposit area. As a result of this error, EPA then reached a scientifically unsupportable conclusion about the magnitude of the negative impact. EPA concluded that on-site mitigation was not possible, in spite of ample evidence of an abundance of on-site opportunities to implement appropriate mitigation measures and a very large body of scientific literature and monitoring data spanning three-quarters of a century documenting the efficacy of such measures.

The habitat improvement techniques reviewed in this document reflect a distillation of those specific techniques that the authors believe are most applicable to the EPA hypothetical mine area and its setting in Southwest Alaska. Many millions of dollars have been spent and continue to be spent on habitat-based enhancement of production of salmon and other fish species in the Pacific Northwest, western Canada and Alaska, and monitoring results from a wide variety of these efforts over the last three-quarters of a century, some of which are reviewed here, attest to their effectiveness. This money is being spent by the private sector for mitigation and by the public sector for mitigation and enhancement because the approaches being funded work. The authors believe that the benefits of habitat improvement using the measures reviewed here are settled science.

In summary, there is clearly an abundance of evidence in the literature that demonstrates the linkage between habitat quality and water quality parameters/nutrients and aquatic production. That these factors were not considered by EPA in BBWA2 seriously undermines that report's credibility and especially its negative conclusion about the applicability of mitigation measures in local watersheds (on-site) and nearby (off-site). By ignoring these demonstrably successful mitigation techniques, the credibility of the BBWA2 and its conclusions regarding mitigation opportunities are very seriously compromised, if not rendered completely invalid.

The following categories of measures highlight the shortcomings of the EPA's position:

1. **Water Management:** Water from EPA's WWTP could be distributed in a manner that reflects the relative importance of certain locations and reaches of streams. For example, instead of arbitrarily distributing water from the WWTP equally to the NFK and SFK, water discharge could be appropriately distributed to the upper portion of UT where the greatest potential magnitude of benefit would accrue to coho salmon. Surprisingly, EPA chose to distribute no water into this watershed. Also, EPA could have ensured that sufficient water was distributed to the South Fork "Springs" area which is the major salmon spawning area in the SFK.



2. **Water Management:** EPA chose to distribute water from their WWTP via surface discharge, which would result in violations of Alaska's Water Quality Standards and change the emergence timing of juvenile salmon, resulting in potentially catastrophic juvenile mortality. EPA should have realized that using the water available to recharge and surcharge groundwater aquifers, with aquifer residence time of generally a year or more, that provide critical stream flow would have eliminated the problems identified. In addition, the default release of WWTP water to recharge and surcharge aquifers would assure that WWTP upset or shutdown would not interfere with the continuing release of water to streams from groundwater storage for extended periods.
3. **Water Management:** EPA should have recognized that the WWTP discharge could be designed to provide water chemistry concentrations that would improve the buffering capacity, primary productivity, secondary productivity, and also reduce the potential toxicity of metals at area downstream of locations where discharge water reenters the stream channels.
4. **Increase Habitat Connectivity:** EPA failed to recognize numerous opportunities in all three principal watersheds to provide fish access to existing, suitable habitats that are not currently connected to a main stem channel. Figures 5.1, 5.2, and 5.3 show representative sites in the NFK, SFK, and UT, respectively. These figures are representative of photographs displayed in the EBD in Chapters 4, 7, and 15, which EPA apparently did not review. These figures are for illustrative purposes only and are not intended to identify any specific potential mitigation site. EPA did not consider providing fish passage over a cataract currently blocking anadromous fish access to suitable habitats in tributary stream UT 1.190.
5. **Increase the Quality of Existing Off-Channel Habitats:** EPA failed to recognize the potential to improve the quality of existing off-channel habitats by increasing the complexity these areas through the use of boulders, large wood, and deepening or altering the shoreline development ratio in order to create better overwintering habitat and more alcoves, and thus contributing to increased survival
6. **Create New Habitats through the Development of Semi-Natural Channels:** EPA failed to recognize the potential for development of new off-channel habitats within the three watersheds. These new channels could provide additional spawning and rearing habitats by locating them in locations where subsurface flow will provide the water to the new channel. The authors have personally reviewed and/or visited dozens of potential sites.
7. **Increase the Primary Productivity and Productive Capacity for Fish:** EPA failed to recognize the potential to increase primary productivity and overall productive capacity for fish by developing an appropriate design for their WWTP so that discharges would increase key water chemistry constituents. They also failed to recognize that the entire area has very soft water and thus low productive potential. This situation could be improved through a carefully designed water chemistry enhancement program.

This review of BBWA2 clearly demonstrates that EPA utterly failed to present a “scientifically defensible” discussion of potential mitigation measures. In fact, most of the potential measures outlined in Appendix J of BBWA2, came from the public and/or peer reviewers, not EPA staff. This fact alone should raise serious questions regarding the technical competence of EPA’s staff to address this issue.

**The bottom line conclusions for this report are that:**

- **EPA failed to use the best readily available science (Section 2 of this report),**
- **EPA failed to understand the applicable published literature on fish habitat improvement (Section 3),**
- **EPA failed to understand the applicability and efficacy of the habitat improvement techniques to their mine development scenarios (Sections 3 and 4),**
- **EPA failed to follow routine scientific methods related to an assessment of this nature, thus exaggerating the magnitude of potential effects on fish habitat/populations and under-estimating the benefit of well-established, successful mitigation measures, and**
- **EPA failed to demonstrate the required technical and professional expertise to develop a mitigation program applicable to their development scenarios (Sections 5 and 6).**

Accordingly, the BBWA2 report is not a scientifically credible document, and its negative conclusions regarding mitigation obligations, opportunities and techniques, and the efficacy of appropriate techniques, are unsupportable. It is a document that provides a very biased, non-objective assessment of the risks/benefits of a mine development at the proposed Pebble location, or elsewhere within the Bristol Bay watershed. It should not be used during future agency/public deliberations on the effects of and mitigation measures for any specific modern mine proposal.

## Section 1

### Introduction

The potential development of a gold/copper/molybdenum deposit, known as the Pebble deposit in Southwestern Alaska, near Iliamna Lake has resulted in an extensive public debate regarding the development. The deposit lies within the upper headwaters of three primary watersheds. The North Fork Koktuli River (NFK) watershed is located north and west of the deposit and the South Fork Koktuli River (SFK) in its source headwaters, with a large portion of the watershed located south and west of the deposit. The NFK and SFK flow generally west and combine about 30 miles west of the deposits to form the Koktuli River. The Koktuli River flows south and west into the Mulchatna River, which is a tributary to the Nushagak River which drains into Bristol Bay near the town of Dillingham. The east edge of the deposit lies in the headwaters area of Upper Talarik Creek (UT). Upper Talarik Creek drains directly to Iliamna Lake which is in the Kvichak River watershed. The Kvichak River drains into Bristol Bay north of the town of Naknek.

These three watersheds show essentially no evidence of anthropogenic influences. They are unroaded areas with relatively low levels of fishing, hunting, and subsistence use occurring. The area is heavily influenced by glacial deposits and remnant glacial lake bottoms which have resulted in extensive areas of fine lake bottom sediments and groundwater and springs which greatly influence the aquatic habitats found here. The aquatic habitats in the watersheds are in a natural condition with abundant, high quality spawning gravels that are used by Pacific salmon and other resident fish species. The glacially-influenced geography has resulted in the formation of many aquatic habitat areas that are off the main river channels. Some of these areas are continually or seasonally connected to the main channel flow. However, many more areas, while containing surface water, are not connected to the main channels and are spring or groundwater fed.

The glacial nature of the geology and the abundance and fairly rapid movement of groundwater in these systems result in some distinct aquatic habitat limitations related to primary productivity and ultimately fish production. The water chemistry of the water bodies found in all three watersheds show very low levels of alkalinity, hardness, total dissolved solids, phosphorus, and nitrogen. The low concentrations of these constituents indicate that primary productivity in the watersheds is limited by natural conditions. From a physical aquatic habitat perspective, the NFK and SFK contain relatively few pools or low water velocity habitat areas suitable as rearing habitat for young juvenile salmonids particularly Pacific salmon. Because these streams are in unforested areas, there is a general lack of habitat complexity and large wood or structure in many stream channels. Also, many off-channel habitats exist, but are currently not accessible to juvenile fish or not on a continual basis. The UT watershed contains a higher percentage of pools and the aquatic habitat is generally more complex and provides substantial rearing areas, particularly for juvenile salmonids.

Responding to public requests, the U.S. Environmental Protection Agency (EPA), in 2012, released an external review draft of a document entitled *An Assessment of Potential Mining Impacts on Salmon Ecosystems of Bristol Bay, Alaska*. This public draft report is commonly

referred to as the Bristol Bay Watershed Assessment (BBWA). This document purported to assess the potential impacts of large scale mining on salmon ecosystems within the broader set of watersheds that drain into Bristol Bay. In fact, EPA attempted to create a hypothetical example of a large mine development and tailings embankment failure, ostensibly based on public information available regarding only one specific project at the Pebble deposit location, as their foundation to complete what they termed an “ecological risk assessment”. Public and EPA’s own Peer Reviewer comments on the BBWA pointed out hundreds of faulty assumptions and conclusions in the report. Two fatal flaws identified in the BBWA was that the hypothetical development scenario could not be permitted under State of Alaska or Federal laws, regulations, and policies and that no mitigation for the hypothetical development was identified by EPA.

In 2013, EPA released a second external review draft of the Assessment (BBWA2). In response to public comments pointing out that the hypothetical project could not obtain permits to operate, especially without implementation of mitigation measures, EPA tried to remedy this defect by developing the information presented in Appendix J of the document. In Appendix J, EPA outlined the appropriate rules and regulations regarding mitigation requirements for large mine development, summarized their hypothetical assessment of the kilometers of fish habitat that would be lost as a result of their development scenarios and flow reductions downstream of their mine and tailings storage facilities, provided a list of suggested mitigation actions identified from the public comments, and finally concluded that: “...*these three watersheds are largely unaltered by human activities, and there appear to be no sites that a mitigation project could restore or enhance to offset the magnitude of impacts expected from the mine scenarios.*”. In other words, EPA concluded that there were no mitigation opportunities available within the three primary mine infrastructure area watersheds or the broader drainage areas which could offset the fish habitat impacts of their hypothetical mine development scenarios.

The purpose of this report is to:

- Evaluate the science used by EPA to reach its conclusions regarding the magnitude of impacts,
- Provide a comprehensive review of fish habitat mitigation techniques that are applicable to mitigate for impacts resulting from EPA’s mine development scenarios,
- Briefly review the efficacy of these mitigation techniques at locations applicable to Southwestern Alaska, and
- Provide an overview of the mitigation techniques that could be applied appropriately within the three primary watersheds and other potential off-site locations that would more than mitigate for EPA’s mine development scenarios.

This document does not deal with wetlands mitigation since there are a different set of rules that specifically deal with wetlands issues.

Section 2 of this report evaluates the scientific basis of the information and assumptions used by EPA to determine the magnitude of the impacts and review and evaluate the conclusions and mitigation measures identified in Appendix J. Section 3 contains a literature review of fish habitat mitigation techniques that are applicable to Southwestern Alaska and could be used to mitigate the types of development envisioned by EPA. Section 4 briefly discusses the efficacy of

the types of mitigation techniques identified in Section 3, based on monitoring of installed projects. Section 5 provides an overview of the types of mitigation techniques that could be applied within the three, primary deposit area watersheds. Section 6 provides an overview of the types of mitigation techniques that could be applied in off-site areas to provide additional mitigation.

## Section 2

### U.S. Environmental Protection Agency's Assumptions and Conclusions Regarding Fish Habitat Mitigation Potential

This section of this report evaluates the assumptions and conclusions used by EPA to reach conclusions regarding the potential for mitigation measures to offset the impacts of their mine development scenarios. EPA's assumptions and conclusions were not developed using the best available scientific information and thus their assumptions and conclusions regarding the magnitude of impact is fatally flawed. A more detailed evaluation of the faulty and scientifically indefensible assumptions and conclusions is presented in Section 2.2.

#### 2.1 BACKGROUND ON ASSUMPTIONS AND CONCLUSIONS

EPA discusses potential mitigation for their mine development scenarios in Chapter 7 and Appendix J of the BBWA2. Selected quotes from these portions of BBWA2, which exemplify assumptions regarding mitigation for their hypothetical large mine development, are presented below:

##### Chapter 7 Page 7-32 states:

*“The mine scenarios evaluated in this assessment identify that the mine footprints alone will result in the loss (i.e., filling, blocking or otherwise eliminating) of high-functioning wetlands and tens of kilometers of salmon-supporting streams. Such extensive habitat losses could also result in the loss of unique salmon populations, potentially eroding the genetic diversity that is essential to the stability of the overall Bristol Bay salmon fishery (i.e., reduction in the portfolio effect discussed in Section 5.2.4).”*

*“The public and peer review comments on the first external review draft of this assessment identified an array of compensation measures that commenter's believed could potentially offset these impacts on wetlands, streams, and fish...”*

*“Potential compensatory mitigation measures identified by commenter's and discussed in Appendix J include mitigation bank credits, in-lieu fee program credits, and permittee-responsible compensatory mitigation projects such as aquatic resource restoration and enhancement within the South and North Fork Kaktuli Rivers and Upper Talarik Creek watersheds as well as more distant portions of the Nushagak and Kvichak River watersheds. The following additional measures are identified in Appendix J:*

- *Beaver dam removal*
- *Flow management*
- *Spawning channel construction*
- *Aquatic resource preservation*
- *Old mine site remediation*
- *Road removal*
- *Road stream crossing retrofits*

- Hatchery construction
- Fish stocking
- Commercial fishery harvest reductions

*As discussed in Appendix J, there are significant challenges regarding the potential efficacy of compensation measures proposed by commenter’s for use in the Bristol Bay region, raising questions as to whether compensation measures could address impacts of the type and magnitude identified for the mine scenarios.”*

**Appendix J states:**

*“...This appendix provides an overview of Clean Water Act Section 404 compensatory mitigation requirements for unavoidable impacts to aquatic resources and discusses an array of measures that various entities have proposed as having the potential to compensate for the unavoidable impacts to wetlands, streams, and fish identified in the Bristol Bay Assessment.”*

**On Page 6:**

*“For the mine scenarios evaluated in the Bristol Bay Assessment, the lost functions and services occur in the watersheds that drain to the North Fork Koktuli (NFK) and South Fork Koktuli (SFK) Rivers and Upper Talarik Creek (UTC). Accordingly, the most appropriate geographic scale at which to compensate for any unavoidable impacts resulting from such a project would be within these same watersheds, as this location would offer the greatest likelihood that compensation measures would replace the “suite of functions typically provided by the affected aquatic resource” (40 CFR 230.93(c)(2)). An important consideration is that compensation projects within these watersheds appear to offer the only opportunity to address impacts to salmon populations that are unique to these drainages (Yocom and Bernard 2013) and thus sustain the population diversity that is key to the stability of the overall Bristol Bay salmon fishery (i.e., the portfolio effect) (Schindler et al. 2010).”*

**On Page 7:**

*“The mine scenarios evaluated in the Bristol Bay Assessment identify that the mine footprints alone will result in the loss of (i.e., filling, blocking or otherwise eliminating) hundreds to thousands of acres of high-functioning wetlands and tens of miles of salmon-supporting streams. Such extensive habitat losses could also result in the loss of unique salmon populations, potentially eroding the genetic diversity that is essential to the stability of the overall Bristol Bay salmon fishery (i.e. reduction in the “portfolio effect”).*

*The public and peer review comments on the draft Bristol Bay Assessment identified an array of compensation measures that commenter’s believed could potentially offset these impacts to wetlands, streams, and fish. Yocom and Bernard (2013) recently reviewed the likely efficacy of a subset of these potential measures [The list of measures presented on Page 7-32 of the Assessment and duplicated above] at offsetting potential adverse effects.”*

## **On Pages 8-9:**

*“In the context of the mine scenario, the primary challenge to both a watershed approach and on-site compensatory mitigation is the absence of existing degraded resources and watershed needs within the NFK, SFK and UTC watersheds. **Specifically, these three watersheds are largely unaltered by human activities, and there appear to be no sites that a mitigation project could restore or enhance to offset the magnitude of impacts expected from the mine scenarios.**” [Emphasis added].*

## **On Page 16, the Conclusion of Appendix J states:**

*“The mine scenarios evaluated in the Bristol Bay Assessment show that the mine footprint alone will result in the loss (i.e., filling, blocking or otherwise eliminating) of hundreds to thousands of acres of high-functioning wetlands and tens of miles of salmon-supporting streams. In addition to these direct losses, these mine scenarios would also result in extensive adverse secondary and cumulative impacts to wetlands, streams, and fish that would have to be addressed. Such extensive habitat losses and degradation could also result in the loss of unique salmon populations, potentially eroding the genetic diversity essential to the stability of the overall Bristol Bay salmon fishery. There are significant challenges regarding the potential efficacy of compensation measures proposed by commenter’s for use in the Bristol Bay region, raising questions as to whether sufficient compensation measures exist that could address impacts of this type and magnitude.”*

Based on the information developed in the BBWA2 in Chapter 7 and the discussion of compensatory mitigation in Appendix J, EPA concludes that: *“Specifically, these three watersheds are largely unaltered by human activities, and there appear to be no sites that a mitigation project could restore or enhance to offset the magnitude of impacts expected from the mine scenarios.”* In addition, EPA generally dismisses the potential mitigation measures identified in comments from the public and EPA’s peer-reviewers on the 2012 external draft of the Bristol Bay Watershed Assessment. EPA failed to identify any measures that could mitigate for the impacts estimated using their analyses and dismissed the list of measures identified by commenter’s and peer-reviewers because of concerns about the efficacy of such measures and general ecological considerations.

In summary, EPA provides no credible scientific basis for their inferred fish habitat/population impacts or for their wholesale rejection of widely recognized fish habitat mitigation methods.

## **2.2 FATAL FLAWS IN EPA’S ASSUMPTIONS AND CONCLUSIONS**

### **2.2.1 Methodology Used by EPA to Determine the Magnitude of Impacts**

The magnitude of impacts presented by EPA in the BBWA2 is based on a fatally flawed and scientifically indefensible methodology, as discussed below.

### **2.2.1.1 Estimation of Kilometers of Fish Habitat Lost as a Result of EPA's Development Scenarios – Incomplete Data Base and Flawed Methodology**

EPA used the National Hydrography Dataset as a basis for determining the number and location of stream channels in areas they claim will be affected by development of their mine pit, waste rock storage, and three tailings storage facilities (TSF 1 on NFK 1.190, TSF 2 on SFK 1.190, and TSF 3 on SFK 1.240) at maximum hypothetical development (BBWA2, Chapter 7, Box 7-1). They then used information from the State of Alaska's Anadromous Waters Catalog (AWC) and Freshwater Fish Inventory (AFFI) to estimate fish species distribution. EPA erroneously assumed that the information contained in these sources was accurate and that fish species distribution, as reflected, indicated the presence of spawning salmon and ecologically important rearing habitats. These assumptions are demonstrably false and not supported by readily available public empirical data from the mine site and the three hypothetical tailings storage facilities.

Several examples illustrate the fatal flaws in EPA's assumptions and conclusions regarding adult salmon spawning distribution and importance:

- If EPA had reviewed, in detail, the adult salmon spawning distribution data presented in Pebble Limited Partnership's Environmental Baseline Document (EBD), presented to EPA in 2011, they would have discovered that no adult salmon have ever been reported as spawning in the SFK watershed upstream of Frying Pan Lake, which is located downstream of EPA's hypothetical mine. This information is also contained in the AWC.
- If EPA had reviewed, in detail, the adult salmon spawning distribution data presented in the EBD they would have concluded that the upper portion of UT contains a relatively large spawning population of coho salmon, sockeye spawning numbers that are a small fraction of those that spawn in the remainder of the stream, and that Chinook salmon spawning consists of a few individuals.
- If EPA had reviewed, in detail, the adult salmon spawning distribution data presented in the EBD they would have concluded that TSF 2 contains a small population of coho, Chinook, and chum, which spawn in the lower portion of the watershed. TSF 3 has a small run of coho salmon.
- If EPA had reviewed, in detail, the adult salmon spawning distribution data presented in the EBD they would have concluded that TSF 1 contains a small population of coho and Chinook.

EPA drew the wrong conclusions regarding adult salmon spawning distribution and relative ecological importance by failing to examine site specific and publically available data on the habitat conditions, fish species distribution, and densities of juvenile salmonids found in their mine development impact areas. This fact alone invalidates the conclusions in the BBWA2 draft relating to impacts.

The following publically available data should have been included in any science based ecological risk assessment. It is also important to note, that EPA staff (one of the co-authors of the BBWA2) was personally made aware of the availability of this information at a June 12, 2008 presentation to the Pebble Fish Technical Workgroup meeting hosted by the Alaska Department of Natural Resources. The following publically available data should have been included in any science based ecological risk assessment:

1. Northern Dynasty Mine's 2005 Progress Report on fish sampling activities in 2004. This report included adult salmon spawning counts for the SFK, NFK, and UT. It also included site specific fish density and fish species composition data for approximately 100 locations within EPA's mine development area, UT watershed, and the watersheds encompassed by EPA's TSF's 1, 2, and 3 (NDM 2005),
2. Two Technical Memoranda, prepared by J.W. Buell (Buell and Associates, Inc.) from 1991 and 1993, which documented fish distribution and relative abundance of fish at approximately 50 locations in and around the Pebble Deposit (Buell 1991, 1994),
3. A 2005 Alaska Department of Fish and Game memorandum which documents fish distribution and species composition, habitat parameters, and fish densities, which can be calculated from information contained in the data sheets, from locations within the TSF 1 and TSF 2 watersheds (ADFG 2005),
4. Information on preliminary adult salmon spawning escapement estimates presented at the annual agency meetings for 2004-2007 (this information was also presented during the technical workgroup meeting), and
5. A binder, containing hundreds of pages, of fish capture data for the period 2004-2007 for all sampling conducted by PLP consultants up to that date and reported to the Alaska Department of Fish and Game per their collection permit reporting requirements. This data contains site specific information on fish species composition, lengths of fish captured, and data which could be used to calculate fish densities at selected locations by incorporating habitat information contained in the 2005 Northern Dynasty Mines Progress Report. This binder of empirical data was offered by PLP to all attendees present at the Technical Workgroup meeting referenced above, including EPA Alaska staff who is one of the co-authors of the BBWA2.
6. As for the transportation corridor, EPA failed to review data for each proposed stream crossing known at the time of sampling, which contains information fish species presence, lengths of captured fishes, stream dimensions, substrate composition, and basic water quality parameters among other data which are contained in Chapter 15 of the EBD (PLP 2011).

In addition to the publically available information available to EPA since 2008, the EBD contains a considerable body of information on habitat conditions and dimensions, fish species composition and distribution, and site specific fish density information. This information is contained in EBD Chapter 15 and its supporting appendices. It is obvious that EPA did not examine the EBD in detail, because several statements regarding the lack of suitable data can be proven false, because that information is contained in the EBD.

What all of this empirical and publically available information shows is that:

- Salmon spawning in the TSF 1 watershed is limited to a few coho salmon and an occasional Chinook. The fish density data from multiple public sources show very low juvenile densities and spotty distribution, which are consistent with small numbers of spawning adults. No sockeye or chum salmon are known to spawn in the TSF 1 watershed.
- Fish density and fish distribution for the TSF 2 watershed shows the same characteristics.
- Available data for TSF 3 shows low densities of coho salmon in the lower portion of the SFK 1.240 watershed.
- In EPA’s hypothetical mine area, no salmon spawning has ever been documented upstream of Frying Pan Lake (FPL), only a few juvenile coho salmon have been found upstream of FPL, supporting juvenile coho to move upstream from spawning location. However, fish density and distribution data show that these fish are confined to the main stem SFK up to about tributary stream SFK 1.370. Fish habitat data from the EBD would show that this portion of the SFK main stem is only about 2 m in width.
- The **AWC erroneously reports juvenile sockeye salmon rearing in FPL.** This distribution is not supported by the known locations of sockeye spawning, the ages of fish represented in the AWC, the number of juveniles reported (3 or 4 depending on the source), and the behavior of juvenile “river type” sockeye after emergence. Data for the UT shows a relatively large spawning population of coho salmon, a few Chinook, and some sockeye in certain years. However, EPA assumed that the upper portion of UT was important for Chinook and sockeye and that sufficient habitat is not available downstream of any cut off areas to accommodate a few occasional and additional spawners. This is also true in the SFK downstream of the ephemeral reach and in the NFK.

If EPA had completed an adequate evaluation of the public sources of information, it is likely that their conclusions regarding the overall ecological significance and magnitude of potential impact would have been different. Having an empirical data-informed conclusion on the relative importance and habitat conditions of these watersheds would have led EPA to a more scientifically defensible assumptions and conclusions about the magnitude of impact and a more defensible conclusion regarding the sufficiency and quantity of potential mitigation measures to mitigate their estimated impacts.

### **2.2.2 EPA Wrongly Concluded that No Mitigation Opportunities exist within the SFK, NFK, and UT Watersheds**

**The BBWA2, in Appendix J concludes:** *“Specifically, these three watersheds are largely unaltered by human activities, and there appear to be no sites that a mitigation project could restore or enhance to offset the magnitude of impacts expected from the mine scenarios.”* [Emphasis added]. This statement by EPA is demonstrably and patently false. There are a number of factors, within EPA’s control, that could have caused EPA to reach this fatally flawed conclusion. For example:

- EPA failed to accurately assess the magnitude of potential impacts from their hypothetical mine development, which resulted in an impression that the magnitude of impacts would be much greater than the empirical data indicates. This is discussed in detail above.
- EPA failed to conduct an effective site visit of the three principal watersheds surrounding the Pebble deposit and thus have no firsthand knowledge of the site about which they are drawing conclusions.
- EPA failed to conduct an effective over flight of the three principal watersheds to view the topography and stream geomorphology of the site, which would have shown numerous mitigation opportunities in the plethora of existing off-channel aquatic habitats.
- EPA failed to review publically available satellite imagery on Google Earth which shows, to an experienced biologist, numerous locations where multiple off-channel habitats exist and could be enhanced.
- EPA failed to review photographs in Chapters 4, 7, 9, and 15 of the EBD, which show close up images of portions of the various stream channels. An experienced biologist would have immediately identified mitigation and enhancement opportunities from these photographs alone.
- EPA failed to conduct a detailed review of the available water quality data contained in Chapter 9 of the EBD, which shows numerous opportunities to increase the primary productivity and fish productive capacity of many existing habitats through a combination of water chemistry enhancements and management of the water chemistry parameters for water discharged from the Wastewater Treatment Plant.
- EPA and the authors of the BBWA2 appear to lack even a rudimentary knowledge of the fish habitat improvement scientific literature and the efficacy of such improvements and are thus unable to render technically and professionally credible conclusions regarding the potential mitigation measures that are available in the three principal watersheds.
- EPA's conclusion that no mitigation opportunities existed is tantamount to reaching an a priori conclusion regarding the impacts of their development scenarios and selectively misleads the reader into reaching the same conclusion. In other words, the mitigation suitability conclusions were justified to reach a pre-conceived ecological conclusion of major impacts without regard to the available site specific data and information and the application of sound scientific principles during their analyses.

Singly and in combination, the factors listed above have contributed to EPA's scientifically indefensible conclusions to reject the potential for a substantial suite of mitigation measures

to be implemented within the three principal watersheds (SFK, NFK, and UT) and other locations within the Kvichak River watershed. The remainder of this document will outline the scientific literature supporting and describing applicable mitigation techniques, a brief discussion of the efficacy of such techniques, an overview of on-site and off-site mitigation techniques that could be used to provide a successful mitigation program for EPA's hypothetical mine development scenario in compliance with the various regulations and policies outlined in Appendix J.

## Section 3

### **Review of the Scientific Literature with Respect to Fish Habitat Mitigation Techniques**

EPA failed to describe any potential fish habitat mitigation techniques that they believed were applicable to the three mine area watersheds. Instead, they relied on input from the public and peer reviewers for suggestions on possible mitigation measures. EPA's failure to acknowledge or consider the considerable body of scientific literature on fish habitat improvement techniques is puzzling to us. This section provide a comprehensive review of fish habitat improvement techniques which we believe are not only applicable to the Pebble deposit area, but are backed by well documented rates of success and efficacy in increasing fish production. These are the techniques that a review of the literature would have revealed to EPA.

#### **3.1 Overview**

EPA concluded in the BBWA2 that no on-site mitigation measures were available to offset the impacts from their development scenarios within the three primary watersheds. This assertion is refuted by a large body of scientific literature combined with the ecological conditions within these watersheds. On the contrary, for more than 75 years fish habitat managers have successfully applied in-stream habitat mitigation measures in numerous salmon supporting watersheds.

This section describes actions and techniques that could be used to implement a fish habitat mitigation program in order to mitigate impacts to aquatic habitats resulting from implementing EPA's mine development scenarios. Section 3.2 describes water management techniques which deal with changes in water flow and water temperature resulting from reducing the area of a watershed that contributes surface and groundwater flow to downstream areas. Section 3.3 outlines measures that have been used by others to improve/create access to existing, suitable habitat areas and the creation or improvement of physical habitats that will increase the total habitat area available or improve the production potential of existing, undisturbed habitats. Section 3.4 evaluates the potential for enhancing certain water chemistry parameters (e.g., alkalinity, hardness, and total dissolved solids) or nutrient levels (nitrogen and phosphorus) in order to improve the primary productivity of area waters at selected locations with a resulting increase in fish production. All of these strategies and associated techniques are discussed below. We have chosen to only review those techniques or approaches that have been used by others to address similar mitigation or habitat improvement issues and which we believe are appropriate for the species and ecological conditions associated with the Pebble deposit area.

#### **3.2 Water Management**

##### **3.2.1 Background**

In Section 7.3 of the BBWA2, EPA describes their assumptions and analyses of changes in stream flows as a result of the elimination of flow contributing portions of the three watersheds in their development scenarios. EPA's operations assumptions result in water surplus being passed through the wastewater treatment plant (WWTP) for treatment and subsequent release into stream channels downstream of project infrastructure. The BBWA2 assumes that WWTP

releases are divided equally between the NFK and SFK, with the SFK providing water to the UT via a subsurface connection and UT tributary 1.190 and that discharges are surface water additions to existing channels. This appears to be the only technique EPA used to distribute surplus WWTP water to the environment. EPA only dealt with flow volume and did not deal with WWTP discharge water chemistry or water temperature. As a result of this flaw in EPA's analyses, they failed to recognize the consequences of their "*realistic development scenarios*", which include **violations of Alaska's Water Quality Standards and disrupting the normal egg incubation water temperature regime for anadromous and resident fish species.** EPA's lack of familiarity with the three principal watersheds, the water flow characteristics within those watersheds, and apparently lack of knowledge regarding salmon egg incubation ecology resulted in this inappropriate and deleterious water management scenario.

### **3.2.2 Water Management Techniques Applicable to the Three Principal Watersheds**

#### **3.2.2.1 Management of Water Discharged from the WWTP**

There are a number of water management techniques and strategies that could be implemented within the principal watersheds which would provide a much greater level of protection to fish populations and their habitat needs than that outlined in Section 7.3 of the BBWA2. The following list briefly describes some of the more obvious techniques and strategies that EPA did not discuss:

1. Manage water discharged from the WWTP according to a hydrologic program of releases rigorously defined by advanced flow and habitat modeling techniques, and thereby ensuring that the availability of downstream fish habitat is ensured.
2. Manage water discharged from the WWTP to comply with Alaska's Water Quality Standards and meet the ecological needs of the fish species downstream of the discharge locations.
3. Manage water discharged from the WWTP in a manner that considers the "ecological importance" of certain key habitat and fish population areas (e.g., South Fork Koktuli "Springs" area and UT immediately downstream of the cut off wall for EPA's waste rock piles).
4. Manage the chemical constituents of water discharged from the WWTP to increase the primary productivity and fish productive capacity in areas downstream from discharge locations.
5. Manage water discharged from the WWTP to the environment in order to meet the ecological water temperature requirements of fish downstream of the discharge locations.
6. Manage the volume of water discharged from the WWTP into each watershed considering whether or not salmon spawning habitat is limiting the population and to offset naturally imposed bottlenecks to fish production (eg. critically low winter flow periods)..

### **3.2.2.2 Techniques to Increase the Total Volume of Water Available to Offset Downstream Flow Reductions**

Three techniques are also available to increase the total volume of water available to offset downstream flow reductions; none of these were considered by EPA in the BBWA2. The first two are really self-explanatory, while the third requires some more detailed explanation for someone not familiar with the technique.

- Develop impoundments to increase the total volume of water available to offset flow reductions downstream of EPA's infrastructure components in each of the three development scenarios.
- Increase the volume of water available to recharge groundwater aquifers and provide additional stream flow by creating ice fields during the fall and winter time periods (Clark and Lauriol 1997; Alamaro 1999; Yoshikawa et al. 2007).
- Use a water pump-back technique to supply water to upstream areas that would otherwise be flow-depleted.

#### **3.2.2.2.1 Water Pump-Back (i.e., Re-circulating Water from Downstream Back to Upstream Areas)**

##### **General Description**

The water pump-back concept involves establishing a well field or screened intake and associated pumping plant in a watershed down-gradient of the reach or reaches where supplemental water is desired. Water from this downstream source is pumped to a storage location, release point, or area upgradient of the reach or reaches to receive water supplementation. Water is then released from the upstream site(s) to maintain or improve aquatic habitats and ultimately the productive capacity of the stream. This water eventually flows downstream and is effectively recycled, through the pumping system, back to the upstream site(s). Once the system is charged (a one-time draw on local surface or groundwater), the water is recycled non-consumptively keeping the desired flow in the reaches between the release area (e.g. wetlands and/or up-gradient aquifer recharge area) and the down-gradient screened intake or well field aquifer recharge area.

##### **Selected Examples**

Several examples of a pump-back technique being used to improve fish and/or aquatic habitat purposes are briefly outlined below. Examples vary considerably in scope and detail, but each uses the water pump-back concept for maintenance or enhancement of fish habitat and other environmental amenities. Most incorporate upstream storage, but some do not.

#### **A. Colorado Water Congress – Upper Colorado River Endangered Fish Recovery Program**

This program has developed a complex array of elements to restore and enhance aquatic habitats providing for irrigation and municipal water supply obligations. Several elements involve pump-

back approaches. Objectives include re-creation of more natural hydrographs for both fish resources and recreational purposes (GrandRiver Consulting 2005; GEI Consulting 2008). Some project elements include:

- The Woford Mountain Reservoir element involves pumping 75 cfs from the Colorado River at the mouth of Muddy Creek to a reservoir about 7 mi upstream where it is released down the creek as part of a multi-purpose storage/release program.
- The Fraser River (Colorado) Pump-Back element recycles 5 cfs via several components for fisheries, recreation, scenic and other environmental purposes.
- The “15-mile Reach Pumpback” element recycles 350 to 400 cfs (150 ft. lift) to an upstream release location at the top of a 15 mi long segment of the Colorado River between Grand Junction and Palisade, Colorado, providing flow enhancement during late summer. No storage is involved.

**B. Los Angeles Water and Power / Inyo County Lower Owens River Plan, (Los Angeles Water and Power 2005).**

This project involves pumping 35-50 cfs from the Owens River to an aqueduct for release to lakes and ponds from which it is returned to the river via surface flow. The primary goal of the project is to establish a “... healthy, functioning Lower Owens River ecosystem... for the benefit of biodiversity and Threatened and Endangered Species, while providing for the continuation of sustainable uses including recreation, livestock grazing, agriculture and other activities.”

**C. Umatilla Basin Project, (Bronson and Duke 2005; USBR 2007)**

An upgrade to this century-old U.S. Department of the Interior, Bureau of Reclamation project involves pumping up to 140 cfs from the Columbia River near the mouth of the Umatilla River upstream in the Umatilla drainage to the off-channel Cold Springs Reservoir (321 ft. rise) (Bronson and Duke 2005). This “conjunctive use” water passes from the reservoir and enters the Umatilla Basin Project irrigation and water supply complex (USBR 2007). This scheme increases flow in the Umatilla River directly through a 1-for-1 exchange for Umatilla River diversions and indirectly through recharge of basin aquifers. Increased Umatilla River discharge provides fish passage flows and fish habitat maintenance in the lower river.

**D. Columbia River Basin Storage Options – Yakima Basin Water Storage, (USBR 2007)**

The Wymer Alternative of this project involves pumping water from the Yakima River to Wymer Reservoir on Lmuma Creek and release of water from the reservoir to return to the Yakima River (USBR 2007). Objectives include fish and aquatic habitat maintenance in Lmuma Creek.

### **E. Oregon Governor’s Watershed Enhancement Board Pump-Back Projects, (Ken Bierly, Watershed Enhancement Board, *pers. comm.*)**

Several pump-back projects have been approved for funding by the Oregon Governor’s Watershed Enhancement Board (Ken Bierly, Watershed Enhancement Board, *pers. comm.*). Most of these projects are in the arid eastern part of the state. Examples incorporating fish and aquatic habitat enhancement include: (1) Willow Creek Pump-back Project, (2) Rudio Creek Re-plumbing Project and (3) Little Butte Creek Pump-back Project.

#### **Hypothetical Application of a “Pump-Back” Project in the Pebble Project Area**

Using the South Fork Koktuli River as a hypothetical example, water could be pumped at a rate of 50 cfs, either from a groundwater well field on the flats near the North Fork – South Fork Koktuli confluence (el. ~700 ft msl) or from a screened intake in the same vicinity, to a storage reservoir or up-gradient aquifer recharge area (*e.g.* South Fork Koktuli “flats”) about 20-25 mi away (el. ~1,000 ft msl). Releases from the storage reservoir or to the recharge area could be programmed to meet channel maintenance and fish production goals as appropriate. Operation would not necessarily have to occur continuously. During periods of elevated natural runoff, it may be that water supplementation using this method would not be needed. A diagrammatic depiction of this concept is illustrated in Figure 3.1.

Establishment of the pumping plant in this application would include providing power at the site and provision of access to maintain project infrastructure. Feasibility of the well field supply approach would depend on an analysis of the recharge capability of the donor aquifer. Environmental risks include the potential for turning some gaining reaches in the vicinity of the North Fork – South Fork Koktuli confluence into losing reaches, thereby influencing aquatic habitat quality. The appropriate regulatory requirements associated with obtaining the applicable permits to build a project like this would need to be addressed..

Water recycled in this way would not represent an inter-basin transfer. As long as this flow supplementation water stayed in its own watershed, there would be no associated risks of introduction of fish pathogens or parasites and it is anticipated that no special studies related to fish pathogens would be required.

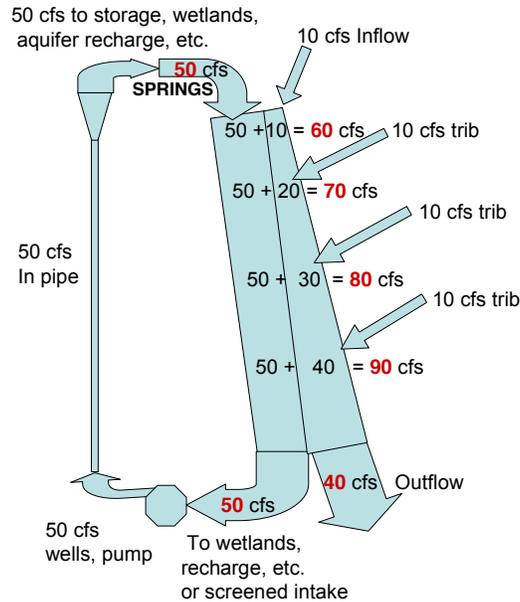


Figure 3.1.—Diagrammatic illustration of a water re-cycling pump-back concept taking water from a screened intake or well field and supplying it to storage, wetlands or aquifer recharge area upstream. Flows are indicated for illustrative purposes only.

### 3.3 Creation and/or Improvement of Physical Habitat Components or Areas

#### 3.3.1 Overview

This subsection describes physical habitat-based techniques for mitigating fish and aquatic habitat impacts that might result from EPA’s mine development scenarios. The techniques described are based on over three-quarters of a century of experience with habitat manipulation, rehabilitation, enhancement, and creation in the fresh water environment in the Pacific Northwest, western Canada and Alaska (Davis et al. 1935, Silcox 1936, Tarzwell 1938, Gee 1952, Ehlers 1956, Summers and Neubauer 1956).

This subsection incorporates selected techniques and examples from Alaska. Other than the Habitat Division of the Alaska Department of Fish and Game (ADFG), there exists no detailed documentation of habitat restoration or improvement work since Parry and Seaman’s 1994 compendium. This conclusion is supported by phone conversations with one state and four federal agency employees familiar with the habitat restoration/improvement actions occurring in the State. The literature documentation and intensive monitoring results are dominated by examples from the Pacific Northwest and Intermountain West of the United States and British Columbia, Canada. It is important for the reader to understand that it was not until the early 1980s that large sums of money became available to “improve salmonid habitats” because of the collapse of salmon runs in the Eastern Pacific Ocean. As a result of the stampede to improve fish habitats, many design mistakes and a general misunderstanding of how streams functioned resulted in failure or disappointing results. Also, other critical factors involved inadequate project planning and misidentification of the factor(s) limiting fish production. However, habitat enhancement and rehabilitation practitioners learned rapidly from their mistakes. In the past

three decades, the science and engineering of “habitat improvement” has advanced greatly and it is rare to see projects implemented now that have the same flaws that led to questionable success in the past.

Early efforts and programs targeting enhancement of salmonid habitats in small rivers and streams met with mixed results (Ehlers 1956, Buell 1982, Beschta et al. 1994), but the evolution of knowledge regarding the relationships among fluvial processes, aquatic habitats and the fish they support has brought the art and science of habitat enhancement and rehabilitation to an advanced state (Hall and Baker 1982; Reeves and Roelofs 1982; National Research Council 1992; Sear 1994; Reeves et al. 1995; Slaney and Zaldokas 1997; Benda et al. 1998; Saldi-Caromile et al. 2004).

Successes in increasing productive capacity (the ability of habitats to produce fish) and actual fish production have been documented extensively in the technical literature. Solazzi et al. (1999) reported on an 8-year program specifically designed to evaluate the effectiveness of instream habitat restoration and enhancement projects on many streams in the Oregon Coast Range. They examined the types of rearing habitat created by various habitat improvement techniques, compared the densities of juvenile coho salmon in summer and winter and compared the productivity of constructed versus natural habitats. They also undertook an intensive investigation of several streams before and after habitat restoration work to determine the effects of this work on smolt production. Their data showed that constructed habitats performed as well as natural habitats, and that alcoves (off-channel) and other low-velocity habitats supported larger numbers of overwintering coho than main channel habitats. The intensive before-and-after studies showed that overwinter survival rates for juvenile coho ranged from 35-52% in constructed habitats, triple the rates from control streams over the 8-year study period. The number of large (>90mm) downstream steelhead and coastal cutthroat trout migrants also increased in the treated versus non-treated streams.

Many monitoring studies are chronicled in British Columbia’s Watershed Restoration Technical Circular entitled “Fish Habitat Restoration Procedures” (Slaney and Zaldokas 1997). This compendium contains large chapters on a number of stream restoration and enhancement approaches, including spawning habitat enhancement, secondary channel and off-channel development, use of large woody debris, boulders and combinations of these elements and fish production enhancement using low-level nutrients. Each chapter summarizes successful (and unsuccessful) applications of these approaches. For example, Table 3.1 summarizes data on stream-rearing fish species from Keeley et al. (1996) for 15 paired studies of treated and untreated areas in streams. These data show significant increases in fish life stage density, up to an order of magnitude, resulting from habitat-based treatments for all species studied.

Citing data from Keeley et al. (1996), Slaney and Zaldokas (1997) report fish production benefits of a 1.8- to 9.3-fold increase adult salmon and steelhead returns resulting from increasing main channel habitat complexity (i.e., introduction of large woody debris, boulders and other complexing elements). Fish production benefits associated with developed secondary channels and off-channel habitats, especially as compared to associated natural habitats, are also documented. More thorough documentation of higher egg-to-fry survival (e.g., Bustard 1986; Marshall 1984; WDFW 1986) and coho salmon overwintering survival and smolt output (Bachen

1984; Bustard 1986; Cederholm and Scarlett 1991; Guillermo and Hinch 2003; Morley et al. 2005) resulting from habitat improvement measures.

The Washington Department of Fish and Wildlife has developed Stream Habitat Restoration Guidelines (Saldi-Caromile et al. 2004), which provide very comprehensive and detailed guidance on habitat-based rehabilitation and enhancement of streams targeted specifically at the production of fish, especially salmonids. Besides chronicling strategies and implementation techniques and instructions, this document stresses the benefits that can be expected from implementation of the approaches and techniques described.

Table 3.1.—Pre- and post-treatment anadromous salmonid densities for stream rearing species (adapted from Keeley et al. 1996).

Stream	Density (no·m <sup>-3</sup> )										Tot. fish Treated	Tot. fish Untreated	% diff	x-fold increase
	Treated Coho-0+	Untreated Coho-0+	Treated Stlh-0+	Untreated Stlh-0+	Treated Stlh-parr	Untreated Stlh-parr	Treated Chinook-0+	Untreated Chinook-0+	Treated Dolly V	Untreated Dolly V				
Tobe Cr., OR	0.49	0.18	0.11	0.07	0.02	0.06	-	-	-	-	0.62	0.31	100	2
E Fork Lobster Cr., OR	0.90	0.45	0.34	0.41	0.04	0.05	-	-	-	-	1.28	0.91	40.4	1.4
Squaw Cr., ID	-	-	0.21	0.16	0.08	0.02	0.08	0.05	-	-	0.37	0.24	54.7	1.5
Papoose Cr., ID	-	-	0.42	0.28	0.17	0.07	0.17	0.06	-	-	0.76	0.40	88.3	1.9
E Fork Papoose Cr., ID	-	-	0.49	0.26	0.16	0.02	-	-	-	-	0.65	0.28	133.3	2.3
Lolo Cr., ID	-	-	0.11	0.12	0.11	0.02	0.41	0.14	-	-	0.63	0.28	127.9	2.3
Pete Cr., ID	-	-	0.42	0.20	0.16	0.04	0.01	0.03	-	-	0.59	0.27	120.0	2.2
Sachs Cr., BC	1.5	0.89	0.35	0.09	0.11	0.09	-	-	-	-	1.96	1.07	83.5	1.8
Macmillan Cr., BC	0.93	0.57	-	-	-	-	-	-	0.20	0.03	1.12	0.60	86.5	1.9
Southbay Dump Cr., BC	0.99	0.69	-	-	-	-	-	-	-	-	0.99	0.69	43.5	1.4
Bonanza Cr., BC	1.51	0.47	-	-	-	-	-	-	0.21	0	1.72	0.47	266.0	3.7
Keogh R., BC	0.28	0.38	-	-	0.09	0.03	-	-	-	-	0.37	0.41	-9.8	0.9
Keogh R., BC	0.34	0.28	0.2	0.15	-	-	-	-	0.07	0.014	0.61	0.44	37.4	1.4
Nechako R., BC	-	-	-	-	-	-	2.71	0.09	-	-	2.71	0.09	2878.0	29.8
Hurdygurdy Cr., CA	-	-	-	-	0.03	0.025	-	-	-	-	0.03	0.03	20.0	1.2
Average:	0.87	0.49	0.29	0.19	0.10	0.04	0.68	0.07	0.16	0.02	0.96	0.43	271.3	2.2
x-fold increase:	1.8		1.5		2.3		9.3		10.4					

The purpose of the remainder of this subsection is to provide the reader with a brief synopsis of the scientific literature and compendiums which clearly demonstrate the potential benefits to fish populations resulting from properly planned and executed habitat improvement projects or programs. More specific improvement actions or techniques are discussed in more detail below, with additional literature-based documentation of the results of implementing specific techniques or combination of techniques also presented. Review of the scientific literature and the authors' extensive personal experiences in planning and implementing habitat improvement projects and managing agency-based regional habitat improvement programs for Pacific salmon form the foundation for the selection of techniques detailed below. It should also be noted, that the authors have several decades of experience in dealing with Alaska ecosystems and their associated fish species.

The techniques reviewed in this document reflect a distillation of those specific techniques that the authors believe are most applicable to the Pebble Deposit area and its setting in Southwest Alaska. Many millions of dollars have been spent and continue to be spent on habitat-based enhancement of production of salmon and other fish species in the Pacific Northwest, western Canada and Alaska, and monitoring results from a wide variety of these efforts over the last quarter century or more, some of which are reviewed here, attest to their effectiveness. This money is being spent by the private sector for mitigation and by the public sector for mitigation and enhancement because the approaches being funded work. The authors believe that the benefits of habitat improvement are settled science.

### **3.3.2 Improved Access to Existing Spawning or Rearing Habitats**

#### **3.3.2.1 Removal or Modification of Seasonal Barriers (beaver dams)**

A major concern to fish managers in their efforts to manage existing natural or newly created aquatic habitats is the potential for beaver to either change the character of the habitat, existing or created, or to prevent access to these habitats by both adult and/or juvenile fish. Beaver dams blocking access to upstream areas for migrating salmon have been documented in the general project area. Coho salmon spawning within a beaver pond in spring areas visible from the air have also been documented in the proposed project area.

Pools created by beaver dams provide some of the most productive aquatic habitat found in and near the Pebble Project area. These pool areas provide relatively productive rearing areas, especially multiple age classes of juvenile coho salmon. They provide significant quantities of overwintering habitat area for a variety of fish species.

Clearly, the negative and positive characteristics of beaver activity in salmon producing watersheds require close management, but more importantly, present substantial opportunities for fish habitat mitigation. Finnigan and Marshall (1997) provide an excellent overview of managing beaver to maintain ecosystem values for fish, such as providing complex and highly productive rearing habitat for juvenile fish. They also describe a variety of techniques to keep beaver construction actions from damaging project infrastructure, such as damming road culverts and causing road prism failure.

#### **3.3.2.2 Creation of Permanent Access over Existing Waterfalls**

The only fish migration impediment currently affecting access to useable fish habitat is a bedrock cataract on UT 1.190 near the confluence of this stream with the UT main stem. Fish sampling efforts have yielded no anadromous fish (juveniles or adults) upstream of this cataract in spite of a base stream flow of about 25 cfs. This level of flow is sustained year around via an underground transfer from the SFK watershed. This stream remains generally ice free during the winter and could provide valuable winter rearing habitat.

### 3.3.3 Physical Habitat Manipulation and Improvement

#### 3.3.3.1 Large Rock Applications (clusters, single elements)

##### 3.3.3.1.1 General Description

The use of large boulders (typically 2-6+ ft. in diameter) to create desired habitat conditions or channel complexity has been used in western North America by a variety of agencies to improve salmonid fish habitat. Boulder placements generally occur in riffles or side channels to create habitat diversity or complexity. The fundamental principle behind boulder placement is creation of desirable conditions within the stream channel by causing localized scour and deposition to create spawning areas due to the sorting and accumulation of suitable bed materials downstream of the rock(s) location (Figure 3.2) (Lisle 1981). Juvenile rearing habitat is also created by changing the water velocity and flow patterns within the channel and creating low or zero velocity areas downstream of the boulder. Enhanced feeding opportunities for juveniles and adult salmonids are created in the shear zones at each downstream corner of the boulder. Drift food organisms are delivered to the quiet, zero velocity area immediately downstream of the rock, thus minimizing energy expenditures for individual fish. Groups of boulders placed in a triangular pattern adjacent to the channel bank can create the same types of habitats as described for a single boulder. In addition, these multiple rock structures can reduce/stop bank erosion, particularly on the outside bends in certain types of channels (Figures 3.3- 3.5).

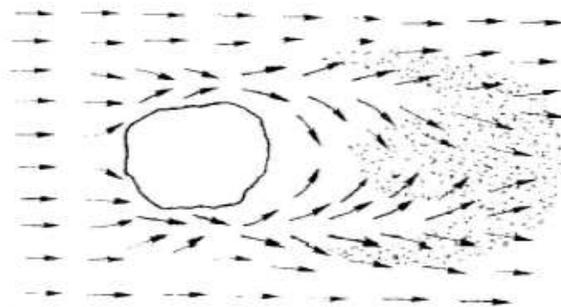


Figure 3.2.—Conceptual view of water velocity vectors around an object in a stream channel. Scour occurs immediately downstream of the object (shaded area) with deposition slightly further downstream (Lisle 1981).

Boulder placements have had two major problems in past applications. The first is placing these large objects on an inappropriate stream bottom. In numerous situations, the bottom substrate was too small to properly accommodate the increased water velocity around the boulder(s) and the resulting scour and deposition resulted in the boulder effectively burying itself in the channel. This situation results in the total loss of any habitat initially gained and in some instances resulted in channel migration away from the “improvement”. The second problem was the improper placement of the boulder(s) within the channel with respect to channel bank stability. In these instances, boulders were placed too close to a bank, which resulted in unacceptable bank scour during high flows or the bank materials themselves were too small to resist the increased water velocity associated with boulder placements in proximity to the bank.

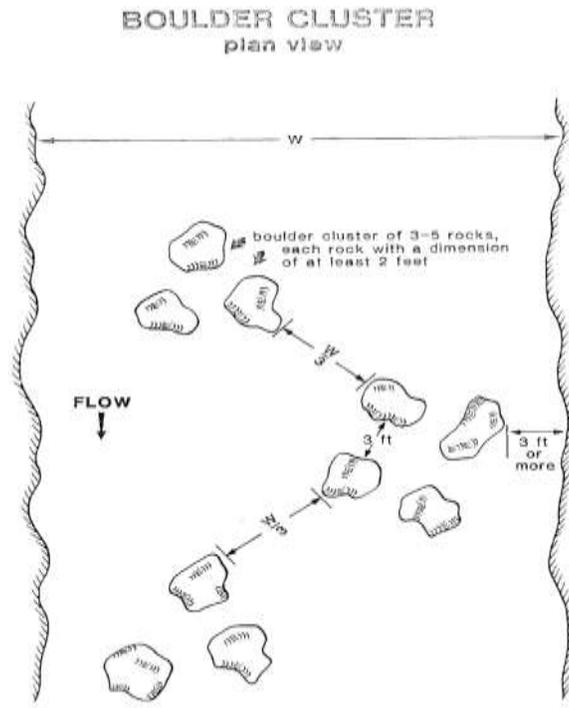


Figure 3.3.—Diagram showing “typical” placement considerations for boulder clusters placed in streams or side channels. (USDA, Forest Service, undated)



Figure 3.4.—Boulders placed in the Mykiss Side Channel, Cheakamus River, British Columbia as habitat enhancement elements. (Halvorson 2004)

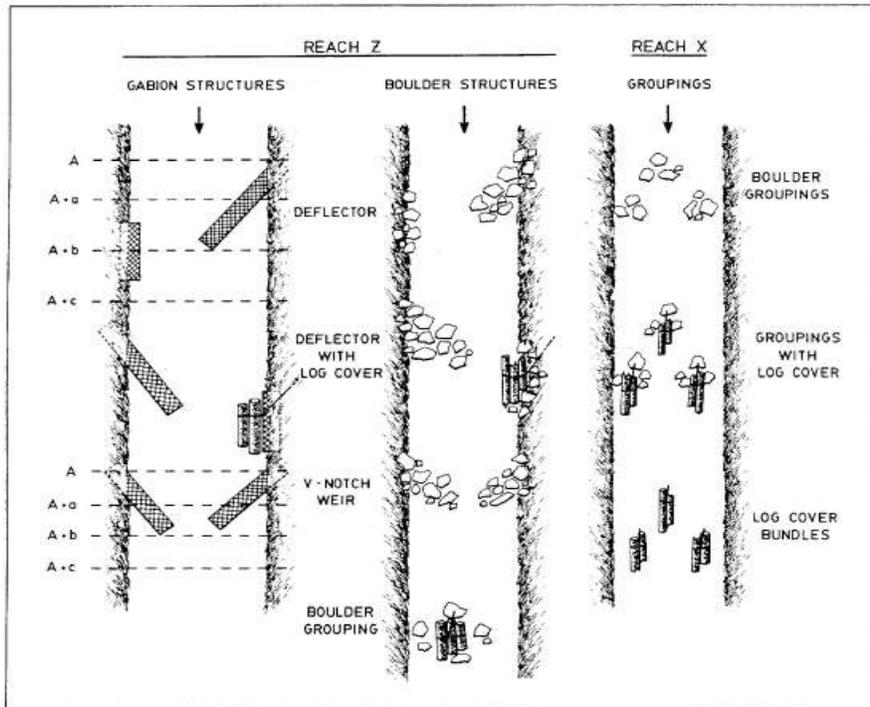


Fig. 2. Designs of boulder and gabion structures installed in the Keogh River (simplified).

Figure 3.5.—Diagram showing placement of boulder clusters individually, in conjunction with large wood habitat elements, and as roughly triangular “spur dikes” in the channel (Ward and Slaney 1979).

### 3.3.3.1.2 Selected Examples

Placement of rock into streams has been accomplished in a variety of configurations ranging from single boulder placement, clusters of varying numbers of rocks, specifically designed spur dikes (Figure 3.5), large downstream or upstream oriented V-shaped structures covering the width of the stream, and placement of “boulder fields” to increase juvenile rearing habitat.

Elser (1968) conducted an evaluation of “rock deflectors” (essentially the same configuration as the “boulder structures” shown in Figure 3.4) placed in channelized sections of Prickly Pear Creek, Montana. Sections of this stream had been channelized and straightened during previous railroad and road construction activities. Approximately 6.75 miles of a 30.5 mile section of stream had been channelized. The objective of the habitat rehabilitation was to restore the sinuosity of the channel and provide structural elements that would create channel scour, resulting in the formation of pool habitat, which had essentially been eliminated from the altered sections of the stream. Rock deflectors were installed primarily in the Wolf Creek Canyon zone of the stream which had about 5.0 miles of its 8.8 mile total length altered. The deflectors were placed at 180-200 foot intervals on opposite sides of the channel. Comparisons of the fish populations before and after installation of the rock deflectors and with adjacent unaltered sections showed that the fish populations and age structure in the sections with rock deflectors were similar to unaltered sections in the same zones. Non-game populations were absent from the altered sections, but comprised 30% of the fish population in the “improved” sections. Trout

populations in the areas with the rock deflectors were 78% higher than in the altered sections. The fish population levels in the “improved” area were significantly different from the altered, but untreated reaches.

Two studies in Norway (Hvidsten and Johnsen 1992 and Bremset et al. 1993) evaluated the placement of large cobble-small boulders across the bottoms of selected reaches of lowland rivers that had been channelized. In the River Soya, (Hvidsten and Johnsen 1992) natural stream bottom materials were generally small 2-4 inches in diameter. Blasted rocks up to 16” in diameter were placed across the stream in a weir formation and in some sections the entire width of the river (20 m) was covered with stones. Densities of Atlantic salmon, > age 0+ increased from about 7 fish/100 m<sup>2</sup> to 25-125 fish/100 m<sup>2</sup> in the channelized section. Salmon densities in reference sections ranged from 7 to 64 fish/100 m<sup>2</sup>. Brown trout densities increased after treatment in the channelized section, but were not significantly different from the reference reaches. However, it was noted that the length of fish in the treatment areas did increase, indicating an increased ability of the habitat created to support larger fish. Fish densities decreased over time as sediment filled the treated areas. However, trout densities again increased when upstream sources of sediment were controlled. In the River Gaula, Central Norway, mean densities of presmolt Atlantic salmon and brown trout were 5-10 times higher than in corresponding “unimproved” areas (Bremset et al. 1993). The authors note that the differences in population densities were greatest for older presmolts, again indicating a greater capacity to support larger juveniles. This latter study again documented the decrease in rearing capacity as sediment from uncontrolled upstream sources altered the newly created habitat.

A combination of boulder wing deflectors, clusters, and boulder weirs was placed in Hurdygurdy Creek, a tributary to the South Fork Smith River in northwestern California (Moreau 1984). Hurdygurdy Creek’s channel morphology had been severely altered by a massive flood event in 1964, resulting in a stream channel that lacked complexity, a thalweg, spawning gravel, and with limited instream cover. These structures were installed in 1981 and worked as projected. Two years after treatment, population estimates for steelhead parr increased 100%, while at the control sections populations declined by 56% and 61%. Spawning gravels did accumulate behind the rock weirs and Chinook salmon did use these gravels.

In Aikens Creek, a tributary to the Klamath River in northwestern California, a control section, a section with just boulder clusters, and a section treated with a combination of boulders and logs attached to the boulders were evaluated. The objective of the project was to provide suitable rearing habitat for steelhead presmolts. Juvenile steelhead numbers increased two and four fold in the boulders only and boulder/log combination treatment area, respectively (Overton et al. 1981).

In Red Cap Creek, in northwestern California, 80 boulders were placed singly or in clusters to increase the rearing habitat capability for steelhead trout. A treatment section was compared to a control section by electrofishing during summer low flow conditions. The before and after comparison showed a decline of 35% in population numbers of 1+ steelhead in the control section versus a 300% increase in the treated section (Overton et al. 1981).

Anderson et al. (1984) describe ten different habitat improvement designs, consisting of 80 total structures placed in southwestern Oregon streams. These structures included various materials (boulders being a main component in many designs) and physical configurations designed to accomplish different objectives. Some were designed to collect gravel sizes suitable for spawning salmonids, while others were designed to provide rearing habitat for specific life stages of anadromous salmonids. In a well documented example from the West Fork Smith River, a before and after treatment evaluation of habitat carrying capacity for coho salmon parr, steelhead age 1+, coastal cutthroat trout age 1+, and unidentified age 0 trout showed values of +17%, +30%, 33%, and -6%, respectively.

Ward (1997) provides an excellent review of the uses of boulders and boulder clusters to increase the carrying capacity for juvenile salmonids. Ward's review documents a number of specific projects, but the results are consistent among studies. If the boulder structures are installed in the appropriate locations and the management objective is to increase the habitat carrying capacity for coho parr and presmolt steelhead or coastal cutthroat trout, then these projects show an increase in carrying capacity of 100-300% over control or pre-project conditions.

Two studies document the use of microhabitats created by boulder structures and single boulder placements for brown trout (Shuler et al. 1994) and rainbow trout (Streubel and Griffith 1993). These two studies demonstrated the disproportional use of the microhabitats created by boulders and boulder structures by these species. In 10 study sections of the Rio Grande River, Colorado, 65-69% of adult and juvenile brown trout, respectively, were associated with two types of boulder structures. No use of single boulder placements was documented. Streubel and Griffith (1993) evaluated the use of the pockets of water created by single boulder placements in Fall River, Idaho by rainbow trout. They describe the use of this microhabitat type by rainbow trout from 150-300 mm in length. Critical factors identified, which strongly influenced habitat use, were water depth and surface area of the pool associated with a particular boulder placement.

### **3.3.3.1.3 Summary**

Boulders, either singly, in clusters, or combined with other materials such as large wood, have been used in a variety of designs and stream situations to improve fish habitat in western North America. Boulder placements or structures can be highly cost effective, generally because the boulders were in proximity to the stream and often with road access. In the Keogh River in British Columbia, boulders were placed with a helicopter and costs were considered comparable with road access and placement with heavy equipment. Cost per boulder has varied from \$50 to \$1,300 per m<sup>3</sup> with most cost estimates at least 20 years old. Another factor to consider is that over time, the recommended size of individual boulders has increased for instream applications to a generally agreed to size of about 1 m in diameter being the most effective at creating the desired microhabitat, requiring little maintenance, and are of sufficient size to stay in place during high flows.

Based on the results of previous habitat improvement projects and experimental design projects, it is apparent that boulders accomplish four things extremely well. First, boulders as rip rap can help stabilize eroding banks and provide fish habitat for a variety of species and life stages.

Second, boulders or boulder clusters provide excellent anchors to attach large wood which together provide a variety of microhabitats for salmonids. Third, boulders have been used to build weirs that span the entire channel width to reduce water velocities and cause deposition of desirable sized gravels that can be used for spawning and provide low water velocity habitat upstream of the weir. This latter habitat's carrying capacity can be improved with the addition of instream wood, brush piles, or smaller cobbles/boulders (see Solazzi et al. 1999 for some evaluations). Fourth, single boulders or boulder clusters create scour and deposition zones that can result in the creation of suitable spawning sites. In addition, these structural elements create low or negative velocity zones immediately downstream of the boulder which results in shear zones which deliver drift organisms directly into a low velocity rearing microhabitat.

Boulder placements provide suitable rearing habitat for age 1+ salmonids, particularly rainbow trout, cutthroat trout, and coho salmon. Age 0 juveniles are seldom found in the evaluations, primarily because they prefer the very low velocity areas associated with the shoreline and/or stream bottom. Age 0 fish generally are unable to fight the current found in boulder dominated areas. Also, given the preference for age 1+ fish to use the microhabitat behind the boulder, any age 0 fish that moved into this microhabitat would soon become prey for an older fish.

Given the fact that many stream channels in EPA's hypothetical mine area lack either large wood or large boulders, placement of boulders to create any of the four conditions outlined above certainly appears feasible. These structural elements can be added to existing or created channels to create habitat complexity or to accomplish specific objectives like providing additional rearing habitat for age 1+ or 2+ fish, which could increase the carrying capacity for juvenile coho and Chinook salmon. However, three factors need to be carefully considered before considering boulder placement: 1) is the type of habitat(s) created limiting smolt or juvenile resident fish production, 2) will the stream bottom on which these boulder(s) be placed suitable to handle the hydraulic conditions that will occur during high flows and allow the desired habitat type to be created, and 3) are the adjacent bank conditions suitable to minimize any bank erosion or additional hydraulic forces that may result from placing boulders in the channel.

Boulders can be used in the right situation to create a variety of desired microhabitats and conditions (e.g., deposition of spawning sized gravel), protect stream banks at appropriate sites, serve as anchors for large wood applications, and create desired instream complexity. Boulder elements may be applied in main stem channels or in side channel or alcove situations, depending on site specific conditions. EPA's exclusion of these types of habitat mitigation measures seriously undermines the credibility of the BBWA2 conclusions.

### **3.3.3.2 Wood Applications (logs, root wads, whole trees, brush bundles)**

#### **3.3.3.2.1 General Description**

Wood as used in this document generally refers to the intentional placement of portions, or in some cases, entire trees into a stream channel to accomplish a specific objective(s) (Reeves and Roelofs 1982). Most commonly, wood is placed either as pieces of a log directly into the channel, a root wad placed in or along the edge of a channel, a log diagonally projecting from the stream bank, a full channel width log perpendicular to the flow creating a dam pool or plunge

pool, or in conjunction with some other habitat element (e.g., logs cabled to a boulder cluster) in order to create habitat complexity within the channel. The size of the channel dictates the appropriate configuration(s) of wood that will achieve the management objectives. Wood in the channel can create a variety of conditions and habitats such as: 1) preventing channel and bank scour, 2) creating water velocity conditions that result in deposition of channel bed materials of varying diameters, 3) creating a variety of water velocity areas that are more conducive to spawning and/or rearing habitat, 4) providing a “substrate” that can be used by aquatic macroinvertebrates and periphyton to establish populations, and 5) provide overhead cover to protect juveniles from predators. Cederholm et al. (1997) provides an excellent summary of the points outlined above.

In some situations, logs have been placed perpendicularly to the channel across smaller streams (< 60 ft. width) to create scour pools which provide both spawning and rearing habitats for salmonids. In Western North America, this type of application has been greatly reduced in recent years because of concerns about long term maintenance costs. While extremely effective at providing desired habitats, current practice is to limit this type of application to relatively stable stream channel conditions.

Two examples of the types of applications currently being employed are shown in Figure 3.6-A and B and Figure 3.7-A and B.

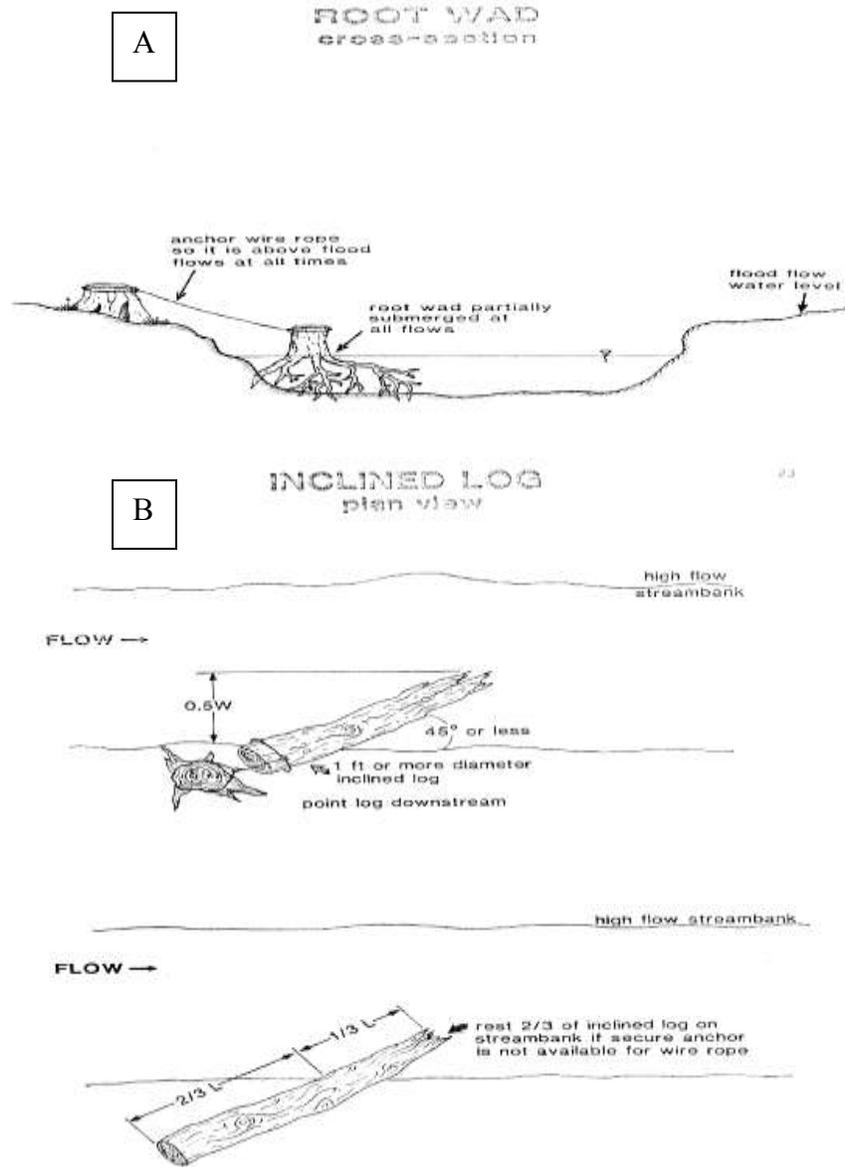


Figure 3.6.-A.—Schematic diagram showing a “typical” placement of a root wad in a stream. B.—Schematic diagram showing placement and how to secure pieces of large woody debris in a stream or channel. (USDA Forest Service, undated)

A



B



Figure 3.7.—Photos showing placement of large woody debris in an engineered secondary channel. Photo A shows wood placement during construction. Photo B shows a completed channel with flow (Melville and McCubbing, 2009).

### 3.3.3.2.2 Selected Examples

Phase I of the Resurrection Creek, near Hope, Alaska, Restoration Project was started in 1992 by the Chugach National Forest in attempt to improve fish habitat conditions in a stream that has been placer mined for nearly 100 years. The objective was to improve juvenile salmon rearing habitat in a 3 mile reach by reducing the amount of coarse-bottomed riffle area by creating more pool habitats using a variety of techniques. A pre-project evaluation demonstrated that juvenile rearing habitat was the predominant limiting factor. As of the date of the report cited (1994), 36 structures had been installed, with more scheduled for the summer of 1994. Several single boulder and boulder clusters were installed using boulder 3-5 ft. in diameter. Two upstream V-shaped rock weirs were installed to increase pool habitat area and create a plunge pool downstream of the structure. Several individual log barbs (logs placed at an upstream angle and keyed into the bank) were installed to increase pool habitat area and help stabilize the stream bank. Several root wads were placed into the channel and anchored to adjacent boulder placements.

High flows moved a number of the boulder structures and removed some of the individual boulders in the V-shaped weirs. The Forest Service recommends that larger boulders be used for similar situations. The wood structures remained in place and provided additional rearing habitat. Post-project monitoring of these structures had fry densities comparable to natural pools. The rock structures were unable to be monitored because of the small size of the pools created and the water turbulence. Additional work was planned for 1994, but no subsequent monitoring information is readily available from the Forest Service. Only costs for equipment rental is available and totaled less than \$9,000 (Parry and Seaman 1994).

Phase II of the Resurrection Creek Restoration Project was undertaken in 2005 by the Chugach National Forest as part of a continuing effort to restore fish habitat to the creek which has been and continues to be altered by placer mining. The 2005 project site is in the lower reaches of Resurrection Creek near Hope, AK on the north side of the Kenai Peninsula. The project improved fish passage and restored aquatic habitats a 1-mile reach of Resurrection Creek, which had been dredged during the early days of Alaska's Gold Rush, to near-natural condition. Large tailings piles were re-distributed, creek meanders were restored, an effective flood plain was established, and the stream was converted from approximately 99% riffle (with some upstream fish passage impediments) to a series of pool-riffle sequences mimicking a natural alluvial stream. Among other things, channel length was increased by 15%, percent riffle was decreased to 53%, percent pools was increased from 1% to 21%, percent runs and glides were increased from 0% to 26%. Off-channel habitats were also established (Figure 3.8).

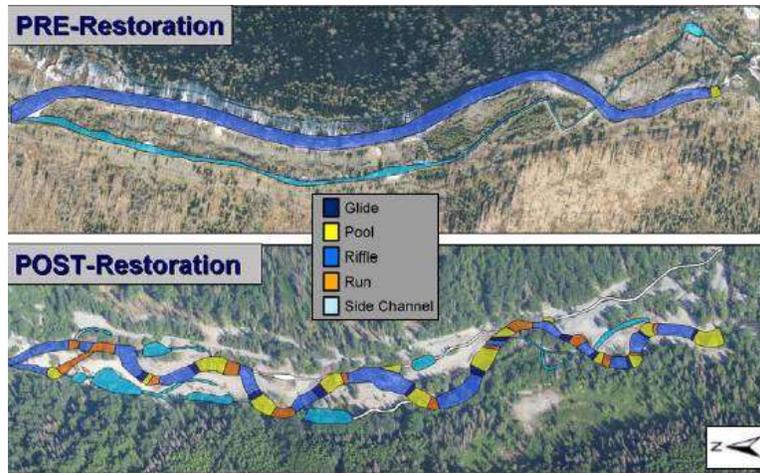


Figure 3.8.—Pre- and post-restoration aquatic habitat distributions in a placer-mined 1-mile reach of Resurrection Creek near Hope, AK.

Other project objectives were to increase spawning habitat from 160 yd<sup>2</sup> to 2,000 yd<sup>2</sup> per mile, increase side channel flow through off-channel habitats from 1% to 20% of nominal stream flow, increase large woody debris pieces (cover habitat) from 8 pieces to 330 pieces per mile and implement riparian area and flood plain rehabilitation.

Post-construction monitoring was carried out by University of Alaska graduate students. Whereas little spawning activity was observed prior to rehabilitation of the 1-mile reach of Resurrection Creek within the Phase I area, monitoring during July and August demonstrated extensive use by four species of salmon (Figure 3.9).

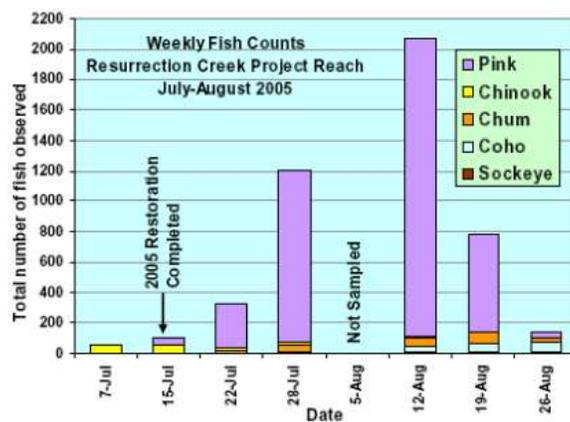


Figure 3.9.—Post-construction monitoring of salmon spawner counts in the restored 1-mile reach of Resurrection Creek near Hope AK.

The Municipality of Anchorage completed a realignment of South Fork Little Campbell Creek in 1988. The project involved realignment of a 725 ft. reach of channel that had been previously channelized into a flat bottomed channel with two 90-degree bends. This previous alignment resulted in flooding of the nearby school playground and a reduction in habitat use by coho salmon and other resident fish species. The new channel followed a more natural meander pattern and the bottom was re-contoured into a series of pools and riffles. Stream banks were graded to permit flood flow passage, but were sloped to encourage the development of riparian vegetation. Bottom substrate added consisted of 4-5 inch diameter stones which were intended to serve as spawning habitat. A graded mixture of substrate sizes containing some fine particles were not added to the stream. Unfortunately, the 4-5 inch substrate proved too large to accommodate spawning and the lack of fines in the bottom substrate encouraged siltation. As a result, the anticipated habitat values were not achieved and an unknown upstream sediment source only contributed to the problem. While the community planning and implementation effort was judged a success, the amount of suitable fish habitat created was negligible. Over \$1 million dollars were expended. No pre-project or post-project monitoring data are available (Parry and Seaman 1994).

Smith and Brannon (2008) describe an engineered channel in Washington state that contains many of the “complexity” elements that have been discussed earlier for boulders and wood placement in general (Figure 3.10). They found that juvenile coho salmon reared in the engineered channel exceeded the values for a variety of reference streams for a number of common growth and survival parameters (e.g., condition factor, length, weight, smolt rearing capacity). More detailed information on this study is presented in Table 3.2.

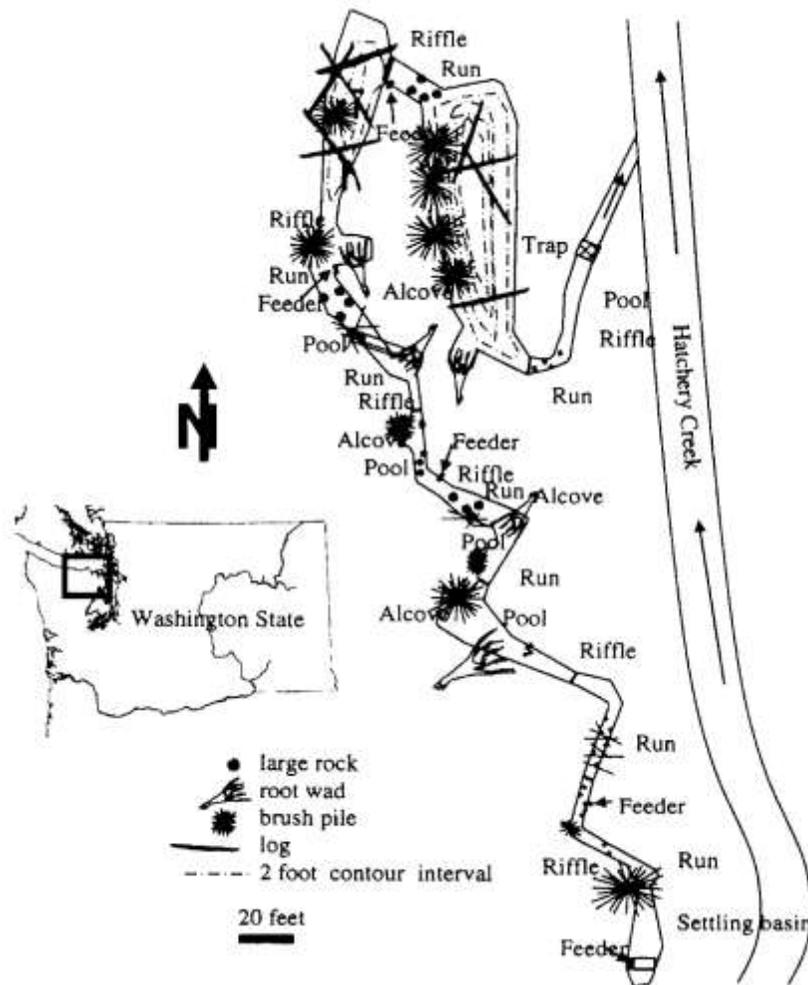


Figure 3.10.—Schematic diagram of a “complex” habitat in an engineered stream channel (Smith and Brannon 2008).

A summary listing of selected habitat improvement projects completed in western North America using large wood elements and some with combinations of wood and boulders is presented in Table 3.2. There are many examples of evaluations of various habitat improvement projects using wood in the literature. The majority of these projects show that fish production generally increases by a factor of 2-5 routinely. Most of the failures occurred in the late 1970s to mid-1980s and resulted primarily from not correctly identifying the limiting factor for the fish populations of interest, inadequate evaluation of the stream substrate or bank stability to prevent serious scour problems, inadequate maintenance, and inadequate engineering design/size of materials necessary to withstand flood flows (Frissell and Nawa 1992; Chapman 1995).

Table 3.2 - Summary table listing examples of physical habitat improvements and fish production results due to those improvements.

Location	N	Type of Structure(s)	Habitat Objective Achieved	Biological Objective Achieved	Biological Monitoring		Reported Results of Improvements	Reference
					Conducted	Quality		
<b>Western Oregon, multiple streams</b>	395	wood, rock, gabions, combinations	Y	Y?	Some	Poor	Increased adult salmon spawning in improved areas; juvenile rearing habitats created, with some fish use noted.	Armantrout, 1991
<b>Lolo Creek, Idaho</b>	692	variety of designs using boulders, and wood	Y	Y	5-year evaluation	Excellent	Significant increase in age 0 Chinook and age 1+ & 2+ steelhead; no significant increase in age 0 steelhead, but high variability.	Espinosa and Lee, 1991
<b>Lochsa River, Idaho</b>								
Eldorado Creek	179	boulders - ~ 40% large wood - ~ 60%	Y	Y				Espinosa and Lee, 1991
Pete King Creek	185	Wood and boulder weirs (102), boulders only (83); ratio of rock to wood 1.3:1	Y	Y	5-year evaluation	Good	Significant increases in all age classes of steelhead and Chinook. Generally a four-fold increase.	Espinosa and Lee, 1991
Crooked Fork Creek	118	wood only	Y					Espinosa and Lee, 1991
White Sand Creek	76	wood only	Y					Espinosa and Lee, 1991
Squaw Creek	265	log weir/deflector - 52; root wad/boulder - 213	Y	Y	5-year evaluation	Good	Significant increases in all age classes of steelhead and Chinook.	Espinosa and Lee, 1991
Doe Creek	122	log weir/deflector - 35 root wad/boulder - 87	Y					Espinosa and Lee, 1991
Papoose Creek	375	log weir/deflector - 112; root wad/boulder - 263	Y	Y	6-year evaluation	Good	Significant increases in all age classes of steelhead, cutthroat, and Chinook.	Espinosa and Lee, 1991
<b>Elk Creek, Oregon</b>	200	Primarily wood with some boulders	Y	Y	5-year evaluation	Poor	Increase in coho spawning in treated reaches; adult only evaluation	Crispin et al., 1993

Table 3.2 (Cont'd)- Summary table listing examples of physical habitat improvements and fish production results due to those improvements.

Location	N	Type of Structure(s)	Habitat Objective Achieved	Biological Objective Achieved	Biological Monitoring		Reported Results of Improvements	Reference
					Conducted	Quality		
<b>Crooked River, Idaho</b>		Wood and boulder weirs			Evaluation of pool use	Good	Documented preferential use of pools created by habitat improvement structures for both hatchery and wild steelhead juveniles	Thompson, 1999
<b>Hatchery Creek, Washington</b>	Multiple	Engineered stream with wood, boulders, alcoves, brush piles	Y	Y	Y	Good	Rearing density: +245% ; Smolt density: +(93-209)%; Egg to smolt survival: +(61-158)%; Smolt capacity: +(219-411)%; All increases compared to published values for coho salmon	Smith and Brannon, 2008
<b>Red River, Idaho</b>	Multiple	Combinations of wood and rock		Partially	Y	Good	Significant increases in age 1+ & 2+ steelhead in one channel type and significant decrease in another channel types	Rich et al., 1993
<b>Western Oregon, 14 streams</b>	812	Combinations of wood and rock	y	Mostly	Y	Fair	13 streams had increases in juvenile densities of coho fry. Three streams had no change in age 1+ steelhead and cutthroat trout. All other streams showed increase in juvenile densities for trout fry and age 1+ steelhead and cutthroat trout	House et al., 1989
<b>Carnation Creek, British Columbia</b>		Woody debris			Yes	Fair	Evaluation of coho fry density as related to density of woody debris. Significant positive linear relationship between fish density and complexity of woody debris. Noted importance of wood outside the main channel as winter habitat for coho.	Forward, 1984
<b>Brierly Brook, Nova Scotia</b>	250 over 12 years	Digger logs	Y	Y	12 year evaluation	Adult Spawning	Significantly more Atlantic salmon redds in treated reaches than in untreated reaches.	MacInnis et al., 2008
<b>Western Oregon, seven streams</b>	41 constructed pools	Addition of brush bundles to constructed pools			Yes	Excellent	Significant difference in coho juveniles in pools with brush bundles added. No use of main channel constructed plunge pools. Winter alcove habitat, with complexity, highly significant.	Solazzi et al., 1999; Nickelson et al., 1992
<b>Nechako River, British Columbia</b>	Multiple	Woody debris bundles and debris catchers	Y	Partially	9 year evaluation	Fair	Most sampling demonstrated significant differences between improvement sites and natural sites. Improved sites appear to provide significant improvements in overwintering habitat.	Triton Environmental Consultants, 2001

### **3.3.3.2.3 Summary**

Habitat improvement projects using large wood in some form can accomplish a number of the recommended mitigation goals outlined in this document. Whether it is restoration of habitats damaged during construction or creation of new habitats, large wood can be used to create a variety of different habitat conditions. Wood can be used to change the water velocity patterns within the channel, creating a variety of microhabitats suitable for multiple age classes of fish. Wood can be used to create complexity within a channel, providing more structure within the water column, which in turn provides cover and additional feeding opportunities for juvenile fish. Wood can be used to create a substrate for algal and aquatic invertebrates, which enhances the food supply for juvenile fish. Large wood can also be used to create scour pools, lateral scour pools, and create stream bed erosion which allows deposition of spawning sized gravels. All of these conditions can be created in both small and large channels. Use of wood in pools or low velocity channels is generally associated with increased cover or feeding opportunities. EPA's exclusion of these types of habitat mitigation measures seriously undermines the credibility of the BBWA2 conclusions.

### **3.3.3.3 Reconnection of Existing Side Channels and Off-Channel Habitats to Main Channels and Creation of New Side Channels and Connected Off-Channel Habitats**

#### **3.3.3.3.1 General Description**

Secondary channel or off-channel habitat improvement or creation for the purposes of enhancing fish production can assume a wide variety of configurations, depending both on the habitat development objectives (i.e., spawning, rearing, overwintering) and conditions present in the available landscape (WDFW 2012). Existing abandoned channels and cut-off oxbows in flood plains of alluvial streams can be re-connected to their parent system with either inflow or outflow channels or both. The site specific configuration will depend on the amount of groundwater infiltration and upwelling and additional inflow needed to achieve the desired flow characteristics. Reconnection of abandoned channels and cut-off oxbows can add large amounts of high quality rearing, overwintering and spawning habitats. Reconnected, low water velocity habitats are especially valuable where existing stream reaches are dominated by relatively uniform high-velocity habitats. Uniform, high-velocity habitats often occur where rivers have been channelized or rip rapped to protect shoreline developments or highway/pipeline alignments, but these conditions also occur naturally. Groundwater-fed channels and channel/pond complexes can be excavated in alluvial floodplains without relying completely on abandoned channels. These excavated habitats provide quality habitats, especially where groundwater aquifers are close to the ground surface and/or copious channel flows can be used to provide flow to the excavated areas. Abandoned flood plain gravel mines or borrow pits, can be connected to natural channels to produce productive off-channel rearing and overwintering habitats.

Understanding and taking advantage of the local land form has been found to be critical to the success of developed secondary channel or off-channel habitats. Some of the most successful off-channel habitat developments have relied wholly or in part on groundwater to develop appropriate flows in the new channels or channel/pond complexes. The schematic (Figure 3.11) and aerial photograph (Figure 3.12) depict examples of how local landform can stimulate hyporheic (groundwater) flow that can be captured by new channel excavation or reconnection of abandoned side channels and oxbows.

Simple groundwater-fed side channels (Figure 3.13) generally consist of an infiltration pond or region, often protected from flood damage by a stabilized rock berm, and a long channel connected to the parent stream at its down-gradient end. Channel margins are generally protected or stabilized with coarse rock which can also provide cover for rearing juvenile fish.

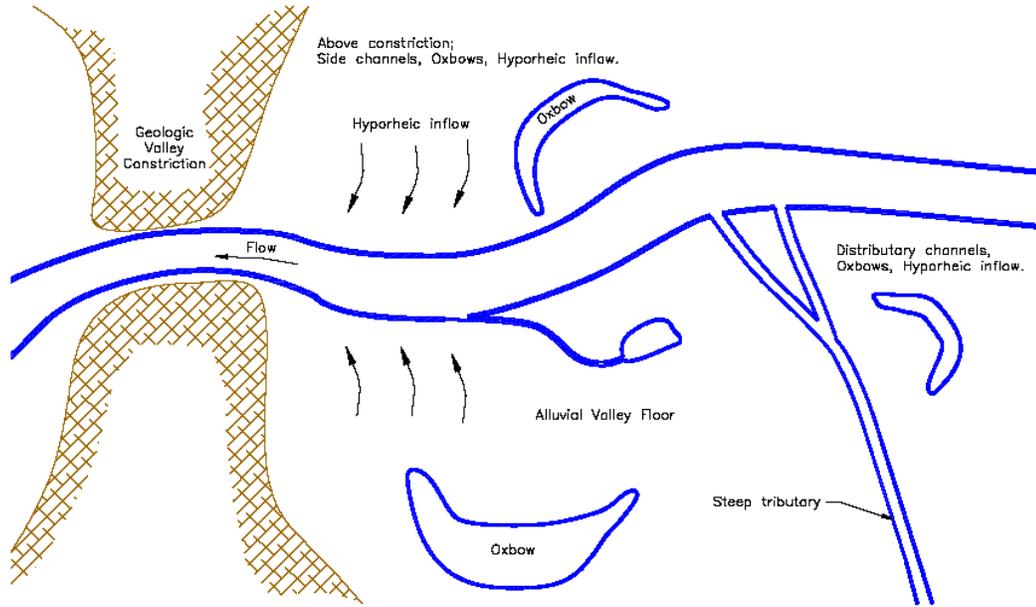


Figure 3.11. –Natural floodplain features that can produce the potential for secondary or side channel habitat development (WDFW 2012).

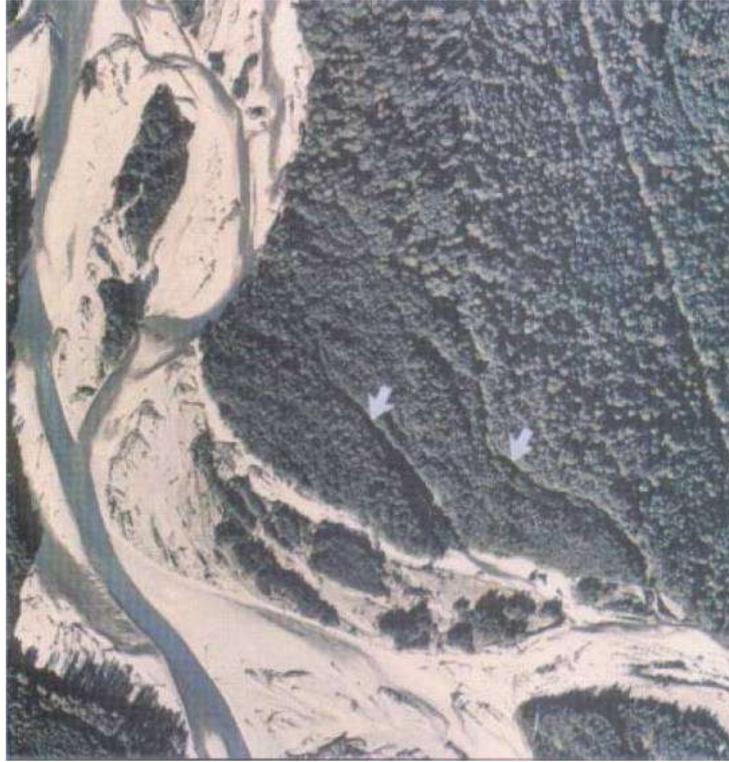


Figure 3.12. –Examples of abandoned channels (arrows) in an alluvial river identified through use of aerial photography (Upper Pitt River, BC; Slaney and Zaldokas 1997).

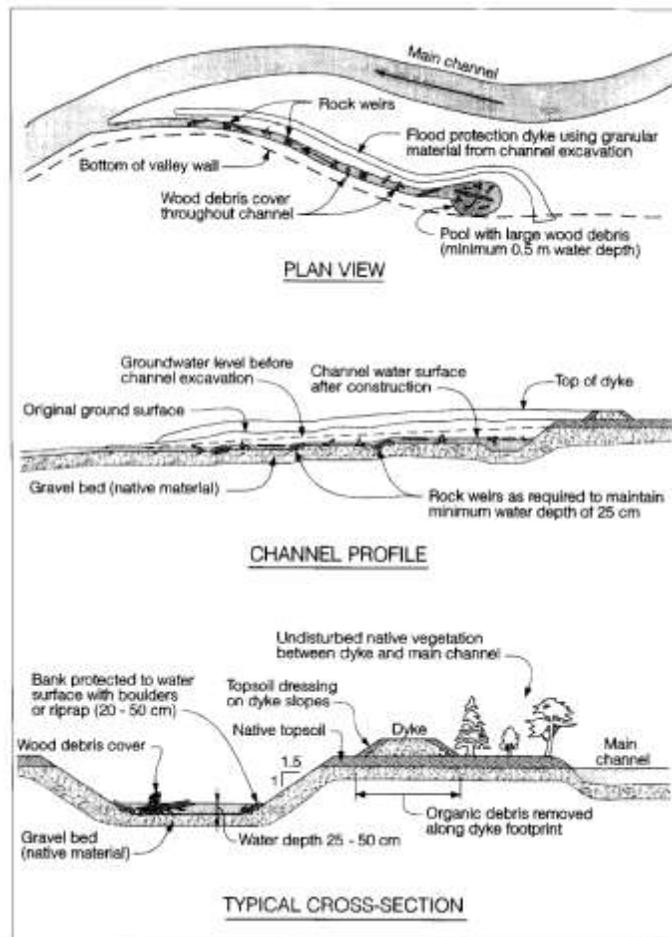


Figure 3.13. –Conceptual diagrams of a simple groundwater-fed spawning and rearing channel for salmon (Slaney and Zaldokas 1997).

Chum and sockeye salmon are the species most commonly associated with secondary channel or off-channel habitats for spawning (Slaney and Zaldokas 1997) and coho for rearing and overwintering and occasionally spawning (Figure 3.14) (Sheng et al. 1990). Chinook salmon juveniles often use off-channel areas for rearing and overwintering as well (Buell, 1991; Melville and McCubbing 2009). These fish appear to be attracted to secondary channels by groundwater infiltration, especially in winter when groundwater is typically several degrees warmer than water in the main channel (Bachen 1984, Sheng et al. 1990, Guillermo and Hinch 2003, Jones et al. 2003, WDFW 2012, Morley et al. 2005). Early in the history of off-channel salmon habitat development, it was found that habitat productivity could be further enhanced if additional habitat elements supplying cover (*e.g.* large woody debris, boulder clusters, and coarse rock channel margins) were supplied (Lister et al. 1980, Slaney and Zaldokas 1997, WDFW 2012). Eventually, elaborate pool/channel complexes with additional habitat elements were designed and became the norm in areas where local landform could accommodate such developments.

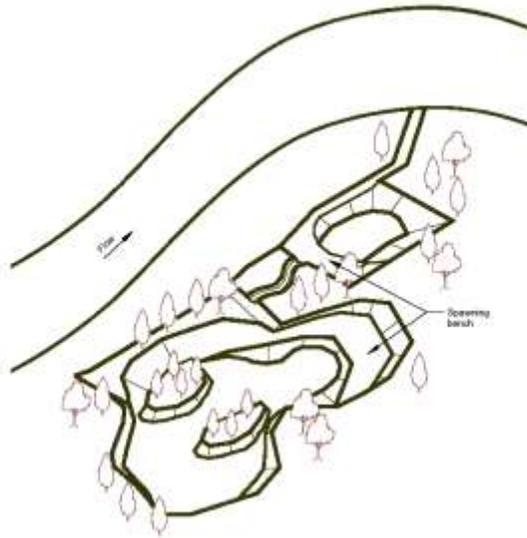


Figure 3.14.—Conceptual schematic diagram of a groundwater-fed pond and channel system with deep areas for rearing and overwintering, spawning “benches” and connecting channels (WDFW 2012).

Connection of developed flood plain habitats to parent streams can involve both upstream and downstream ends through diversion of some of the flow of the main stem stream into the secondary channel or can rely solely on groundwater infiltration, with a single connection at the down-gradient end. Although the former approach often involves formal headworks which must be protected against flood and ice damage, and has maintenance and especially sediment accumulation disadvantages, the latter approach avoids these difficulties to a large degree. In settings with high sediment loads and heavy ice accumulations, surface inflows to developed flood plain habitat areas should generally be avoided. A generalized small intake design schematic is shown in Figure 3.15. Intakes such as this are generally connected to a buried pipe and fitted with a flow control such as a wheel-operated knife gate. Operation of surface flow intakes, especially those containing metal components, can be problematic in winter where air temperatures routinely drop well below freezing for extended periods.

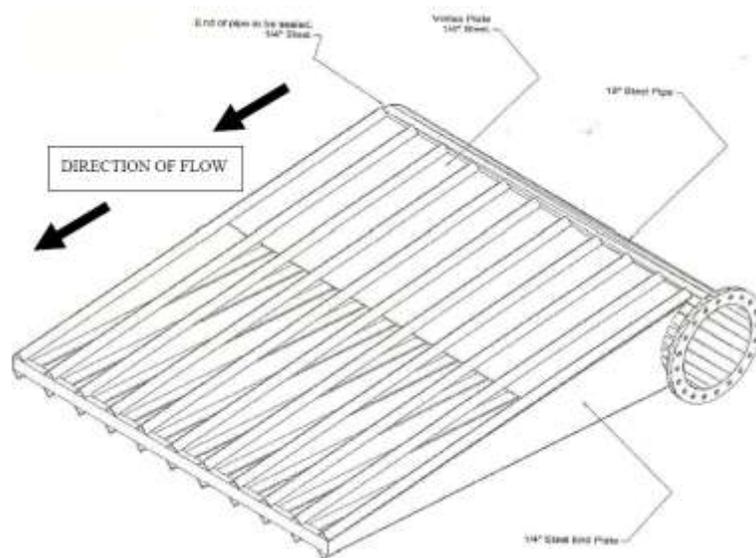


Figure 3.15.—Schematic of a “typical” small intake to supply surface water from a parent stream to a developed secondary channel. Slotted pipe diameter can be in the 30-50 cm range. This type of intake is designed to operate in 1-2 m water depth with sweeping velocities  $>0.5$  m/sec.

Spawning success, including egg-to-fry survival rates has been found to be higher in developed secondary channels than main channel areas. Bustard (1986) studied relative chum egg-to-emergence survival rates for four groundwater-fed side channels, two associated with coastal (maritime) and two with interior (cold) winter areas. He reported 30-34% survival for cold winter channels and 46-60% for maritime winter channels, both rates being extremely high when compared to natural spawning areas, usually in the 5-7% range (Lister et al. 1980). A Washington Department of Fish and Wildlife study calculated chum egg-to-fry survival rates of 60.8%, 37.6% and 78.4% for three re-excavated side channels, with relatively low spawner densities, on the East Fork Satsop River, WA (WDFW 1986).

Marshall (1984) reported on chum egg-to-fry survival in two groundwater-fed spawning channels, the Worth Creek Channel in the Norrish Creek drainage near Mission, BC (Lower Fraser Valley) and the Upper Paradise Channel in the Squamish River drainage, BC. He found survival rates of 22% for the Worth Creek Channel and 30% for the Upper Paradise channel. When results from these two channels were combined with those from five additional sites, average chum egg-to-fry survival rates were over 16%, more than twice the average reported by Lister et al. (1980) for natural spawning areas throughout British Columbia.

Bonnell (1991) investigated groundwater-fed secondary channels constructed for chum salmon spawning and found that fry survival was inversely related to the number of spawners (spawner densities  $> \sim 0.5$  females/m<sup>2</sup>) and varied directly with intragravel dissolved oxygen concentration. Egg-to-fry survival rates generally ranged from 10% to 48% (average about 20%), with fry production rates between 100 and 600 fry/m<sup>2</sup> at female spawner densities below approximately 0.5 females/m<sup>2</sup>. Bonnell also found that fry production rates tended to decline significantly from four to eight years after construction, suggesting the

need for maintenance, such as scarifying spawning areas to clear them of accumulated organic material and fine sediment.

Reconnected secondary channels and oxbows and developed channels that rely at least in part on groundwater to develop outflow generally provide warmer water for overwintering juveniles and often cooler water for summer rearing, often an added benefit, especially in arctic or sub-arctic areas (Slaney and Zaldokas 1997). Overwintering habitat for salmon species with extended stream rearing juvenile life stages (coho, Chinook) can be extremely important in arctic and sub-arctic regions, especially where deeper, low velocity habitat features are rare (Cederholm and Scarlett 1991). Groundwater-fed secondary channels with deeper water and elements that increase habitat complexity incorporated into their design provide ideal overwintering habitats for these fish. Bustard (1986) found that overwinter survival of juvenile coho was directly proportional to the percent of side channel area remaining wetted (range: 0.9% to 44.7%) at the end of winter, with survival approaching 60% (range: 33.7% to 59.8%) in the channel with the most late-winter wetted area.

Bachen (1984) found that winter temperatures in a groundwater-fed channel flowing into the Chilkat River near Haines AK, used for spawning by chum and coho salmon and rearing by coho salmon and Dolly Varden char, were as much as 6<sup>o</sup> C warmer than the parent stream. Morley et al. (2005) in a study of 11 constructed secondary channels with added cover elements and 11 control areas found that the constructed channels supported about twice the number of coho/m<sup>2</sup> in summer and nearly four times the number of overwintering coho/m<sup>2</sup> than the control channels. Guillermo and Hinch (2003) studied two constructed side channels in British Columbia (Upper Mamquam Channel along the Mamquam River; Upper Paradise Channel along the Cheakamus River), one receiving mostly surface flow and the other receiving mostly groundwater flow. Both channels were treated by adding large woody debris as cover in certain sections. Results indicated that addition of cover elements increased winter carrying capacity and smolt output in the surface-fed side channel, but did not benefit the groundwater-fed side channel. This is an important finding, since it has significant cost implications for design of groundwater-fed or surface water-fed secondary channels. Water temperature appears to be the primary factor driving the differences between the results from the two channels. Adding cover to surface flow fed channels, whose water temperature is controlled by air temperature, appears to be more beneficial than adding cover to groundwater fed channels (Tobe 2005).

The productive capacity of reconnected secondary channels and oxbows can be significantly enhanced through the addition of habitat complexing agents such as large wood or boulders, especially if the developed habitats are fed by surface flow (see above). This is particularly important for optimizing overwintering habitat for juvenile coho and Chinook salmon.

Developed or reconnected secondary channels can vary in length from a few hundred meters to several kilometers for more elaborate complexes, depending on the prevailing landform and proximity of potential secondary channel elements (e.g., several oxbow or abandoned channel segments aligned within the floodplain). The sizes of particular elements (e.g., ponds, flowing channels) can influence the relative productivity of complex secondary channel developments. Rosenfeld et al. (2008) comprehensively reviewed data from published sources in an effort to determine the influences of design features on productive capacities for juvenile coho salmon. They found that coho parr (rearing juveniles) were more abundant in stream-type habitats during the growing season than in pond-type habitats, and that constructed habitats supported greater densities of parr than nearby natural habitats. They also found that smolt densities and output and smolt weights were greater for pond-type habitats than channel-type

habitats, suggesting that overwintering in ponds was beneficial when it comes to overall production. When comparing outputs of habitat elements according to size, they concluded that the optimum pond-type or stream-type element size is 5,000-10,000 m<sup>2</sup>.

Keeley et al. (1996) regressed smolt production on pond area and stream area sizes and concluded that 10,000 m<sup>2</sup> was optimum for ponds but found no significant relationship for stream-type habitat elements. Reeves et al. (1989) suggested that natural beaver ponds less than 500 m<sup>2</sup> provided better overwintering conditions than larger ponds, but these data may be less relevant for constructed or re-connected habitats.

Keeley et al. (1996) and Koning and Keeley (1997) developed empirical equations for calculating the production of coho smolts from developed ponds and flowing channels based on a large number of production and monitoring studies. These equations are:

$$\begin{aligned} \text{Log}_{10} \text{ smolt number} &= 0.51 \log_{10} \text{ pond area (ha)} + 3.47 \\ &\text{and} \\ \text{smolt number} &= 0.69 \text{ smolts/m}^2 \text{ secondary channel area.} \end{aligned}$$

One aspect of secondary channel development not frequently discussed in the technical literature is the need for maintenance, especially with regard to beaver activities. Depending on their size, developed secondary channels can provide excellent opportunities for beaver invasion, which can, in some cases, impair access into the habitat intended for fish. Although beaver impoundments can and do provide good habitat for rearing juvenile salmonids and other fish species, beaver dams can also deter overall production. For this reason, beaver management (see Subsection 3.3.2.1 above) should be considered an important aspect of secondary channel development where these animals are present (Foy and Logan 1997, Slaney and Zaldokas 1997, WDFW 2012).

### **3.3.3.3.2 Selected Examples**

In 1991, as part of the mitigation requirements for the Bradley Lake Hydroelectric Project near Homer, Alaska, the Alaska Energy Authority converted four former borrow pits on the Martin River Delta into rearing ponds targeting coho salmon. In addition, a 2,800+ ft. long spawning channel was constructed adjacent to the 30 acres of ponds. Minnow trapping in the summer of 1993 captured two age classes of juvenile coho salmon, but the monitoring trip was too early in the summer to determine if coho salmon were using the spawning channel. A review of Google Earth satellite photos in July 2010 clearly show the ponds and spawning channel are still in existence, but no additional monitoring information is available (Doug Palmer, U.S. Fish and Wildlife Service, Kenai Fish and Wildlife Office, pers. comm. July 2010).

In 1987, the Alaska Department of Transportation and Public Facilities constructed a series of 8 rearing ponds, on Box Canyon Creek, as mitigation for construction a coal loading facility near Seward, Alaska. These ponds were connected to an existing ½ acre pond and each other by a series of 25 ft. long constructed riffles. The ponds were 100 ft. long and 6 ft. deep. Early monitoring found juvenile coho and Chinook salmon and Dolly Varden char. However, the real success is the use of the connecting riffles by spawning salmon. Chinook, coho, sockeye, chum, and pink salmon have all been documented using the area. Additional work on a nearby road was planned for 1994 with improvements to this pond series

included as mitigation for this new work. Improvements were to include resloping some of the original banks to encourage riparian vegetation growth and placement of woody debris in order to improve biological productivity and increase rearing habitat effectiveness. Cost of the original project was about \$25,000, but no additional monitoring data are available (Parry and Seaman 1994).

The City of Seward Alaska constructed two 600 ft. long spawning channels in areas adjacent to Fourth of July Creek that had a copious groundwater supply as mitigation for construction of the Seward Marine Industrial Center. The channels were completed in 1982, and pink salmon were documented spawning immediately after construction. Floods damaged much of the area in late 1982. Because the channels were constructed near or at tidewater, the downstream end of the merged channel was closed by storm surge and resulting beach berms which prevent salmon access. Groundwater flows were less than anticipated, but the channels had less silt than adjacent Fourth of July Creek. After all of these problems, the City of Seward abandoned this project and no further monitoring was conducted. No cost estimates were provided (Parry and Seaman 1994).

The USDA Forest Service constructed two adjacent spawning channels at Mile 25.25 of the Copper River Highway near Cordova, Alaska in 1987. The objective of these channels was to provide spawning habitat for coho salmon to help support the local commercial fishery. The channels were constructed in known groundwater upwelling areas with a placed sorted bottom substrate of uniform size. Counts of adult spawners ranged from about 100 to a peak of 550 in 1991. Over time, sediments have accumulated in the “clean” gravels placed in the bottom of the channels, reducing groundwater inflow and reducing egg to fry survivals. As of 1994, the fry production rate was highly variable, ranging from 2,000-50,000, but appeared to decline after 1990. No additional monitoring data are available. Cost of the project was \$22,000 for construction of the 22,000 ft.<sup>2</sup> channel habitat (Parry and Seaman 1994).

A 1,500 ft. long by 20 ft. wide spawning channel for chum salmon was constructed by the Northern Southeast Regional Aquaculture Association near Haines, Alaska in 1989. The channel was excavated out of native materials on a nominal 1% gradient with some variation in bottom contour to provide varying water depths. All bottom materials were from the excavation area and were not sorted or washed. The original objective was to provide 3 to 7 cfs of groundwater inflow. After construction, flow has been measured at 13 cfs. The channel, up to 1994, had been judged a success with approximately 5,000 chum salmon spawning in the newly constructed channel (Parry and Seaman 1994). No information on spawning has been obtained, if it exists, since the 1994 report.

There are many examples of constructed or reconnected secondary floodplain channels and oxbows for salmon habitat enhancement and rehabilitation in British Columbia and the Pacific Northwest. One of the most comprehensive examples is a large complex of efforts constructed over a 25-year+ span from 1982 to 2007, with additional elements currently in the planning and implementation stages, on the lower Cheakamus River north of Squamish, BC. This complex of elements has been named the Dave Marshall Salmon Reserve after a pioneer in the development of groundwater-fed secondary channels for salmon. Figure 3.16 shows the layout of various elements.

Funding has been obtained from a variety of sources, including BC Hydro as mitigation for the Daisy Lake hydroelectric diversion, the Canadian government and, following a train derailment and sodium hydroxide spill in 2005, from Canadian Northern Railway. Early monitoring of the Upper Paradise Valley Side Channel, one of the first components of what would become the Dave Marshall Salmon Reserve (Foy 1985) determined that the carrying capacity of the channel was 3.1 coho smolts/m<sup>2</sup> (4.4 g/m<sup>2</sup> biomass).

This was 5.2 times the carrying capacity (7.2 times the biomass) of natural streams of similar wetted area in the region as determined by Marshall and Britton (1990). According to monitoring data for 2000 through 2008, the main elements of this complex produced annual averages of approximately 250,000 chum fry, 60,000 pink fry, 100,000 Chinook fry, 2,000 Chinook smolts (data for 2000-2003 only), 70,000 coho smolts and 4,000 steelhead smolts (data for 2000-2003 and 2008 only; Melville and McCubbing 2009).

The Cheakamus River km8 Side Channel Rewatering project was constructed in 2008 at the upper end of the Dave Marshall Salmon Reserve. This project involved deepening, widening and bank stabilization of an ephemeral side channel of the Cheakamus River, adding boulder and large wood habitat complexing agents and installation of a small, submerged supplemental intake structure to provide sufficient flow in the channel during the start-up phase (Figure 3.17). The km8 Side Channel is 590 m long with an average channel wetted width of 7.4 m (ranging from 5.4 – 11.3 m, Cheakamus River discharge ~50 m<sup>3</sup>/s). The average depth in September 2008 was 0.64 m, ranging from 0.28 m to 1.47 m. Twelve holding/rearing pools greater than 20 m<sup>2</sup> in size and another 15 ranging in size from 2 to 5 m<sup>2</sup> were excavated in the channel. Residual depths in the larger pools were typically 0.5-2 m. Residual depths in small pools were generally ≤ 0.5 m, with no residual depths < 0.2 m. One hundred eleven habitat complexing features were installed in the side channel, at a frequency of approximately one structure per 5.1 linear meters of channel. Habitat features included 71 woody debris structures, 37 boulder clusters and two boulder riffles.

# Dave Marshall Salmon Reserve

**Legend:**

- Enhanced Aquatic Habitat
- Cheakamus River
- Major roadways
- NVOS internal roadways
- Steep Trails
- Flat Trails
- River bar

Updated Feb. 2007. C Halvorson

## Far Point Intake

Completed in 1996 to provide water to the Far Point system. The intake was rebuilt in 2004. A former arm of the river isolated by the dyke allows silt in the river water to settle out before entering the channels.

## Mykiss Channel

A relic sidechannel, rewatered and complexed with LWDs and cobbles. Completed in 2004 to provide spawning area and rearing habitat for coho, pink, chinook and steelhead.

## Far Point Connector

This former dry creek channel was connected to the Far Point system with a short channel and habitat ponds during construction of phase 2 in 1997. It provides year round habitat for Coho and other aquatic species.

The Far Point Connector joins the Far Point pond and the Birth of a Stream creeks to the Hydro Pond and Upper Paradise Channel.

## Far Point Channel Phase 2

Former services roads were converted into a series of riffles and pools augmented with woody debris. This complex habitat provides for the needs of rearing Coho fry as well as increasing spawning habitat. Water was also introduced into adjacent wetlands, providing year round habitat for other aquatic species.

This phase connected new and existing channels in the northwest corner of the property to Upper Paradise Channel.

## Phase 3 of the Far Point project

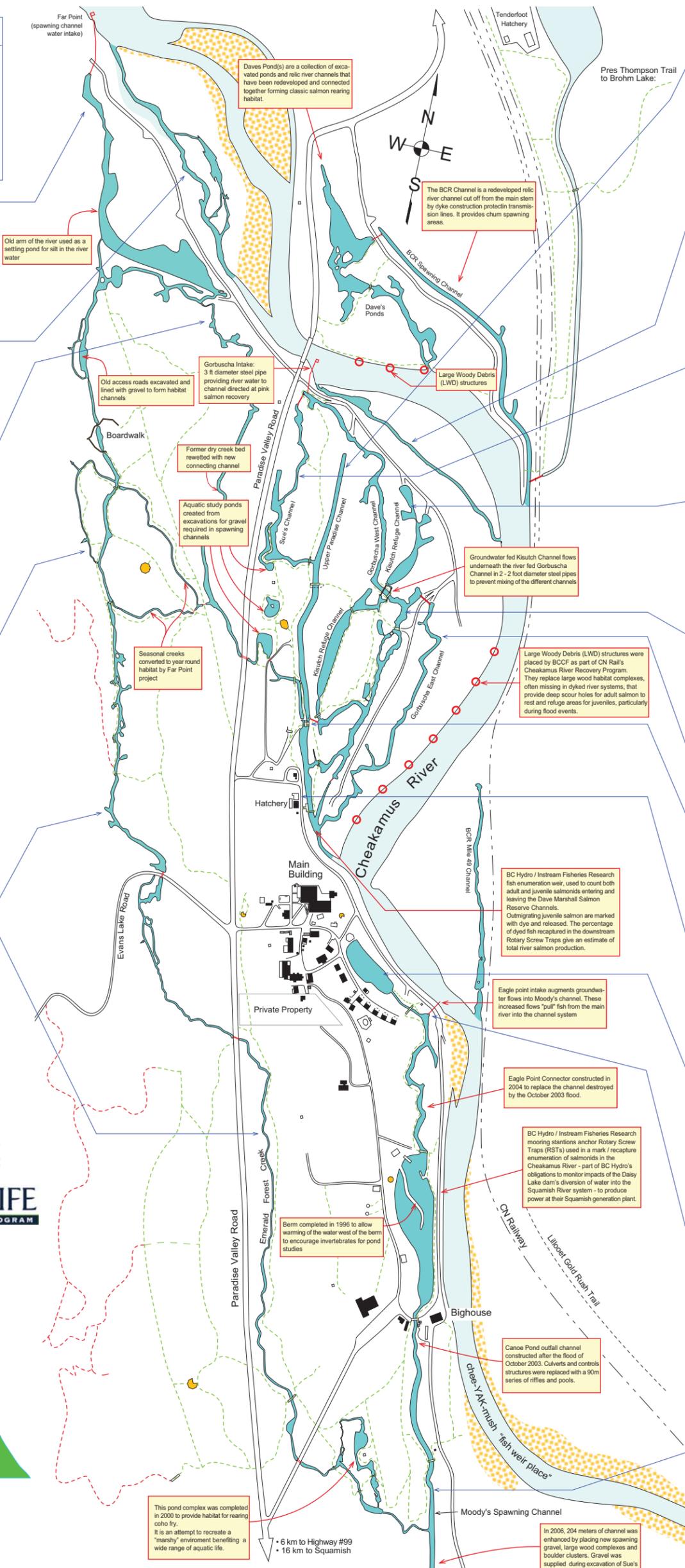
is the connection of the Far Point system to Emerald Forest Creek which flows through Outdoor School to the Moody's Spawning Channel. Completed in 1998 with future additions possible.

This project entails converting existing access roads to waterways.

The Far Point project is primarily directed at Coho salmon and trout, with some benefit expected to Chum salmon.



North Vancouver Outdoor School  
School District #44



## Upper Paradise Spawning Channel

Completed in 1982 to provide protected side channel spawning habitat. Constructing side channels behind protective berms ensures that the developing eggs are not washed away or covered by silt during typical river flood events. This channel led to an increase in Chum salmon returns.

## Km 6.5 (Wountie) Channel

Completed in 2007 as part of the CN Rail Cheakamus River Recovery Program. This river fed main stem side channel is intended to provide habitat and spawning potential for pink, chinook, coho and steelhead. The August 2005 sodium hydroxide spill resulted in widespread mortalities of all free swimming life in the mainstem river.

## Sue's Channel

Completed in 2006 to provide spawning and rearing habitats for chum, coho, pink salmon and trout; having both groundwater and river fed components. Sue's Channel was funded by BC Hydro's Bridge Coastal Fish and Wildlife Program as a memorial to the late Sue Emerson, BCRP's program director.

## Kisutch Channel

Completed in 1994 to increase rearing habitat for Coho fry. In addition to the spawning beds, this project includes side pockets filled with woody debris and deep holes to provide cover for Coho fry which spend a year in fresh water before migrating to the sea.

## Gorbusha Channels

Phase 1 was completed in 2002 to provide protected side channel spawning habitat. This channel was constructed with the special needs of pink salmon in mind. They prefer swifter, river water rather than groundwater flows. Habitat features will also benefit chinook, coho and trout.

Phase 2 in 2003 expanded the channel, providing more habitat directed at pink, chinook and steelhead.

## Fish Traps

The control structures in this area have two important functions. In early winter it may be set up as an upstream trap for spawners used as breeding stock for the hatchery. In spring it may be set up as a downstream trap for counting ocean-bound fry.

## NVOS Hatchery

Dedicated in 1982 as part of the Vancouver Sun Save the Salmon legacy. This project provides hands on learning experiences for students in brood stock capture, egg fertilization and incubation, and rearing of up to 160,000 salmon fry.

## Duck Pond

The Duck Pond was a gravel pit in the early 1960's. It was then used as a trout pond for the original Paradise Valley Resort. In 1995 the old concrete control structure was replaced with a naturalized spillway connecting the pond and Eagle Point channel. This pond and spillway have provided additional habitat and spawning capacity as well as bird study opportunities.

## Eagle Point

The intake and connecting channel were constructed in 1989 to provide additional water supply for Moody's Channel system. At the same time the Canoe Pond spillway was restructured to provide access for fish stocks to the pond system. The addition of colder river water to the pond system allowed incubation boxes for Pink salmon eggs to be placed in the spillway structure.

## Moody's Spawning Channel

Completed in 1986 to provide protected side channel spawning habitat. This channel led to an increase in Chum salmon returns. This channel is often called the Bighouse Channel because of its location beside the Skw'one-was program's Bighouse. There is a reproduction of a Coast Salish fish camp just downstream of the Bighouse.

Figure 3-17. Dave Marshall Salmon Reserve on the lower Cheakamus River, British Columbia



Figure 3.17.—Photos of the Cheakamus River km8 Side Channel Rewatering Project showing pre-construction, during construction and nominal flow conditions ( $90 \text{ m}^3/\text{s}$ ) after construction. Physical habitat elements such as boulders and large woody debris were important features incorporated into the design.

The Gorbusha East Channel was added to the Dave Marshall Reserve in 2003 and added  $3,225 \text{ m}^2$  of salmonid habitat (Figure 3.18) (BC Hydro Fish and Wildlife 2003). The Mykiss Side-Channel, within the Dave Marshall Reserve, which was undertaken in 2004, supplied year-round flow to a partially excavated 300 m-long channel, which produced approximately  $2,500 \text{ m}^2$  of new habitat for Chinook and pink salmon and juvenile steelhead trout (Halvorson 2004).

Another complex of flood plain habitat developments is located along the Chilliwack River, BC, between Chilliwack Lake and Cultus Lake in the lower Fraser River Valley. Nineteen habitat restoration projects focusing primarily on off-channel salmon habitat have been implemented (Figure 3.19). The combined efforts have restored or developed over  $50,000 \text{ m}^2$  of secondary channel stream habitat and over  $200,000 \text{ m}^2$  of pond habitat.

One portion of the Chilliwack River restoration program, the Centennial/Bulbeard channel and pond complex, was completed in 1998 (Figure 3.20). This complex has headworks, which supplies a controlled  $1.1 \text{ m}^3/\text{sec}$  inflow from the Chilliwack River main stem. This complex incorporates development of  $80,000 \text{ m}^2$  of pond habitat and  $15,000 \text{ m}^2$  ( $1.5 \text{ km}$ ) of stream habitat. The habitats developed provided for spawning for chum and coho salmon and rearing and overwintering for coho salmon. Monitoring during the second year after completion of the Centennial/Bulbeard complex demonstrated the production of

approximately 30,325 coho smolts, most from the Bulbeard portion which contains the most pond area (Cleary 2001).

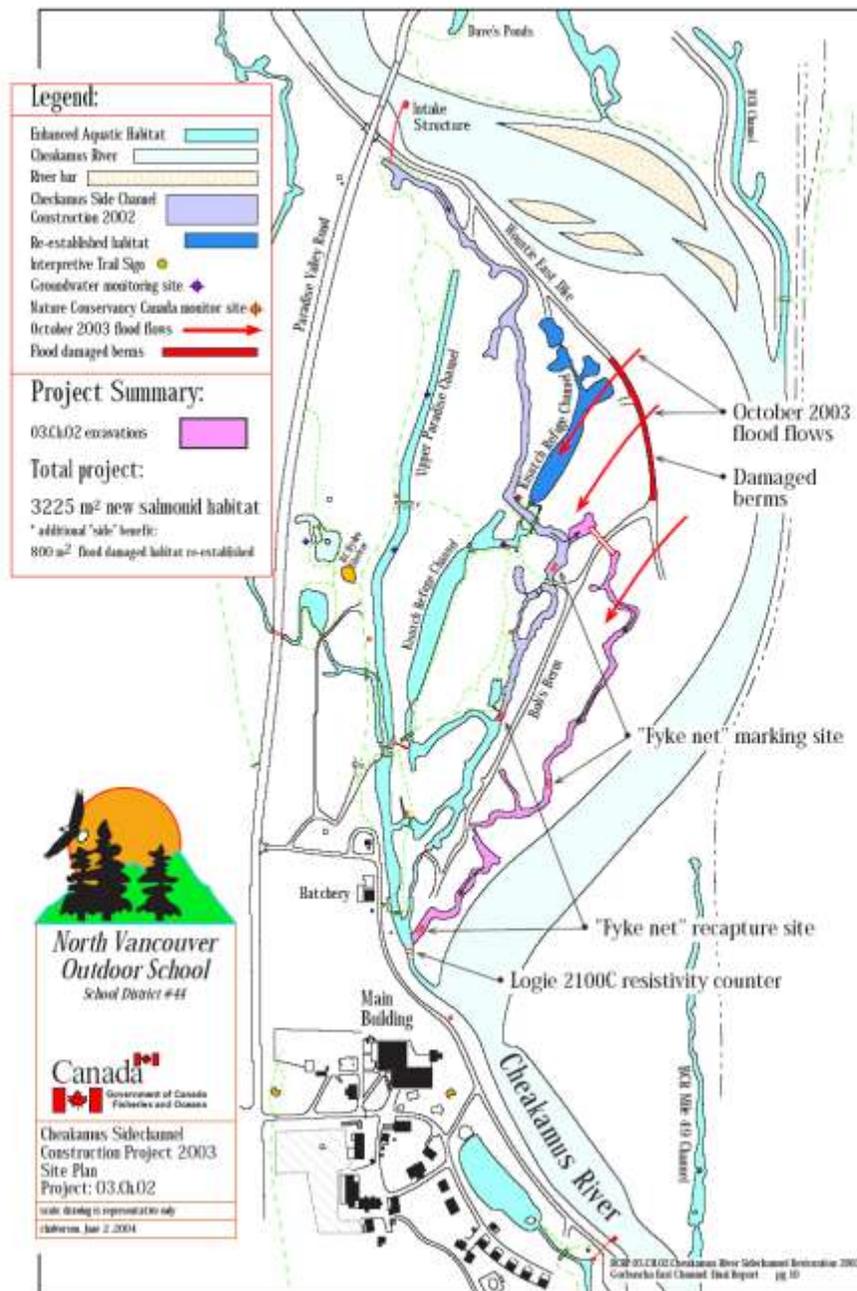


Figure 3.18.—Gorbusha East Channel (478 m long; pink) added to the Dave Marshall Reserve salmon enhancement complex along the Cheakamus River in 2003 (Anon. 2003).

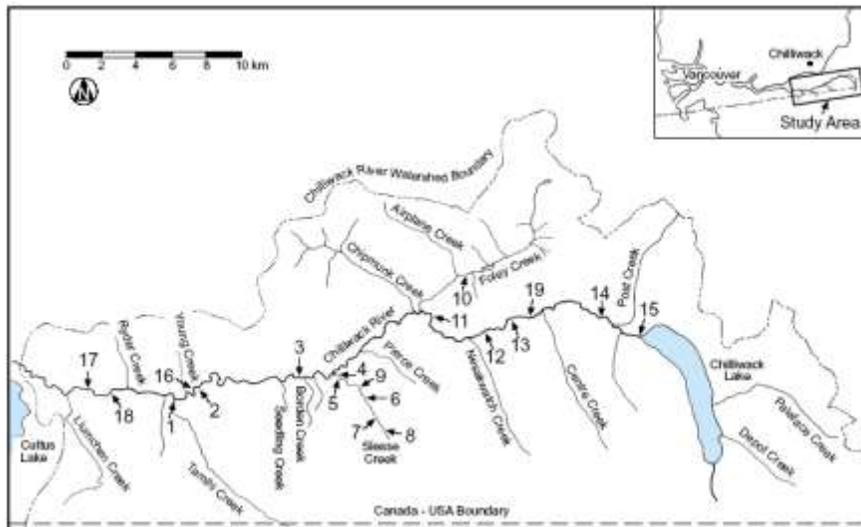


Figure 3.19.—Locations of 19 off-channel salmon habitat restoration and development sites, Chilliwack R. BC (Cleary 2001). The Centennial/Bulbeard complex is site No. 19.

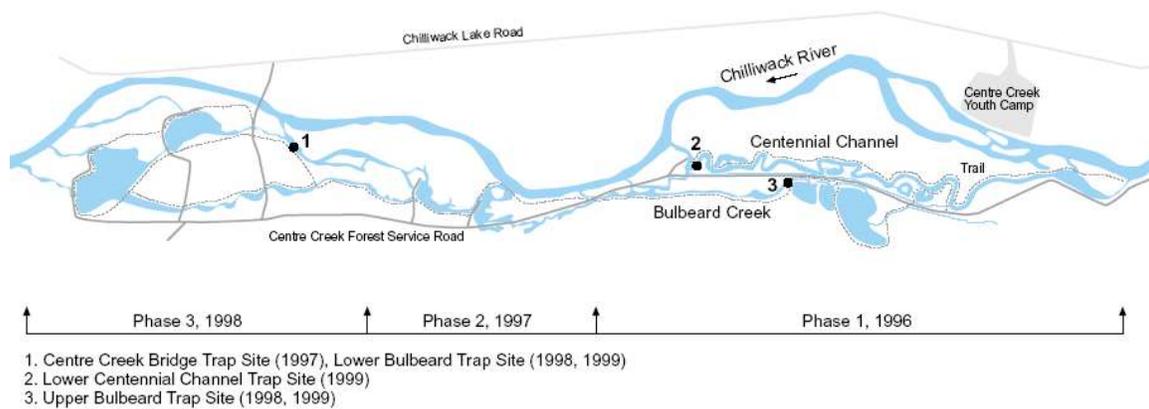


Figure 3.20.—Diagram of the Centennial/Bulbeard off-channel salmon habitat development complex on the Chilliwack River, BC (Cleary 2001).

Another portion of the Chilliwack River off-channel habitat development complex is the Anderson Creek channel rehabilitation project completed in 1995 (Figures 3.21 and 3.22). This project corrected a highway culvert passage problem and reclaimed an old meander channel for fish production at the same time. A new culvert was installed to carry part of the Anderson Creek flow to the old channel, creating a 1.5 ha pond and 200 m of inlet and outlet stream spawning and rearing habitats. Part of the old channel was deepened to provide overwintering habitat for juvenile coho and deter beaver dam construction (Foy and

Logan 1997). Additionally, anadromous fish access was provided to upper Anderson Creek. Monitoring showed use of deeper areas for overwintering, good benthic invertebrate food production in the inlet and outlet streams (Slaney and Zaldokas 1997).

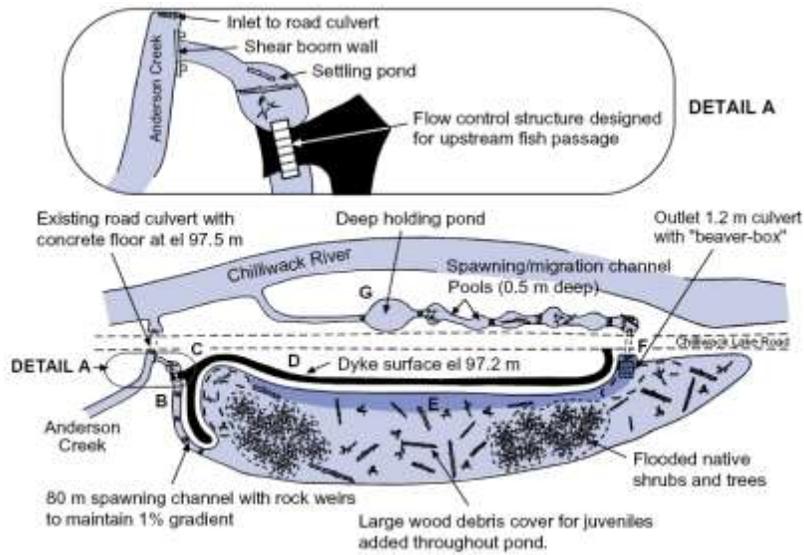


Figure 3.21.—Schematic diagram of Anderson Pond with inlet and outlet stream habitat (Foy and Logan 1997).



Figure 3.22.—Anderson Pond on a rehabilitated secondary channel of the Chilliwack River, BC.

Four restored secondary pond and channel habitat development sites (Anderson Pond, Bulbeard Pond, Peach Channel and R4 Channel) and three natural off-channel sites along the Chilliwack River were monitored for coho production in 1997 and 1998 (Blackwell et al. 1999). Smolt outputs were highly variable (<2 to >50 per 100 m<sup>2</sup>), but the restored habitats produced coho smolts at rates comparable to natural off-channel habitats preferred by this species. They concluded that newly reconnected channels may take at least one year of “seasoning” before full coho smolt output potential is realized. Blackwell et al. (1999) found that average smolt weight was inversely proportional to number of smolts per unit area, suggesting density-dependent competition in some ponds.

Cleary (2001) looked at production of coho smolts produced by developed off-channel habitats in the Centennial/Bulbeard complex in a different way. Using analyses of coho smolt production in 22 natural streams in British Columbia from Marshall and Britton (1990) and equations developed by Keeley et al. (1996) and Koning and Keeley (1997), Cleary (2001) calculated the expected output of the 3 km reach of the Chilliwack River paralleling the Centennial/Bulbeard complex should be approximately 5,700 smolts (i.e., 1,900 smolts/km). Monitoring data suggest that this complex produced approximately 30,300 smolts (i.e., 10,100 smolts/km), over 5 times the expected production of the main Chilliwack River channel paralleling the off-channel complex.

Foy (2006) performed population estimation sampling of the Wingfield Creek Project and the Thompson Park Project as well as an untreated reach of Ryder Creek, all part of the Chilliwack River floodplain restoration complex. He found coho smolt production rates in the developed habitats averaged 1.62 smolts/m<sup>2</sup>, 157% of the production rate for untreated habitat in Ryder Creek.

Bachen (1984) monitored a 450 m long (~2,750 m<sup>2</sup>) excavated groundwater-fed chum spawning channel in the outwash area of the Chilkat River near Haines, AK and reported the use of this habitat by about 700 and 450 spawners, respectively in the first two years following construction. In the second year, 97,444 fry were detected during outmigrant monitoring, yielding an egg-to-outmigrant survival rate of 22-24% based on estimated egg deposition. Bachen also reported winter water temperatures about 6° C higher than the Chilkat River itself and use of the spawning channel by rearing coho salmon and Dolly Varden char, especially in areas where coarse “armor” rock had been used to stabilize the channel banks. A borrow pit developed during construction of the Chilkat spawning channel filled with water; this pit was connected to the channel and provided with cover to enhance rearing habitat for juvenile coho. Food organism production was reported to be high and rearing coho growth was reported to persist throughout the winter, attributed to the warmer water and abundant food supply.

Much less formal but still effective habitat development sites have been monitored for effectiveness in terms of fish production. For example, Bryant (1988) monitored four gravel borrow pit ponds developed for road construction by Alaska Department of Transportation and Public Facilities on the outwash of the Yakutat forelands. These ponds had been connected to adjacent streams by artificial channels a decade or more earlier. Three of the four ponds supported significant populations of juvenile coho salmon (2,000-8,000 fish; varying by pond and season); the fourth pond, with no contemporary well-defined channel, supported only a few fish. On a unit area basis, two of the ponds with areas of 10,010 m<sup>2</sup> and 7,644 m<sup>2</sup> supported an average of 2.9 and 3.3 juveniles/m<sup>2</sup>, respectively. The third, much larger pond (34,954 m<sup>2</sup>) supported 0.12 juvenile fish/m<sup>2</sup>. These findings suggest that a well-defined connection may be important for the exploitation of off-channel rearing habitats by juvenile salmon; a point emphasized by WDFW (2004), and supports the notion of a point of diminishing returns with respect to off-channel pond size on the order of 10,000m<sup>2</sup>.

The ADFG's Habitat Division has a long history of developing fish habitat from gravel borrow pits created to support development in specific areas of the State or at specific isolated sites. The key to making this type of project successful is providing access, as appropriate, for fish to be able to move between active stream channels and the pit, contouring the pit shoreline to provide a shallow littoral area to promote biological productivity and provide for vegetation growth, ensuring that the pit has sufficient winter water depth to maintain suitable living space, and ensuring that pit water quality is adequate to support fish life. This type of project can also be successful in situations where a stream access connection is not possible. In these cases, the pit must provide suitable spawning and rearing conditions for the species of interest. There are numerous examples of borrow pit development in Alaska. Excellent examples are documented in Hemming (1988), Hemming (1990), Hemming (1991), Roach (1993), Hemming (1994), and Parry and Seaman (1994).

### **3.3.3.3 Summary**

Reconnecting abandoned secondary channels and oxbows and development of connected secondary channels in flood plains constitutes a direct supplementation of existing physical aquatic habitat. As illustrated by the selected examples summarized above, these developed habitat areas can be and usually are designed to incorporate features that complement and often significantly enhance productive capacities of natural habitats associated with the parent stream. Monitoring results frequently indicate higher production of standing fish stock and smolt output per unit habitat area or stream corridor length than associated natural stream channels. For example, overwintering habitat elements (*e.g.*, deep pools with incorporated cover elements) can be incorporated into groundwater-fed secondary channel design to supplement existing natural habitats or supply such habitats in areas where they are rare. Likewise, low-velocity rearing areas for young-of-the-year life stages can be provided in developed secondary channels alongside stream reaches dominated by high-velocity riffles and runs with little or no coarse boulders or large woody debris to provide velocity refugia. The large secondary off-channel habitat complexes described above provide ample evidence of the feasibility of designing and constructing very high quality off-channel habitats in systems like those in the Pebble Deposit area.

Developed secondary channels are typically designed to provide specific habitat needs for target species and life stages, usually anadromous salmonids, according to analyses of factors limiting or potentially limiting those species. Over a quarter century of experience with a wide variety of habitat needs spanning north-temperate to Arctic climate conditions has resulted in a high rate of success for modern designs. Developed secondary channels have been shown through monitoring to complement natural habitats both in areas previously degraded by human activities or natural events (*e.g.* floods) and in non-degraded settings.

Contemporary developed secondary channels and connected off-channel pond-stream complexes are typically designed with trophic considerations, particularly natural aquatic invertebrate food production, in mind. Monitoring data often demonstrate superior growth and overwintering survival in developed secondary channels compared to adjacent natural stream channels. These data also demonstrate high rates of use of off-channel habitats by target and non-target species, reflecting robust aquatic biological communities. Extensive wildlife use of developed secondary channels has been documented (WDFW 2012), sometimes leading to maintenance issues to manage beaver activities (See Subsection 3.3.2.1 above).

Developed secondary channels and channel/pond complexes can and should be integrated with nutrient supplementation, if that measure is used to increase carrying capacities for salmon, trout, grayling and other fish species in the Pebble Deposit area or along the road corridor. The quantities of nutrient supplementation to bring main stem streams such as the North Fork Koktuli, the South Fork Koktuli and Upper Talarik Creek up to optimum levels may prove to be prohibitive because of stream flows, especially in middle and lower reaches of these streams. Applying nutrient supplements to developed secondary channels, however, would likely significantly lower the quantity requirements and enable these measures to focus directly on areas with the highest fish production potential. EPA's exclusion of these types of habitat mitigation measures seriously undermines the credibility of the BBWA2 conclusions.

### **3.4 Water Chemistry Enhancements**

#### **3.4.1 General Description**

This subsection discusses the opportunity to enhance a suite of water chemistry parameters to increase the biological productivity of the three primary watersheds in and near the deposit area. This suite of parameters has been divided into two groups. The first consists of "basic" parameters and includes alkalinity, hardness, and total dissolved solids (TDS). The second group includes nitrogen and phosphorus and is referred to as "nutrient" parameters. Some of the literature, related to marine derived nutrients (i.e., nutrients supplied by anadromous fish carcasses), also include considerations of carbon (C), but while it constitutes another potential measure, C levels have not been evaluated at this time.

The two groups of parameters are discussed separately below. It is important to separate these two groups for discussion because one or the other or both may limit biological productivity in a stream. For example, a stream may have sufficient nutrient levels [i.e., nitrate nitrogen (NO<sub>3</sub>-N) and orthophosphate (PO<sub>4</sub>)], but the alkalinity and hardness are sufficiently low to limit primary productivity and ultimately fish production (e.g., Cada et al. 1987). In other instances, low levels of nutrients have been shown to limit primary productivity and ultimately fish production (e.g., Perrin et al. 1987). A preliminary review of the water quality chapter of the EBD's water quality data indicates that both conditions occur in the three primary watersheds associated with the deposit area and most likely both groups of water chemistry parameters are limiting at most sampling sites (PLP 2011).

The sequence of how fish production may be limited by these factors is as follows:

- Low concentrations of the basic parameters and/or nutrient parameters limit the production of algae/chlorophyll *a*. (Perrin et al. 1987; Wipfli et al. 1998).
- Low levels of algal production decreases the production of aquatic macroinvertebrates and the level of habitat complexity, which can increase the amount of invertebrate drift. (Hinterleitner-Anderson et al. 1992; Lee and Hershey 2000).
- Low levels of aquatic macroinvertebrate production can reduce overall fish production, reduce the growth rates of individual fish, and/or result in fish movements away from low production areas. (Larkin and Slaney 1997; LTER 2009).

The goal of this particular mitigation approach is to increase the biological productivity, as appropriate, in those aquatic habitats not lost by mine development. The authors believe it is possible to increase the productive capacity of the remaining aquatic habitats so that net fish production may equal or exceed pre-

development levels. This increase in productive capacity may be partially or completely realized by increasing the basic and/or nutrient parameter concentrations through a combination of water management, specific actions to increase one or more parameter concentration(s), nutrient additions at the appropriate places and times, and/or a combination of habitat creation in association with manipulation of certain water chemistry parameters.

### **3.4.2 “Basic” Parameters: Alkalinity/Hardness/Total Dissolved Solids**

#### **3.4.2.1 Background for the Mine Site Area**

Since the main ore body is located at the geographic headwaters of the three primary watersheds (NFK, SFK, and UT) and the geology of this area is both porous and relatively recent, there has been little opportunity for natural surface waters in these watersheds to develop levels of alkalinity, hardness, and total dissolved solids that support a robust level of primary productivity. A preliminary examination of PLP water quality data from selected main stem sites combined for the period 2004-2008 shows that main stem surface waters in the mine area and downstream have what are considered low concentrations of these three parameters (PLP 2011).

The summary analysis presented in the EBD shows that the surface waters associated with the mine area watersheds are generally very soft, lack buffering capacity (low alkalinity concentrations), and the fundamental concentrations of ions needed to support a robust biological community starting at the primary production level. For example, a number of the alkalinity measurements for the NFK, SFK, and main stem Koktuli River (KR), respectively are below the state water quality minimum standard of 20 mg/l. The notable exception is UT where essentially all of the data exceed the minimum standard. However, nearly all of the concentrations of alkalinity for all four locations are less than 50 mg/l (PLP 2011). The same pattern is present for the hardness and TDS concentrations leading to a conclusion that the area is dominated by “soft” water in general, which is limiting primary productivity.

Scarnecchia and Bergersen (1987) found a significant relationship between conductivity (strongly correlated with TDS), alkalinity, hardness, and two other non-chemistry variables, and trout annual production and biomass in 10 streams in northern Colorado. Four of the 10 streams had alkalinity and hardness concentrations > 50 mg/l, which compares with less than 2% of the concentrations in Table 3.5 exceeding this level. The same pattern was shown for TDS. Their data shows decreasing levels of trout annual production and biomass in streams with lower concentrations of alkalinity and hardness and lower conductivity readings. These authors also cite five studies from North America and Northern Europe that showed increased fish and/or benthic organism production in streams with higher levels of conductivity and calcium concentration (alkalinity) (McFadden and Cooper 1963; Egglisshaw 1968; Le Cren 1969; Mortensen 1977).

LaPerriere et al. (1989) studied algal and primary productivity in 15 subarctic streams in north central Alaska between Fairbanks and the Canadian border. They found a significant positive relationship between maximum standing crop of benthic algae, measured as chlorophyll *a*, and mean summer alkalinity concentration in five clear water streams. They also found a similar significant relationship for sestonic chlorophyll *a* concentration for 10 clear streams, but not for the five brown water streams in the study area. They concluded that the organic nature of these latter streams give “false alkalinity” readings because of the chemical nature of the water in this type of stream. They found a highly significant relationship

between total phosphorus (summer means) and sestonic chlorophyll *a* concentrations for the 13 streams sampled in 1979. When data from two additional streams were added to the analysis in 1983, the relationship between total phosphorus (summer means) and sestonic chlorophyll *a* concentrations became non-significant. However, a separate analysis of just the brown water streams again showed a significant relationship between total phosphorus (summer means) and sestonic chlorophyll *a* concentration.

Koetsier et al. (1996) examined the relationship between water chemistry and habitat parameters and benthic macroinvertebrate density (number/m<sup>2</sup>) and drift biomass (mg/m<sup>2</sup>), and benthic organic matter (BOM) biomass (g/m<sup>2</sup>) from six streams in the Salmon River basin in Idaho. They found a significant positive relationship between alkalinity concentration and production of macroinvertebrates, and subsequent drift biomass, and BOM. The authors cite three studies that showed a relationship between alkalinity and increased periphyton and macrophyte production and cite five studies that show an increase in fish production as a result of increasing primary productivity leading to increased benthic macroinvertebrate production. They also cite four studies in which the authors of those studies identify an “alkalinity threshold” of either 20 or 50 mg/L, which resulted in low benthic densities or a “physiological constraint” on some invertebrate taxa, particularly genera of Ephemeroptera (mayflies) and Plecoptera (stoneflies), which are major food items for young salmonids. The alkalinity data in the EBD clearly indicate that the surface waters represented are extremely low in buffering capacity and are limiting primary productivity in the watersheds (PLP 2011).

Bailey (1974) reviewed the primary factors influencing trout stream productivity and recommended concentrations to obtain maximum benthic macroinvertebrate production and thus fish production. He recommended alkalinity concentrations should be greater than 55 mg/l, hardness should be greater than 125 mg/l, and total dissolved solids (reported as conductivity) greater than 128 mg/l to support a healthy, productive stream. Wurts (2002) recommended optimum alkalinity concentrations of 50-150 mg/l in fish production ponds.

Cada et al. (1987) examined the relationships among water select water chemistry parameters, benthic macroinvertebrate biomass, and trout diets and growth at eight sites in four streams in the southern Appalachian Mountains. Three of the four streams (7 of 8 sites studied) all had alkalinity and hardness concentrations of less than 15 mg/l, with conductivity values less than 18  $\mu$ S/cm (approximately 20 mg/l TDS). One stream had mean concentrations of alkalinity, hardness, and conductivity of 44 mg/l, 51 mg/l, and 110  $\mu$ S/cm (approximately 66 mg/l TDS) which are at the upper end of PLP’s data for these parameters (PLP 2011). What this study showed was a reduction in trout growth rate during the mid-summer to early fall time period, despite having suitable stream temperatures. The authors attribute the lower growth rates to cropping of periphyton by benthic macroinvertebrates at such high rates that the macroinvertebrate community could not be sustained or increased over the summer/fall time period as would normally be expected. The decrease in macroinvertebrate levels resulted in a flat growth rate of trout in these streams. They also report this situation has been documented at other locations in North America. Almodovar et al. (2006) report a significant positive correlation between alkalinity and brown trout production in Spain and other European counties. These studies are quite relevant as a preliminary evaluation of the growth patterns of resident salmonids from the Pebble Project area strongly suggests a similar growth pattern (PLP 2011).

### **3.4.2.2 General Description of the Technique**

A technique that could address the issue of low levels of alkalinity, hardness, and total dissolved solids in Pebble mine area surface waters is the addition of limestone ( $\text{CaCO}_3$ ) to increase the buffering capacity of the water. Variations on this technique, mainly limestone particle size, have been used extensively in Eastern Canada and the U.S. to add buffering capacity to surface waters that have a low pH resulting from acid runoff and acid rain. These areas also had high concentrations of aluminum (Al) which were adversely affecting fish distribution and population levels.

The technique originally started in Scandinavian countries in the 1930s by adding spawning sized gravel pieces of limestone into Atlantic salmon streams. This method was extremely cost effective and required no maintenance. However, because of the low stream pH and high concentrations of AL found in these waters, precipitates formed on the limestone rocks, coating them, and thus reducing the ability of the rock to release calcium ions into the water. Subsequent refinement of the technique has resulted in particle diameter being reduced to crushed-sized or smaller sand-sized particles being applied to a stream. In Sweden, smaller particle sized limestone was added to wetland areas in a watershed to reduce the acidity of waters with a resulting increase in alkalinity and biological productivity (Hasselrot and Hultberg 1984; Clayton et al. 1998). Zurbuch (1984) reviewed the use of this technique in West Virginia and concluded that larger particle sizes could be effective if the introduced limestone was of sufficient size that the stream would cause the particles to move, thus exposing new sides without a precipitate present. A note of caution is required here because many of the streams treated with this technique had low pH values in the 4-5 range. An evaluation of the potential to form precipitates on larger sized limestone pieces placed in the water should be completed, based on each individual watershed's water chemistry. Particle size will have a major influence on limestone renewal interval, distance between treatment sites, and maintenance requirements.

Subsequent to these initial efforts using larger sized particles, particle size has decreased to where the current practical size is sand sized down to  $\leq 30 \mu\text{m}$  (Rosseland and Skogheim 1984). Experiments conducted in Eastern Canada showed statistically significant increases in pH, total inflection point alkalinity as  $\text{CaCO}_2$ , conductivity ( $\mu\text{S}/\text{cm}$ ), calcium, and magnesium concentrations downstream of a crushed limestone bed installed in the stream bottom (Gunn and Keller 1984; Lacroix 1992).

### **3.4.2.3 Selected Examples**

Most of the literature relating to alkalinity and liming describe various techniques for treating acid runoff from specific sites, whole watershed applications to treat acid rain related or natural soil acidity problems, liming of naturally soft water lakes to improve productivity, or the use of anoxic limestone drains (ALD) to treat concentrated acid mine runoff. All of these techniques result in an increase in alkalinity, hardness, and TDS downstream of the treatment point. Limestone particle size varies among techniques from 150 mm down to  $\leq 30 \mu\text{m}$ . Treatments include: 1) running an entire stream through a rotating drum system containing fine limestone particles, 2) placing various sized particles directly in a stream bed, and 3) distributing fine limestone particles over a wetland adjacent to the stream and letting natural runoff and seepage deliver higher alkalinity water to the stream channel.

These types of applications are currently used in the major government programs over various parts of the world. Sweden and Norway have active programs today that started in the 1930s. The United States and

Canada still have active programs to deal with acid runoff in the eastern portions of both countries. Active evaluations of effects are ongoing in the Appalachian Plateau of the U.S. (McClurg et al. 2007).

Two other techniques to raise alkalinity, and other key water chemistry parameters as well, are not well described in the literature. The first is a variation on a limestone application observed by Randy Bailey in 1973. This technique involved placing wind rows of large limestone chunks (150-250 mm) along a stream channel that was a natural soft water stream. The treatment consisted of approximately quarter mile long wind rows on both sides of the channel. While no water chemistry or macroinvertebrate samples were collected, Bailey and graduate school colleagues did sample the fish populations both upstream of and within the treatment area. Electrofishing upstream of the treatment area produced few rainbow, brown, and brook trout with a maximum size of about 150-200 mm in length. Sampling in the lower 1/8 mile of the treated area produced large numbers of trout with fish of all three species in the 3-5 pound range. The difference in populations and production was remarkable.

The second technique consists of pumping groundwater of higher alkalinity to reduce pH levels and increase key water chemistry parameters. In an experiment using this technique in Pennsylvania, pH, total dissolved aluminum, and alkalinity all showed statistically significant increases (Gagen et al. 1989). Of particular interest was the fact that alkalinity concentrations increased from below a detection limit of <0.05 mg/l to 1.8 mg/l, an increase of 38 times.

Given the information presented in the sections above, there is an opportunity to increase stream productivity in one of two ways. The addition of limestone in some form at the appropriate locations could increase the concentrations of biologically key water chemistry parameters. The second opportunity could result in the discharge of higher alkalinity water into fish producing streams through a water management program. It is clear that increasing key water chemistry parameters (nitrogen and phosphorus additions as nutrients are discussed immediately below) would increase the primary production, benthic macroinvertebrate populations, and fish production, if sufficient nutrients are also available. Also, increasing the concentrations of these water chemistry parameters to improve biological productivity results in no deleterious effects on the biological ecosystem and can reduce the potential toxicity of certain metals listed in EPA's Aquatic Life Criteria.

### **3.4.3 "Nutrient" Parameters: Nitrogen and Phosphorus**

#### **3.4.3.1 Background for the Mine Site Area**

The discussion above focused on the basic parameters that are necessary to support certain levels of primary productivity. However, having concentrations of these parameters at levels necessary to support robust levels of primary productivity in a stream may be an insufficient condition in and of itself. The second part of the primary production equation must include a consideration of the basic nutrients, particularly NO<sub>3</sub>-N and PO<sub>4</sub>. Either nitrogen or phosphorus levels may limit primary production or they may be co-limiting (Stockner and Ashley 2003). Cederholm et al. (1999) displayed the food web pathways in which nutrients (defined as carbon (C), nitrogen (N), and Phosphorus (P)) are delivered from spawning anadromous fish through various pathways to support the biological productivity of the stream (Figure 3.23).

There is a substantial body of literature on the use of nutrient addition (primarily N and P, with some studies documenting C additions) to improve the biological productivity of lake and stream systems (Perrin

et al. 1987; Raastad et al. 1993; Larkin and Slaney 1997; Wipfli et al. 1998; Cederholm et al. 1999; Stockner 2003). Canada has been the world leader in evaluating the effects on biological productivity of adding nutrients to lake and stream systems with Slaney et al. (2003); Stockner (2003); and Ward et al. (2003) providing concise summaries of several programs, while Quamme and Slaney (2003) evaluated varying concentrations of nutrients on stream insect abundance.

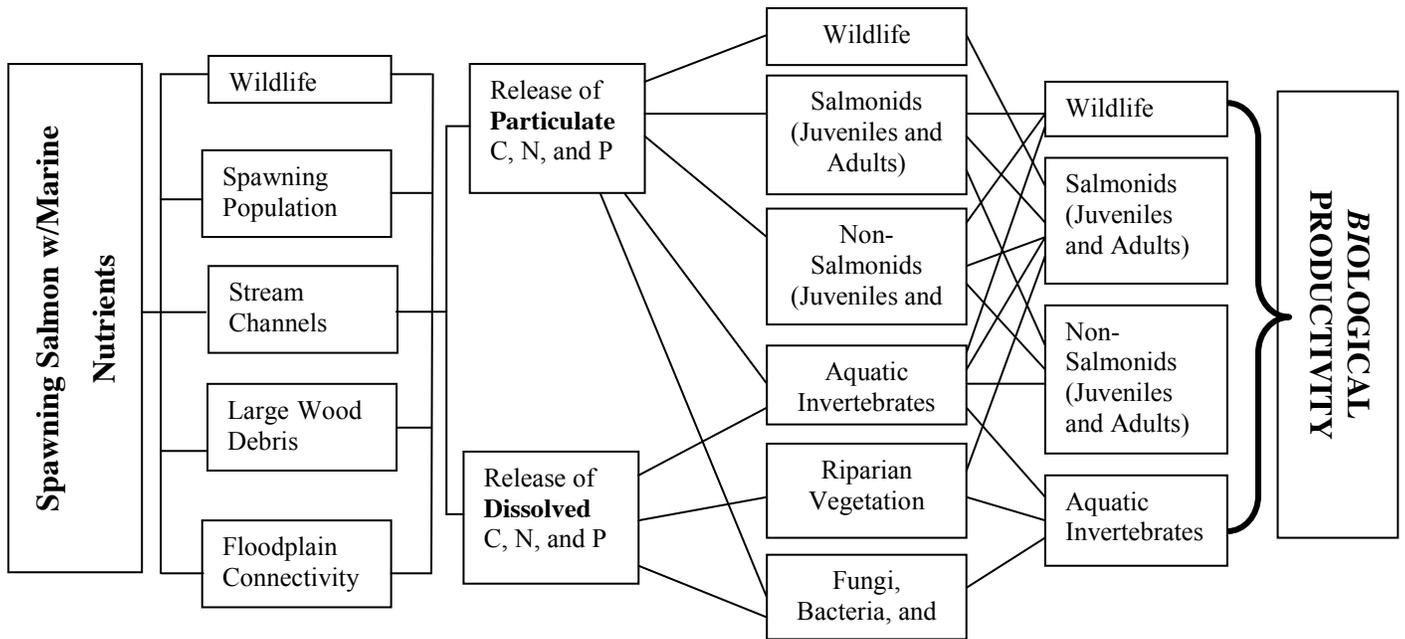


Figure 3.23. — The influence of stream complexity and marine derived nutrients on biological productivity (adapted from Cederholm et al. 1999).

Two key factors determine whether or not nutrient(s) are limiting in a particular stream or location within a watershed. First is the existing absolute concentration of the nutrient(s) of interest during the growing season for the target organisms. The second is the ratio of N:P, which is critical in determining which parameter is limiting or whether both are co-limiting.

Slaney et al. (2003) characterized the nutrient concentrations in the Keogh River on northern Vancouver Island prior to nutrient enhancement as:

“Nutrient concentrations in spring to summer are *extremely low* [emphasis added]: orthophosphorus, < 1 mg/L; total dissolved phosphorus, 5 mg/L; nitrate nitrogen, usually < 15 mg/L.”

However, Koch and Hainline (1976) evaluated benthic macroinvertebrate populations at 11 stations along the Truckee River in California which drains Lake Tahoe, flows down the eastern slope of the Sierra Nevada mountains, through Reno, Nevada and terminates at Pyramid Lake in western Nevada. At those

stations (6) upstream of a major population center (Reno) and not heavily influenced by groundwater containing large quantities of septic tank effluent, their data show annual average NO<sub>3</sub>-N and PO<sub>4</sub> concentrations of about 0.3 and 0.02 mg/l, respectively. This approximately 90 km reach of stream is considered very productive and supports a robust trout population (Scoppettone and Bailey 1983).

Ashley and Stockner (2003) recommend concentrations of soluble reactive phosphorus (SRP = orthophosphate) in the 0.003-0.005 mg/l range, approximately ½ of the reported nuisance level in their paper. Bailey (1974) recommended PO<sub>4</sub> concentrations of < 0.01 mg/l as optimum for controlling algal growth, but did indicate that levels up to 0.07 mg/l could be acceptable in certain situations, particularly where nitrogen is limiting at this concentration of orthophosphate. Quamme and Slaney (2003) evaluated varying concentrations of total phosphorus up to 0.01 mg/l and found the greatest aquatic insect increase at this level. The concentrations in these three references are significantly less than those cited by Slaney et al. (2003).

Ashley and Stockner (2003) recommend concentrations of dissolved inorganic nitrogen [ammonium, NH<sup>4+</sup> + nitrite, NO<sub>2</sub> + nitrate, NO<sub>3</sub>; collectively DIN (dissolved inorganic nitrogen)] of 0.03-0.05 mg/l as a minimum target level to ensure a DIN to SRP ratio of 10:1 on an atomic weight basis. Bailey (1974) recommended NO<sub>3</sub> concentrations of < 0.10 mg/l to support appropriate biological productivity, but also realized the importance of maintaining the appropriate N:P ratio to prevent overstimulation of algae growth.

The characterization of Slaney et al. (2003) of nitrate concentrations of < 15 mg/l as extremely low should be reviewed in light of current knowledge. A critical factor when dealing with N:P concentrations in aquatic systems is identifying the limiting nutrient(s) and maintaining the appropriate ratio. Sterling and Ashley (2003), citing Borchardt (1996), state: “Streams are considered N-limited when the N:P atomic weight ratio is less than 10:1, co-limited when N:P is between 10:1-20:1, and P limited when N:P is greater than 20:1.

### **3.4.3.2 General Description of the Technique**

In general terms this technique would increase the nitrogen and/or phosphorus levels at selected locations and times to increase the primary productivity of streams in the project area. Nutrient additions would occur in the three primary watersheds near the mine deposit. However, other locations or tributaries in these watersheds could supply other suitable sites and additional opportunities along the transportation corridor for any streams or lakes that could benefit

Three factors are critical when nutrient additions are contemplated. First is determining the spatial and temporal distribution of the limiting nutrient(s). Both nitrogen and phosphorus can be co-limiting. Second is determining the timing and duration of nutrient application(s). Depending on the source of nutrients, multiple applications may be necessary to achieve the desired concentrations in the receiving waters. Third is determining the desired concentrations of each nutrient and the ratio between N and P for each application location.

For mitigation of the hypothetical EPA mine development, the primary focus of nutrient enhancement could be in either existing or newly created side channels, sloughs, beaver ponds, or alcoves. Providing

nutrient rich outflow from these areas may be sufficient to meet the nutrient objectives for the main channels of the major streams. If this approach proves insufficient for the main channels (emphasis on rainbow trout and Chinook salmon, with some secondary benefits to sockeye and other resident species), then applications could be made at approximately 10 km downstream intervals in the main channels. These additions could be made during the growing season (i.e., after breakup through August initially). However, it might be beneficial to add nutrients earlier or potentially all winter in open water locations where the water temperatures are a few degrees Celsius and suitable for biological production to continue year around.

Calculating the current nutrient concentrations from existing water quality data and then determining where nutrient enhancement could occur would be critical. The type of nutrient delivery varies from liquid fertilizer to slow-release fertilizer to nutrient analogs which are essentially slow release pellets. All of these methods have been used successfully. The key consideration is access cost and maintenance requirements. Sterling and Ashley (2003), provide a good general overview of the various formulations tried and delivery mechanisms. Slaney et al. (2003) provide insight into some of the problems associated with direct fertilization techniques used in the Keogh and Salmon Rivers on Vancouver Island.

### **3.4.3.3 Selected Examples**

The literature reviewed above demonstrates a broad base of countries that are using nutrient enhancement in a variety of lakes and streams to increase fish production. Alaska had a lake fertilization program aimed at sockeye salmon production. Stream and lake nutrient enhancement projects are still routine programs in Sweden and Norway. Canada has programs centered in British Columbia on a variety of lakes and streams. Finally, the Northwest Power and Conservation Council and Bonneville Power Administration announced in January 2010 funding for a 10-year nutrient enhancement program in the Snake River Basin. The program, to be managed by the Shoshone-Bannock Tribe, will use nutrient analogs of C, N, and P in high elevation streams to increase fish productivity with a target of increasing anadromous fish populations.

The benefits of fertilization of oligotrophic waters for the stimulation of fish production have been demonstrated in several venues. For example, whole-stream fertilization of the Keogh and Salmon rivers in British Columbia resulted in up to 2 to 3-fold increases in the average weight of juvenile steelhead trout just 3 months after fertilizer application in the Keogh River (Slaney et al. 1986, Johnston et al. 1990, Slaney and Ward 1993). These studies also documented striking increases in fry densities, growth rates (mass and length) and a doubling of survival to the smolt stage from 25% to 50%. This translated into a 65% increase in adult returns. Similar results were found in the Salmon River. Stream fertilization in the Kuparuk River (AK) resulted in a 1.4 to 1.9-fold increase in age 0+ Arctic grayling size and a 1.5 to 2.4-fold increase in growth rate for adults (Deegan and Peterson 1992).

Concentrations of nitrogen and/or phosphorus that are high relative to the needs of a desirable biological community can result in a number of changes in the aquatic habitat(s) or biological community that are deemed negative. The classic example is a discharge from a wastewater treatment plant that puts excessive amount of ammonia, nitrate, or orthophosphate into a receiving water. Excessive concentrations of these constituents result in direct mortality to fish (ammonia) or blooms of attached algae that alter stream habitats and may cause dissolved oxygen concentration sags during night time hours, resulting in fish kills

(Lee and Hershey 2000). Having a stream choked with filamentous algae may force a shift from dominance by one fish species to another. In Fraser Lake, Alaska the Alaska Department of Fish and Game implemented a fertilization project to enhance overall lake productivity. While they determined that smolt production did increase, they also found that the primary phytoplankton response to increased nutrient levels was a species that was generally inedible by desirable zooplankton (Kyle 1994).

Three important lessons have been learned by the multitude of experiences in altering the nutrient chemistry of aquatic habitats:

- Detailed pre-project information on the biological species composition of the water body and completion of a low level nutrient analysis are essential to understanding the ecosystem proposed for alteration.
- An assessment of the spatial and temporal requirements needed to achieve the management objectives.
- A determination of the desired ratio of nitrogen to phosphorus desired in this water body. Maintaining the proper ratio is critical to achieving the biological response and preventing unwanted shifts in habitat quantity and quality. It is important to note that the concentrations which produce the desired level of primary productivity are orders of magnitude below any human health criteria (see Sterling and Ashley (2003) and Ashley and Stockner (2003) for detailed discussions.

In summary, there is clearly an abundance of evidence in the literature that demonstrates the linkage between these general water quality parameters/nutrients and aquatic production. Since these topics were not considered by EPA in the BBWA2, it seriously undermines that reports credibility, and especially its negative conclusion about the applicability of mitigation measures. By ignoring these demonstrably successful mitigation techniques, the credibility of the BBWA2 is scientifically diminished.

#### 4. Review of the Documented Efficacy of Selected Fish Habitat Mitigation Techniques

The previous sections of this report have chronicled a wide variety of measures that can be applied appropriately to mitigate unavoidable impacts of the development and operation of a mine at the Pebble deposit location. The efficacy track record of these measures has also been documented for over three-quarters of a century of application. There is no question about the effectiveness of an appropriate application of these measures to enhance production of aquatic biological resources, especially salmon. Large amounts of money continue to be dedicated towards the implementation of these kinds of measures because they work; this is settled science.

On the other hand, not all mitigation measures implemented to compensate for unavoidable impacts of human activities work all the time. Many individual mitigation exercises have failed to meet stated objectives, and these failures have occurred for many reasons. One of the most comprehensive and detailed investigations of the most detailed and comprehensive reviews of the efficacy of fish habitat mitigation measures (as opposed to jurisdictional wetland mitigation banks, which are usually the subject of CWA Sec. 404 mitigation success) was conducted as a formal evaluation program by Jason Quigley and David Harper of the Department of Fisheries and Oceans, Environment Canada, in the mid-2000s (Harper and Quigley 2005a, Quigley and Harper 2006a, Quigley and Harper 2006b). A summary version of their early findings was published in Fisheries (Harper and Quigley 2005b). The evaluation program had four parts:

- **Literature Review** – Detailed file reviews were conducted of all studies in the peer-reviewed and grey literature that could be found relating to assessment of habitat compensation/mitigation projects to determine success in achieving the national No-Net-Loss policy for fish habitat;
- **Detailed File Review** – Permits and associated conditions for 124 projects and developments issued between 1994 and 1997 were collected and analyzed to provide an indication of the types of projects permitted, mitigation approaches used and associated monitoring/evaluation programs;
- **Compliance Audit** – A subset of 52 of the 124 permitted projects and developments were subjected to field inspections to assess compliance with biological, physical and chemical parameters identified in permits and associated regulatory documents;
- **Effectiveness Audit** – A subset of 16 of the 52 field-audited projects and developments in the compliance audit were quantitatively evaluated for achievement of No-Net-Loss by comparing habitat productivity at treatment and control (reference) sites.

This detailed evaluation concluded that the national Habitat Policy requiring No-Net-Loss for fish habitat, particularly that part requiring compensatory habitat development or enhancement to offset losses “**is an excellent conservation strategy, potentially serving as a model for other jurisdictions**” (Quigley and Harper 2006a). [Emphasis added]. They also found that, in the aggregate, success in meeting the No-Net-Loss objective was not always met, and that significant improvement was called for. In all, only 64% of the 124 projects and developments subjected to a detailed file review were successful in meeting or exceeding the No-Net-Loss fish habitat goal.

The Evaluation Program, as reported in the references cited above, identified the reasons for compliance failure. These reasons cover a broad spectrum, and are informative when it comes to development of a

mitigation program for any large project if such a program is to succeed. These reasons can be grouped as follows:

- **Non-Achievement of No-Net-Loss**
  - **Permits / Authorizations**
    - Required mitigation/compensation ratios are often too small
    - Temporal losses in fish habitat productive capacity result from *avoidable* time lags
    - Technical regulatory reviews of mitigation/compensation proposals are inadequate
    - Limiting factors influencing productive capacities are overlooked or wrongly analyzed during the mitigation/compensation design process
  - **Compliance**
    - Non-compliance with permit specifications is undetected and/or not enforced
    - Monitoring is inadequate
    - Project/development design changes are not reflected in new or modified mitigation requirements
    - Field audits are rarely conducted to assure compliance with mitigation and monitoring requirements
    - Insufficient financial security (performance bonding) is required to assure continued compliance through time
  - **Mitigation / Compensation Science**
    - Ecosystem function is inadequately incorporated into mitigation plans
    - Knowledge from fish habitat enhancement/restoration is not adequately incorporated into mitigation/compensation programs
- **Measuring No-Net-Loss**
  - **Permits / Authorizations**
    - Permits and permit conditions often lack specific goals and objectives
  - **Monitoring Programs**
    - Monitoring programs are often not designed to measure No-Net-Loss
    - Frequency and duration of monitoring is often insufficient to measure No-Net-Loss
    - Inappropriate variables are often incorporated into monitoring programs
    - Statistical power is seldom considered in monitoring programs
    - Delineation of mitigation/compensation sites is often unclear
- **Organizational Memory, Learning, Transparency**
  - **Transparency in Decision-Making**
    - Links between monitoring results and regulatory action are often missing
    - Communication of regulatory and administrative goals to project/development owners is muddled or lacking
    - Rationales governing financial securities (performance bonds) are not clear
    - Magnitudes of performance bonds are often not proportional to actual needs
  - Improvements in learning and organizational memory are needed
  - Improvements in program effectiveness and adaptive management are needed, especially for long-term mitigation/compensation programs.

To address the specific shortcomings of many mitigation/compensation projects, Quigley, Harper and Galbraith (2006) developed a suite of 39 specific recommendations. All of these recommendations are

consistent with good biological and regulatory sense and are grounded in good science. All are reasonable, practical and achievable in a modern regulatory setting.

**It is very important to note that most of the reasons for failure of a significant proportion of mitigation/compensation measures to achieve the No-Net-Loss goal for fish habitat, and the Quigley-Harper-Galbraith recommendations to rectify these shortcomings, reflect a failure of regulatory and administrative functions, not the measures themselves.** The next-most-important reason for failure to achieve mitigation goals is the failure to incorporate what is already known about habitat enhancement and rehabilitation, as reflected in the track record of achievement documented in earlier sections of this document.

It is also important to note that most of Quigley-Harper-Galbraith recommendations are effectively embodied in the large project regulatory framework that currently exists in Alaska. This can be demonstrated by three hard rock mining examples: Red Dog Mine near Kotzebue, Greens Creek Mine near Juneau and Fort Knox Mine near Fairbanks. All three of these large mines have clear mitigation program requirements with associated goals and objectives. All three have detailed, hierarchical, multi-parameter monitoring programs with compliance thresholds and action plans. All three have very close regulatory authority involvement (ADFG), with annual technical monitoring reports incorporating quantitative multi-parameter biological benchmarks. All three monitoring programs have detected occasional deviations from parameter limits specified in permit compliance documents, and in all three examples measures have been undertaken to correct or compensate for these deviations in a timely manner. In other words, the program works as designed.

In summary, the discussion regarding the efficacy of mitigation compensation projects reviewed above point to inadequate regulatory implementation. Throughout Section 3 of this report there are embedded numerous examples and documentation of the proven efficacy of the fish habitat improvement techniques reviewed there. While there were some early failures resulting from a lack of knowledge about stream hydraulics and geomorphology, resulting in faulty designs. A lack of maintenance funding in many agencies also contributed to the poor performance. Those types of problems are now decades behind us as the knowledge base and sophistication of designs have demonstrated successes. As a result, agencies are now committing billions of dollars to restore anadromous and resident fish populations in Western North America. EPA's failure to demonstrate their knowledge of the large body of scientific literature describing the efficacy of fish habitat improvement techniques in BBWA2 only undermines the scientific credibility of the conclusions reached in their document.

## Section 5

### Identification of Fish Habitat Mitigation Techniques and their Applicability to Pebble Deposit Area Watersheds

The authors of this report have extensive professional experience and training in aquatic habitat mitigation techniques. They are familiar with the scientific literature and have participated in numerous evaluations of the applicability and efficacy of fish habitat improvement programs, including a \$500 million program funded by the Cal/Fed Bay Delta Program. One of the authors has designed and installed fish habitat improvements for anadromous fish and served as a regional technical expert for the U.S. Forest Service on their fish habitat improvement program and as a national oversight committee member of the Forest Service's fish habitat research program. Both authors have extensive experience in Alaska and both have intimate knowledge of the Pebble Deposit area. Author Bailey served as Chief, Fisheries Resources Division for the U.S. Fish and Wildlife Service in Anchorage for nine years and has been working as a senior fish biologist on the Pebble Project since 2007 specifically. Author Buell conducted the original fish distribution and relative abundance reconnaissance surveys of the Pebble deposit area beginning in 1991 and has spent a great deal of time in the three watersheds used by EPA in their hypothetical example since then. He has been active in other mining projects in Alaska throughout his career and has been a senior fish biologist on the Pebble Project since 2004.

Given these technical and professional credentials, the authors have identified the following types and techniques that could be used as part of a mitigation program at on-site locations to mitigate the fish habitat impacts associated with EPA's mine development scenarios.

1. **Water Management:** Water from EPA's WWTP could be distributed in a manner that reflects the relative importance of certain locations and reaches of streams. For example, instead of arbitrarily distributing water from the WWTP equally to the NFK and SFK, water discharge could be appropriately distributed to the upper portion of UT where the greatest potential magnitude of benefit would accrue to coho salmon. Surprisingly, EPA chose to distribute no water into this watershed. Also, EPA could have ensured that sufficient water was distributed to the South Fork "Springs" area which is the major salmon spawning area in the SFK.
2. **Water Management:** EPA chose to distribute water from their WWTP via surface discharge, which would result in violations of Alaska's Water Quality Standards and change the emergence timing of juvenile salmon, resulting in potentially catastrophic juvenile mortality. EPA should have realized that using the water available to recharge and surcharge groundwater aquifers, with aquifer residence time of generally a year or more, that provide critical stream flow would have eliminated the problems identified. In addition, the default release of WWTP water to recharge and surcharge aquifers would assure that WWTP upset or shutdown would not interfere with the continuing release of water to streams from groundwater storage for extended periods.
3. **Water Management:** EPA should have recognized that the WWTP discharge could be designed to provide water chemistry concentrations that would improve the buffering capacity, primary productivity, secondary productivity, and also reduce the potential toxicity of metals at area downstream of locations where discharge water reenters the stream channels.

4. **Increase Habitat Connectivity:** EPA failed to recognize numerous opportunities in all three principal watersheds to provide fish access to existing, suitable habitats that are not currently connected to a main stem channel. Figures 5.1, 5.2, and 5.3 show representative sites in the NFK, SFK, and UT, respectively. These figures are representative of photographs displayed in the EBD in Chapters 4, 7, and 15, which EPA apparently did not review. These figures are for illustrative purposes only and are not intended to identify any specific potential mitigation site. EPA did not consider providing fish passage over a cataract currently blocking anadromous fish access to suitable habitats in tributary stream UT 1.190.
5. **Increase the Quality of Existing Off-Channel Habitats:** EPA failed to recognize the potential to improve the quality of existing off-channel habitats by increasing the complexity these areas through the use of boulders, large wood, and deepening or altering the shoreline development ratio in order to create better over wintering habitat and more alcoves, and thus contributing to increased survival
6. **Create New Habitats through the Development of Semi-Natural Channels:** EPA failed to recognize the potential for development of new off-channel habitats within the three watersheds. These new channels could provide additional spawning and rearing habitats by locating them in locations where subsurface flow will provide the water to the new channel. The authors have personally reviewed and/or visited dozens of potential sites.
7. **Increase the Primary Productivity and Productive Capacity for Fish:** EPA failed to recognize the potential to increase primary productivity and overall productive capacity for fish by developing an appropriate design for their WWTP so that discharges would increase key water chemistry constituents. They also failed to recognize that the entire area has very soft water and thus low productive potential. This situation could be improved through a carefully designed water chemistry enhancement program.



Figure 5.1.—Example of a North Fork Koktuli reach with potential opportunities to create new/improved fish access and/or creation of new aquatic habitat areas.



Figure 5.2.—This aerial photo shows a portion of the South Fork Koktuli River main stem channel and associated off-channel ponds and isolated channels.



Figure 5.3.—This aerial photo shows a portion of the Upper Talarik Creek main stem channel and associated off-channel ponds and isolated channels.

## Section 6

### Identification of Fish Habitat Mitigation Opportunities at Off-Site Locations

#### 6.1 Overview

The purpose of this section is to identify the types of mitigation techniques, of which the authors are aware that would be suitable for off-site mitigation actions for EPA's hypothetical large mine development in the Bristol Bay Watershed. The techniques listed are examples are those of which the authors are personally aware. This list is not comprehensive; the list of actions presented should be considered potential opportunities.

#### 6.2 Degraded Habitat Rehabilitation, Reconnection, and/or Development of New Habitat

Projects identified are *examples* of areas where aquatic habitats have been degraded or eliminated by various mining-related activities. Opportunities are known to exist. Mitigation at these sites would involve the rehabilitation, reconnection, and/or development of new habitat in areas previously disturbed by mining activities.

#### 6.3 Repair or Replacement of Culverts Impairing or Preventing Fish Passage

There opportunities to assist agencies in fixing problem culverts and other types of structures at road crossings. ADFG has established a Fish Passage Program within the Sport Fish Division. This program has begun an inventory of fish passage barriers or impediments which include a large number of improperly sized and/or installed culverts that result in fish passage impairment. At the present time, this inventory is limited to major road networks in Central and South-Central Alaska and Kodiak Island. Although it is acknowledged that many problem culverts exist in other regions, including Southwest Alaska, these have not yet been added to the ADFG inventory. According to program documents, approximately 44% of 130 culverts in the Matanuska-Susitna Valley, 78% of 97 culverts on the Kenai Peninsula and 83% of 29 culverts near Tyonek are known or assumed to be inadequate for passage of juvenile salmonids, according to criteria for water depth, culvert size and installation (Albert and Weiss, in review; Rich, in review a; Rich, in review b).

#### 6.4 Access to New Habitats (Fish Passage around Natural Barriers)

Both the Nushagak River watershed and the Kvichak River watershed are very large. The Nushagak Watershed is about 8 million acres in size (excluding the Wood River watershed); the Kvichak watershed is about 5 million acres in size (excluding the Alagnak River watershed). Within these large areas there are numerous opportunities to provide access to habitats not currently accessible to anadromous fish. Within the Kvichak River watershed alone, for example, several reconnaissance efforts by one of the authors have identified several large river systems and some smaller but significant streams with barrier falls low in their watersheds. Evaluation has confirmed preliminary feasibility for providing new anadromous access as mitigation for EPA's hypothetical mine development scenario. If passage at barrier falls were provided, these systems could, in the aggregate, provide several tens of miles of river/stream access and many thousands of acres of lake habitat available to anadromous fish that are

**presently inaccessible.** The consequence of this would be significant new runs of salmon for exploitation by subsistence, recreational and commercial fisheries alike, and would, in time, add to the genetic diversity of salmon runs in the Kvichak watershed, adding significantly to the important genetic portfolio effect in that watershed.

## Section 7

### **Relevant Examples of Large, Successful Fish Habitat Mitigation Programs in the U.S.**

EPA is undoubtedly aware of other major large scale fish habitat mitigation programs along the West Coast of North America. British Columbia has a well documented program of fish habitat improvements, spanning decades. The Fish and Wildlife Program of the Bonneville Power Administration has spent billions of dollars in mitigating hydropower development impacts to anadromous and resident fish in the Columbia River Basin. This program was initiated in the early 1980's. Of more recent vintage are the Central Valley Project Improvement Act and the CALFED Bay/Delta programs in the Central Valley of California. These programs have spent a few billion dollars on ecosystem restoration activities aimed at protecting and recovering anadromous and resident fish populations. These three programs are briefly discussed in more detail below.

#### **7.1 Central Valley Project Improvement Act**

The Central Valley Project Improvement Act (CVPIA) passed by Congress in 1992 added protection of fish and wildlife resources as a primary purpose of the Central Valley Project (CVP). The CVP was constructed in the 1930s by the federal government to provide a reliable agricultural water supply to farmers in the Central Valley of California. Three major dams dominate the infrastructure of the project. Shasta Dam, which is located at the northern end of the Sacramento River Valley, is a high dam without fish passage facilities and blocks anadromous fish access to hundreds of miles of habitat formerly used by three races of Pacific salmon and steelhead trout. Folsom Dam is located on the American River, near Sacramento and blocks salmon and steelhead trout access to many miles of former anadromous fish habitat. Friant Dam is located near the southern end of the San Joaquin River Valley and blocks anadromous fish access to former high elevation spring Chinook salmon habitat. In addition, the minimum flow releases from Friant were insufficient to maintain a wetted river channel for over 100 miles downstream of the dam. Construction of these dams and associated infrastructure resulted in major impact to anadromous fish resources in California's Central Valley.

In passing the CVPIA, Congress added fish and wildlife resource protection as a primary purpose of the project. Major provisions of the act included: a land retirement program which required marginal farmland from receiving project water, the dedication of 800,000 acre feet of project water yield being dedicated to fish and wildlife purposes, and an annual allocation of \$50 million for ecosystem restoration actions. These restoration actions have included providing fish passage improvements, habitat restoration, creation of new habitat areas, providing cold water to lower water temperatures in downstream areas. **This program has been highly successful and is continuing with a significant amount of restoration work still to be accomplished.**

#### **7.2 CALFED Bay/Delta Program**

The CALFED Bay/Delta Program is a companion program to the CVPIA. This program is a joint state/federal effort to address four major issues in the Central Valley of California. The four major functions of the program are to:

- Improve flood protection in the Sacramento/San Joaquin River Delta through a levee rehabilitation program,
- Improve the water supply reliability to both agricultural and domestic water users. The State Water Project (SWP), which exports water from the Delta to Southern California, provides domestic water to approximately 20 million residents,
- Improve the domestic drinking water quality of that water exported through the SWP and,
- Restore the ecosystem of the Central Valley, to the extent practical, by mitigating for impacts caused by construction and operation of the SWP and CVP.

The program has gone through several administrative configurations since its inception in 1994. The program has developed a plan which addresses the four program areas and the voters of California have approved \$3 billion in bonds to begin implementing the approved plan. Full cost of implementing the plan was estimated at \$8 billion, but actual costs are expected to be much greater.

### **7.3 Bonneville Power Administration Fish and Wildlife Program**

The Northwest Power Planning and Conservation Act of 1982 directed the Bonneville Power Administration (BPA) to increase the reliability of electrical power it marketed to Northwest customers and to mitigate the impacts of construction of the federally owned dams in the Columbia River system which produce hydroelectric power that BPA markets. The focus of the fish and wildlife program has been to provide fish passage improvements at a variety of project dams, implement a massive ecosystem restoration and habitat creation program covering four states, providing a major source of funding to support the region's hatchery mitigation programs, and providing funds to implement the variety of actions required under the biological opinion developed under the auspices of the Endangered Species Act for continued project operations.

As of 2010, BPA has expended \$11 billion dollars through their fish and wildlife program. The annual budget for the program is currently \$700 million encompassing some 750 individual projects. While some of the budget does fund research, the vast majority of the funding supports ecosystem restoration and management efforts. Also, while BPA's program is the largest in the region, other agencies such as the U.S. Army Corps of Engineers and U.S. Bureau of Reclamation also contribute significant funding outside the fish and wildlife program.

Fish and wildlife agencies in the West have been successfully implementing these programs for decades and at a geographic scale and budget scope much greater than anything even contemplated for a project the size of EPA's mine development scenarios. There is technical knowledge and expertise to implement any mitigation program required for the project as described in the BBWA2. Restoration and mitigation programs like that needed for EPA's mine development scenarios are being carried out every day at other locations in the West.

## Section 8

### Conclusions

In the BBWA2, EPA makes four outlandish and demonstrably false assertions and conclusions regarding the scientific quality, ecological risk assessment methodology, and availability of mitigation opportunities available within the NFK, SFK, and UT watersheds. EPA states:

1. *“This assessment is a scientific investigation.”* (Page 1-4),
2. *“Detailed background characterizations for the resources of the watershed are included in the assessment’s appendices.”* (Page 1-4)
3. *“We based his assessment on the U.S. Environmental Protection Agency (USEPA) guidelines for ecological risk assessment (ERA) [citation omitted].”* (Page 2-1), and
4. ***“Specifically, these three watersheds are largely unaltered by human activities, and there appear to be no sites that a mitigation project could restore or enhance to offset the magnitude of impacts expected from the mine scenarios.”*** [Emphasis added]. (Appendix J, pages 8-9).

While the primary focus of this report is EPA’s assertion that no mitigation opportunities existed on-site to mitigate for their estimated impacts, the authors believe it is important to point out that the conclusion regarding the magnitude of impact, which was one of the justifications for their conclusion, is based on a scientifically indefensible evaluation and failure to use publically available and site specific data that we believe would have changed EPA’s conclusion regarding the level of impact. That topic is the focus of Section 2 of this report. The remainder of this report deals with the lack of mitigation opportunities conclusion by EPA.

EPA’s claim that the BBWA2 is a “scientific investigation” is not supported by the facts. EPA ignored a large volume of **site specific fish distribution and species composition data that was known to them and made available to them in 2008 by the Pebble Limited Partnership (PLP).** They also ignored site specific data collected by Buell and Associates and the Alaska Department of Fish and Game.

It is also apparent that EPA did not complete a detailed evaluation or review of the large volume of fish data contained in Chapter 15 of PLP’s EBD. As a result, the BBWA2 did not examine the most recent and site specific fish data available on which to base their ecological risk assessment for fish. In fact, neither Appendix A (anadromous fish) or Appendix B (resident fish) contain any reference to the 6,500 pages of site specific fish information from Chapter 15 of the EBD. If EPA had examined these sources, they would have concluded, for example, that sockeye salmon, the focus of the BBWA2’s “portfolio effect” discussion do not spawn in the TSF 1 watershed, **any of the SFK watersheds directly impacted by the mine development scenarios, and that sockeye spawning is intermittent and occasional in the upper portion of the UT.** Instead, EPA relied on generalized literature for fish from the Bristol Bay area and misinformed modeling to develop their ecological risk assessment.

Failure to use the best available science is in direct opposition to the requirements of the ERA guidelines. **By failing to use the best available scientific data, EPA over estimated the quantity and quality of fish habitats lost from their mine development scenarios.** Yet the magnitude of loss is stated in Appendix J as one of the factors which led to their erroneous conclusion that mitigation, specifically on-site, was not available in the affected watersheds.

EPA's claim in, Appendix J, that: "... *there appear to be no sites that a mitigation project could restore or enhance to offset the magnitude of impacts expected from the mine scenarios.*" [Emphasis added], is so patently false as to be absurd. Any competent, experienced fish biologist, who was familiar with the area in and around the hypothetical mine site and tailings storage facilities, had over-flown the area and observed it, examined satellite imagery, looked with an experienced eye at the photos and data in the EBD, or was familiar with the very large body of published scientific literature could not have concluded that no on-site opportunities for mitigation existed. They are everywhere.

In addition, anyone familiar with Alaska's Water Quality Standards and the water quality data contained in Chapter 9 of the EBD would have realized that EPA's water management scenario was not "realistic" and that **multiple opportunities existed to mitigate fish habitat losses through the manipulation of water chemistry parameters in the WWTP discharge and at other locations in the watersheds to improve primary production and the productive capacity for fish populations.**

Two possible conclusions can be reached, regarding EPA's assertion that no on-site opportunities for mitigation existed:

1. The EPA staff that authored the BBWA2 are ignorant of the scientific literature regarding the techniques and efficacy of salmonid fish habitat improvement and/or totally unfamiliar with the stream geomorphology and/or fish habitats existing within the three watersheds.
2. The EPA deliberately understated the availability of fish habitat mitigation opportunities in order to influence the impact conclusions presented to the general public.

Whatever the reason, the BBWA2 clearly demonstrates that EPA critically failed to present a "scientifically defensible" discussion of potential mitigation measures. In fact, most of the potential measures outlined in Appendix J, came from the public and/or peer reviewers, not EPA staff. This fact alone should raise serious questions regarding the technical competence of EPA's staff to address this issue.

**The bottom line conclusion for this report is that:**

- **EPA failed to use the best readily available science (Section 2 of this report),**
- **EPA failed to understand the applicable published literature on fish habitat improvement (Section 3),**
- **EPA failed to understand the applicability and efficacy of the habitat improvement techniques to their mine development scenarios (Sections 3 and 4),**

- **EPA failed to follow routine scientific methods related to an assessment of this nature, thus exaggerating the magnitude of potential effects on fish habitat/populations and under-estimating the benefit of well-established, successful mitigation measures, and**
- **EPA failed to demonstrate the required technical and professional expertise to develop a mitigation program applicable to their development scenarios (Sections 5 and 6).**

Accordingly, the BBWA2 report is not a scientifically credible document, and its conclusions are unsupported. It is a document that provides a biased, non-objective assessment of the risks/benefits of a mine development at the Pebble location, or elsewhere within the Bristol Bay watershed. It should not be used during future agency/public deliberations on the effects of and mitigation measures for a specific modern mine proposal.

## Section 9

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