United States
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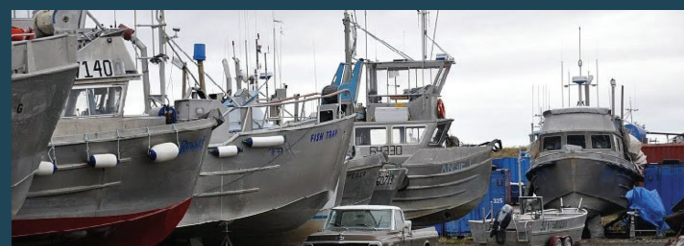
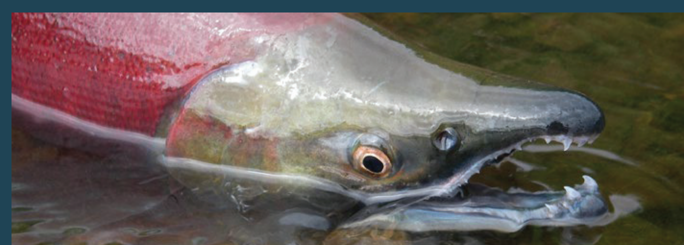
Agency

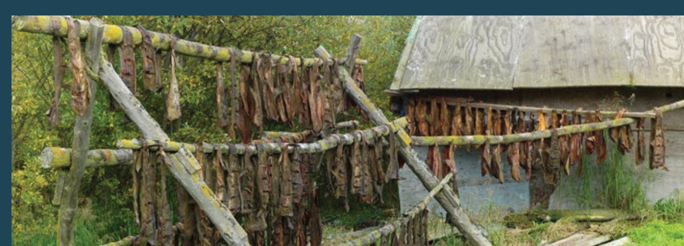
May 2022

Proposed Determination of the U.S. Environmental Protection Agency Region 10 Pursuant to Section 404(c) of the Clean Water Act

Pebble Deposit Area, Southwest Alaska







Region 10, Seattle, WA
www.epa.gov/bristolbay

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U.S. Environmental Protection Agency
Region 10
Seattle, WA

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Acronyms and Abbreviations

AAC	Alaska Administrative Code
ADEC	Alaska Department of Environmental Conservation
ADF&G	Alaska Department of Fish and Game
ADNR	Alaska Department of Natural Resources
AFFI	Alaska Freshwater Fish Inventory
ANCSA	Alaska Native Claims Settlement Act
ANILCA	Alaska National Interest Lands Conservation Act
AS	Alaska Statute
ASA	Alaska Statehood Act
AWC	Anadromous Waters Catalog
BBA	Bristol Bay Assessment
BBAP	Bristol Bay Area Plan for State Lands
BBMA	Bristol Bay Sport Fish Management Area
CAA	Clean Air Act
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
CILEA	Cook Inlet Land Exchange Act
CMP	Compensatory Mitigation Plan
CWA	Clean Water Act
DEIS	Draft Environmental Impact Statement
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
FEIS	Final Environmental Impact Statement
FMEA	Failure Modes Effects Analysis
FR	Federal Register
HUC	Hydrologic Unit Code
ITEK	indigenous traditional ecological knowledge
LEDPA	Least Environmentally Damaging Practicable Alternative
MCO	Mineral Closing Order
ML	metal leaching
MDN	marine-derived nutrients
MOA	Memorandum of Agreement
NDM	Northern Dynasty Minerals, Ltd.
NEPA	National Environmental Policy Act
NFK	North Fork Koktuli River
NHD	National Hydrography Dataset
NMFS	National Marine Fisheries Service
NPS	National Park Service
NWI	National Wetlands Inventory
PAG	potentially acid-generating
PLP	Pebble Limited Partnership
RAP	Riverscape Analysis Project
RFI	Request For Information
ROD	Record of Decision

SEC	U.S. Securities and Exchange Commission
Secretary	Secretary of the Army
SFK	South Fork Koktuli River
TEK	traditional ecological knowledge
TSF	tailings storage facility
TSS	total suspended solids
USACE	U.S. Army Corps of Engineers
U.S.C.	United States Code
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UTC	Upper Talarik Creek
WMP	water management pond
WQC	water quality criteria
WTP	water treatment plant

Cover Photo Credits

Main photo: Upper Talarik Creek (Joe Ebersole, USEPA)
Thumbnail 1: Fishing boats at Naknek, Alaska (USEPA)
Thumbnail 2: Sockeye salmon in the Wood River (Thomas Quinn, University of Washington)
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Thumbnail 4: Age-0 coho salmon in the Chignik watershed (Jonny Armstrong)

EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency (EPA) Region 10 is publishing for public comment this proposed determination (2022 Proposed Determination) to prohibit and restrict the use of certain waters in the Bristol Bay watershed as a disposal site for the discharge of dredged or fill material associated with mining at the Pebble deposit, a large ore body in southwest Alaska. EPA Region 10 is exercising its authority under Section 404(c) of the Clean Water Act (CWA) (Box ES-1) and its implementing regulations at 40 Code of Federal Regulations (CFR) Part 231 because of the unacceptable adverse effects on anadromous[1] fishery areas in the Bristol Bay watershed that could result from discharges of dredged or fill material associated with such mining. Development of a mine at the Pebble deposit and such a mine's potential effects on aquatic resources have been the subject of study for nearly two decades; the 2022 Proposed Determination is based on this extensive record of scientific and technical information. The scope of the 2022 Proposed Determination applies only to specified discharges of dredged or fill material associated with mining the Pebble deposit.

Alaska's Bristol Bay watershed (Figure ES-1) is an area of unparalleled ecological value, boasting salmon diversity and productivity unrivaled anywhere in North America. As a result, the region is a globally significant resource. The Bristol Bay watershed provides intact, connected habitats—from headwaters to ocean—that support abundant, genetically diverse wild Pacific salmon populations. These salmon populations, in turn, help to maintain the productivity of the entire ecosystem, including numerous other fish and wildlife species.

The Bristol Bay watershed's streams, wetlands, and other aquatic resources support a more than 4,000-year-old subsistence-based way of life for Alaska Natives, as well as world-class, economically important commercial and sport fisheries for salmon and other fishes. The Bristol Bay watershed supports the world's largest runs of Sockeye Salmon, producing approximately half of the world's Sockeye Salmon. These Sockeye Salmon represent the most abundant and diverse populations of this species remaining in the United States. Bristol Bay's Chinook Salmon runs are also frequently at or near the world's largest, and the region also supports significant Coho, Chum, and Pink salmon populations. Because no hatchery fishes are raised or released in the watershed, Bristol Bay's salmon populations are entirely wild and self-sustaining. Bristol Bay is remarkable as one of the last places on Earth with such bountiful and sustainable harvests of wild salmon. One of the main factors leading to the success of this fishery is the fact that its diverse aquatic habitats are largely untouched and pristine, unlike the waters that support many other salmon fisheries worldwide.

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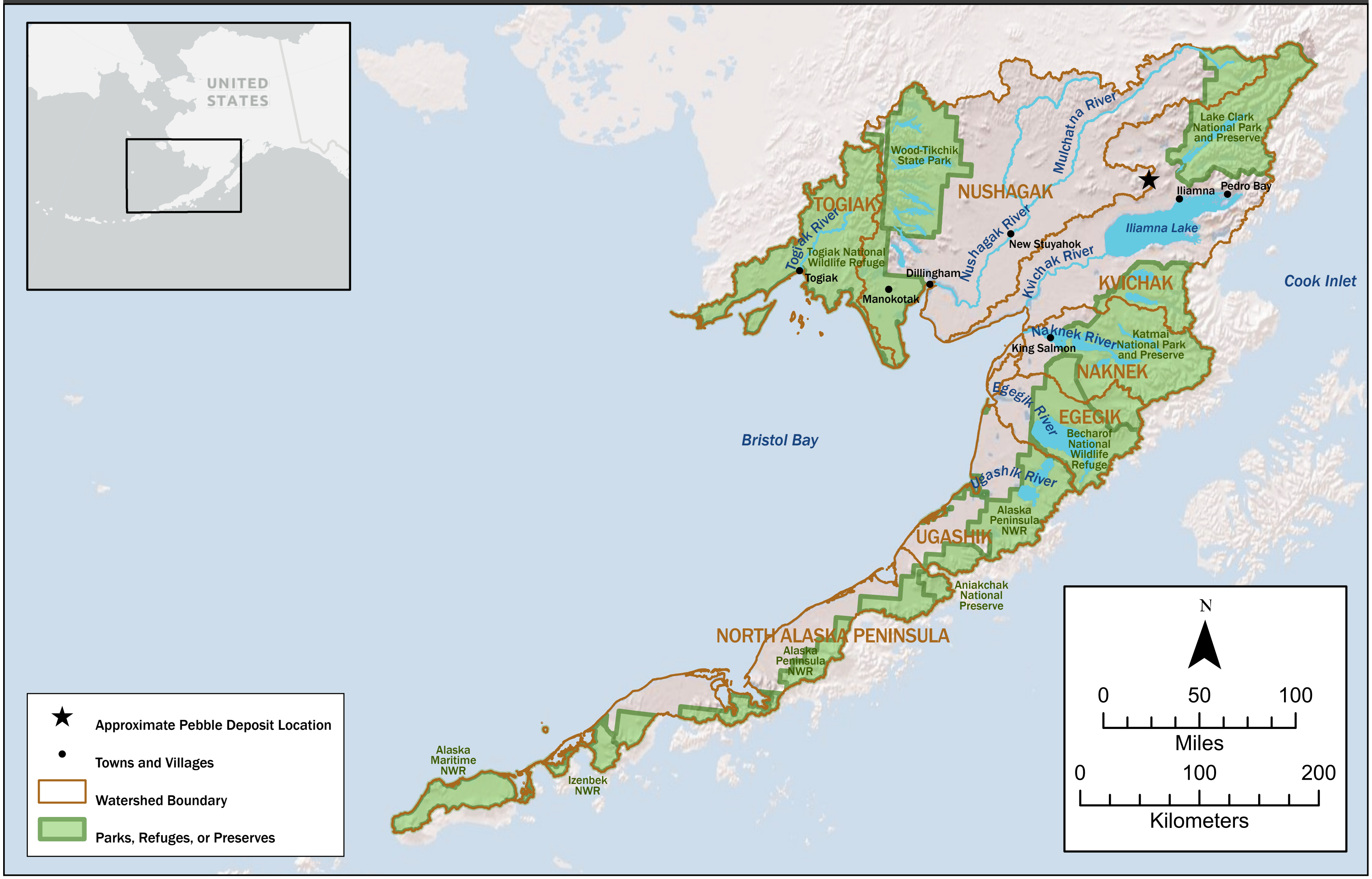
[1] Anadromous fishes are those that hatch in freshwater habitats, migrate to sea for a period of relatively rapid growth, and then return to freshwater habitats to spawn. For the purposes of the 2022 Proposed Determination, "anadromous fishes" refers only to Coho or Silver salmon (*Oncorhynchus kisutch*), Chinook or King salmon (*O. tshawytscha*), Sockeye or Red salmon (*O. nerka*), Chum or Dog salmon (*O. keta*), and Pink or Humpback almon (*O. gorbuscha*).

Figure ES-1. The Bristol Bay watershed, composed of the Togiak, Nushagak, Kvichak, Naknek, Egegik, and Ugashik River watersheds and the North Alaska Peninsula. Only selected towns and villages are shown on this map.



Nearly 70 percent of Bristol Bay's Sockeye and large numbers of its Coho, Chinook, Pink, and Chum salmon are sustainably harvested in subsistence, commercial, and recreational fisheries before they can return to their natal lakes and streams to spawn. Thus, these salmon resources have significant nutritional, cultural, economic, and recreational value, both within and beyond the Bristol Bay region. The total economic value of the Bristol Bay watershed's salmon resources, including subsistence uses, was estimated at more than $2.2 billion in 2019 (McKinley Research Group 2021). The Bristol Bay commercial salmon fishery generates the largest component of this economic activity, resulting in 15,000 jobs and an economic benefit of $2.0 billion in 2019, $990 million of which was in Alaska (McKinley Research Group 2021). Section 3 of the 2022 Proposed Determination provides an overview of the streams, wetlands, and other aquatic resources of the Bristol Bay watershed and discusses their role in supporting important subsistence, commercial, and recreational fisheries.

BOX ES-1. SECTION 404 OF THE CLEAN WATER ACT

The objective of the Clean Water Act (CWA) is to restore and maintain the chemical, physical, and biological integrity of the nation's waters. Section 404(c) of the CWA authorizes the U.S. Environmental Protection Agency (EPA) to (1) prohibit or withdraw the specification of any defined area in waters of the United States as a disposal site, and (2) restrict, deny, or withdraw the use of any defined area in waters of the United States for specification as a disposal site whenever it determines, after notice and opportunity for public hearing, that the discharge of dredged or fill material into the area will have an unacceptable adverse effect on municipal water supplies, shellfish beds and fishery areas (including spawning and breeding areas), wildlife, or recreational areas. EPA has used its Section 404(c) authority judiciously, having completed only 13 Section 404(c) actions in the 50-year history of the CWA.

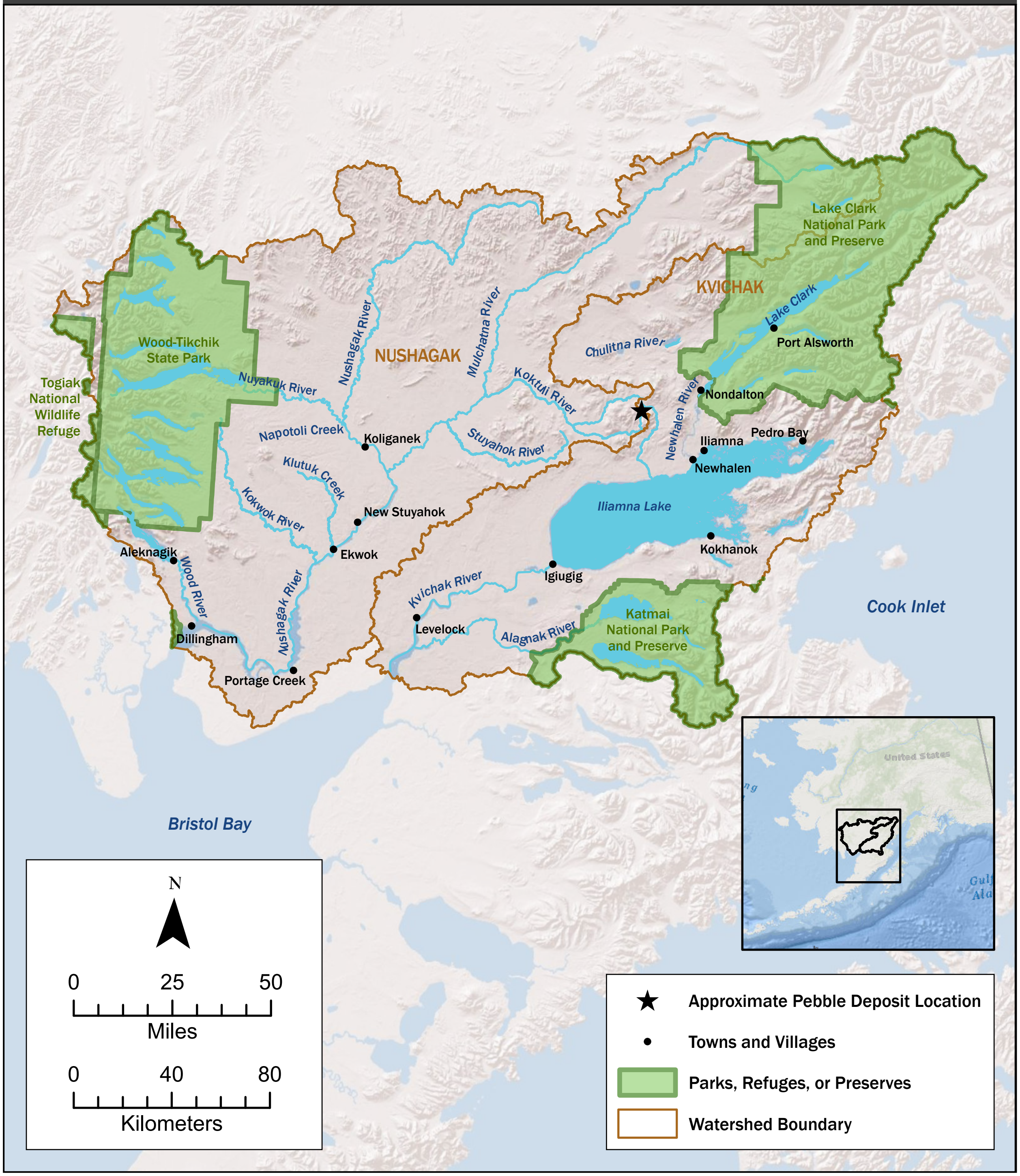
Proposed Mine at the Pebble Deposit

The Pebble deposit, a large, low-grade deposit containing copper-, gold-, and molybdenum-bearing minerals, is located at the headwaters of the pristine Bristol Bay watershed. The Pebble deposit underlies portions of the South Fork Koktuli River (SFK), North Fork Koktuli River (NFK), and Upper Talarik Creek (UTC) watersheds. The SFK, NFK, and UTC drain to two of the largest rivers in the Bristol Bay watershed, the Nushagak and Kvichak Rivers (Figure ES-2).

Since 2001, Northern Dynasty Minerals Ltd. (NDM) and subsequently the Pebble Limited Partnership (PLP)[2] have been conducting data collection and analysis as part of efforts to pursue the development of a large-scale mine at the Pebble deposit. Construction and operation of a mine at the Pebble deposit would necessitate the discharge of dredged or fill material into wetlands, streams, and other waters of

[2] PLP was created in 2007 by co-owners NDM and Anglo American PLC to design, permit, construct, and operate a long-life mine at the Pebble deposit (Ghaffari et al. 2011). In 2013, NDM acquired Anglo American's interest in PLP, and NDM now holds a 100 percent interest in PLP (Kalanchey et al. 2021).

Figure ES-2. Major water bodies within the Nushagak and Kvichak River watersheds.



the United States and would, therefore, require a CWA Section 404 permit from the U.S. Army Corps of Engineers (USACE). In December 2017, PLP submitted a CWA Section 404 permit application to USACE to develop a mine at the Pebble deposit, which triggered the development of an Environmental Impact Statement (EIS) pursuant to the National Environmental Policy Act (NEPA). In response to the Section 404 permit review/NEPA review process, PLP submitted a revised permit application in June 2020 (the 2020 Mine Plan) (PLP 2020b).

In the 2020 Mine Plan, PLP proposes to develop the Pebble deposit as a surface mine at which 1.3 billion tons of ore would be mined over 20 years. The project consists of four primary elements: (1) the mine site situated in the SFK, NFK, and UTC watersheds (Figure ES-3); (2) the Diamond Point port; (3) the transportation corridor, including concentrate and water return pipelines; and (4) the natural gas pipeline and fiber optic cable. The first element, a fully developed mine site, would include an open pit, bulk tailings storage facility (TSF), pyritic TSF, a 270-megawatt power plant, water management ponds (WMPs), water treatment plants (WTPs), milling and processing facilities, and supporting infrastructure (Figure ES-4). Under the 2020 Mine Plan, PLP would progress through four distinct mine phases: construction, operations (also referred to as production), closure, and post-closure. The construction period would last approximately four years, followed by 20 years of operation. Closure, including physical reclamation of the mine site, is projected to take approximately 20 years. Post-closure activities, including long-term water management and monitoring, would last for centuries (USACE 2020a).

On July 24, 2020, USACE published a Notice of Availability for the Final EIS (FEIS) in the *Federal Register* (USACE 2020a), and on November 20, 2020, USACE issued its Record of Decision (ROD) denying PLP's CWA Section 404 permit application on the basis that the 2020 Mine Plan would not comply with the CWA Section 404(b)(1) Guidelines and would be contrary to the public interest (USACE 2020b). By letter dated November 25, 2020, USACE notified PLP that the proposed project failed to comply with the CWA Section 404(b)(1) Guidelines because, even after consideration of proposed mitigation measures, "the proposed project would cause unavoidable adverse impacts to aquatic resources which would result in Significant Degradation to aquatic resources."

On January 19, 2021, PLP filed a request for an appeal of the USACE permit denial with USACE. USACE accepted the appeal on February 25, 2021, and review of the appeal is ongoing.

The USACE permit denial addresses only PLP's specific permit application for the 2020 Mine Plan; it does not address other future plans to mine the Pebble deposit that would have adverse effects similar or greater in nature and magnitude to the 2020 Mine Plan. Information regarding the Pebble deposit and the 2020 Mine Plan can be found in Section 2 of the 2022 Proposed Determination.

Figure ES-3. Mine site hydrography. Figure 2-1 from PLP's June 8, 2020, Clean Water Act Section 404 permit application (PLP 2020b).

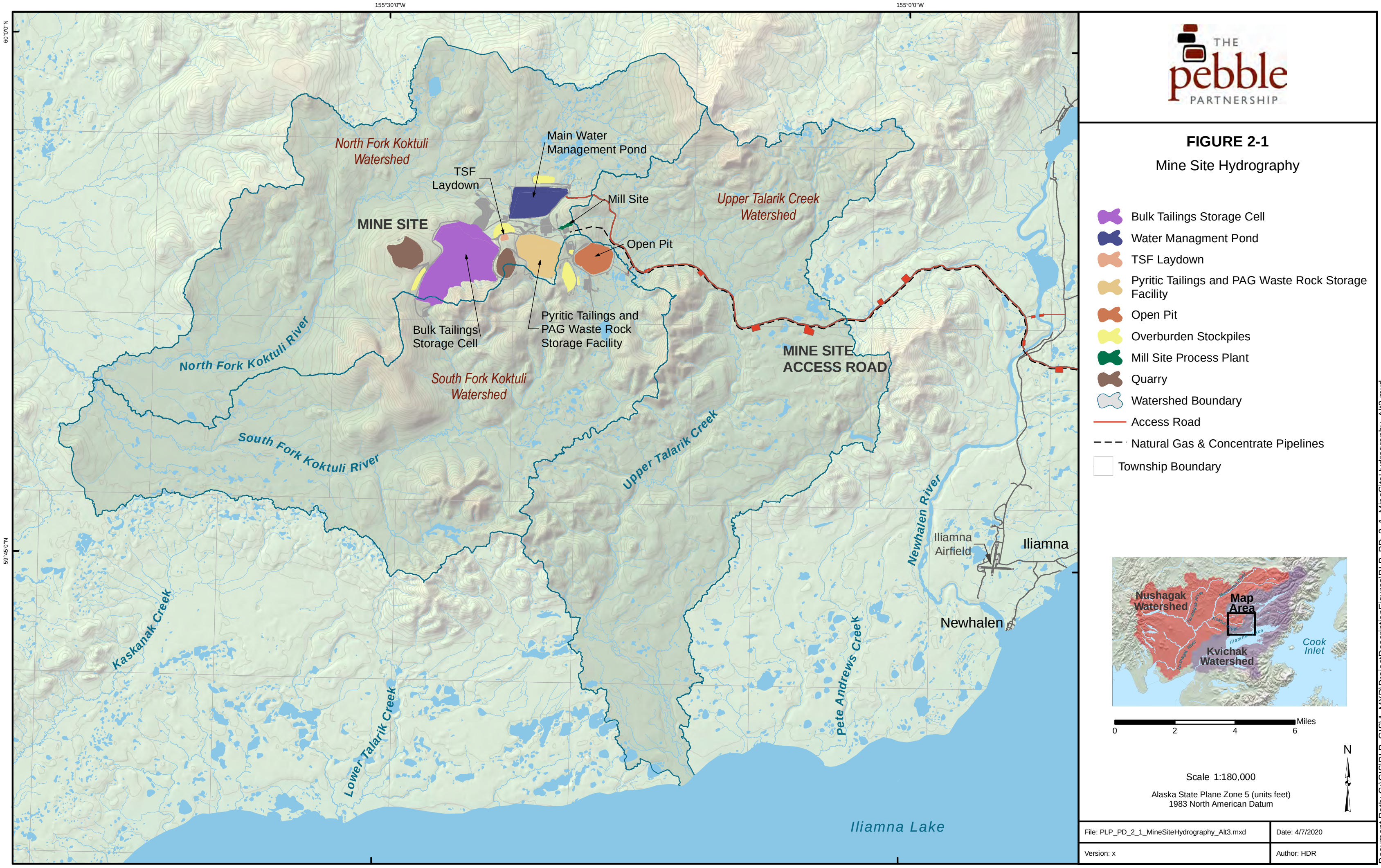
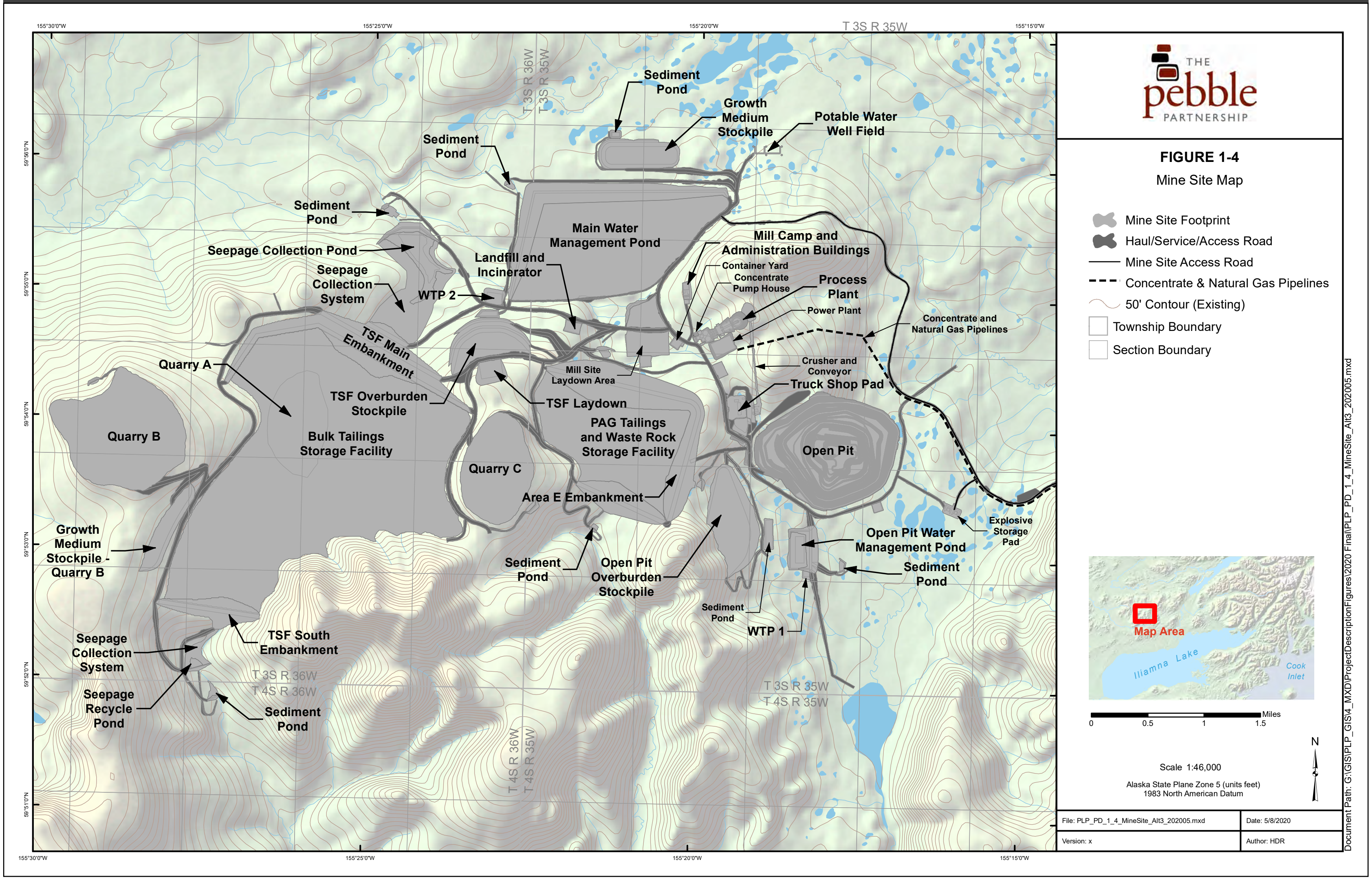


Figure ES-4. Mine site map. Figure 1-4 from PLP's June 8, 2020, Clean Water Act Section 404 permit application (PLP 2020b).



2014 Proposed Determination

For more than a decade, Alaska Native communities in the Bristol Bay watershed; subsistence, commercial, and recreational fishing interests; conservation groups; and others have raised concerns about the potential impacts a large-scale mine at the Pebble deposit could have on the region's socially, ecologically, and economically important fishery areas. Starting in May 2010, these groups and others began requesting that EPA use its CWA Section 404(c) authority to protect the region's fishery areas. In February 2011, EPA decided to conduct an ecological risk assessment before considering any additional steps. In January 2014, after three years of study, two rounds of public comment, and independent, external peer review, EPA released its *Assessment of Potential Mining Impacts on Salmon Ecosystems of Bristol Bay, Alaska*[3] (Bristol Bay Assessment or BBA) (EPA 2014). In July 2014, after careful consideration of available information, including the findings of the BBA and consultation with PLP and the State of Alaska, EPA Region 10 published a proposed determination under Section 404(c) of the CWA to restrict the use of certain waters in the SFK, NFK, and UTC watersheds as disposal sites for dredged or fill material associated with mining the Pebble deposit (2014 Proposed Determination) for public comment.

As a result of litigation brought by PLP, EPA Region 10's CWA Section 404(c) review process was halted in November 2014, until EPA and PLP resolved the case in a May 2017 settlement agreement. As part of that settlement agreement, EPA Region 10 proposed to withdraw the 2014 Proposed Determination. EPA ultimately withdrew the 2014 Proposed Determination in August 2019. In October 2019, 20 tribal, fishing, environmental, and conservation groups challenged EPA's withdrawal of the 2014 Proposed Determination. The ultimate result of the litigation was an October 29, 2021 decision by the U.S. District Court for the District of Alaska to vacate EPA's 2019 decision to withdraw the 2014 Proposed Determination and remand the action to the Agency for reconsideration.

The District Court's vacatur of EPA's 2019 decision to withdraw the 2014 Proposed Determination had the effect of reinstating the 2014 Proposed Determination and reinitiating EPA's CWA Section 404(c) review process. The next step in the CWA Section 404(c) review process required the Region 10 Regional Administrator to decide whether to withdraw the 2014 Proposed Determination or prepare a recommended determination within 30 days. On November 23, 2021, EPA Region 10 published in the *Federal Register* a notice extending the applicable time requirements through May 31, 2022, to provide sufficient time to consider available information and determine the appropriate next step in the CWA Section 404(c) review process. In its notice, EPA concluded that it should consider information that had become available since EPA issued the 2014 Proposed Determination. Information regarding the 2014 Proposed Determination and the history of EPA's work in the Bristol Bay watershed can be found in Section 2 of the 2022 Proposed Determination.

[3] For more information about EPA's efforts in Bristol Bay or copies of the Bristol Bay Assessment, see http://www.epa.gov/bristolbay.

2022 Proposed Determination

EPA Region 10 considered a wide array of information that has become available since it issued the 2014 Proposed Determination, including the following:

- More than 670,000 public comments submitted to EPA Region 10 in response to the 2014 Proposed Determination.
- PLP's CWA Section 404 permit application, including the 2020 Mine Plan (PLP 2020b).
- USACE's FEIS evaluating the 2020 Mine Plan, including the FEIS appendices, technical support documents, and references (USACE 2020a).
- EPA's and the U.S. Fish and Wildlife Service's 12-week coordination process with USACE in Spring 2020 to evaluate PLP's proposed project for compliance with the CWA Section 404(b)(1) Guidelines.
- USACE's ROD denying PLP's CWA Section 404 permit application for the 2020 Mine Plan, including the ROD supporting documents (USACE 2020b).
- NDM's *Pebble Project Preliminary Economic Assessment* dated September 9, 2021 (Kalanchey et al. 2021).
- Updated data regarding fishery resources in the Bristol Bay watershed.
- New scientific and technical publications.

In January 2022, consistent with its regulatory procedures for proposed determinations at 40 CFR 231.3(a), EPA Region 10 notified USACE, Alaska Department of Natural Resources (ADNR), PLP, Pebble East Claims Corporation, Pebble West Claims Corporation, and Chuchuna Minerals[4] (the Parties) of EPA Region 10's intention to issue a revised proposed determination because, based on a review of information available to that date, it continued to believe that the discharge of dredged or fill material associated with mining the Pebble deposit could result in unacceptable adverse effects on fishery areas. EPA Region 10 provided the Parties with an opportunity to submit information that demonstrated that no unacceptable adverse effects would result from discharges associated with mining the Pebble deposit or that actions could be taken to prevent unacceptable adverse effects on fishery areas.

ADNR, PLP, and Chuchuna Minerals submitted information asserting legal, policy, scientific, and technical issues. As discussed in Section 2.2.2 of the 2022 Proposed Determination, this information did not demonstrate to the satisfaction of EPA Region 10 that no unacceptable adverse effects would occur as a result of the discharge of dredged or fill material associated with mining the Pebble deposit. Accordingly, consistent with 40 CFR 231.3(a)(2), EPA Region 10 is publishing a public notice of the 2022 Proposed Determination because EPA Region 10 continues to have reason to believe that the discharge

[4] EPA Region 10 notified Chuchuna Minerals because USACE's FEIS for the 2020 Mine Plan indicates that it is reasonably foreseeable for discharges associated with mining the Pebble deposit to expand in the future into portions of areas where Chuchuna Minerals holds mining claims.

of dredged or fill material associated with mining at the Pebble deposit could result in unacceptable adverse effects on anadromous fishery areas. Section 4 of the 2022 Proposed Determination provides the basis for EPA Region 10's findings regarding unacceptable adverse effects on anadromous fishery areas.

As demonstrated in the FEIS and ROD, construction and routine operation of the mine proposed in the 2020 Mine Plan would result in the discharge of dredged or fill material into waters of the United States, including streams, wetlands, lakes, and ponds overlying the Pebble deposit and within adjacent watersheds. The direct effects (i.e., resulting from placement of fill in aquatic habitats) and certain secondary effects of such discharges (i.e., associated with a discharge of dredged or fill material, but not resulting from the actual placement of such material) would result in the total loss of aquatic habitats important to anadromous fishes. These losses are the result of the construction and routine operation of the various components of the mine site, including the open pit, bulk TSF, pyritic TSF, power plant, WMPs, WTPs, milling/processing facilities, and supporting infrastructure. According to the FEIS and ROD, discharges of dredged or fill material to construct and operate the mine site proposed in the 2020 Mine Plan would result in the total loss of approximately 99.7 miles (160.5 km) of stream habitat, representing approximately 8.5 miles (13.7 km) of anadromous fish streams and 91.2 miles (146.8 km) of additional streams that support anadromous fish streams. Such discharges of dredged or fill material also would result in the total loss of approximately 2,113 acres (8.6 km^2) of wetlands and other waters that support anadromous fish streams.

Additional secondary effects of the proposed discharges of dredged or fill material at the mine site would degrade anadromous fishery areas downstream of the mine site. Specifically, the stream, wetland, and other aquatic resource losses from the footprint of the 2020 Mine Plan would reverberate downstream, depriving downstream anadromous fish habitats of nutrients, groundwater inputs, and other ecological subsidies from lost upstream aquatic resources. Further, streamflow alterations from water capture, withdrawal, storage, treatment, or release at the mine site are another secondary effect of the discharge of dredged or fill material associated with the construction and routine operation of the 2020 Mine Plan. Such streamflow alterations would adversely affect at least 29 miles (46.7 km) of anadromous fish streams downstream of the mine site due to greater than 20 percent changes in average monthly streamflow.[5] These streamflow alterations would result in major changes in ecosystem structure and function and would reduce both the extent and quality of anadromous fish habitat downstream of the mine. As recognized in the FEIS, all instances of complete loss of aquatic habitat and most impairment to fish habitat function would be permanent.

Although Alaska has many streams and wetlands that support salmon, individual streams, stream reaches, wetlands, lakes, and ponds play a critical role in supporting individual salmon populations and

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[5] Streamflow alterations would vary seasonally. Streamflow reductions exceeding 20 percent of average monthly streamflow would occur in at least one month per year in at least 13.1 miles (21.4 km) of anadromous fish streams downstream of the mine site, and operation of the 2020 Mine Plan would increase streamflow by more than 20 percent of baseline average monthly streamflow in at least 25.7 miles (41.3 km) of downstream anadromous fish streams due to WTP discharges.

protecting the genetic diversity of Bristol Bay's wild salmon populations. The diverse array of watershed features across the region creates and sustains a diversity of aquatic habitats that support multiple populations of salmon with asynchronous run timings and habitat use patterns (i.e., biocomplexity, after Hilborn et al. 2003). These population differences are reflected in salmon genetic diversity and adaptation to local conditions within Bristol Bay's component watersheds (e.g., Quinn et al. 2012) and provide stability to the overall system (Schindler et al. 2010). Impacts of the 2020 Mine Plan are concentrated in the SFK and NFK watersheds, which are a part of the Nushagak River watershed. Recent analysis specific to the Nushagak River watershed underscores the important role that the streams, wetlands, lakes, and ponds across the entire Nushagak River watershed, including those that would be adversely affected by the 2020 Mine Plan, play in stabilizing the Nushagak River's productive Sockeye and Chinook salmon fisheries (Brennan et al. 2019). Similarly, both the Koktuli River (the SFK and NFK are tributaries to the Koktuli River) and UTC have been documented to support genetically distinct populations of Sockeye Salmon (Dann et al. 2012, Shedd et al. 2016, Dann et al. 2018). Loss of salmon habitats and associated salmon diversity in the SFK, NFK, and UTC watersheds would erode both the habitat complexity and biocomplexity that help buffer these populations from sudden and extreme changes in abundance and ultimately maintain their productivity.

In addition to supporting genetically distinct salmon populations, the streams and wetlands draining the Pebble deposit area provide key habitat for numerous other fish species and supply water, invertebrates, organic matter, and other resources to downstream waters (Meyer et al. 2007, Colvin et al. 2019, Koenig et al. 2019). This is particularly true in dendritic stream networks like the SFK, NFK, and UTC systems, which have a high density of headwater streams. As a result, headwater streams and wetlands play a vital role in maintaining diverse, abundant anadromous fish populations—both by providing important fish habitat and supplying the energy and other resources needed to support anadromous fishes in connected downstream habitats.

EPA Region 10 believes the discharge of dredged or fill material for the construction and routine operation of the 2020 Mine Plan could result in unacceptable adverse effects on anadromous fishery areas in the SFK and NFK watersheds. In this regard, EPA makes four independent unacceptability findings, each of which is based on one or more factors, including the large amount of permanent loss of anadromous fish habitat (including spawning and breeding areas); the particular importance of the permanently lost habitat for juvenile Coho and Chinook salmon; the degradation of additional downstream spawning and rearing habitat for Coho, Chinook, and Sockeye salmon due to the loss of ecological subsidies provided by the eliminated anadromous fish streams; and the resulting erosion of both habitat complexity and biocomplexity within the SFK and NFK watersheds, which are key to the abundance and stability of salmon populations within these watersheds. This conclusion supports the proposed prohibition described in Section 5.1 of the 2022 Proposed Determination.

Further, EPA Region 10 believes the discharge of dredged or fill material for the construction and routine operation of a mine at the Pebble deposit anywhere in the SFK, NFK, and UTC watersheds could result in unacceptable adverse effects on anadromous fishery areas if the effects of such discharges are similar or greater in nature and magnitude to the adverse effects of the 2020 Mine Plan. In this regard, EPA makes four independent unacceptability findings, each of which is based on one or more factors, including the pristine condition and productivity of anadromous habitat throughout the SFK, NFK, and UTC watersheds; the large amount of permanent loss of anadromous fish habitat; the degradation of additional downstream spawning and rearing habitat for Coho, Chinook, and Sockeye salmon due to the loss of ecological subsidies provided by the eliminated streams, wetlands, and other waters; and the resulting erosion of both habitat complexity and biocomplexity within the SFK, NFK, and UTC watersheds, which are key to the abundance and stability of salmon populations within these watersheds. This conclusion supports the proposed restriction described in Section 5.2 of the 2022 Proposed Determination.

Based on the foregoing, EPA Region 10 determined that the appropriate next step in this CWA Section 404(c) review process was to revise the 2014 Proposed Determination.

Overview of Prohibition and Restriction in the 2022 Proposed Determination

The 2022 Proposed Determination includes two parts: a proposed prohibition and a proposed restriction, which are described in more detail in Sections 5.1 and 5.2, respectively.

Proposed Prohibition

The EPA Region 10 Regional Administrator has reason to believe that discharges of dredged or fill material for the construction and routine operation of the mine at the Pebble deposit identified in the 2020 Mine Plan (PLP 2020b) could result in unacceptable adverse effects on anadromous fishery areas in the SFK and NFK watersheds. Based on information in PLP's CWA Section 404 permit application, the FEIS, and the ROD, such discharges would have the following impacts on aquatic resources:

- The loss of approximately 8.5 miles (13.7 km) of documented anadromous fish streams (Section 4.2.1).
- The loss of approximately 91.2 miles (146.8 km) of additional streams that support anadromous fish streams (Section 4.2.2).
- The loss of approximately 2,113 acres (8.6 km^2) of wetlands and other waters that support anadromous fish streams (Section 4.2.3).
- Adverse impacts to at least 29 additional miles (46.7 km) of anadromous fish streams resulting from greater than 20 percent changes in average monthly streamflow (Section 4.2.4).

Sections 4.2.1 through 4.2.4 describe the basis for EPA Region 10's determination that each of the above impacts could, independently, result in unacceptable adverse effects on anadromous fishery areas (including spawning and breeding areas).

Accordingly, the Regional Administrator proposes that EPA prohibit the specification of waters of the United States within the mine site footprint for the 2020 Mine Plan located in the SFK and NFK watersheds (Figure ES-4) (PLP 2020b) as disposal sites for the discharge of dredged or fill material for the construction and routine operation of the 2020 Mine Plan (PLP 2020b, USACE 2020a: Appendix J). The Defined Area for Prohibition is the portion of the mine site footprint for the 2020 Mine Plan within the SFK and NFK watersheds (Figure ES-4) (PLP 2020b). The discharges prohibited in the Defined Area for Prohibition are dredged or fill material for the construction and routine operation of the 2020 Mine Plan.

Proposed Restriction

Based on the same record, the Regional Administrator has reason to believe that discharges of dredged or fill material associated with future plans to mine the Pebble deposit could result in unacceptable adverse effects on anadromous fishery areas anywhere in the SFK, NFK, and UTC watersheds if the effects of such discharges are similar or greater in nature[6] and magnitude[7] to the adverse effects of the 2020 Mine Plan described in Sections 4.2.1 through 4.2.4 of the 2022 Proposed Determination.

Accordingly, the Regional Administrator proposes to restrict the use of waters of the United States within the Defined Area for Restriction (Figures ES-5 and ES-6) for specification as disposal sites for the discharge of dredged or fill material for the construction and routine operation of any future plan to mine the Pebble deposit that would either individually or collectively result in adverse effects similar or greater in nature and magnitude to those described in Sections 4.2.1 through 4.2.4 of the 2022 Proposed Determination. Because each of the impacts described in Sections 4.2.1 through 4.2.4 could, independently, result in unacceptable adverse effects on anadromous fishery areas, a proposal that triggers any one of these four unacceptability findings would be subject to the restriction.

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[6] *Nature* means "the type or main characteristic of something" (see Cambridge Dictionary available at: https://dictionary.cambridge.org/us/dictionary/english/nature).

[7] *Magnitude* means "the large size or importance of something" (see Cambridge Dictionary available at: https://dictionary.cambridge.org/us/dictionary/english/magnitude).

Figure ES-5. The Defined Area for Restriction and the defined area for prohibition overlain on wetlands from the National Wetlands Inventory (USFWS 2021).

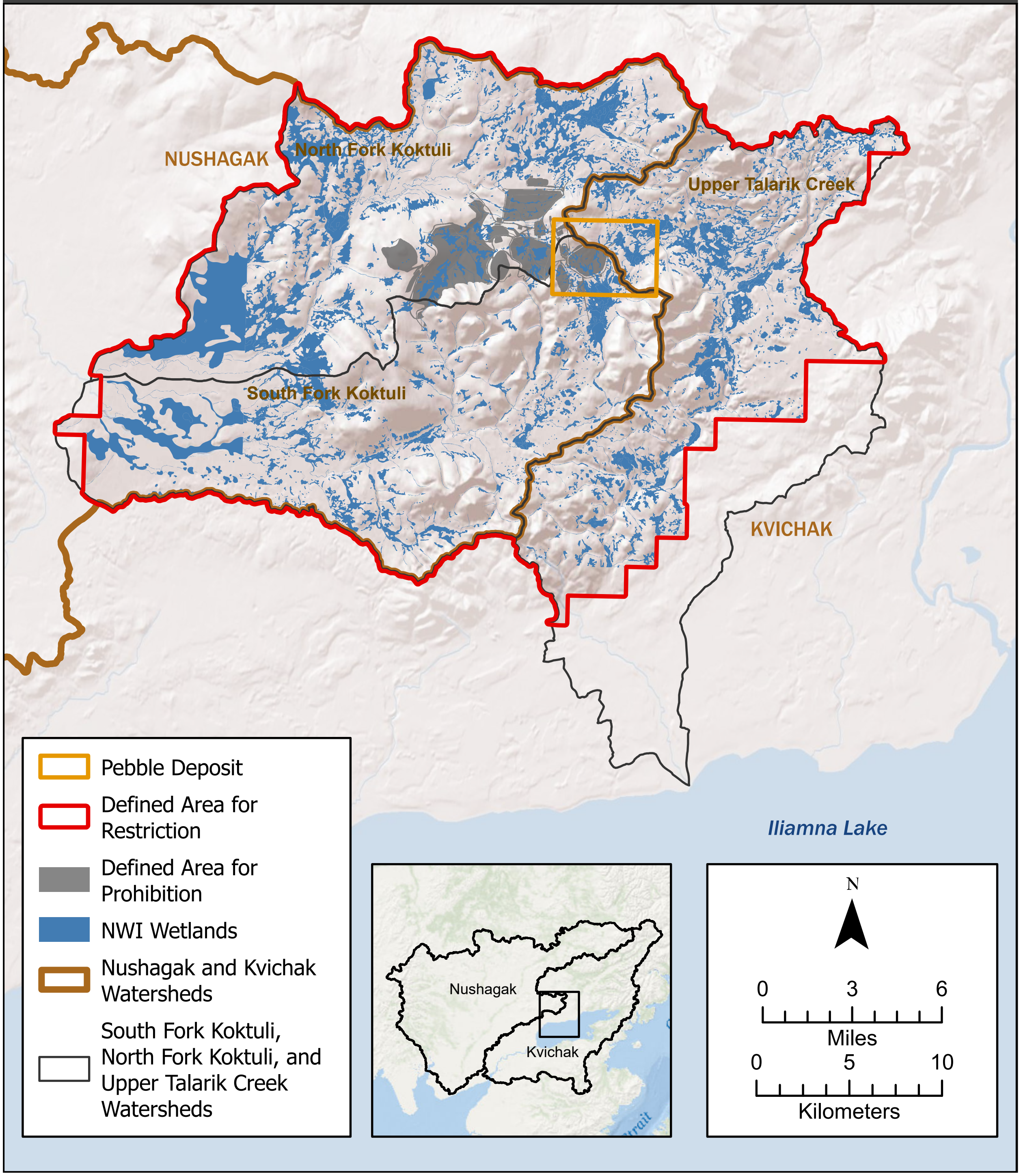
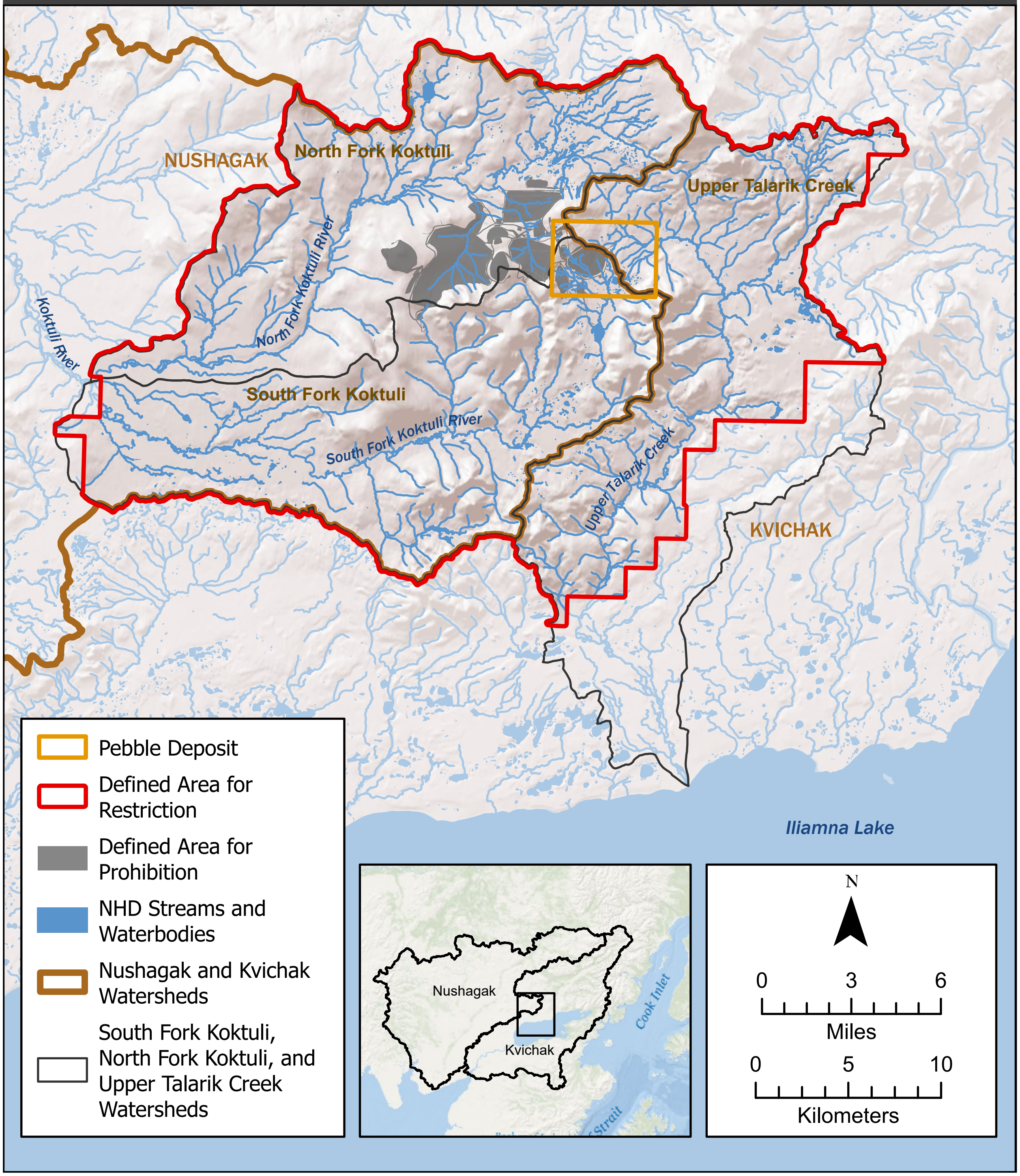


Figure ES-6. The Defined Area for Restriction and the defined area for prohibition overlain on streams and waterbodies from the National Hydrography Dataset (USGS 2021).



Evaluation of Portions of the CWA Section 404(b)(1) Guidelines

EPA's Section 404(c) regulations provide that consideration should be given to the "relevant portions of the Section 404(b)(1) Guidelines" in evaluating the "unacceptability" of effects (40 CFR 231.2(e)). EPA Region 10's consideration of the relevant portions of the Section 404(b)(1) Guidelines further confirm EPA's proposed unacceptable adverse effects finding.

Specifically, EPA Region 10 has determined that direct and secondary effects of the discharge of dredged or fill material for the construction and routine operation of the 2020 Mine Plan, as well as discharges that would result in effects similar or greater in nature and magnitude to the 2020 Mine Plan, would result in significant degradation under the Section 404(b)(1) Guidelines. These findings are based on the significantly adverse effects of the discharge of dredged or fill material on special aquatic sites, life stages of anadromous fishes, anadromous fish habitat, and aquatic ecosystem diversity, productivity, and stability under the Section 404(b)(1) Guidelines.

Region 10 evaluated PLP's two compensatory mitigation plans and neither plan adequately mitigates adverse effects described in the 2022 Proposed Determination to an acceptable level. EPA Region 10 also evaluated additional potential compensation measures for informational purposes. Available information demonstrates that known compensation measures are unlikely to adequately mitigate effects described in the 2022 Proposed Determination to an acceptable level. Information regarding the evaluation of the Section 404(b)(1) Guidelines can be found in Section 4.3 of the 2022 Proposed Determination.

Information about Other Adverse Effects of Concern on Aquatic Resources

While not a basis for EPA Region 10's 2022 Proposed Determination, EPA Region 10 has identified additional potential adverse effects of concern on aquatic resources within the SFK, NFK, and UTC watersheds associated with discharges of dredged or fill material from mining the Pebble deposit and is presenting this discussion solely for informational purposes. First, adverse effects could result from accidents and failures, such as a tailings dam failure. Uncertainty exists as to whether severe accidents or failures could be prevented over a management horizon of centuries (or in perpetuity), particularly in such a geographically remote area. If such events were to occur, they would have profound ecological ramifications. Second, there are potential adverse impacts associated with the ancillary project components along the transportation corridor and at the Diamond Point port. Third, there are potential adverse impacts associated with the reasonably foreseeable expansion of the 2020 Mine Plan evaluated in the FEIS. The FEIS finds that it is reasonably foreseeable that the 2020 Mine Plan would expand in the future into a plan that would mine approximately 8.6 billion tons of ore over 78 years. The FEIS estimates that the discharge of dredged or fill material for the construction and operation of this expanded mine would result in the total loss of approximately 430 miles (6921 km) of streams at the expanded mine site, representing approximately 43.5 miles (70 km) of anadromous fish streams and approximately 386 miles (621 km) of additional streams that support anadromous fish streams. Further, the FEIS estimates that discharges of dredged or fill material to construct and operate the expanded mine site would also result in the total loss of more than 10,800 acres (43.7 km^2) of wetlands and other waters that support anadromous fish streams. These would represent extraordinary and unprecedented levels of anadromous fish habitat loss and degradation, dramatically expanding the unacceptable adverse effects identified for the 2020 Mine Plan. For example, significant additional anadromous fish habitat losses and degradation in SFK, NFK, and UTC caused by future expansion of the mine would threaten genetically distinct Sockeye Salmon populations in both the Koktuli River and UTC.

See Section 6 of the 2022 Proposed Determination for a discussion of other concerns and considerations that EPA describes for informational purposes but do not serve as a basis for its findings.

Authority and Justification for Undertaking a CWA Section 404(c) Review at this Time

EPA may act "whenever" it makes the required determination under the statute and regulations. The Agency may use its CWA Section 404(c) authority "at any time," including before a permit application has been submitted, at any point during the permitting process, and after a permit has been issued (33 U.S.C. 1344(c); 40 CFR 231.1(a), (c); *Mingo Logan Coal Co. v. EPA,* 714 F.3d 608, 613 (D.C. Cir. 2013)).

Congress enacted CWA Section 404(c) to provide EPA the ultimate authority, if it chooses on a case-by-case basis, to make decisions regarding specification of disposal sites for dredged and fill material discharges under CWA Section 404 (*Mingo Logan Coal Co. v. EPA*, 714 F.3d 608, 612-13 (D.C. Cir. 2013)). EPA Region 10 has reviewed the available information, including the permitting record, and the record supports the findings reported in the 2022 Proposed Determination.

If EPA acts now, based on an extensive and carefully considered record, EPA, USACE, and the regulated community can avoid unnecessary expenditure of resources. By acting now, EPA clarifies its assessment of the effects of discharges for the construction and routine operation of the 2020 Mine Plan in light of the importance of the anadromous fishery areas at issue[8] and, therefore, promotes regulatory certainty for all stakeholders.

It also promotes transparency, clarity, and predictability for EPA to act now to restrict discharges for the construction and routine operation of a mine at the Pebble deposit anywhere in the SFK, NFK, and UTC watersheds that would either individually or collectively result in adverse effects similar or greater in nature and magnitude to those associated with the 2020 Mine Plan. By including this restriction, EPA is providing clarity to the regulated community and all interested stakeholders, which will help avoid unnecessary costs and investments. The federal government, the State of Alaska, federally recognized

[8] In this proposed determination, EPA Region 10 has concluded that each of the impacts on aquatic resources identified in Sections 4.2.1 through 4.2.4 could, independently, result in unacceptable adverse effects. That finding is distinguishable from the USACE permit denial, in which USACE reached its conclusions based on consideration of total project impacts to aquatic resources.

tribal governments, PLP, and many interested stakeholders have devoted significant resources over many years of engagement and review. Considering the extensive record before EPA supporting this restriction, EPA believes that it would not be reasonable or necessary to engage in another multi-year NEPA and CWA Section 404 review process for future plans[9] that propose to discharge dredged or fill material in the Defined Area for Restriction that could result in effects that are similar or greater in nature and magnitude to effects of the 2020 Mine Plan. Ultimately, proposing the restriction now provides the most effective, transparent, and predictable protection of anadromous fishery areas throughout the Defined Area for Restriction from discharges that could result in unacceptable adverse effects on the valuable anadromous fishery areas within the SFK, NFK, and UTC watersheds.

Conclusion

After evaluating available information, EPA Region 10 has reason to believe that unacceptable adverse effects on anadromous fishery areas (including spawning and breeding areas) could result from the discharge of dredged or fill material associated with mining at the Pebble deposit as identified in the 2020 Mine Plan.

EPA Region 10 is soliciting public comment on all issues discussed in the 2022 Proposed Determination. EPA Region 10 will fully consider all comments as it decides whether to withdraw the 2022 Proposed Determination or forward to EPA Headquarters a recommended determination. If EPA Region 10 prepares a recommended determination and forwards it to EPA Headquarters, EPA Headquarters will review the recommended determination, public comments received on the proposed determination, and all other available relevant information, and issue a final determination affirming, modifying, or rescinding Region 10's recommended determination.

[9] USACE's denial of PLP's permit application does not address other plans to mine the Pebble deposit that would have adverse effects similar or greater in nature and magnitude to the 2020 Mine Plan.

SECTION 1. INTRODUCTION

The Clean Water Act (CWA), 33 U.S. Code (U.S.C.) § 1251 et seq., prohibits the discharge of pollutants, including dredged or fill material, into waters of the United States (including wetlands) except in compliance with, among other provisions, Section 404 of the CWA, 33 U.S.C. §1344, 33 U.S.C. § 1311. Section 404(a) of the CWA authorizes the Secretary of the Army (Secretary), acting through the Chief of Engineers (U.S. Army Corps of Engineers or USACE), to authorize the discharge of dredged or fill material at specified disposal sites. This authorization is conducted, in part, through the application of environmental guidelines developed by the U.S. Environmental Protection Agency (EPA), in conjunction with the Secretary, under Section 404(b) of the CWA. Section 404(c) of the CWA authorizes EPA to prohibit the specification (including the withdrawal of specification) of any defined area as a disposal site and to restrict or deny the use of any defined area for specification (including the withdrawal of specification) as a disposal site whenever it determines, after notice and opportunity for public hearing, that the discharge of such materials into such area will have an unacceptable adverse effect on municipal water supplies, shellfish beds and fishery areas (including spawning and breeding areas), wildlife, or recreational areas.

The procedures for implementation of CWA Section 404(c) are set forth in Title 40 of the Code of Federal Regulations (CFR) Part 231 and establish a four-step CWA Section 404(c) review process.

- **Step 1: Initial Notification.** If the EPA Regional Administrator has reason to believe, after evaluating the information available to him, that an unacceptable adverse effect could result from the specification or use of a defined area for the disposal of dredged or fill material on one or more of the statutorily listed resources, the Regional Administrator may initiate the CWA Section 404(c) review process by notifying USACE,[10] the owner(s) of record of the site, and the permit applicant (if any), that he intends to issue a public notice of a proposed determination to prohibit or withdraw the specification, or to deny, restrict, or withdraw the use for specification, whichever the case may be, of any defined area as a disposal site. Each of those parties then has 15 days to demonstrate to the satisfaction of the Regional Administrator that no unacceptable adverse effects will occur, or that corrective action to prevent an unacceptable adverse effect will be taken.
- **Step 2: Proposed Determination.** If USACE, the owner(s) of record of the site, and the applicant (if any) have not demonstrated to the satisfaction of the Regional Administrator that no unacceptable adverse effects will occur, or USACE has not notified the Regional Administrator to his satisfaction of its intent to take corrective action to prevent an unacceptable adverse effect, the Regional

[10] The state would be notified here if the site is covered by an EPA-approved state program (CWA Section 404(g)) to issue permits for discharges of dredged or fill material at specified sites in waters of the United States (40 CFR 231.3(a)(1)).

Administrator shall publish notice of a proposed determination in the *Federal Register*, soliciting public comment on the proposed determination and offering an opportunity for public hearing.

- **Step 3: Recommended Determination.** Following a public hearing and close of the comment period, the Regional Administrator must decide whether to withdraw the proposed determination or prepare a recommended determination. If the Regional Administrator prepares a recommended determination, the Regional Administrator must forward the recommended determination and the administrative record to the Assistant Administrator for Water at EPA Headquarters. If the Regional Administrator decides to withdraw the proposed determination, he must notify the Assistant Administrator for Water, who may review the withdrawal at her discretion.[11]
- **Step 4: Final Determination.** The Assistant Administrator for Water will review the recommended determination of the Regional Administrator and the information in the administrative record. The Assistant Administrator for Water will also consult with USACE, the owner(s) of record of the site, and the applicant (if any). Following consultation and consideration of the record, the Assistant Administrator for Water will make the final determination affirming, modifying, or rescinding the recommended determination.

EPA Region 10 is publishing for public comment this proposed determination to prohibit and restrict the use of certain waters in the Bristol Bay watershed as a disposal site for the discharge of dredged or fill material associated with mining at the Pebble deposit, a large ore body in southwest Alaska. EPA Region 10 is exercising its authority under Section 404(c) of the CWA and its implementing regulations at 40 CFR Part 231 because of the unacceptable adverse effects on anadromous[12] fishery areas in the Bristol Bay watershed that could result from discharges of dredged or fill material associated with such mining.

This proposed determination represents Step 2 in the above process. In this proposed determination, EPA Region 10 is proposing to (1) prohibit the specification of a defined area as a disposal site, and (2) restrict the use of a defined area for specification as a disposal site because it has reason to believe that discharges of dredged or fill material into these areas could result in unacceptable adverse effects on anadromous fishery areas. EPA Region 10 is soliciting public comment on all issues discussed in this

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[11] In 1984, the EPA Administrator delegated the authority to make final determinations under Section 404(c) to EPA's national CWA Section 404 program manager, who is the Assistant Administrator for Water. That delegation remains in effect. With regard to EPA's Section 404(c) action for the Pebble deposit area, on March 22, 2019, Administrator Wheeler delegated to the General Counsel the authority to perform all functions and responsibilities retained by the Administrator or previously delegated to the Assistant Administrator for Water related to that action due to the recusals of then Administrator Wheeler and Assistant Administrator for Water David Ross from participation in matters related to Pebble Mine, which is associated with the Pebble deposit area. The Administrator rescinded the March 22, 2019 one-time delegation on May 17, 2022 because neither the current Administrator nor the current Assistant Administrator for Water have such recusals in place. As a result, the 1984 delegation controls and all functions and responsibilities retained by the Administrator related to the Pebble deposit are delegated to the Assistant Administrator for Water.

[12] Anadromous fishes are those that hatch in freshwater habitats, migrate to sea for a period of relatively rapid growth, and then return to freshwater habitats to spawn. For the purposes of this proposed determination, "anadromous fishes" refers only to Coho or Silver salmon (*Oncorhynchus kisutch*), Chinook or King salmon (*O. tshawytscha*), Sockeye or Red salmon (*O. nerka*), Chum or Dog salmon (*O. keta*), and Pink or Humpback salmon (*O. gorbuscha*).

proposed determination. EPA will consider all these public comments in reaching a decision to either withdraw the proposed determination or forward a recommended determination to EPA Headquarters.

This proposed determination is organized as follows.

- Section 2 provides background information on the Pebble deposit, a large, low-grade, porphyry copper deposit that underlies portions of the South Fork Koktuli River (SFK), North Fork Koktuli River (NFK), and Upper Talarik Creek (UTC) watersheds; a description of the mine plan developed by the Pebble Limited Partnership (PLP) in support of its CWA Section 404 permit application (the 2020 Mine Plan); a timeline of key events related to the Pebble deposit; and a summary of EPA Region 10's actions taken related to CWA Section 404(c) in this case.
- Section 3 provides an overview of the streams, wetlands, and other aquatic resources of the Bristol Bay watershed and discusses their role in supporting important subsistence, commercial, and recreational fisheries. It also describes the streams, wetlands, and other aquatic resources of the SFK, NFK, and UTC watersheds within the Bristol Bay watershed and discusses how they are integral to maintaining the productivity, integrity, and sustainability of both salmon and non-salmon fishery resources. This section also describes how salmon population diversity and dynamics interact to create a portfolio of biological assets resulting in a sustainable fishery.
- Section 4 describes the basis for EPA's determination that the direct and secondary effects of the discharge of dredged or fill material associated with construction and routine operation of the 2020 Mine Plan into certain streams, wetlands, and other aquatic resources of the SFK, NFK, and UTC watersheds could result in unacceptable adverse effects on anadromous fishery areas under EPA's regulations. These unacceptable adverse effects include the permanent loss and degradation of streams, wetlands, and other aquatic resources that are important for supporting anadromous fish habitat.
- Section 5 presents the proposed prohibition and the proposed restriction, which are designed to protect anadromous fishery areas in the SFK, NFK, and UTC watersheds from unacceptable adverse effects that could result from the discharge of dredged or fill material associated with mining at the Pebble deposit.
- Section 6 identifies other concerns that could further inform EPA Region 10's deliberations regarding this proposed determination, such as the potential for discharges of dredged or fill material associated with mining the Pebble deposit to result in adverse effects on wildlife, recreation, or public water supplies. It also includes other concerns and considerations, such as potential impacts on subsistence resources, environmental justice issues, traditional ecological knowledge, and potential spills and failures associated with mine infrastructure at the Pebble deposit.
- Section 7 highlights a set of specific issue areas upon which EPA Region 10 is seeking public comment.
- Section 8 lists references cited in the proposed determination.

SECTION 2. PROJECT DESCRIPTION AND BACKGROUND

2.1 Project Description

2.1.1 Overview of the Pebble Deposit

The Pebble deposit is a large, low-grade deposit containing copper-, gold-, and molybdenum-bearing minerals that underlies portions of the SFK, NFK, and UTC watersheds. The SFK and NFK watersheds are part of the Nushagak River watershed, and the UTC watershed is part of the Kvichak River watershed (Figure ES-2). Extraction at the Pebble deposit would involve the creation of a large open pit and the production of large amounts of waste rock and mine tailings (USACE 2020a).

The Pebble deposit covers an area of at least 1.9 by 2.8 miles and consists of two contiguous segments, Pebble West and Pebble East. The approximate center of the deposit is about 9.2 miles north–northeast of Sharp Mountain and 18.7 miles northwest of Iliamna. It covers portions of sections 14 to 16, 20 to 23, and 26 to 29, T. 3 S., R. 35 W., Seward Meridian.[13] The full extent of the Pebble deposit is not yet defined, but Kalanchey et al. (2021) indicate that the Pebble mineral resource may approach 11 billion tons of ore.

PLP holds the largest mine claim block in the Nushagak and Kvichak River watersheds. In 2017, PLP submitted a CWA Section 404 permit application to USACE to develop a mine at the Pebble deposit, which triggered USACE's development of a Final Environmental Impact Statement (FEIS) pursuant to the National Environmental Policy Act (NEPA). As discussed in Section 2.2.1, PLP revised its application during the NEPA and CWA Section 404 review processes, and the final revision (the 2020 Mine Plan) was submitted to USACE in June 2020.

2.1.2 Overview of the 2020 Mine Plan

This section describes the 2020 Mine Plan, as presented in PLP's June 8, 2020, CWA Section 404 permit application to USACE (PLP 2020b).[14] The 2020 Mine Plan is evaluated in USACE's FEIS and is identified in the FEIS as Alternative 3 – North Road Only Alternative, Concentrate Pipeline and Return Pipeline Variant.

[13] Mine claims may be located by what is known as aliquot part legal description, which is meridian, township, range, section, quarter section, and if applicable quarter-quarter section. These claims are known as MTRSC locations, and they are generally located using global positioning system (GPS) latitude and longitude coordinates. A quarter section location is typically about 160 acres in size, and a quarter-quarter section location is typically 40 acres in size (ADNR 2022a).

[14] Pebble Project Department of the Army Application for Permit POA-2017-00271.

In the 2020 Mine Plan, PLP proposes to develop the Pebble copper-gold-molybdenum porphyry deposit as a surface mine. The closest communities are the villages of Iliamna, Newhalen, and Nondalton, each of which is approximately 17 miles from the deposit (USACE 2020b). The project consists of four primary elements: the mine site; the Diamond Point port; the transportation corridor, including concentrate and water return pipelines; and the natural gas pipeline and fiber optic cable (Figure 2-1).

For the purposes of this proposed determination, EPA Region 10 evaluated the mine site, which is described in more detail below (Figure ES-3). EPA did not evaluate the ancillary project components along the transportation corridor or at the Diamond Point port; therefore, this proposed determination does not address these components.

The 2020 Mine Plan would progress through four distinct phases: construction, operations (also referred to as production), closure, and post-closure. The construction period would last approximately 4 years, followed by 20 years of operation. Closure, including physical reclamation of the mine site, is projected to take approximately 20 years. Post-closure activities, including long-term water management and monitoring, is expected to last for centuries (USACE 2020a).

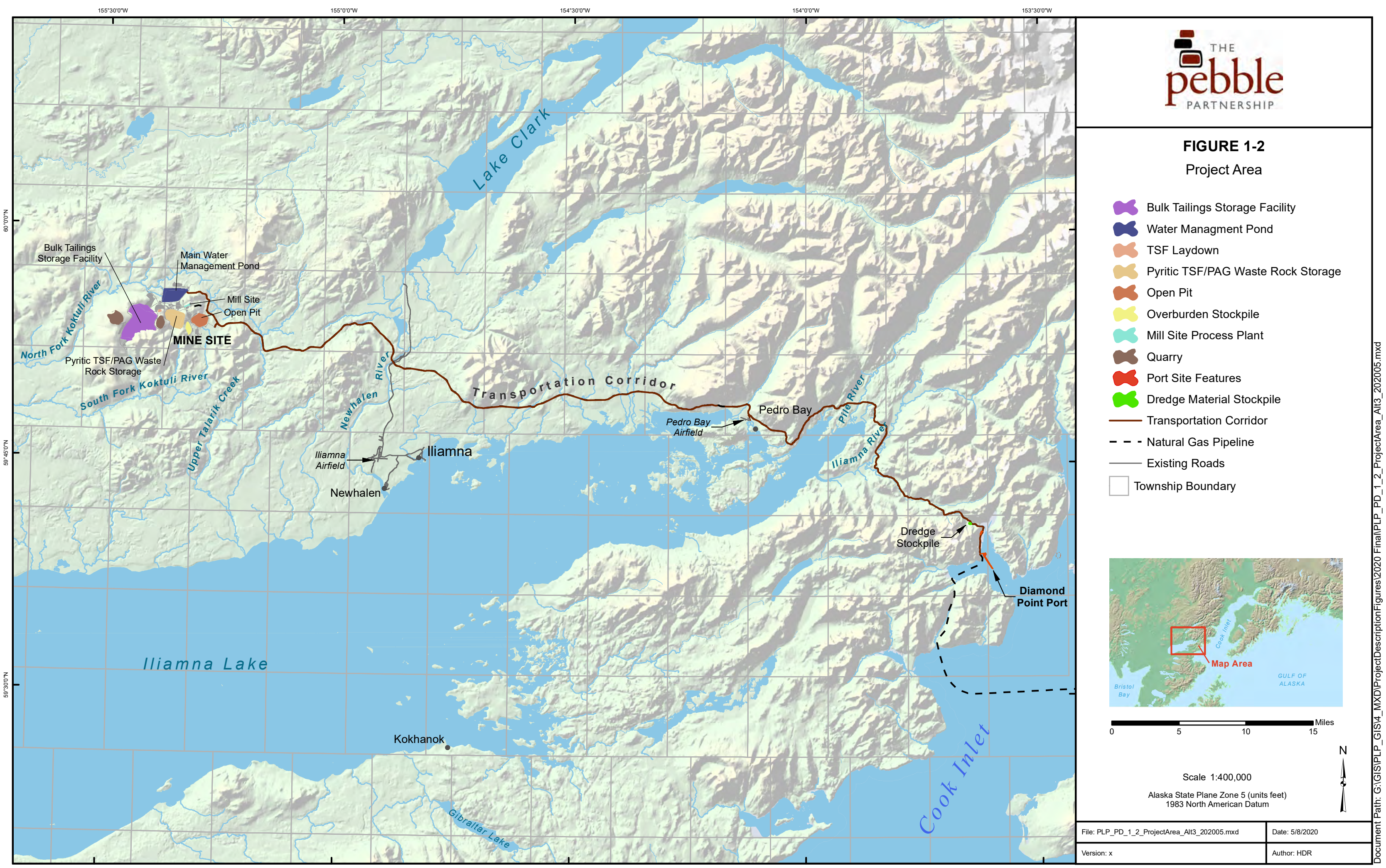
2.1.2.1 Mine Site

According to USACE, the 2020 Mine Plan is proposed to be a conventional drill, blast, truck, and shovel operation with a mining rate of up to 73 million tons of ore per year. Approximately 1,300 million tons of mineralized rock and 150 million tons of waste rock and overburden would be mined over the project's life. The mineralized material would be crushed and sent to a coarse ore stockpile to feed the process plant. The process plant would include grinding and flotation steps, with a processing rate of up to 66 million tons per year, to produce on average 613,000 tons of copper-gold concentrate and 15,000 tons of molybdenum concentrate annually (USACE 2020b).

The fully developed mine site would include an open pit, bulk tailings storage facility (TSF), pyritic TSF, a 270-megawatt power plant, water management ponds (WMPs), water treatment plants (WTPs), and milling/processing facilities, as well as supporting infrastructure. Non-potentially acid generating and non-metal leaching waste rock would be used in the construction of infrastructure needed to support the mine. In addition to waste rock, three quarries (material sites) would be needed (USACE 2020b) (Figure ES-4).

Bulk tailings would be placed in the bulk TSF, while pyritic tailings would be placed in the lined pyritic TSF. Potentially acid generating (PAG) and metal leaching waste rock would be stored in the lined pyritic TSF until closure, when it would be back-hauled into the open pit. The bulk TSF would have two embankments: the main embankment, constructed using the centerline construction method; and the south embankment, constructed using the downstream construction method to facilitate lining of the upstream face. The pyritic TSF would be fully lined and would have three embankments constructed using the downstream method (USACE 2020b).

Figure 2-1. Project area map. Figure 1-2 from PLP (2020b).



Soils and other overburden would be stored in stockpile areas at various locations throughout the site. Stockpiled soils and other overburden would be used for reclamation during mine closure. The proposed mine site is currently undeveloped and is not served by any transportation or utility infrastructure (USACE 2020b).

According to USACE, PLP would manage water flows through the mine area, while providing a water supply for operations. PLP would capture runoff water contacting the facilities at the mine site and water pumped from the open pit, then either reuse the water in the milling process or treat the water before releasing it to surface waters (USACE 2020b).

The open-pit area would be dewatered through groundwater withdrawal from approximately 30 groundwater wells installed around the open-pit perimeter. As the pit is deepened, dewatering would continue via in-pit ditches, in-pit wells, and/or perimeter wells. The water level in the open pit would continue to be managed via pumping of groundwater wells and transfer to the open-pit WMP (USACE 2020b).

As described by USACE, mine facilities would be closed at the end of operations and reclaimed. Reclamation and closure of the project would fall under the jurisdiction of Alaska Department of Natural Resources (ADNR) Division of Mining, Land, and Water and the Alaska Department of Environmental Conservation (ADEC). The Alaska Reclamation Act (Alaska Statute 27.19) is administered by ADNR. It applies to state, federal, municipal, and private land, as well as water subject to mining operations. PLP has prepared a Reclamation and Closure Plan providing guidelines for implementing stabilization and reclamation procedures for various facilities associated with the project (USACE 2020a: Appendix M4.0). USACE indicates that revisions to PLP's Reclamation and Closure Plan may be necessary to address changes during preliminary and detailed design work and state permitting (USACE 2020b).

2.2 Background

2.2.1 Timeline of Key Events Related to the Pebble Deposit (1984–October 2021)

In 1984, the State of Alaska adopted the *Bristol Bay Area Plan for State Lands* (BBAP). The 1984 BBAP placed fish and wildlife habitat and harvest as a primary use throughout the Bristol Bay study area (ADNR 1984a). To carry out its goals, the 1984 BBAP included Mineral Closing Order (MCO) 393, along with 18 other MCOs, which closed the stream channel plus 100 feet on either side of designated anadromous reaches of 64 streams in the Bristol Bay region to new mineral entry. Implementing MCO 393 was consistent with ADNR's determination that new mineral entry "creates an incompatible surface use conflict with salmon propagation and production, and jeopardizes the economy of the Bristol Bay region and the management of the commercial, sport, and subsistence fisheries in the Bristol Bay area" (ADNR 1984b: Page 2). The BBAP was subsequently amended in 2005 and 2013, but the MCOs established by the initial 1984 BBAP were not affected by these amendments.[15] While the protections associated with MCO 393 apply to portions of the SFK, NFK, and UTC located downstream of the Pebble deposit,[16] the portions of SFK, NFK, and UTC and their tributaries that overlie the Pebble deposit and would be directly affected by the 2020 Mine Plan are not covered by MCO 393.

The Pebble deposit was first explored by Cominco Alaska, a division of Cominco Ltd, now Teck, between 1985 and 1997, with exploratory drilling between 1988 and 1997 (Ghaffari et al. 2011). In November 1987, Teck staked claims in the Pebble prospect and added claims to that area in July 1988. In 2001, Northern Dynasty Minerals Ltd. (NDM) acquired claims related to the Pebble deposit. From 2001 to 2019, NDM, and subsequently PLP,[17] conducted significant mineral exploration at the Pebble deposit, including deposit delineation, and developed environmental, socioeconomic, and engineering studies of the Pebble deposit (Kalanchey et al. 2021).

Beginning in 2004, NDM engaged with USACE in pre-CWA Section 404 permit application meetings. Through these meetings, USACE confirmed that NDM/PLP would need a CWA Section 404 permit to develop a mine at the Pebble deposit and that the permit review process would include a public interest review, development of an environmental document in accordance with NEPA, and a review for compliance with the CWA Section 404(b)(1) Guidelines (Lestochi pers. comm.).

Also in 2004, EPA Region 10 met numerous times with NDM to discuss the potential environmental impacts associated with developing a mine at the Pebble deposit, including early environmental baseline study plans and preparation for the review of the mine project pursuant to NEPA and Section 404 of the CWA. Later that year, NDM established and began coordinating a Baseline Environmental Team of federal and state agency technical staff, including EPA Region 10, to continue reviewing the draft environmental baseline study plans. NDM also provided periodic updates on its process to develop a mine, as well as findings from its environmental baseline studies and findings related to cultural resources that could be affected.

In 2006, NDM submitted water rights permit applications to ADNR for water rights to use UTC and the Koktuli River in mining operations (NDM 2006). In total, NDM applied for rights to approximately 35 billion gallons of groundwater and surface water per year (ADNR 2022b).

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[15] The 2013 BBAP designates land uses in the footprint of the 2020 Mine Plan. The 2013 BBAP specifies that these lands are to be retained in public ownership and managed for multiple uses—including recreation, timber, minerals, and fish and wildlife—as well as natural scenic, scientific, and historic values (USACE 2020b). This specification does not preclude construction of the mine and related facilities, and the State of Alaska has made no specific determinations whether the 2020 Mine Plan is consistent with the BBAP (USACE 2020b).

[16] Specifically, MCO 393 closed the designated anadromous portions of the South Fork Koktuli River (AWC # 325-30-10100-2202-3080), North Fork Koktuli River (AWC # 325-30-10100-2202-3080-4083), and Upper Talarik Creek (AWC # 324-10-10150-2183), as well as any state-owned lands 100 feet from ordinary high water (on both sides of the stream) to new mineral entry (ADNR 1984b).

[17] PLP was created in 2007 by co-owners NDM and Anglo American PLC to design, permit, construct, and operate a long-life mine at the Pebble deposit (Ghaffari et al. 2011). In 2013, NDM acquired Anglo American's interest in PLP, and NDM now holds a 100 percent interest in PLP (Kalanchey et al. 2021).

Between 2007 and 2010, nine state and federal agencies, including Alaska Department of Fish and Game (ADF&G), ADNR, National Marine Fisheries Service (NMFS), National Park Service (NPS), USACE, U.S. Fish and Wildlife Service (USFWS), and EPA Region 10 participated in the Pebble Project Technical Working Group, which was formed by PLP to facilitate coordinated agency review of environmental studies to support future NEPA and subsequent permitting actions (ADNR 2022b).

On May 2, 2010, former EPA Administrator Lisa P. Jackson and former Region 10 Regional Administrator Dennis McLerran received a letter from six federally recognized Bristol Bay tribal governments requesting that EPA initiate a process under Section 404(c) of the CWA to protect waters, wetlands, fishes, wildlife, fisheries, subsistence, and public uses in the Nushagak and Kvichak River watersheds and Bristol Bay from metallic sulfide mining, including a potential Pebble mine. Signatories included Nondalton Tribal Council, New Stuyahok Traditional Council, Levelock Village Council, Ekwok Village Council, Curyung Tribal Council, and Koliganek Village Council. Subsequently, three additional federally recognized Bristol Bay tribal governments signed this letter: Native Village of Ekuk, Village of Clark's Point, and Twin Hills Village Council.

Following the letter from the tribes, EPA and former President Obama received numerous letters from additional partners and stakeholders expressing their interests and concerns regarding potential EPA action to protect Bristol Bay fishery resources. Some requests favored immediate action to comprehensively protect Bristol Bay, including a public process under Section 404(c) of the CWA. Others favored a targeted CWA Section 404(c) action that would restrict only mining associated with the Pebble deposit. In addition to other Bristol Bay tribes, EPA received letters from the Bristol Bay Native Association, the Bristol Bay Native Corporation, other tribal organizations, stakeholder groups dependent on the fishery (i.e., commercial and recreational fishers, seafood processors and marketers, chefs and restaurant and supermarket owners, and sport fishing and hunting lodge owners and guides), sporting goods manufacturers and vendors, a coalition of jewelry companies, conservation organizations, members of the faith community, and elected officials from Alaska and other states.

Other requests received during this time urged EPA to refrain from taking action under CWA Section 404(c). These requests included those that asked for more time to understand potential implications of mine development in the Bristol Bay watershed. Others requested EPA wait until formal mine permit applications had been submitted and an Environmental Impact Statement (EIS) had been developed. These requestors included four federally recognized Bristol Bay tribal governments (Newhalen Tribal Council, South Naknek Tribal Council, King Salmon Traditional Village Council, and Iliamna Village Council), other tribal organizations, former Governor Parnell of Alaska, and attorneys representing PLP.

In response to these requests, EPA met with tribal governments and stakeholders, including those that supported and those that opposed a mine at the Pebble deposit, to hear their concerns and receive any information they wished to provide. These meetings occurred in the villages in the Bristol Bay watershed, Anchorage, Seattle, and Washington, DC.

Former EPA Administrator Jackson and former Region 10 Regional Administrator McLerran visited Alaska in August 2010 to learn about the challenges facing rural Alaska towns and Alaska Native villages. Their itinerary included a meeting with PLP for a briefing on the proposed mining of the Pebble deposit. They also visited Dillingham, where they participated in two listening sessions, one specifically for tribal leaders from Bristol Bay and one meeting open to all local and regional entities.

In February 2011, NDM submitted a preliminary assessment for mining the Pebble deposit to the U.S. Securities and Exchange Commission (SEC) (SEC 2011) entitled *Preliminary Assessment of the Pebble Project, Southwest Alaska* (Ghaffari et al. 2011). The preliminary assessment described three stages of mine development at the Pebble deposit: an initial 2-billion-ton mine consisting of 25 years of open-pit mining, a 3.8-billion-ton mine consisting of 45 years of open-pit mining, and a 6.5-billion-ton mine consisting of 78 years of open-pit mining. The preliminary assessment also indicated that the total Pebble mineral resource might approach 11 billion tons of ore.

Also in February 2011, in response to the competing requests regarding CWA Section 404(c) described previously, former Region 10 Regional Administrator McLerran announced EPA's intent to conduct a scientific assessment to evaluate how future large-scale mining projects might affect water quality and Bristol Bay's salmon fishery. This ecological risk assessment was ultimately entitled *Assessment of Potential Mining Impacts on Salmon Ecosystems of Bristol Bay, Alaska* (Bristol Bay Assessment or BBA).[18] Concurrent with this announcement, EPA Region 10 notified by letter 31 Bristol Bay tribes, ADEC, ADF&G, ADNR, the Bureau of Land Management, NMFS, NPS, USACE, USFWS, and the U.S. Geological Survey (USGS) of its intent to develop the BBA. The same week, EPA Region 10 met with Nuna Resources, which represents several Alaska Native Claims Settlement Act (ANCSA) Village Corporations,[19] and had meetings with other partners and stakeholders. NFMS, USFWS, and USGS worked closely with EPA on the development of the BBA, including authoring appendices to the BBA (see Table 2-1 for a timeline of BBA development).[20]

In December 2011, PLP provided EPA Region 10 with an advance, embargoed copy of its more than 25,000-page environmental baseline document, which presented the results of baseline studies conducted from 2004 through 2008 (PLP 2011). The environmental baseline document was designed to characterize the existing physical, chemical, biological, and social environments in the SFK, NFK, and UTC watersheds where the Pebble deposit is located, as well as the proposed mine's transportation corridor that would link the mine site to a proposed port site on Cook Inlet. The extensive environmental baseline document developed by PLP (PLP 2011) and NDM's preliminary assessment for mining the Pebble deposit that was submitted to the SEC in February 2011 (Ghaffari et al. 2011) were key resources used in the development of the BBA.

EPA's purpose in conducting the BBA was to characterize the biological and mineral resources of the Bristol Bay watershed; increase understanding of the potential impacts of large-scale mining on the

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[18] EPA conducted the BBA consistent with its authority under CWA Section 104(a) and (b).

[19] Congress created Regional and Village Corporations (Alaska Native Corporations) to manage the lands, funds, and other assets conveyed to Alaska Natives by ANCSA.

[20] For more information about EPA's efforts in Bristol Bay or copies of the Bristol Bay Assessment, see http://www.epa.gov/bristolbay.

region's fish resources, in terms of both day-to-day operations and potential accidents and failures; and inform future decisions by government agencies and others related to protecting and maintaining the chemical, physical, and biological integrity of the watershed. The BBA represents a review and synthesis of information available at that time to identify and evaluate potential risks of future large-scale mining development on the Bristol Bay watershed's fish habitats and populations and consequent effects on the region's wildlife and Alaska Native communities.

Table 2-1. Bristol Bay Assessment timeline.

2/7/2011	Announced intent to conduct the BBA.
8/2011	Met with Intergovernmental Technical Team to gather information to inform the scope of the BBA.
2/24/2012	Invited the public to nominate qualified experts to be considered for the external peer review panel.
3/2012	Distributed internal review draft of the BBA for Agency technical review.
5/18/2012	Released first external review draft of the BBA for public comment and external peer review.
5/31/2012 and 6/4–7/2012	Held public meetings in Dillingham, Naknek, New Stuyahok, Nondalton, Levelock, Igiugig, Anchorage, and Seattle to communicate the results of the draft BBA and receive public comments.
6/5/2012	Announced the names of the 12 independent peer reviewers to review the draft BBA and released the draft charge questions, providing the public the opportunity to comment on the draft charge questions.
8/7–9/2012	Held external peer review meeting in Anchorage.
11/2012	Released the final peer review report containing the external peer review of the May 2012 draft of the BBA.
4/30/2013	Released second external review draft of the BBA for public comment and follow-on review by external peer reviewers, to evaluate how well the second external review draft responded to peer reviewers' comments on the first external review draft.
1/15/2014	Released the final BBA and EPA Response to Peer Review Comments document.
3/21/2014	Released EPA Response to Public Comments documents.

Meaningful engagement with tribal governments, Alaska Native Corporations, and all stakeholders was essential to ensure that EPA heard and understood the full range of perspectives on both the BBA and potential effects of mining in the region. EPA released two drafts of the BBA for public comment. Approximately 233,000 and 890,000 comments were submitted to the EPA docket during the 60-day public comment periods for the May 2012 and April 2013 drafts, respectively. EPA also held eight public comment meetings in May and June 2012 in Dillingham, Naknek, New Stuyahok, Nondalton, Levelock, Igiugig, Anchorage, and Seattle. Approximately 2,000 people attended these meetings. An overview of these meetings was shared via two webinars in July 2012.

Consistent with Executive Order 13175,[21] entitled *Consultation and Coordination with Indian Tribal Governments,* and EPA Region 10 Tribal Consultation and Coordination Procedures (EPA 2012), EPA Region 10 invited all 31 Bristol Bay tribal governments to participate in consultation and coordination on both drafts of the BBA. Pursuant to Public Law 108-199, 118 Stat. 452, as amended by Public Law 108-447, 118 Stat. 3267, EPA also invited all 26 Alaska Native Corporations in Bristol Bay to participate in engagement on both drafts of the BBA. Throughout the development of the BBA, 20 tribal governments and 1 tribal consortium participated in the consultation and coordination process, and 17 Alaska Native Corporations participated in the engagement process.

The BBA also underwent external peer review by a panel of 12 independent experts (Table 2-1). The peer review panel reviewed the May 2012 draft and provided EPA with their comments. A 3-day peer review meeting was held in Anchorage on August 7 through 9, 2012, during which peer reviewers heard testimony from approximately 100 members of the public. The peer review panel also reviewed the April 2013 draft and provided EPA with a second round of comments that evaluated whether the April 2013 draft was responsive to their original comments.

In January 2014, EPA released both the final BBA (EPA 2014) and the final Response to Peer Review Comments document. In March 2014, EPA released the final Response to Public Comments documents for both the May 2012 and April 2013 drafts of the BBA.

On February 28, 2014, after careful consideration of available information, including information collected as part of the BBA, other existing scientific and technical information, and extensive information provided by stakeholders, EPA Region 10 notified USACE, the State of Alaska, and PLP that it had decided to proceed under the CWA Section 404(c) regulations, 40 CFR Part 231, to review potential adverse environmental effects of discharges of dredged or fill material associated with mining the Pebble deposit. EPA Region 10 stated that it was taking this step because it had reason to believe that porphyry copper mining of the scale contemplated at the Pebble deposit could result in unacceptable adverse effects on fishery areas. In accordance with the regulation at 40 CFR 231(a)(1), EPA Region 10 provided USACE, the State of Alaska, and PLP an opportunity to submit information for the record, to demonstrate to the satisfaction of the EPA Region 10 Regional Administrator that no unacceptable adverse effects on aquatic resources would result from discharges associated with mining the Pebble deposit, or that USACE intended to take corrective action to prevent unacceptable adverse effects satisfactory to the EPA Region 10 Regional Administrator.

Also on February 28, 2014, EPA Region 10 invited all 31 Bristol Bay tribal governments to participate in tribal consultation, and all 26 Alaska Native Corporations to participate in consultation and engagement on the 2014 Proposed Determination. In total, 17 tribal governments participated in the consultation process, and 6 Alaska Native Corporations participated in the consultation and engagement process.

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[21] On January 26, 2021, President Biden issued the Presidential Memorandum, *Tribal Consultation and Strengthening Nation-to-Nation Relationships*, which charges each federal agency to engage in regular, meaningful, and robust consultation and to implement the policies directed in Executive Order 13175.

EPA Region 10 held two meetings on March 25, 2014, one with PLP executives and one with the Alaska Attorney General. On April 29, 2014, PLP and the Alaska Attorney General separately provided information as part of the initial CWA Section 404(c) consultation period. In these submittals, PLP and the Alaska Attorney General raised several legal, policy, scientific, and technical issues, including questions regarding EPA's authority to initiate a Section 404(c) review before PLP had submitted a Section 404 permit application to USACE, the scientific credibility of the BBA, and whether the BBA should be used to inform decision-making under Section 404(c). Most of the scientific and technical issues detailed in these documents had been raised before; EPA had provided responses to these issues in individual correspondence to PLP and the Alaska Attorney General and, most comprehensively, in the 400-page BBA Response to Peer Review Comments document released in January 2014 and the 1,200-page BBA Response to Public Comments documents released in March 2014.

After fully considering the April 29, 2014 submittals from PLP and the Alaska Attorney General, the EPA Region 10 Regional Administrator was not satisfied that no unacceptable adverse effect could occur, or that adequate corrective action could be taken to prevent an unacceptable adverse effect. Thus, EPA Region 10 decided to take the next step in the Section 404(c) process, publication of a proposed determination.

On July 21, 2014, EPA Region 10 published in the *Federal Register* a Notice of Proposed Determination under Section 404(c) of the CWA to restrict the use of certain waters in the SFK, NFK, and UTC watersheds as disposal sites for dredged or fill material associated with mining the Pebble deposit (79 FR 42314, July 21, 2014). The notice started a public comment period that ended on September 19, 2014. EPA Region 10 also held seven hearings during the week of August 11, 2014. These hearings took place in Anchorage, Nondalton, New Stuyahok, Dillingham, Kokhanok, Iliamna, and Igiugig. More than 830 community members participated in the seven hearings, more than 300 of whom provided oral statements. In addition to testimony taken at the hearings, EPA Region 10 received more than 670,000 written comments during the public comment period, more than 99 percent of which supported the 2014 Proposed Determination. The public comments and transcripts from the public hearings can be found in the docket for the 2014 Proposed Determination.[22]

Before EPA could reach the next step in the CWA Section 404(c) review process—to either withdraw the 2014 Proposed Determination or prepare a recommended determination pursuant to 40 CFR 231.5(a)—PLP filed multiple lawsuits against the Agency. On November 25, 2014, the U.S. District Court for the District of Alaska (District Court) issued a preliminary injunction against EPA in one of those lawsuits, which halted EPA Region 10's CWA Section 404(c) review process until the case was resolved (Order Granting Preliminary Injunction at 1-2, Pebble Limited Partnership v. EPA, No. 3:14-cv-00171 (D. Alaska Nov. 25, 2014)). On May 11, 2017, EPA and PLP settled that lawsuit, as well as PLP's other outstanding lawsuits, and the court subsequently dissolved the injunction and dismissed the case with prejudice.

[22] Information regarding the 2014 Proposed Determination can be found in the docket for this effort at www.regulations.gov, see docket ID No. EPA-R10-OW-2014-0505.

Under the terms of the settlement, EPA agreed to "initiate a process to propose to withdraw the Proposed Determination" by July 11, 2017. EPA also agreed not to forward a signed recommended determination to EPA Headquarters until May 11, 2021, or until EPA published a notice of USACE's FEIS on PLP's CWA Section 404 permit application for the proposed Pebble mine, whichever came first. To take advantage of this period of forbearance, PLP was required to submit its CWA Section 404 permit application to USACE within 30 months of execution of the settlement agreement.[23]

On July 11, 2017, EPA signed a *Federal Register* notice that initiated the process and proposed to withdraw the 2014 Proposed Determination. Also on July 11, 2017, EPA invited all 31 Bristol Bay tribal governments to participate in consultation and coordination, and all 26 Alaska Native Corporations to participate in consultation on the 2017 proposal to withdraw. In total, 18 tribal governments and 3 Alaska Native Corporations participated in the consultation processes.

On July 19, 2017, in accordance with the terms of the settlement agreement, EPA Region 10 published in the *Federal Register* a notice of its proposal to withdraw the 2014 Proposed Determination (82 FR 33123, July 19, 2017). EPA stated that the Agency was proposing to withdraw the 2014 Proposed Determination because it would (1) provide PLP with additional time to submit a CWA Section 404 permit application to USACE; (2) remove any uncertainty, real or perceived, about PLP's ability to submit a permit application and have that permit application reviewed; and (3) allow the factual record regarding any forthcoming permit application to develop. EPA explained that "[i]n light of the basis upon which EPA is considering withdrawal of the Proposed Determination, EPA is not soliciting comment on the proposed restrictions or on science or technical information underlying the Proposed Determination" (82 FR 33124, July 19, 2017).

The July 19, 2017 notice started a public comment period that ended on October 17, 2017. EPA also held hearings in Dillingham and Iliamna the week of October 9, 2017. EPA received more than one million public comments regarding its proposal to withdraw the 2014 Proposed Determination. Approximately 99 percent of commenters expressed opposition to the withdrawal of the 2014 Proposed Determination. The public comments, transcripts from the public hearings, and summaries of the tribal and Alaska Native Corporation consultations can be found in the docket for the 2017 proposal to withdraw the 2014 Proposed Determination.[24]

On December 22, 2017, PLP submitted to USACE a CWA Section 404 permit application for the discharge of dredge and fill material to waters of the United States to develop a mine at the Pebble deposit, as well as associated infrastructure (e.g., ports, roads, and pipelines). On January 5, 2018, USACE issued a public notice that provided PLP's permit application to the public and stated that an EIS would be required as part of its permit review process, consistent with NEPA. USACE also invited relevant federal, state, and local agencies, as well as tribal governments, to be cooperating agencies on the development of this EIS.

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[23] For a copy of the settlement agreement, *see* https://www.epa.gov/bristolbay/2017-settlement-agreement-between-epa-and-pebble-limited-partnership.

[24] Information regarding the proposal to withdraw can be found in the docket for this effort at www.regulations.gov, see docket ID No. EPA-R10-OW-2017-0369.

EPA, the United States Coast Guard, the Bureau of Safety and Environmental Enforcement, the Advisory Council on Historic Preservation, USFWS, NPS, the Pipeline and Hazardous Materials Safety Administration, the State of Alaska, the Lake and Peninsula Borough, the Curyung Tribal Council, and the Nondalton Tribal Council accepted the USACE invitation and became NEPA cooperating agencies.

On January 26, 2018, EPA Region 10 announced a "suspension" of the proceeding to withdraw the 2014 Proposed Determination. This action was published in the *Federal Register* on February 28, 2018 (83 FR 8668, February 28, 2018).

On March 29, 2018, USACE published in the *Federal Register* a Notice of Intent to prepare an EIS and a Notice of Scoping for the Pebble Project (83 FR 13483, March 29, 2018). The EIS scoping public comment period opened on April 1, 2018 and closed on June 29, 2018. USACE received 174,889 total submissions during the scoping comment period, which are summarized in the FEIS, Appendix A. On June 29, 2018, EPA Region 10 submitted a comment letter to USACE, pursuant to the White House Council on Environmental Quality (CEQ) NEPA regulations and Section 309 of the Clean Air Act (CAA), that contained recommendations for the EIS in response to the scoping process.

On March 1, 2019, USACE released the Draft EIS (DEIS) for public comment. Also on March 1, 2019, USACE published a public notice soliciting comment on PLP's CWA Section 404 permit application (Public Notice POA-2017-00271). The public comment period for both the DEIS and the CWA Section 404 permit application opened on March 1, 2019, and closed July 1, 2019. USACE also held nine public hearings on the DEIS throughout March and April 2019. USACE received 311,885 public comments on the DEIS, which are summarized in the FEIS, Appendix D. USACE held public hearings on the DEIS in Naknek, Kokhanok, Newhalen, Igiugig, New Stuyahok, Nondalton, Dillingham, Homer, and Anchorage, Alaska.

On July 1, 2019, EPA sent a letter to USACE with its comments and recommendations on the DEIS, pursuant to EPA's review responsibilities under the CEQ NEPA regulations and CAA Section 309. On July 1, 2019, EPA sent a separate letter to USACE with comments on the CWA Section 404 permit public notice.

On August 30, 2019, after conferring with EPA's General Counsel,[25] EPA Region 10 published in the *Federal Register* its decision to withdraw the 2014 Proposed Determination, thereby concluding the withdrawal process that was initiated on July 19, 2017 (84 FR 45749, August 30, 2019). EPA identified that it was withdrawing the Proposed Determination because: (1) new information had been generated since 2014, including information and preliminary conclusions in USACE's DEIS, which EPA would need to consider before any potential future decision-making regarding the matter; (2) the record would continue to develop throughout the permitting process; and (3) EPA could and then had initiated the

[25] See footnote 11 in Section 1.

CWA Section 404(q) Memorandum of Agreement dispute resolution process[26] and it was appropriate to use that process to resolve issues before engaging in any potential future decision-making regarding the matter.

In its August 30, 2019 notice of withdrawal of the 2014 Proposed Determination, EPA stated that "[a]s in EPA's prior notices, EPA is not basing its decision-making on technical consideration or judgments about whether the mine proposal will ultimately be found to meet the requirements of the 404(b)(1) Guidelines or results in 'unacceptable adverse effects' under CWA section 404(c)" (84 FR 45756, August 30, 2019).

In October 2019, twenty tribal, fishing, environmental, and conservation groups challenged EPA's withdrawal of the 2014 Proposed Determination in the District Court. The District Court granted EPA's motion to dismiss the case.

In February 2020, USACE released the preliminary FEIS to the cooperating agencies for comment. EPA Region 10 submitted comments and recommendations to the USACE on the preliminary FEIS on March 26, 2020.

From March 12, 2020 through May 28, 2020, an interagency team of managers and scientific and technical staff from USACE, EPA, and USFWS met weekly to evaluate the proposed project for compliance with the CWA Section 404(b)(1) Guidelines.

Based on its review of the Section 404(b)(1) Guidelines, USACE determined that EIS Alternative 3 (North Road Only with concentrate and return water pipelines) was the least environmentally damaging practicable alternative (LEDPA). In June 2020, PLP submitted to USACE a revised permit application (i.e., the 2020 Mine Plan) to incorporate changes to the project based on USACE's LEDPA determination (USACE 2020b). USACE determined that the changes to the project described in the revised permit application were not significant enough to warrant development of a Supplemental DEIS.[27]

On July 24, 2020, USACE published a Notice of Availability for the FEIS in the *Federal Register* (USACE 2020a).

On November 20, 2020, USACE issued its Record of Decision (ROD) denying PLP's CWA Section 404 permit application on the basis that the proposed project would not comply with the CWA Section 404(b)(1) Guidelines and would be contrary to the public interest (USACE 2020b). The USACE permit denial addresses only PLP's specific permit application. By letter dated November 25, 2020, USACE notified PLP that the proposed project failed to comply with the CWA Section 404(b)(1) Guidelines

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[26] CWA Section 404(q) directs the Secretary of the Army to enter into agreements with various federal agencies, including EPA "to minimize, to the maximum extent practicable, duplication, needless paperwork, and delays in the issuance of permits under this section" (33 U.S.C. 1344(q)). EPA and USACE have entered into various agreements pursuant to Section 404(q). The operative agreement was entered in 1992. Part IV, paragraph 3 of the 1992 EPA and Army Memorandum of Agreement to implement Section 404(q) (hereinafter referred to as the "404(q) MOA") sets forth the "exclusive procedures" for elevation of individual permits cases (EPA and DOA 1992).

[27] PLP also submitted an updated permit application to USACE in December 2019 and USACE made a similar finding at that time that a Supplemental DEIS was not warranted.

because "the proposed project would cause unavoidable adverse impacts to aquatic resources which would result in Significant Degradation to aquatic resources" and that PLP's compensatory mitigation plan submitted to USACE on November 4, 2020 did not alter that finding.

On January 19, 2021, PLP filed a request for an appeal of the USACE permit denial with USACE, pursuant to 33 CFR Part 331. USACE accepted the appeal on February 25, 2021. USACE's review of the appeal is ongoing.

On June 17, 2021, the Ninth Circuit Court of Appeals reversed the District Court's decision to dismiss the tribal, fishing, environmental, and conservation groups' challenge to EPA's withdrawal of the 2014 Proposed Determination. The Ninth Circuit concluded that under EPA's regulations at 40 CFR 231.5(a), EPA is authorized to withdraw a proposed determination "*only* if the discharge of materials would be unlikely to have an unacceptable adverse effect." Trout Unlimited v. Pirzadeh, 1 F.4th 738, 757 (9th Cir.) (emphasis in original). The Ninth Circuit remanded the case to the District Court for further proceedings.

On September 28, 2021, EPA filed a motion in the District Court requesting that the court vacate the Agency's 2019 decision to withdraw the 2014 Proposed Determination and remand the action to the Agency for reconsideration. The District Court granted EPA's motion on October 29, 2021.

2.2.2 Re-initiation of Clean Water Act Section 404(c) Review Process (November 2021–Present)

The District Court's vacatur of EPA's 2019 decision to withdraw the 2014 Proposed Determination had the effect of reinstating the 2014 Proposed Determination and reinitiating EPA's CWA Section 404(c) review process. Because the next step in the CWA Section 404(c) review process required the EPA Region 10 Regional Administrator to, within 30 days, decide whether to withdraw the 2014 Proposed Determination or prepare a recommended determination, EPA Region 10 published in the *Federal Register* on November 23, 2021, a notice extending the applicable time requirements through May 31, 2022, to consider available information and determine the appropriate next step in the CWA Section 404(c) review process. In its notice, EPA concluded that it should consider information that has become available since EPA issued the 2014 Proposed Determination.

On January 27, 2022, EPA Region 10 sent letters inviting consultation to 31 tribal governments located in the Bristol Bay watershed. Separately, it also invited consultation with 5 Alaska Native Corporations and offered engagement to 21 Alaska Native Corporations with lands in the Bristol Bay watershed. EPA Region 10 will continue to provide opportunities for tribal consultation and coordination and consultation and engagement with Alaska Native Corporations, going forward.

Also on January 27, 2022, EPA Region 10 notified USACE, ADNR, PLP, Pebble East Claims Corporation, Pebble West Claims Corporation, and Chuchuna Minerals[28] (the Parties) of EPA's intention to issue a

[28] EPA Region 10 included Chuchuna Minerals in this notification step because USACE's FEIS for the 2020 Mine Plan indicates that discharges associated with mining the Pebble deposit could expand in the future into portions of areas where Chuchuna Minerals holds mining claims.

revised proposed determination because, based on EPA Region 10's evaluation to date of available information, it continued to have reason to believe that the discharge of dredged or fill material associated with mining the Pebble deposit could result in unacceptable adverse effects on fishery areas.

Consistent with EPA's Section 404(c) regulations at 40 CFR 231(a)(1), EPA Region 10 provided the Parties with the opportunity to submit information for the record to demonstrate to the satisfaction of the EPA Region 10 Regional Administrator that no unacceptable adverse effects on aquatic resources would result from discharges associated with mining the Pebble deposit or that USACE intended to take corrective action to prevent unacceptable adverse effects satisfactory to the EPA Region 10 Regional Administrator. Consistent with EPA's Section 404(c) regulations, EPA requested that the Parties respond by February 11, 2022. On January 29, 2022, PLP requested a total of 45 days—through March 28, 2022—to provide its submission. EPA granted this request and provided the same extension to all Parties.

EPA Region 10 held a meeting with Chuchuna Minerals on February 9, 2022, and one with PLP on February 18, 2022. On March 28, 2022, ADNR, PLP, and Chuchuna Minerals separately provided information as part of the initial Section 404(c) consultation period. In these submittals, ADNR, PLP, and Chuchuna Minerals raised several legal, policy, scientific, and technical issues, including questions regarding continued reliance on the 2014 Proposed Determination, EPA's authority and justification for undertaking a Section 404(c) review at this time, whether the 2020 Mine Plan's potential impacts on fishery areas warrant review pursuant to Section 404(c), and whether a Section 404(c) action would violate the rights established in the Alaska Statehood Act (ASA), Cook Inlet Land Exchange Act (CILEA), Alaska National Interest Lands Conservation Act (ANILCA), and ANCSA.

USACE did not request a meeting or provide information as part of this initial Section 404(c) consultation period.

Below is a brief summary of the issues raised in responses to EPA Region 10's January 27, 2022 notification letters and EPA's assessment of the information at this time. EPA will continue to consider all information submitted as the Agency continues the Section 404(c) review process.

- **Continued reliance on the 2014 Proposed Determination.** PLP refers to the 2014 Proposed Determination as "obsolete," and PLP and ADNR indicate that it would not be appropriate for EPA Region 10 to continue to rely on the document. EPA Region 10 recognizes that the scientific and technical record for the development of a mine at the Pebble deposit has evolved since it issued the 2014 Proposed Determination and, as stated in its November 23, 2021 *Federal Register* Notice, agrees that EPA should consider information that has become available since the Agency issued the 2014 Proposed Determination in any CWA Section 404(c) review process for the Pebble deposit area. Accordingly, the 2014 Proposed Determination has been extensively revised based on EPA Region 10's consideration of information that has become available since the issuance of the 2014 Proposed Determination (Appendix A).

- **EPA's authority and justification for undertaking a Section 404(c) review at this time.** PLP takes the position that EPA's use of CWA Section 404(c) at this time is unnecessary because EPA could use it later if PLP overturns USACE's permit denial, or if a new permit application is submitted in the future. ADNR takes the position that use of CWA Section 404(c) would be premature because it believes USACE's permit denial inappropriately terminated the permit review process and that "critical information on the effects and measures the agencies would employ to avoid and minimize [project] impacts was not completed or published." EPA Region 10 has fully considered these issues and provides its rationale for pursuing a CWA Section 404(c) review at this time in Section 2.2.3 of this proposed determination.
- **Whether the 2020 Mine Plan's potential impacts on fishery areas warrant review pursuant to Section 404(c).** ADNR, PLP, and Chuchuna Minerals question the basis for EPA Region 10's concerns that a mine at the Pebble deposit could adversely affect fishery areas. ADNR and PLP provide quotes from the 2020 Mine Plan's FEIS, which suggest that the 2020 Mine Plan's impacts on fishes would not be "measurable." As discussed in detail in Sections 3 and 4, as well as in Appendix B, of this proposed determination, EPA Region 10 believes that information in the FEIS and other parts of the record indicates that discharges of dredged or fill material associated with the 2020 Mine Plan could result in unacceptable adverse effects on fishery areas.
- **Whether a Section 404(c) action in this case would violate the rights established in the ASA, CILEA, ANILCA, and ANCSA.** Nothing in the ASA, CILEA, ANILCA, or ANCSA, nor any other relevant authority, precludes the application of a duly enacted federal law, including Section 404(c) of the CWA, nor does any such law serve as a barrier to EPA's use of Section 404(c) of the CWA to prohibit or restrict discharges of dredged or fill material from mining the Pebble deposit into waters of the United States.

After fully considering the March 28, 2022 submittals from ADNR, PLP, and Chuchuna Minerals, the EPA Region 10 Regional Administrator was not satisfied that no unacceptable adverse effect could occur or that adequate corrective action could be taken to prevent an unacceptable adverse effect. Thus, EPA Region 10 decided that the appropriate next step in this CWA Section 404(c) process is the publication of this revised proposed determination.

2.2.3 Authority and Justification for Undertaking a Section 404(c) Review at this Time

Consistent with Congressional intent that EPA have authority to prevent unacceptable adverse effects on specific aquatic resources, Congress provided broad authority to EPA to decide whether or when to use its Section 404(c) authority. Section 404(c) authorizes EPA to act "whenever" it makes the required determinations under the statute. As a result, EPA may use its CWA Section 404(c) authority "at *any* time," including before a permit application has been submitted, at any point during the permitting process, or after a permit has been issued (33 U.S.C. 1344(c); 40 CFR 231.1(a), (c); *Mingo Logan Coal Co. v. EPA,* 714 F.3d 608, 613 (DC Cir. 2013)).

Relationship to USACE Permitting Process. Section 404(c) provides EPA with independent authority, separate and apart from the USACE permitting process, to review and evaluate potential discharges of dredged or fill material into waters of the United States. While the statutory language in Section 404(b) expressly makes USACE's authority "subject to subsection (c)," there is no comparable text in Section 404(c) that constrains EPA's authority. The statute and EPA's CWA Section 404(c) implementing regulations provide USACE with a consultation role when EPA uses its Section 404(c) authority. Furthermore, EPA's determination of unacceptable adverse effects under Section 404(c) is not coterminous with the requirements that apply to USACE's permitting decisions.

Nothing in the CWA or EPA's CWA Section 404(c) regulations precludes EPA from exercising its authority where USACE has denied a permit. Although EPA's 1979 preamble to the Section 404(c) regulations recognized that EPA may choose not to exercise its authority in instances "where the Regional Administrator also has reason to believe that [the] permitting authority will deny the permit" because "a 404(c) proceeding would be unnecessary," that was a statement of policy rather than an indication of a limitation on EPA's authority (44 FR 58079, October 9, 1979). Moreover, in this instance, PLP filed an administrative appeal of USACE's permit denial on January 19, 2021. USACE's review of this appeal is ongoing, and USACE has not stated when its review will be completed. EPA need not wait until USACE acts on an appeal of a permit denial to exercise its independent authority to prevent unacceptable adverse effects. Furthermore, in this proposed determination, EPA Region 10 has concluded that each of the impacts on aquatic resources identified in Sections 4.2.1 through 4.2.4 could, independently, result in unacceptable adverse effects. That finding is distinguishable from the USACE permit denial, in which USACE reached its conclusions based on consideration of total project impacts on aquatic resources.

Relationship between CWA Section 404(c) and CWA Section 404(q) Process. EPA's CWA Section 404(c) regulations authorize the Regional Administrator to initiate the CWA Section 404(c) process "after evaluating the information available to him, including any record developed under the section 404 referral process" (40 CFR 231.3(a)). EPA's regulations include a comment, which states that "[i]n cases involving a proposed disposal site for which a permit application is pending, it is anticipated that the procedures of the section 404 referral process will normally be exhausted prior to any final decision of whether to initiate a 404(c) proceeding" (see *Comment* at 40 CFR 231.3(a)(2)). EPA has explained that the reference to the "404 referral process" in the regulations is now manifested as the coordination processes EPA and USACE have established under CWA Section 404(q) (84 FR 45749, 45752, August 30, 2019).[29]

All that is required in EPA's CWA Section 404(c) regulations concerning 404(q) is that EPA consider any information generated during the Section 404(q) MOA interagency coordination process, if applicable. However, the statement is also a statement of policy but in no way constrains EPA's legal authority under CWA Section 404(c). Nothing in the statute or EPA's regulations restricts EPA to considering information or concerns raised during the Section 404(q) elevation process, if any. Indeed, the Section

[29] See footnote 26 in Section 2.

404(q) MOA itself recognizes that it does not constrain EPA's statutory authority under CWA Section 404(c): "[t]his agreement does not diminish either Army's authority to decide whether a particular individual permit should be granted, including determining whether the project is in compliance with the Section 404(b)(1) Guidelines, or the Administrator's authority under Section 404(c) of the Clean Water Act" (EPA and DOA 1992: Part I, paragraph 5).

EPA Policy and Precedent Regarding Use of Its CWA Section 404(c) Authority. EPA has used its Section 404(c) authority judiciously, including in instances before a permit application has been submitted, at various stages during the permitting process, and after permit issuance. In the 50 years since Congress enacted CWA Section 404(c), EPA has only initiated the process 30 times and only issued 13 final determinations. Each instance where EPA initiated a CWA Section 404(c) process has involved EPA's case-by-case determination of when and how to exercise its CWA Section 404(c) authority based on the specific facts of each situation consistent with applicable statutory and regulatory requirements.

EPA's 1979 preamble to the Section 404(c) regulations includes statements describing EPA's general policy intentions regarding the use of its Section 404(c) authority. It states the following:

> EPA's announcement of intent to start a 404(c) action will ordinarily be preceded by an objection to the permit application, and under § 325.8 such objection serves to halt issuance of the permit until the matter is resolved. . . . The promulgation of regulations under 404(c) will not alter EPA's present obligations to make timely objections to permit applications where appropriate. It is not the Agency's intention to hold back and then suddenly to spring a veto action at the last minute. The fact that 404(c) may be regarded as a tool of last resort implies that EPA will first employ its tool of 'first resort,' e.g., comment and consultation with the permitting authority at all appropriate stages of the permit process (44 FR 58080, October 9, 1979).

The clear intention behind this policy is that EPA voice any concerns it has throughout the process. EPA has done that here, as summarized below.

EPA's actions throughout the entire Pebble Mine project history, including during the USACE permitting process, are consistent with the general policy articulated in the 1979 preamble. EPA employed its tools of first resort, including comment and consultation with USACE during the permitting process. EPA also initiated the CWA Section 404(q) process by providing USACE a CWA Section 404 "3a" letter on July 1, 2019, out of concern regarding "the extent and magnitude of the substantial proposed impacts to streams, wetlands, and other aquatic resources that may result, particularly in light of the important role these resources play in supporting the region's valuable fishery resources" (EPA 2019: Page 3). As part of the CWA Section 404(q) MOA dispute resolution process. EPA engaged in 12 weeks of coordination with USACE to evaluate the 2020 Mine Plan for compliance with the Section 404(b)(1) Guidelines, from March 2020 through May 2020. On May 28, 2020, EPA sent a letter to USACE that had the effect of discontinuing the formal CWA Section 404(q) MOA dispute resolution process. In its letter, EPA explained that the "[USACE] has demonstrated its commitment to the spirit of the dispute resolution process pursuant to the 1992 Memorandum of Agreement between EPA and the Department of the Army regarding CWA Section 404(q) by the extensive engagement with the EPA over the recent months" and "recent commitment to continue this coordination into the future, outside of the formal dispute process." The letter recognized that although there was not a need at that time for a formal dispute process, substantive discussions among USACE, EPA, and USFWS regarding compliance with the Guidelines were ongoing and the agencies were continuing to discuss and raise concerns.

Timing of EPA's Action. Congress enacted CWA Section 404(c) to provide EPA the ultimate authority, if it chooses on a case-by-case basis, to make decisions regarding disposal sites for dredged and fill material discharges under CWA Section 404 (*Mingo Logan Coal Co. v. EPA*, 714 F.3d 608, 612-13 (D.C. Cir. 2013)). EPA Region 10 has reviewed the available information,[30] including the relevant portions of the USACE permitting record, and this information supports the findings reported in this proposed determination.

If EPA acts now, based on an extensive and carefully considered record, EPA, USACE, and the regulated community can avoid unnecessary expenditure of resources. By acting now, EPA clarifies its assessment of the effects of discharges of dredged or fill material associated with the construction and routine operation of the 2020 Mine Plan in light of the importance of the anadromous fishery areas at issue and, therefore, promotes regulatory certainty for all stakeholders.

In this proposed determination, EPA also proposes to restrict the use of a defined area for specification as a disposal site, because it has reason to believe that the discharge of dredged or fill material into waters of the United States within this area could result in unacceptable adverse effects on fishery areas (including spawning and breeding areas). By acting now to restrict discharges for the construction and routine operation of any future plan to mine the Pebble deposit that would either individually or collectively result in adverse effects similar or greater in nature and magnitude to those associated with the 2020 Mine Plan, EPA provides clarity to the regulated community and all interested stakeholders, which will help avoid unnecessary costs and investments. The federal government, the State of Alaska, federally recognized tribal governments, PLP, and many interested stakeholders have devoted significant resources over many years of engagement and review. Considering the extensive record, it is not reasonable or necessary to engage in one or more additional multi-year NEPA and CWA Section 404 processes for future plans[31] that propose to discharge dredged or fill material associated with mining the Pebble deposit that could result in effects that are similar or greater in nature and magnitude to the effects of the 2020 Mine Plan. Ultimately, proposing the restriction now provides the most effective, transparent, and predictable protection of valuable anadromous fishery areas against unacceptable adverse effects throughout the Defined Area for Restriction (Section 5.2.1).

[30] The available information includes, among other things, pre-CWA Section 404 permit application and advance NEPA coordination meetings beginning in 2004; NDM's preliminary mine plans submitted to the SEC (Ghaffari et al. 2011, SEC 2011); PLP's initial and supplemental Environmental Baseline Documents (PLP 2011, PLP 2018a); EPA's BBA (EPA 2014); PLP's CWA Section 404 permit application (PLP 2017, PLP 2020b); and USACE's FEIS and ROD regarding PLP's permit application (USACE 2020a, USACE 2020b).

[31] USACE's denial of PLP's permit application does not address any other plan to mine the Pebble deposit that would have adverse effects similar or greater in nature and magnitude to the 2020 Mine Plan.

SECTION 3. IMPORTANCE OF THE REGION'S ECOLOGICAL RESOURCES

The Bristol Bay watershed represents a largely pristine, intact ecosystem with outstanding ecological resources. It is home to at least 29 fish species, more than 40 terrestrial mammal species, and more than 190 bird species. This ecological wealth supports a number of sustainable economies that are of vital importance to the region, including subsistence, commercial, and sport fishing; subsistence and sport hunting; and non-consumptive recreation. The undisturbed habitats of the Bristol Bay watershed support one of the last salmon-based cultures in the world (EPA 2014: Appendix D), and the subsistence way of life in this region is irreplaceable. Between 2013 and 2019, the annual economic output generated by Bristol Bay's wild salmon resources has been estimated at more than $1 billion (Wink Research and Consulting 2018, McKinley Research Group 2021), with total economic value (including subsistence uses) estimated at more than $2 billion in 2019 (McKinley Research Group 2021).

The following sections consider the Bristol Bay watershed's ecological resources, with particular focus on the region's fish habitats and populations and the watershed characteristics that support these resources. These topics are considered at multiple geographic scales. The Pebble deposit is located in the headwaters of tributaries to both the Nushagak and Kvichak Rivers. The three tributaries that originate within the Pebble deposit are the SFK, which drains the western part of the Pebble deposit area and converges with the NFK west of the Pebble deposit; the NFK, located immediately west of the Pebble deposit; and UTC, which drains the eastern portion of the Pebble deposit and flows into the Kvichak River via Iliamna Lake.[32] The SFK, NFK, and UTC watersheds are the areas that would be most directly affected by mine development at the Pebble deposit. Streams and wetlands in these watersheds provide habitat for five species of Pacific salmon and numerous other fish species; they also support fish habitats and populations in larger downstream systems via contributions of water, organisms, organic matter, and other resources. Thus, ecological resources across broader geographic scales (i.e., throughout the Nushagak and Kvichak River watersheds) are considered.

3.1 Physical Setting

Bristol Bay is a large gulf of the Bering Sea located in southwestern Alaska. The land area draining to Bristol Bay consists of six major watersheds—from west to east, the Togiak, Nushagak, Kvichak, Naknek, Egegik, and Ugashik River watersheds—and a series of smaller watersheds draining the North Alaska Peninsula (Figure ES-1). The Pebble deposit is located in the headwaters of tributaries to both the

[32] The SFK comprises two 12-digit hydrologic unit codes (HUCs): the Headwaters Koktuli River (190303021101) and the Upper Koktuli River (109303021102). The NFK comprises two 12-digit HUCs: Groundhog Mountain (190303021103) and 190303021104 (located immediately west of the Pebble deposit). UTC represents one 10-digit HUC (1903020607).

Nushagak and Kvichak Rivers; together, the watersheds of the Nushagak and Kvichak Rivers account for approximately half of the land area in the Bristol Bay watershed (USACE 2020a: Section 3.24).

Detailed information on the Bristol Bay watershed's physical setting, in terms of physiography, hydrologic landscapes, and seismicity, can be found in Chapter 3 of the BBA (EPA 2014). One component of the watershed's physical setting, however, is particularly important to note: the watersheds draining to Bristol Bay provide intact, connected, and free-flowing habitats from headwaters to ocean. Unlike most other areas supporting Pacific salmon populations, the Bristol Bay watershed is undisturbed by significant human development and impacts. It is located in one of the last remaining virtually roadless areas in the United States (EPA 2014: Chapter 6). Large-scale, human-caused modification of the landscape—a factor contributing to extinction risk for many native salmonid populations (Nehlsen et al. 1991)—is absent, and development in the watershed consists of only a small number of towns, villages, and roads. The Bristol Bay watershed also encompasses Iliamna Lake, the largest undeveloped lake in the United States.

The primary human manipulation of the Bristol Bay ecosystem is the marine harvest of approximately 70 percent of salmon returning to spawn (EPA 2014: Chapter 5). Management of Alaska's salmon fisheries is geared toward maintenance of a sustainable fishery through protection of its wild salmon populations, or stocks (5 AAC 39.200, 5 AAC 39.220, 5 AAC 39.222, 5 AAC 39.223). A key goal of ADF&G's policy for the management of sustainable salmon fisheries is "to ensure conservation of salmon and salmon's required marine and aquatic habitats" (5 AAC 39.222), highlighting the importance of maintaining sustainable salmon-based ecosystems. Fishery management in Bristol Bay is unique in part because no hatchery fishes are reared or released in the watershed, whereas approximately 5 billion hatchery-reared juvenile Pacific salmon are released annually across the North Pacific (Irvine et al. 2012). This lack of hatchery fishes in the Bristol Bay region is notable, given the economic investment that rearing and releasing hatchery fishes requires and the fact that its benefits are highly variable and difficult to quantify (Naish et al. 2008). Hatchery fishes also can have significant adverse effects on wild fish populations (e.g., Levin et al. 2001, Araki et al. 2009, Rand et al. 2012, Evenson et al. 2018, Tillotson et al. 2019).

3.2 Aquatic Habitats

The Bristol Bay region encompasses complex combinations of physiography, climate, geology, and hydrology, which interact to control the amount, distribution, and movement of water through a landscape shaped by processes such as tectonic uplift, glaciation, and fluvial erosion and deposition. Ultimately, these factors result in a landscape marked by abundant, diverse freshwater habitats. These diverse habitats, in conjunction with the enhanced ecosystem productivity associated with anadromous salmon runs, support a high level of biological complexity (biocomplexity) that contributes to the environmental integrity and resilience of the Bristol Bay watershed's ecosystems (Section 3.3.3) (Schindler et al. 2010, Ruff et al. 2011, Lisi et al. 2013, Schindler et al. 2018, Brennan et al. 2019).

This section presents key aspects of these aquatic habitats, in terms of characteristics that contribute to their quality and diversity, the quantity and types of streams and wetlands found in the region, and their importance in the larger landscape.

3.2.1 Quantity and Diversity of Aquatic Habitats

In general, conditions in the Bristol Bay watershed are highly favorable for Pacific salmon. The region encompasses an abundant and diverse array of aquatic habitats (Section 3.2) that in turn support a diverse salmonid assemblage (Section 3.3). Together, these factors result in high degrees of phenotypic and genotypic diversity across the region's salmon populations. This biocomplexity produces the asynchronous dynamics that stabilize the overall portfolio of salmon returns to the region (Section 3.3.3).

In the Nushagak and Kvichak watersheds, freshwater habitats range from headwater streams to braided rivers, small ponds to large lakes, and side channels to off-channel alcoves. Overall physical habitat complexity is higher in the Bristol Bay watershed than in many other systems supporting Sockeye Salmon populations. Of 1,509 North Pacific Rim watersheds, the Kvichak, Wood, and Nushagak (exclusive of Wood) Rivers (Figure ES-2) ranked third, fourth, and forty-fourth, respectively, in physical habitat complexity, based on an index including variables such as lake coverage, stream junction density, floodplain elevation and density, and human footprint (Luck et al. 2010, RAP 2011).

Lakes and associated tributary and outlet streams are key spawning and rearing areas for Sockeye Salmon. Lakes cover relatively high percentages of watershed area in the Bristol Bay region, with 7.9 percent lake cover for the Bristol Bay watershed and 13.7 percent lake cover for the Kvichak River watershed within the larger Bristol Bay watershed (RAP 2011). In other North Pacific river systems supporting Sockeye Salmon populations, from northern Russia to western North America, these values tend to be much lower (0.2 to 2.9 percent) (RAP 2011). Relatively low watershed elevations and the absence of artificial barriers to migration (e.g., dams and roads) mean that not only are streams, lakes, and other aquatic habitats abundant in the Bristol Bay region, but they also tend to be accessible to anadromous salmonids (EPA 2014: Appendix A).

Gravel is an essential substrate for salmon spawning and egg incubation (Bjornn and Reiser 1991, Quinn 2005). Specific substrate and hydraulic requirements vary slightly by species (EPA 2014: Appendix A), but stream-spawning salmon generally require relatively clean gravel-sized substrates with interstitial flow, and sufficient bed stability to allow eggs to incubate in place for months prior to fry emergence (Quinn 2005). In the Bristol Bay watershed, gravel substrates are abundant (EPA 2014: Chapter 7). The Pebble deposit area is heavily influenced by past glaciation (PLP 2011: Chapter 3), and unconsolidated glacial deposits cover most of the area's lower elevations (Detterman and Reed 1973). As a result, the SFK, NFK, and UTC stream valleys have extensive glacial sand and gravel deposits (PLP 2011: Chapter 8).

A key aspect of the Bristol Bay watershed's aquatic habitats is the importance of groundwater exchange. Because salmon rely on clean, cold water flowing over and upwelling and downwelling through porous gravel for spawning, egg incubation, and rearing (Bjornn and Reiser 1991), areas of groundwater exchange create high-quality salmon habitat (EPA 2014: Appendix A). For example, densities of beach-spawning Sockeye Salmon in the Wood River watershed (within the larger Nushagak River watershed) were highest at sites with strong groundwater upwelling and zero at sites with no upwelling (Burgner 1991). Significant portions of the Nushagak and Kvichak River watersheds, including the Pebble deposit area, contain coarse-textured glacial drift with abundant, high-permeability gravels and extensive connectivity between surface waters and groundwater (EPA 2014: Chapter 3).

Groundwater is the source of baseflow in most streams draining the Pebble deposit area (Rains 2011, USACE 2020a: Section 3.17). Groundwater contributions to streamflow, along with the influence of run-of-the-river lakes, support flows in the region's streams and rivers that are more stable than those typically observed in many other salmon streams (e.g., in the Pacific Northwest or southeastern Alaska). This results in more moderated streamflow regimes with lower peak flows and higher baseflows, creating a less temporally variable hydraulic environment (EPA 2014: Figure 3-10). Interactions between surface waters and groundwater in the SFK, NFK, and UTC watersheds are complex and dependent on factors such as local soil type and land and water table gradients. These watersheds include reaches that gain water from groundwater and reaches that lose water to groundwater, with hyporheic flows occurring at very local scales (USACE 2020a: Section 3.17).

This groundwater–surface water connectivity also has a strong influence on stream thermal regimes in the Nushagak and Kvichak River watersheds, providing a moderating influence against both summer heat and winter cold extremes. Average monthly stream water temperatures in the Pebble deposit area in July or August can range from 6°C to 16°C, and temperatures do not uniformly increase with decreasing elevation (PLP 2011: Appendix 15.1E, Attachment 1). This spatial variability in temperatures in the Pebble deposit area is consistent with streams influenced by a variety of thermal modifiers, including groundwater inputs, upstream lakes, and tributary contributions (Mellina et al. 2002, Armstrong et al. 2010). Longitudinal temperature profiles from August and October indicate that the mainstem SFK and NFK reaches just downstream of the tributaries draining the potential mine area experience significant summer cooling and winter warming compared to adjacent upstream reaches (PLP 2011: Chapter 9), suggesting significant groundwater contributions. Consistent winter observations of ice-free conditions in the area's streams also suggest the presence of upwelling groundwater in strongly gaining reaches of the SFK, NFK, and UTC (PLP 2011: Chapter 7, Woody and Higman 2011). Areas of groundwater downwelling are also important to fish and aquatic species and are documented to occur in the SFK, NFK, and UTC watersheds (USACE 2020a: Section 3.17).

These groundwater–surface water interactions and their influence on water temperature are extremely important for fishes, particularly salmon. Water temperature controls the metabolism and behavior of salmon and, if temperatures are stressful, fishes can be more vulnerable to disease, competition, predation, or death (McCullough et al. 2009). The State of Alaska has maximum temperature limits for salmon migration routes, spawning and rearing areas, and fry incubation areas (ADEC 2020). However, summer is not the only period of temperature sensitivity for salmon (Poole et al. 2004). For example, small temperature changes during salmon egg incubation in gravels can alter the timing of emergence by months (Brannon 1987, Beacham and Murray 1990, Quinn 2005). Groundwater moderates winter temperatures, which strongly control egg development, egg hatching, and emergence timing (Brannon 1987, Hendry et al. 1998). Groundwater contributions that maintain water temperatures above 0^{0}C are critical for maintaining winter refugia in streams that might otherwise freeze (Power et al. 1999). Thus, winter groundwater connectivity may be critical for fishes in such streams (Cunjak 1996, Huusko et al. 2007, Brown et al. 2011).

Since the timing of migration, spawning, and incubation are closely tied to seasonal water temperatures, groundwater-influenced thermal heterogeneity can also facilitate diversity in run timing and other salmon life-history traits (Hodgson and Quinn 2002, Rogers and Schindler 2011, Ruff et al. 2011). Any thermal regime alterations resulting from changes in groundwater–surface water connectivity could disrupt life-history timing cues and result in mismatches between fishes and their environments that adversely affect survival (Angilletta et al. 2008).

In terms of water quality, streams draining the Pebble deposit area tend to be near-neutral, with low conductivity, alkalinity, dissolved solids, suspended solids, and dissolved organic carbon (USACE 2020a: Section 3.18). In these respects, they are characteristic of undisturbed streams. However, as would be expected for a metalliferous site, levels of sulfate and some metals (copper, molybdenum, nickel, and zinc) are elevated, particularly in the SFK. Copper levels in approximately 40 percent of samples from the SFK exceeded Alaska's chronic water quality standard (USACE 2020a: Section 3.18). However, most exceedances were in or close to the deposit area, and the number and magnitude of exceedances decreased with distance downstream (USACE 2020a: Appendix K3.18).

In summary, the Bristol Bay watershed in general, and the SFK, NFK, and UTC watersheds specifically, provide diverse and productive habitat for salmon and other fishes. Suitable substrates for salmon spawning, egg incubation, and rearing are abundant. Extensive connectivity between groundwater and surface waters creates and maintains a variety of streamflow and thermal regimes across the region, resulting in favorable spawning and rearing habitats for salmonids and helping to support diverse fish assemblages.

3.2.2 Streams

The Nushagak and Kvichak River watersheds contain over 33,000 miles (54,000 km) of streams, approximately 670 miles (1,085 km) of which are in the SFK, NFK, and UTC watersheds. The stream and river habitats of the SFK, NFK, and UTC watersheds can be characterized in terms of attributes that generally represent fundamental aspects of the physical and geomorphic settings in streams. Evaluation of stream and river habitats within the SFK, NFK, and UTC watersheds based on these attributes provides important context for how these streams and rivers contribute to fish habitats (Burnett et al. 2007, Shallin Busch et al. 2013). EPA (2014) describes stream and river valley attributes for each of the 52,277 stream and river reaches in the Nushagak and Kvichak River watersheds documented in the

National Hydrography Dataset (NHD) (USGS 2012).[33] Three key attributes were estimated for each reach: mean channel gradient, mean annual streamflow, and percentage of flatland in the contributing watershed lowland (EPA 2014: Chapters 3 and 7). Stream reaches were then categorized according to each attribute to evaluate the relative suitability of these reaches as fish habitat.[34]

Results of the stream reach classification show that a high proportion of stream channels in the SFK, NFK, and UTC watersheds possess the broad geomorphic and hydrologic characteristics that create stream and river habitats highly suitable for fishes such as Pacific salmon, Rainbow Trout, and Dolly Varden: low stream gradients, mean annual streamflows greater than or equal to 5.3 ft^3/s (0.15 m^3/s), and at least 5 percent flatland in lowland (an indicator of the potential for floodplain development) (EPA 2014: Chapter 7).

The substrate and hydraulic conditions required by stream-spawning salmon are most frequently met in stream channels with gradients less than 3 percent (Montgomery et al. 1999). Pool-riffle channels have moderate slopes (<1.5 to 2 percent) and are indicative of quality spawning habitat (Miller et al. 2008, Buffington et al. 2004). At gradients above 3 percent, the size, stability, and frequency of pockets of suitable spawning substrates decrease substantially (Montgomery and Buffington 1997). In the SFK, NFK, and UTC watersheds, low-gradient (<3 percent) channels account for 87 percent of the stream network, highlighting the availability of quality salmon spawning habitat in this region.

Mean annual streamflow is a metric of stream size. Pacific salmon in the Bristol Bay region use a wide range of river and stream sizes for migration, spawning, and/or rearing habitat, but low-gradient streams of medium size (5.3 to 100 ft^3/s [0.15 to 2.8 m^3/s] mean annual streamflow) or greater likely provide high-capacity, high-quality habitats for salmonids (EPA 2014: Chapter 7). Such streams and rivers account for 34 percent of the stream network in the SFK, NFK, and UTC watersheds (Table 3-1). However, salmonid species differ in their propensities for small streams. Dolly Varden have been documented using all stream sizes, including some of the smallest channels. Of the Pacific salmon species, Coho Salmon are most likely to use small streams for spawning and rearing and have been observed in many of the smaller streams near the Pebble deposit. Larger-bodied Chinook Salmon adults are less likely to access smaller streams for spawning (Quinn 2005), although each year 12 to 21 percent of radio-tagged Chinook Salmon in the Togiak River watershed (located southwest of the Nushagak River watershed) spawned in smaller order tributaries (Sethi and Tanner 2014). Juvenile Chinook Salmon also have been observed in small tributaries where spawning has not been documented (Bradford et al. 2001), including in smaller streams near the Pebble deposit. In the SFK, NFK, and UTC watersheds, small streams account for 65 percent of the stream network.

[33] Analysis is based on the 2012 iteration of the NHD (USGS 2012); total mapped stream length in the SFK, NFK, and UTC watersheds changed by only 1 percent between the 2012 and 2021 iterations of the NHD.

[34] EPA (2014: Chapters 3 and 7) provides a detailed discussion of the importance of each attribute in determining fish habitat and the method used to categorize each attribute.

Streams in the larger valleys of the SFK, NFK, and UTC watersheds tend to have extensive flat floodplains or terraces (Table 3-1). These unconstrained channels generally have higher complexity of channel habitat types and hydraulic conditions and higher frequencies of off-channel habitats such as side channels, sloughs, and beaver ponds. Such habitat complexity can be beneficial to salmon by providing a diversity of spawning and rearing habitats throughout the year (Stanford et al. 2005). For Coho and Chinook salmon, as well as river-rearing Sockeye Salmon that may overwinter in streams, such habitats may be particularly valuable for juvenile rearing and overwintering by providing unique thermal, foraging, and growth advantages not available in the main channel (Bradford et al. 2001, Huntsman and Falke 2019). In addition, smaller, steeper streams in the watersheds provide both seasonal (and some year-round) habitat for other fish species and important nutrient supply to downstream waters (Section 3.2.4).

Table 3-1. Distribution of stream channel length classified by channel size (based on mean annual streamflow), channel gradient, and floodplain potential for streams and rivers in the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek watersheds. See EPA (2014) Chapters 3 and 7 for additional details on the methods used to classify stream channels. [a]

	Gradient							
	<1%		≥1% and <3%		≥3% and <8%		≥8%	
Channel Size	FP [b]	NFP [b]	FP [b]	NFP [b]	FP [b]	NFP [b]	FP [b]	NFP [b]
Small headwater streams [c]	15%	5%	5%	28%	0%	12%	0%	0%
Medium streams [d]	14%	6%	0%	3%	0%	1%	0%	0%
Small rivers [e]	8%	2%	0%	1%	0%	0%	0%	0%
Large rivers [f]	0%	0%	0%	0%	0%	0%	0%	0%

Notes:

[a] Analysis is based on 2012 iteration of the NHD (USGS 2012); total mapped stream length in the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek watersheds changed by only 1 percent between 2012 and 2021 iterations of the NHD.

[b] FP = high floodplain potential (greater than or equal to five percent of flatland in lowland); NFP = no or low floodplain potential (less than five percent of flatland in lowland).

[c] 0–5.3 ft^3/s (0–0.15 m^3/s); most tributaries in the mine footprints defined in the BBA (EPA 2014: Chapter 6).

[d] 5.3–100 ft^3/s (0.15–2.8 m^3/s); upper reaches and larger tributaries of the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek.

[e] 100–1000 ft^3/s (2.8–28 m^3/s); middle to lower portions of the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek, including mainstem Koktuli River.

[f] >1000 ft^3/s (>28 m^3/s); the Mulchatna River below the Koktuli River confluence, the Newhalen River, and other large rivers. Note that there are no large rivers in the SFK, NFK, and UTC watersheds.

3.2.3 Wetlands, Lakes, and Ponds

A thorough inventory of wetland, lake, and pond habitats within the Bristol Bay watershed, or even the Nushagak and Kvichak River watersheds, has not been completed. However, the National Wetlands Inventory (NWI) (USFWS 2021) has data for approximately 96 percent of the area encompassed by the SFK, NFK, and UTC watersheds (Table 3-2).

Table 3-2. Acreage of wetland habitats in the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek watersheds.

Wetland Type	Description	Area (acres) [a]	Percent of Total Area [b]
Freshwater emergent wetland	Non-tidal wetlands dominated by erect, rooted herbaceous hydrophytes	11,228	5
Freshwater forested/scrub-shrub wetland	Non-tidal wetlands dominated by either trees greater than 20 feet in height (forested) or shrubs and tree saplings less than 20 feet in height (scrub-shrub)	24,108	11
Freshwater pond	Non-tidal wetlands and shallow water (less than 6.6 feet deep) habitats that are at least 20 acres in size, have either less than 30 percent vegetative cover or a plant community dominated by species that principally grow on or below water surface, and have at least 25 percent of substrates less than 2.75 inches in size	3,419	2
Lake	Wetlands and deep-water (deeper than 6.6 feet) habitats that are situated in topographic depressions, have less than 30 percent vegetative cover, and are greater than 20 acres in size	1,737	1
Riverine	Wetlands and deep-water (deeper than 6.6 feet) habitats in natural or artificial channels that contain flowing water at least periodically	1,169	1
TOTAL		**42,111**	**18**

Notes:

[a] Approximately 96 percent of the area within these watersheds has National Wetlands Inventory (NWI) coverage; the 4 percent of the area without coverage is located in lower elevation areas of the Upper Talarik Creek watershed.

[b] Total area of the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek watersheds = 228,640 acres.

Source: USFWS 2021.

It is important to note that the characterization of aquatic habitat area is limited by resolution of the available NWI data, which tend to underestimate their extents. For example, multiple sources of high-resolution remote imaging and ground-truthing were used to map streams and wetlands at the mine site (USACE 2020a). This high-resolution mapping identifies approximately 400 percent more stream miles than the NHD and approximately 40 percent more wetland acres than the NWI (USFWS 2021) in this area (see Box 4-2 for additional information on water resources mapping at the mine site). However, this high-resolution mapping of aquatic resources is not available for the entire SFK, NFK, and UTC watersheds. Thus, most of the stream length estimates included in this section are based on the most recent iteration of the NHD (USGS 2021).

3.2.4 Importance of Headwater Stream and Wetland Habitats to Fish

Headwater streams and wetlands are the small channels and wetland areas located in the upstream source areas of river networks. The branched nature of river networks means that watersheds are dominated by headwater streams, in terms of both stream number and stream length (Hill et al. 2014, Callahan et al. 2015). Small headwater streams make up approximately 65 percent of assessed stream length in the SFK, NFK, and UTC watersheds (Table 3-1).[35] Thus, headwater streams—and their associated headwater wetlands—are key habitat features in this region. These headwater systems provide key habitat for numerous fish species, as well as supply water, invertebrates, organic matter, and other resources to larger downstream waters. Because of their large influence on downstream

[35] Based on the 2012 iteration of the NHD (USGS 2012); total mapped stream length in the SFK, NFK, and UTC watersheds changed by only 1 percent between the 2012 and 2021 iterations of the NHD.

water flow, water chemistry, and biota, the importance of headwater systems reverberates throughout entire watersheds downstream (Freeman et al. 2007, Meyer et al. 2007, Fritz et al. 2018, Schofield et al. 2018).

Headwater streams and spring (headwater) wetland habitats are particularly important in establishing and maintaining fish diversity (Cummins and Wilzbach 2005, Colvin et al. 2019). They support resident fish assemblages, as well as provide key habitats for specific life stages of migratory fishes. For example, headwaters provide spawning and nursery areas for fish species that use larger streams, rivers, and lakes for most of their freshwater life cycles (e.g., Pacific salmon and Rainbow Trout) (Quinn 2005). The use of headwater streams and wetlands by a variety of fish species has been observed in many aquatic ecosystems (see Meyer et al. 2007 for a thorough review). Headwater streams in southeastern Alaska can be an important source area for downstream Dolly Varden populations (Bryant et al. 2004). Foley et al. (2018) examined the distribution of juvenile Coho Salmon in three headwater streams of the Little Susitna River, Alaska; they found that juveniles occurred throughout these headwater streams where stream gradients were less than 4 to 5 percent. In the Nushagak and Kvichak River watersheds, 96 percent of 108 surveyed headwater streams contained fishes, including rearing Coho and Chinook salmon, adult Coho and Sockeye salmon, Rainbow Trout, Dolly Varden, Arctic Grayling, Round Whitefish, Burbot, and Northern Pike (Woody and O'Neal 2010).

Summer and early fall can provide opportunities for maximum growth for juvenile salmon rearing in headwater systems, as both stream temperatures and food availability increase (Quinn 2005). Although seasonal fish distribution patterns are poorly understood for the region, lower-gradient headwater streams and associated wetlands may also provide important habitat for stream fishes during other seasons. Thermally diverse habitats in off-channel wetlands can provide rearing and foraging conditions that may be unavailable in the mainstream channel, increasing capacity for juvenile salmon rearing (Brown and Hartman 1988, Nickelson et al. 1992, Cunjak 1996, Collen and Gibson 2001, Sommer et al. 2001, Henning et al. 2006, Lang et al. 2006, PLP 2011). Loss of wetlands in more developed regions has been associated with reductions in habitat quality and salmon abundance, particularly for Coho Salmon (Beechie et al. 1994, Pess et al. 2002).

Winter habitat availability for juvenile rearing has been shown to limit salmonid productivity in streams of the Pacific Northwest (Nickelson et al. 1992, Solazzi et al. 2000, Pollock et al. 2004), and may be limiting for fishes in the SFK, NFK, and UTC watersheds given the relatively cold temperatures and long winters in the region (Morrow 1980, Reynolds 1997). Overwintering habitats for stream fishes must provide suitable instream cover, dissolved oxygen, and protection from freezing (Cunjak 1996). Beaver ponds and groundwater upwelling areas in headwater streams and wetlands in the SFK, NFK, and UTC watersheds likely meet these requirements. In winter, beaver ponds typically retain liquid water below the frozen surface, creating important winter refugia for stream fishes (Cunjak 1996). Beaver ponds provide excellent habitat for rearing salmon by trapping organic materials and nutrients and creating structurally complex, large-capacity pool habitats with potentially high macrophyte cover, low streamflow velocity, and/or moderate temperatures (Nickelson et al. 1992, Collen and Gibson 2001, Pollock et al. 2004, Lang et al. 2006). Additionally, beaver dams, including ponds at a variety of successional stages, provide a mosaic of habitats for not just salmon but other fish and wildlife species (e.g., lamprey).

An October 2005 aerial survey of active beaver dams in the Pebble deposit area mapped 113 active beaver colonies (PLP 2011: Chapter 16:16.2-8). As detailed in Section 3.2.2, the SFK, NFK, and UTC watersheds are dominated by low-gradient headwater streams. Beavers preferentially colonize headwater streams—particularly those with gradients less than 6 percent—because of their shallow depths and narrow widths (Collen and Gibson 2001, Pollock et al. 2003). Beaver ponds provide important and abundant habitat within the Pebble deposit area and may be particularly important for overwinter rearing of species such as Coho Salmon and for providing deeper pool habitats for additional species during low streamflow conditions (PLP 2011: Appendix 15.1D, USACE 2020a: Section 3.24).

The lateral expansion of floodplain wetland habitats during flooding greatly influences habitat connectivity by determining whether and how long fishes can reach newly created or existing habitats (Bunn and Arthington 2002). In the Bristol Bay watershed, field observations have indicated the presence of salmon in stream sites disconnected from surface-water flows (Woody and O'Neal 2010). Annual floods during spring and fall likely reconnect these habitats through a network of ephemeral wetlands and streams. The use of these temporary stream and wetland habitats by fishes is not well understood in the Bristol Bay watershed, but they appear to be important in establishing habitat connectivity.

Inputs of groundwater-influenced streamflow from headwater tributaries likely benefit fishes by moderating mainstem temperatures and contributing to thermal diversity in downstream waters (Cunjak 1996, Power et al. 1999, Huusko et al. 2007, Armstrong et al. 2010, Brown et al. 2011, Ebersole et al. 2015). Such thermal diversity can be an important attribute of stream systems in the region, providing localized water temperature patches that may offer differing trade-offs for species bioenergetics. For example, salmon may select relatively cold-temperature sites—often associated with groundwater upwelling—for spawning, whereas juvenile salmon rearing in those same streams may take advantage of warm-temperature patches for optimal food assimilation (Armstrong and Schindler 2013). Headwater streams in the SFK and NFK watersheds may provide a temperature-moderating effect and serve as sources of thermal heterogeneity, providing cooler temperatures in summer and warmer temperatures in winter.

It has long been recognized that, in addition to providing habitat for stream fishes, headwater streams and wetlands serve an important role in the stream network by contributing water, nutrients, organic material, macroinvertebrates, algae, and bacteria downstream to higher-order streams in the watershed (Vannote et al. 1980, Meyer et al. 2007). This is particularly true in dendritic stream networks like the SFK, NFK, and UTC systems, which have a high density of headwater streams. For example, Koenig et al. (2019) found that small streams with relatively low primary productivity can exert a disproportionate effect on overall gross primary productivity in the river network, due to the large collective surface area of these small channels. Because of their narrow width, headwater streams also receive proportionally greater inputs of organic material from the surrounding terrestrial vegetation than larger stream channels (Vannote et al. 1980). This material is either used locally (Tank et al. 2010) or transported downstream to larger streams in the network (Wipfli et al. 2007).

Headwater streams—including streams with only intermittent or ephemeral flow—are important suppliers of invertebrates and detritus to downstream areas that support juvenile salmonids and other fishes (Wipfli and Gregovich 2002, Cummins and Wilzbach 2005, Colvin et al. 2019, Hedden and Giddo 2020). In transporting these materials downstream, headwaters provide an important energy subsidy for juvenile salmonids (Wipfli and Gregovich 2002). For example, Wipfli and Gregovich (2002) found that fishless headwater streams in southeastern Alaska were a year-round source of invertebrate prey for salmonids. They estimated that these streams could provide downstream salmonid-bearing habitat with enough invertebrate prey and detritus to support up to 2,000 juvenile salmonids per kilometer (Wipfli and Gregovich 2002). Recent experimental studies have also shown that disturbance and degradation of small tributaries can affect invertebrate populations in downstream reaches (Chará-Serna and Richardson 2021, González and Elosegi 2021).

The export value of headwater streams can be influenced by the surrounding vegetation. For example, riparian alder (a nitrogen-fixing shrub) was positively related to aquatic invertebrate densities and the export rates of invertebrates and detritus in southeastern Alaska streams (Piccolo and Wipfli 2002, Wipfli and Musslewhite 2004). Riparian vegetation in the Pebble deposit area is dominated by deciduous shrubs such as willow and alder (USACE 2020a: Section 3.24); thus, these streams are likely to provide abundant, high-quality detrital inputs to downstream reaches.

Headwater streams can also have high instream rates of nutrient processing and storage, thereby influencing downstream water chemistry due to relatively large organic matter inputs, high retention capacity, high primary productivity, bacteria-induced decomposition, and/or extensive hyporheic zone interactions (Richardson et al. 2005, Alexander et al. 2007, Meyer et al. 2007). In examining network-wide patterns in water chemistry of the Kuskokwim River, Alaska, French et al. (2020) found that watershed attributes of headwaters were the best predictor for almost all streamwater constituents (e.g., nitrate, phosphate, dissolved organic carbon) across the entire network. They concluded that headwaters are governing river biogeochemistry in this system (French et al. 2020). Similarly, when the natural flow regimes of headwater streams are altered, adverse effects on downstream water quality often occur (Colvin et al. 2019). Accurate assessment of these physical and chemical connections between headwaters and downstream waters—and perhaps more important, their consequences for the integrity of those downstream waters—should consider aggregate connections over multiple years to decades (Fritz et al. 2018).

In summary, headwater streams and wetlands play a vital role in maintaining diverse, abundant fish populations—both by providing important fish habitat and by supplying the energy and other resources needed to support fishes in connected downstream habitats (Colvin et al. 2019). Headwater streams and wetlands are abundant in the Pebble deposit area and likely play a crucial role in supporting local and downstream fish populations.

3.3 Fish Resources

Given the abundant, diverse, and high-quality freshwater habitats found in the Nushagak and Kvichak River watersheds, it is not surprising that this region supports world-class fishery resources. This section considers the fish species found in the Nushagak and Kvichak River watersheds, with particular focus on the SFK, NFK, and UTC watersheds; life-history, distribution, and abundance information for these species; the ecological importance of these fish populations, in terms of both maintaining biocomplexity and diversity at local and global scales and providing nutrient subsidies to habitats; and the importance of subsistence, commercial, and recreational fisheries in the region. As this section illustrates, this region supports a robust, diverse fish assemblage of considerable ecological, economic, and cultural value, and loss of these fisheries could have significant repercussions.

3.3.1 Species and Life Histories

The Bristol Bay watershed is home to at least 29 fish species, representing at least nine different families. The 29 species documented to occur in the Nushagak and Kvichak River watersheds, as well as information on their migratory patterns and general abundance, habitat types, and predator-prey relationships, are listed in Table 3-3. At least 20 of these species are known to inhabit the SFK, NFK, and UTC watersheds (USACE 2020a: Section 3.24). The region is renowned for its fish populations, and it supports world-class fisheries for multiple species of Pacific salmon and other subsistence and game fishes (Dye and Borden 2018, Halas and Neufeld 2018). These resources generate significant benefit for commercial fishers (Section 3.3.5), provide nutritional and cultural sustenance for Alaska Native populations and other residents (Section 3.3.6), and support valued recreational fisheries (Section 3.3.7).

Five species of Pacific salmon spawn and rear in the Bristol Bay watershed's freshwater habitats: Coho or Silver salmon, Chinook or King salmon, Sockeye or Red salmon, Chum or Dog salmon, and Pink or Humpback salmon. Because no hatchery fishes are raised or released in the watershed, Bristol Bay's salmon populations are entirely wild.

All five salmon species share life-history traits that contribute to their success and significance in the Bristol Bay region. First, they are anadromous: they hatch in freshwater habitats, migrate to sea for a period of relatively rapid growth, and then return to freshwater habitats to spawn. Second, the vast majority of adults return to their natal freshwater habitats to spawn. This homing behavior fosters reproductive isolation, thereby enabling populations to adapt to the particular environmental conditions of their natal habitats (Blair et al. 1993, Dittman and Quinn 1996, Ramstad et al. 2010, Eliason et al. 2011) (Section 3.3.3). Finally, each species is semelparous: adults return to their natal stream to spawn once and die, thereby releasing the nutrients incorporated into their bodies in their spawning habitats (Section 3.3.4).

The seasonality of spawning and incubation is roughly the same for all five Pacific salmon species, although the timing can vary somewhat by species, population, and region. For example, Coho Salmon tend to spawn later in the season and have shorter incubation periods (Spence 1995). In general, salmon spawn from summer through fall, and fry emerge from spawning gravels the following spring to summer. Freshwater habitats used for spawning and rearing vary across and within species, and include headwater streams, larger mainstem rivers, side- and off-channel wetlands, ponds, and lakes (Table 3-4; Section 3.3.3). With some exceptions, preferred spawning habitat consists of gravel-bedded stream reaches of moderate water depth (12 to 24 in [30 to 60 cm]) and current (12 to 40 in/s [30 to 100 cm/s]) (Quinn 2005). In Alaska, studies have also found groundwater exchange to be of key importance for spawning salmon site selection (MacLean 2003, Curran et al. 2011, Mouw et al. 2014, McCracken 2021). Sockeye Salmon are unique among the species in that most populations rely on lakes as the primary freshwater rearing habitat (Table 3-4); see Section 3.3.3 for a discussion of river-type Sockeye Salmon populations in the Bristol Bay watershed.

Table 3-3. Fish species reported in the Nushagak and Kvichak River watersheds. Species in bold have been documented to occur in aquatic habitats within the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek watersheds. (H) indicates species considered to be harvested—that is, they are well-distributed across the Nushagak and Kvichak River watersheds and are or have been targeted by subsistence, commercial, or recreational fisheries. This list does not include primarily marine species that periodically venture into the lower reaches of coastal streams.

Family	Species	Migratory Pattern(s) [a]	Relative Abundance	Predator–Prey Relationships [b]
Salmonids (Salmonidae)	Bering Cisco *(Coregonus laurettae)*	N and A	Very few specific reports	-
	Humpback Whitefish (H) *(C. pidschian)*	N and A	Common in large lakes; locally and seasonally common in large rivers	Feed primarily on aquatic invertebrates (mollusks, insect larvae), also salmon eggs and small fry Eaten by other fishes (Northern Pike, Lake Trout); eggs eaten by Round Whitefish, Arctic Grayling)
	Least Cisco *(C. sardinella)*	N and A	Locally common in some lakes (e.g., Lake Clark, morainal lakes near Iliamna Lake); less common in Iliamna Lake and large slow-moving rivers, such as the Chulitna, Kvichak, and lower Alagnak	Feed on aquatic invertebrates (insect larvae, copepods) Eaten by other fishes (Lake Trout, Northern Pike, Burbot) and fish-eating birds
	Pygmy Whitefish *(Prosopium coulterii)*	N	Locally common in a few lakes or adjacent streams	Feed on aquatic invertebrates (insect larvae, zooplankton, mollusks) and whitefish eggs Eaten by other fish (Lake Trout, Arctic Char, Dolly Varden) and fish-eating birds
	Round Whitefish *(P. cylindraceum)*	N	Abundant/widespread throughout larger streams in upland drainages; not found in headwaters or coastal plain areas	Feed on aquatic invertebrates (insect larvae, snails) and salmon and whitefish eggs Eaten by other fishes (Burbot, Lake Trout, Northern Pike)
	Coho Salmon (H) *(Oncorhynchus kisutch)*	A	Juveniles abundant/widespread in flowing waters of Nushagak River watershed and in some Kvichak River tributaries downstream of Iliamna Lake; present in some Iliamna Lake tributaries; not recorded in the Lake Clark watershed	Juveniles feed primarily on aquatic invertebrates (insect larvae) and salmon eggs and carcasses
	Chinook Salmon (H) *(O. tshawytscha)*	A	Juveniles abundant and widespread in upland flowing waters of Nushagak River watershed and in Alagnak River; infrequent upstream of Iliamna Lake	Juveniles feed primarily on aquatic invertebrates (insect larvae)
	Sockeye Salmon (H) *(O. nerka)*	A	Abundant	Juveniles feed primarily on zooplankton
	Chum Salmon (H) *(O. keta)*	A	Abundant in upland flowing waters of Nushagak River watershed and in some Kvichak River tributaries downstream of Iliamna Lake; rare upstream of Iliamna Lake	-

Family	Species	Migratory Pattern(s) [a]	Relative Abundance	Predator–Prey Relationships [b]
	Pink Salmon (H) *(O. gorbuscha)*	A	Abundant (in even years), with restricted distribution, in the Nushagak River watershed and in some Kvichak River tributaries downstream of Iliamna Lake; rare upstream of Iliamna Lake	-
	Rainbow Trout (H) *(O. mykiss)*	N [c]	Frequent/common; in summer, closely associated with spawning salmon	Feed on aquatic invertebrates (insect larvae), terrestrial invertebrates, sockeye salmon eggs, and salmon carcasses Eaten by other fishes; eggs eaten by Slimy Sculpin
	Arctic Char (H) *(Salvelinus alpinus)*	N	Locally common in upland lakes	Feed on aquatic invertebrates (insect larvae, snails, mollusks) and fishes (Threespine Stickleback, sculpin) Eaten by other fishes (Lake Trout, larger Arctic Char)
	Dolly Varden (H) *(S. malma)*	N and A	Abundant in upland headwaters and selected lakes	Feed on aquatic invertebrates (insect larvae, zooplankton), terrestrial invertebrates, juvenile salmon, and salmon eggs Eaten by larger Dolly Varden, Lake Trout, and terrestrial predators (River Otters, fish-eating birds)
	Lake Trout (H) *(S. namaycush)*	N	Common in larger upland lakes and seasonally present in lake outlets; absent from the Wood River lakes	Feed on aquatic invertebrates when small and fishes (Least Cisco, salmon, Arctic Grayling, many others) when large Eaten by other fishes (Burbot, large Lake Trout); eggs eaten by other fish (Slimy Sculpin, Round Whitefish, other Lake Trout)
	Arctic Grayling (H) *(Thymallus arcticus)*	N	Abundant/widespread	Feed on aquatic and terrestrial invertebrates and salmon eggs Eaten by Lake Trout and Dolly Varden
Lampreys (Petromyzontidae)	**Arctic Lamprey** [d] *(Lethenteron camtschaticum)*	A	Juveniles common/widespread in sluggish flows where fine sediments accumulate	Feed on detritus and salmon carcasses Eaten by rainbow trout, other fish, birds, and mammals
	Alaskan Brook Lamprey [d] *(L. alaskense)*	N		
	Pacific Lamprey *(Entosphenus tridentatus)*	A	Rare	
Suckers (Catostomidae)	Longnose Sucker *(Catostomus catostomus)*	N	Common in slower flows of larger streams	Feed on aquatic invertebrates and plants Eaten by other fish (Lake Trout, Northern Pike, Burbot) and River Otters
Pikes (Esocidae)	**Northern Pike** (H) *(Esox lucius)*	N	Common/widespread in still or sluggish waters	Feed on aquatic invertebrates when small (insect larvae, zooplankton) and fishes when large (salmon, Arctic Char, Lake Trout, many others)

Family	Species	Migratory Pattern(s) [a]	Relative Abundance	Predator–Prey Relationships [b]
Mudminnows (Umbridae)	Alaska Blackfish *(Dallia pectoralis)*	N	Locally common/abundant in still or sluggish waters in flat terrain	Feed on aquatic invertebrates (copepods, cladocerans, insect larvae, snails) and algae Eaten by Northern Pike and larger Alaska Blackfish
Smelts (Osmeridae)	**Rainbow Smelt** *(Osmerus mordax)*	A	Seasonally abundant in streams near the coast	Feed on aquatic invertebrates and fishes (Slimy Sculpin) Eaten by fish-eating birds, Rainbow Trout, and River Otters
	Pond Smelt *(Hypomesus olidus)*	N	Locally common in coastal lakes and rivers, Iliamna Lake, inlet spawning streams, and the upper Kvichak River; abundance varies widely interannually	Feed primarily on zooplankton Eaten by other fishes (Arctic Char, Lake Trout)
	Eulachon *(Thaleichthys pacificus)*	A	No or few specific reports; if present, distribution appears limited and abundance low	-
Cods (Gadidae)	**Burbot** *(Lota lota)*	N	Infrequent to common in deep, sluggish, or still waters	Feed on aquatic invertebrates when small (insect larvae) and fishes when large (Least Cisco, Lake Trout, sculpin, Round Whitefish) Eaten by other fishes (larger Burbot)
Sticklebacks (Gasterosteidae)	**Threespine Stickleback** *(Gasterosteus aculeatus)*	N and A	Locally abundant in still or sluggish waters; abundant in Iliamna Lake	Feed on aquatic invertebrates (cladocerans, copepods, amphipods) Eaten by other fishes (Arctic Char, Northern Pike, Rainbow Trout, others), fish-eating birds, and large aquatic invertebrates (predatory insect larvae)
	Ninespine Stickleback *(Pungitius pungitius)*	N	Abundant/widespread in still or sluggish waters	
Sculpins (Cottidae)	Coastrange Sculpin *(Cottus aleuticus)*	N	Abundant/widespread [e]	Feed on aquatic invertebrates (insect larvae) and salmon eggs, alevins, and fry Eaten by other fishes (salmon fry, Burbot, Humpback Whitefish, Northern Pike, others)
	Slimy Sculpin *(C. cognatus)*	N		

Notes:

[a] A = anadromous (fishes that spawn in freshwaters and migrate to marine waters to feed); N = non-anadromous (fishes that spend their entire life in fresh waters, with possible migrations between habitats within a watershed). N and A indicates fishes in which some individuals have non-anadromous and some have anadromous migratory patterns.

[b] For anadromous species, only predator-prey relationships in freshwater habitats are presented. Dash (-) indicates either that the species is rare and detailed information is not available for the region, or that the species spends limited time in fresh water (i.e., for pink and chum salmon).

[c] In the Bristol Bay watershed, anadromous individuals (steelhead) are known to spawn and rear only in the North Alaska Peninsula watershed.

[d] Juveniles of these two species, which are the most commonly encountered life stages in these watersheds, are indistinguishable. Both species are present in the watershed, but it is possible that all documented occurrences are for one of these species.

[e] These species are combined here, because they are not reliably distinguished in field conditions, although Slimy Sculpin is thought to be more abundant and widely distributed.

Source: EPA 2014, USACE 2020a: Table 3.24-11; see Appendix B, Table 1 in EPA (2014) for references and additional information on the abundance and life history of each species.

Both Chum and Pink salmon migrate to the ocean soon after fry emergence (Heard 1991, Salo 1991). Because Coho, Chinook, and Sockeye salmon spend a year or more rearing in the Bristol Bay watershed's streams, rivers, and lakes before their ocean migration (Table 3-4), these species are more dependent on upstream freshwater resources than Chum and Pink salmon.

Table 3-4. Life history, habitat characteristics, and total documented stream length occupied for Bristol Bay's five Pacific salmon species in the Nushagak and Kvichak River watersheds.

Salmon Species	Freshwater Rearing Period (years)	Freshwater Rearing Habitat	Ocean-Feeding Period (years)	Spawning Habitat	Documented Stream Length Occupied (miles)
Coho	1–3	Headwater streams to moderate-sized rivers, headwater springs, beaver ponds, side channels, sloughs	1+	Headwater streams to moderate sized rivers	4,470
Sockeye	0–3	Lakes, rivers	2–3	Beaches of lakes, streams connected to lakes, larger braided rivers	3,174
Chinook	1+	Headwater streams to large-sized mainstem rivers	2–4	Moderate-sized streams to large rivers	3,108
Chum	0	Limited	2–4	Moderate-sized streams and rivers	2,170
Pink	0	Limited	1+	Moderate-sized streams and rivers	1,334

Source: EPA 2014: Appendix A (life history and habitat characteristics), the Anadromous Waters Catalog (Giefer and Blossom 2021) (stream lengths).

In addition to the five Pacific salmon species, the Bristol Bay region is home to at least 24 resident fish species, most of which typically (but not always) remain within the watershed's freshwater habitats throughout their life cycles. The region contains highly productive waters for such subsistence and sport fish species as Rainbow Trout,[36] Dolly Varden, Arctic Char, Arctic Grayling, Humpback Whitefish, Northern Pike, and Lake Trout, as well as numerous other species that are not typically harvested (Table 3-3). These fish species occupy a variety of habitats throughout the watershed, including headwater streams, rivers, off-channel habitats, wetlands, and lakes.

Given the importance of Rainbow Trout, Dolly Varden, and Northern Pike that rely on salmon populations to both subsistence and sport fisheries (Sections 3.3.6 and 3.3.7), it is worth considering key life-history and habitat-use traits of these species. The spawning habitat and behavior of Rainbow Trout are generally similar to those of the Pacific salmon species, with a few key exceptions. First, Rainbow Trout are iteroparous, meaning that they can spawn repeatedly. Second, spawning occurs in spring, versus summer and early fall for salmon. Juveniles emerge from spawning gravels in summer (Johnson

[36] The species *O. mykiss* includes both a non-anadromous or resident form (commonly referred to as Rainbow Trout) and an anadromous form (commonly referred to as Steelhead). In the Bristol Bay watershed, Steelhead generally are restricted to a few spawning streams near Port Moller, on the Alaska Peninsula.

et al. 1994, ADF&G 2022a), and immature fishes may remain in their natal streams for several years before migrating to other freshwater habitats (Russell 1977).

Rainbow Trout in the Bristol Bay watershed exhibit complex migratory patterns, moving between spawning, rearing, feeding, and overwintering habitats. For example, many adults in the region spawn in inlet or outlet streams of large lakes, then migrate shortly after spawning to feeding areas within those lakes. Some mature fishes may seasonally move distances of 120 miles (200 km) or more (Russell 1977, Burger and Gwartney 1986, Minard et al. 1992, Meka et al. 2003). Often, these migratory patterns ensure that Rainbow Trout are in close proximity to the eggs and carcasses of spawning salmon, which provide an abundant, high-quality food resource (Meka et al. 2003). The variety of habitat types used by Rainbow Trout is reflected by different life-history types identified in the region, including lake, lake-river, and river residents (Meka et al. 2003).

Dolly Varden is a highly plastic fish species, with multiple genetically, morphologically, and ecologically distinct forms that can co-exist in the same water bodies (Ostberg et al. 2009). Both anadromous and non-anadromous Dolly Varden are found in the Bristol Bay watershed, and both life-history forms can exhibit complex and extensive migratory behavior (Armstrong and Morrow 1980, Reynolds 2000, Scanlon 2000, Denton et al. 2009). Anadromous individuals usually undertake three to five ocean migrations before reaching sexual maturity (DeCicco 1992, Lisac and Nelle 2000, Crane et al. 2003). During these migrations, Dolly Varden frequently leave one drainage, travel through marine waters, and enter a different, distant drainage (DeCicco 1992, DeCicco 1997, Lisac 2009). Non-anadromous individuals also may move extensively between different habitats (Scanlon 2000).

Dolly Varden spawning occurs in fall, upstream of overwintering habitats (DeCicco 1992). Northern-form anadromous Dolly Varden (the geographic form of Dolly Varden found north of the Alaska Peninsula) overwinter primarily in lakes and in lower mainstem rivers where sufficient groundwater provides suitable volumes of free-flowing water (DeCicco 1997, Lisac 2009). Within the Nushagak and Kvichak River watersheds, juveniles typically rear in low-order, high-gradient stream channels (ADF&G 2022a). Because Dolly Varden occur in headwater lakes and high-gradient headwater streams (ADF&G 2022a)—farther upstream than many other fish species and above migratory barriers to anadromous salmon populations—they may be especially vulnerable to habitat degradation in these headwater areas.

Northern Pike primarily spawn in sections of lakes, wetlands, or very low-gradient streams that provide shallow (<3 feet [1 m]), slow, or still waters with aquatic vegetation and soft substrates (EPA 2014: Appendix B). Their summer habitat is typically deeper, but still relatively warm water with dense aquatic vegetation. Northern Pike overwinter in lakes, spring-fed rivers, and larger deep rivers where water and oxygen are sufficient for survival until spring (EPA 2014: Appendix B). In spring, mature Northern Pike ascend tributaries, beneath the ice, to reach spawning areas, then move to deeper waters to feed. Fry remain near or downstream of spawning areas. Many mature Northern Pike do not travel far, but some river-system individuals make extensive seasonal migrations—sometimes as far as 180 miles (290 km) per year—between spawning, feeding, and overwintering areas (EPA 2014: Appendix B).

Table 3-3 provides summary information on the other 21 fish species that have been documented to occur in the Nushagak and Kvichak River watersheds. It is important to note that none of these species exists in isolation—rather, they together make up diverse fish assemblages that interact with each other in numerous ways. For example, sculpins, Dolly Varden, and Rainbow Trout are well-known predators of salmon eggs and emergent fry (including lamprey ammoceotes), and Northern Pike can be effective predators of juvenile salmon and other fish species (Sepulveda et al. 2013, Schoen et al. 2022). Insectivorous and planktivorous fishes may compete with juvenile salmonids for food (e.g., Hartman and Burgner 1972). These types of prevalent interactions among species mean that impacts on any one fish species could affect the entire assemblage.

3.3.2 Distribution and Abundance

As Section 3.3.1 illustrates, the Nushagak and Kvichak River watersheds in general—and the SFK, NFK, and UTC watersheds in particular—support a robust assemblage of fishes, including several species that support valuable subsistence, commercial, and recreational fisheries (Sections 3.3.5 through 3.3.7). These fishes use a diversity of freshwater habitats throughout their life cycles. Fish populations across the Bristol Bay watershed have not been sampled comprehensively; thus, estimates of total distribution and abundance across the region are not available. However, available data[37] provide at least minimum estimates of where key species are found and how many individuals of those species have been caught.[38] More information on the distribution and abundance of key fish species can be found in Section 3.24 of USACE (2020a) and Appendices A and B of the BBA (EPA 2014).

3.3.2.1 Nushagak and Kvichak River Watersheds

Most (72 percent) of the smaller watersheds within the Nushagak and Kvichak River watersheds are documented to contain at least one species of spawning or rearing salmon within their boundaries; 19 percent are documented to contain all five species (Figure 3-1). Reported distributions for the five salmon species in the Nushagak and Kvichak River watersheds are shown in Figure 3-2.

Coho Salmon spawn and rear in many stream reaches throughout the Nushagak and Kvichak River watersheds. Juveniles distribute widely into headwater streams, where they are often the only salmon species present (Woody and O'Neal 2010, King et al. 2012). Because Coho Salmon spend 1 to 3 years in

[37] Notable sources of data include the AWC (Giefer and Blossom 2021), AFFI (ADF&G 2022a), and fish escapement and harvest data. The AWC is the State of Alaska's official record of anadromous fish distributions and, if available, the life stages present (categorized as spawning, rearing, or present but life stage unspecified). The AFFI includes all fish species found at specific sampling points; some observers also documented life stage (adult or juvenile).

[38] AWC stream reach designations and AFFI observation points should be interpreted with care, because not all streams could be sampled, and there are potential errors associated with fish identification and mapping. See Appendix B of this document for additional information on the interpretation of available fish distribution data.

fresh water, rearing habitat in headwater streams can be an especially important factor influencing their productivity (Nickelson et al. 1992, Solazzi et al. 2000).

Chinook Salmon spawn and rear throughout the Nushagak River watershed and in several tributaries of the Kvichak River. Although Chinook Salmon is the least common salmon species across the Bristol Bay region, the Nushagak River watershed supports a large Chinook Salmon fishery: on average, more than 75 percent of Bristol Bay's commercial Chinook Salmon catch comes from the Nushagak fishing district (Section 3.3.5). Chinook Salmon returns to the Nushagak River are consistently greater than 100,000 fish per year and have exceeded 200,000 fish per year in 11 years between 1966 and 2010, which places the Nushagak River at or near the size of the world's largest Chinook Salmon runs (EPA 2014: Chapter 5).

Sockeye Salmon is by far the most abundant salmon species in the Bristol Bay watershed (Tiernan et al. 2021).[39] Between 2010 and 2019, the average annual inshore run of Sockeye Salmon was 17.9 million fish in the Naknek-Kvichak district and 12.9 million fish in the Nushagak district (Tiernan et al. 2021). Tributaries to Iliamna Lake, Lake Clark, and, in the Nushagak River watershed, the Wood-Tikchik Lakes are major Sockeye Salmon spawning areas, and juveniles rear in each of these lakes. Iliamna Lake provides the majority of Sockeye Salmon rearing habitat in the Kvichak River watershed and historically has produced more Sockeye Salmon than any other lake in the Bristol Bay region (Fair et al. 2012). Riverine Sockeye Salmon populations spawn and rear throughout the Nushagak River watershed.

Chum Salmon is the second most abundant salmon species in the Nushagak and Kvichak River watersheds. Both Chum and Pink salmon spawn throughout the Nushagak and Kvichak River watersheds, but do not have extended freshwater rearing stages.

Extensive sampling for Rainbow Trout, Dolly Varden, Arctic Grayling, Northern Pike, and other fishes has not been conducted throughout the Bristol Bay region, so total distributions and abundances are unknown. Reported occurrences of a subset of these resident fishes, which provide a minimum estimate of their extents throughout the Nushagak and Kvichak River watersheds, are shown in Figures 3-3 and 3-4: Rainbow Trout, Dolly Varden, and Arctic Grayling (Figure 3-3) and Northern Pike, stickleback, and sculpin (Figure 3-4).

3.3.2.2 South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek Watersheds

This section highlights the abundance and diversity of fish resources found in the SFK, NFK, and UTC watersheds, particularly in terms of Pacific salmon. The important relationship between the region's aquatic habitats and its fish populations—and the resulting ecological value of this relationship—is discussed in greater detail in Section 3.3.3.

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[39] Bristol Bay is home to the largest Sockeye Salmon fishery in the world, with 46 percent of the average global abundance of wild Sockeye Salmon between 1956 and 2005 (Ruggerone et al. 2010, EPA 2014: Figure 5-9A). Between 2010 and 2019, the average annual inshore run of Sockeye Salmon in Bristol Bay was approximately 45.5 million fish (ranging from a low of 24.4 million in 2013 to a high of 63.0 million in 2018) (Tiernan et al. 2021).

Summer fish distributions in the SFK, NFK, and UTC watersheds have been sampled over several years (PLP 2011: Chapter 15, PLP 2018a: Chapter 15). The catalogued distributions of the five Pacific salmon species (Coho, Chinook, Sockeye, Chum, and Pink), resident Rainbow Trout, Dolly Varden (both anadromous and non-anadromous forms are present), and Arctic Grayling in these watersheds are shown in Figures 3-5 through 3-10. In addition, Arctic-Alaskan Brook Lamprey, Northern Pike, Humpback Whitefish, Least Cisco, Round Whitefish, Burbot, Threespine Stickleback, Ninespine Stickleback, and Slimy Sculpin occur in these watersheds (Table 3-5) (ADF&G 2022a). Summary information about these species is provided in Table 3-3; more detailed information on distributions, abundances, habitats, life cycles, predator-prey relationships, and harvests is provided in Appendix B of EPA (2014) and Section 3.6 of USACE (2020a).

Table 3-5. Documented fish species occurrence in the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek watersheds.

Species [a]	Number of Unique Sites [b]
Humpback Whitefish	2
Least Cisco	3
Round Whitefish	3
Coho Salmon	525
Chinook Salmon	183
Sockeye Salmon	102
Chum Salmon	7
Rainbow Trout	110
Dolly Varden [c]	682
Arctic Grayling	199
Arctic-Alaskan Brook Lamprey [c]	4
Northern Pike	74
Burbot	2
Threespine Stickleback	32
Ninespine Stickleback	67
Unspecified stickleback species	27
Slimy Sculpin	533
Unspecified sculpin species	226

Notes:

[a] This is not a complete list of species found in the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek watersheds, because it is based only on the Alaska Freshwater Fish Inventory (ADF&G 2022a); for example, Pink Salmon are only listed in the Anadromous Waters Catalog (Giefer and Blossom 2021).

[b] Number of unique sample sites for each species (i.e., number of sample sites where at least one life stage was found).

[c] Juveniles of these two species, which are the most commonly encountered life stages in these watersheds, are indistinguishable. Both species are present in the watersheds, but it is possible that all documented occurrences are for one of these species.

Source: Alaska Freshwater Fish Inventory (ADF&G 2022a).

Of the 667 stream miles (1,073 km) that have been mapped in the SFK, NFK, and UTC watersheds, 201 miles (323 km) or 30 percent have been documented to contain anadromous fishes (Table 3-6; see Appendix B for discussion of why this likely represents a significant underestimation of actual anadromous waters). Coho Salmon have the most widespread distribution of the five salmon species in the three watersheds and make extensive use of mainstem and tributary habitats, including headwater streams (Figure 3-5). Chinook and Sockeye salmon have been documented throughout mainstem reaches of the three watersheds, as well as several tributaries (Figures 3-6 and 3-7). The distributions of Chum and Pink salmon are generally restricted to mainstem reaches where spawning and migration have been documented. Chum Salmon have been found in all three watersheds, whereas Pink Salmon, at very low numbers, have been reported only in the lowest section of UTC and in the Koktuli River below the confluence of the SFK and NFK (Figures 3-8 and 3-9). Rainbow Trout have been collected at many mainstem and several tributary locations, especially in UTC (Figure 3-10). Dolly Varden are found throughout the three watersheds, with fish surveys indicating that they are commonly found in the smallest streams (i.e., first-order tributaries) (Figure 3-10). Arctic Grayling are also found throughout the three watersheds, particularly in the SFK headwaters (Figure 3-10).

Table 3-6. Total documented anadromous fish stream length and stream length documented to contain different salmonid species in the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek watersheds.

	South Fork Koktuli River (miles)	North Fork Koktuli River (miles)	Upper Talarik Creek (miles)	Total (miles)
Total mapped streams [a]	194	209	264	667
Total anadromous fish streams [b]	60	65	76	201
By species				
Chinook Salmon	38	42	39	119
Chum Salmon	23	20	28	71
Coho Salmon	59	64	76	199
Pink Salmon	0	0	4	4
Sockeye Salmon	40	29	49	119

Notes:

[a] From the National Hydrography Dataset (USGS 2021).

[b] From the Anadromous Waters Catalog (Giefer and Blossom 2021).

Figure 3-1. Diversity of Pacific salmon species production in the Nushagak and Kvichak River watersheds. Counts of salmon species (Coho, Chinook, Sockeye, Chum, and Pink) spawning and rearing, based on the Anadromous Waters Catalog (Giefer and Blossom 2021), are summed by 12-digit hydrologic unit codes.

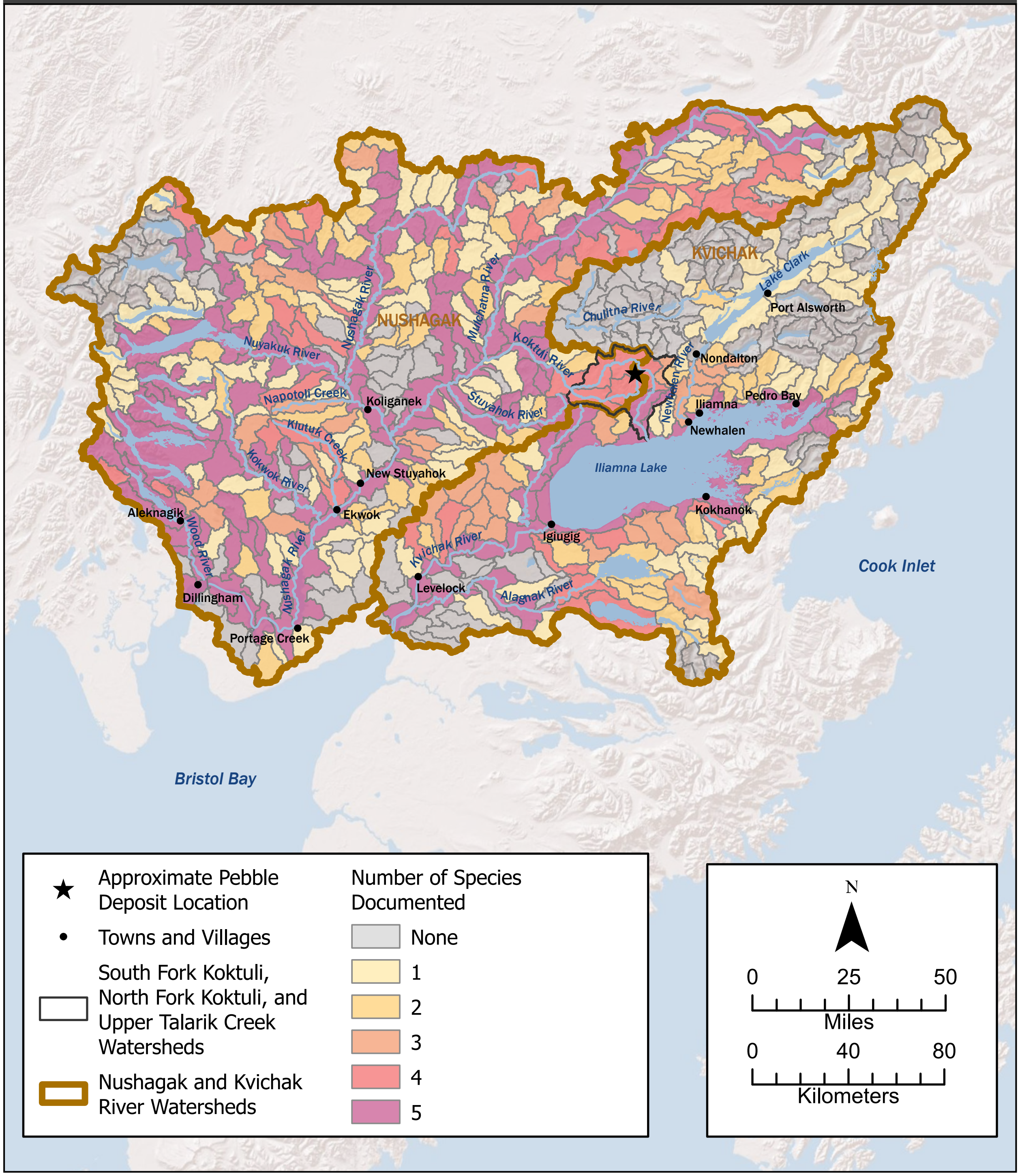


Figure 3-2. Anadromous fish distribution in the Nushagak and Kvichak River watersheds. Documented salmon use indicates that at least one Pacific salmon species (Coho, Chinook, Sockeye, Chum, or Pink) has been documented at the most upstream point in the channel, based on the Anadromous Waters Catalog (Giefer and Blossom 2021).

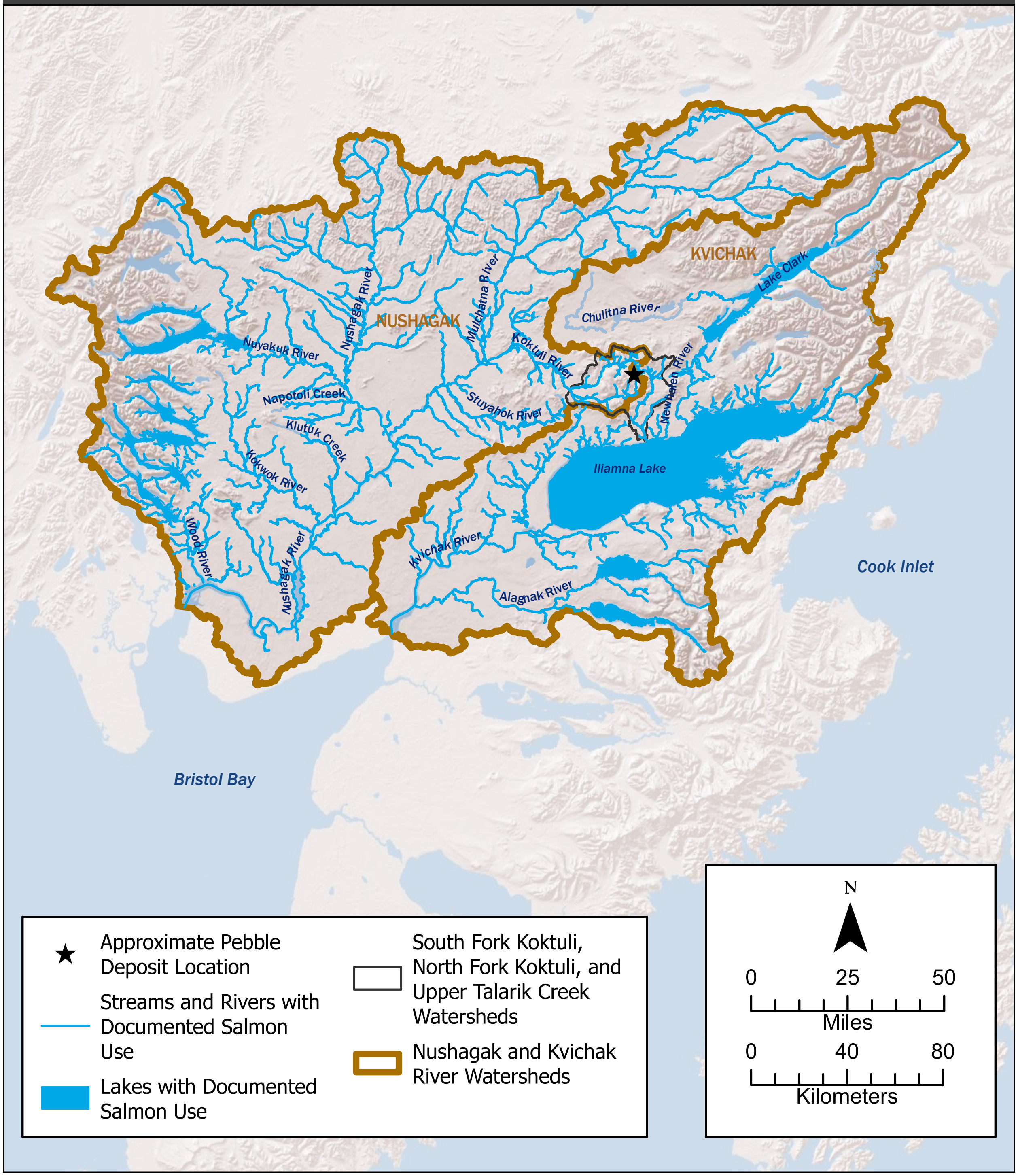


Figure 3-3. Rainbow Trout, Dolly Varden, and Arctic Grayling occurrence in the Nushagak and Kvichak River watersheds. Designation of species presence is based on the Alaska Freshwater Fish Inventory (ADF&G 2022a). Note that points shown on land actually occur in smaller streams not shown on this map and that species absence cannot be inferred from this map.

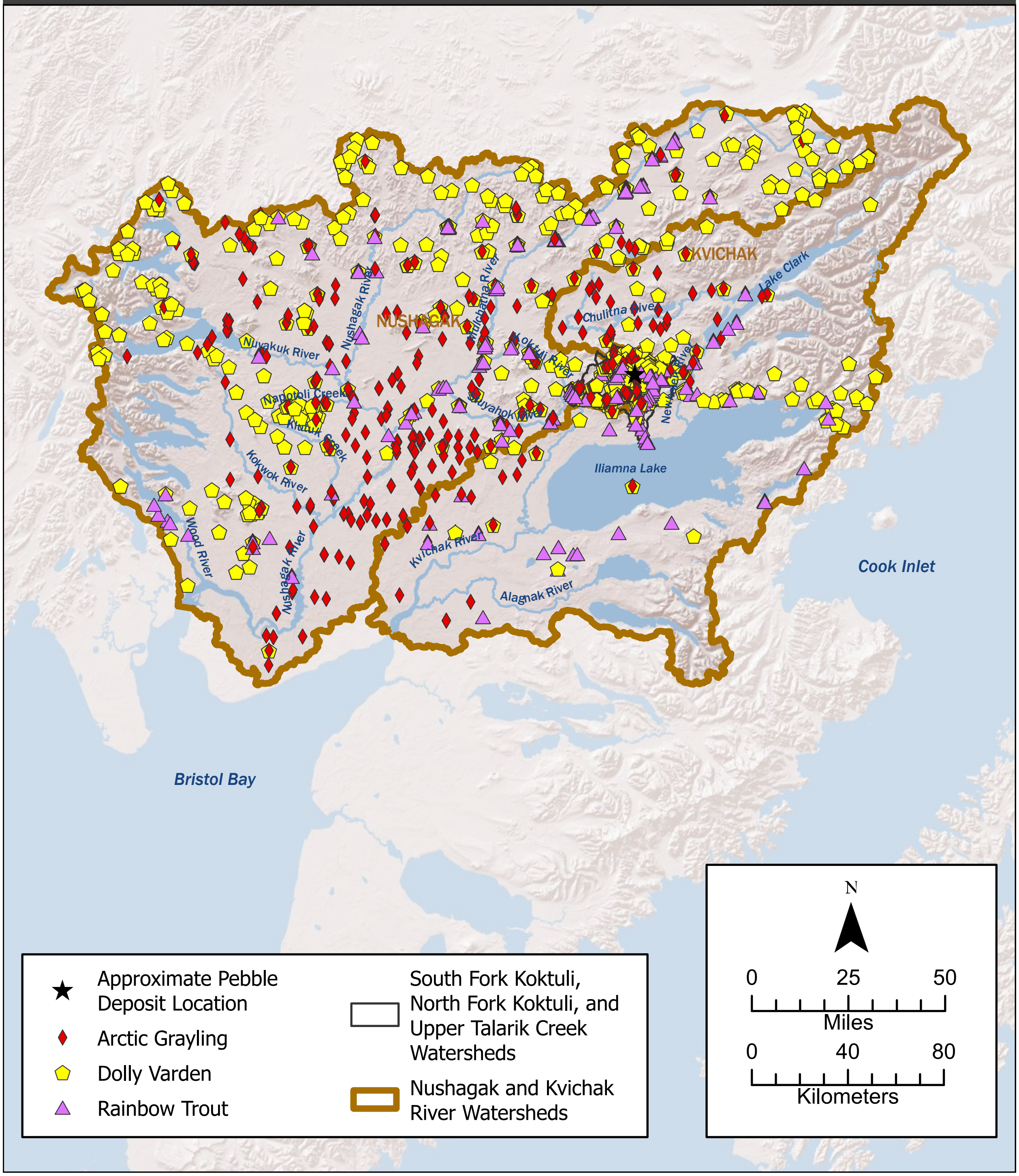


Figure 3-4. Northern Pike, stickleback, and sculpin occurrence in the Nushagak and Kvichak River watersheds. Designation of species presence is based on the Alaska Freshwater Fish Inventory (ADF&G 2022a). Note that points shown on land actually occur in smaller streams not shown on this map and that species absence cannot be inferred from this map.

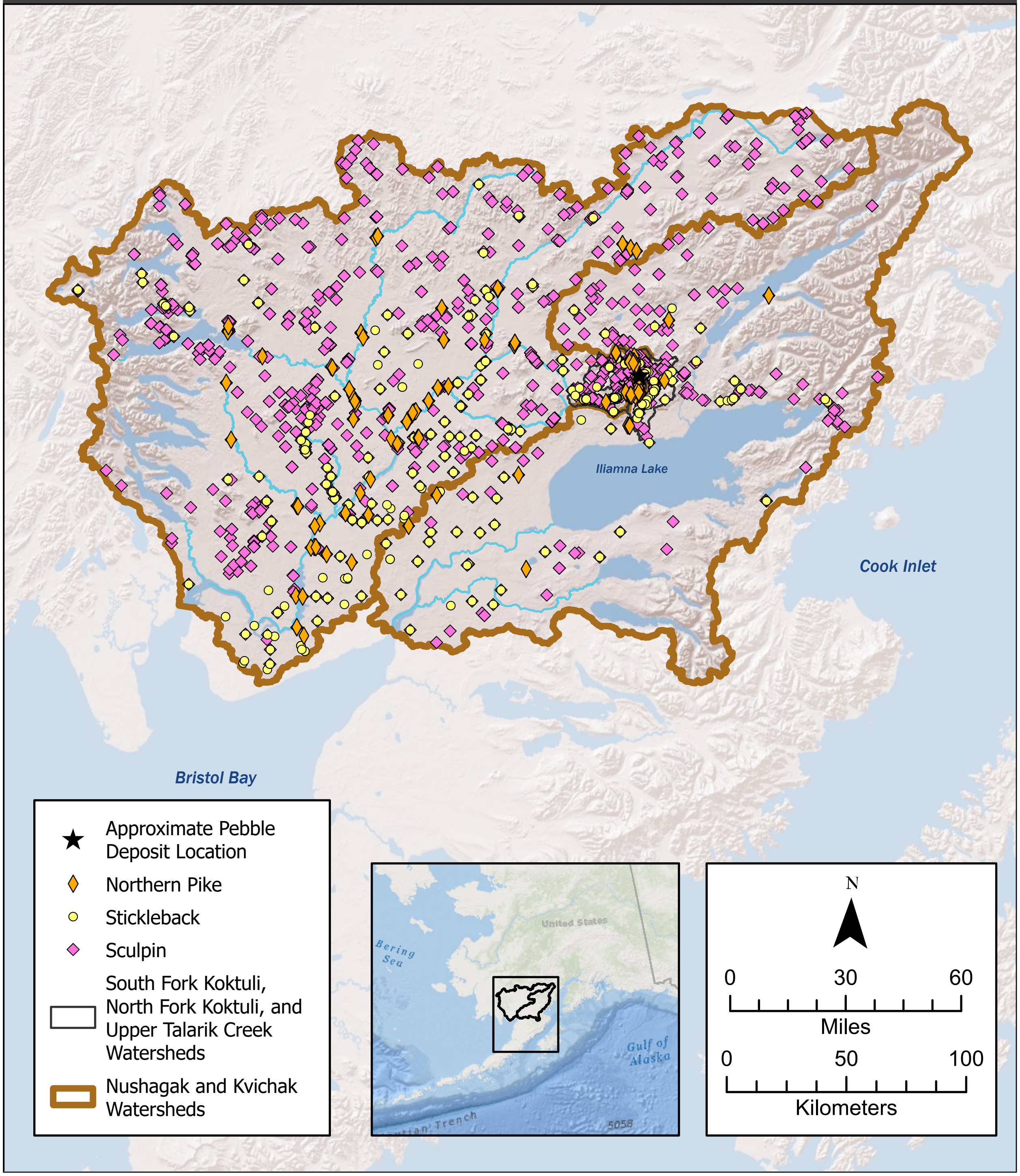


Figure 3-5. Reported Coho Salmon distribution in the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek watersheds. "Present" indicates the species was present but life-stage use was not determined; "spawning" indicates spawning adults were observed; and "rearing" indicates juveniles were observed. Present, spawning, and rearing designations are based on the Anadromous Waters Catalog (Giefer and Blossom 2021).

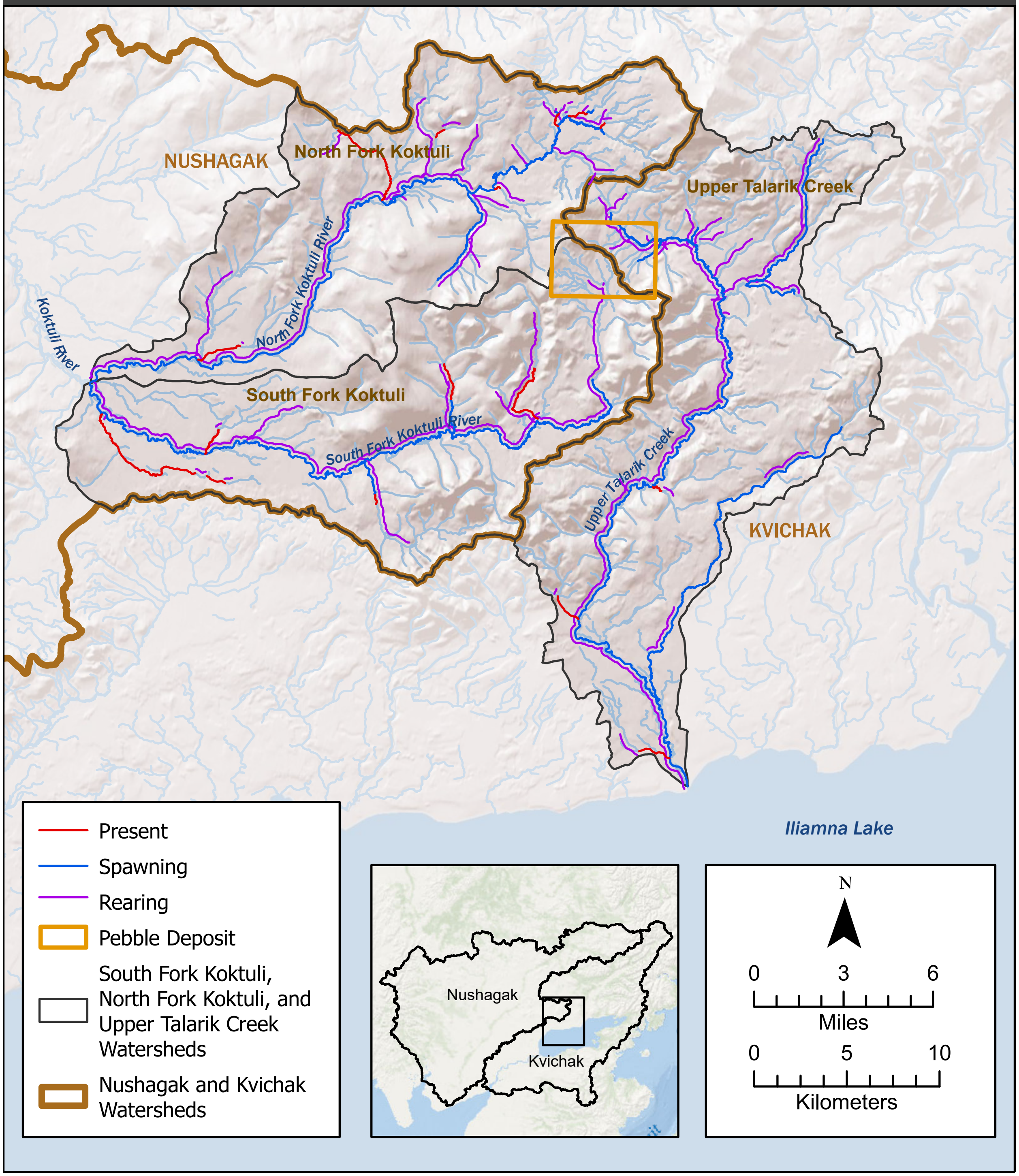


Figure 3-6. Reported Chinook Salmon distribution in the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek watersheds. "Present" indicates the species was present but life-stage use was not determined; "spawning" indicates spawning adults were observed; and "rearing" indicates juveniles were observed. Present, spawning, and rearing designations are based on the Anadromous Waters Catalog (Giefer and Blossom 2021).

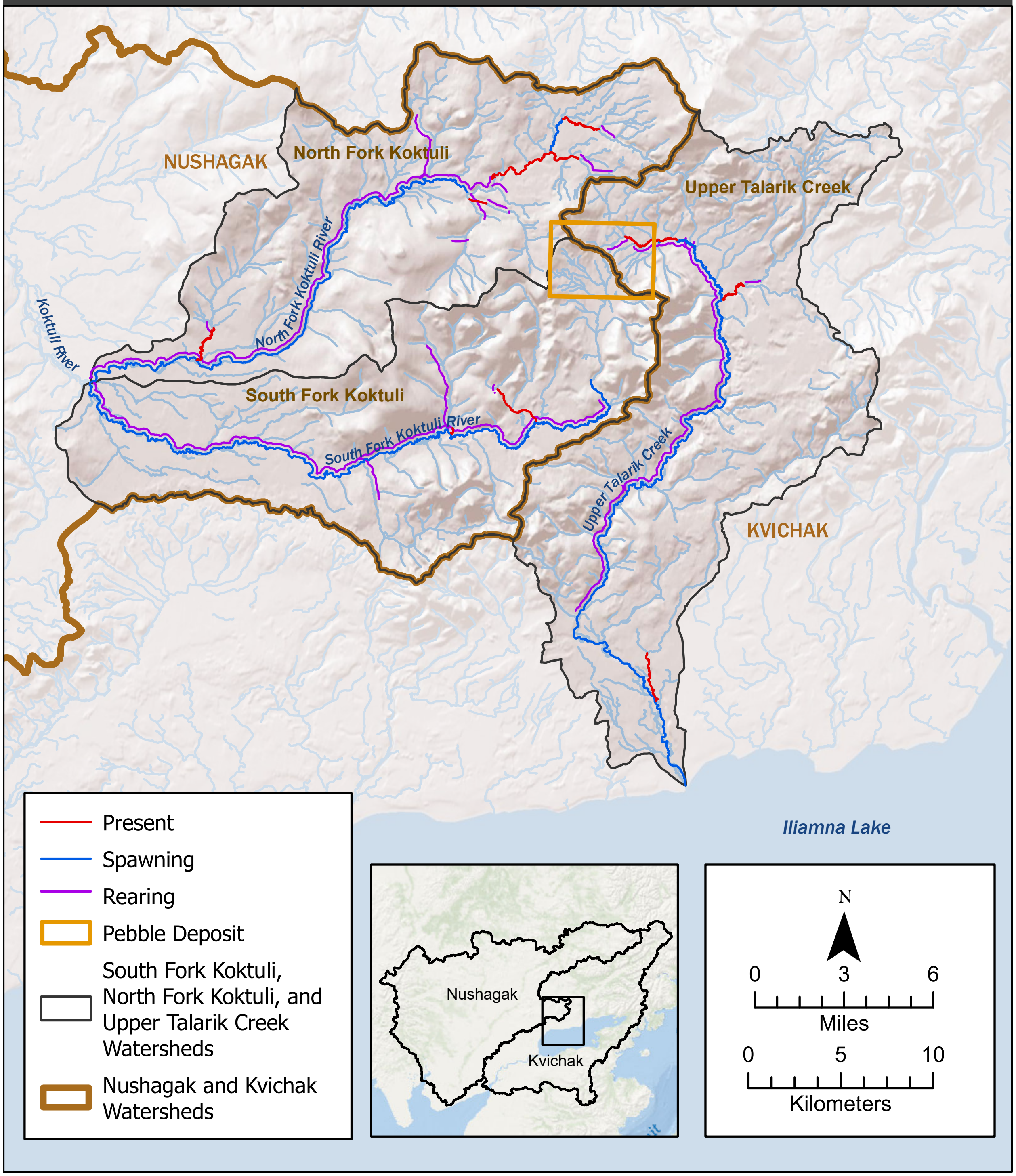


Figure 3-7. Reported Sockeye Salmon distribution in the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek watersheds. "Present" indicates the species was present but life-stage use was not determined; "spawning" indicates spawning adults were observed; and "rearing" indicates juveniles were observed. Present, spawning, and rearing designations are based on the Anadromous Waters Catalog (Giefer and Blossom 2021).

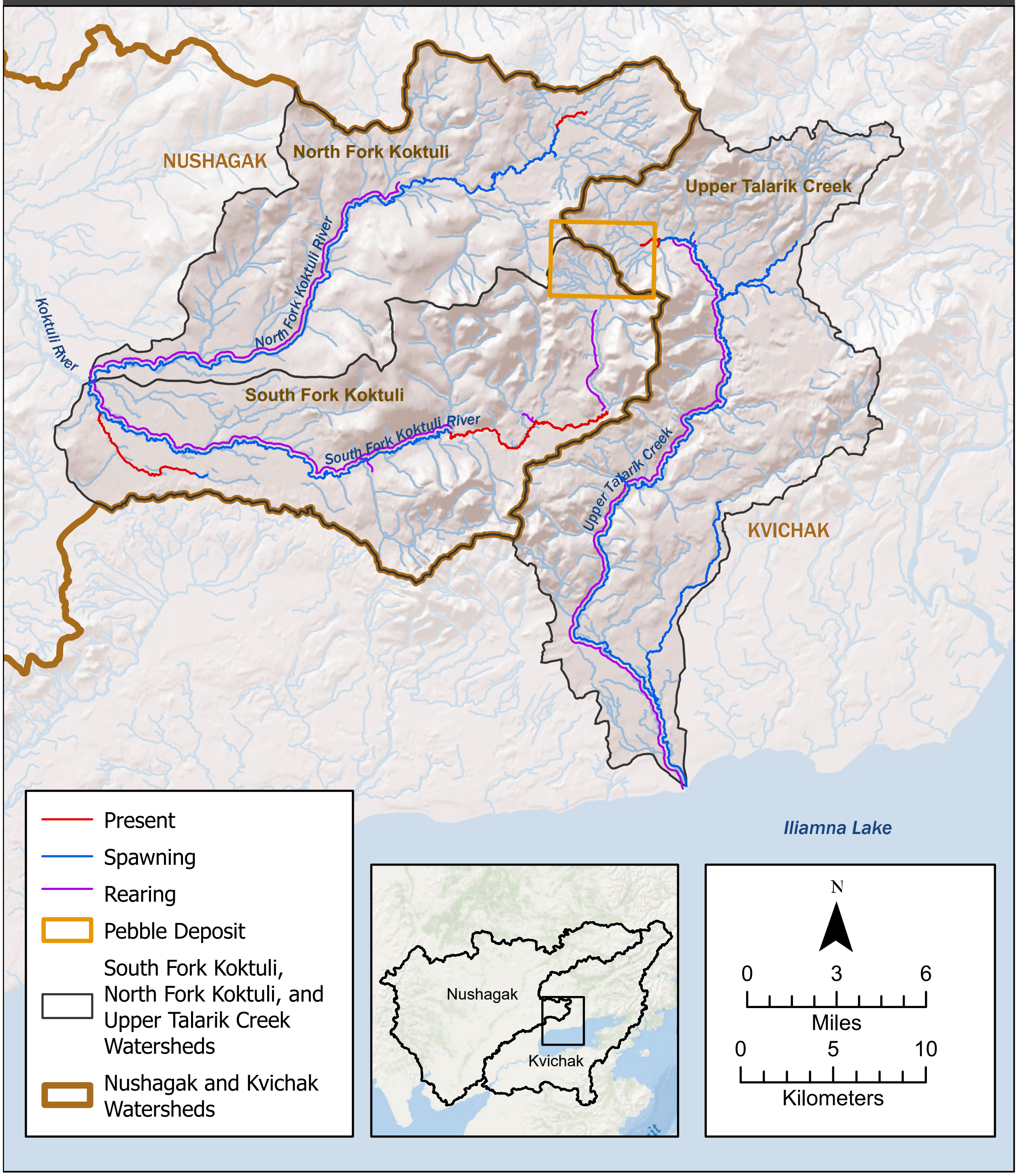


Figure 3-8. Reported Chum Salmon distribution in the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek watersheds. "Present" indicates the species was present but life-stage use was not determined; "spawning" indicates spawning adults were observed; and "rearing" indicates juveniles were observed. Present, spawning, and rearing designations are based on the Anadromous Waters Catalog (Giefer and Blossom 2021).

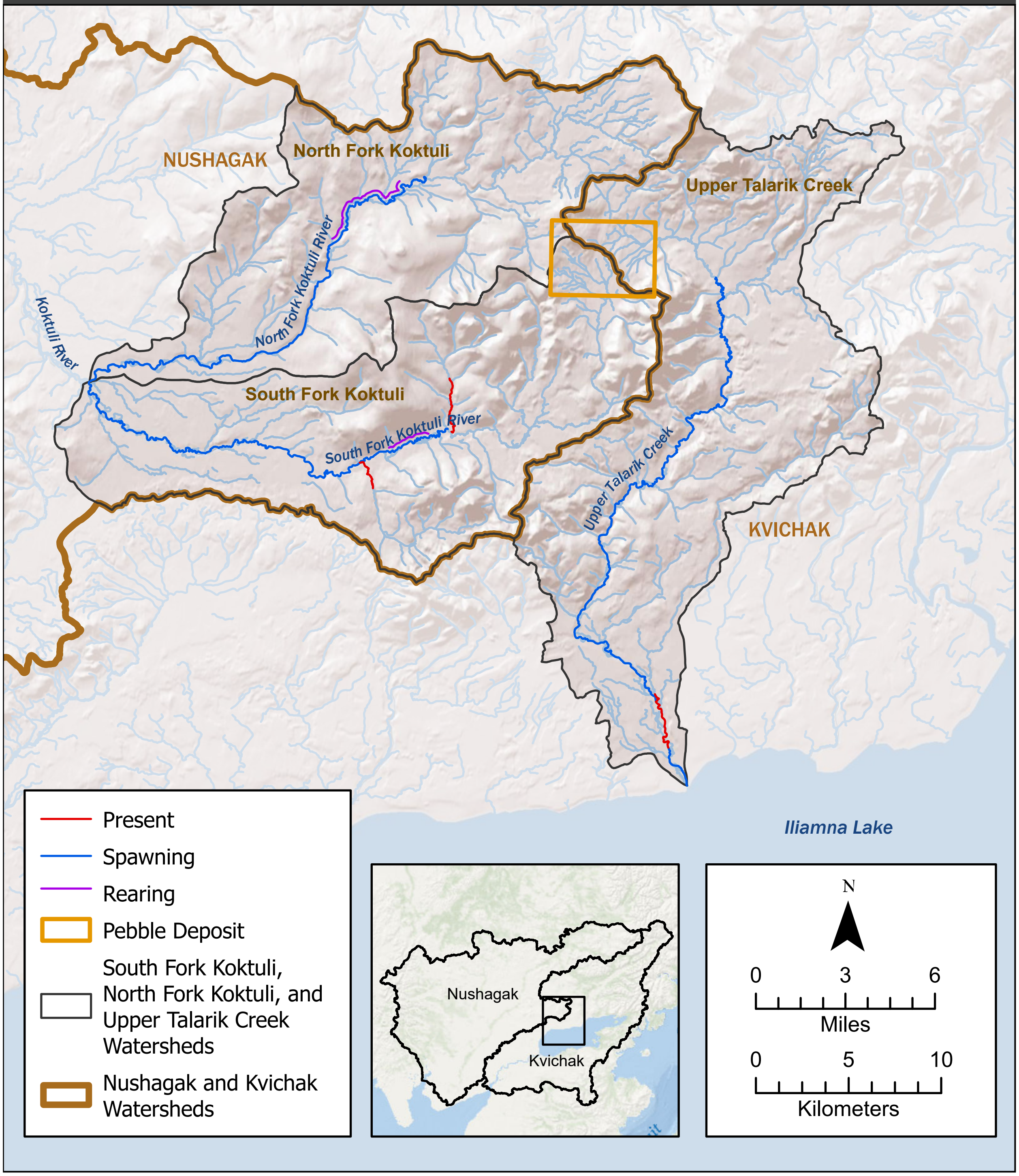


Figure 3-9. Reported Pink Salmon distribution in the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek watersheds. "Present" indicates the species was present but life-stage use was not determined; "spawning" indicates spawning adults were observed; and "rearing" indicates juveniles were observed. Present, spawning, and rearing designations are based on the Anadromous Waters Catalog (Giefer and Blossom 2021).

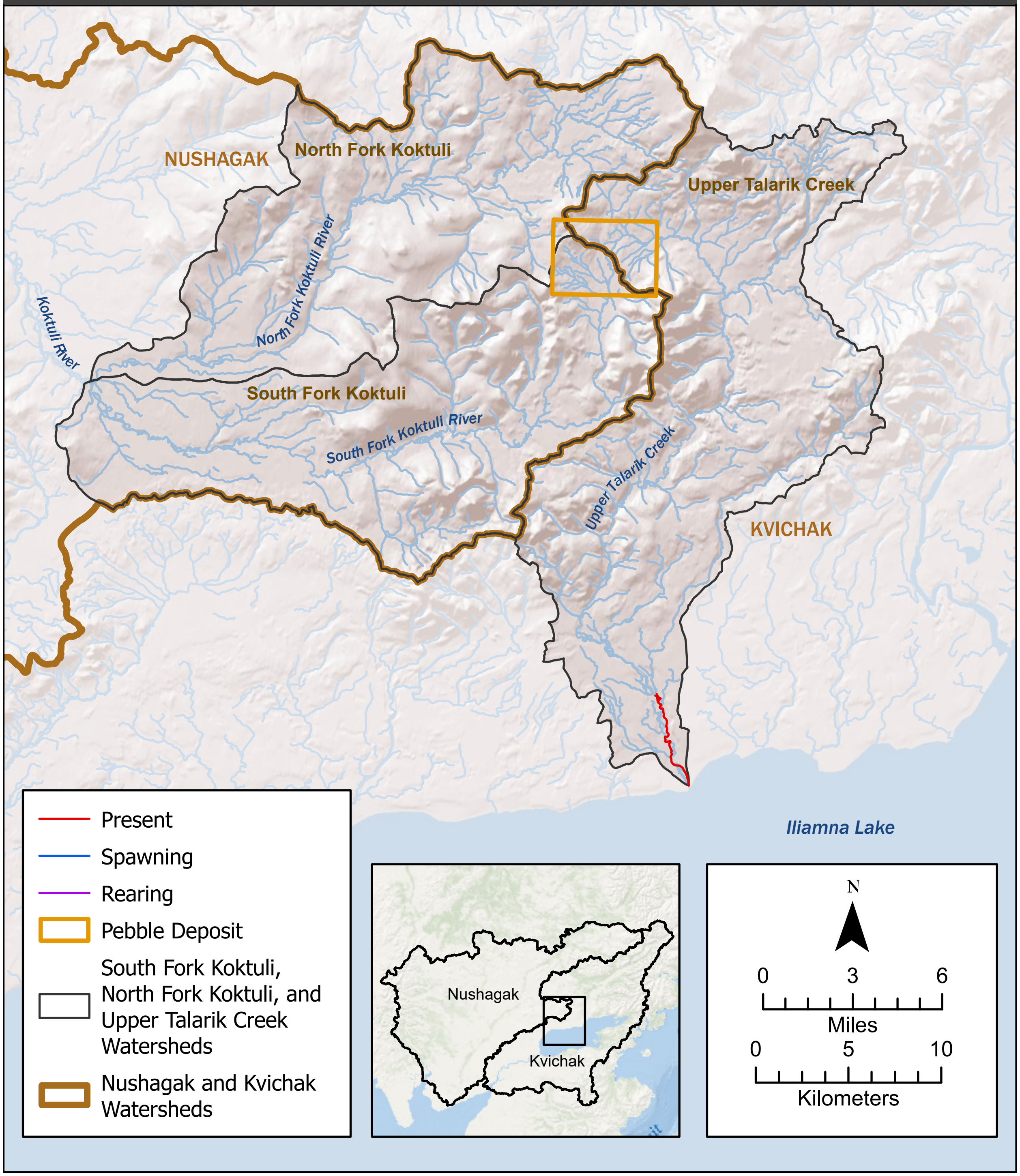
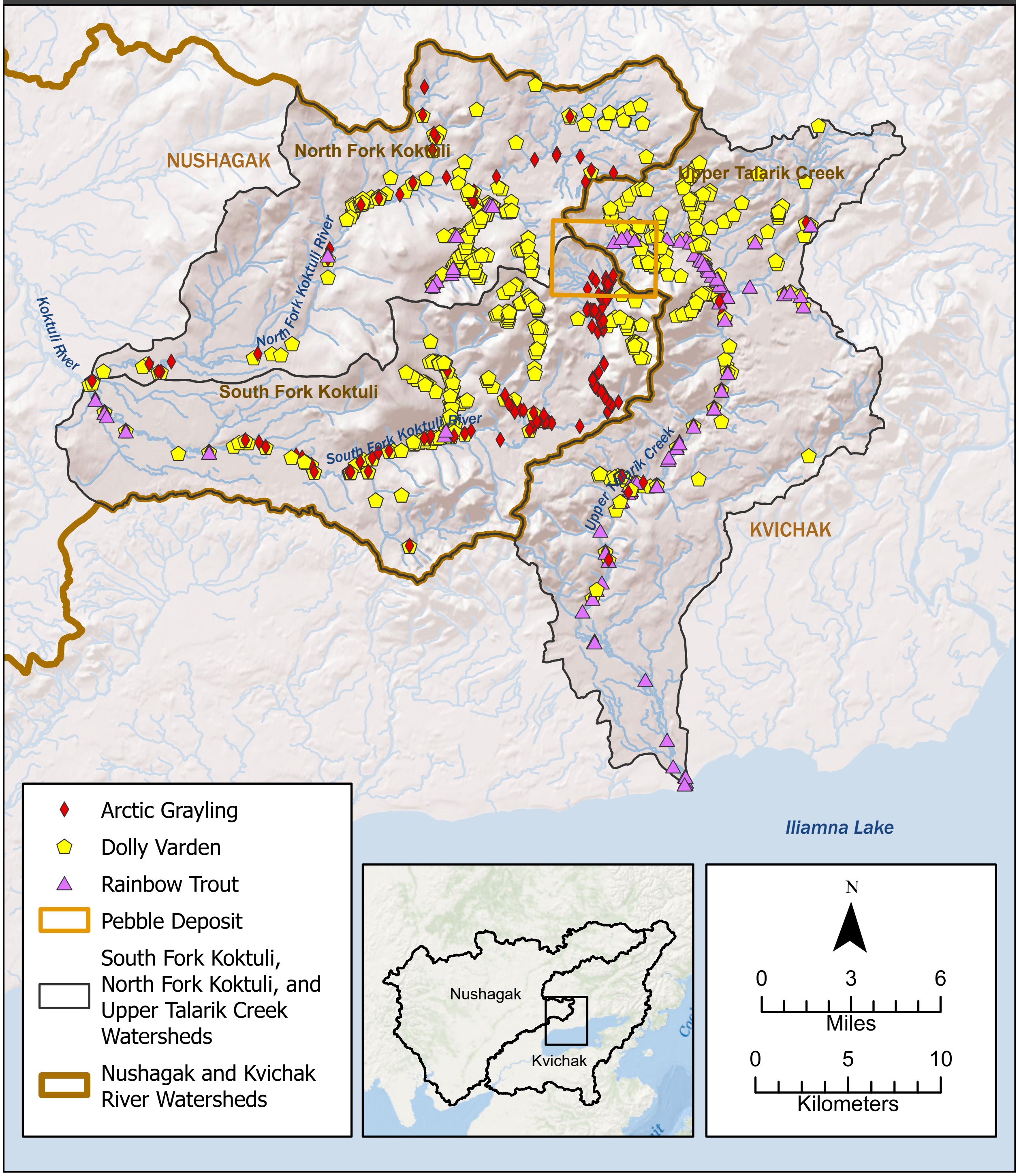


Figure 3-10. Rainbow Trout, Dolly Varden, and Arctic Grayling occurrence in the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek watersheds. Designation of species presence is based on the Alaska Freshwater Fish Inventory (ADF&G 2022a). Note that species absence cannot be inferred from this map.



Index estimates of relative spawning salmon abundance in the SFK, NFK, and UTC watersheds are available for Sockeye, Coho, Chinook, and Chum salmon. Both ADF&G and PLP have conducted aerial index counts of spawning salmon at different points in time. This type of survey is used primarily to track variation in run size over time. Survey values tend to underestimate true abundance: for example, USACE (2020a: Section 3.24) states that aerial surveys capture only an average of 18 percent of total abundance. This underestimation occurs for several reasons. An observer in an aircraft is not able to count all fishes in dense aggregations or those concealed under overhanging vegetation or undercut banks, and only a fraction of the fishes that spawn at a given site are present at any one time (Bue et al. 1998, Jones et al. 2007). Weather, water clarity, and other factors that influence fish visibility can also contribute to underestimates. In addition, surveys intended to capture peak abundance may not always do so. For example, aerial surveys counted, on average, only 44 percent of the Pink Salmon counted by surveyors walking the same Prince William Sound spawning streams (Bue et al. 1998). Peak aerial counts of Pink Salmon in southeastern Alaska are routinely multiplied by 2.5 to represent more accurately the number of fishes present at the survey time (Jones et al. 2007). Helicopter surveys of Chinook Salmon on the Kenai Peninsula's Anchor River over 5 years counted only 5 to 10 percent of the fishes documented by a concurrent sonar/weir counting station (Szarzi et al. 2007).

ADF&G conducts aerial index counts that target peak Sockeye Salmon spawning periods on UTC and peak Chinook Salmon spawning periods on the Koktuli River system. Sockeye Salmon counts have been conducted in most years since 1955 (Morstad 2003), and Chinook Salmon counts in most years since 1967 (Dye and Schwanke 2009). Between 1955 and 2011, Sockeye Salmon counts in UTC ranged from 0 to 70,600, with an average of 7,021 over 49 count periods (Morstad pers. comm.). Between 1967 and 2009, Chinook Salmon counts in the Koktuli River system ranged from 240 to 10,620, with an average of 3,828 over 29 count periods (Dye and Schwanke 2009). The mean aerial count of Chinook Salmon in the Koktuli River represents nearly one-quarter of the mean total for the entire Nushagak-Mulchatna watershed (Dye and Schwanke 2009). Thus, the Nushagak River is the largest producer of Chinook Salmon in the Bristol Bay watershed, and the Koktuli River is the largest producer of Chinook Salmon in the Nushagak River watershed.

PLP (2018a) provides aerial index counts for Chinook, Chum, Coho, and Sockeye salmon adults in the SFK, NFK, and UTC mainstem segments and select tributaries from 2004 to 2008. Surveys on the SFK and NFK began at their confluence and extended upward to the intermittent reach or Frying Pan Lake on the SFK and upward to Big Wiggly Lake or river kilometer 56 on the NFK. Surveys on UTC ran from the mouth and extended upstream to Tributary 1.350 (just east of Koktuli Mountain) or to the headwaters. Multiple counts were usually made for each stream and species in a given year.

Table 3-7 reports the minimum and maximum values for highest index spawner count in the SFK, NFK, and UTC mainstems, from 2004 through 2008 (SFK and NFK) or 2009 (UTC) (PLP 2018a: Chapter 15, Tables 15-14 through 15-17). Peak index counts capture only a portion of total spawning run abundance, because only a portion of the spawning population is present on the spawning grounds on any given day. Individual spawners are visible on their spawning grounds for days to weeks (e.g., Bue et al. 1998), but the spawning season can extend for weeks to months in the SFK, NFK, and UTC watersheds

(PLP 2018a). The highest peak index counts for Coho and Sockeye salmon were in UTC, whereas the highest counts for Chinook and Chum salmon were in the SFK and NFK (Table 3-7). The overall highest count was for Sockeye Salmon in UTC in 2008, when approximately 50,317 fish were estimated (Table 3-7).

Table 3-7. Highest reported index spawner counts in the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek, based on mainstem aerial surveys.

Watershed	Years Surveyed	Salmon Species	Number of Surveys Counted Per Year (Min-Max)	Highest Index Spawner Count (Year of Count) [a]	
				Minimum Value	Maximum Value
South Fork Koktuli River	2004–2008	Chinook	3–9	327 (2006)	2,780 (2004)
		Chum [b]	4–11	189 (2007)	917 (2008)
		Coho	2–21	270 (2004)	1,955 (2008)
		Sockeye	3–14	1,730 (2004)	6,133 (2008)
North Fork Koktuli River	2004–2008	Chinook	3–8	434 (2008)	2,889 (2005)
		Chum	1–9	350 (2005)	1,432 (2008)
		Coho	1–17	114 (2007)	1,704 (2008)
		Sockeye	2–11	563 (2004)	2,188 (2007)
Upper Talarik Creek	2004–2009	Chinook	2–9	80 (2009)	272 (2004)
		Chum [b]	1–8	3 (2005)	44 (2008)
		Coho	2–21	1,041 (2005)	7,542 (2009)
		Sockeye	2–20	10,557 (2007)	50,317 (2008)

Notes:

[a] Values likely underestimate true spawner abundance (see Appendix B of this document for additional information).

[b] Chum were not counted in the North Fork Koktuli or Upper Talarik Creek in 2004.

Source: PLP 2018a: Chapter 15, Tables 15-14 through 15-17.

Aerial counts of adult salmon were also conducted in tributaries of the SFK, NFK, and UTC between 2004 and 2009 (Table 3-8). Adult Coho and Chum salmon were counted in SFK tributaries; adult Coho and Sockeye salmon were counted in NFK tributaries; and adult Coho, Chinook, Chum, and Sockeye salmon were counted in UTC tributaries. The highest number of adults reported in tributaries of each watershed were 50 Coho Salmon (SFK 1.190), 111 Sockeye Salmon (NFK 1.240), and 31,922 Sockeye Salmon (UTC 1.160) (Table 3-8).

Table 3-8. Highest reported number of adult salmon in tributaries of the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek, based on aerial surveys.

Watershed	Tributary	Years Surveyed	Total Number of Surveys (Min-Max Number of Surveys Per Year) [a]	Salmon Species [b]	Highest Reported Number in an Individual Survey
South Fork Koktuli River	SFK 1.130	2004–2008	26 (0–24)	Chum	6
				Coho	48
	SFK 1.190	2004–2008	42 (0–24)	Chum	28
				Coho	50
	SFK 1.240	2004–2008	26 (0–14)	Coho	5
North Fork Koktuli River	NFK 1.190 [c]	2004–2008	39 (0–21)	Coho	27
	NFK 1.240 [c]	2004–2008	26 (1–17)	Coho	12
				Sockeye	111
	NFK 1.260	2004–2008	11 (0–10)	Coho	4
	NFK 1.270	2004–2008	6 (0–5)	Coho	23
	NFK 1.280	2006–2008	2 (0–1)	Coho	2
Upper Talarik Creek	UTC 1.160	2008–2009	42 (18–24)	Coho	1,079
				Sockeye	31,922
	UTC 1.190	2004–2009	53 (0–22)	Sockeye	49
	UTC 1.350 [c]	2004–2009	52 (1–25)	Chum	3
				Coho	571
				Sockeye	57
	UTC 1.390 [c]	2007–2009	(1–27)	Coho	29
				Sockeye	115
	UTC 1.410	2004–2009	34 (0–19)	Chinook	2
				Chum	21
				Coho	43
				Sockeye	30
	UTC 1.460	2004–2005	3 (1–2)	Coho	7

Notes:
[a] In all but one case, the maximum number of surveys occurred in 2008.
[b] Only tributaries and salmon species with at least one survey count greater than one are listed.
[c] NFK 1.190 also includes NFK 1.190.10; NFK 1.240 also includes NFK 1.240P1, 1.240P1 Big Wiggly Lake, and 1.240.20.P1; UTC 1.350 also includes 1.350.20, 1.350.20P1, 1.350.20P2, and 1.350.20P3; UTC 1.390 also includes 1.390.20P2.
Source: PLP 2018a: Chapter 15, Appendix 15B2.

Mainstem and off-channel habitats of the SFK, NFK, and UTC also provide abundant habitat for juvenile salmonids. Table 3-9 presents maximum estimated densities and total numbers observed for juvenile Pacific salmon species in mainstem SFK, NFK, and UTC reaches (PLP 2018a: Chapter 15, USACE 2020a). Reported fish densities summarized over the 5-year period vary widely by stream and reach, which is typical for fishes in heterogeneous stream environments. The highest maximum estimated density for juvenile salmon was approximately 124 juvenile Coho Salmon in UTC Reach F (Table 3-9). Habitat-specific densities were much higher, however: for example, approximately a density of 1,600 Coho Salmon (of which roughly 90 percent were juveniles) per 100 m^2 of pool habitat was estimated in UTC Reach D (PLP 2011: Figure 15.1-82).

Table 3-9. Maximum estimated densities and total observed number of juvenile Pacific salmon in mainstem habitats of the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek.

Watershed/Reach (River Kilometers)	Maximum Estimated Density (# per 100 m^2) [a]			Total Number Observed at Mainstem Index Sites [b]		
	Chinook	Coho	Sockeye	Chinook	Coho	Sockeye
South Fork Koktuli River						
SFK-A (0.0–24.9)	24.86	37.40	1.77	1,246	762	29
SFK-B (24.9–34.3)	0.21	20.21	0.57	4	292	8
SFK-C (34.3–51.7)	0.12	19.77	0.35	4	101	-
SFK-D (51.7–54.7)	1.39	2.52	0.00	-	-	-
SFK-E (54.7–64.2)	0.00	1.18	0.00	-	1	-
North Fork Koktuli River						
NFK-A (0.0–13.7)	18.84	17.67	0.15	802	415	7
NFK-B (13.7–21.1)	30.68	34.52	1.18	95	190	-
NFK-C (21.1–36.6)	8.24	28.07	1.89	213	624	42
NFK-D (36.6–48.4)	0.38	2.73	0.12	-	23	1
NFK-E (48.4–52.5)	0.00	0.00	0.00	-	-	-
Upper Talarik Creek						
UTC-A (0.0–5.9)	0.38	1.25	0.00	10	33	-
UTC-B (5.9–16.8)	17.62	46.24	0.14	61	931	-
UTC-C (16.8–24.8)	11.31	67.24	2.28	101	422	1
UTC-D (24.8–36.3)	4.64	48.99	0.29	6	868	-
UTC-E (36.3–45.1)	4.77	115.42	4.12	5	1,240	5
UTC-F (45.1–59.1)	1.53	123.78	0.67	-	992	1
UTC-G (59.1–62.4)	0.00	21.53	0.00	-	2	-

Notes:

[a] Maximum estimated juvenile density across values reported for 2004–2007, 2008, and 2009.

[b] Total number of juveniles observed across index sites within given reach in 2009, surveyed by beach seine and snorkel methods. South Fork Koktuli River sites were sampled 7/24 to 8/28; North Fork Koktuli River sites were sampled 7/25 to 8/21; Upper Talarik Creek sites were sampled 7/26 to 8/28. Dash (-) indicates that no counts for the given species were reported within that reach.

Source: USACE 2020a: Table 3.24-9, PLP 2018a: Chapter 15, Table 15-11.

Abundant and diverse off-channel habitats are also found in the SFK, NFK, and UTC watersheds (Section 3.2.2). Aerial imagery shows that roughly 70 percent of the mainstem SFK and UTC and roughly 90 percent of the mainstem NFK are bordered by some form of off-channel habitat (USACE 2020a: Section 3.24), most commonly beaver complexes (Section 3.2.2) (USACE 2020a: Section 3.24). Off-channel habitats provide important rearing habitat for many fish species but may be especially important as rearing and overwintering habitats for juvenile salmonids (Huntsman and Falke 2019, USACE 2020a: Section 3.24). Table 3-10 highlights the diversity of both off-channel habitats and the fish species that rely on them in the SFK, NFK, and UTC watersheds. Relative abundance in these habitats is highest for Coho Salmon, with an estimate of more than 1,300 fish per 100 meters.

Table 3-10. Relative abundance of salmonids in off-channel habitats of the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek.

Watershed	Off Channel Habitats		Number of Fish Per 100 Meters					
	Type	No. of Sites	Chinook Salmon	Coho Salmon	Sockeye Salmon	Arctic Grayling	Dolly Varden	Rainbow Trout
South Fork Koktuli River [a]	Alcove	-	-	-	-	-	-	-
	Beaver pond	36	2.94	30.38	10.84	7.37	4.29	0
	Beaver pond outlet channel	-	-	-	-	-	-	-
	Isolated pool	2	0	8.22	2.35	0	0	0
	Percolation channel	2	0	11.43	0	0	0	0
	Side channel	3	10.34	66.41	5.17	0.52	0	0.52
North Fork Koktuli River [b]	Alcove	1	2.06	1,334.02	24.74	0	12.37	0
	Beaver pond	9	0.18	78.19	0.53	0	1.07	0
	Beaver pond outlet channel	1	0	0	0	0	0	0
	Isolated pool	2	0	0	0	0	0	0
	Percolation channel	16	2.49	51.60	0.62	0	8.70	0
	Side channel	8	0	568.13	0	0	69.21	0
Upper Talarik Creek [c]	Alcove	1	0	87.10	0	0	0	0
	Beaver pond	24	1.38	317.41	0.42	0.26	1.38	0.42
	Beaver pond outlet channel	3	0	42.38	0	0	1.32	1.32
	Isolated pool	4	0	15.09	0	0	0	0
	Percolation channel	10	0.63	144.38	3.92	12.54	0.16	0.78
	Side channel	3	0.75	270.33	1.51	0	0.75	0

Notes:
[a] Off-channel sites in the South Fork Koktuli River were sampled in September 2005, June and August 2006, and July 2007; it is not clear if or how data from sampling dates were combined to arrive at table values.
[b] Off-channel sites in the North Fork Koktuli River were sampled between late July to mid-August 2008; it is not clear if or how data from sampling dates were combined to arrive at table values.
[c] Off-channel sites in Upper Talarik Creek were sampled in July and October 2007; it is not clear how data from these sampling dates were combined to arrive at table values.
Source: PLP 2011: Chapter 15, Appendix 15.1D, Table 6.

As Table 3-3 illustrates, the SFK, NFK, and UTC watersheds are home to several fish species in addition to Pacific salmon. Maximum estimated densities for a subset of these other fishes in the SFK, NFK, and UTC mainstem reaches are shown in Table 3-11. Estimated densities are highest for Artic Grayling, particularly in upstream reaches of all three watersheds.

Table 3-11. Maximum estimated densities of resident fishes in mainstem habitats of the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek.

Watershed/Reach (River Kilometers)	Maximum Estimated Density (# per 100 m²) [a]					
	Rainbow Trout	Dolly Varden	Arctic Grayling	Northern Pike	Sculpin spp.	Stickleback spp.
South Fork Koktuli River						
SFK-A (0.0–24.9)	0.03	3.44	0.67	0.00	2.52	0.00
SFK-B (24.9–34.3)	0.29	0.64	2.47	0.00	1.29	0.00
SFK-C (34.3–51.7)	0.00	0.82	35.31	0.47	4.94	0.21
SFK-D (51.7–54.7)	0.00	5.55	45.02	1.26	19.78	0.00
SFK-E (54.7–64.2)	0.00	0.00	15.90	2.36	9.29	0.15
North Fork Koktuli River						
NFK-A (0.0–13.7)	0.23	0.74	2.44	0.00	1.52	0.00
NFK-B (13.7–21.1)	0.00	0.24	0.21	0.00	2.01	0.00
NFK-C (21.1–36.6)	0.00	1.76	6.68	0.00	1.76	0.00
NFK-D (36.6–48.4) [b]	0.00	1.05	6.01	0.10	6.77	0.19
NFK-E (48.4–52.5) [b]	0.00	0.00	0.00	0.00	10.00	0.00
Upper Talarik Creek						
UTC-A (0.0–5.9) [b]	0.11	0.00	0.04	0.00	0.66	14.55
UTC-B (5.9–16.8) [b]	10.64	0.20	0.61	0.00	1.96	0.00
UTC-C (16.8–24.8)	11.03	0.47	32.10	0.00	13.31	0.54
UTC-D (24.8–36.3)	0.45	1.22	1.19	0.00	3.70	0.44
UTC-E (36.3–45.1)	0.32	0.44	0.70	0.00	7.53	0.04
UTC-F (45.1–59.1)	0.87	3.35	0.43	0.00	28.65	0.17
UTC-G (59.1–62.4)	0.00	7.46	0.00	0.00	16.58	0.00

Notes:
[a] Maximum estimated adult and juvenile density across values reported for 2004–2007, 2008, and 2009.
[b] Reach was not sampled from 2004–2007.
Source: USACE 2020a: Table 3.24-9.

3.3.3 Habitat Complexity, Biocomplexity, and the Portfolio Effect

The world-class salmon fisheries in Bristol Bay result from numerous, interrelated factors. Closely tied to the Bristol Bay region's physical habitat complexity (Section 3.2) is its biocomplexity, which greatly increases the region's ecological productivity and stability. This biocomplexity operates at multiple scales and across multiple species, but it is especially evident in the watershed's Pacific salmon populations (Shedd et al. 2016). As a result, the loss of even a small, discrete population within the Bristol Bay watershed's overall salmon populations may have more significant effects than expected, due to associated decreases in biocomplexity.

3.3.3.1 The Relationship between Habitat Complexity and Biocomplexity

The five Pacific salmon species found in the Bristol Bay watershed vary in life-history characteristics (Table 3-4). Even within a single species, life histories can vary significantly. For example, Sockeye Salmon may spend anywhere from 0 to 3 years rearing in freshwater habitats, then 2 to 3 years feeding at sea, before returning to the Bristol Bay watershed anytime within a 4-month window (Table 3-4). Coho Salmon similarly may spend anywhere from 1 to 3 years rearing in freshwater habitats

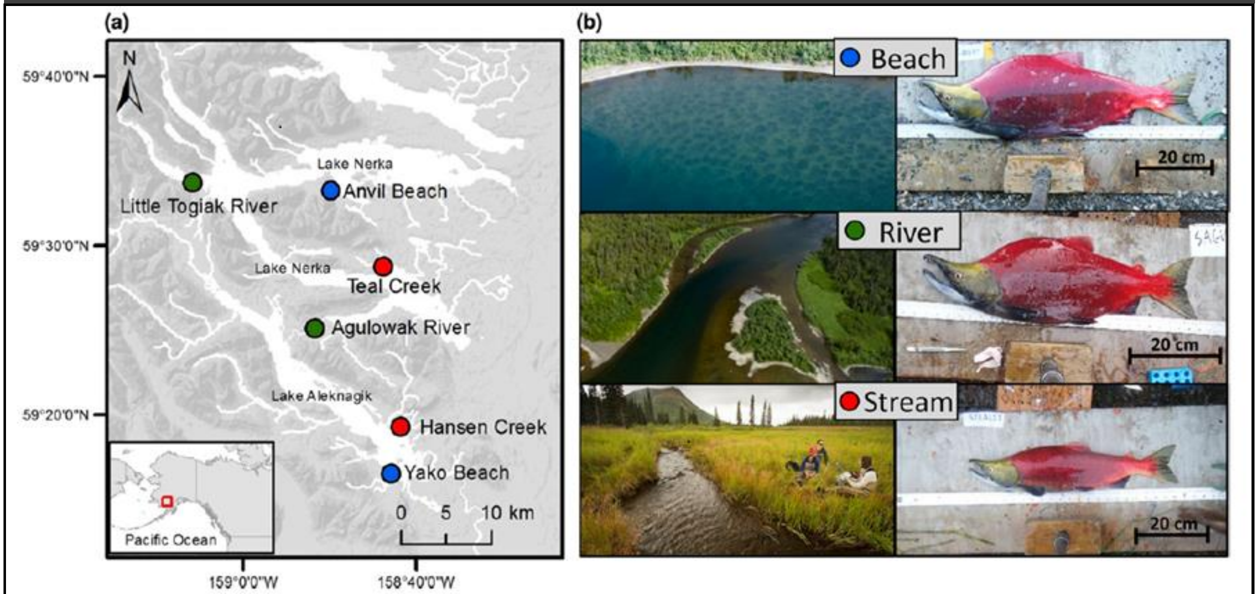
(Table 3-4). This staggered and overlapping age structure reduces variation in recruitment because it reduces the probability that all individuals in a cohort of siblings will encounter unfavorable environmental conditions over the course of their life cycles.

Pacific salmon also exhibit homing behavior, which means that they return to their natal streams to spawn. This homing behavior, in combination with life-history variability, results in discrete populations within each species that are adapted to their own specific spawning and rearing habitats (Hilborn et al. 2003, Ramstad et al. 2010, Schindler et al. 2010, Larson et al. 2019). Spawning populations return at different times and to different locations, creating and maintaining a degree of reproductive isolation due to reduced genetic exchange and allowing development of genetically distinct populations (Varnavskaya et al. 1994, Hilborn et al. 2003, McGlauflin et al. 2011). Within discrete spawning areas, natural selection may favor traits differently based on the unique environmental characteristics of spawning or rearing areas. In the Bristol Bay region, phenotypic variation in Sockeye Salmon body size and shape has been related to gravel size and spawning habitat (Quinn et al. 1995, Quinn et al. 2001, Larson et al. 2017, Schindler et al. 2018), illustrating the apparent adaptive significance of this variation.

These life history characteristics allow Pacific salmon species to fully exploit the range of habitats available throughout the Bristol Bay watershed, where many populations of each of these species are arrayed across a diverse landscape. Hydrologically diverse riverine and wetland landscapes across the region provide a variety of large river, small stream, floodplain, pond, and lake habitats for salmon spawning and rearing. Environmental conditions can differ among habitats in close proximity, and variations in temperature and streamflow associated with seasonality and groundwater–surface water interactions create a habitat mosaic that supports a range of spawning times across the watersheds (Lisi et al. 2013, Schindler et al. 2018).

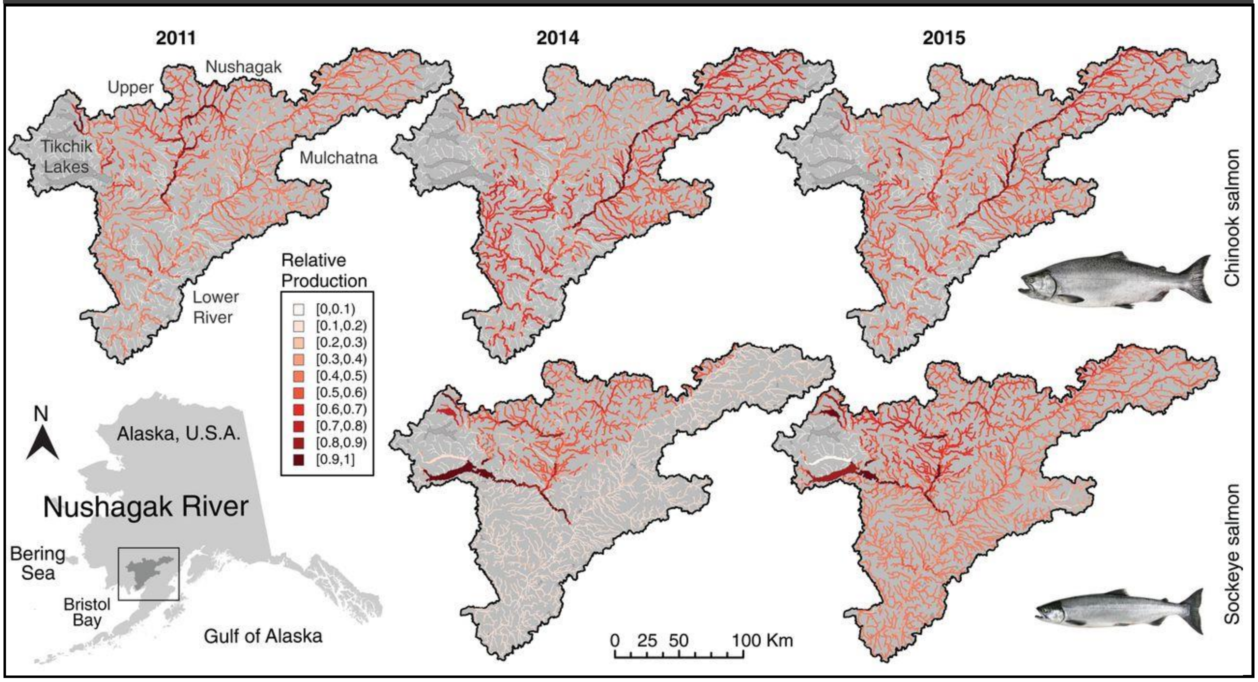
Bristol Bay is home to the largest Sockeye Salmon fishery in the world (Section 3.3.5). Sockeye Salmon from Bristol Bay produce relatively consistent returns due to the high degree of population diversity found within both the species and the region (Hilborn et al. 2003, Wood et al. 2008, Schindler et al. 2010, Schindler et al. 2015, Moore et al. 2021). A major component of this population diversity is associated with the diversity of habitats used for spawning, which has resulted in the formation of distinct spawning ecotypes (Figure 3-11) (Quinn et al. 1995, Lin et al. 2008, Dann et al. 2012, Larson et al. 2017, Schindler et al. 2018).

Figure 3-11. Bristol Bay salmon genetic lines of divergence linked to ecotypes. Genotypic and phenotypic diversity are linked in Sockeye Salmon from the Wood River system in Bristol Bay, providing an example of phenotypic variation due to selective adaptive pressures from the diversity of habitats (beaches, rivers, and streams) across the landscape. From Larson et al. (2017); reprinted with permission.



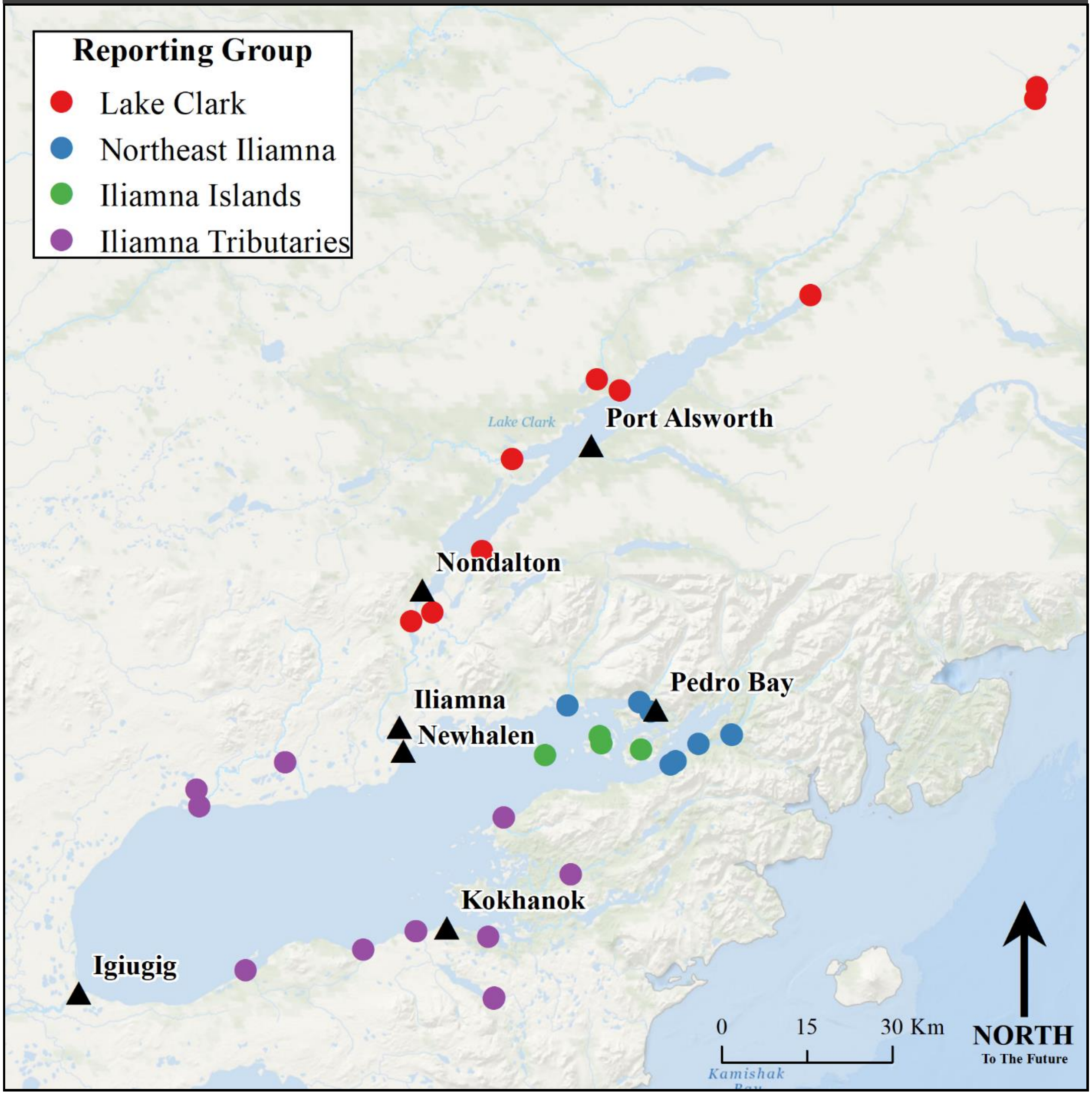
For both Chinook and Sockeye salmon, biocomplexity—operating across a continuum of integrated, nested spatial and temporal scales—has been found to stabilize salmon production and fisheries in the Nushagak River watershed (Brennan et al. 2019). Productivity of Sockeye and Chinook salmon shifts within the Nushagak River watershed from year tvo year (Figure 3-12). Because the productivity of individual habitats and sub-watersheds in the Nushagak River watershed varies from year to year depending on environmental conditions, maintaining habitat diversity across the landscape is critical for maintaining the sustainability and productivity of the watershed's salmon populations. The phenotypic, genotypic, and behavioral diversity of these salmon populations depends on the diversity of aquatic habitats in space and time (Davis et al. 2017, Schindler et al. 2018, Brennan et al. 2019).

Figure 3-12. Productive habitats for Chinook and Sockeye salmon across the Nushagak River watershed shift over time. From Brennan et al. (2019); reprinted with permission.



Although this genetic differentiation and associated phenotypic differences tend to increase with distance between the populations, even populations in relatively close proximity can exhibit high degrees of differentiation (May et al. 2020). As a result, these discrete populations can occur at localized spatial scales. For example, Sockeye Salmon that use spring-fed ponds and streams approximately 1 km apart exhibit differences in spawn timing, spawn site fidelity, productivity, and other traits that are consistent with discrete populations (Quinn et al. 2012). Multiple beach-spawning populations of Sockeye Salmon are found in Iliamna Lake (Figures 3-11 and 3-13) (Stewart et al. 2003, Larson et al. 2017). Genetically distinct river-type and lake-type populations can co-occur within watersheds (Dann et al. 2013, Shedd et al. 2016, Larson et al. 2017), and inlet and outlet spawners with distinct migration patterns can occur within the same lake (Burger et al. 1997). Iliamna Lake supports genetically unique populations within tributary, island, and lake shoreline ecotones, with UTC identified as one of the 22 populations (Figure 3-13). Genetic diversity of Sockeye Salmon in Bristol Bay has been found to be distributed hierarchically between ecotypes, among drainages within ecotypes, and among populations within drainages (Figure 3-11) (Dann et al. 2013, Larson et al. 2017, Schindler et al. 2018, Larson et al. 2019).

Figure 3-13. Kvichak River Sockeye Salmon populations. 22 populations of Sockeye Salmon (color-coded by reporting group) have been identified in the Kvichak River. From Dann et al. 2018; reprinted with permission.



Sockeye Salmon that spawn in small streams are much smaller than those that spawn on beaches or in rivers because sexual selection for large body size is overwhelmed by size-selective predation from bears and physical constraints of stream depth (Figure 3-11) (Quinn et al. 2001, Larson et al. 2017). The spawning environments of these ecotypes also vary in other characteristics, including temperature, gravel size, and spawning density, which also results in differences in egg morphology (Quinn et al. 1995, Hendry et al. 2000), spawn timing (Schindler et al. 2010) and pathogen susceptibility (hypothesized in Larson et al. 2014). Local adaptation to these diverse habitats is key to creating and preserving salmon genetic diversity.

The river-type form of Sockeye Salmon is relatively rare in Bristol Bay (Wood et al. 2008) but is found in the Nushagak River watershed, including in the Koktuli River (Dann et al. 2012). River-type Sockeye Salmon represent an important form of genetic diversity, as these populations typically exhibit greater diversity within and less diversity among populations than the more abundant lake-type sockeye salmon (Larson et al. 2019). Given that river-type Sockeye Salmon have a greater tendency to stray from natal areas and are, thus, considered the colonizers of the species (Wood 1995, Wood et al. 2008), this within-population genetic diversity can help "seed" new freshwater habitats that become available as glaciers recede (e.g., due to climate change) (Pitman et al. 2020).

3.3.3.2 The Portfolio Effect

The life-history complexity of Bristol Bay's Pacific salmon species is superimposed on localized adaptations, resulting in a high degree of biocomplexity organized into discrete, locally distinct fish populations. For example, the Bristol Bay watershed includes a complex of different Sockeye Salmon populations—that is, a combination of hundreds of genetically distinct, wild populations, each adapted to specific, localized environmental conditions (Hilborn et al. 2003, Schindler et al. 2010, Schindler et al. 2018). As genetic tools and techniques develop, the science continues to advance our understanding of the prevalence and importance of individual populations.

Management of Alaska's salmon fisheries is geared toward protection of these wild salmon populations, or stocks (5 AAC 39.222, 5 AAC 39.220, 5 AAC 39.223, 5 AAC 39.200). The ADF&G Genetic Policy provides the fundamental document for guiding decisions made to protect the genetic integrity of significant and unique wild stocks (Evenson et al. 2018), and the mission of the ADF&G Gene Conservation Laboratory includes the protection of these genetic resources. The foundational premise behind the Genetic Policy guidelines is that salmonid populations have adapted to their native habitats over long periods of time and, thus, have maximized their fitness. These adaptations among populations provide increased resilience to variation in environmental conditions (Figge 2004, Schindler et al. 2010); disruption of these adaptations reduces the long-term fitness of populations.

This complex structure of genetically distinct populations can be likened to a financial portfolio in which assets are divided among diverse investments to increase financial stability. Essentially, it creates a biological portfolio effect (Lindley et al. 2009, Schindler et al. 2010, Schindler et al. 2015): under any given set of conditions, some assets (e.g., discrete Sockeye Salmon populations) will perform well while others perform less well, but maintenance of the diversified portfolio stabilizes returns over time.

The portfolio concept is based on three key principles: (1) diversity provides stabilization; (2) habitat diversity creates genetic and phenotypic diversity in space and time; and (3) genetic and phenotypic diversity dampen ecological risk through asynchrony of population dynamics (i.e., spawning, rearing, migration) across the landscape (Schindler et al. 2010). Across the entire watershed, overall salmon productivity is stabilized as the relative contribution of Sockeye Salmon that differ in genetic structure and life-history characteristics, and inhabit different regions of the Bristol Bay watershed, changes over time in response to changing environmental conditions (Hilborn et al. 2003).

Asynchrony in the productivity of different populations within the complex has been demonstrated at both local and regional scales—that is, across individual tributaries and across the Bristol Bay watershed's major river systems (Rogers and Schindler 2008, Schindler et al. 2010, Griffiths et al. 2014, Raborn and Link 2022). This asynchrony among populations is an important characteristic of stable ecosystems (Rogers and Schindler 2008, Quinn et al. 2012). At the local scale, for example, salmon populations that spawn in small streams may be negatively affected by low-streamflow conditions, whereas populations that spawn in lakes may not be affected (Hilborn et al. 2003). At the regional scale, the relative productivity of Bristol Bay's major rivers has changed over time during different climatic regimes (Hilborn et al. 2003, Raborn and Link 2022). For example, small Sockeye Salmon runs in the Egegik River were offset by large runs in the Kvichak River prior to 1977, whereas declining runs in the Kvichak River were offset by large runs in the Egegik River in the 2000s (EPA 2014: Appendix A, Figure 9). Figure 3-14 illustrates how the proportion of Sockeye Salmon catch from each of Bristol Bay's major rivers varies both within and across years. Asynchrony of population dynamics across a diverse set of habitats has enabled the sustainable Bristol Bay salmon fishery (Figure 3.14) (Davis and Schindler 2021).

The high level of system-wide biocomplexity inherent in the overall population complex structure reduces year-to-year variability in salmon run sizes, making the fishery much more reliable than it would be otherwise. Without the portfolio effect, annual variability in the size of Bristol Bay's Sockeye Salmon runs would be expected to more than double, and fishery closures would be expected to become more frequent due to a weakening of the portfolio (Schindler et al. 2010, Griffiths et al. 2014). Simulations have shown that loss of headwater salmon populations can reverberate throughout the river network, resulting in reduced catch stability and increased fishery variability at the most downstream locations (Moore 2015). In other watersheds with previously robust salmon fisheries, such as the Sacramento River's Chinook Salmon fishery, losses of biocomplexity have contributed to overall salmon population declines (Lindley et al. 2009). Loss of accessible floodplain and headwater habitats also can be a significant driver of these declines, as illustrated in Canada's Lower Fraser River (Finn et al. 2021).

ADF&G has identified 11 genetic reporting groups (stocks), equating to nine major watersheds of Bristol Bay[40] and the two flanking regions (North Peninsula to the south and Kuskokwim to the north) (Figure 3-15). In Bristol Bay, a "stock" has been defined as a composite of all populations of a given species

[40] Figure ES-1 shows six major watersheds draining to Bristol Bay, whereas Dann et al. (2009) refer to nine major watersheds. This difference results from consideration of the Igushik and Wood River watersheds as distinct from the Nushagak River watershed and the Alagnak River watershed as distinct from the Kvichak River watershed in Dann et al. (2009).

within each of those 11 watersheds (Dann et al. 2009). Each river stock contains tens to hundreds of wild, locally adapted populations distributed among tributaries and lake habitats. In Bristol Bay, the ADF&G Sockeye Salmon genetic baseline, which is assembled by sampling spawning populations contributing to the commercial fishery (Section 3.3.5), has recently increased from 96 populations to 146 distinct populations that range from the Kuskokwim River (to the north) to the Aleutian Islands (to the south) (Dann et al. 2013).

Figure 3-14. Seasonal catch plus escapement of Sockeye Salmon for each genetically distinct stock in Bristol Bay, Alaska, 2012–2021. Black vertical lines denote July 4, to facilitate run timing comparison across years. From Raborn and Link (2022); reprinted with permission.

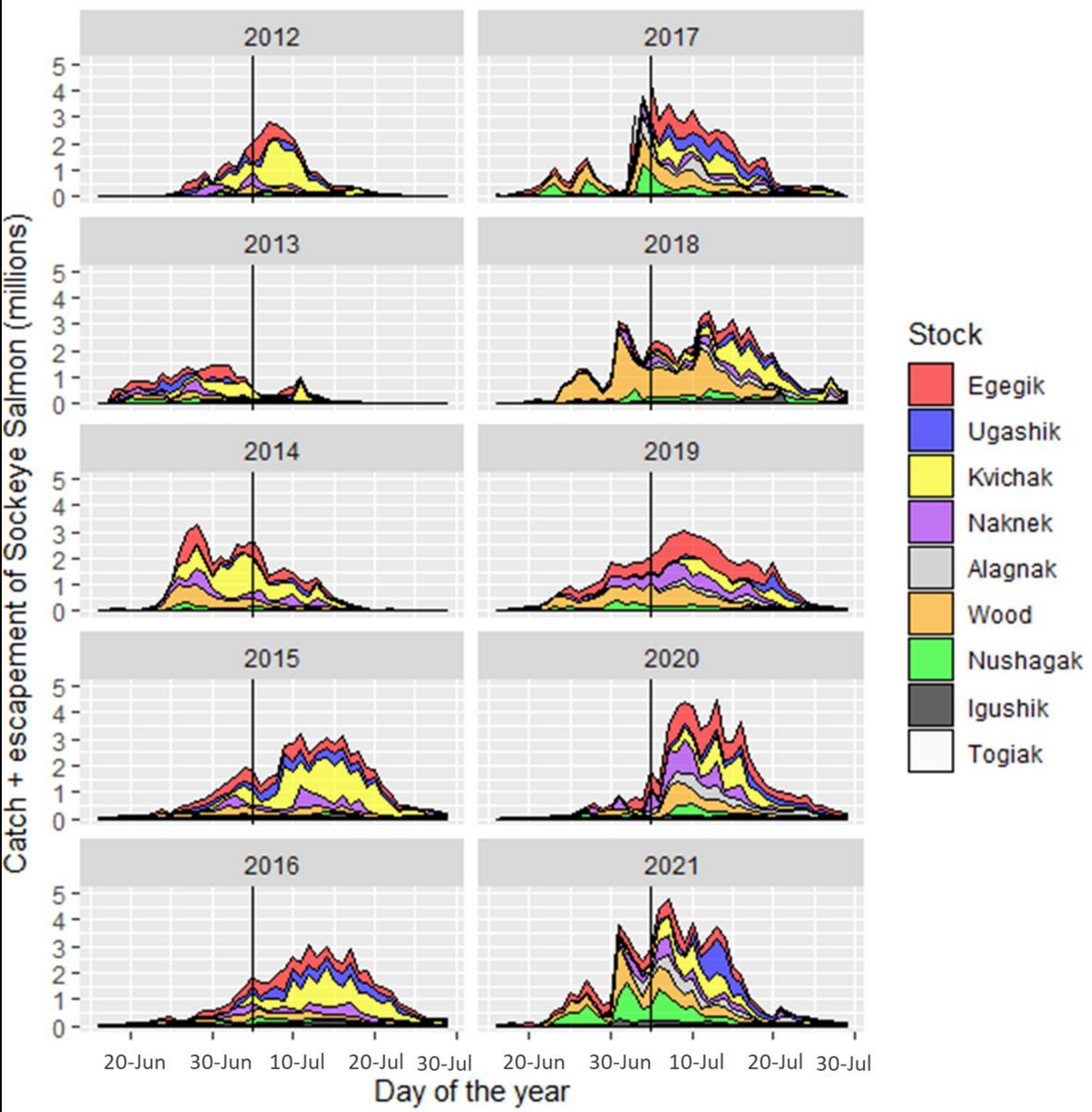
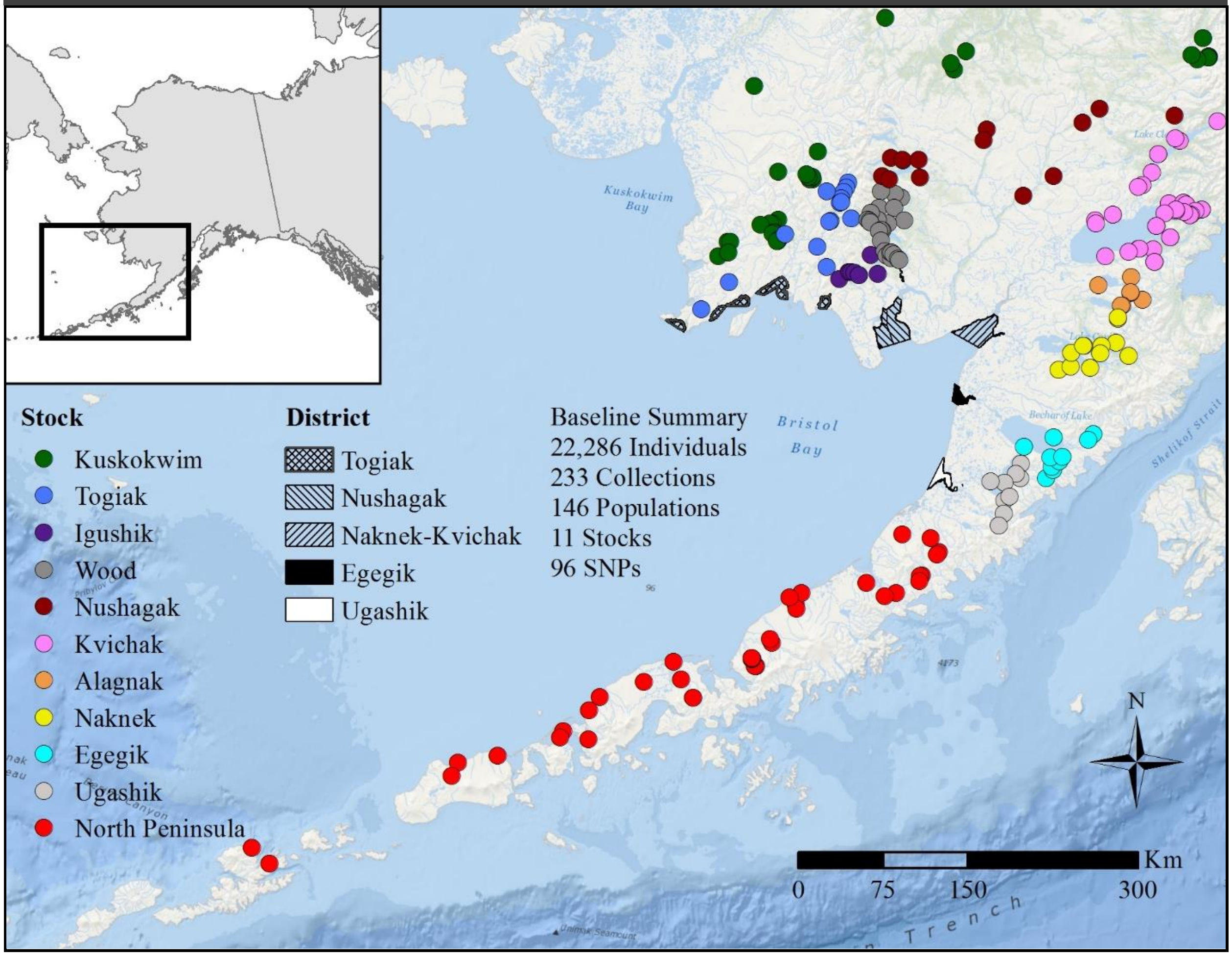


Figure 3-15. Reporting group affiliation for 146 Sockeye Salmon populations in Bristol Bay. These populations are used to estimate stock composition of catch samples from the Port Moller Test Fishery and district harvests. SNP = single nucleotide polymorphism, a common type of genetic marker. From Dann et al. 2013; reprinted with permission.



The genetic population structure of Bristol Bay Sockeye Salmon indicates that upper Mulchatna River fish are distinct from lower Mulchatna River fish, and that both of these populations are genetically distinct from the upper Nushagak River fish. Sockeye Salmon spawning in the Koktuli River are part of the Lower Mulchatna River and have recently been determined to be genetically distinct (Dann et al. 2012, Shedd et al. 2016). This incredible local diversity of Sockeye Salmon—which translates to the robustness of the region's Sockeye Salmon portfolio—reflects the species' ability to exploit a wide range of habitat conditions, the reproductive isolation of populations created by precise homing to natal spawning sites and, thus, the species' capacity for microevolution.

The close management of mixed-stock fisheries allows for the capitalization of genotypic and phenotypic diversity of Bristol Bay Sockeye Salmon while spreading the risk to any one stock across the stock portfolio (Veale and Russello 2017). The buffering effect of the salmon portfolio is reflected in the 2022 Bristol Bay Sockeye Salmon Forecast (ADF&G 2021b), which reports that individual river forecasts have greater uncertainty compared to the Bristol Bay-wide forecast. ADF&G (2021b) notes that since 2001, the forecast has, on average, underestimated returns to the Alagnak (-33 percent), Togiak (-14 percent), Kvichak (-21 percent), Wood (-20 percent), Nushagak (-25 percent), Ugashik (-5 percent), and Naknek (-15 percent) Rivers, and overestimated returns to the Igushik (11 percent) and Egegik Rivers (13 percent). Over-forecasting returns to some rivers while under-forecasting returns to other rivers means that the overall Bristol Bay forecast is often more accurate than the forecast to any individual river. This illustrates the power of a diverse stock portfolio to provide sustained resiliency to Bristol Bay's Sockeye Salmon fishery, by buffering risk to any one stock temporally and spatially across multiple stocks: certain rivers may have lower than expected returns in a given year due to environmental conditions and other factors, but these losses can be offset by higher than expected returns in other rivers (Figure 3-14).

Baseline genetic research suggests that other Bristol Bay fisheries, in addition to Sockeye Salmon, may also be stabilized by the portfolio effect; however, genetic baselines for these other species are not currently as advanced as they are for Sockeye Salmon. Coho Salmon in western Alaska tend to occur in smaller, more isolated populations (Olsen et al. 2003). Thus, Coho Salmon may have higher rates of genetic differentiation than nearby populations of other salmon species (e.g., Chum Salmon) in this region, and the loss of Coho Salmon populations may be more likely to translate to loss of significant amounts of overall genetic variability (Olsen et al. 2003, Schindler et al. 2018). Chinook Salmon populations also tend to be relatively small (Healey 1991) and exhibit a diversity of life history traits (e.g., variations in size and age at migration, duration of freshwater and estuarine residency, time of ocean entry) (Lindley et al. 2009). Chinook populations in the Togiak River exhibit differences in spawning habitats (mainstem versus tributary) and migration timing, which translate to a clear stock structure (Sethi and Tanner 2014, Clark et al. 2015). Radio telemetry, tagging, and genetic studies also indicate that multiple rainbow trout populations are found in the Bristol Bay watershed (Burger and Gwartney 1986, Minard et al. 1992, Krueger et al. 1999, Meka et al. 2003, Dye and Borden 2018).

The potential for fine-scale population structuring of salmon fisheries, particularly in terms of Sockeye and Coho salmon, exists throughout the entire Bristol Bay watershed. Finer-scale habitats can sustain unique, genetically distinct populations, each of which helps to maintain the integrity of overall salmon stocks across the Bristol Bay watershed and contributes to the overall resilience of these stocks to perturbation. For example, Sockeye Salmon that use spring-fed ponds and streams as close as approximately 0.6 mile (1 km) apart exhibit differences in traits (e.g., spawn timing, spawn site fidelity, and productivity) that suggest they may comprise discrete populations (Rand et al. 2007, Ramstad et al. 2010, Quinn et al. 2012). Genetic population structure also occurs at a fine geographic scale for Coho Salmon, with many populations found in small first- and second-order headwater streams (Olsen et al. 2003). The ability of Bristol Bay to sustain diverse salmon populations is, therefore, dependent on sustaining the viability of the vast network of unique habitats at small spatial scales across the landscape. This suggests that even the loss of a small population within the Bristol Bay watershed's overall salmon populations may have more significant effects than expected, due to associated loss of genetic and phenotypic diversity of a discrete population (Schindler et al. 2010, Moore et al. 2014, Waples and Lindley 2018).

In summary, a substantial body of research supports the conclusion that a diversity of habitats is necessary for maintaining locally adapted populations that create a stock portfolio of individual species. The multiple, genetically distinct populations of Sockeye Salmon that have been documented in the SFK, NFK, and UTC watersheds contribute to the region's wild salmon portfolio. It is clear from the evolving understanding of the stabilizing effects of the salmon portfolio that the conservation of habitat diversity, which leads to locally adapted population diversity across the landscape, is critical to achieve and maintain the sustainability of Bristol Bay's salmon populations.

3.3.4 Salmon and Marine-Derived Nutrients

Salmon play a crucial role in maintaining and supporting the overall productivity of the Bristol Bay watershed. Salmon are a cornerstone species in the Bristol Bay region in that they comprise a significant portion of the resource base upon which both aquatic and terrestrial ecosystems in the region depend (Willson et al. 1998). Approximately 95 to 99 percent of the carbon, nitrogen, and phosphorus in an adult salmon's body is derived from the marine environment during their ocean feeding period (Larkin and Slaney 1997, Schindler et al. 2005). Adult salmon returning to their natal freshwater habitats to spawn import these marine-derived nutrients (MDN) back into these freshwater habitats, spatially and temporally across the watershed (Cederholm et al. 1999, Gende et al. 2002). MDN from salmon account for a significant portion of nutrient budgets in the Bristol Bay watershed (Kline et al. 1993). For example, Sockeye Salmon are estimated to import approximately 14 tons (12.7 metric tons) of phosphorus and 11 tons (10.1 metric tons) of nitrogen into the Wood River system, and 55 tons (50.2 metric tons) of phosphorus and 438 tons (397 metric tons) of nitrogen into the Kvichak River system, annually (Moore and Schindler 2004). These nutrients provide the foundation for aquatic and terrestrial foodwebs via two main pathways: direct consumption of salmon in any of its forms (spawning adults, eggs, carcasses, and/or juveniles) and nutrient recycling (Gende et al. 2002).

Given that aquatic systems in the Bristol Bay watershed tend to be nutrient-poor, MDN contributions play a significant role in the Bristol Bay region's productivity. However, the distribution and relative importance of the trophic subsidies provided by MDN within salmon-bearing watersheds are not expected to be spatially or temporally uniform (Janetski et al. 2009). MDN concentrations will be highest in areas of high spawning density and where carcasses accumulate. Adult salmon are found in headwater streams of the SFK, NFK, and UTC watersheds, sometimes in extremely high numbers (Table 3-8); thus, MDN are likely contributing to the biological productivity of these headwaters and downstream habitats.

Where salmon are abundant, productivity of the Bristol Bay region's fish and wildlife species is highly dependent on this influx of MDN into the region's freshwater habitats (EPA 2014: Box 5-3). When and where available, salmon-derived resources—in the form of eggs, carcasses, and invertebrates that feed upon carcasses—are important dietary components for many fishes (e.g., juvenile Pacific salmon, Rainbow Trout, Dolly Varden, Arctic Grayling). Numerous studies have shown that the availability of

MDN benefits stream-dwelling fishes via enhanced growth rate (Bilby et al. 1996, Wipfli et al. 2003, Giannico and Hinch 2007), body condition (Bilby et al. 1998), energy storage (Heintz et al. 2004), and ultimately increased chance of survival to reproductive age and adulthood (Gardiner and Geddes 1980, Wipfli et al. 2003, Heintz et al. 2004).

Eggs from spawning salmon are a major food source for Bristol Bay Rainbow Trout and are likely responsible for much of the growth attained by these fish and the abundance of trophy-sized Rainbow Trout in the Bristol Bay system. Scheuerell et al. (2007) report that upon arrival of spawning salmon in the Wood River basin, Rainbow Trout shifted from consuming aquatic insects to primarily salmon eggs, resulting in a five-fold increase in ration and energy intake. With this rate of intake, a bioenergetics model predicted a 3.5-ounce (100-g) trout would gain 2.9 ounces (83 g) in 76 days; without the salmon-derived subsidy, the same fish was predicted to lose 0.2 ounce (5 g) (Scheuerell et al. 2007). Rainbow Trout in Lower Talarik Creek, a stream immediately west of UTC, were significantly fatter (i.e., had a higher condition factor) in years with high salmon spawner abundance than in years with low abundance (Russell 1977).

Rainbow Trout are not the only fish species to benefit from these MDN subsidies. Research in Iliamna Lake suggests that between 29 percent and 71 percent of the nitrogen in juvenile Sockeye Salmon, and even higher proportions in other aquatic taxa, comes from MDN, and that the degree of MDN influence increases with escapement (Kline et al. 1993). In the Kvichak River, Dolly Varden move into ponds where Sockeye Salmon are spawning and experience three-fold higher growth rates when salmon eggs are available as a food source (Denton et al. 2009).

By dying in the habitats in which they spawn, adult salmon add their nutrients to the ecosystem that will feed their young and, thus, subsidize the next generation. In lakes and streams, MDN help to fuel the production of algae, bacteria, fungi, and other microorganisms that make up aquatic biofilms. These biofilms, in turn, provide food for aquatic invertebrates. MDN inputs are associated with increased standing stocks of macroinvertebrates (Claeson et al. 2006, Lessard and Merritt 2006, Walter et al. 2006), a primary food resource for juvenile salmon and other stream-dwelling fishes.

The importance of MDN to fish populations is perhaps most clearly demonstrated in cases where MDN supplies are disrupted by depletion of salmon populations. For example, prolonged depression of salmon stocks in the Columbia River basin in Oregon has resulted in a chronic nutrient deficiency that hinders the recovery of endangered and threatened Pacific salmon stocks (Gresh et al. 2000, Petrosky et al. 2001, Achord et al. 2003, Peery et al. 2003, Scheuerell et al. 2005, Zabel et al. 2006) and diminishes the potential of expensive habitat improvement projects (Gresh et al. 2000). Density-dependent mortality has been documented among juvenile Chinook Salmon, despite the fact that populations have been reduced to a fraction of historical levels, suggesting that nutrient deficits have reduced the carrying capacity of spawning streams in the Columbia River basin (Achord et al. 2003, Scheuerell et al. 2005). Thus, diminished salmon runs can create a negative feedback loop, in which the decline in spawner abundance reduces the capacity of streams to produce new spawners (Levy 1997).

It is not just aquatic systems that benefit from these salmon-based MDN subsidies. Terrestrial mammals (e.g., Brown Bears, wolves, foxes, minks) and birds (e.g., Bald Eagles, waterfowl) also benefit from these subsidies (Brna and Verbrugge 2013, EPA 2014: Chapter 5; Armstrong et al. 2016). Alaskan Brown Bears have been shown to aggregate and exhibit fidelity in their foraging of salmon in small streams in the Bristol Bay watershed (Wirsing et al. 2018). Availability and consumption of salmon-derived resources can have significant benefits for these species, including increased growth rate, energy storage, litter size, nesting success, and population density (Brna and Verbrugge 2013). In response to temporal shifting distributions of spawning Sockeye Salmon, species such as Brown Bears and gulls change their spatial distributions within the Bristol Bay watershed over the course of the summer (Schindler et al. 2013). Bears, wolves, and other wildlife also transport carcasses and excrete wastes throughout their ranges (Darimont et al. 2003, Helfield and Naiman 2006), thereby providing food and nutrients for other terrestrial species.

3.3.5 Commercial Fisheries

All five species of Pacific salmon are commercially harvested in Bristol Bay, across five fishing districts identified by specific rivers draining to the bay (Table 3-12). Sockeye Salmon dominate the region's salmon runs and harvest by a large margin (Table 3-12). Management of the Sockeye Salmon fishery in Bristol Bay is focused on discrete stocks (Section 3.3.3.2) (Tiernan et al. 2021), and the fishery's success depends on the conservation of biodiversity and sound, conservative management based on sustainable yields (ADF&G 2022c). Bristol Bay is home to the largest Sockeye Salmon fishery in the world, with 46 percent of the average global abundance of wild Sockeye Salmon between 1956 and 2005 (Ruggerone et al. 2010); between 2015 and 2019, Bristol Bay contributed 53 percent of global Sockeye Salmon production (McKinley Research Group 2021). Annual commercial harvest of Sockeye Salmon averaged 31.5 million fish between 2010 and 2019 (Table 3-12) (Tiernan et al. 2021). The 2021 harvest of 40.4 million Sockeye Salmon was 44 percent higher than the recent 20-year average of 28.0 million for all districts (ADF&G 2021a). A total of 75.27 million Sockeye Salmon are forecast to return to Bristol Bay in 2022 (ADF&G 2021b). More than half of the Bristol Bay watershed's Sockeye Salmon harvest comes from the Nushagak and Kvichak River watersheds (Table 3-12) (EPA 2014: Figure 5-9B).

Table 3-12. Mean annual commercial catch (number of fish) by Pacific salmon species and Bristol Bay fishing district, 2010–2019. Number in parentheses indicates percentage of total found in each district.

Salmon Species	Bristol Bay Fishing District					
	Naknek-Kvichak [a]	Egegik	Ugashik	Nushagak [a]	Togiak	TOTAL
Sockeye	10,737,106 (34)	7,595,433 (24)	3,439,233 (11)	9,059,705 (29)	636,660 (2)	31,468,532
Chinook	2,168 (7)	930 (3)	753 (2)	25,111 (76)	3,983 (12)	32,945
Coho	2,316 (2)	8,012 (6)	630 (2)	91,263 (72)	25,215 (18)	127,436
Chum	233,281 (22)	72,472 (7)	50,366 (5)	540,280 (51)	163,062 (15)	1,059,464
Pink [b]	12,362 (1)	1,972 (<1)	539 (<1)	802,849 (88)	94,282 (10)	912,004

Notes:

[a] Naknek-Kvichak district includes the Alagnak River; Nushagak district includes the Wood and Igushik Rivers.

[b] Pink Salmon data are from even-numbered years only; harvest is negligible during odd-year runs.

Source: Tiernan et al. 2021.

The Nushagak River watershed supported 72 percent of commercial Coho Salmon catch in the region between 2010 and 2019 (Table 3-12). Although Chinook Salmon is the least common salmon species across the Bristol Bay region, the Nushagak River watershed also supports a large Chinook Salmon fishery, and its commercial harvests are greater than those of all other Bristol Bay river systems combined (Table 3-12). Between 2010 and 2019, on average 76 percent of Bristol Bay's commercial Chinook Salmon catch came from the Nushagak fishing district (Table 3-12). Chinook Salmon returns to the Nushagak River are consistently greater than 100,000 fish per year and have exceeded 200,000 fish per year in 11 years between 1966 and 2010. This frequently places the Nushagak River at or near the size of the world's largest Chinook Salmon runs, which is notable given the Nushagak River's small watershed area compared to other Chinook-producing rivers (EPA 2014: Chapter 5).

Given the productivity of Pacific salmon, the commercial salmon fishery currently provides the Bristol Bay region's greatest source of economic activity, creating thousands of jobs and generating $1 billion or more in economic output value through commercial fishing, processing, and support activities (Knapp et al. 2013, Wink Research and Consulting 2018, USACE 2020a, McKinley Research Group 2021). The McKinley Research Group (2021) estimates that in 2019, Bristol Bay's commercial fishery and related activities resulted in 15,000 jobs and an economic impact of $2.0 billion, $990 million of which was in Alaska. From 2000 through 2019, annual commercial salmon harvest in Bristol Bay averaged more than 27 million fishes across all five species (Tiernan et al. 2021). The annual ex-vessel commercial value[41] of this catch averaged $147.9 million, $146.4 million of which resulted from the Sockeye Salmon fishery (Table 3-13). In 2019, approximately 23 percent of Bristol Bay salmon permit holders were residents of the Bristol Bay watershed, and an additional 29 percent were residents of other areas in Alaska (McKinley Research Group 2021). This ex-vessel value translates to even higher wholesale values: for example, the 2010 Bristol Bay Sockeye Salmon harvest was worth $165 million in direct harvest value and $390 million in first wholesale value after processing (Knapp et al. 2013).

Table 3-13. Estimated ex-vessel value of Bristol Bay's commercial salmon catch by species, 2000–2019. Values are in thousands of dollars; number in parentheses indicates year that minimum or maximum value was obtained.

Salmon Species	Mean Value	Minimum Value (Year)	Maximum Value (Year)
Sockeye	146,372	31,962 (2002)	344,253 (2018)
Chinook	420	135 (2001)	1,240 (2006)
Coho	409	18 (2002)	1,990 (2014)
Chum	1,392	228 (2000)	2,891 (2018)
Pink [a]	436	0 (2002)	1,567 (2010)
TOTAL	147,874	32,544 (2002)	348,579 (2018)

Notes:
[a] Pink Salmon data are from even-numbered years only; harvest is negligible during odd-year runs.
Source: Tiernan et al. 2021: Appendix A24.

[41] Ex-vessel commercial value is the value paid to the fisher or permit holder upon delivery.

3.3.6 Subsistence Fisheries

In the Bristol Bay region, the subsistence way of life is irreplaceable. Subsistence resources provide high-quality foods, foster a healthy lifestyle, and form the basis for social relations. Alaska Natives are the majority population in the Bristol Bay region, and salmon has been central to their health, welfare, and culture for thousands of years. In fact, Alaska Native cultures in the region represent one of the last intact salmon-based cultures in the world (EPA 2014: Appendix D). Much of the region's population—including both Alaska Natives and non-Alaska Natives—practices subsistence, with salmon making up a large proportion of subsistence diets. Thus, residents in this region are particularly vulnerable to potential changes in salmon resources (see Section 6.3 for discussion of tribal considerations, including environmental justice concerns).

There are 31 Alaska Native villages in the wider Bristol Bay region, 25 of which are located in the Bristol Bay watershed. Fourteen of these communities are within the Nushagak and Kvichak River watersheds, with a total population of 4,197 in 2020 (U.S. Census Bureau 2022). Dillingham (population 2,249) is the largest community; other communities range in size from four (year-round) residents (Portage Creek) to 512 residents (New Stuyahok). In some communities the population increases during the subsistence fishing season. Thirteen of these 14 villages—all but Port Alsworth—have federally recognized tribal governments and had an Alaska Native population majority in 2020. No towns, villages, or roads are currently located in the SFK, NFK, and UTC watersheds. However, this area has been noted as important to the health and abundance of subsistence resources by traditional knowledge experts from communities in the area.

This following sub-sections discuss the use of subsistence fisheries in the region and its nutritional, cultural, and spiritual importance. Subsistence related to foods other than fish is discussed in Section 6.3.1.

3.3.6.1 Use of Subsistence Fisheries

Alaska Native populations of the Bristol Bay watershed, as well as non-Alaska Native residents, have continual access to a range of subsistence foods. As described by Fall et al. (2009), these subsistence resources are the most consistent and reliable component of local economies in the Bristol Bay watershed, even given the world-renowned commercial fisheries and other recreational opportunities the region supports.

Virtually every household in the Nushagak and Kvichak River watersheds uses subsistence resources (EPA 2014: Appendix D, Table 12). No watershed-wide data are available for the proportion of residents' diets made up of subsistence foods, as most studies focus on harvest data and are not dietary surveys. However, data from 2014 indicate that the overall composition of wild food harvest in the Bristol Bay area is composed of 58 percent salmon, 20 percent land mammals (mostly moose and caribou), 9 percent other fishes, and 13 percent other sources (marine mammals, birds, eggs, marine invertebrates and wild plants) (Halas and Neufeld 2018). In 2004 and 2005, annual subsistence consumption rates in the Nushagak and Kvichak River watersheds were over 300 pounds per person in many villages and reached as high as 900 pounds per person (EPA 2014: Appendix D, Table 12).[42]

Subsistence use varies throughout the Bristol Bay watershed, as villages differ in the per capita amount of subsistence harvest and the variety of subsistence resources used (Table 3-14). Salmon and other fishes are harvested throughout the Nushagak and Kvichak River watersheds (Figure 3-16) and provide the largest portion of subsistence harvests of Bristol Bay communities. On average, about 50 percent of the subsistence harvest by local community residents (measured in pounds usable weight) is Pacific salmon, and about 10 percent is other fishes (Fall et al. 2009). The percentage of salmon harvest in relation to all subsistence resources ranges from 29 percent to 82 percent in the villages (EPA 2014: Appendix D, Table 11); see Section 6.3.1 for further discussion of non-fish subsistence resources.

Table 3-14. Harvest of subsistence fisheries resources in selected communities of the Bristol Bay watershed.

Community	Year	Total Harvest (pounds) [a]	Estimated Per Capita Harvest (pounds)				Households Using Salmon (%)		
			All Salmon	Sockeye Salmon	Chinook Salmon	Non-Salmon Fishes	Used	Gave	Received
Aleknagik	2008	51,738	143	40	72	26	100	59	59
Dillingham	2010	486,533	131	46	55	7	91	57	56
Ekwok	1987	77,268	456	160	180	68	93	48	52
Igiugig	2005	22,310	205	168	5	59	100	83	83
Iliamna	2004	34,160	370	370	0	34	100	31	39
Kokhanok	2005	107,644	513	480	3	36	97	63	60
Koliganek	2005	134,779	565	688	194	90	100	61	54
Levelock	2005	17,871	152	86	43	40	93	36	79
New Stuyahok	2005	163,927	188	36	113	28	90	55	63
Newhalen	2004	86,607	502	488	10	32	100	64	32
Nondalton	2004	58,686	219	219	0	34	92	55	63
Pedro Bay	2004	21,026	250	250	0	15	100	72	78
Port Alsworth	2004	14,489	89	88	1	12	100	46	55

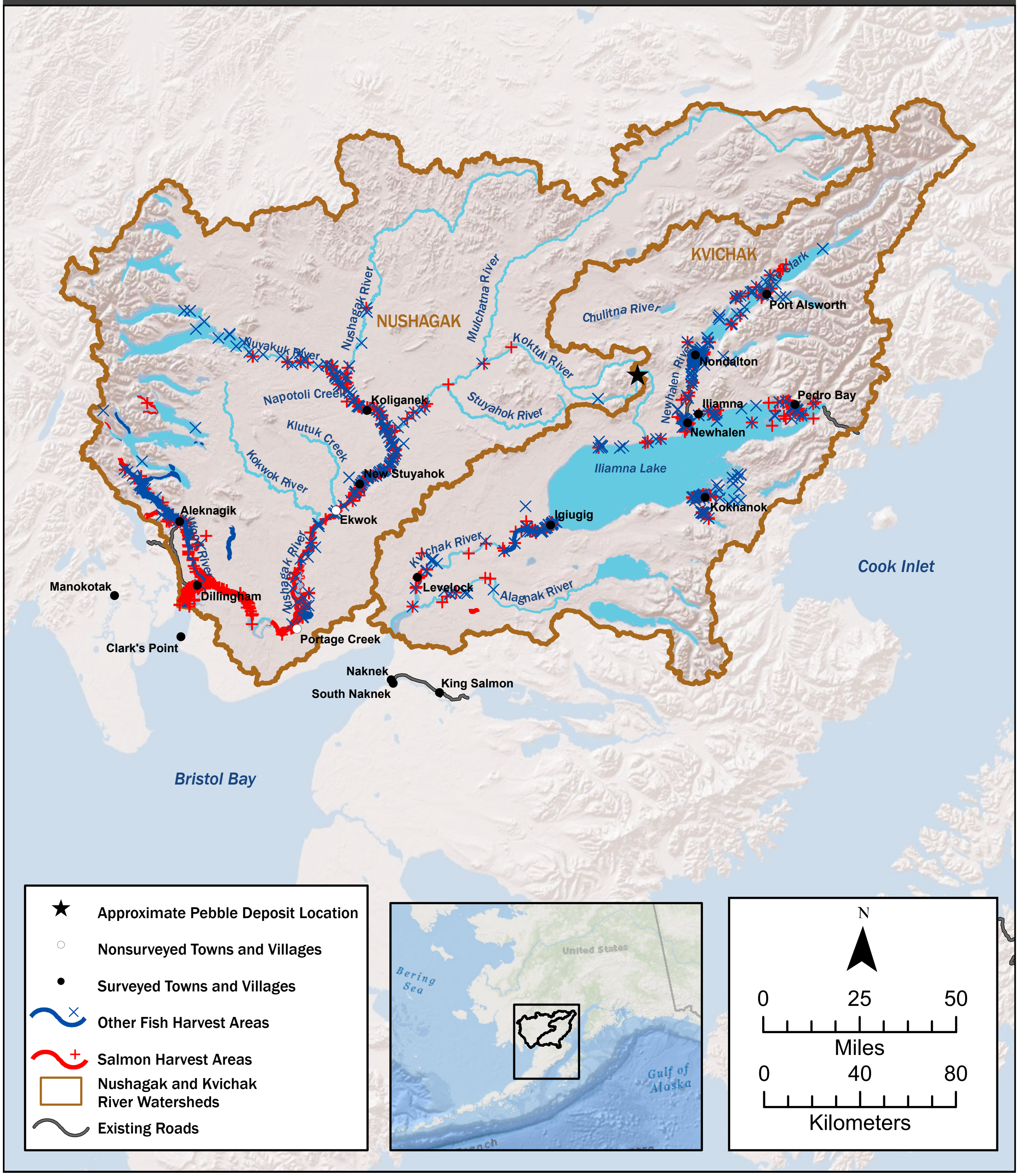
Notes:

[a] Total harvest values represent usable weight and include fishes, land mammals, freshwater seals, beluga, other marine mammals, plant-based foods, birds or eggs, and marine invertebrates. See Section 6.3.1 for additional information on non-fish subsistence resources.

Source: Schichnes and Chythlook 1991 (Ekwok), Fall et al. 2006 (Iliamna, Newhalen, Nondalton, Pedro Bay, and Port Alsworth); Krieg et al. 2009 (Igiugig, Kokhanok, Koliganek, Levelock, New Stuyahok); Holen et al. 2012 (Aleknagik); Evans et al. 2013 (Dillingham).

[42] For comparison, an average American consumes roughly 2,000 pounds of food per year.

Figure 3-16. Subsistence harvest and harvest-effort areas for salmon and other fishes in the Nushagak and Kvichak River watersheds. Other fishes are those classified as Arctic Char, Dolly Varden, Humpback Whitefish, Lake Trout, Least Cisco, Rainbow Trout, Round Whitefish, Steel head (anadromous Rainbow Trout), trout, and whitefish in relevant subsistence use reports (Fall et al. 2006, Krieg et al. 2009, Holen and Lemons 2010, Holen et al. 2011, Holen et al. 2012).



Between 2008 and 2017, average annual subsistence salmon harvest in the Nushagak district was 49,024 fishes and in the Naknek-Kvichak district was 66,174 fishes (Halas and Neufeld 2018). There are differences in the relative importance of different subsistence fisheries between the two watersheds, however. Sockeye Salmon comprised 97 percent of this harvest in the Naknek-Kvichak district but only 53 percent in the Nushagak district, where Chinook Salmon (25 percent) and Coho Salmon (11 percent) were larger subsistence resources (Halas and Neufeld 2018). Villages along the Nushagak River (e.g., Ekwok, New Stuyahok) are particularly dependent on Chinook Salmon as a subsistence resource (Table 3-14), in part because Chinook Salmon are the first spawners to return each spring (EPA 2014: Appendix D). Between 2008 and 2017, average annual subsistence harvest of Sockeye Salmon ranged from 740 fish in Levelock to 27,755 fish in Dillingham (Table 3-15).

Table 3-15. Estimated subsistence salmon harvest in communities of the Bristol Bay watershed, 2008–2017. Values represent numbers of fish.

Community	Average Annual Subsistence Harvest of Salmon [a]	Minimum Annual Subsistence Harvest of Sockeye Salmon (Year)	Maximum Annual Subsistence Harvest of Sockeye Salmon (Year)
Aleknagik	2,623	1,570 (2010)	3,560 (2014)
Dillingham	27,755	22,037 (2012)	33,220 (2016)
Ekwok	1,849	1,253 (2012)	2,700 (2014)
Igiugig	1,346	345 (2013)	2,901 (2010)
Iliamna/Newhalen	10,564	6,403 (2017)	15,433 (2011)
Kokhanok	11,136	5,430 (2017)	16,530 (2012)
Koliganek	3,573	2,085 (2015)	7,290 (2013)
Levelock	740	30 (2008)	1,265 (2016)
New Stuyahok	6,727	5,062 (2012)	11,104 (2013)
Nondalton	7,215	2,320 (2016)	10,550 (2013)
Pedro Bay	3,742	1,678 (2017)	7,802 (2009)
Port Alsworth	4,024	3,155 (2009)	6,588 (2015)

Notes:

[a] For communities in the Kvichak River watershed, number represents Sockeye Salmon harvest; for communities in Nushagak River watershed, number represents all salmon species.

Source: Halas and Neufeld 2018.

All communities in the Nushagak and Kvichak River watersheds also rely on non-salmon fishes, including Northern Pike, various whitefish species, Dolly Varden, Arctic Char, and Arctic Grayling, but to a lesser extent than salmon. These fishes are taken throughout the year by a variety of harvest methods and fill an important seasonal component of subsistence cycles (Halas and Neufeld 2018). Non-salmon fishes are particularly important subsistence resources in spring and fall, when salmon and other resources are less available (Hazell et al. 2015). For example, in the mid-2000s, annual subsistence harvests for 10 communities in the Nushagak and Kvichak River watersheds were estimated at 3,450 Dolly Varden/Arctic Char (Alaska's fisheries statistics do not distinguish between the two species); 4,385 Northern Pike; and 7,790 Arctic Grayling (Fall et al. 2006, Krieg et al. 2009). Northern Pike were the most important non-salmon fishes in four of those villages during that time (Fall et al. 2006, Krieg et al. 2009). From the mid-1970s to the mid-2000s, Dolly Varden/Arctic Char, Northern Pike, and Arctic Grayling were estimated to represent roughly 16 to 27 percent, 10 to 14 percent, and 7 to 10 percent of the total weight of the Kvichak River watershed's non-salmon freshwater fish subsistence harvest, respectively (Krieg et al. 2005).

Although subsistence is a non-market economic activity that is not officially measured, the effort put into subsistence activities is estimated to be the same as or greater than full-time equivalent jobs in the cash sector (EPA 2014: Appendix E). There is a strong and complex relationship between subsistence and the market economy (largely commercial fishing and recreation) in the area (Wolfe and Walker 1987, Krieg et al. 2007). For example, income from the market economy funds household purchases of goods and services that are then used for subsistence activities (e.g., boats, rifles, nets, snowmobiles, and fuel). When Alaskan households spend money on subsistence-related supplies, the subsistence harvest of fishes generates regional economic benefits. In total, individuals in Bristol Bay communities harvest about 2.6 million pounds of subsistence foods per year (EPA 2014: Chapter 5). In 2010, the U.S. Census Bureau reported an estimated 1,873 Alaska Native and 666 non-Alaska Native households in the Bristol Bay region. Goldsmith et al. (1998) estimated that Alaska Native households spend an average of $3,054 on subsistence harvest supplies, whereas non-Alaska Native households spend an estimated $796 on supplies (values updated to 2009 price levels). Based on these estimates, subsistence harvest activities resulted in expenditures of approximately $6.3 million (EPA 2014: Table 5-4).

The estimates above reflect only the annual economic activity generated by subsistence activities and not the value of the subsistence resources harvested. A study by the McKinley Research Group (2021) estimated that the replacement value of the 2017 Bristol Bay subsistence salmon harvest—that is, the cost of replacing subsistence salmon protein with store-bought substitutes—was between $5 million and $10 million (Table 3-16).

Table 3-16. Estimated replacement value of 2017 Bristol Bay subsistence salmon harvest.

Variable	Chinook	Chum	Coho	Pink	Sockeye	TOTAL
Number of fish	12,985	4,907	8,154	553	89,704	116,303
Pounds of usable fish	98,199	22,907	39,776	1,441	341,567	503,890
Species-specific % of total usable fish	19	5	8	0	68	100
Replacement value at $10 per pound	$981,992	$229,066	$397,762	$14,411	$3,415,673	$5,038,904
Replacement value at $20 per pound	$1,963,980	$458,140	$795,524	$28,820	$6,831,346	$10,077,800

Source: McKinley Research Group 2021.

3.3.6.2 Importance of Subsistence Fisheries

The salmon-dependent diet of Alaska Natives benefits their physical and mental well-being in multiple ways, in addition to encouraging high levels of fitness based on subsistence activities. Salmon and other traditional wild foods make up a large part of people's daily diets throughout their lives, beginning as soon as they are old enough to eat solid food (EPA 2014: Appendix D). Disproportionately high amounts of total diet protein and some nutrients come from subsistence foods. For example, a 2009 study of two rural Alaska regions found that 46 percent of protein, 83 percent of vitamin D, 37 percent of iron, 35 percent of zinc, 34 percent of polyunsaturated fat, 90 percent of eicosapentaenoic acid, and 93 percent of docosahexaenoic acid came from subsistence foods consumed by Alaska Natives (Johnson et al. 2009). These foods have demonstrated nutritional benefits, including lower cumulative risk of nutritionally mediated health problems such as diabetes, obesity, high blood pressure, and heart disease (Murphy et al. 1995, Dewailly et al. 2001, Dewailly et al. 2002, Din et al. 2004, Hall et al. 2005, Chan et al. 2006, Ebbesson et al. 2007) and provision of essential micronutrients and omega-3 fatty acids (Murphy et al. 1995, Nobmann et al. 2005, Bersamin et al. 2007, Ebbesson et al. 2007). In addition, the cost of replacing subsistence salmon in diets, even with lower-quality protein sources, is likely to be significant (Table 3-16).

However, for Alaska Natives, subsistence is much more than the harvesting, processing, sharing, and trading of foods. Subsistence holistically subsumes the cultural, social, and spiritual values that are the essence of Alaska Native cultures (USACE 2020a: Section 3.9). Traditional and more modern spiritual practices place salmon in a position of respect and importance, as exemplified by the First Salmon Ceremony and the Great Blessing of the Waters (EPA 2014: Appendix D). The salmon harvest provides a basis for many important cultural and social practices and values, including the sharing of resources, fish camp, gender and age roles, and the perception of wealth. Tribal Elders and culture bearers continue to instruct young people, particularly at fish camps where cultural values, as well as fishing and fish processing techniques, are shared. The social system that forms the backbone of the culture, by nurturing the young, supporting the producers, and caring for the tribal Elders, is based on the virtue of sharing wild foods harvested from the land and waters.

The importance of salmon as a subsistence food source is inseparable from it being the basis for Alaska Native cultures. The characteristics of the subsistence-based salmon cultures in the Bristol Bay region have been widely documented (EPA 2014: Appendix D). The cultures have a strong connection to the landscape and its resources, and in the Bristol Bay watershed this connection has been maintained for centuries by the uniquely pristine condition of the region's landscape and resources. In turn, the respect and importance given salmon and other wildlife, along with Alaska Natives' traditional knowledge of the environment, have produced a sustainable, subsistence-based economy (EPA 2014: Appendix D). This subsistence-based way of life is a key element of Alaska Native identity and serves a wide range of economic, social, and cultural functions (USACE 2020a: Section 3.9).

3.3.7 Recreational Fisheries

In addition to commercial and subsistence fisheries, the Bristol Bay region also supports world-class recreational or sport fisheries. The Bristol Bay watershed (as reflected by the Bristol Bay Sport Fish Management Area, or BBMA) has been acclaimed for its sport fisheries, for fishes such as Pacific salmon, Rainbow Trout, Arctic Grayling, Arctic Char, and Dolly Varden, since the 1930s (Dye and Borden 2018). The uncrowded, pristine wilderness setting of the Bristol Bay watershed attracts recreational fishers, and aesthetic qualities are rated by Bristol Bay anglers as most important in selecting fishing locations (Duffield et al. 2007).

The importance of recreational fisheries can be estimated in several ways, including their economic value, the effort expended by recreational fishers, the number of fishes harvested, and the number of fishes caught (i.e., those harvested in addition to those caught and released).

Sport fishing in the Bristol Bay watershed accounts for approximately $66.58 million expenditures, expressed in 2020 dollars (USACE 2020a: Section 3.6). In 2009, approximately 29,000 sport-fishing trips were taken to the Bristol Bay region (12,000 trips by people living outside of Alaska, 4,000 trips by Alaskans living outside the Bristol Bay area, and 13,000 trips by Bristol Bay residents). These sport-fishing activities directly employ over 800 full- and part-time workers. In 2010, 72 businesses and 319 guides were operating in the Nushagak and Kvichak River watersheds alone, down from a peak of 92 businesses and 426 guides in 2008 (Rinella et al. 2018).

Between 2007 and 2017, angler-days of effort within the BBMA ranged from 74,560 to 102,844 annually, with total annual sport harvest for the same period ranging from 42,082 to 58,658 fishes (Dye and Borden 2018). Guided sport-fishing effort between 2007 and 2016 averaged 32,821 angler-days across the BBMA, of which approximately 7,059 and 1,704 angler-days were spent in the Nushagak River and Kvichak River watersheds, respectively (Dye and Borden 2018).

The majority of sport fishes harvested in the BBMA are Sockeye, Chinook, and Coho salmon, although Rainbow Trout, Dolly Varden, Arctic Char, and other species are also harvested throughout the BBMA (Table 3-17) (Dye and Borden 2018). The Nushagak and Kvichak River watersheds support several popular recreational fisheries, particularly for Sockeye and Chinook salmon (Figure 3-17), as well as Rainbow Trout. The Nushagak River watershed accounted for more than 50 percent of the annual average sport harvest (2004–2017) of Chinook Salmon in the BBMA, with an estimated harvest of 6,467 out of a total estimated harvest of 10,937 fish (Dye and Borden 2018); estimated recreational Chinook Salmon catches are much higher (Table 3-18). In the Kvichak River, recreational harvests are dominated by Sockeye Salmon, whereas recreational catches are dominated by Rainbow Trout.

Table 3-17. Estimated sport harvest by species in the Bristol Bay Sport Fish Management Area. Values are mean annual sport harvests from 2004 to 2017, and ranges observed during that same period. The years that the low and high values of each range were recorded are noted in brackets.

Fish	Mean Annual BBMA Sport Harvest	Range
Sockeye Salmon	15,876	11,925 [2005]–23,842 [2017]
Chinook Salmon	10,836	6,224 [2010]–13,821 [2007]
Coho Salmon	15,682	12,380 [2013]–20,699 [2014]
Chum Salmon	1,627	501 [2007]–2,946 [2013]
Pink Salmon	805	47 [2009]–3,138 [2004]
Rainbow Trout	1,117	323 [2013]–2,411 [2007]
Dolly Varden/Arctic Char	2,498	1,040 [2013]–6,365 [2004]
Arctic Grayling	1,179	361 [2016]–3,010 [2004]
Lake Trout	759	188 [2012]–1,370 [2011]
Northern Pike	931	216 [2016]–1,751 [2004]

Source: Dye and Borden 2018.
BBMA = Bristol Bay Sport Fish Management Area

Figure 3-17. Approximate extents of popular Chinook and Sockeye salmon recreational fisheries in the Nushagak and Kvichak River watersheds. Areas were digitized from previously published maps (Dye et al. 2006). Recreational Rainbow Trout fisheries are also distributed throughout the watersheds.

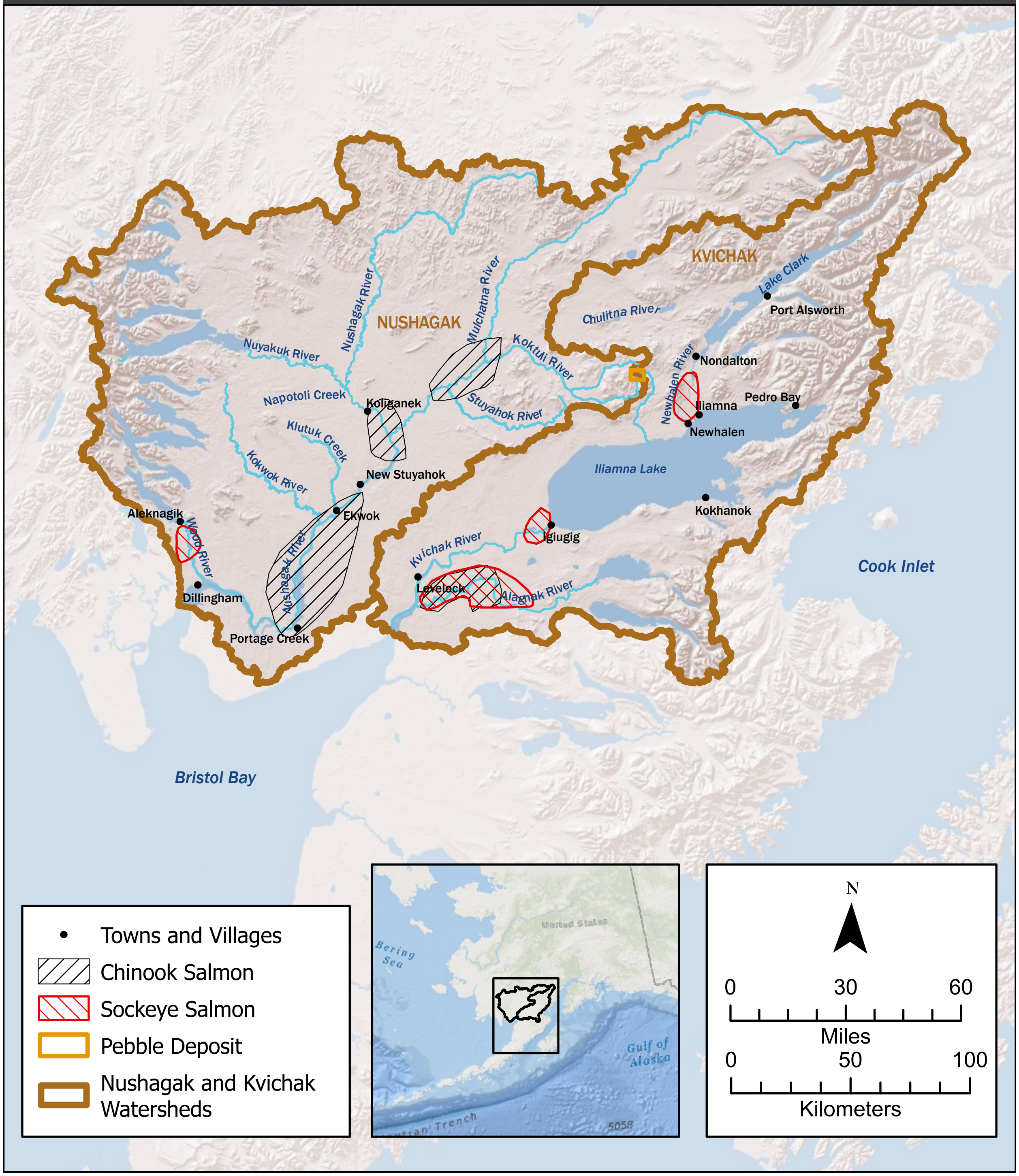


Table 3-18. Estimated annual sport harvest and catch of fishes in the Kvichak River watershed and the Nushagak, Wood, and Togiak River watersheds, 2008–2017. Estimated annual sport harvest is presented as the range between the minimum and maximum estimated annual harvest over the 2008–2017 period; estimated sport catch is shown for 2017.

Watershed	Fish	Estimated Annual Sport Harvest (Range, 2000–2010)	Estimated 2010 Sport Catch
Kvichak River	Pacific salmon [a]	7,199–14,731	56,492
	Sockeye	5,383–13,025	30,349
	Chinook	206–1,427	4,424
	Coho	342–676	9,138
	Chum	26–898	11,950
	Pink	10–625	631
	Rainbow Trout	48–996	114,431
	Dolly Varden/Arctic Char	46–605	16,239
	Arctic Grayling	84–757	18,695
	Lake Trout	124–856	2,224
	Northern Pike	11–547	1,938
	Whitefish	0–449	179
Nushagak, Wood, and Togiak River	Pacific salmon [a]	10,252–15,435	85,719
	Sockeye	1,598–5,504	12,514
	Chinook	4,514–9,283	31,631
	Coho	839–1,924	30,034
	Chum	561–2,560	9,216
	Pink	0–664	2,324
	Rainbow Trout	52–450	30,282
	Dolly Varden/Arctic Char	740–2,051	25,222
	Arctic Grayling	54–725	20,833
	Lake Trout	10–206	1,196
	Northern Pike	78–1,064	1,654
	Whitefish	0–514	602

Notes:
[a] Total for all five Pacific salmon species (Coho, Chinook, Sockeye, Chum, Pink).
Source: Romberg et al. 2021.

3.3.8 Region's Fisheries in the Global Context

The Bristol Bay region is a unique environment supporting world-class fisheries, particularly in terms of Pacific salmon populations. The region takes on even greater significance when one considers the status and condition of Pacific salmon populations throughout their native geographic distributions. These declines are discussed briefly below; for additional information on threatened and endangered salmon stocks, see Appendix A of the BBA (EPA 2014).

Although it is difficult to quantify the true number of extinct Pacific salmon populations around the North Pacific, estimates for the western United States (California, Oregon, Washington, and Idaho) range from 106 to 406 populations (Nehlsen et al. 1991, Augerot 2005, Gustafson et al. 2007). Pacific salmon are no longer found in 40 percent of their historical breeding ranges in the western United States, and populations tend to be significantly reduced or dominated by hatchery fishes where they do remain

(NRC 1996). In contrast, Bristol Bay's salmon fisheries are robust and entirely wild, with no contribution from hatchery fishes in the watershed (Section 3.1).

For example, 214 salmon and steelhead (anadromous Rainbow Trout) stocks were identified as facing risk of extinction in the western United States; 76 of those stocks were from the Columbia River basin alone (Nehlsen et al. 1991). In general, these losses have resulted from cumulative effects of habitat loss, water quality degradation, climate change, overfishing, dams, and other factors (NRC 1996, Schindler et al. 2010). Species with extended freshwater rearing periods—species such as Coho, Chinook, and Sockeye salmon—are more likely to be extinct, endangered, or threatened than species that spend less time in freshwater habitats (NRC 1996, Gustafson et al. 2007). No Pacific salmon populations from Alaska are known to have gone extinct, although many show signs of population declines.

The status of Pacific salmon throughout the United States highlights the value of the Bristol Bay watershed as a salmon sanctuary or refuge (Rahr et al. 1998, Pinsky et al. 2009). This value is likely to increase under changing climate conditions, which pose a key challenge for Pacific salmon conservation (Shanley and Albert 2014, Ebersole et al. 2020). Climate-associated changes in water temperature and streamflow, resulting changes in spawning and rearing habitats, responses of salmon populations, and the inherent uncertainties involved in predicting these relationships highlight the increasing importance of maintaining and protecting areas currently supporting diverse and robust salmon habitats and populations (Schindler et al. 2008, Anderson et al. 2015, Ebersole et al. 2020, Vynne et al. 2021).

The Bristol Bay watershed contains intact, connected habitats that extend from headwaters to ocean with minimal influence of human development. These characteristics, combined with the region's high Pacific salmon abundance and life-history diversity, make the Bristol Bay watershed a significant resource of global conservation value (Pinsky et al. 2009). Because the region's salmon resources have supported Alaska Native cultures in the region for thousands of years and continue to support one of the last intact wild salmon-based cultures in the world (EPA 2014: Appendix D, USACE 2020a: Section 3.7), the watershed also has global cultural significance.

3.4 Summary

Because of its climate, geology, hydrology, pristine environment, and other characteristics, the Bristol Bay watershed is home to abundant, diverse, high-quality aquatic habitats. These streams, rivers, wetlands, lakes, and ponds support world-class subsistence, commercial, and recreational fisheries for multiple species of Pacific salmon, as well as numerous other fish species valued as subsistence and recreational resources.

The productivity and diversity of the watershed's aquatic habitats are closely tied to the productivity and diversity of its wild fisheries, and waters of the SFK, NFK, and UTC watersheds are critical for maintaining the integrity, productivity, and sustainability of the region's salmon and non-salmon fishery resources. Aquatic habitats in the three watersheds are ideal for maintaining high levels of fish production with clean, cold water, gravel substrates, and abundant areas of groundwater exchange (upwelling and downwelling). These conditions create preferred salmon spawning habitat and provide favorable conditions for egg incubation and survival and juvenile rearing. They also provide high-quality habitat for fishes, such as Rainbow Trout, Dolly Varden, Arctic Grayling, and Northern Pike. Wetlands provide essential off-channel habitats that protect young Coho Salmon and other resident and anadromous fish species, as well as provide spawning areas for Northern Pike. All of these species move throughout the region's freshwater habitats during their life cycles, and all are fished—commercially, for subsistence use, and recreationally—in downstream waters. Thus, the intact headwater-to-larger river systems found in the SFK, NFK, and UTC watersheds, with their associated wetlands, lakes, and ponds, help sustain the overall productivity of these fishery areas.

Not only do the aquatic habitats of the SFK, NFK, and UTC watersheds directly provide habitat for salmon and other fishes, they also provide critical support for downstream habitats. By contributing water, organic matter, and macroinvertebrates to downstream systems, these headwater areas help maintain downstream habitats and fuel their fish productivity. Together, these functions—direct provision of high-quality habitat and indirect provision of other resources to downstream habitats—help support the valuable fisheries of the Bristol Bay watershed.

This support is particularly important in terms of Coho, Chinook, and Sockeye salmon fisheries. Chinook Salmon are the rarest of the North American Pacific salmon species and are a critical subsistence resource, particularly along the Nushagak River. The SFK, NFK, and UTC watersheds are known to support small, discrete populations of Sockeye Salmon that are genetically programmed to return to specific, localized reaches or habitats to spawn. The current state of understanding surrounding Pacific salmon genetic baselines in the region indicates that the watersheds also support small, discrete populations of Coho Salmon and Chinook Salmon. This portfolio of multiple small populations, which exists as a result of the region's habitat complexity, is essential for maintaining the genetic diversity and, thus, the stability and productivity, of the region's overall wild salmon stocks.

SECTION 4. BASIS FOR PROPOSED DETERMINATION

This section synthesizes the information EPA Region 10 considered in its evaluation of the 2020 Mine Plan to determine if the proposed discharge of dredged or fill material could result in unacceptable adverse effects on anadromous fishery areas (including spawning and breeding areas).

Section 4.1 presents a brief review of the Section 404(c) Standards. Section 4.2 provides the unacceptability findings that support the proposed prohibition and proposed restriction described in Section 5. Section 4.3 provides an overview of EPA Region 10's evaluation of the effects of discharges associated with the 2020 Mine Plan under the relevant portions of the CWA Section 404(b)(1) Guidelines (40 CFR Part 230).

4.1 Section 404(c) Standards

The purpose of the CWA is to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (33 U.S.C. 1251(a)). The CWA sets several goals, including attainment and preservation of "water quality which provides for the protection and propagation of fish, shellfish and wildlife" (33 U.S.C. 1251(a)(2)).

To this end, CWA Section 404(c) specifically authorizes EPA to exercise its discretion to act "whenever" it determines that the discharge of dredged or fill material will have an unacceptable adverse effect on specific aquatic resources. Section 404(c) provides the following:

> The Administrator is authorized to prohibit the specification (including the withdrawal of specification) of any defined area as a disposal site, and he is authorized to deny or restrict the use of any defined area for specification (including the withdrawal of specification) as a disposal site, whenever he determines, after notice and opportunity for public hearings, **that the discharge of such materials into such area will have an unacceptable adverse effect on municipal water supplies, shellfish beds and fishery areas (including spawning and breeding areas), wildlife, or recreational areas**. Before making such determination, the Administrator shall consult with the Secretary. The Administrator shall set forth in writing and make public his findings and his reasons for making any determination under this subsection. [emphasis added]

Importantly, Section 404(c) specifically directs EPA to consider adverse effects from the discharge of dredged or fill material to fishery areas, including spawning and breeding areas. As a scientific matter, evaluating adverse effects to fishery areas involves consideration of numerous factors, including adverse effects that discharges of dredged or fill material can have on aquatic areas where fish are present and that provide ecosystem functions and values that support fishery areas. Therefore, this section includes discussion of these considerations.

Section 404(c) does not define the term "unacceptable adverse effect." EPA's regulations at 40 CFR 231.2(e) define "unacceptable adverse effect" as follows:

> Impact on an aquatic or wetland ecosystem which is likely to result in significant degradation of municipal water supplies or significant loss of or damage to fisheries, shellfishing, or wildlife habitat or recreation areas. In evaluating the unacceptability of such impacts, consideration should be given to the relevant portions of the Section 404(b)(1) Guidelines (40 CFR Part 230).

The preamble to EPA's final rule promulgating 40 CFR Part 231 further explained that "[t]he term 'unacceptable' in EPA's view refers to the significance of the adverse effect" (44 FR 58076, 58078). EPA also discussed that, for example, an unacceptable adverse effect "is a large impact" and "one that the aquatic and wetland ecosystem cannot afford" (44 FR 58078).

EPA's determination of an "unacceptable adverse effect" necessarily involves a case-by-case determination based on many factors, including the unique characteristics of the aquatic resource that would be affected by discharges of dredged or fill material. EPA's preamble to the Section 404(c) regulations explained that "[b]ecause 404(c) determinations are by their nature based on predictions of future impacts, what is required is a reasonable likelihood that unacceptable adverse effects will occur – not absolute certainty but more than mere guesswork" (44 FR 58078). As discussed in Section 3, the Bristol Bay watershed is an outstanding global resource, providing pristine, intact, connected aquatic habitats from headwaters to ocean. These aquatic habitats provide extensive spawning and rearing areas for and support genetically diverse populations of wild salmon. Like the larger Bristol Bay watershed, the SFK, NFK, and UTC watersheds also contain pristine, intact aquatic habitats that provide extensive spawning and rearing areas for and support genetically diverse populations of wild salmon.

EPA Region 10 has prepared this proposed determination because it has reason to believe that unacceptable adverse effects on fishery areas could result from the discharge of dredged or fill material into waters of the United States for the construction and routine operation of the 2020 Mine Plan. These effects are described in detail in Section 4.2.

4.2 Effects on Fishery Areas from Construction and Routine Operation of the 2020 Mine Plan

Development of the 2020 Mine Plan would require the discharge of dredged or fill material into waters of the United States at the mine site (PLP 2020b, USACE 2020a, USACE 2020b). This section considers both the direct and secondary effects of such discharges on fishery areas. Direct effects are impacts on aquatic resources associated with the discharge (actual placement) of dredged or fill material into waters of the United States. Direct adverse effects of the 2020 Mine Plan would include elimination of streams and other aquatic resources within the footprints of the mine site components (e.g., TSFs, WMPs, stockpiles, and the open pit). Secondary effects are associated with the discharge of dredged or fill material, but do not result from actual placement of this material (40 CFR 230.11(h)(1)). Secondary effects "are an important consideration in evaluating the acceptability of a discharge site" under the Section 404(b)(1) Guidelines (45 FR 85343).[43]

Direct and secondary (indirect) effects evaluated in the FEIS include the following (USACE 2020a: Section 4.22.3):

- Direct effects from:
  - Clearing and removal of vegetation
  - Excavation or removal of soil and vegetation
  - Placement of fill materials
  - Dredging and discharges of dredged materials
  - Alteration and removal of stream channels
- Secondary effects from:
  - Fragmentation of aquatic resources
  - Fugitive dust
  - Downstream habitat degradation
  - Dewatering

This proposed determination identifies key impacts of discharges of dredged or fill material that could have unacceptable adverse effects on specific aquatic resources. The direct and secondary effects of the discharge of dredged or fill material for the construction and routine operation of the 2020 Mine Plan would result in both the permanent loss of certain aquatic resources and the degradation of additional aquatic resources. The loss and additional degradation of aquatic resources would adversely affect anadromous fishery areas. Section 4.2 considers the following impacts from the discharge of dredged or fill material for the construction and routine operation of the 2020 Mine Plan:

- The loss of approximately 8.5 miles (13.7 km) of documented anadromous fish streams[44] (Section 4.2.1).
- The loss of approximately 91.2 miles (146.8 km) of additional streams that support anadromous fish streams (Section 4.2.2).
- The loss of approximately 2,113 acres (8.6 km^2) of wetlands and other waters that support anadromous fish streams (Section 4.2.3).
- Adverse impacts on at least 29 additional miles (46.7 km) of documented anadromous fish streams resulting from greater than 20 percent changes in average monthly streamflow (Section 4.2.4).

[43] Depending on its severity and permanence, a secondary effect of the discharge of dredged or fill material can result in the permanent loss of aquatic resources.

[44] For the purposes of this proposed determination, anadromous fishery areas include anadromous fish streams.

Sections 4.2.1 through 4.2.4 describe the basis for EPA Region 10's determination that each of these impacts could, independently, result in unacceptable adverse effects on anadromous fishery areas (including spawning and breeding areas).[45]

BOX 4-1. KEY DEFINITIONS

The following definitions are provided to clarify key terms in this proposed determination.

Anadromous fishes are those that hatch in freshwater habitats, migrate to sea for a period of relatively rapid growth, and then return to freshwater habitats to spawn. For the purposes of this proposed determination, "anadromous fishes" refers to Coho or Silver salmon (*Oncorhynchus kisutch*), Chinook or King salmon (*O. tshawytscha*), Sockeye or Red salmon (*O. nerka*), Chum or Dog salmon (*O. keta*), and Pink or Humpback salmon (*O. gorbuscha*). For these five species of Pacific salmon, the majority of adults return to their natal freshwater habitats to spawn. This homing behavior fosters reproductive isolation, thereby enabling populations to adapt to the particular environmental conditions of their natal habitats (Section 3.3.3). Each of these species is semelparous: adults die after spawning a single time, thereby depositing the nutrients incorporated in their body mass into their spawning and rearing habitats (Section 3.3.4).

Documented anadromous fish occurrence means any use by anadromous Coho, Chinook, Sockeye, Chum, or Pink salmon. As a general matter, EPA has relied on the Catalog of Waters Important for the Spawning, Rearing or Migration of Anadromous Fishes (Giefer and Blossom 2021) and its associated Atlas to describe use by the five salmon species. The catalog and atlas identify the streams, rivers, and lakes specified by the Alaska Department of Fish and Game as being important for the spawning, rearing, or migration of anadromous fish pursuant to AS 16.05.871.

Streams that support anadromous fish streams refers to streams that do not currently have documented anadromous fish occurrence. However, such streams support downstream anadromous fish streams. Although such streams may also be used by anadromous fish, the potential for such use is not a basis for this proposed determination (see also Section 4.2.2 and Appendix B). These aquatic resources are identified as *stream habitat* in the FEIS.

4.2.1 Adverse Effects of Loss of Anadromous Fish Streams

EPA Region 10 believes that the discharge of dredged or fill material for the construction and routine operation of the 2020 Mine Plan, resulting in the loss of approximately 8.5 miles (13.7 km) of anadromous fish streams, could have unacceptable adverse effects on anadromous fishery areas in the NFK watershed. As discussed in Section 4.2.1.1, this conclusion is based on the permanent loss of anadromous fish streams[46] and the permanent loss of ecological subsidies these anadromous fish streams provide to downstream waters.

4.2.1.1 Anadromous Fish Streams That Would Be Permanently Lost at the Mine Site

The streams at the mine site for the 2020 Mine Plan provide habitat for anadromous fishes (Figure 4-1). Discharges of dredged or fill material associated with the 2020 Mine Plan would result in the permanent loss of approximately 8.5 miles (13.7 km) of streams with documented anadromous fish occurrence, specifically Coho and Chinook salmon (Table 4-1, Figure 4-2) (PLP 2020b, USACE 2020a: Section 4.24,

[45] This proposed determination evaluates the effects of the discharge of dredged or fill material for the 2020 Mine Plan and similar effects anywhere within the SFK, NFK, and UTC watersheds.

[46] These permanent losses are the result of streams filled or otherwise eliminated for the construction of various mine components and from streams that would no longer be accessible to fish due to mine site infrastructure.

Giefer and Blossom 2021). The loss of all 8.5 miles (13.7 km) would be confined to the NFK watershed, specifically in Tributary NFK 1.190, Tributary NFK 1.200, and their sub-tributaries (Figure 4-2). The loss of 8.5 miles (13.7 km) of anadromous waters represents approximately 13 percent of the anadromous waters in the NFK watershed (USACE 2020a: Section 4.24, Giefer and Blossom 2021).

Table 4-1. Length of anadromous fish streams permanently lost in tributaries to the North Fork Koktuli River associated with the 2020 Mine Plan footprint.

Tributary	AWC Code [a]	Length of Anadromous Habitat (miles) [b]
NFK 1.190	325-30-10100-2202-3080-4083-5215	4.2
NFK 1.190.10	325-30-10100-2202-3080-4083-5215-6001	1.7
NFK 1.190.10.03	325-30-10100-2202-3080-4083-5215-6001-7012	0.05
NFK 1.190.30	325-30-10100-2202-3080-4083-5215-6006	0.5
NFK 1.190.40	325-30-10100-2202-3080-4083-5215-6007	0.9
NFK 1.200	325-30-10100-2202-3080-4083-5217	1.1
TOTAL		8.5

Sources:
[a] = Giefer and Blossom 2021.
[b] = USACE 2022.

The discharge of dredged or fill material from the 2020 Mine Plan would permanently eliminate at least 7.1 miles (11.4 km) of Coho Salmon habitat and 3.6 miles (5.9 km) of Chinook Salmon habitat (Table 4-2) (Giefer and Blossom 2021).[47] Most of these losses would occur where the bulk TSF would be built (Figure 4-1) (USACE 2020a: Section 4.24). Construction of the bulk TSF alone would permanently eliminate 5.6 miles (9.1 km) of anadromous fish streams in Tributaries NFK 1.190, NFK 1.190.30, and NFK 1.190.40 (USACE 2022). These three anadromous fish streams provide at least 4.8 miles (7.7 km) of rearing habitat and 3.7 miles (6.0 km) of spawning habitat for Coho Salmon and at least 2.1 miles (3.4 km) of rearing habitat for Chinook Salmon (Giefer and Blossom 2021). Construction of other mine site components, including the main WMP (Figure 4-1), would result in the remaining documented anadromous fish stream losses in Tributaries NFK 1.190.10, NFK 1.190.20.03, and NFK 1.200 (Figure 4-2).

Table 4-2. Coho and Chinook salmon stream habitat permanently lost in the North Fork Koktuli River watershed associated with the 2020 Mine Plan footprint. From Giefer and Blossom (2021).

Species	Length of Anadromous Habitat (miles)			
	Rearing	Spawning	Present	TOTAL [a]
Coho Salmon	7.1	3.7	-	7.1
Chinook Salmon	3.0 [b]	-	0.6	3.6 [b]

Notes:
[a] Coho and Chinook salmon habitat overlap, and rearing and spawning habitat overlap, so individual values cannot be added together. The totals represent the total extent of habitat to be lost for each species of Coho and Chinook salmon.
[b] These values include 0.76 mile (1.2 km) of Chinook Salmon rearing habitat associated with Tributary NFK 1.190 that currently is erroneously missing from Anadromous Waters Catalog; Joe Giefer at ADF&G confirmed that it would be included in the next update of Anadromous Waters Catalog (Giefer pers. comm.).

[47] Coho Salmon are documented to occur in 7.1 miles (11.4 km) of the 8.5 miles (13.7 km) of lost anadromous fish streams and Chinook Salmon are documented to occur in 3.6 miles (5.9 km) of the 8.5 miles (13.7 km) of lost anadromous fish streams (Table 4.2).

Figure 4-1. Mine site area fish distribution. Figure 4.24-1 from the FEIS (USACE 2020a: Section 4.24).

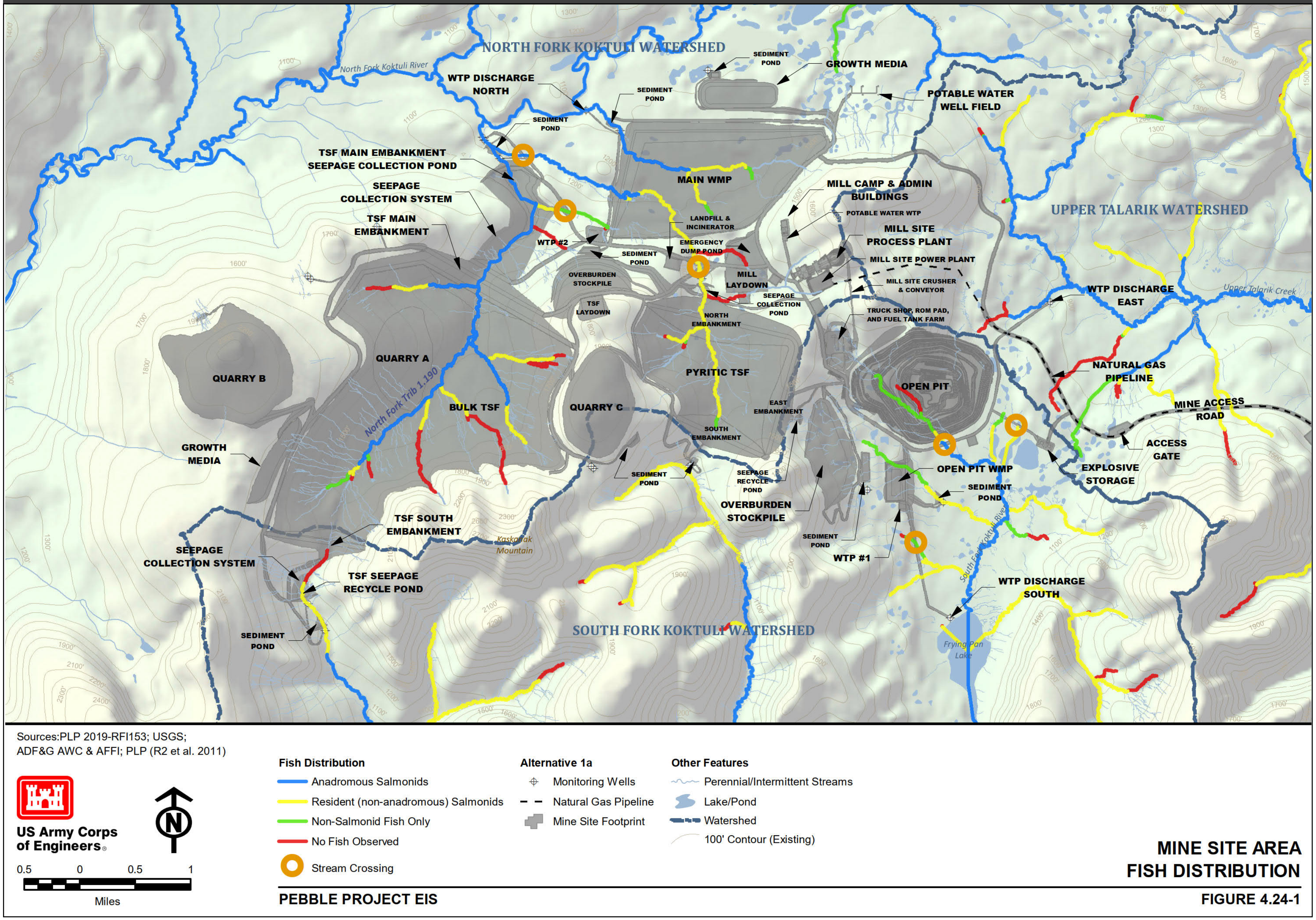
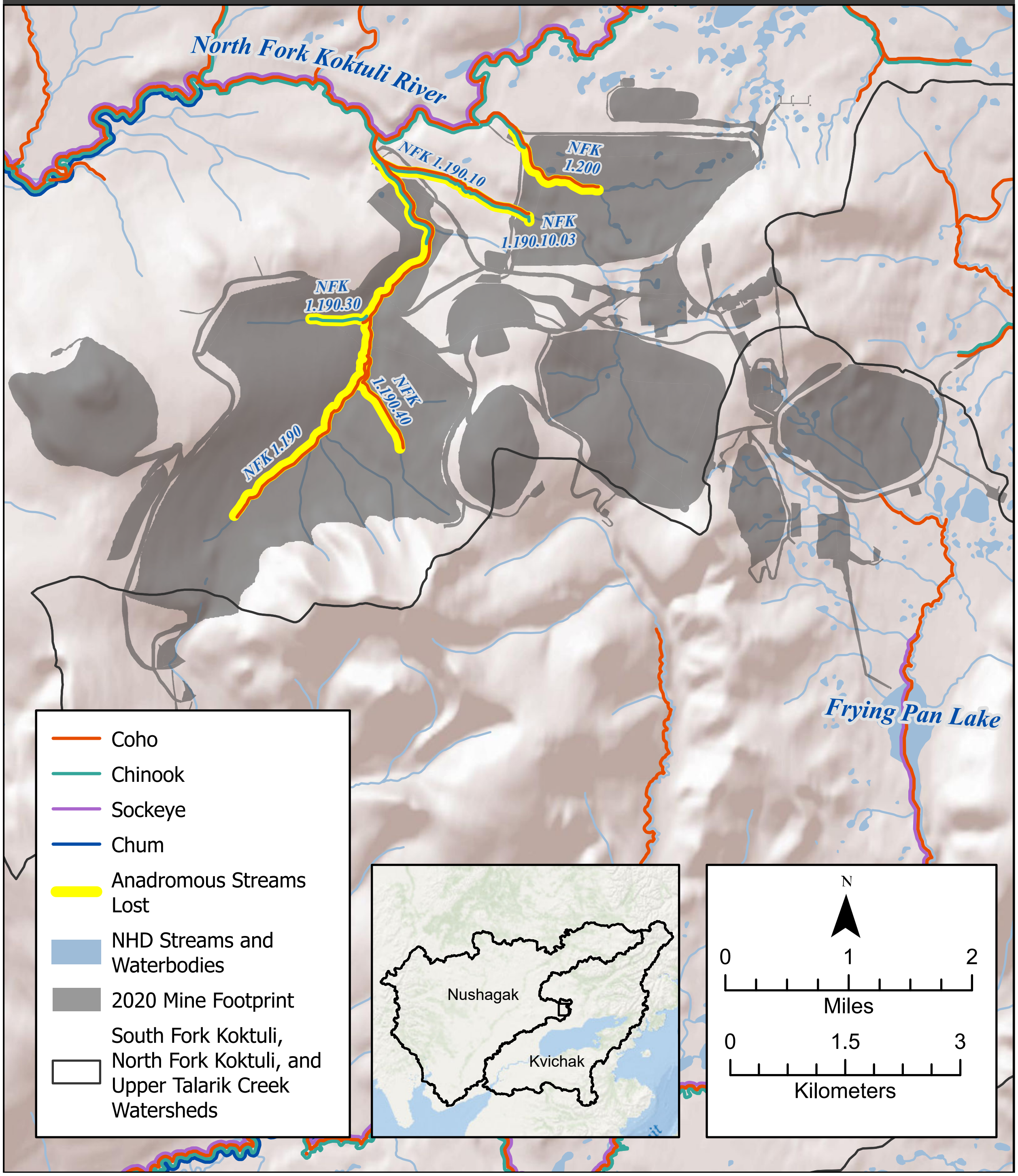


Figure 4-2. Streams, rivers, and lakes with documented salmon use overlain with the Pebble 2020 Mine Plan. Anadromous streams lost are the streams identified as lost in the FEIS and are listed in Table 4-1 (USACE 2022). Species distributions are based on the Anadromous Waters Catalog (Giefer and Blossom 2021).



Tributary NFK 1.190 and its sub-tributaries have been documented to provide Coho Salmon spawning habitat, and rearing juvenile salmon have been observed in Tributaries NFK 1.190 and NFK 1.200 (USACE 2020a: Section 4.24). Rearing juvenile Chinook Salmon have been documented to occur in Tributary NFK 1.200 (USACE 2020a: Section 4.24). Chinook Salmon rear in the third-order beaver-modified stream that the bulk TSF would eliminate (i.e., Tributary NFK 1.190), along with 0.5 mile (0.8 km) of Tributary NFK 1.190.30 (Figure 4-2) (Giefer and Blossom 2021).[48]

4.2.1.2 Adverse Effects from Permanent Losses of Anadromous Fish Streams at the Mine Site

The 8.5 miles (13.7 km) of permanent anadromous stream losses would result in fish displacement, injury, and mortality. In addition to the permanent removal of streamflow and impacts on fish migration, "fisheries, invertebrate, and riparian habitat and productivity would be permanently removed" from lost streams (USACE 2020a: Pages 4.24-3 and 4.24-4).

The permanent loss of 8.5 miles (13.7 km) of anadromous fish streams from a single project is unprecedented in the context of the CWA Section 404 regulatory program in Alaska. These streams would be completely eliminated and, thus, would permanently lose the ability to support salmon in these waters. Coho Salmon would lose at least 7.1 miles (11.4 km) of habitat as a direct result of discharges of dredged or fill material associated with the 2020 Mine Plan, which amounts to more than 11 percent of documented Coho Salmon habitat in the NFK watershed (Table 3-6). Habitat losses for Chinook Salmon would be 8.7 percent of documented habitat in the NFK watershed. As discussed below, the loss of 8.5 miles (13.7 km) of anadromous fish streams could result in long-term adverse effects on salmon populations in the NFK watershed.

The anadromous fish streams that the discharge of dredged or fill material associated with the 2020 Mine Plan would permanently eliminate are ecologically valuable, particularly for juvenile salmon (Section 3.2.4). Tributary NFK 1.190 is interconnected with ponds and seasonally to permanently inundated wetlands resulting from beaver activity (USFWS 2021).[49] These features provide excellent rearing habitat and important overwintering and flow velocity refugia for salmonids (Section 3.2.4) (Nickelson et al. 1992, Cunjak 1996, Collen and Gibson 2001, Lang et al. 2006). The permanent loss of anadromous fish streams resulting from the discharges of dredged or fill material associated with the 2020 Mine Plan would also result in the loss of salmon spawning habitat, which would, in turn, result in the loss of marine-derived nutrients those fish would have contributed upon death. Given the naturally low nutrient concentrations in these streams, these inputs of marine-derived nutrients may be especially important in supporting biological production and, thus, food for juvenile salmonids in these and downstream habitats (Section 3.3.4). These streams also support biological production via inputs of leaf litter from deciduous shrubs and grasses in riparian areas (Meyer et al. 2007, Dekar et al. 2012),

[48] Fish surveys have documented juvenile Coho Salmon in a short (260-foot) reach at the downstream end of this tributary, NFK 1.190.30 (Giefer and Blossom 2021).

[49] Connection to such floodplain wetland and pond habitats can greatly enhance the carrying capacity and productive potential of anadromous fish streams (Section 3).

which help fuel the production of macroinvertebrates, a key food for salmonids (Table 3-3). Thus, the anadromous fish streams that the 2020 Mine Plan would eliminate, as well as similar habitats in the SFK, NFK, and UTC watersheds, play an important role in the life cycle of salmon.

These anadromous fish stream losses alone would be significant, but the effects of these losses would be compounded by the fact that such losses would affect Coho and Chinook salmon populations that are uniquely adapted to the spatial and temporal conditions of their natal streams (i.e., stream of birth, see Section 3.3.1). Adaptation to local environmental conditions results in discrete, genetically distinct salmonid populations. This biocomplexity—operating across a continuum of integrated, nested spatial and temporal scales—depends on the abundance and diversity of aquatic habitats in the area and acts to stabilize overall salmon production and fishery resources (Section 3.3.3) (Schindler et al. 2010, Schindler et al. 2018, Brennan et al. 2019). As discussed below, the substantial spatial and temporal extent of anadromous fish stream losses resulting from the discharge of dredged or fill material associated with the 2020 Mine Plan suggest that these losses would reduce the overall capacity and productivity of Coho and Chinook salmon in the entire NFK watershed.

Pacific salmon exhibit high fidelity to their natal spawning and rearing environments resulting in genetic variation among discrete populations (Quinn 2005). The existence of discrete, genetically distinct salmon populations has been well-documented in the Bristol Bay watershed (Olsen et al. 2003, Ramstad et al. 2010, Quinn et al. 2012, Dann et al. 2012, Shedd et al. 2016, Brennan et al. 2019, Raborn and Link 2022). Both the Koktuli River (including the SFK and NFK) and UTC are known to support genetically distinct populations of Sockeye Salmon (Dann et al. 2012, Shedd et al. 2016, Dann et al. 2018). Research has shown that these distinct populations can occur at very fine geographic scales (Section 3.3.3). For example, Sockeye Salmon that use spring-fed ponds and streams as close as approximately 0.6 mile (1 km) apart exhibit differences in traits (e.g., spawn timing, spawn site fidelity, and productivity), which suggests they may comprise discrete populations (Rand et al. 2007, Ramstad et al. 2010, Quinn et al. 2012).

Research on the presence of genetically distinct populations of Coho and Chinook salmon in Alaska is ongoing, and existing evidence suggests that local adaptation and fine-scale population structure likely exist for these species as well (Olsen et al. 2003, Sethi and Tanner 2014, Clark et al. 2015).[50] Similar patterns of genetic variation among species (across a landscape) emphasize the vital importance that landscape heterogeneity (i.e., habitat complexity across the intact ecosystem) plays in determining genetic structure (Ackerman et al. 2013).

Coho and Chinook salmon are the two rarest of North America's five species of Pacific salmon (Healey 1991, Woody 2018) and are particularly vulnerable to losses of small, discrete populations. As a result, these species may be especially vulnerable to habitat losses resulting from the 2020 Mine Plan. Coho and Chinook salmon have the greatest number of population extinctions among the five species of Pacific

[50] Advances in genomics and other techniques are allowing detection of genetic structure at increasingly fine scales; as methods to evaluate these genetic differences improve, researchers are uncovering more fine-scaled population structure in many salmon species (Meek et al. 2020).

salmon (Nehlsen et al. 1991, Augerot 2005). Many of the patterns of population extinction relate to longer periods of their life history spent rearing in freshwater, which makes them more vulnerable to freshwater habitat loss and degradation. For example, Chinook Salmon populations that rear for 1 or more years in freshwater—the dominant type in the Bristol Bay watershed (Healey 1991)—have a higher rate of extinction than populations that migrate to sea within their first year of life (Gustafson et al. 2007).

Alaska Coho Salmon populations are generally small, isolated, and likely exhibit local adaptation to different spawning and freshwater rearing habitats (Olsen et al. 2003). They occupy a wide array of freshwater habitat types, with many populations occupying small first- and second-order headwater streams with limited spawning and juvenile rearing habitat (Sandercock 1991, McCracken 2021). Small genetically diverse populations of Coho Salmon represent reproductively isolated populations innately adapted to their spawning and rearing habitats (Dittman and Quinn 1996, Olsen 2003, Peterson et al. 2014, Bett and Hinch 2016, McCracken 2021). The loss of these habitats would threaten the long-term fitness of these locally adapted populations (Olsen 2003, Mobley et al. 2019). ADF&G has developed a genetic baseline for Coho Salmon for Cook Inlet, but genetic baselines have not been completed elsewhere in Alaska due to a lack of representative samples. In the Cook Inlet watersheds, the most genetically divergent populations are generally those farthest upstream and those from the most southern portion of Cook Inlet (Barclay and Habicht 2019).

Olsen et al. (2003) summarize the implications of Coho Salmon population structuring at fine geographic scales for conservation of the species:

> Fishery management and conservation actions affecting coho salmon in Alaska must recognize that the genetic population structure of coho salmon occurs on a fine geographic scale. Activities or conditions that cause declines in population abundance are more likely to have strong negative impacts for coho than for species in which genetic variation is distributed over a broader geographic scale (e.g., chum salmon). Coho salmon are probably more susceptible to extirpation, less likely to be augmented or "rescued" by other populations through straying (gene flow), **and the loss of populations means loss of significant amounts of overall genetic variability. These risks underscore the importance of single populations to the long term viability of coho salmon in Alaska and justify managing and conserving coho salmon at a fine geographic scale**. (Page 568) [emphasis added]

Chinook Salmon populations also tend to be relatively small (Healey 1991) and exhibit a diversity of life history traits (e.g., variations in size and age at migration, duration of freshwater and estuarine residency, time of ocean entry) (Lindley et al. 2009). Chinook Salmon populations in the Togiak River exhibit differences in spawning habitats (mainstem versus tributary) and migration timing, which translate to a clear stock structure (Sethi and Tanner 2014, Clark et al. 2015). Patterns of genetic differentiation between upstream and downstream populations along the same river network have also been found for other salmonids (Olsen et al. 2011, Ackerman et al. 2013, Barclay and Habicht 2019, Miettinen et al. 2021). Chinook Salmon populations in western Alaska similarly show fine-scale population differences across the four major regions (Norton Sound, the Yukon River, the Kuskokwim River, and Bristol Bay). This finding supports the contention that discrete Chinook Salmon populations likely exist in this region, which includes the Koktuli River (Larson et al. 2014, McKinney et al. 2020). Brennan et al. (2019) provide further support for this contention, demonstrating that the relative productivity of different portions of the Nushagak River varies over even relatively short (1- to 4-year) time frames for both Chinook and Sockeye salmon.

Because Coho and Chinook salmon spend longer periods of time rearing in the freshwater streams that would be permanently eliminated by the discharge of dredged or fill material associated with the 2020 Mine Plan, these species are more susceptible to losses of what are likely small, discrete populations. The importance of maintaining this diversity among populations (e.g., in terms of migration timing, other life history traits, and genetic composition) for long-term population persistence and sustainability has been well-documented (Moore et al. 2014, Schindler et al. 2010, Brennan et al. 2019, Davis and Schindler 2021).

Thus, the permanent loss of 8.5 miles (13.7 km) of anadromous fish streams would reduce both habitat complexity and biocomplexity in the NFK watershed, thereby contributing to the unacceptable adverse effects of the loss of anadromous fish streams. In addition, this biocomplexity at relatively localized geographic scales contributes to the resilience and persistence of downstream populations. Biocomplexity, operating across a continuum of nested spatial and temporal scales, acts to buffer salmon populations from sudden and extreme changes in abundance, thereby maintaining overall salmon productivity (Section 3.3.3). Brennan et al. (2019: Page 785) underscore the important role that streams and other aquatic habitats across the entire Nushagak River watershed, including those that would be adversely affected by the 2020 Mine Plan, play in stabilizing the Nushagak River's productive Sockeye and Chinook salmon fisheries, concluding that "[u]ltimately, entire landscapes are involved in stabilizing biological production"

4.2.1.3 Adverse Effects from Permanent Losses of Ecological Subsidies to Anadromous Fish Streams Downstream of the Mine Site

The permanent destruction of 8.5 miles of anadromous fish streams would also adversely affect downstream habitat for salmon. The following downstream secondary effects would result from the loss of these anadromous fish streams: reduced primary production, reduced nutrient cycling, reduced or lost gravel recruitment, reduced terrestrial inputs, and altered water chemistry (USACE 2020a: Section 4.24). These impacts "would be certain to occur if the project is permitted and constructed" (USACE 2020a: Page 4.24-9).

Coho, Chinook, and Sockeye salmon spawn and Coho and Chinook salmon rear in stream reaches immediately downstream of the 8.5 miles (13.7 km) of anadromous fish streams that would be permanently lost under the 2020 Mine Plan (Figures 3-5 through 3-7). These downstream spawning and rearing areas would be deprived of the ecological subsidies provided by the 8.5 miles (13.7 km) of anadromous fish streams that would be destroyed.

Because of their crucial influence on downstream water flow, chemistry, and biota, impacts on headwaters reverberate throughout entire watersheds (Freeman et al. 2007, Meyer et al. 2007, Colvin et al. 2019, Koenig et al. 2019, French et al. 2020). As described in Section 3.2.4, headwater streams such as the 8.5 miles (13.7 km) of anadromous fish streams that would be permanently lost are important sources of water, nutrients, organic material, macroinvertebrates, and algae for habitats lower in the watersheds, and thereby provide important year-round subsidies for juvenile salmonids in those lower watershed habitats (Figures 4-3 and 4-4) (Vannote et al. 1980, Wipfli and Gregovich 2002, Meyer et al. 2007, Wipfli et al. 2007, Colvin et al. 2019). For example, Alexander et al. (2007) found that perennial headwaters have a significant influence on downstream water quality and quantity, contributing roughly 55 percent of mean annual water volume and 40 percent of nitrogen flux in fourth and higher-order streams and rivers. Where they provide salmon spawning areas, the anadromous fish streams that would be permanently lost are also a source of marine-derived nutrients for downstream waters (Section 3.3.4). Thus, elimination of these spawning areas would reduce the downstream transport of these marine-derived energy subsidies.

Permanent loss of approximately 8.5 miles (13.7 km) of anadromous fish streams due to discharges of dredged or fill material associated with the 2020 Mine Plan would also fundamentally alter surface water and groundwater hydrology and, in turn, the flow regimes of receiving—or formerly receiving—streams. Such alterations would reduce the extent and frequency of stream connectivity to off-channel habitats, as well as reduce groundwater inputs and their modifying influence on the thermal regimes of downstream habitats, including to spawning, rearing and overwintering areas (Section 4.2.4). Lost streams also would no longer support or export macroinvertebrates, which are a critical food source for developing alevins, juvenile salmon, and all life stages of other salmonids.

This degradation of downstream salmon habitats in the NFK watershed and the resulting impacts on salmon populations that rely on those habitats would erode both the habitat complexity and biocomplexity that help buffer these populations from sudden and extreme changes in abundance and ultimately maintains their productivity (Section 4.2.1.2).

4.2.1.4 Impacts on Other Fish Species

Although this proposed determination is based solely on adverse effects on anadromous fishery areas, EPA Region 10 notes that the 8.5 miles (13.7 km) of anadromous fish streams that would be lost under the 2020 Mine Plan also provide habitat for non-anadromous fish species. The assemblage of non-anadromous fishes found in and supported by these anadromous fish streams is an important component of these habitats and further underscores the biological integrity and ecological value of these pristine, intact headwater networks.

Based on currently available fish survey data (ADF&G 2022a), the anadromous fish streams that would be permanently eliminated support three non-anadromous salmonid species (Rainbow Trout, Dolly Varden, and Arctic Grayling) and one other resident fish species (Slimy Sculpin) (Figures 4-4 through 4-7). Rainbow Trout, Dolly Varden, and Arctic Grayling are targets of downstream subsistence and recreational fisheries. Slimy Sculpin support those fisheries as forage fish (Section 3.3.1). The three non-anadromous salmonid species may migrate substantial distances (120 miles [200 km] to 200 miles [320 km]) within their freshwater habitats (Section 3.3.1), suggesting that individuals move between headwaters and downstream areas. Most of the individuals observed in fish surveys in the 2020 Mine Plan footprint area were juvenile or sub-adults (ADF&G 2022a), further supporting that fish rearing in headwater tributaries may contribute to downstream harvests.

Figure 4-3. Streams, rivers, and lakes with documented salmon use in the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek watersheds, downstream of the Pebble 2020 Mine Plan. Species distributions are based on the Anadromous Waters Catalog (Giefer and Blossom 2021).

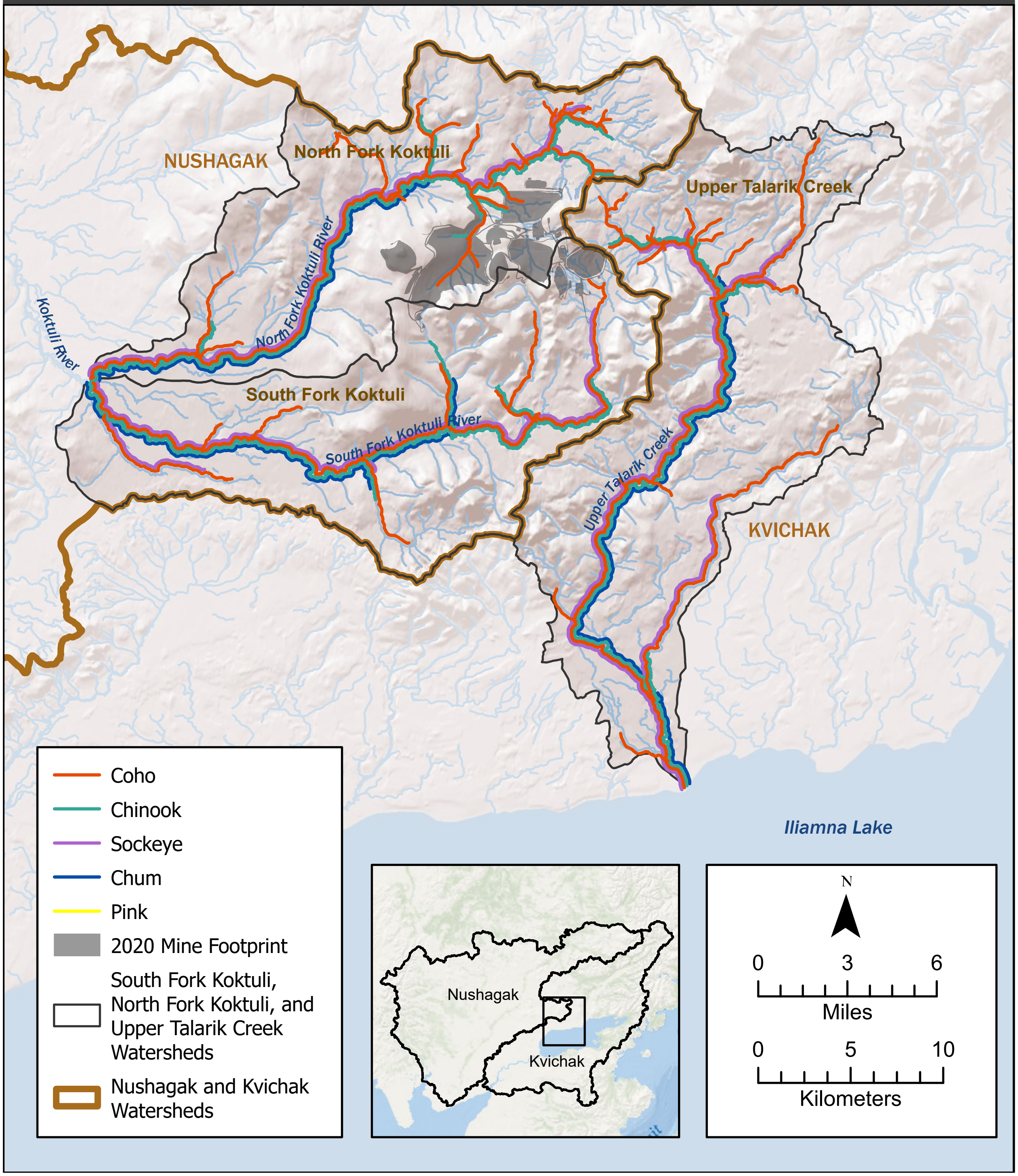


Figure 4-4. Reported occurrence of Arctic Grayling, Rainbow Trout, and Dolly Varden in the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek watersheds, downstream of the Pebble 2020 Mine Plan. Species distributions are based on the Alaska Freshwater Fish Inventory (ADF&G 2022a).

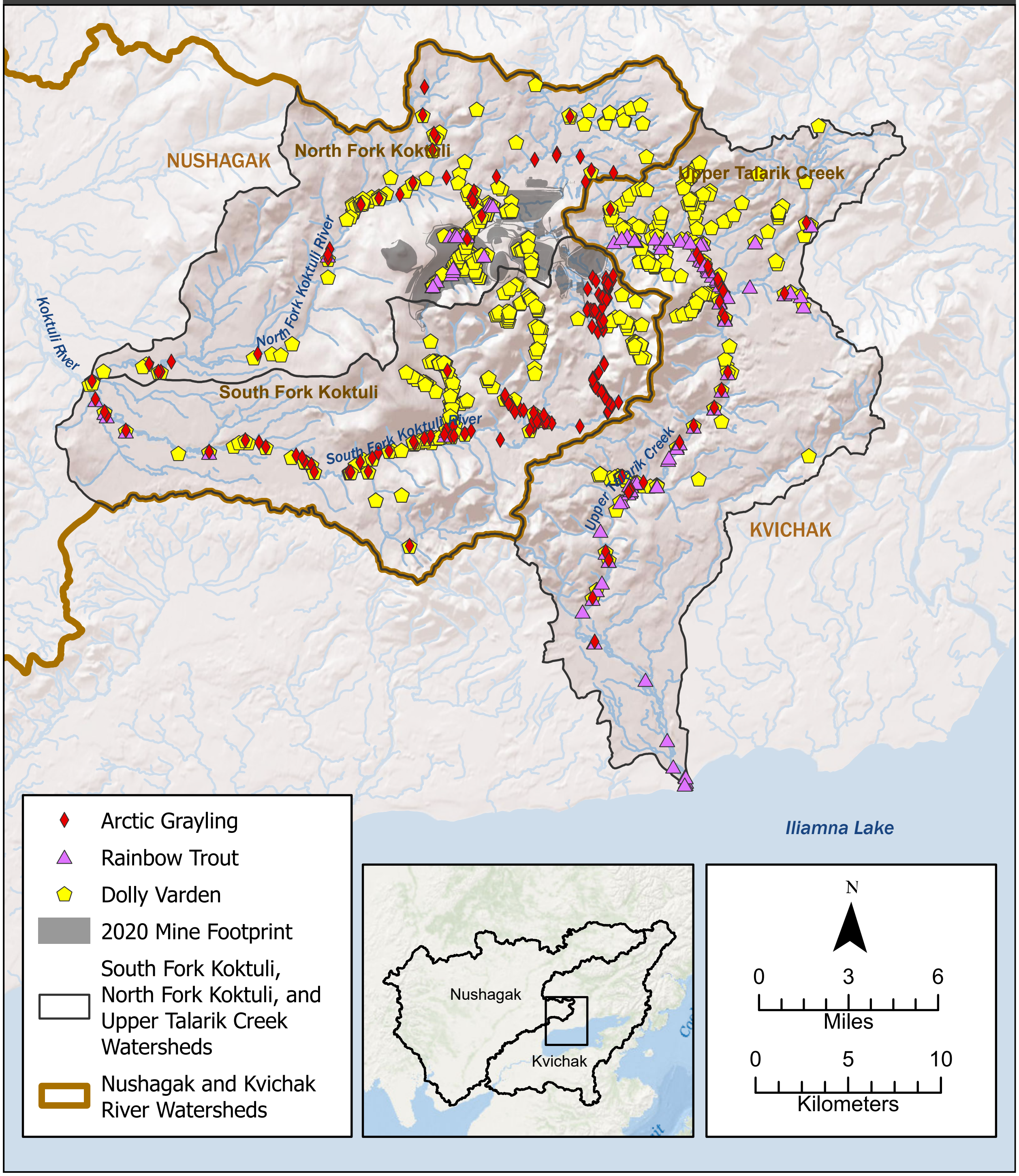


Figure 4-5. Reported occurrence of other resident fish species in the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek watersheds, downstream of the Pebble 2020 Mine Plan. Species distributions are based on the Alaska Freshwater Fish Inventory (ADF&G 2022a).

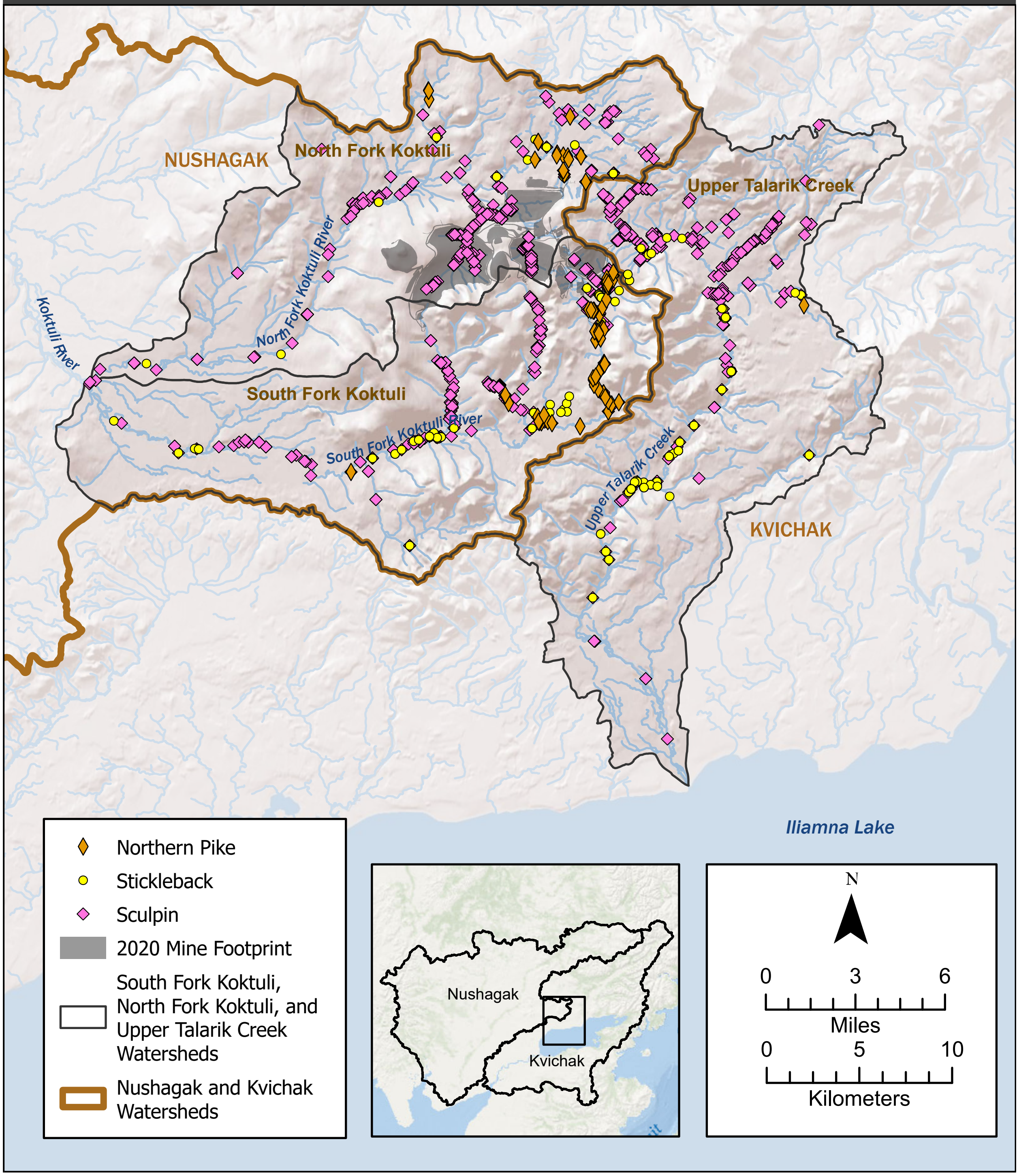


Figure 4-6. Reported occurrence of Arctic Grayling, Rainbow Trout, and Dolly Varden overlain with the Pebble 2020 Mine Plan. Species distributions are based on the Alaska Freshwater Fish Inventory (ADF&G 2022a).

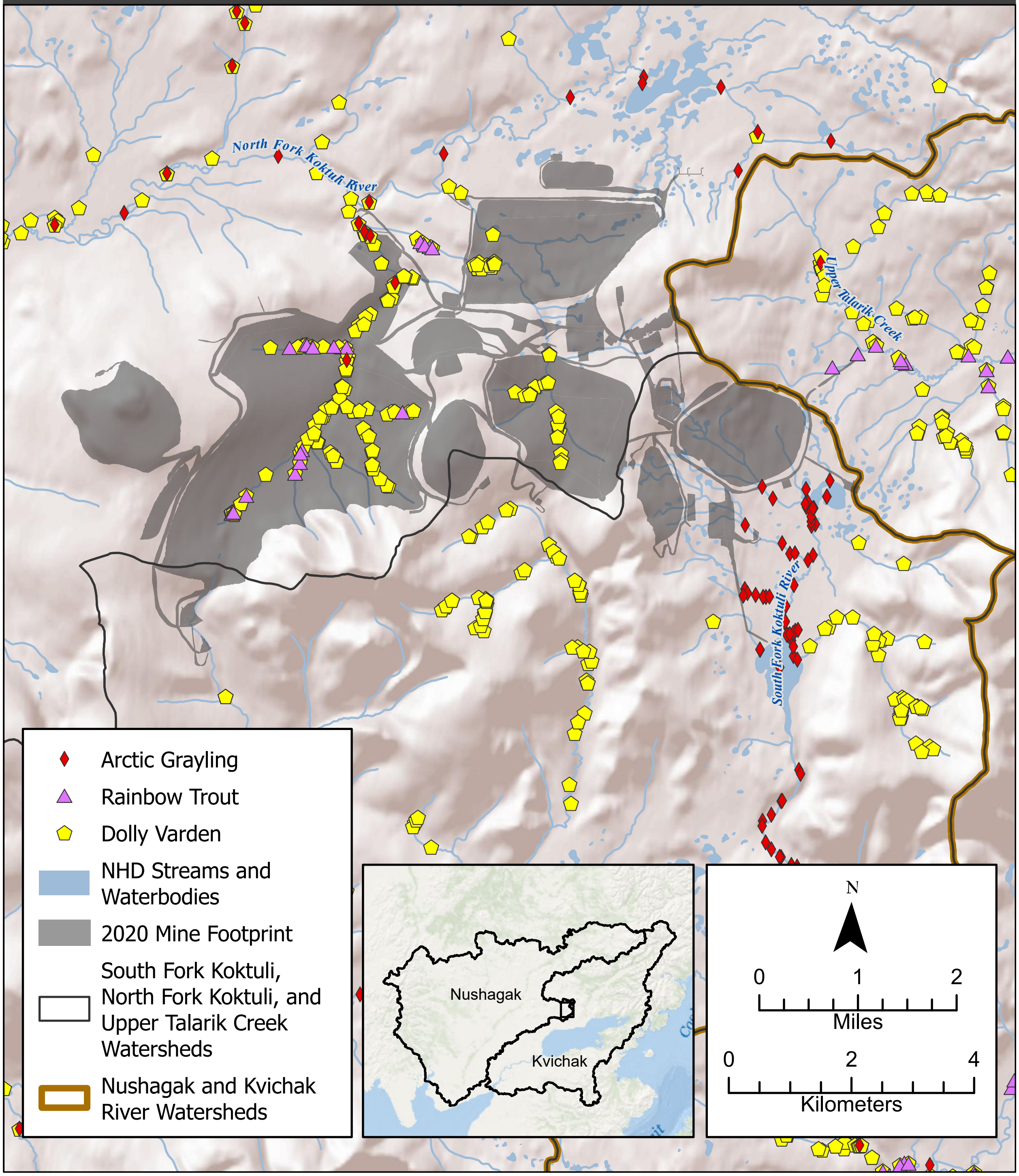
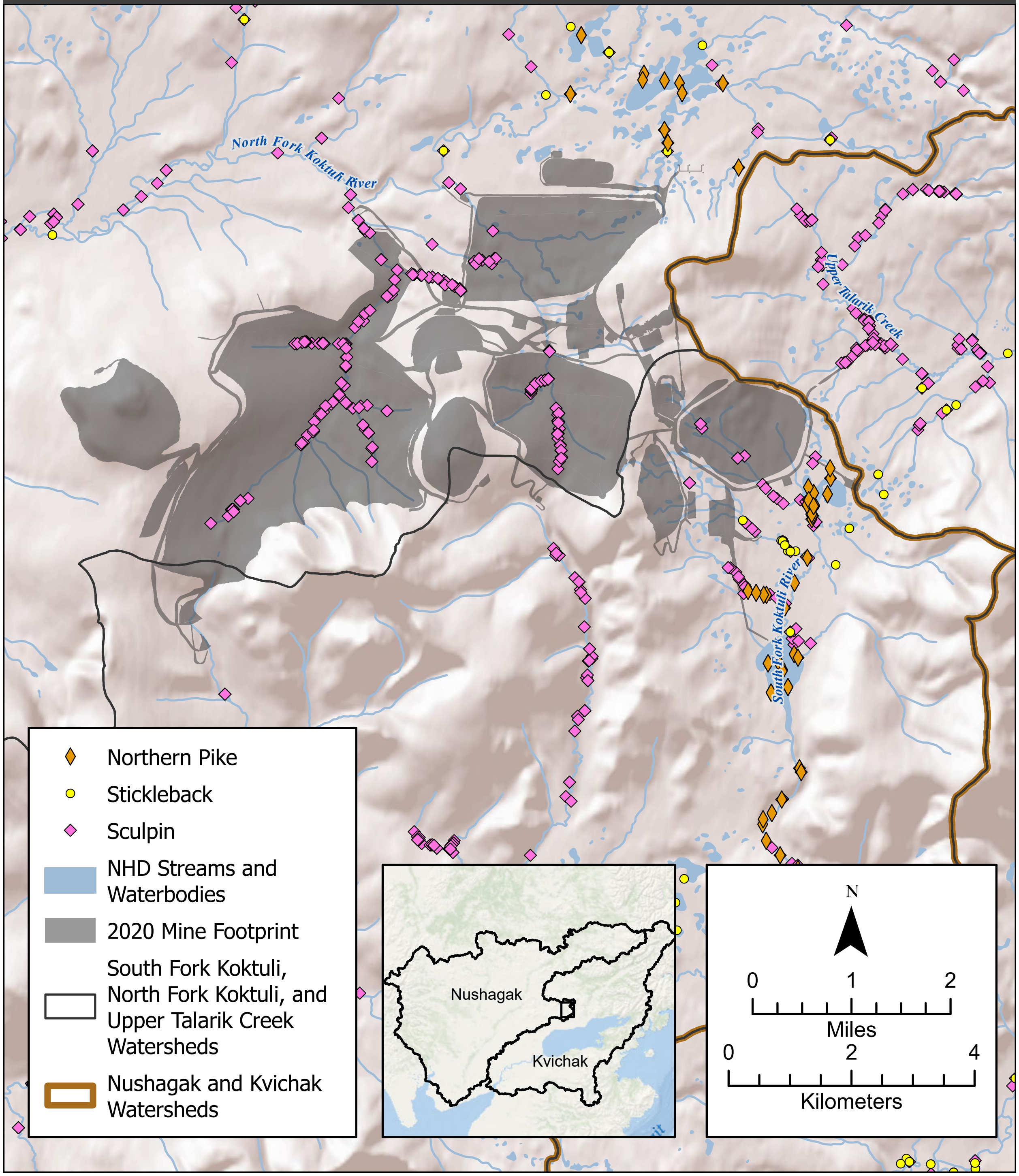


Figure 4-7. Reported occurrence of other resident fish species overlain with the Pebble 2020 Mine Plan. Species distributions are based on the Alaska Freshwater Fish Inventory (ADF&G 2022a).



4.2.1.5 Summary

EPA Region 10 believes that the discharge of dredged or fill material for the construction and routine operation of the 2020 Mine Plan, resulting in the loss of approximately 8.5 miles (13.7 km) of anadromous fish streams, could have unacceptable adverse effects on anadromous fishery areas in the NFK watershed. This conclusion is based on the following factors: the large amount of permanent loss of anadromous fish habitat (including spawning and breeding areas); the particular importance of the permanently lost habitat for juvenile Coho and Chinook salmon; the degradation of additional downstream spawning and rearing habitat for Coho, Chinook, and Sockeye salmon due to the loss of ecological subsidies provided by the eliminated anadromous fish streams; and the resulting erosion of both habitat complexity and biocomplexity within the NFK watershed, which are key to the abundance and stability of salmon populations within this watershed. This conclusion supports the proposed prohibition described in Section 5.1.

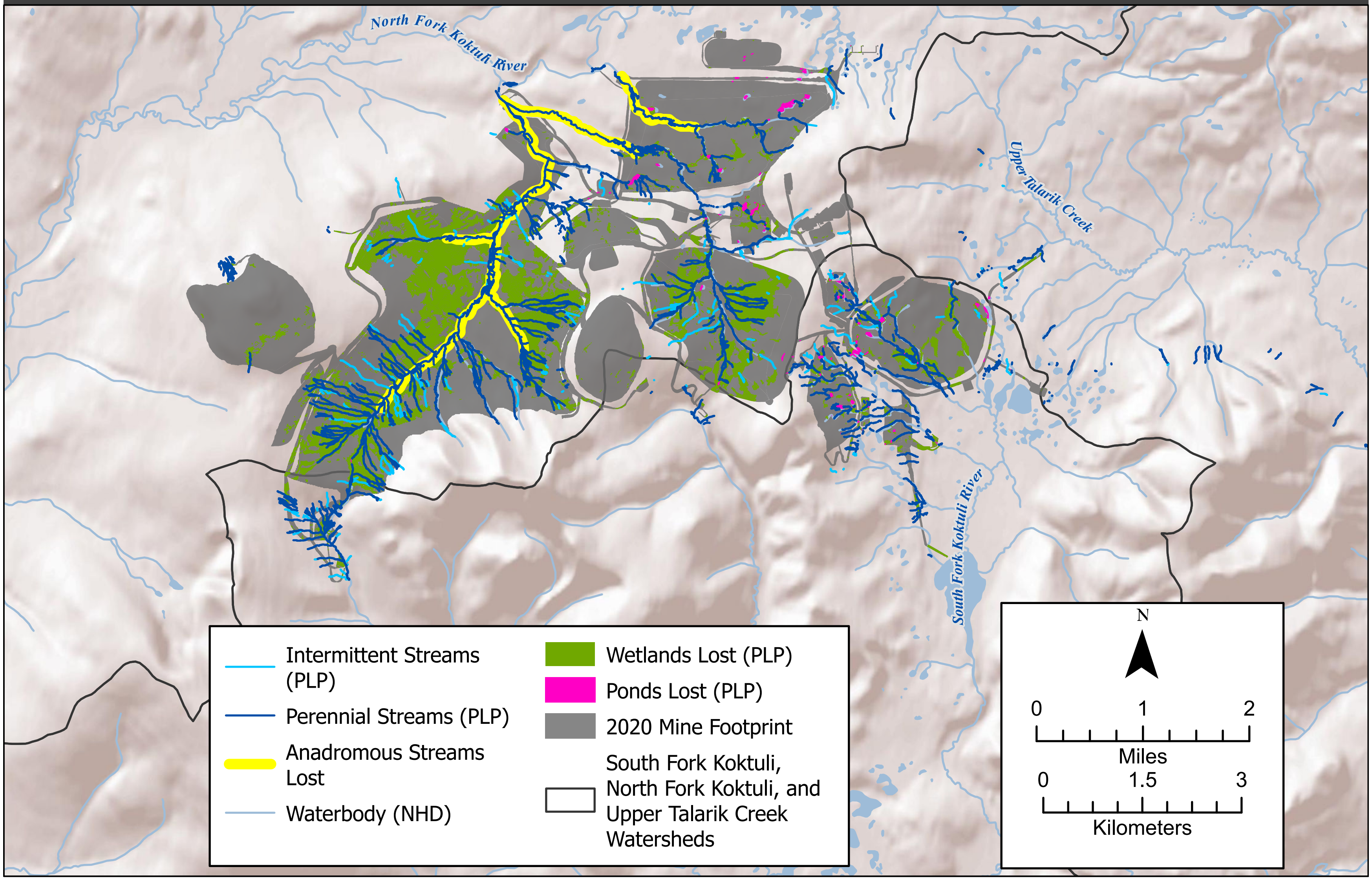
Further, based on the same record, EPA Region 10 believes the discharge of dredged or fill material associated with mining the Pebble deposit anywhere in the SFK, NFK, and UTC watersheds, resulting in the loss of approximately 8.5 miles (13.7 km) of anadromous fish streams, could have unacceptable adverse effects on anadromous fishery areas in these watersheds. This conclusion is based on the following factors: the pristine condition and productivity of anadromous fish streams throughout the SFK, NFK, and UTC watersheds (Section 3); the large amount of permanent loss of anadromous fish habitat; the degradation of additional downstream anadromous fish habitat due to the loss of ecological subsidies provided by the eliminated anadromous fish streams; and the resulting erosion of both habitat complexity and biocomplexity within the SFK, NFK, and UTC watersheds, which are key to the abundance and stability of salmon populations within these watersheds. This conclusion supports the proposed restriction described in Section 5.2.

4.2.2 Adverse Effects of Loss of Additional Streams that Support Anadromous Fish Streams

In addition to the permanent loss of approximately 8.5 miles (13.7 km) of documented anadromous fish streams, discharges of dredged or fill material at the mine site under the 2020 Mine Plan would result in the permanent loss of an additional 91.2 miles (146.8 km) of streams that support anadromous fish streams[51] in the SFK, NFK, and UTC watersheds (USACE 2020a: Section 4.24) (Figure 4-8, Box 4-2). EPA Region 10 believes that the permanent loss of these additional streams could have unacceptable adverse effects on anadromous fishery areas in the SFK and NFK watersheds. As discussed in this section, this conclusion is based on the extensive permanent loss of additional streams that support anadromous fish

[51] *Streams that support anadromous fish streams* refers to streams that do not currently have documented anadromous fish occurrence. As explained in this section, such streams still support downstream anadromous fish streams. Although there is not currently documented anadromous fish occurrence in these streams, they may nonetheless be used by anadromous fish; however, the potential for such use is not a basis for this proposed determination (see Box 4-1 and Appendix B).

Figure 4-8. Streams, wetlands, and ponds lost under the Pebble 2020 Mine Plan. Streams, wetlands, and ponds at the mine site are based on PLP's June 2020 Permit Application (PLP 2020b).



BOX 4-2. WATER RESOURCES MAPPING AT THE MINE SITE

As shown in Figure 4-8, PLP completed field-verified mapping of wetlands and other waters at the mine site. This type of higher resolution stream and wetland mapping would be necessary to accurately predict impacts on water resources from the discharge of dredged or fill material for the purposes of any final determination in this case. Project-specific map layers provide more detail and include more water courses than publicly available stream and wetland databases. A brief review of these datasets is provided to demonstrate how the water resource impacts described in the FEIS and this proposed determination differ from the typical stream and wetland mapping available for the rest of the SFK, NFK, and UTC watersheds.

National stream and wetland datasets are readily accessible for these watersheds, but these data come with limitations. The U.S. Geological Survey provides a nationwide database of streams, waterbodies, and watersheds as part of the National Hydrography Dataset (NHD). The NHD is a feature-based database that identifies stream segments or reaches that make up the nation's surface water drainage system. These data are mapped at 1:63,360 scale or larger in Alaska (USGS 2022). Similarly, the U.S. Fish and Wildlife Service maintains the National Wetlands Inventory (NWI) to provide information on the status, extent, characteristics, and functions of the nation's wetlands, riparian, and deepwater habitats (USFWS 2022). The NWI mapping available for the SFK, NFK, and UTC watersheds is derived from 1:65,000 scale aerial photography (USFWS 2021). While NWI is not available nationwide, it is currently available for approximately 96 percent of the SFK, NFK, and UTC watersheds.

The stream and wetland mapping generated by PLP was developed using more site-specific information than is typically used in the development of NHD or NWI. For approximately 44 percent of the SFK, NFK, and UTC watershed areas, PLP developed high resolution vegetation and stream mapping layers using a combination of field data collection and aerial photography interpretation. Wetland boundaries were digitized on aerial photography at a scale between 1:1,200 and 1:1,500. Waterbodies were digitized based on aerial photography scaled at 1:400 using an average minimum mapping unit of 0.05 acre (USACE 2020a: Section 3.22). This mapping addressed some data gaps that otherwise exist when using non-project–specific stream and wetland mapping layers like NHD or NWI.

A comparison of these stream and wetland mapping sources helps demonstrate how impacts on water resources can appear to vary due solely to changes in map resolution. EPA understands the area under the 2020 Mine Plan footprint was subject to more review by USACE during the CWA Section 404 permit review process. Therefore, this area is assumed to provide the most accurate comparison area of national datasets to higher resolution water resources maps. While the NHD only shows approximately 25.8 miles (41.5 km) of streams under the 2020 Mine footprint (USGS 2021), PLP identified 99.7 miles (160.5 km) of stream habitat that would be impacted in this same area, including the 8.5 miles (13.7 km) of stream documented to contain anadromous fish (USACE 2020a: Section 4.24). These values indicate there may be almost four times as many streams in these headwater areas than are mapped in the NHD. As indicated in the FEIS, PLP's identification of additional small-scale watercourses resulted in an increase in stream miles expected to receive direct and indirect impacts in the mine site analysis areas than had been disclosed in the DEIS (USACE 2020a: Section 4.22).

Similarly, while PLP's CWA Section 404 application identified 2,113 acres (8.6 km^2) of wetlands and other waters that would be permanently lost due to the discharge of dredged or fill material at the mine site, NWI identified only 1,492 acres (6.0 km^2) of wetlands and deepwater habitats in this same area. These values indicate that there may be over 40 percent more wetlands and other deepwater habitats in the vicinity of the Pebble deposit compared to NWI.

Most of these losses would occur in the NFK watershed, where 72.4 miles (116.5 km) of additional streams would be permanently lost (in addition to the 8.5 miles [13.7 km] of anadromous fish stream losses discussed in Section 4.2.1). Permanent additional stream losses in the SFK and UTC watersheds would be 18.8 miles (30.3 km) and 0.02 mile (0.02 km), respectively (PLP 2020b). The combined 99.7 miles (160.5 km) of anadromous fish stream and additional stream losses would represent about 20 percent of available stream habitat in the Headwaters Koktuli River watershed (i.e., the SFK, NFK, and streams and the corresponding permanent loss of ecological subsidies these additional streams provide to downstream anadromous fish streams. Middle Koktuli River HUC-12 watersheds) and 12 percent of available stream habitat in the larger Koktuli River watershed (USACE 2020a: Section 4.24).

This permanent loss of additional streams from discharges of dredged or fill material for the construction and routine operation of the 2020 Mine Plan would result in reduced stream productivity in downstream anadromous fishery areas of the SFK and NFK due to the loss of physical and biological inputs that would no longer be provided to downstream fishery areas that support Coho, Chinook, Sockeye, and Chum salmon. These impacts would be permanent and certain to occur (USACE 2020a: Section 4.24).

The majority of additional streams that would be permanently lost are small headwater streams. There is an extensive body of scientific evidence demonstrating that headwater streams are important aquatic habitats and play a critical role in the structure and function of downstream reaches (Section 3.2.4). The small size and large collective surface area of headwater streams result in a disproportionate effect on larger downstream habitats (Vannote et al. 1980, Alexander et al. 2007, Koenig et al. 2019). Thus, loss of these headwater streams and their important ecological subsidies (e.g., food resources, nutrients, surface water flows, groundwater exchange) can have larger than expected impacts on downstream reaches.

Headwater streams that would be eliminated by the 2020 Mine Plan contribute spawning gravels, invertebrate drift, organic matter, nutrients, surface water flows, groundwater flows, and woody debris to downstream channels (USACE 2020a: Section 4.24). The loss of the temperature moderation via groundwater-influenced flows to downstream anadromous fish streams would exacerbate the potentially substantial changes in stream temperature caused by WTP discharges (USACE 2020a: Section 4.24). Headwater streams also can serve as refugia for fishes that may seasonally or periodically use these habitats (USACE 2020a: Section 3.24). For example, headwater streams can provide refuge from predators (Sepulveda et al. 2013), floods (Brown and Hartman 1988), or otherwise temporarily inhospitable conditions in downstream waters.

The 91.2 miles (146.8 km) of additional streams that would be permanently lost under the 2020 Mine Plan provide both important provisioning functions (via ecological subsidies) and habitat functions (via refugia) that are beneficial for downstream anadromous fishery areas. As a result, headwater streams such as those that would be permanently lost at the mine site play a vital role in maintaining diverse, abundant anadromous fish populations (Section 3.2.4). Losses of this magnitude would degrade downstream anadromous fishery areas that provide spawning and rearing habitat for Coho, Chinook, Sockeye, and Chum salmon in the SFK and NFK watersheds (Figures 3-5 through 3-8, Figures 4-2 and 4-3). These losses would adversely affect genetically distinct populations of Sockeye Salmon in the Koktuli River (including the SFK and NFK), as well as Coho and Chinook salmon populations that may be uniquely adapted to the spatial and temporal conditions of their natal streams (Section 3.3.1).

As explained for the loss of 8.5 miles (13.7 km) of anadromous fish streams, the loss and degradation of downstream anadromous fishery areas in the SFK and NFK watersheds that would result from elimination of 91.2 miles (146.8 km) of additional streams would further erode both habitat complexity and biocomplexity within these watersheds. This diversity of salmon habitats and associated salmon population diversity helps buffer these salmon populations from sudden and extreme changes in abundance and ultimately maintain their stability and productivity. By itself, the permanent destruction of approximately 91.2 miles (146.8 km) of additional streams from a single project would be unprecedented for the CWA Section 404 regulatory program in Alaska. The effects of these additional stream losses would propagate to downstream habitats and adversely affect species such as Coho, Chinook, Sockeye, and Chum salmon in the SFK and NFK watersheds, all of which support important subsistence, commercial, and recreational fisheries.

4.2.2.1 Impacts on Other Fish Species

Although this proposed determination is based solely on adverse effects on anadromous fishery areas, EPA Region 10 notes that the 91.2 miles (146.8 km) of additional streams that support anadromous fishery areas in the SFK, NFK, and UTC watersheds and would be lost under the 2020 Mine Plan also provide habitat for non-anadromous fish species. The assemblage of non-anadromous fishes found in and supported by these additional streams is an important component of these habitats and further underscores the biological integrity and ecological value of these pristine, intact headwater networks.

The permanent loss of approximately 91.2 miles (146.8 km) of additional streams from the discharge of dredged or fill material under the 2020 Mine Plan would adversely affect non-anadromous fish species and assemblages. Available data indicate that approximately 14.1 miles (22.7 km) of this 91.2 miles (146.8 km) of additional streams support non-anadromous fish species such as Rainbow Trout, Dolly Varden, Arctic Grayling, Ninespine Stickleback, and Slimy Sculpin (Figures 4-6 and 4-7). Approximately 1.4 miles (2.3 km) of streams in the SFK watershed that would be lost at the mine footprint (Figure 4-8; USACE 2020a: Section 4.24) provide habitat for Arctic Grayling, Northern Pike, Slimy Sculpin, and Ninespine Stickleback. The remaining 12.7 miles (20.4 km) that would be permanently lost are located in the NFK watershed (USACE 2020a: Section 4.24) and provide habitat for Dolly Varden, Rainbow Trout, and Slimy Sculpin (ADF&G 2022a). As described in Section 4.2.1, Rainbow Trout, Dolly Varden, and Arctic Grayling are targets of downstream subsistence and recreational fisheries. Stickleback and Slimy Sculpin support those fisheries as forage fishes (Table 3-3).

As discussed previously in this section, waters downstream of the mine site would be degraded as a result of the elimination of 91.2 miles (146.8 km) of additional streams at the mine site. In addition to the four Pacific salmon species already discussed, these waters support Rainbow Trout, Dolly Varden, Arctic Grayling, Northern Pike, Ninespine Stickleback, and Slimly Sculpin. Thus, the ecological value of the approximately 91.2 miles (146.8 km) of additional streams that would be eliminated is further highlighted by the fact that they provide both habitat and habitat support functions for six non-anadromous fish species important to subsistence and recreational fisheries and aquatic food webs (Section 3.3.1).

4.2.2.2 Summary

EPA Region 10 believes that the discharge of dredged or fill material for the construction and routine operation of the 2020 Mine Plan, resulting in the loss of approximately 91.2 miles (146.8 km) of additional streams, could have unacceptable adverse effects on anadromous fishery areas in the SFK and NFK watersheds. This conclusion is based on the following factors: the large amount of permanent loss of additional streams and the crucial role that these headwater streams play in providing ecological subsidies to downstream anadromous fish streams; the degradation of downstream anadromous fish streams, including spawning and rearing habitat for Coho, Chinook, Sockeye, and Chum salmon, due to the loss of ecological subsidies provided by the eliminated headwater streams; and the resulting erosion of both habitat complexity and biocomplexity within the SFK and NFK watersheds, which are key to the abundance and stability of salmon populations within these watersheds. This conclusion supports the proposed prohibition described in Section 5.1.

Further, based on the same record, EPA Region 10 believes the discharge of dredged or fill material associated with mining the Pebble deposit anywhere in the SFK, NFK, and UTC watersheds, resulting in the loss of approximately 91.2 miles (146.8 km) of additional streams, could have unacceptable adverse effects on anadromous fishery areas in these watersheds. This conclusion is based on the following factors: the pristine condition of streams in the SFK, NFK, and UTC watersheds and the important role headwater streams play in supporting Pacific salmon populations, as discussed in this section and in Section 3; the large amount of outright loss of stream habitat and the crucial role that these headwater streams play in providing ecological subsidies to downstream anadromous fish streams; the degradation of downstream anadromous fish streams from the loss of ecological subsidies provided by the lost headwater streams; and the resulting erosion of both habitat complexity and biocomplexity within the SFK, NFK, and UTC watersheds, which are key to the abundance and stability of salmon populations within these watersheds. This conclusion supports the proposed restriction described in Section 5.2.

4.2.3 Adverse Effects of Loss of Wetlands and Other Waters that Support Anadromous Fish Streams

In addition to the losses of anadromous fish streams and additional streams that support anadromous fish streams, the discharge of dredged or fill material for the construction and routine operation of the 2020 Mine Plan would also result in the permanent loss of approximately 2,113 acres (8.6 km^2) of wetlands and other waters at the mine site (Figure 4-8, Table 4-3, see also Box 4-2) (USACE 2020a, USACE 2020b). EPA Region 10 believes that these permanent losses of wetlands and other waters could have unacceptable adverse effects on anadromous fishery areas in the SFK and NFK watersheds. As discussed in this section, this conclusion is based on the extensive permanent loss of wetlands and other waters and the corresponding permanent loss of ecological subsidies these wetlands provide to downstream anadromous fish streams.

Wetlands and other waters that would be permanently lost play a critically important role in the life cycles of anadromous fishes in the SFK and NFK watersheds (Section 3.2.3) (PLP 2011: Appendix 15.1.D), given that "…all wetlands are important to the greater function and value of ecosystems and subsistence cultures they support" (USACE 2020a: Page 3.22-8). The wetlands and other waters affected by the 2020 Mine Plan "possess unique ecological characteristics of productivity, habitat, wildlife protection, and other important and easily disrupted values" (USACE 2020a: Page 3.22-1). In addition, the specific wetlands and other waters that would be permanently lost are relatively free from human-induced alteration and provide extensive and heterogeneous habitats (Table 4-3) (USACE 2020a: Section 3.22). A diverse portfolio of pristine aquatic habitats is crucial to supporting the productivity and stability of salmon populations in these watersheds (Section 3.3.3).

The permanent removal of wetlands and other waters would destroy habitat, result in mortality of aquatic organisms, and reduce the collective functional capacity and value of wetlands and other waters across multiple watersheds, as well as cause the displacement, injury, and/or mortality of species that rely on these aquatic environments for all or part of their life cycles (USACE 2020a: Section 4.22). The permanent loss of wetlands from development of the mine site represents about 6 percent of mapped wetlands in the Headwaters Koktuli River watershed (i.e., the SFK, NFK, and Middle Koktuli River HUC-12 watersheds) and 4 percent of mapped wetlands in the Headwaters Koktuli River and UTC watersheds (Table 4-3, Box 4-2) (USACE 2020a: Section 4.22).

The discharge of dredged or fill material into the wetlands and other waters described previously is expected to reduce the biological productivity of wetland ecosystems by smothering, dewatering, permanently flooding, or altering substrate elevation or the periodicity of water movement. The decreased productivity and/or alteration of water current patterns and velocities could eliminate or reduce the cycling of nutrients and compounds, and disruption of wetland hydrology can interfere with the filtration, aquifer recharge, and storm and floodwater modification functions of wetlands (USACE 2020a: Section 4.22). Many of the affected wetlands at the mine site, especially slope wetlands, are considered headwater wetlands from a watershed perspective, meaning they are the primary source of intermittent and upper perennial streams. Impacts to these wetlands could alter groundwater discharge that maintains hydrology and water quality and buffers water temperatures in these streams; this alteration of hydrologic function is likely to extend to wetlands and other waters immediately downgradient from the affected wetlands (USACE 2020a: Section 4.22).

Changes in flow in the SFK, NFK, and UTC due to modification of upgradient wetlands and mine operations have the potential to change the hydrologic connectivity of off-channel habitats and associated wetlands (USACE 2020a: Section 4.22). Off-channel habitats, including fringing riparian wetlands, provide cover important to juvenile salmon rearing (Section 3.2) (USACE 2020a: Section 4.22). Changes to flow and loss of connectivity between wetlands and other waters and stream channels also can affect nutrient availability, the downstream transport of invertebrates, and available habitat for benthic macroinvertebrate production, thereby adversely affecting overall productivity of downgradient anadromous fish streams and streams that support anadromous fish streams (USACE 2020a: Section 4.22).

Table 4-3. Area of wetlands and other waters lost under the Pebble 2020 Mine Plan.

		Hydrogeomorphic (HGM)/NWI Group	Headwaters Koktuli River [a]	Upper Talarik Creek [b]	Combined Watershed Area (acres)
SLOPE	Wetlands	Total Wetlands	1,909	4	1,913
		Herbaceous	547	1	547
		Deciduous Shrubs	1,352	3	1,355
		Evergreen Shrubs	11	–	11
	Other Waters	Total Other Waters	16		16
		Aquatic Bed	2	–	2
		Ponds	13	–	13
		TOTAL SLOPE	1,925	4	1,929
DEPRESSIONAL	Wetlands	Total Wetlands	12	<1	12
		Herbaceous	5	<1	5
		Deciduous Shrubs	7	–	7
	Other Waters	Total Other Waters	38	<1	39
		Ponds	38	<1	39
		TOTAL DEPRESSIONAL	50	<1	50
FLAT	Wetlands	Total Wetlands	8		8
		Herbaceous	3	–	3
		Deciduous Shrubs	6	–	6
		TOTAL FLAT	8		8
LACUSTRINE FRINGE	Wetlands	Total Wetlands	<1		<1
		Herbaceous	<1	–	<1
		TOTAL LACUSTRINE FRINGE	<1		<1
RIVERINE	Wetlands	Total Wetlands	118		118
		Herbaceous	42	–	42
		Deciduous Shrubs	76	–	76
	Other Waters	Total Other Waters	7		7
		Ponds	7	–	7
		TOTAL RIVERINE	125		125
Total Impacts to Wetlands (acres)			**2,047**	**4**	**2,051**
Total Impacts to Other Waters (acres)			**61 [c]**	**<1**	**61 [c]**
Total Impacts to Wetlands and Other Waters (acres)			**2,108 [c]**	**4**	**2,113 [c]**
Total Area of NWI Wetlands and Other Waters (acres)			**36,458**	**13,193**	**49,651**
Percent Total of NWI Wetlands and Other Waters			**6**	**<1**	**4**

Notes:

[a] 100 percent of the Headwaters Koktuli River watershed has been mapped in NWI.

[b] 91 percent of the Upper Talarik Creek watershed has been mapped in NWI.

[c] To be consistent with the USACE's ROD (USACE 2020b), stream area was removed from values presented in FEIS Table 4.22-3 such that the Other Waters acres values only include the following NWI group types: aquatic bed and ponds (USACE 2022).

Source: Adapted from FEIS Table 4.22-3 (USACE 2020a).

As described in Section 4.2.1, the wetlands and other waters that discharges of dredged or fill material associated with the 2020 Mine Plan would permanently remove include beaver ponds and wetlands inundated as a result of beaver activity (USFWS 2021). Coho and Chinook salmon rear in many of the beaver-modified waters or the streams they abut (Giefer and Blossom 2021). Beaver-modified waters provide excellent rearing habitat and important overwintering and flow-velocity refugia for anadromous fishes (Section 3.2.4) and may be especially important in maintaining salmon productivity (Nickelson et al. 1992, Solazzi et al. 2000, Pollock et al. 2004).

Wetlands that are contiguous with and adjacent to anadromous fish streams likely provide additional anadromous fish habitat, but have not yet been surveyed at spatial and temporal scales sufficient to document periodic use by salmon (Appendix B). Such areas often provide habitat to juveniles of species such as Coho Salmon (Henning et al. 2006, EPA 2014: Appendix B). The lower gradient of lakes, ponds, and inundated wetlands connected to anadromous fish streams also can provide beneficial rearing and foraging conditions that may be unavailable in the main stream channel (Sommer et al. 2001, Henning et al. 2006), thereby increasing capacity for juvenile salmon growth and rearing (Nickelson et al. 1992, Sommer et al. 2001).

Wetlands also indirectly support anadromous fish streams by providing cover; moderating temperatures and streamflows; maintaining baseflows; serving as groundwater recharge zones; and supplying nutrients, organic material, macroinvertebrates, algae, and other materials to abutting streams and streams lower in the watershed. These inputs serve as important subsidies for juvenile salmonids (Vannote et al. 1980, Wipfli and Gregovich 2002, Meyer et al. 2007, Dekar et al. 2012). Abundant wetlands and small ponds, for example, have been documented to contribute disproportionately to groundwater recharge in this region (Rains 2011). Given the importance of groundwater–surface water exchange in the SFK, NFK, and UTC watersheds, groundwater inputs are likely a significant determinant of surface water quantity and quality. Moreover, leaf litter from deciduous shrubs and herbaceous vegetation is an important source of food for stream food webs and helps fuel the production of macroinvertebrates, a key food for juvenile salmonids (Table 3-3) (Meyer et al. 2007, Dekar et al. 2012). Riparian wetlands with deciduous shrubs and grasses are prevalent in the SFK, NFK, and UTC watersheds, indicating they likely provide this energy source to downgradient waters.

The permanent loss of approximately 2,113 acres (8.6 km^2) of wetlands and other waters under the 2020 Mine Plan would result in loss of both habitat and the provision of key ecological subsidies to both abutting and downstream waters (Section 3.2.4). These headwater wetlands play a vital role in maintaining diverse, abundant anadromous fish populations, via the downgradient transport of surface and groundwater inputs and food sources critical to the survival, growth, and spawning success of downstream anadromous fishes (Section 3.2.4). The loss of such waters would eliminate structurally complex and thermally and hydraulically diverse habitats—including crucial overwintering areas—that are essential to rearing salmonids.

Downstream waters that would be degraded by the elimination of wetlands and other waters at the mine site are ecologically important and provide rearing and spawning habitat for Coho, Chinook, Sockeye, and Chum salmon in the SFK and NFK watersheds (Figures 3-5 through 3-8). In addition, degradation of downstream anadromous fish streams would adversely affect genetically distinct populations of Sockeye Salmon in the Koktuli River (including SFK and NFK) and Coho and Chinook salmon populations that may be uniquely adapted to the spatial and temporal conditions of their natal streams (Section 3.3.1).

As explained for the loss of 8.5 miles (13.7 km) of anadromous fish streams, the loss and degradation of downstream anadromous fishery areas in the SFK and NFK watersheds that would result from elimination of approximately 2,113 acres (8.6 km^2) of wetlands and other waters would further erode both habitat complexity and biocomplexity within these watersheds. This diversity of salmon habitats and associated salmon population diversity helps buffer these salmon populations from sudden and extreme changes in abundance and ultimately maintain their stability and productivity. By itself, the permanent destruction of approximately 2,113 acres (8.6 km^2) of wetlands and other waters from a single project would be unprecedented for the CWA Section 404 regulatory program in Alaska. The effects of these losses would propagate to downstream habitats and adversely affect species such as Coho, Chinook, Sockeye, and Chum salmon in the SFK and NFK watersheds, all of which support important subsistence, commercial, and recreational fisheries.

4.2.3.1 Impacts on Other Fish Species

Although this proposed determination is based solely on adverse effects on anadromous fishery areas, EPA Region 10 notes that the 2,113 acres (8.6 km^2) of wetlands and other waters at the mine site that would be lost under the 2020 Mine Plan also provide habitat for non-anadromous fish species. The assemblage of non-anadromous fishes found in and supported by these wetlands and other waters is an important component of these habitats and further underscores the biological integrity and ecological value of these pristine, intact headwater networks. Dolly Varden and sculpin rear in many of the same beaver-modified habitats as Coho and Chinook salmon, and Ninespine Stickleback and sculpin rear in headwater ponds of the SFK watershed (Figures 4-6 and 4-7). Furthermore, waters downstream of the mine site that would be degraded by elimination of wetlands and other waters at the mine site support Rainbow Trout, Dolly Varden, Arctic Grayling, Northern Pike, Ninespine Stickleback, and sculpin—species that support regional biodiversity (Meyer et al. 2007) and are important to subsistence and recreational fisheries and aquatic food webs (Section 3.3.1).

4.2.3.2 Summary

EPA Region 10 believes that the discharge of dredged or fill material for the construction and routine operation of the 2020 Mine Plan, resulting in the loss of approximately 2,113 acres (8.6 km^2) of wetlands and other waters, could have unacceptable adverse effects on anadromous fishery areas in the SFK and NFK watersheds. This conclusion is based on the following factors: the large amount of outright loss of wetlands and other waters; the importance of wetlands and other waters to salmon populations, both as habitat and as sources of groundwater inputs, nutrients, and other subsidies important to salmon productivity in downstream waters; the degradation of downstream anadromous fish streams, including spawning and rearing habitat for Coho, Chinook, Sockeye, and Chum salmon, from the loss of ecological subsidies provided by the lost headwater wetlands and other waters; and the resulting erosion of both habitat complexity and biocomplexity within the SFK and NFK watersheds, which are key to the abundance and stability of salmon populations within these watersheds. This conclusion supports the proposed prohibition described in Section 5.1.

Further, based on the same record, EPA Region 10 believes the discharge of dredged or fill material associated with mining the Pebble deposit anywhere in the SFK, NFK, and UTC watersheds, resulting in the loss of approximately 2,113 acres (8.6 km^2) of wetlands and other waters, could have unacceptable adverse effects on anadromous fishery areas in these watersheds. This conclusion is based on the following factors: the pristine condition of wetlands and other waters in the SFK, NFK, and UTC watersheds and the important role that headwater wetlands and other waters play in supporting Pacific salmon populations, as discussed in this section and in Section 3; the large amount of outright loss of wetlands and other waters; the importance of wetlands and other waters to salmon populations, both as habitat and as sources of groundwater inputs, nutrients, and other subsidies important to salmon productivity in downstream waters; the degradation of downstream anadromous fish streams from the loss of ecological subsidies provided by the lost headwater wetlands and other waters; and the resulting erosion of both habitat complexity and biocomplexity within the SFK, NFK, and UTC watersheds, which are key to the abundance and stability of salmon populations within these watersheds. This conclusion supports the proposed restriction described in Section 5.2.

4.2.4 Adverse Effects from Changes in Streamflow in Downstream Anadromous Fish Streams

EPA Region 10 believes that the discharge of dredged or fill material associated with the construction and routine operation of the 2020 Mine Plan, resulting in streamflow alterations greater than 20 percent of average monthly streamflow in at least 29 miles (46.7 km) of anadromous fish streams, could have unacceptable adverse effects on anadromous fishery areas in the SFK and NFK watersheds. This conclusion is based on the extent and magnitude of changes to streamflow in anadromous fish streams downstream of the mine site and associated adverse effects on the extent and quality of anadromous fish habitat, including spawning and rearing habitat.

This section first describes the methodology used for identifying anadromous fish stream reaches that would experience unacceptable adverse effects (Section 4.2.4.1). It then summarizes the specific anadromous fish streams where excessive streamflow changes are expected (Section 4.2.4.2), the downstream anadromous habitat that would be affected (Section 4.2.4.3), and the unacceptable adverse effects on anadromous habitat that would occur as a result of the predicted streamflow alterations (Section 4.2.4.4).

4.2.4.1 Methodology for Analyzing Streamflow Changes in Downstream Anadromous Fish Streams

The natural flow regime, defined as the characteristic pattern of streamflow magnitude, timing, duration, frequency, and rate of change (Poff et al. 1997), plays a critical role in supporting and maintaining both the ecological integrity of streams and rivers and the services they provide. Human-induced alteration of the natural flow regime can degrade the physical, chemical, and biological properties of a water body, leading to loss of aquatic life and reduced aquatic biodiversity (e.g., Poff et al. 1997, Bunn and Arthington 2002, Naiman et al. 2002, Annear et al. 2004, Poff and Zimmerman 2010). Fischenich (2006) identified the flow regime as the most significant of stream functions because it directly or indirectly affects all other functions.

As the science of flow ecology has uncovered aquatic life needs across the full spectrum of the flow regime (e.g., base flows, high flows, floods), water resource managers now recognize that protecting aquatic life from the adverse effects of streamflow alteration involves maintaining multiple components of the flow regime within their typical ranges of variability. This perspective requires an understanding of natural flow regimes over space and time and the many ways in which habitats and all species and life stages of biota respond to varied flow conditions (Novak et al. 2016).

For streams in the Bristol Bay region, natural temporal streamflow variability results from fall storm events, winter low flows under ice cover, spring snowmelt peak flows, and subsequent recession of streamflow into summer (EPA 2014: Chapters 3 and 7, USACE 2020a: Section 3.16). These seasonal flow regimes affect channel development and maintenance; connectivity between active channels and off-channel habitats; transport of sediment and nutrients; timing and success of fish migration and spawning; and survival of fish eggs and juveniles (EPA 2014: Chapter 7).

Recognizing the importance of natural flow regimes to habitat-forming processes and the biotic integrity of salmon ecosystems in the SFK, NFK, and UTC watersheds (EPA 2014: Chapter 7), the 2020 Mine Plan was evaluated using projected streamflow changes in terms of percent change from natural flows. Such an approach targets the entire aquatic ecosystem, rather than focusing on a specific species or set of species (e.g., salmon) that may have different habitat requirements than other biota in the natural system.

Based on case studies from around the world and literature on ecological flows dating to the 1970s, Richter et al. (2012) found that regardless of geographic location, daily streamflow alterations of greater than 20 percent can cause major changes in the structure and function of streams. Streamflow alterations between 11 and 20 percent can also result in changes in ecosystem structure and function, but to a lesser extent. Although Richter et al. (2012) note that limiting daily flow alterations to 20 percent or less may be protective in some circumstances, they also caution that it may be insufficient to fully protect ecological values in certain rivers. Because Pacific salmon are locally adapted to environmental cues such as small differences or changes in water temperature, chemical composition, and the natural flow regime of natal waters (Vannote et al. 1980, Poff et al. 1997, Fausch et al. 2002), it is likely that a lower threshold of streamflow modification would be necessary to adequately protect these species.

Flow modeling conducted for the 2020 Mine Plan, as presented in the FEIS and outlined in Section 4.2.4.2, describes streamflow alteration in terms of percent changes to average monthly streamflows rather than percent changes to daily streamflows. EPA Region 10 recognizes that daily flows would be more variable than monthly averages; however, EPA Region 10 believes that the extent of impacts identified on a monthly time scale provides a reasonable approximation of the extent of impacts from the 2020 Mine Plan, given the amount of error that can be associated with estimations of daily flows generated by models.[52] In addition, the streamflow impact information provided in the FEIS has been subject to public review and, thus, represents the best available information for this project. EPA Region 10 recognizes using average monthly streamflows to identify the extent of impacts may under-represent the true extent of unacceptable adverse effects, because relying on average monthly streamflow does not reflect the full breadth of streamflow changes that anadromous fishes and their habitats would experience on a daily or sub-daily basis.

As such, the following evaluation of average monthly streamflow alteration identifies the specific anadromous fish streams where streamflow changes would be expected to vary more than 20 percent from baseline average monthly streamflows (Section 4.2.4.2), the anadromous habitat that would be affected (Section 4.2.4.3), and the unacceptable adverse effects that would occur as a result of these streamflow alterations (Section 4.2.4.4).

4.2.4.2 Overview of Mine Site Operations that Affect Downstream Streamflow

The FEIS describes how the 2020 Mine Plan would change the volume, distribution, and flowpath of surface water and groundwater flows in and beyond the mine footprint (USACE 2020a: Sections 4.16 and 4.17). It describes how construction and routine operation of the 2020 Mine Plan would affect surface water quantity and distribution in the SFK, NFK, UTC, and several tributaries. Operational impacts of mining on streamflow were estimated based on the conditions expected at the end of operations (i.e., end-of-mine) rather than at periodic time steps during operations (USACE 2020a: Section 4.16). Table 4-4 provides estimated percent changes in average monthly streamflows, by river reach, between baseline and end-of-mine.[53] Dewatering of the pit area would be necessary during construction and operation, beginning approximately two years before the start of ore processing. The groundwater drawdown associated with dewatering the open pit would be responsible for much of the predicted streamflow reduction, along with the collection and rerouting of surface water runoff from the mine site footprint.

During operation, two WTPs would treat water collected within the mine site footprint prior to its release to the environment (Figure 4-1). WTP #1 would treat surplus groundwater and surface water runoff collected in the open pit and the surrounding areas. WTP #2 would collect and treat water from the main WMP, which would receive water from the TSFs and the TSF main embankment seepage. Treated water from the WTPs would be routed to three outfall locations and then discharged into the SFK, NFK, and UTC.[54] In an average year, mean monthly discharges to the SFK, NFK, and UTC would vary between 1.3 to 10 cubic feet per second (cfs), 17 to 27 cfs, and 0.2 to 1.4 cfs, respectively (Knight Piésold 2019a: Table 2).

[52] USACE did not present or analyze daily flow information in the FEIS. Impacts of predicted changes to fish habitat were run on a daily time step (PLP 2019c: RFI 149), but the daily discharges used in that analysis were estimated from the monthly flows. RFI 161 provides daily streamflow estimates that could be used to evaluate project impacts on daily flows (PLP 2020d: RFI 161), but this information was not subject to public review prior to its release. Questions remain regarding the methods, assumptions, and limitations of the daily streamflow estimates provided in RFI 161 (PLP 2020d: RFI 161).

[53] River reaches are lettered in order of in the upstream direction (i.e., Reach A is the most downstream reach, located just above the confluence of the SFK and NFK; Reach B is the reach upstream of Reach A; and so forth).

[54] These locations are shown in FEIS Figure 4.18-1 (Knight Piésold 2019b, USACE 2020a: Section 4.18).

Table 4-4. Change in the average monthly streamflow between baseline and end-of-mine with water treatment plant discharge, 2020 Mine Plan. FEIS Table 4.16-3 (USACE 2020a).

Location	Change in Average Monthly Streamflow from Baseline to End of Mine in Percent (50th Percentile Probability)												Annual Mean Monthly Change
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	
NFK, Reach A	+2.2	+10.6	+19.1	+23.5	-6.2	-12.1	-8.7	-9.2	-8.0	-7.2	-3.5	-3.3	-0.2
NFK, Reach B	+2.9	+11.6	+21.5	+29.0	-9.0	-13.5	-9.5	-10.2	-9.1	-8.1	-3.2	-3.4	-0.1
NFK, Reach C	+8.2	+29.0	+68.1	+110.2	-13.3	-20.4	-15.6	-16.4	-13.9	-13.4	-6.3	-5.4	+9.2
NFK, Reach D	+101.2	+127.9	+157.6	+170.0	+26.9	+23.1	+44.2	+46.1	+36.1	+34.3	+44.4	+73.2	+73.7
NFK, Trib 1.19	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0
SFK, Reach A	-2.7	-2.7	-2.1	-0.8	-1.4	-1.6	-2.8	-2.4	-2.3	-2.5	-2.3	-2.7	-2.2
SFK, Reach B	-2.2	-1.7	-0.5	+1.3	-2.4	-2.6	-3.3	-3.0	-3.2	-2.7	-2.5	-2.4	-2.1
SFK, Reach C	+3.8	0.0	0.0	0.0	-2.5	-2.8	-4.5	-3.9	-4.6	-3.1	-1.5	-1.2	-1.7
SFK, Reach D	+14.6	+27.5	+50.9	+109.0	-13.5	-15.0	-12.9	-11.9	-12.5	-10.2	+3.7	+9.3	+11.6
SFK, Reach E	-50.7	-51.5	-53.0	-52.2	-32.1	-33.1	-34.6	-37.4	-35.6	-38.8	-44.9	-49.4	-42.8
SFK, Trib 1.19	-13.4	-15.2	-17.1	-19.0	-3.7	-4.8	-7.2	-6.6	-5.3	-8.1	-10.6	-12.6	-10.3
SFK, Trib 1.24	+18.4	+97.9	0.0	+2.2	+2.7	+7.7	+11.0	+5.8	+4.8	+4.0	+7.0	+7.3	+14.1
UTC, Reach A	+0.4	+0.5	+0.7	+0.8	0.0	-0.1	-0.2	0.0	0.0	-0.1	0.0	+0.2	+0.2
UTC, Reach B	+0.4	+0.5	+0.6	+0.7	0.0	-0.1	-0.2	0.0	0.0	-0.1	0.0	+0.2	+0.2
UTC, Reach C	+0.5	+0.7	+0.8	+0.9	+0.1	-0.1	-0.2	0.0	0.0	-0.1	0.0	+0.3	+0.2
UTC, Reach D	+0.8	+1.1	+1.3	+1.7	+0.1	-0.2	-0.3	0.0	0.0	-0.2	+0.1	+0.4	+0.4
UTC, Reach E	+1.2	+1.9	+2.5	+3.2	+0.1	-0.2	-0.4	-0.1	-0.1	-0.2	+0.1	+0.6	+0.7
UTC, Reach F	+3.8	+5.5	+6.8	+8.6	+0.4	-0.8	-1.3	-0.2	-0.2	-0.7	+0.3	+1.9	+2.0
UTC, Trib 1.19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Although operations would change the availability of surface flows to area streams, surplus-treated water would be released from the mine site in an effort to benefit priority fish species and life stages (USACE 2020a: Section 4.24). Monthly habitat flow needs were identified for each month of the year in the SFK, NFK, and UTC based on priority species and life stages. In the SFK and NFK, the priority species used to determine habitat flow needs were Chinook Salmon, Coho Salmon, Rainbow Trout, and Arctic Grayling; these same species were used to determine habitat flow needs in UTC, except Sockeye Salmon replaced Chinook Salmon. In terms of life stage priorities for flow optimization, the spawning life stage was given a higher priority than juvenile rearing (PLP 2018b: RFI 048).

The FEIS indicates water from both WTPs would be strategically discharged, based on modeling and monitoring during discharge. However, the only monitoring proposed by PLP appears to be quarterly streamflow and fish presence surveys (PLP 2019b: RFI 135).[55] WTP discharges would, therefore, be preplanned based on modeling and a set of assumptions. Monthly WTP discharges would be the amount needed to "optimize" downstream habitat assuming the historic monthly average streamflow (i.e., given an "average climatic year," or 50 percent exceedance probability) was to occur at the representative downstream gage location.[56]

EPA Region 10 has concerns with the methods used to establish the ecosystem flow requirements and predict impacts on downstream anadromous fish habitat as presented in the FEIS (Appendix B: Sections B.3 and B.4). However, as described previously, the streamflow impact information provided in the FEIS provides a reasonable minimum approximation of impacts and the best available information for this project.

4.2.4.3 Extent of Streamflow Changes in Downstream Anadromous Fish Streams

The FEIS predicted changes in streamflow down to the confluence of the SFK and NFK, with and without the addition of treated water.[57] These estimates indicate that reaches of the SFK and NFK closest to the mine site would experience greater changes in average monthly streamflow than reaches farther from the mine site (USACE 2020a: Section 4.16). The FEIS states that the geographic extent of impacts to average monthly streamflows in the SFK and NFK may extend to just below the confluence of the two rivers. [58] After flows combine at the confluence of the SFK and NFK rivers, discernible changes in flow

[55] The Monitoring Summary provided by PLP states that monitoring of surface water flow and quality is proposed to be conducted downstream of water discharge points on a quarterly basis and will focus on streamflow and fish presence surveys (PLP 2019b: RFI 135).

[56] Wet, average, and dry years were determined for each target species and life stage between 1942 and 2017 at Gage NK100A (USGS Gage 15302250) for WTP#1 and Gage SK100B (USGS Gage 1530220) for WTP#2. (PLP 2018b: RFI 048).

[57] EPA Region 10's review only evaluated changes to streamflow with the addition of treated water. If WTPs were unable to discharge treated water for any period of time, streamflow reductions experienced in downstream anadromous fish streams would be greater than are discussed herein (USACE 2020a: Section 4.16).

[58] The FEIS indicates streamflow in the UTC and the Koktuli River below the confluence of the NFK and SFK would not be negatively impacted by the project (USACE 2020a: Section 4.24).

would be unlikely and are expected to be within historic and seasonal variation in the Koktuli River (USACE 2020a: Section 4.16).

Based on information presented in the FEIS, EPA Region 10 has estimated that operation of the 2020 Mine Plan with the addition of treated water would alter (i.e., either increase or decrease) streamflows by more than 20 percent of baseline average monthly flow in at least 29 miles (46.7 km) of anadromous fish streams downstream of the mine site (Figure 4-9, Table 4-5).[59] These streamflow alterations are derived from Table 4-4 (USACE 2020a: Table 4.16-3), which presents changes in average monthly streamflow that would result after the discharge of treated water from the WTPs. These streamflow changes would affect 18.7 miles (30.1 km) or 29 percent of anadromous fish streams in the NFK watershed and approximately 10.4 miles (16.7 km) or 17 percent of anadromous fish streams in the SFK watershed (Giefer and Blossom 2021) (Figure 4-9).

In the majority of the SFK and NFK, streamflow alterations would vary seasonally. Reaches that would experience streamflow reductions between the spring and the winter would also experience streamflow increases between the winter and spring. In total, streamflow reductions exceeding 20 percent of average monthly streamflow would occur in at least one month per year in at least 13.1 miles (21.4 km) of anadromous fish streams downstream of the mine site, specifically in NFK Reach C, Tributaries NFK 1.190 and 1.200, and SFK above Frying Pan Lake (i.e., upstream of SK100G) (Table 4-5). Additionally, operation of the 2020 Mine Plan would increase streamflow by more than 20 percent of baseline average monthly streamflow in at least 25.7 miles (41.3 km) of downstream anadromous fish streams due to WTP discharges (Table 4-5). The majority of streamflow increases would occur in the mainstem NFK, where at least 18.1 miles (29.1 km) would experience seasonal streamflow increases of more than 20 percent of baseline average monthly flow. The remaining 7.6 miles (12.2 km) of anadromous fish streams that would experience streamflow increases of more than 20 percent from baseline average monthly flows are located in the SFK watershed, in the mainstem at Frying Pan Lake and in Tributary SFK 1.240.

[59] The streamflow alteration values presented in FEIS Table 4.16-3 (Table 4-4 here) were estimated using data from specific PLP stream gages or by averaging two gages in the reach (PLP 2019a: RFI 109f). To provide conservative estimates of impacts (i.e., to ensure not to overestimate impacts), streamflow estimates described herein for the mainstem rivers were assigned to the river location of gages identified in RFI 109f (PLP 2019a: RFI 109f), rather than for extended reach lengths downstream. Streamflow alteration estimates were assumed to extend upstream from the source gage to at least the next gage, major confluence point, the mine footprint, or the end anadromous habitat. As a result, streamflow impacts may extend further downstream than stated herein.

Figure 4-9. Streams and rivers with documented salmon use that would experience streamflow alterations greater than 20 percent of baseline average monthly streamflows as a result of the Pebble 2020 Mine Plan. Species distributions are based on the Anadromous Waters Catalog (Giefer and Blossom 2021). Streamflow alteration is assigned at a gage and extends upstream (see Footnote 59 in Section 4.2.4.3 for a discussion of methodology).

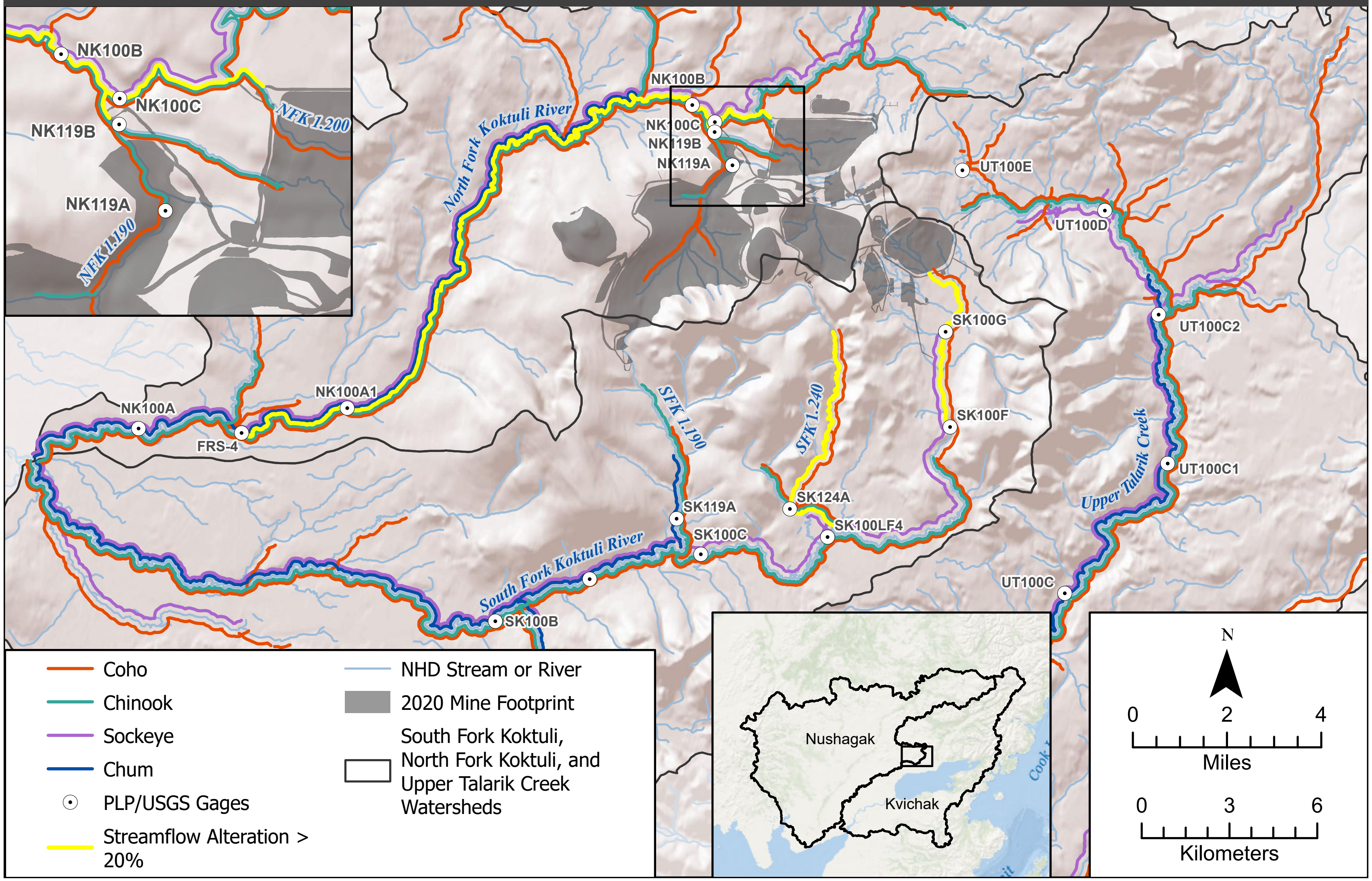


Table 4-5. Salmon species documented to occur in downstream reaches that would experience greater than 20 percent streamflow alterations under the Pebble 2020 Mine Plan.

Stream	Reach [a]	Affected Stream Length (miles) [b]	Information from FEIS Table 4.16-3 (USACE 2020a)		Salmon Species and Life Stages Present [c]			
			Location	Largest Change in Monthly Average Streamflow	Coho	Chinook	Sockeye	Chum
SFK mainstem	Upstream of SK100G	2.8	SFK, Reach E	-53.0%	Rearing	- [g]	- [g]	- [g]
SFK mainstem	SK100G to SK100F	1.4	SFK, Reach D	109.0%	Rearing	- [g]	Rearing	- [g]
SFK tributary	SFK 1.240	6.2 [d]	SFK, Trib 1.24	97.9%	Rearing, present	Present	Rearing	- [g]
NFK tributaries	NFK 1.190	0.27 [e]	NFK, Trib 1.19	-100.0%	Spawning, rearing	Rearing	- [g]	- [g]
NFK tributaries	NFK 1.200	0.36 [e]	NFK, Trib 1.20	- [f]	Rearing, present	Rearing	- [g]	- [g]
NFK mainstem	NFK below Tributary 1.200 and above Tributary 1.190	1.2	NFK, Reach D	170.0%	Spawning, rearing	Rearing	Spawning	- [g]
NFK mainstem	NFK below Tributary 1.190 to FRS-4	9.6	NFK, Reach C	110.2%	Spawning, rearing	Spawning, rearing	Spawning, rearing	Spawning, rearing
NFK mainstem	NFK below Tributary 1.190 to FRS-4	4.6	NFK, Reach B	29.0%	Spawning, rearing	Spawning, rearing	Spawning, rearing	Spawning
NFK mainstem	NFK below Tributary 1.190 to FRS-4	2.7	NFK, Reach A	23.5%	Spawning, rearing	Spawning, rearing	Spawning, rearing	Spawning

Notes:

[a] Reaches defined by stream gages, as shown in Figure 4-9.

[b] Affected lengths were determined by EPA based on information in the FEIS and typically extend upstream from the source gage to at least the end of the FEIS reach, the next upstream gage, major confluence point, the mine footprint, or the end of documented anadromous fish streams.

[c] From the Anadromous Waters Catalog (Giefer and Blossom 2021).

[d] This length includes the entirety of Tributary SFK 1.240 down to its confluence with Tributary SFK 1.260.

[e] This length is the extent that is assumed would still be accessible to anadromous fishes below the sediment pond.

[f] No streamflow information was provided for this reach in FEIS Table 4.16-3 (Table 4-4).

[g] Blanks indicate that the species has not been documented to occur in that reach in the Anadromous Waters Catalog (Giefer and Blossom 2021).

4.2.4.4 Downstream Anadromous Fish Habitat Affected by Streamflow Changes

Changes in surface water and groundwater contributions to streams associated with the discharge of dredged and fill material for the construction and routine operation of the 2020 Mine Plan would reduce both the extent and quality of anadromous fish habitats downstream of the mine site. As described in Section 4.2.1, little or no spawning or rearing habitat for Coho and Chinook salmon would remain in Tributary NFK 1.190 due to placement of mine site features just upstream of its confluence with the mainstem NFK; most of Tributary NFK 1.200 also would be eliminated by the main WMP (Figure 4-9). The FEIS states that the expected loss of headwater aquatic habitats, including 125 acres (0.5 km^2) of riverine wetlands, would affect downstream surface water flows and groundwater exchange, resulting in impacts to aquatic resources in approximately 66 miles (106.2 km) of streams. The duration of flow changes would be permanent, beginning at project construction, continuing through mine operations, and remaining post-closure (USACE 2020a: Section 4.24).

The most notable streamflow reductions downstream of the mine site would occur in the 2.8-mile (3.4-km) reach of anadromous fish habitat in the SFK mainstem leading to Frying Pan Lake, immediately below the open pit drawdown zone, in which average monthly streamflow would be reduced by between 32 and 53 percent from the baseline average monthly streamflow in every month of the year (Tables 4-4 and 4-5). These affected reaches provide juvenile rearing habitat for Coho Salmon (Giefer and Blossom 2021).

As a result of dewatering at the open pit, streamflow reductions in the SFK would reduce natural inflows to Frying Pan Lake, a 150-acre (0.6 km^2) shallow lake located on the SFK, 2.5 miles (4.0 km) downstream of the open pit (Figure 4-1). Frying Pan Lake provides rearing habitat for juvenile Coho and Sockeye salmon, as well as other resident fishes (ADF&G 2022a). As previously discussed, WTP discharges would be used to mitigate these streamflow reductions. Even with such WTP discharges, there would still be net reductions in streamflow between May and October, when streamflow at gage SK100F is estimated to be reduced between 10.2 to 15 percent below the baseline average monthly flow. During the winter and spring, WTP discharges would go beyond offsetting streamflow reductions and result in significant streamflow increases: average monthly streamflow would increase 27.5 percent over the baseline average monthly streamflow in February, 50.9 percent over baseline in March, and 109 percent over baseline in April (Figure 4-9, Table 4-4). Sustaining such increases above the natural flow regime for months at a time could have a dramatic effect on aquatic resources associated with this reach of the SFK.

These impacts to streamflow in the SFK would continue some distance downstream of gage SK100F, but it is unclear how far due to a lack of detail in the FEIS (USACE 2020a: Section 4.16). The next downstream location for which streamflow data are presented in Table 4-4 (FEIS Table 4.16-3) is SFK Reach C, based on streamflow at gage SK100C (PLP 2019a: RFI 109f), 11.7 river miles (18.9 km) downstream of SK100F (PLP 2020d: RFI 161). At this point, impacts to streamflow resulting from operations at the mine would be less than 5 percent below baseline average monthly flow, assuming streamflow and WTP discharges occurred as modeled during the average climatic year.

Reductions in streamflow would also affect 5.1 miles (8.2 km) of anadromous fish spawning and rearing habitat in Tributary SFK 1.190 (USACE 2020a: Section 4.24), due to water captured in the south seepage recycle pond and returned to the bulk TSF main seepage pond (Figure 4-1; USACE 2020a: Section 4.16). Tributary SFK 1.190 would experience streamflow reductions every winter and spring ranging between approximately 12.6 percent (in December) to the maximum reduction of 19 percent (in April) below the baseline average monthly streamflow (Table 4-4).

The streamflow estimates for this tributary were generated based on streamflow gage SK119A (PLP 2019a: RFI 109f), approximately 3 miles (4.8 km) downstream of mine footprint components associated with the south embankment of the bulk TSF, including a seepage collection system and sediment pond. The upper reaches of Tributary SFK 1.190 closest to the mine are expected to experience even greater reductions in streamflow compared to those estimated at streamflow gage SK119A. The upper extent of anadromous fish habitat is Chinook Salmon rearing habitat, located within approximately 600 feet (182.9 m) of the mine footprint. Coho Salmon also use this tributary for rearing beginning approximately 1.3 miles (2.1 km) downstream of the mine footprint, and Chum Salmon are present approximately 1.8 miles (2.9 km) downstream of the mine footprint (Giefer and Blossom 2021). The FEIS indicates Sockeye Salmon are also present in this reach. Although streamflow reductions in Tributary SFK 1.190 are estimated to reach only 19 percent below baseline average monthly streamflow, the FEIS predicts these reductions would nonetheless result in losses of spawning habitat area in Tributary SFK 1.190. These losses would eliminate 18.1, 13, 5.9, and 8.6 percent of spawning habitat for Chinook, Coho, Chum, and Sockeye salmon, respectively, in Tributary SFK 1.190 during an average climatic year (USACE 2020a: Table K4.24-1).[60]

Streamflow reductions would also be expected in mainstem reaches of the SFK and NFK during spring, summer, and fall. In total, approximately 21.4 miles (34.4 km) of the SFK and NFK would experience some degree of streamflow reduction from baseline conditions between May through late fall or winter due to loss of headwater and groundwater contributions. These reaches would also experience seasonal increases from baseline average monthly streamflow between January and April due to discharges of surplus water. For example, average monthly streamflow in the mainstem NFK below the mine site (i.e., NFK Reach C) would vary from 110.2 percent more flow in April to 20.4 percent less in June relative to baseline average monthly streamflows (Table 4-4).

Streamflow reductions in the NFK would extend 16.9 miles (27.2 km) downstream of the mine site. These reductions would begin in NFK Reach C below the confluence with Tributary NFK 1.190 (Figure 4-9), where streamflow would be reduced by more than 20 percent from the baseline average monthly flow. Streamflow reductions would continue downstream to at least stream gage FRS-4, where streamflow is estimated to be reduced by 12 to 13 percent from the baseline average monthly flow (Tables 4-4 and 4-5, Figure 4-9). These NFK reaches provide spawning and rearing habitat for Chinook, Coho, Sockeye, and Chum salmon (Table 4-5, Figure 4-9) and these streamflow reductions would affect at least 26 percent of the anadromous fish habitat in the NFK watershed (Giefer and Blossom 2021). The FEIS predicts a loss of Chinook spawning habitat area in all NFK reaches downstream of the mine site: 9.9 percent in NFK Reach C, 3.3 percent in NFK Reach B, and 1.8 percent in NFK Reach A (USACE 2020a: Table K4.24-1).[61]

Across the SFK and NFK watersheds, although treated water discharges were included, streamflow would still be reduced by more than 20 percent from the baseline average monthly flow in at least one month of the year in approximately 13.1 miles of anadromous fish streams, specifically in NFK Reach C, Tributaries NFK 1.190 and 1.200, and SFK above Frying Pan Lake (i.e., upstream of SK100G) (Table 4-5, Figure 4-9).

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[60] EPA Region 10 believes the habitat losses described in the FEIS under-represent impacts on downstream anadromous fish streams (Appendix B: Sections B.3 and B.4).

[61] EPA Region 10 believes the habitat losses described in the FEIS under-represent impacts on downstream anadromous habitat area (Appendix B: Sections B.3 and B.4).

Operation of the 2020 Mine Plan would also increase streamflow by more than 20 percent of baseline average monthly streamflow in at least 25.7 miles (41.3 km) of anadromous fish streams due to WTP discharges (Table 4-5). The majority of streamflow increases would occur in the mainstem NFK, where at least 18.1 miles (29.1 km) would seasonally experience streamflow increases of more than 20 percent of baseline average monthly flow. These 18.1 miles (29.1 km) include the 16.9 miles (27.2 km) of the mainstem NFK (i.e., down to gage FRS-4) that would also experience some degree of streamflow reduction between May and December, and the remaining 1.2 miles (1.9 km) of the NFK between the confluence of Tributaries NFK 1.200 and 1.190, where WTP discharges would result in increases to flow year-round.

The remaining 7.6 miles (12.2 km) of anadromous fish streams that would experience streamflow increases of more than 20 percent from baseline average monthly flow are the SFK between SK100G and SK100F and Tributary SFK 1.240 (Table 4-5, Figure 4-9). Increases in the SFK would result from WTP discharges to Frying Pan Lake, and Tributary SFK 1.240 would receive discharges from a diversion channel of non-contact water collected around the project's infrastructure (Knight Piésold 2019b).

In an effort to optimize fish habitat farther downstream, reaches closest to the WTP discharge points would experience more dramatic increases in streamflow velocities that could impede salmon migration, particularly for juveniles. For example, NFK Reach D, immediately downstream of the WTP discharge point, would experience streamflow increases of 101 to 170 percent from baseline average monthly flow every month between January and April (Table 4-4). This reach provides spawning habitat for Coho and Sockeye salmon, and rearing habitat for juvenile Coho and Chinook salmon (Giefer and Blossom 2021). Habitat quality for juvenile salmon rearing and benthic macroinvertebrates could be degraded due to increased scour and mobilization of sediments and increased turbidity. Streamflow increases would be expected to dissipate farther downstream from the mine site, but even the most downstream NFK point evaluated (i.e., PLP's project-specific stream gage FRS-4, which was used to estimate streamflow in NFK Reach A) would vary from 23.5 percent more to 12.1 percent less than the baseline average monthly streamflow (Table 4-4). Based on information in the FEIS, these streamflow increases would likely extend down to the confluence of the SFK and NFK (USACE 2020a: Section 4.16).

4.2.4.5 Adverse Effects of Streamflow Changes in Downstream Anadromous Fish Streams

Streamflow reductions of the extent and duration predicted by analysis of streamflow data associated with the 2020 Mine Plan could reduce instream habitat availability, particularly during periods of natural low flows; fragment stream habitats; and preclude normal seasonal movements by anadromous and migratory resident fishes (West et al. 1992, Cunjak 1996, EPA 2014: Chapter 7). Diminished streamflows would also likely reduce the frequency and duration of connectivity to off-channel habitats such as side channels, riparian wetlands, and beaver ponds, reducing the spatial extent of such habitats or eliminating them altogether. At present, some off-channel habitats likely connect to the main channels at least during annual spring and fall floods (Section 3.2.4). The loss of access to off-channel areas, particularly those with groundwater connectivity, would remove critical rearing habitats for several species of juvenile salmonids (Table 3-10) (Quinn 2005, Huntsman and Falke 2019).

Groundwater drawdown associated with dewatering the open pit would be responsible for much of the predicted streamflow reductions. The loss of groundwater inputs in affected reaches would not only reduce streamflow volumes, but would also have profound adverse impacts on stream thermal regimes (EPA 2014: Chapter 7). The FEIS predicts temperature changes from -1.6 to +2.8 °C in the SFK, NFK, and UTC drainages from about 0.5 to 2.75 miles downstream of WTP discharges (USACE 2020a: Section 4.18). Warmer summer water temperatures could limit summer habitat for salmon, whereas colder winter water temperatures could adversely affect egg development, hatching, and emergence timing (Brannon 1987, Beacham and Murray 1990, Hendry et al. 1998, Quinn 2005). The threshold between completely frozen and partially frozen streams can be a narrow one (Irons et al. 1989), especially for small streams with low winter groundwater discharge such as many of the headwater streams in the SFK, NFK, and UTC watersheds. Predicted reductions in flow and associated changes in thermal regimes could substantially alter fish habitat, particularly the extent of critical unfrozen overwintering habitat (Huusko et al. 2007, Brown et al. 2011).

Warmer summer and colder winter temperatures resulting from the loss of groundwater inputs also would likely change the species composition and richness of macroinvertebrates, a key food for juvenile salmonids, and alter overall macroinvertebrate abundance and productivity in the affected reaches (e.g., Campbell et al. 2020). In addition to changes in species composition and richness of macroinvertebrates, reduced hydrologic connectivity between streams and riparian wetlands would also likely reduce or eliminate the export of detritus, macroinvertebrates, and other ecological subsidies from wetlands and off-channel habitats to streams.

Reduced streamflows would also likely change sediment transport dynamics, resulting in the deposition of more or finer sediment that could smother eggs or render stream substrates less suitable for spawning. Streambed aggradation from increased sedimentation could lead to further hydrologic modification, loss of habitat complexity, simplification of pools important for rearing salmon, and outright loss or fragmentation of habitat. Lower streamflows could also result in reduced dissolved oxygen levels. Taken together, streamflow changes could alter channel geometry and destabilize channel structure, with effects propagating downstream.

At the other extreme, streamflow increases greater than 20 percent likely would degrade habitat suitability for salmon (EPA 2014: Chapter 7). Brekkan et al. (2022: Page 8) conclude that the stream type at the mainstem SFK, NFK, and UTC immediately downstream of the mine site is "very susceptible to scour and erosion and can be significantly altered and rapidly de-stabilized by channel or landscape disturbances and changes in the flow or sediment regimes of the contributing watershed." As result, increases in streamflow could increase mobilization of sediments, leading to altered spawning gravel quality, reduced survival of salmon eggs that could be scoured or buried (Buffington et al. 2004), or reduced foraging efficiency of juvenile salmon (Bjornn and Reiser 1991). Increased streamflows could also eliminate off-channel habitat through the erosion of streambanks, and could reduce invertebrate populations as a result of streambed scour and erosion.

Moreover, WTP discharges would also significantly change stream temperatures (EPA 2014: Chapter 8).[62] Because the timing of salmon migration, spawning, and incubation is closely tied to seasonal water temperatures, any change in the thermal regime could disrupt life history timing cues and result in mismatches between fishes and their environments that adversely affect survival (Angilletta et al. 2008). Thus, streamflow reductions resulting from the loss of temperature-moderating groundwater inputs or streamflow increases resulting from temperature-altering WTP discharges could reduce diversity of run timing and other salmon life history traits (Hodgson and Quinn 2002, Rogers and Schindler 2011, Ruff et al. 2011), which play an important role in creating and maintaining biocomplexity (Section 3.3.3). Although fish populations may be adapted to periodic disturbances associated with natural flow variability (Poff et al. 1997, Matthews and Marsh-Matthews 2003), changes that disrupt life history timing cues can adversely affect survival; prolonged changes in streamflow regimes could have longer-term impacts on fish populations (Jensen and Johnsen 1999, Lytle and Poff 2004).

Overall, the adverse effects of flow alteration on stream and off-channel habitats could substantially reduce spawning success for Coho Salmon, survival of overwintering Coho, Chinook, and Sockeye salmon, and ultimately Coho, Chinook, and Sockeye salmon productivity in the SFK and NFK watersheds. Many of the effects of substantially altered streamflows would reverberate downstream beyond the directly affected waters, due to reduced quantity and diversity of available food sources such as macroinvertebrates and reduced success of upstream salmon spawning and rearing. Streamflow changes associated with the 2020 Mine Plan also would affect many other factors that determine high-quality salmon habitat (e.g., water depth and velocity, substrate size, groundwater exchange, water temperature, food availability), although effects of streamflow on these other factors are not evaluated in the FEIS (see Appendix B).

As with the habitat losses and degradation described in Sections 4.2.1 through 4.2.3, adverse impacts of streamflow modification would adversely affect downstream habitat for salmon (Sections 3.2.4 and 4.2.1, Figure 4-3 through 4-5). These downstream waters are ecologically important and provide spawning and rearing habitat for Coho, Chinook, Sockeye, and Chum salmon in the SFK and NFK watersheds (Figures 4-2 and 4-3). The magnitude and extent of streamflow changes expected would degrade downstream anadromous fish streams and adversely affect genetically distinct populations of Sockeye Salmon in the Koktuli River (including the SFK and NFK) and Coho and Chinook salmon populations that may be uniquely adapted to the spatial and temporal conditions of their natal streams (Section 3.3.1). As explained for the loss of 8.5 miles (13.7 km) of anadromous fish streams, the loss and degradation of downstream anadromous fishery areas in the SFK and NFK watersheds that would result from elimination of approximately 2,113 acres (8.6 km^2) of wetlands and other waters would further erode both habitat complexity and biocomplexity within these watersheds. This diversity of salmon habitats and associated salmon population diversity helps buffer these salmon populations from sudden and extreme changes in abundance and ultimately maintain their stability and productivity.

[62] The extent and duration of temperature changes would depend on the temperature, quantity, and timing of WTP discharges, as well as the influence of other inputs such as groundwater and tributary inflows.

Once mining stops, potentially acid generating waste rock and pyritic tailings would be backfilled into the open pit. Water would continue to be pumped from the open pit during backfilling. After backfilling is complete (approximately 16 years after mine closure), the open pit would gradually refill with water, which would begin to restore groundwater inputs to downstream flows (Knight Piésold 2019b). Refilling of the pit during the closure phase is estimated to take approximately 8 years, (Knight Piésold 2019b). Although groundwater contributions to the SFK would eventually return to pre-mine conditions, the time periods required for this return far exceed the 2- to 5-year life spans of Coho, Chinook, and Sockeye salmon. Thus, long-term severe degradation of spawning and rearing habitat for these species could be sustained for several generations.

As previously discussed, proposed water management under the 2020 Mine Plan uses treated discharges to offset some of the streamflow reductions and address stream habitat losses. According to the FEIS, treated water releases would be discharged on a monthly basis in direct proportion to the water captured from each of the three watersheds in the mine footprint area, and discharges would be managed to optimize downstream priority fish species and life stages. However, the complexity inherent in surface water–groundwater interactions in the SFK, NFK, and UTC watersheds makes prediction, regulation, and control of such interactions during large-scale landscape development very difficult (Hancock 2002). Adequately protecting the critical services that groundwater provides to fishes, via its influence on surface waters, is complicated by the fact that groundwater flow paths vary at multiple scales and connections between distant recharge areas and local groundwater discharge areas are difficult to predict (Power et al. 1999).

4.2.4.6 Impacts on Other Fish Species

Although this proposed determination is based solely on adverse effects on anadromous fishery areas, EPA Region 10 notes that anadromous fish streams that would be degraded by these alterations in streamflow also provide habitat for non-anadromous fish species (Figures 4-10 and 4-11). The assemblage of non-anadromous fishes found in and supported by these streams is an important component of these habitats and further underscores the biological integrity and ecological value of these pristine, intact stream networks. The SFK mainstem that would be subject to streamflow alterations downstream from the mine provides habitat for Arctic Grayling, Northern Pike, sculpin, and stickleback. Streamflow alterations in Tributary SFK 1.190 would affect habitat for Arctic Grayling, Dolly Varden, sculpin, and stickleback. Streamflow alterations in Tributary SFK 1.240 would affect habitat for these same species plus Northern Pike (ADF&G 2022a).

In the NFK watershed, secondary effects of downstream flow alteration would affect mainstem NFK habitats for Arctic Grayling, Dolly Varden, Rainbow Trout, Round Whitefish, and sculpin. Dolly Varden, Northern Pike, and Arctic Grayling are harvested in downstream subsistence and recreational fisheries (Section 4.2.1). Thus, in addition to providing salmon habitat, streams that would be affected by streamflow alterations also provide habitat for other non-anadromous fish species important to subsistence and recreational fisheries.

Figure 4-10. Streams and rivers with occurrence of Arctic Grayling, Rainbow Trout, and Dolly Varden that would experience streamflow changes as a result of the Pebble 2020 Mine Plan. Species distributions are based on the Alaska Freshwater Fish Inventory (ADF&G 2022a). Streamflow alteration is assigned at a gage and extends upstream (see Footnote 59 in Section 4.2.4.3 for a more detailed discussion of methodology).

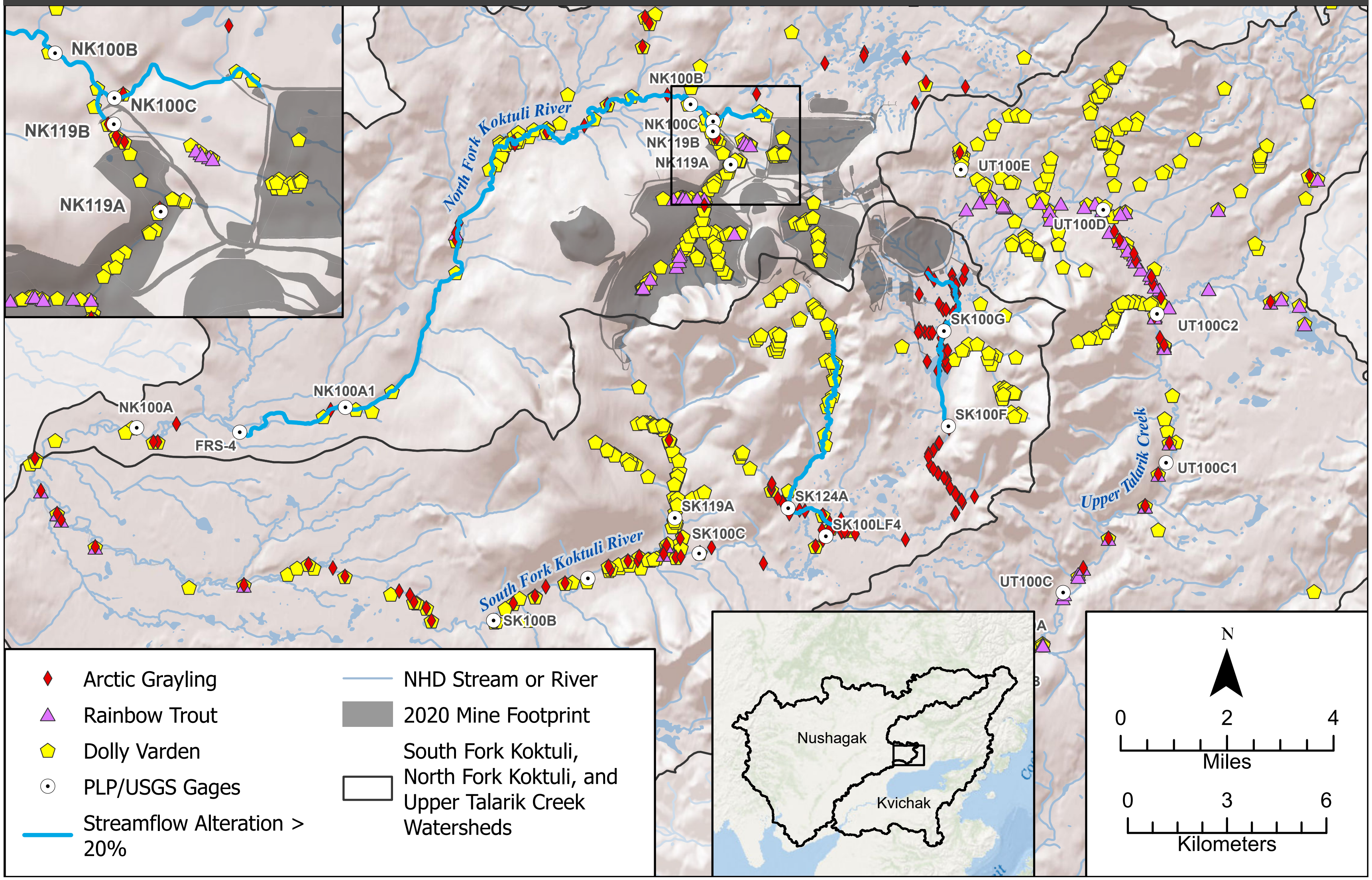
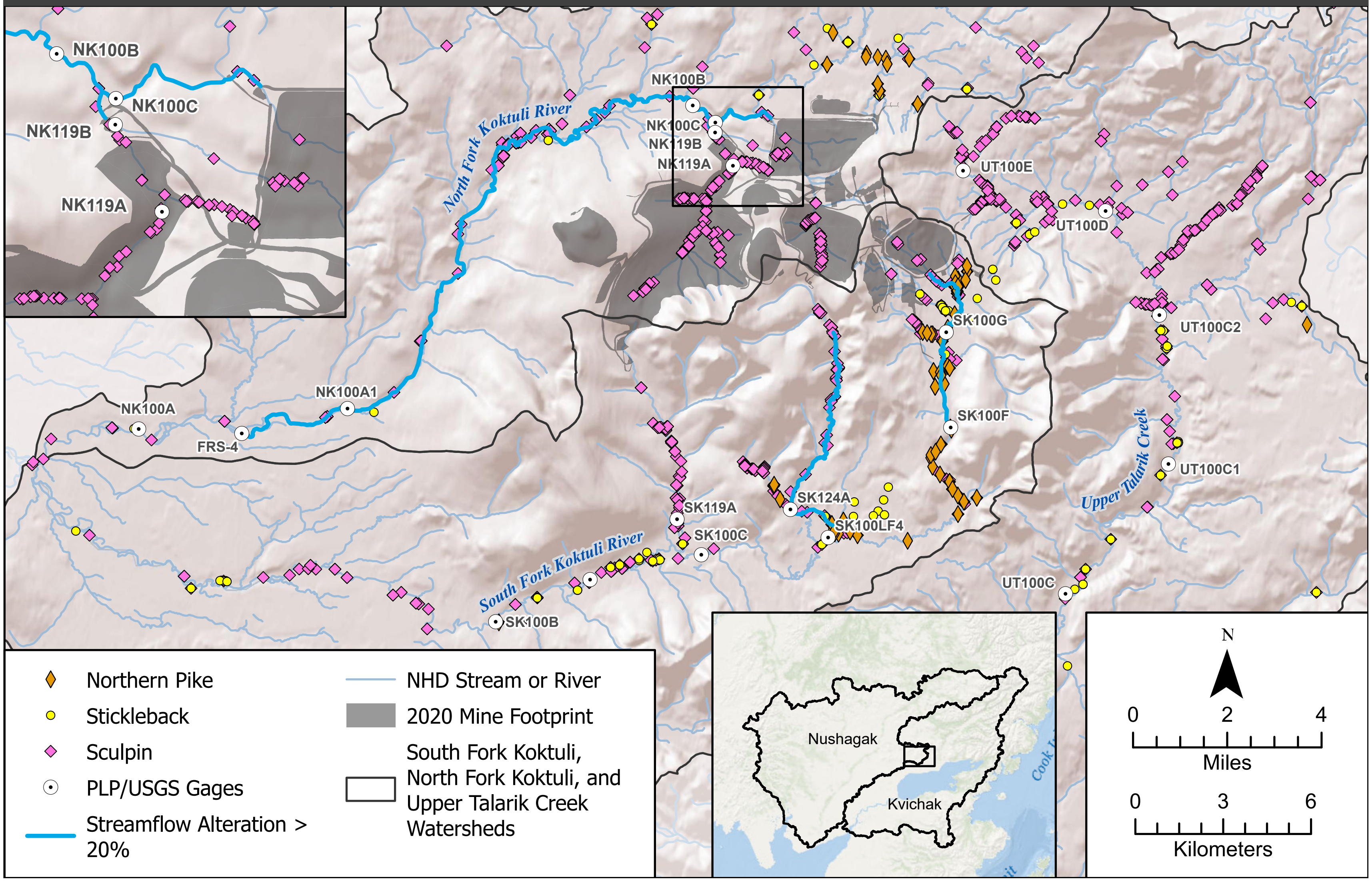


Figure 4-11. Streams and rivers with occurrence of other resident fish species that would experience streamflow changes as a result of the Pebble 2020 Mine Plan. Species distributions are based on the Alaska Freshwater Fish Inventory (ADF&G 2022a). Streamflow alteration is assigned at a gage and extends upstream (see Section 4.2.4.2 for a more detailed discussion of methodology).



4.2.4.7 Summary

EPA Region 10 believes that the discharge of dredged or fill material for the construction and routine operation of the 2020 Mine Plan, resulting in streamflow alterations greater than 20 percent of average monthly streamflow in approximately 29 miles (46.7 km) of anadromous fish streams, could have unacceptable adverse effects on anadromous fishery areas in the SFK and NFK watersheds. This conclusion is based on the following factors: the large extent and magnitude of streamflow changes in anadromous fish streams; the corresponding degradation of anadromous fish streams, including spawning and rearing habitat for Coho, Chinook, Sockeye, and Chum salmon, resulting from these streamflow changes; and the resulting erosion of both habitat complexity and biocomplexity within the SFK and NFK watersheds, which are key to the abundance and stability of salmon populations within these watersheds. This conclusion supports the proposed prohibition described in Section 5.1.

Further, based on the same record, EPA Region 10 believes the discharge of dredged or fill material associated with mining the Pebble deposit anywhere in the SFK, NFK, and UTC watersheds, resulting in streamflow alterations greater than 20 percent of average monthly streamflow in approximately 29 miles (46.7 km) of anadromous fish streams, could have unacceptable adverse effects on anadromous fishery areas in these watersheds. This conclusion is based on the following factors: the pristine condition and productivity of anadromous fish streams throughout the SFK, NFK, and UTC watersheds (Section 3); the large extent and magnitude of streamflow changes in anadromous fish streams; the corresponding degradation of anadromous fish streams, including spawning and rearing habitat, resulting from these streamflow changes; and the resulting erosion of both habitat complexity and biocomplexity within the SFK, NFK, and UTC watersheds, which are key to the abundance and stability of salmon populations within these watersheds. This conclusion supports the proposed restriction described in Section 5.2.

4.2.5 Summary of Effects on Fishery Areas from Construction and Routine Operation of the 2020 Mine Plan

In summary, EPA Region 10 has reason to believe that discharges of dredged or fill material into waters of the United States for the construction and routine operation of the 2020 Mine Plan could result in unacceptable adverse effects on anadromous fishery areas (Sections 4.2.1 through 4.2.4). EPA Region 10 also has reason to believe that discharges of dredged or fill material associated with future plans to mine the Pebble deposit could result in unacceptable adverse effects on anadromous fishery areas in the SFK, NFK, and UTC watersheds if the effects of such discharges are similar or greater in nature and magnitude to those described in Sections 4.2.1 through 4.2.4.

4.3 Compliance with Relevant Portions of the Section 404(b)(1) Guidelines

EPA has broad discretion under CWA Section 404(c) in evaluating and determining whether a discharge would result in an "unacceptable adverse effect" on fishery areas, including breeding and spawning areas. EPA Region 10 has concluded that discharges of dredged or fill material for the construction and routine operation of the 2020 Mine Plan could have unacceptable adverse effects on anadromous fishery areas, as described in Section 4.2.

EPA's Section 404(c) regulations at 40 CFR 231.2(e) provide that in evaluating the "unacceptability" of effects, consideration should be given to the "relevant portions of the Section 404(b)(1) Guidelines." As detailed in this section, evaluation of compliance with relevant portions of the Guidelines supports and confirms EPA Region 10's preliminary conclusion that discharges of dredged or fill material for the construction and routine operation of the 2020 Mine Plan could result in unacceptable adverse effects on anadromous fishery areas.

For the purposes of evaluating the unacceptability of effects from discharges of dredged or fill material associated with the 2020 Mine Plan, EPA Region 10 evaluated the following portions of the Section 404(b)(1) Guidelines in the manner discussed in this section:

- Significant degradation of waters of the United States (40 CFR 230.10(c))
  - Cumulative effects (40 CFR 230.11(g))
  - Secondary effects (40 CFR 230.11(h))
- Minimization of adverse impacts on aquatic ecosystems (40 CFR 230.10(d))

4.3.1 Significant Degradation

The Section 404(b)(1) Guidelines direct that no discharge of dredged or fill material shall be permitted if the discharge will cause or contribute to significant degradation of waters of the United States (40 CFR 230.10(c)). Of particular relevance, the Guidelines state that effects contributing to significant degradation, considered individually or collectively, include the following:

1. Significantly adverse effects of the discharge of pollutants on human health or welfare, including but not limited to effects on municipal water supplies, plankton, fish, shellfish, wildlife, and special aquatic sites;
2. Significantly adverse effects of the discharge of pollutants on life stages of aquatic life and other wildlife dependent on aquatic ecosystems, including the transfer, concentration, and spread of pollutants or their byproducts outside of the disposal site through biological, physical, and chemical processes;
3. Significantly adverse effects of the discharge of pollutants on aquatic ecosystem diversity, productivity, and stability. Such effects may include, but are not limited to, loss of fish and wildlife habitat or loss of the capacity of a wetland to assimilate nutrients, purify water, or reduce wave energy; and

4. Significantly adverse effects of discharge of pollutants on recreational, aesthetic, and economic values.

Findings of significant degradation related to proposed discharges must be based on appropriate factual determinations, evaluations, and tests, as described in 40 CFR 230.11, with special emphasis on the persistence and permanence of the effects evaluated.

EPA's regulations at 40 CFR 230.5 identify the stepwise process to assess the potential for significant degradation. The assessment of impacts pursuant to subparts C through F (40 CFR 230.20–230.54) informs the required factual determinations found in 40 CFR 230.11. The factual determinations, in turn, inform the significant degradation finding and the finding of compliance or non-compliance with the Guidelines. The Guidelines require the consideration of potential losses of environmental characteristics or values resulting from direct, secondary, and cumulative impacts.

4.3.1.1 Direct and Secondary Effects of the 2020 Mine Plan

USACE provided its evaluation of the anticipated impacts from the discharge of dredged or fill material associated with the 2020 Mine Plan under the 404(b)(1) Guidelines (40 CFR Part 230) in its Section 404 ROD (USACE 2020b). USACE concluded the 2020 Mine Plan did not comply with the Section 404(b)(1) Guidelines because impacts to waters of the United States "from discharges of dredged or fill material at the mine site have been determined to cause significant degradation to the aquatic ecosystem" (USACE 2020b: Page B2-2). USACE (2020b) concluded that the discharge of dredged or fill material associated with the 2020 Mine Plan would result in significant adverse effects in all four effects categories in 40 CFR 230.10(c):

- Human health or welfare (40 CFR 230.10 (c)(1)).
- Life stages of aquatic life and other wildlife dependent on aquatic ecosystems (40 CFR 230.10 (c)(2)).
- Aquatic ecosystem diversity, productivity, and stability (40 CFR 230.10 (c)(3)).
- Recreational, aesthetic, and economic values (40 CFR 230.10 (c)(4)).

USACE also concluded that "[t]he proposed avoidance, minimization, or compensatory mitigation measures would not reduce the impacts to aquatic resources from the proposed project to below a level of significant degradation" (USACE 2020b: Page B2-6).

EPA Region 10 also considered relevant portions of the Section 404(b)(1) Guidelines when evaluating the unacceptability of the potential direct and secondary effects of the discharge of dredged or fill material for the construction and routine operation of the 2020 Mine Plan, pursuant to EPA's Section 404(c) regulations at 40 CFR 231.2(e). The following discussion provides an overview of EPA Region 10's evaluation.

4.3.1.1.1 Adverse Effects of Loss of Anadromous Fish Streams

As discussed in Section 4.2.1, the discharge of dredged or fill material for the construction and routine operation of the 2020 Mine Plan would result in the permanent loss of approximately 8.5 miles (13.7 km) of anadromous fish streams. This loss represents approximately 13 percent of the anadromous waters in the NFK watershed.

The anadromous fish streams that the discharge of dredged or fill material associated with the 2020 Mine Plan would permanently eliminate are ecologically valuable, particularly for juvenile salmon (Section 3.2.4). Tributary NFK 1.190 is interconnected with ponds and seasonally to permanently inundated wetlands resulting from beaver activity (USFWS 2021).[63] These features provide excellent rearing habitat and important overwintering and flow velocity refugia for salmonids (Section 3.2.4) (Nickelson et al. 1992, Cunjak 1996, Collen and Gibson 2001, Lang et al. 2006). The permanent loss of anadromous fish streams resulting from discharges of dredged or fill material associated with the 2020 Mine Plan would also result in the loss of salmon spawning habitat, which would, in turn, result in the loss of marine-derived nutrients transported upstream by those fishes. Given the naturally low nutrient concentrations in these streams, these inputs of marine-derived nutrients may be especially important in supporting biological production and, thus, food for juvenile salmonids in these and downstream habitats (Section 3.3.4). These streams also support biological production via inputs of leaf litter from deciduous shrubs and grasses in riparian areas (Meyer et al. 2007, Dekar et al. 2012), which help fuel the production of macroinvertebrates, a key food for salmonids (Table 3-3). Thus, the anadromous fish streams that the 2020 Mine Plan would eliminate, as well as similar habitats in the SFK, NFK, and UTC watersheds, play an important role in the life cycle of salmon.

These anadromous fish stream losses would adversely affect Coho and Chinook salmon populations uniquely adapted to the spatial and temporal conditions of their natal streams (Section 3.3.1). Such adaptation to local environmental conditions results in discrete, genetically distinct populations. This biocomplexity—operating across a continuum of integrated, nested spatial and temporal scales—depends on the abundance and diversity of aquatic habitats in the area and acts to stabilize overall salmon production and fishery resources (Section 3.3.3) (Schindler et al. 2010, Schindler et al. 2018, Brennan et al. 2019). The substantial spatial and temporal extent of stream habitat losses resulting from the discharge of dredged or fill material associated with the 2020 Mine Plan suggest that these losses would reduce the overall capacity and productivity of Coho and Chinook salmon in the entire NFK watershed.

The 8.5 miles (13.7 km) of anadromous fish streams that would be lost are mapped as upper perennial streams (PLP 2020b) and considered special aquatic sites with riffle/pool complexes (USACE 2020b). Under Subpart E of the Guidelines (40 CFR 230.41 and 230.45), special aquatic sites "are generally recognized as significantly influencing or positively contributing to the general overall environmental health or vitality of the entire ecosystem of a region" (40 CFR 230.3 (m)). Loss of these 8.5 miles (13.7

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[63] Connection to such floodplain wetland and pond habitats can greatly enhance the carrying capacity and productive potential of anadromous fish streams (Section 3).

km) of anadromous fish streams is significant due to the effects on fishery areas. These special aquatic sites act as fish habitat and as sources of groundwater inputs, nutrients, and other subsidies important for salmon productivity (Section 3.2.4). Their loss would result in significant adverse effects on fish (40 CFR 230.10(c)(1)), life stages of anadromous fish (40 CFR 230.10(c)(2)), anadromous fish habitat, and aquatic ecosystem diversity, productivity, and stability (40 CFR 230.10(c)(3)).

Further, based on the record, EPA Region 10 believes eliminating approximately 8.5 miles (13.7 km) of anadromous fish streams anywhere in the SFK, NFK, and UTC watersheds, due to the discharge of dredged or fill material associated with mining the Pebble deposit, would result in similar significantly adverse effects on anadromous fish habitats and populations. This conclusion is based on the following factors: the pristine condition and productivity of anadromous streams throughout the SFK, NFK, and UTC watersheds (Section 3); the large amount of permanent loss of anadromous fish habitat; the degradation of additional downstream anadromous fish habitat due to the loss of ecological subsidies provided by the eliminated anadromous fish streams; and the resulting erosion of both habitat complexity and biocomplexity within the SFK, NFK, and UTC watersheds, which are key to the abundance and stability of salmon populations within these watersheds.

4.3.1.1.2 Adverse Effects of Loss of Additional Streams that Support Anadromous Fish Streams

As discussed in Section 4.2.2, the discharge of dredged or fill material for the construction and routine operation of the 2020 Mine Plan would result in the permanent loss of an additional 91.2 miles (146.8 km) of streams that support anadromous fish streams, primarily in the SFK and NFK watersheds. The permanent loss of additional streams would result in reduced stream productivity in downstream reaches of the SFK and NFK due to the loss of physical, chemical, and biological inputs that would no longer be provided to downstream channels. Most of these permanently lost streams (77.0 miles [124 km]) are mapped as upper perennial streams (PLP 2020b) and considered special aquatic sites (USACE 2020b). The loss of upper perennial streams is likely to reduce water-holding capacity of the watershed by eliminating stream pools and meanders, thereby degrading downstream anadromous fish habitat through the reduced capacity for aeration and filtration (USACE 2020b).

The permanent loss of additional streams would adversely affect downstream habitat for salmon and other fish species (Section 3.2.4, Figures 4-3 through 4-5). These downstream waters are ecologically important and provide spawning and rearing habitat for Coho, Chinook, Sockeye, and Chum salmon in the SFK and NFK watersheds (Figures 4-3 and 3-5 through 3-8). Permanent loss of these habitats would adversely affect genetically distinct populations of Sockeye Salmon in the Koktuli River (including the SFK and NFK), as well as Coho and Chinook salmon populations that may be uniquely adapted to the spatial and temporal conditions of their natal streams (Section 3.3.1). As explained for the loss of 8.5 miles (13.7 km) of anadromous fish streams, the loss and degradation of downstream anadromous fishery areas in the SFK and NFK watersheds that would result from elimination of 91.2 miles (146.8 km) of additional streams would further erode both habitat complexity and biocomplexity within these watersheds. This diversity of salmon habitats and associated salmon population diversity helps buffer these salmon populations from sudden and extreme changes in abundance and ultimately maintain their stability and productivity.

These losses would result in significant adverse effects on fish and special aquatic sites (40 CFR 230.10(c)(1)), life stages of anadromous fish (40 CFR 230.10(c)(2)), anadromous fish habitat, and aquatic ecosystem diversity, productivity, and stability (40 CFR 230.10(c)(3)). These impacts are significant due to the effects on downstream anadromous fishery areas (Section 4.2.2) and the extensive loss of special aquatic sites, which are important sources of groundwater inputs, nutrients, and other subsidies crucial to salmon productivity (Section 3.2.4).

Further, based on the same record, EPA Region 10 believes eliminating approximately 91.2 miles (146.8 km) of streams that support anadromous fish streams anywhere in the SFK, NFK, and UTC watersheds, due to the discharge of dredged or fill material associated with mining the Pebble deposit, would result in similar significantly adverse effects on anadromous fish habitats and populations. This conclusion is based on the following factors: the pristine condition of streams in the SFK, NFK, and UTC watersheds and the important role headwater streams play in supporting Pacific salmon populations (Section 3.2.4); the large amount of permanent loss of additional streams and the crucial role that these headwater streams play in providing ecological subsidies to downstream anadromous fish streams; the degradation of downstream anadromous fish streams from the loss of ecological subsidies provided by the lost headwater streams; and the resulting erosion of the habitat complexity and biocomplexity that is key to the uniquely abundant wild SFK, NFK, and UTC salmon stocks.

4.3.1.1.3 Adverse Effects of Loss of Wetlands and Other Waters that Support Anadromous Fish Streams

As discussed in Section 4.2.3, the discharge of dredged or fill material for the construction and routine operation of the 2020 Mine Plan would result in the permanent loss of approximately 2,113 acres (8.6 km^2) of wetlands and other waters, primarily in the SFK and NFK watersheds.

Approximately 2,052 acres (8.3 km^2) of this permanently lost habitat are wetlands, a special aquatic site under the Guidelines. Wetlands and other waters that would be permanently lost play a critically important role in the life cycles of anadromous fishes in the SFK and NFK watersheds (Section 3.2.3) (PLP 2011: Appendix 15.1.D), given that "…all wetlands are important to the greater function and value of ecosystems and subsistence cultures they support" (USACE 2020a: Page 3.22-8). Moreover, wetlands and other waters affected by the 2020 Mine Plan "possess unique ecological characteristics of productivity, habitat, wildlife protection, and other important and easily disrupted values" (USACE 2020a: Page 3.22-1). The permanent removal of wetlands and other waters would destroy habitat, cause mortality of aquatic organisms, and reduce the collective functional capacity and value of wetlands and other waters across multiple watersheds. These permanent losses also would cause the displacement, injury, and/or mortality of species that rely on these aquatic environments for all or part of their life cycles (USACE 2020a: Section 4.22).

The discharge of dredged or fill material to these aquatic resources is expected to reduce the biological productivity of wetland ecosystems by smothering, dewatering, permanently flooding, or altering substrate elevation or the periodicity of water movement (USACE 2020a: Section 4.22). The loss of such waters would eliminate structurally complex and thermally and hydraulically diverse habitats, including crucial overwintering areas, that are essential to rearing salmonids.

In addition to the direct loss of habitat, loss of these wetlands and other waters would result in a total loss of their functions that support fish habitat, such as supplying nutrients and organic material and maintaining baseflows, in both abutting and downstream waters (Section 3.2.4). Downstream waters that would be degraded by the elimination of wetlands and other waters at the mine site are ecologically important and provide rearing and spawning habitat for Coho, Chinook, Sockeye, and Chum salmon in the SFK and NFK watersheds (Figures 3-5 through 3-8). This degradation of downstream anadromous fish streams would adversely affect genetically distinct populations of Sockeye Salmon in the Koktuli River (including the SFK and NFK) and Coho and Chinook salmon populations that may be uniquely adapted to the spatial and temporal conditions of their natal streams (Section 3.3.1). As explained for the loss of 8.5 miles (13.7 km) of anadromous fish streams, the loss and degradation of downstream anadromous fishery areas in the SFK and NFK watersheds that would result from elimination of 2,113 acres (8.6 km^2) of wetlands and other waters would further erode both habitat complexity and biocomplexity within these watersheds. This diversity of salmon habitats and associated salmon population diversity helps buffer these salmon populations from sudden and extreme changes in abundance and ultimately maintain their stability and productivity.

These losses would result in significant adverse effects on fishes and special aquatic sites (40 CFR 230.10(c)(1)), life stages of anadromous fishes (40 CFR 230.10(c)(2)), anadromous fish habitat, and aquatic ecosystem diversity, productivity, and stability (40 CFR 230.10(c)(3)). These losses are significant due to their effects on downstream anadromous fishery areas and the extensive loss of special aquatic sites, which are key sources of groundwater inputs, nutrients, and other subsidies important for salmon productivity (Section 3.2).

Further, based on the same record, EPA Region 10 believes eliminating approximately 2,113 acres (8.6 km^2) of wetlands and other waters anywhere in the SFK, NFK, and UTC watersheds, due to the discharge of dredged or fill material associated with mining the Pebble deposit, would result in similar significantly adverse effects on anadromous fish habitats and populations. This conclusion is based on the following factors: the pristine condition of wetlands and other waters in the SFK, NFK, and UTC watersheds and the important role headwater wetlands and other waters play in supporting Pacific salmon populations (Section 3.2.4); the large amount of wetlands and other waters that would be permanently lost; the importance of wetlands and other waters to salmon populations, both as habitat and as sources of groundwater inputs, nutrients, and other subsidies crucial to salmon productivity in downstream waters; the degradation of downstream anadromous fish streams from the loss of ecological subsidies provided by the lost headwater wetlands and other waters; and the resulting erosion of the habitat complexity and biocomplexity that are key to the uniquely abundant wild SFK, NFK, and UTC salmon stocks.

4.3.1.1.4 Adverse Effects from Changes in Streamflow in Downstream Anadromous Fish Streams

As discussed in Section 4.2.4, the discharge of dredged or fill material for the construction and routine operation of the 2020 Mine Plan would result in streamflow alterations greater than 20 percent of average monthly streamflow in approximately 29 miles (46.7 km) of anadromous fish streams in the SFK and NFK watersheds. These changes in streamflow would alter the natural flow regimes of these systems (Poff et al. 1997) and could result in major changes in ecosystem structure and function (Richter et al. 2012), both of which could significantly reduce the extent and quality of anadromous fish habitats downstream of the mine site. Streamflow reductions would reduce habitat availability for salmon and other fishes, particularly during low-streamflow periods (West et al. 1992, Cunjak 1996); reduce macroinvertebrate production (Chadwick and Huryn 2007); and increase stream habitat fragmentation due to increased frequency and duration of stream drying. Increases in streamflow above baseline levels could result in increased scour and transport of gravels, affecting important salmon spawning areas (Brekken et al. 2022). Increased streamflows could also adversely affect distributions of water velocities favorable for various fish life stages (Piccolo et al. 2008, Donofrio et al. 2018).

As with the habitat losses and degradation described previously (Section 4.3.1.1) and in Sections 4.2.1 through 4.2.3, streamflow alterations would adversely affect downstream habitats for salmon and other fish species (Section 3.2.4, Figures 4-3 through 4-5). These downstream waters are ecologically important and provide spawning and rearing habitat for Coho, Chinook, Sockeye, and Chum salmon in the SFK and NFK watersheds (Figures 4-3 and 3-5 through 3-8).

These streamflow changes would result in significant adverse effects on fishes and special aquatic sites (40 CFR 230.10(c)(1)), on life stages of anadromous fishes (40 CFR 230.10(c)(2)), anadromous fish habitat, and aquatic ecosystem diversity, productivity, and stability (40 CFR 230.10(c)(3)). These streamflow changes would degrade downstream anadromous fish streams, adversely affecting genetically distinct populations of Sockeye Salmon in the Koktuli River (including the SFK and NFK) and Coho and Chinook salmon populations that may be uniquely adapted to the spatial and temporal conditions of their natal streams (Section 3.3.1). As explained for the loss of 8.5 miles (13.7 km) of anadromous fish streams, the loss and degradation of downstream anadromous fishery areas in the SFK and NFK watersheds that would result from streamflow alterations greater than 20 percent of average monthly streamflow in approximately 29 miles (46.7 km) of anadromous fish streams would further erode both habitat complexity and biocomplexity within these watersheds. This diversity of salmon habitats and associated salmon population diversity helps buffer these salmon populations from sudden and extreme changes in abundance and ultimately maintain their stability and productivity.

Further, based on the same record, EPA Region 10 believes streamflow alterations greater than 20 percent of average monthly streamflow in approximately 29 miles (46.7 km) of anadromous fish streams anywhere in the SFK, NFK, and UTC watersheds, due to the discharge of dredged or fill material associated with mining the Pebble deposit, would result in similar significantly adverse effects on anadromous fish habitats and populations. This conclusion is based on the following factors: the pristine condition and productivity of anadromous streams throughout the SFK, NFK, and UTC watersheds

(Section 3); the large extent and magnitude of the streamflow changes to anadromous fish streams; the corresponding degradation of anadromous fish streams, including spawning and rearing habitat, that would result from these streamflow changes; and the resulting erosion of the habitat complexity and biocomplexity that are key to the uniquely abundant wild SFK, NFK, and UTC salmon stocks (Section 4.2.4).

4.3.1.1.5 Summary

EPA Region 10 has determined that direct and secondary impacts of the discharge of dredged or fill material for the construction and routine operation of the 2020 Mine Plan, as well as discharges that would result in effects similar or greater in nature and magnitude to the 2020 Mine Plan, would result in significant degradation under the Section 404(b)(1) Guidelines. These findings are based on the significantly adverse effects of the discharge of dredged or fill material on special aquatic sites; life stages of anadromous fishes; anadromous fish habitat; and aquatic ecosystem diversity, productivity, and stability under the Section 404(b)(1) Guidelines.

EPA Region 10 recognizes that losses and degradation of these aquatic resources could be even more pronounced when the extensive cumulative impacts on the aquatic ecosystem expected to occur with successive stages of mine expansion are considered (Section 4.3.1.2).

4.3.1.2 Cumulative Effects of Mine Expansion

The Guidelines describe as "fundamental" the "precept that dredged or fill material should not be discharged into the aquatic ecosystem, unless it can be demonstrated that such a discharge will not have an unacceptable adverse impact either individually or in combination with known and/or probable impacts of other activities affecting the ecosystems of concern" (40 CFR 230.1(c)). The Guidelines require consideration of cumulative impacts in determining whether a project complies with the significant degradation prohibition of 40 CFR 230.10(c). The Guidelines state that "cumulative effects attributable to the discharge of dredged or fill material…should be predicted to the extent reasonable and practical." 40 CFR 230.11(h)(2). The Guidelines describe "cumulative effects" as follows:

> The changes in an aquatic ecosystem that are attributable to the collective effect of a number of individual discharges of dredged or fill material. Although the impact of a particular discharge may constitute a minor change in itself, the cumulative effect of numerous such piecemeal changes can result in a major impairment of the water resources and interfere with the productivity and water quality of existing aquatic ecosystems (40 CFR 230.11(g)).

USACE considered expansion of the 2020 Mine Plan (hereafter the Expanded Mine Scenario) a reasonably foreseeable future action and, therefore, evaluated the Expanded Mine Scenario for cumulative effects during its CWA Section 404 permitting process (Figure 4-12) (USACE 2020a: Section 4.1).[64] PLP's 2021 Preliminary Economic Assessment evaluated mine expansion as part of its projected

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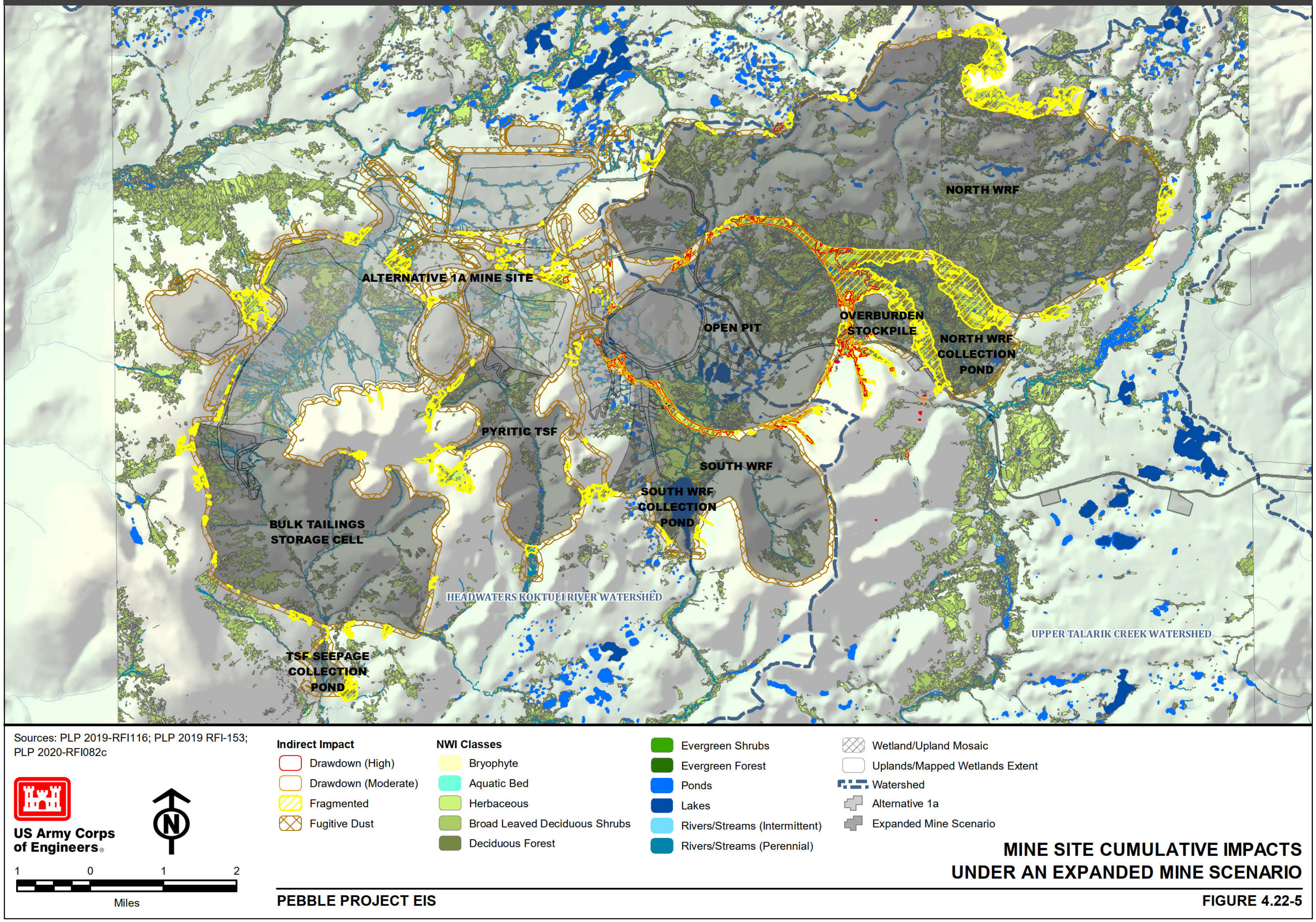
[64] For the purposes of the FEIS, "cumulative effects are interactive, synergistic, or additive effects that would result from the incremental impact of the proposed action when added to other past, present, and reasonably foreseeable future actions (RFFAs) regardless of what agency (federal or non-federal) or person undertakes those other actions (40 CFR Part 1508.7)" (USACE 2020a: Page 4.1-3).

production economics, indicating that mine expansion continues to be reasonably foreseeable (Kalanchey et al. 2021). The Expanded Mine Scenario is not part of the 2020 Mine Plan, has not otherwise been proposed, and would require additional and separate permitting (USACE 2020a: Section 4.1, PLP 2018c: RFI 062). Therefore, it is not a basis for this proposed determination. EPA Region 10 has concluded that the direct and secondary impacts of the discharge of dredged or fill material for the construction and routine operation of the 2020 Mine Plan, as well as discharges that would result in effects similar or greater in nature and magnitude to the 2020 Mine Plan, would result in significant degradation under the Section 404(b)(1) Guidelines. However, the Guidelines also require EPA Region 10 to evaluate cumulative effects.

Under the Expanded Mine Scenario, approximately 8.6 billion tons of ore would be mined (Kalanchey et al. 2021) over 58 years, with additional milling occurring over another 20 to 40 years, for a total of 78 to 98 years of additional activity at the mine site (USACE 2020a: Table 4.1-2). The Expanded Mine Scenario would use infrastructure included in the 2020 Mine Plan, such as the transportation facilities, power plant, and natural gas pipeline facilities, but would include a larger open pit; development of additional tailings storage, water storage, and waste rock storage facilities; and a concentrate pipeline and deepwater loading facility (USACE 2020a: Section 4.1).

The following subsections evaluate the cumulative effects on fishery areas associated with the mine site of the 2020 Mine Plan and the Expanded Mine Scenario. The following analysis does not consider associated facilities and transportation corridors.

Figure 4-12. Cumulative impacts of the mine site under the Expanded Mine Scenario. Figure 4.22-5 from the FEIS (USACE 2020a: Section 4.22)



4.3.1.2.1 Cumulative Effects of Loss of Anadromous Fish Streams

As discussed in Section 4.2.1, the 2020 Mine Plan would result in the permanent loss of approximately 8.5 miles (13.7 km) of streams in the NFK watershed with documented occurrence of anadromous fishes, specifically Coho and Chinook salmon. The Expanded Mine Scenario would eliminate an additional 35 miles (56.3 km) of streams in the SFK and UTC watersheds with documented occurrence of anadromous fishes (Figures 4-13 and 4-14) (USACE 2020a: Section 4.24). These additional stream losses represent 25.7 percent of anadromous fish streams across the SFK and UTC watersheds combined.[65] The Expanded Mine Scenario would also result in the complete loss of 544 acres (2.2 km^2) of lakes and ponds with documented anadromous fish use (Giefer and Blossom 2021), including the 150-acre (0.6-km^2) Frying Pan Lake in the SFK watershed. Frying Pan Lake, which would be inundated by the south collection pond, provides rearing habitat for Sockeye Salmon, Arctic Grayling, Northern Pike, whitefish, stickleback, and sculpin. Across the SFK, NFK, and UTC watersheds, the Expanded Mine Scenario would cause losses to documented Sockeye, Coho, Chinook, and Chum salmon habitat (Table 4-6) (USACE 2020a: Section 4.24).

Table 4-6. Anadromous stream habitat that would be permanently lost in the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek watersheds under the 2020 Mine Plan plus the Expanded Mine Scenario.

Species	Life History / Habitat	Length of Stream (miles) by Watershed [a]			
		SFK	NFK	UTC	TOTAL [b]
Coho Salmon	Spawning	0.4	3.7	9.2	13.4
	Rearing	8.0	7.1	16.9	32.0
	Present	1.3	-	0.4	1.7
	Total Lost Habitat	8.0	7.1	17.8	32.8
Chinook Salmon	Spawning	-	-	3.6	3.6
	Rearing	2.7	3.0 [c]	6.6	12.4
	Present	-	0.6	2.7	3.3
	Total Lost Habitat	2.7	3.6 [c]	7.3	13.7
Sockeye Salmon	Spawning	-	-	4.8	4.8
	Rearing	1.6	-	3.7	5.3
	Present	-	-	1.1	1.1
	Total Lost Habitat	1.6	-	6.2	7.8
Chum Salmon	Spawning	-	-	0.5	0.5
	Present	1.2	-	-	1.2
	Total Lost Habitat	1.2	-	0.5	1.6

Notes:

[a] From the Anadromous Waters Catalog (Giefer and Blossom 2021).

[b] Salmon habitat types overlap and may be coincident, so these numbers cannot be added together.

[c] These values include 0.76 mile (1.2 km) of Chinook Salmon rearing habitat associated with Tributary NFK 1.190 that is currently erroneously missing from the Anadromous Waters Catalog; Joe Giefer at ADF&G confirmed that it would be included in the next update of Anadromous Waters Catalog (Giefer pers. comm.).

[65] The SFK watershed contains 60.0 miles of anadromous waters and the UTC watershed contains 76.2 miles of anadromous waters, based on AWC and PLP stream layers (USACE 2020a: Section 3.24).

Figure 4-13. Streams, rivers, and lakes with documented salmon use overlain with the footprints of the Pebble 2020 Mine Plan and the Expanded Mine Scenario. Species distributions are based on the Anadromous Waters Catalog (Giefer and Blossom 2021).

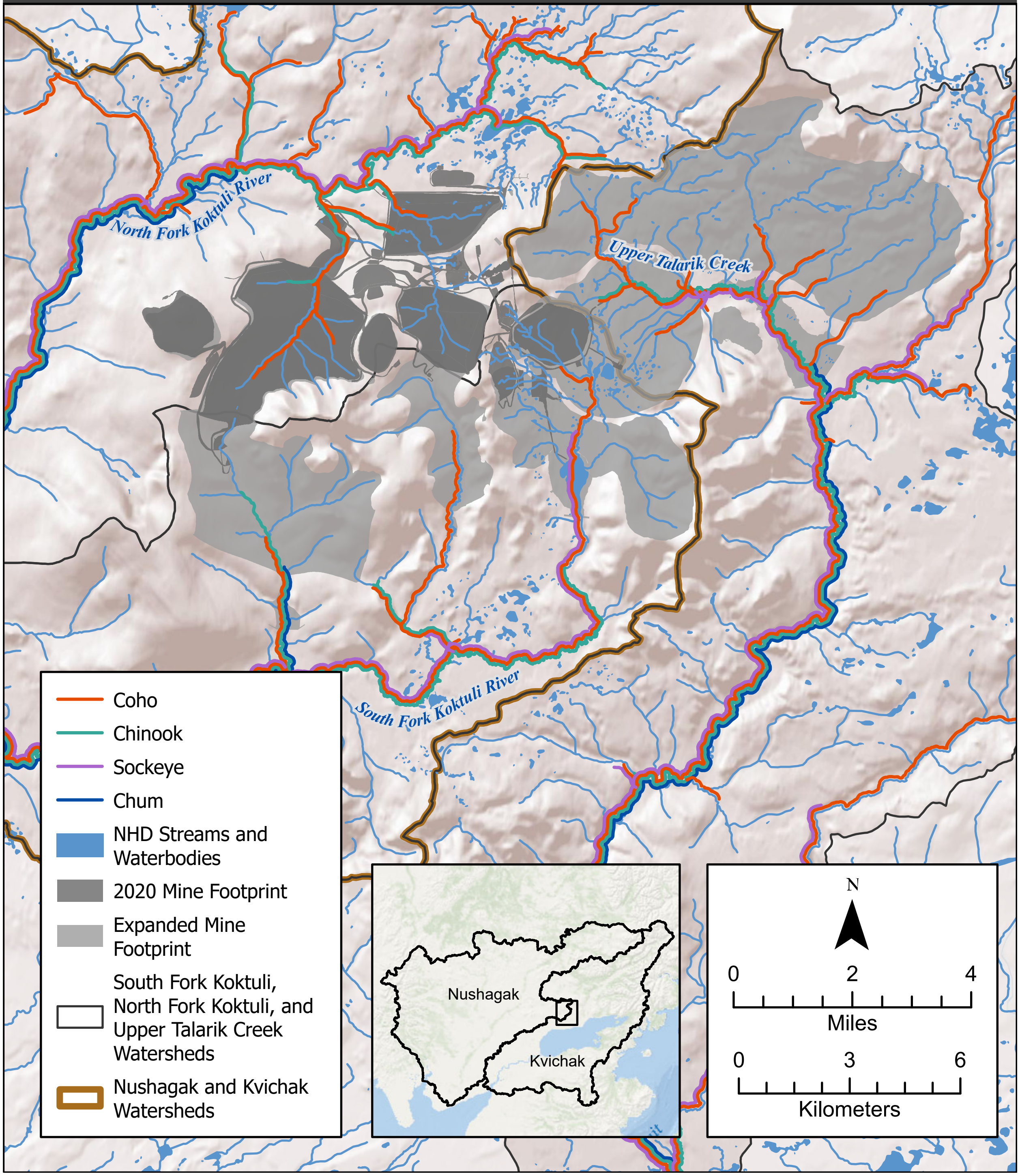
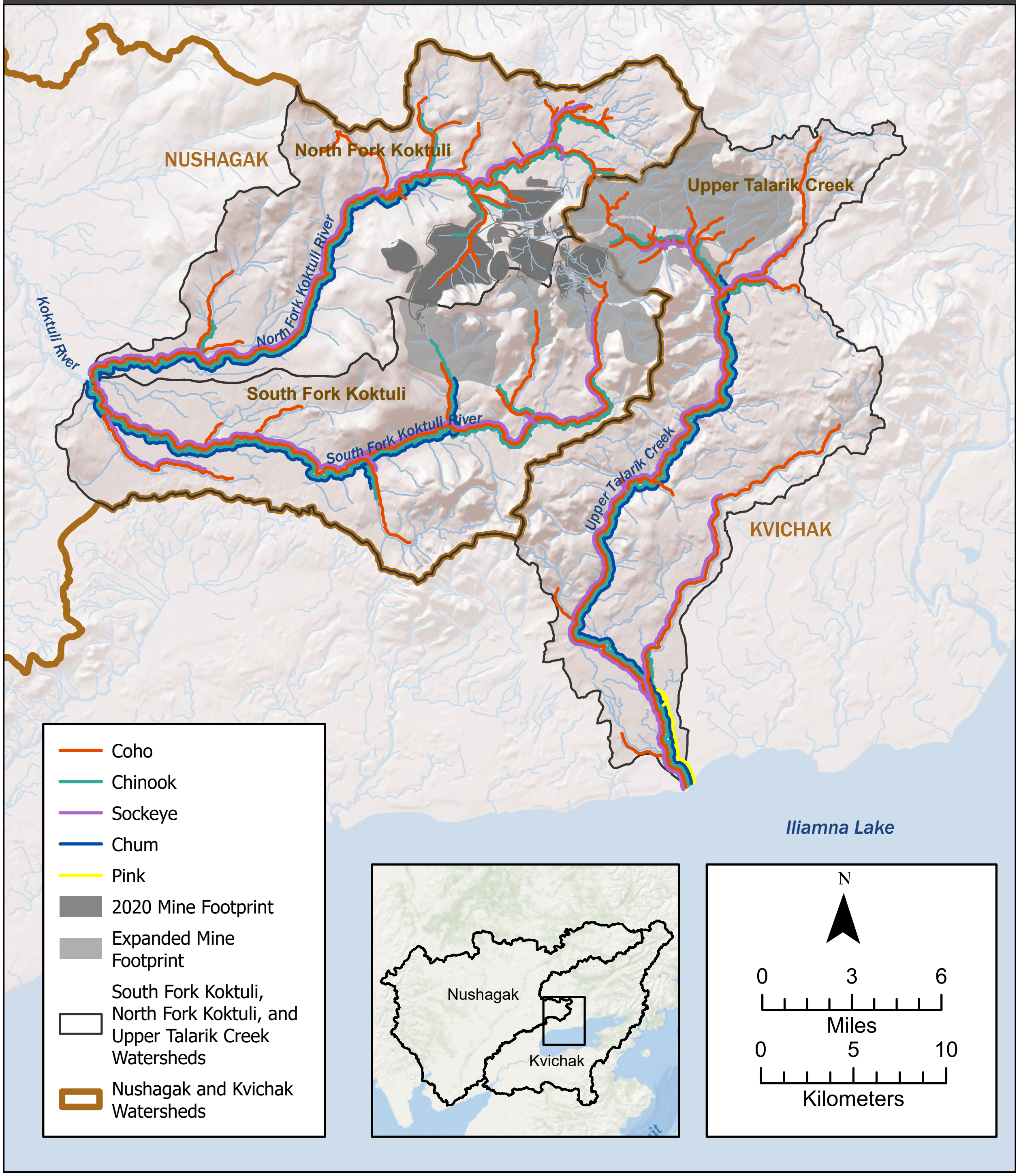


Figure 4-14. Streams, rivers, and lakes with documented salmon use in the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek watersheds, downstream of the Pebble 2020 Mine Plan and Expanded Mine Scenario. Species distributions are based on the Anadromous Waters Catalog (Giefer and Blossom 2021).



The 2020 Mine Plan and the Expanded Mine Scenario would cumulatively eliminate nearly 33 miles (53.1 km) of documented Coho Salmon habitat, 13.7 miles (22 km) of documented Chinook Salmon habitat, and 7.8 miles (12.6 km) of documented Sockeye Salmon habitat across the SFK, NFK, and UTC watersheds. Each species would lose both spawning and rearing habitat (Table 4-6). The 2020 Mine Plan and the Expanded Mine Scenario would also cumulatively eliminate 1.6 miles (2.6 km) of Chum Salmon habitat across the three watersheds.

Eliminated and dewatered habitat likely would permanently lose the ability to support salmon. As discussed for the NFK watershed in Section 4.2.1, the substantial spatial and temporal extent of stream habitat losses under the Expanded Mine Scenario would also reduce the overall capacity and productivity of Coho, Chinook, and Sockeye salmon in the SFK and UTC watersheds. The genetic structure of these populations varies across fine spatial scales, and such extensive habitat losses within three watersheds would adversely affect genetically distinct populations of Sockeye Salmon in the Koktuli River (including the SFK and NFK) and the UTC, as well as Coho and Chinook salmon populations in these watersheds that may be uniquely adapted to the spatial and temporal conditions of their natal streams (Section 3.3.1). Coho Salmon may be particularly susceptible to extirpation through the loss of such populations (Olsen et al. 2003). Losses of small Chinook Salmon populations with diverse life histories have been reported in other regions (Lindley et al. 2009), with resulting impacts on overall population resilience (Healey 1991). Because Coho and Chinook salmon are the rarest of the Pacific salmon species, losses that eliminate unique local populations could result in the loss of significant amounts of overall genetic variability. The extensive habitat losses associated with the Expanded Mine Scenario would likely put such populations at risk.

The loss of 8.5 miles (13.7 km) of documented anadromous fish streams associated with the 2020 Mine Plan would already represent an unprecedented loss of documented anadromous fish streams in the context of the CWA Section 404 regulatory program in Alaska (Section 4.2.1). The loss of an additional 35 miles (56.3 km) of documented anadromous fish streams associated with the Expanded Mine Scenario would represent an extraordinary loss of anadromous fish habitat, which would be compounded by the complete loss of 544 acres (2.2 km^2) of lakes and ponds with documented anadromous fish use, including the destruction of the 150-acre (0.6-km^2) Frying Pan Lake.

4.3.1.2.2 Cumulative Effects of Loss of Additional Streams that Support Anadromous Fish Streams

As discussed in Sections 4.2.1 and 4.2.2, the discharge of dredged or fill material for the construction and routine operation of the 2020 Mine Plan would eliminate 8.5 miles (13.7 km) of anadromous fish streams and 91.2 miles (146.8 km) of additional streams that support anadromous fish streams. The discharge of dredged or fill material for the Expanded Mine Scenario would eliminate 35 additional miles (56.3 km) of anadromous fish streams and result in the permanent loss of an additional 295.5 miles (475.6 km) of streams that support downstream anadromous fish streams across the SFK and UTC watersheds, most of which would be perennial streams (USACE 2020a: Table 4.22-40). These permanent losses would substantially increase adverse impacts on anadromous fishes in the SFK and

UTC watersheds (USACE 2020a: Section 4.22). Many of the eliminated streams likely contain anadromous fish habitat that has not yet been documented (Sections 3.2.4 and 4.2.1) but may be particularly valuable for juvenile salmonids. The unprecedented habitat losses in the SFK and UTC watersheds that would result from the Expanded Mine Scenario would exacerbate any unacceptable adverse effects on salmon and other fish populations caused by the 2020 Mine Plan.

Rainbow Trout, Dolly Varden, Arctic Grayling, Northern Pike, Ninespine Stickleback, and Slimy Sculpin also would lose additional habitat under the Expanded Mine Scenario (Figures 4-15 through 4-18). The Expanded Mine Scenario would eliminate Rainbow Trout habitat beyond the NFK watershed and include losses in the UTC watershed (Figures 4-15 and 4-17). The Expanded Mine Scenario would eliminate Dolly Varden habitat beyond the NFK watershed and include losses in the SFK and UTC watersheds (Figures 4-15 and 4-17). The Expanded Mine Scenario would increase habitat losses for Arctic Grayling, Northern Pike, Ninespine Stickleback, and Slimy Sculpin in the SFK watershed. The Expanded Mine Scenario would also eliminate habitat for Arctic Grayling, Ninespine Stickleback, and Slimy Sculpin in the UTC watershed (Figures 4-15 through 4-18). In addition to direct habitat losses, increased loss of stream habitat under the Expanded Mine Scenario would substantially alter streamflows and other ecological subsidies provided to downstream fish habitats in the SFK and UTC watersheds (Figures 4-14 and 4-18). Associated reductions in streamflow to downstream fishery areas would likely reduce the extent and frequency of stream connectivity to off-channel habitats, as well as alter the thermal regimes of downstream habitats (Section 4.2.4). These habitats also would no longer support or export macroinvertebrates, an important food source for juvenile salmon and other fish species.

4.3.1.2.3 Cumulative Effects of Loss of Wetlands and Other Waters that Support Anadromous Fish Streams

In addition to the 2,113 acres (8.6 km^2) of wetlands and other waters that would be permanently lost under the 2020 Mine Plan, the Expanded Mine Scenario would result in the permanent loss of an additional 8,756 acres (35.4 km^2) of wetlands and other waters in the SFK and UTC watersheds, primarily affecting broad-leaved deciduous shrub and herbaceous type wetlands (Figure 4-12) (USACE 2020a: Table 4.22-40). The greatest losses of wetlands and other waters under the Expanded Mine Scenario would occur in the Headwaters Koktuli River (i.e., the SFK, NFK, and Middle Koktuli River HUC-12 watersheds) and UTC watersheds, with losses of wetlands and other waters in these watersheds increasing from 6 percent under the 2020 Mine Plan to 23 percent (USACE 2020a: Section 4.22). The unprecedented loss of thousands of acres of wetlands under the Expanded Mine Scenario would eliminate nutrient-rich, structurally complex, and thermally and hydraulically diverse habitats—including crucial overwintering areas—that are essential to rearing salmonids (EPA 2014: Chapter 7). Coho, Chinook, Sockeye, and Chum salmon would be adversely affected under the Expanded Mine Scenario (Figures 4-13 and 4-14). The Expanded Mine Scenario would also result in a loss or reduction of water, nutrient, detritus, and macroinvertebrate exports to downstream areas, the losses of which would affect downstream food webs. These losses, of an even greater scope and scale than losses anticipated from the 2020 Mine Plan, would reduce the overall capacity and productivity of Coho, Chinook, Sockeye, and Chum salmon across the SFK, NFK, and UTC watersheds.

In addition to salmon, Rainbow Trout, Arctic Grayling, and Northern Pike rear in these wetland areas; Northern Pike also spawn in these habitats (Figures 4-15 and 4-16). These species support both subsistence and recreational fisheries in downstream areas. Because these species can move significant distances across diverse freshwater habitats throughout their life cycles, large losses of wetland rearing habitat could adversely affect these downstream fisheries.

4.3.1.2.4 Cumulative Effects of Additional Degradation of Streams, Wetlands, and Other Waters Beyond the Mine Site Footprint

The 2020 Mine Plan is expected to degrade additional wetlands, streams, and other waters beyond the mine site footprint due to dewatering, fragmentation, and fugitive dust. These secondary effects of the discharge of dredged or fill material from construction and routine operation of the 2020 Mine Plan would result in adverse impacts to approximately 845 additional acres of wetlands and other waters (3.4 km^2) and 29.9 miles (48.1 km) of streams at the mine site (PLP 2020b, USACE 2020b). Impacts from dewatering, fragmentation, and fugitive dust would increase under the Expanded Mine Scenario and further reduce the quality and extent of fish habitats in the SFK and UTC watersheds (USACE 2020a: Section 4.22).

Under the Expanded Mine Scenario, aquatic resources could experience multiple secondary impacts, resulting in overlap in the area or miles affected when accounting for the effects of dewatering, habitat fragmentation, and fugitive dust deposition individually. After correcting for this overlap, the Expanded Mine Scenario would adversely affect an additional 1,829 acres of wetlands and other waters (7.4 km^2) and 17 miles (27.4 km) of streams at the mine site from dewatering, habitat fragmentation, and fugitive dust. The following discussion considers these secondary impacts individually, without adjusting for overlap (USACE 2020a: Table 4.22-40).

Dewatering associated with the Expanded Mine Scenario would impact 338 acres (1.4 km^2) of wetlands and other waters and 3.2 miles (5.1 km) of streams (USACE 2020a: Table 4.22-40). Dewatering of wetlands and other waters causes the alteration or loss of wetland hydrology and may result in the conversion of habitats to more mesic types. Drawdown of groundwater is expected primarily around the open pit due to dewatering activities, but would also occur around quarries, TSFs, and WMPs due to diversions and drainage/underdrain systems. Altered saturated surface flow and shallow interflow resulting from a depression of the groundwater table is expected to adversely affect wetlands, surface waters, and vegetation in the drawdown area (USACE 2020a: Section 4.22). Dewatering impacts to slope wetlands (which constitute the majority of wetland acres impacted at the mine site) would be severe and “[d]ue to the groundwater storage and organic matter production and nutrient cycling capacity of slope wetlands, their loss would likely reduce the functional capacity of the watershed to maintain downstream baseflows, as well as reducing the subsidy of organic matter and nutrients to downstream aquatic ecosystems and organisms” (USACE 2020a: Page 4.22-30). Dewatering represents a secondary but permanent impact to wetlands, streams, and other waters (USACE 2020a: Section 4.22).

Figure 4-15. Reported Arctic Grayling, Rainbow Trout, and Dolly Varden occurrence overlain with the footprints of the Pebble 2020 Mine Plan and the Expanded Mine Scenario. Species distributions are based on the Alaska Freshwater Fish Inventory (ADF&G 2022a).

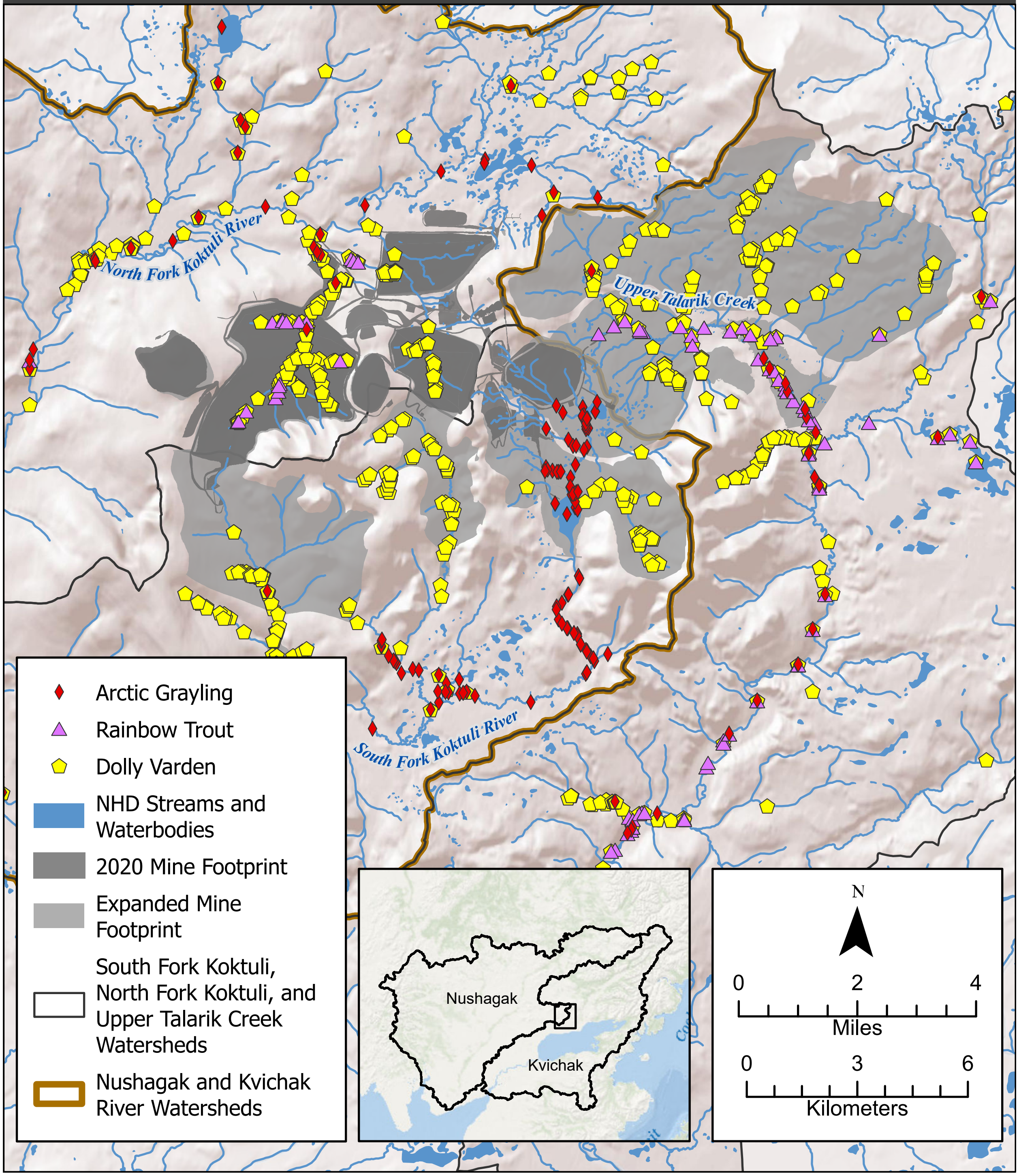


Figure 4-16. Reported occurrence of other resident fish species overlain with the footprints of the Pebble 2020 Mine Plan and the Expanded Mine Scenario. Species distributions are based on the Alaska Freshwater Fish Inventory (ADF&G 2022a).

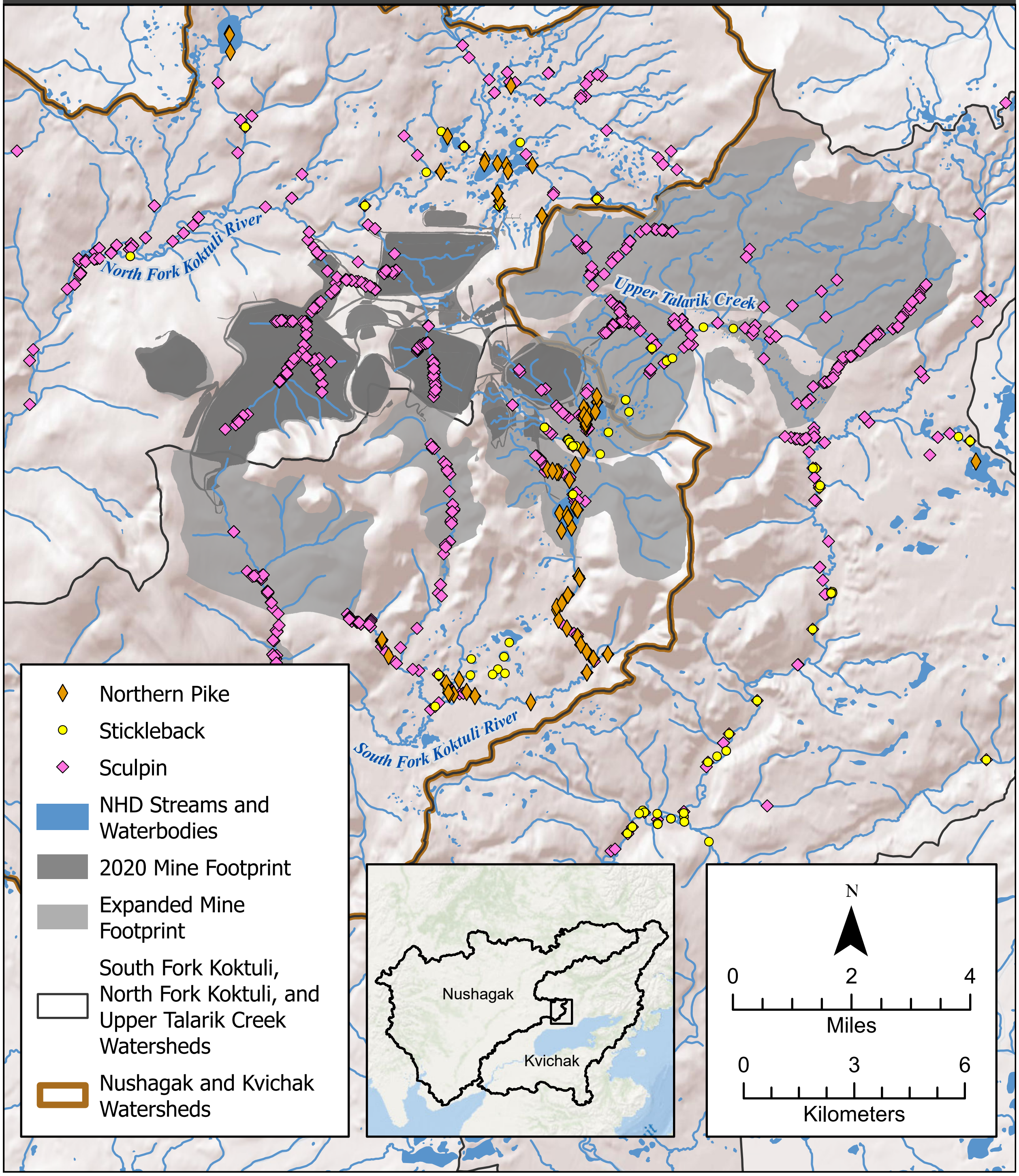


Figure 4-17. Reported Arctic Grayling, Rainbow Trout, and Dolly Varden occurrence in the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek watersheds, downstream of the Pebble 2020 Mine Plan and Expanded Mine Scenario. Species distributions are based on the Alaska Freshwater Fish Inventory (ADF&G 2022a).

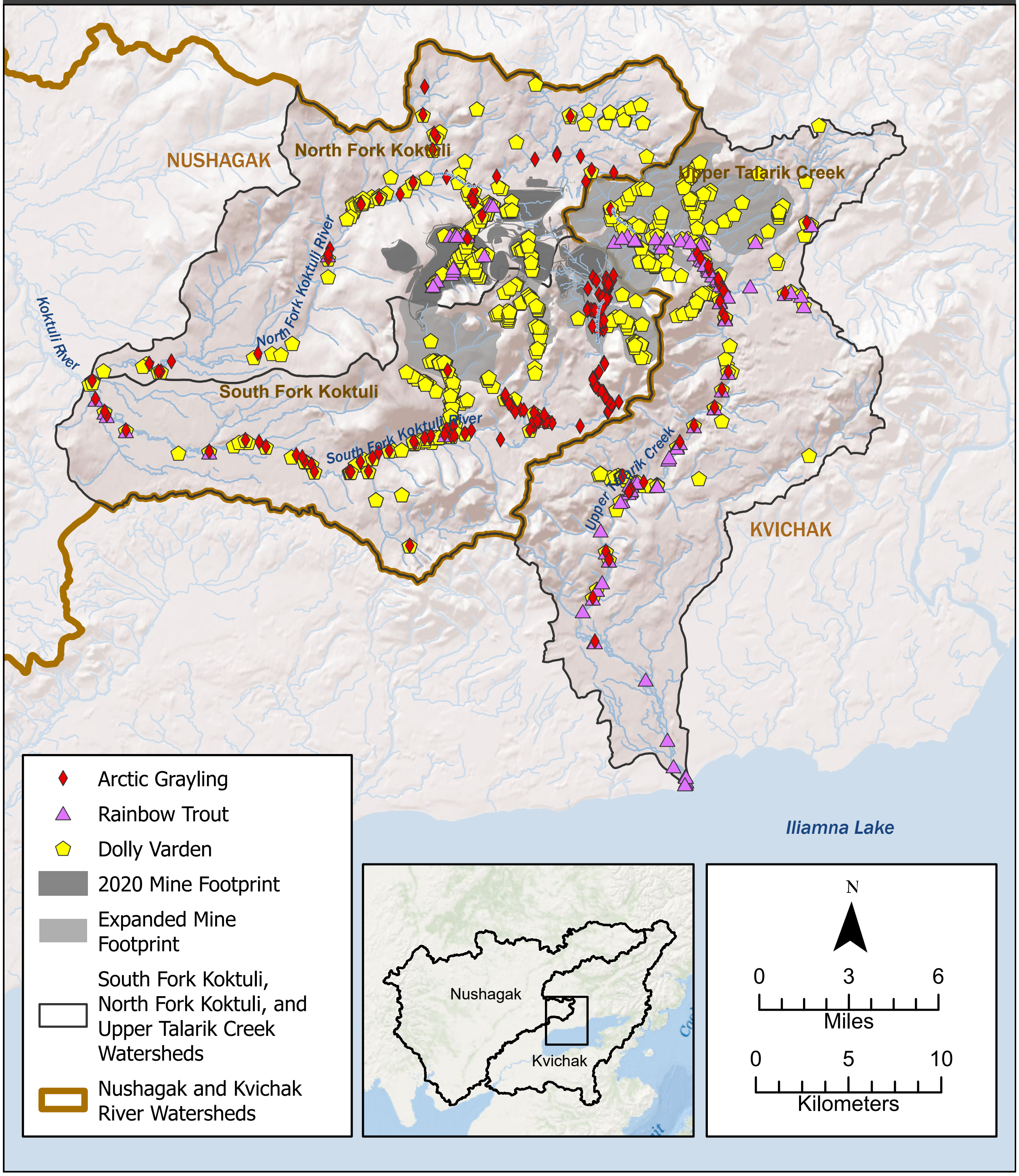
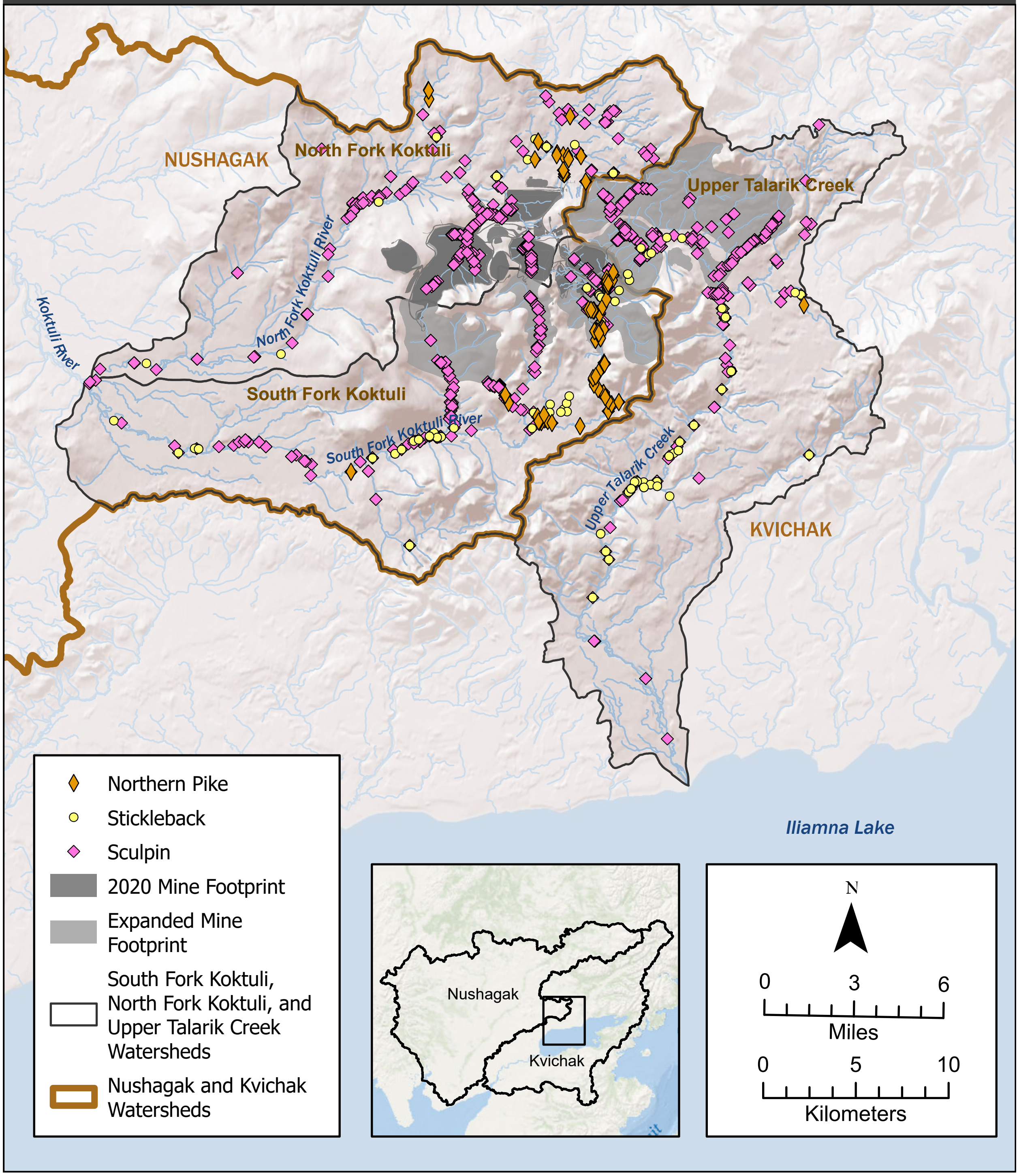


Figure 4-18. Reported occurrence of other non-salmon fish species in the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek watersheds, downstream of the Pebble 2020 Mine Plan and Expanded Mine Scenario. Species distributions are based on the Alaska Freshwater Fish Inventory (ADF&G 2022a).



Fragmentation associated with the Expanded Mine Scenario would affect 1,538 acres (6.2 km^2) of wetlands and other waters and 8.4 miles (13.5 km) of streams (USACE 2020a: Table 4.22-40). This represents a nearly 600 percent increase in fragmentation impacts on wetlands and other waters and a 91 percent increase in fragmentation impacts on streams when compared to the 2020 Mine Plan. Fragmentation of wetlands and other waters results when development divides a formerly continuous aquatic resource into smaller, more isolated remnants. Habitat fragmentation represents a secondary but permanent impact on wetlands, streams, and other waters (USACE 2020a: Section 4.22). Decreased connectivity of aquatic ecosystems could preclude the completion of aquatic organisms' life cycles; for example, anadromous fish may be unable to reach spawning grounds or access off-channel habitat (USACE 2020a: Section 4.22). Fragmentation of stream channels and adjacent wetlands without hydrologic surface connections are expected to result in a complete loss of function; partial loss of function would be expected for other types of wetlands, such as slope and depressional wetlands, which would likely become drier due to the diversion of shallow groundwater and surface water and the reduction of catchment areas (USACE 2020a: Section 4.22). Habitat fragmentation would likely reduce the functional capacity of the watershed to maintain downstream baseflows, as well as reduce the subsidy of organic matter and nutrients to downstream aquatic ecosystems and organisms (USACE 2020a: Section 4.22).

Fugitive dust associated with the Expanded Mine Scenario would affect 1,093 acres (4.4 km^2) of wetlands and other waters and 15 miles (24.1 km) of streams (USACE 2020a: Table 4.22-40). Fugitive dust would be produced from ground-disturbing actions during construction, operations, and closure, and from wind or vehicle dispersal of exposed soil in the post-closure period (USACE 2020a: Section 4.22). Fugitive dust has the potential to collect on wetland vegetation and accumulate in waters, with adverse consequences for plant physiology, water quality, biotic community composition, and the overall functions and values of wetlands, streams, and other waters (USACE 2020a: Section 4.22). The majority of the potentially affected wetlands at the mine site are particularly susceptible to the adverse effects of dust deposition because of their vegetation type and structure (USACE 2020a: Section 4.22).

4.3.1.3 Summary

EPA Region 10 has determined that direct and secondary impacts of the discharge of dredged or fill material from construction and routine operation of the 2020 Mine Plan and discharges that would result in effects similar or greater in nature and magnitude to the 2020 Mine Plan would result in significant degradation under the Section 404(b)(1) Guidelines (40 CFR 230.10(c), Section 4.3.1.1). These findings are based on the significantly adverse effects that the discharge of dredged or fill material would have on special aquatic sites, life stages of anadromous fishes, anadromous fish habitat, and aquatic ecosystem diversity, productivity, and stability under the Section 404(b)(1) Guidelines.

The Expanded Mine Scenario represents a reasonably foreseeable expansion of mine size over time, from 1.3 billion tons up to 8.6 billion tons. This expansion would dramatically increase the amount of destruction and degradation of anadromous fishery areas in the SFK, NFK, and UTC watersheds, including a more than 400 percent increase in the amount of anadromous fish streams permanently lost.

There are no examples of other projects resulting in this level of permanent loss of anadromous fish streams in the CWA Section 404 regulatory program in Alaska.

In addition to the losses estimated for the 2020 Mine Plan, estimated impacts of the Expanded Mine Scenario include the permanent loss of an additional 35 miles (56.3 km) of documented anadromous fish streams, an additional 295.5 miles (475.6 km) of streams that support anadromous fish streams, and an additional 8,756 acres (35.4 km^2) of wetlands and other waters across the SFK and UTC watersheds (USACE 2020a: Table 4.22-40). These losses would represent extraordinary and unprecedented levels of anadromous fish habitat loss and degradation, significantly expanding the unacceptable adverse effects identified for the 2020 Mine Plan.

Secondary effects of the discharge of dredged or fill material from construction and routine operation of the 2020 Mine Plan would result in adverse impacts to approximately 845 acres of wetlands and other waters (3.4 km^2) and 29.9 miles (48.1 km) of streams at the mine site from dewatering, habitat fragmentation, and fugitive dust (PLP 2020b, USACE 2020b). The FEIS estimates that these secondary effects of the discharge of dredged or fill material from the construction and routine operation of the Expanded Mine Scenario would adversely affect an additional approximately 1,829 acres of wetlands and other waters (7.4 km^2) and 17 miles (27.4 km) of streams at the mine site (USACE 2020a: Table 4.22-40) and would further reduce the quality and extent of anadromous fish habitat in the SFK and UTC watersheds.

The losses of and impacts on salmon habitat could cause the extirpation of unique local populations of Coho, Sockeye, and Chinook salmon that would affect the overall genetic diversity of each species. This reduction in genetic diversity could adversely affect the stability and sustainability of valuable subsistence, commercial, and recreational salmon fisheries. Subsistence harvests and recreational fishing of non-salmon species could also suffer. For example, Rainbow Trout, Dolly Varden, and Northern Pike are found in the affected waters, and would experience habitat losses as a result of mine expansion.

Species with extended freshwater rearing periods, such as Coho, Chinook, and Sockeye salmon, are more likely to be extinct, endangered, or threatened than species that spend less time in freshwater habitats (NRC 1996, Gustafson et al. 2007). Therefore, the losses and degradation of discrete, productive freshwater habitats for salmon estimated under the Expanded Mine Scenario could threaten multiple distinct populations of species such as Coho, Chinook, and Sockeye salmon. Losses of these populations would degrade the overall stability of fisheries within the SFK, NFK, and UTC watersheds. Ultimately, cumulative effects on streams, wetlands, and other aquatic resources from the discharge of dredged or fill material associated with the Expanded Mine Scenario would likely impair the health of the SFK, NFK, and UTC watersheds and cause or contribute to significant degradation (40 CFR 230.10(c)) of the watersheds' fishery areas.

4.3.2 Compensatory Mitigation Evaluation

EPA Region 10 has reason to believe that discharges of dredged or fill material into waters of the United States for the construction and routine operation of the 2020 Mine Plan could result in unacceptable adverse effects on anadromous fishery areas (Sections 4.2.1 through 4.2.4). EPA Region 10 also has reason to believe that discharges of dredged or fill material associated with future plans to mine the Pebble deposit could result in unacceptable adverse effects on anadromous fishery areas in the SFK, NFK, and UTC watersheds if the effects of such discharges are similar or greater in nature and magnitude to those described in Sections 4.2.1 through 4.2.4.

The Section 404(b)(1) Guidelines direct that no discharge of dredged or fill material shall be permitted unless all appropriate and practicable steps have been taken to minimize and compensate for the project's adverse impacts on the aquatic ecosystem (40 CFR 230.10(d)). Discharges of dredged or fill material for the construction and routine operation of the 2020 Mine Plan would have extensive unavoidable adverse impacts to aquatic resources that would require compensatory mitigation (USACE 2020b).

Under Section 404(c) of the CWA, EPA has discretionary authority to deny or restrict the use of any defined area as a disposal site "whenever" it determines that the discharge of dredged or fill material will have an unacceptable adverse effect on statutorily enumerated aquatic resources. The statutory standard does not direct EPA to consider mitigation when determining what constitutes an unacceptable adverse effect nor restrict EPA to exercising its authority unless and until EPA has before it a USACE permit identifying required mitigation. EPA's regulations provide that "[i]n evaluating the unacceptability of such impacts, consideration should be given to the relevant portions of the section 404(b)(1) guidelines" (40 CFR 231.2). EPA does not view the mitigation provisions to be a relevant portion of the Guidelines that should be considered in determining unacceptability in this circumstance because there is no permit requiring mitigation and in fact, USACE expressly rejected PLP's proposed mitigation.

Nonetheless, although not required, EPA Region 10 evaluated the two compensatory mitigation plans (CMPs) PLP submitted to USACE in 2020. As described in Section 4.3.2.2, both plans fail to adequately mitigate the adverse effects that are the subject of this proposed determination to an acceptable level.

In addition to the two CMPs PLP proposed to USACE in 2020, during development and finalization of the 2014 BBA, PLP and other commenters suggested an array of measures as having the potential to compensate for the nature and magnitude of adverse impacts on wetlands, streams, and fishes from the discharge of dredged or fill material associated with mining the Pebble deposit. EPA Region 10 evaluated the numerous additional measures that PLP and others proposed prior to issuing the 2014 Proposed Determination. During the public comment period for the 2014 Proposed Determination, several commenters, including PLP, suggested additional measures as having the potential to compensate for the nature and magnitude of adverse impacts on wetlands, streams, and fishes from the discharge of dredged or fill material associated with mining the Pebble deposit.

PLP did not propose such measures to USACE during the Section 404 permit review process. EPA Region 10 provides, for informational purposes, an updated evaluation of the measures in Appendix C. Available information demonstrates that known compensation measures are unlikely to adequately mitigate effects described in this proposed determination to an acceptable level.

4.3.2.1 Overview of Compensatory Mitigation Requirements

Compensatory mitigation refers to the restoration, establishment, enhancement, and/or in certain circumstances preservation of wetlands, streams, or other aquatic resources. Compensatory mitigation regulations jointly promulgated by EPA and USACE state that "the fundamental objective of compensatory mitigation is to offset environmental losses resulting from unavoidable impacts to waters of the United States authorized by [Clean Water Act Section 404 permits issued by the USACE]" (40 CFR 230.93(a)(1)). Compensatory mitigation enters the analysis only after a proposed project design has incorporated all appropriate and practicable means to avoid and minimize adverse impacts on aquatic resources (40 CFR 230.91(c)).

4.3.2.2 Review of Compensatory Mitigation Plans Submitted by the Pebble Limited Partnership

During the permit review process, PLP submitted two CMPs in an effort to address the project's unavoidable aquatic resource impacts, the first in January 2020 (PLP 2020a) and the second in November 2020 (PLP 2020c). Provided in this section is a discussion of both CMPs and why they failed to adequately address the unacceptable adverse effects that are the subject of this proposed determination.

Consistent with the Section 404(b)(1) Guidelines, in developing its CMPs, PLP first evaluated whether its project impacts fell within the service area(s)[66] of an approved mitigation bank or in-lieu fee program with appropriate credits available. Because mitigation bank and in-lieu fee program options were not available, both of PLP's CMPs involved permittee-responsible compensatory mitigation proposals.[67]

4.3.2.2.1 January 2020 Compensatory Mitigation Plan

PLP's January 2020 CMP included the following three components (PLP 2020a):

1. Improvements to wastewater collection and treatment systems in three villages in the Kvichak River watershed.
2. Rehabilitation of 8.5 miles (13.7 km) of salmon habitat through replacement or removal of some number of unidentified culverts.
3. One-time clean-up of 7.4 miles (11.9 km) of coastal habitat on Kamishak Bay (Cook Inlet).

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[66] The service area is the watershed, ecoregion, physiographic province, and/or other geographic area within which the mitigation bank or in-lieu fee program is authorized to provide compensatory mitigation (40 CFR 230.98(d)(6)(ii)(A)).

[67] Permittee-responsible mitigation means an aquatic resource restoration, establishment, enhancement, and/or preservation activity undertaken by the permittee to provide compensatory mitigation for which the permittee retains full responsibility (40 CFR 230.92).

In an August 20, 2020 letter to PLP, USACE stated "that discharges at the mine site would cause unavoidable adverse impacts to aquatic resources and, preliminarily, that those adverse impacts would result in significant degradation to those aquatic resources." Because of its concerns that adverse impacts at the mine site would not be adequately mitigated by the January 2020 CMP, USACE "determined that in-kind compensatory mitigation within the Koktuli River watershed will be required to compensate for all direct and indirect [secondary] impacts caused by discharges into aquatic resources at the mine site." In its letter, USACE requested that PLP submit a new CMP that would 1) comply with all requirements of the compensatory mitigation regulations, 2) be "sufficient to offset the unavoidable adverse impacts to aquatic resources," and 3) "overcome significant degradation at the mine site."

EPA Region 10 shares USACE's concerns regarding the nature and magnitude of the adverse effects on aquatic resources in the Koktuli River watershed that would result from discharges of dredged or fill material at the mine site. Like USACE, EPA Region 10 also identified deficiencies in the January 2020 CMP. As discussed here, EPA Region 10 also does not believe that the January 2020 CMP adequately mitigates the adverse effects of the 2020 Mine Plan that are the subject of this proposed determination to an acceptable level.

- **Improvements to wastewater collection and treatment systems in three villages in the Kvichak River watershed.** Ninety-four percent of the 2020 Mine Plan's impacts on wetlands, streams, and other aquatic resources occur in the Koktuli River watershed. However, all of these infrastructure projects would occur in other watersheds, and none would address the substantial impacts in the Koktuli River watershed that are the subject of this proposed determination. Further, such wastewater infrastructure projects would not qualify as acceptable compensatory mitigation under the regulations.[68]
- **Rehabilitation of 8.5 miles (13.7 km) of salmon habitat through replacement or removal of some number of unidentified culverts.** The Koktuli River watershed is an almost entirely roadless area and, thus, offers few, if any, viable culvert replacement or removal opportunities (none are identified in the January 2020 CMP). Therefore, to the extent that such a component would provide any environmental benefits, those benefits would not approach the level necessary to reduce the adverse effects from the discharges of dredged or fill material associated with the 2020 Mine Plan that are the subject of this proposed determination to an acceptable level.[69]
- **One-time clean-up of 7.4 miles (11.9 km) of coastal habitat on Kamishak Bay (Cook Inlet).** Like the proposed wastewater infrastructure projects in component 1, this component does nothing to address the substantial impacts in the Koktuli River watershed that are the subject of this proposed

[68] Such infrastructure construction projects do not meet the definition of compensatory mitigation, which can only occur through four methods: aquatic resource restoration, establishment, enhancement, or in certain circumstances, preservation (40 CFR 230.93(a)(2)).

[69] The UTC watershed is also an almost entirely roadless area, thus this compensation measure would suffer from the same deficiencies if it were applied to address impacts in the UTC watershed.

determination. This component is not even located in the larger Bristol Bay watershed. Further, to the extent that this component provides an environmental benefit, it would be *temporary* and would not address the nature and magnitude of the *permanent* aquatic resource losses at the mine site from construction and routine operation of the 2020 Mine Plan.

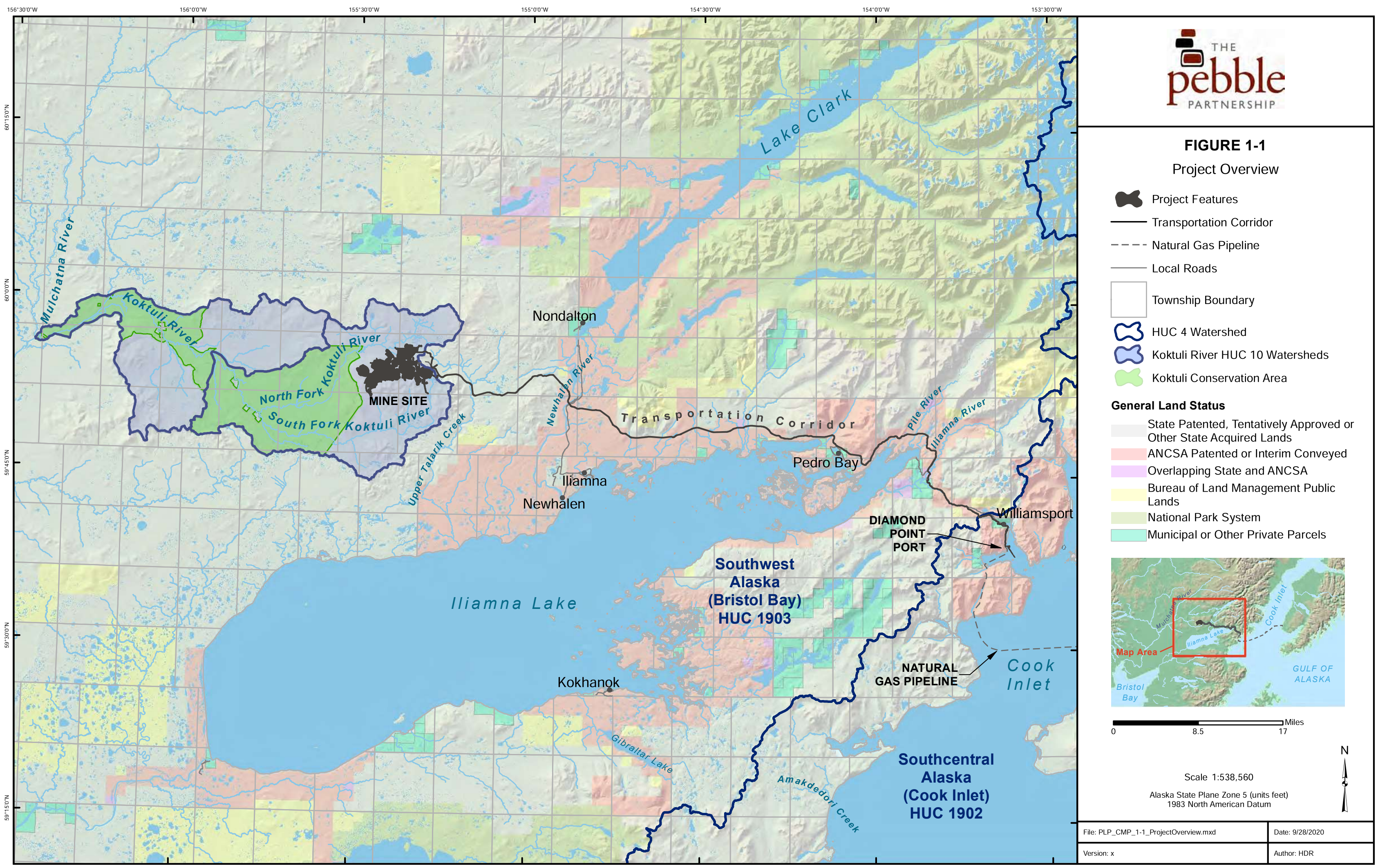
4.3.2.2.2 November 2020 Compensatory Mitigation Plan

In response to USACE's August 20, 2020 letter, PLP submitted a new CMP in November 2020 that superseded the January 2020 CMP. When evaluating what compensation measures could reduce the severity of the adverse effects estimated for the Koktuli River watershed, PLP ruled out all other potential measures aside from preservation stating that "[r]estoration, establishment, or enhancement projects within the identified watershed are not plentiful enough in size or scale to mitigate for the identified acreage of direct and indirect impacts to be mitigated; therefore, preservation is the only available compensatory mitigation option" (PLP 2020c: Page 6). The November 2020 CMP includes a single component-proposed preservation of 112,445 acres (455.0 km^2) of state-owned land within the Koktuli River watershed downstream from the mine site (Figure 4-19). The November 2020 CMP proposed to do this by recording a deed restriction that would limit future uses of the land. The proposed "Koktuli Conservation Area" may contain approximately 31,026 acres (125.6 km^2) of wetlands, lakes, and ponds, and 814 miles (1310 km) of streams (PLP 2020c).

In its ROD, USACE determined that the November 2020 CMP did not overcome significant degradation at the mine site, and that it failed to comply with all of the requirements of the compensatory mitigation regulations (USACE 2020b). Specifically, the ROD found the following regulatory compliance deficiencies with the November 2020 CMP and provided the following explanation (Attachment B6):

> **Lacks Sufficient Detail-Not Compliant:** The level of detail of the mitigation plan is not commensurate with the scale and scope of the impacts. [33 CFR 332.4(c)(1)]
>
> **Preservation Waiver-Not Compliant:** Preservation shall be done in conjunction with aquatic resource restoration, establishment, and/or enhancement activities. This requirement may be waived by the district engineer where preservation has been identified as a high priority using a watershed approach. No restoration, establishment, and/or enhancement were proposed and justification identifying the proposed preservation as a high priority using a watershed approach was not submitted. [33 CFR 332.3(h)(2)]
>
> **Amount of Compensatory Mitigation-Not Compliant:** No compensatory mitigation was proposed by the applicant to offset impacts from the port site. [33 CFR 332.3(f)]
>
> **Site Protection-Not Compliant:** Deed restrictions proposed for 99 years. The goal of 33 CFR 332 is to ensure permanent protection of all compensatory mitigation project sites. Justification not provided as to why a perpetual conservation easement with third-party holder is not practicable. A site protection instrument was not provided; therefore, could not be evaluated. The Final Plan did provide partial deed restriction language; however, the site protection information was not complete, e.g. the Final Plan did not provide the required 60-day advance notification language. No supporting real estate information was submitted; therefore, could not review title insurance, reserved rights, rights-of-way, etc. Baseline information was also not submitted; therefore, could not determine existing disturbances such as roads, culverts, trails, fill pads, etc. USACE cannot enforce the deed restrictions since third-party enforcement rights were not given to USACE. [33 CFR 332.7(a)]
>
> **Maintenance Plan-Not Compliant:** No maintenance plan was submitted. [33 CFR 332.4(c)(8)]

Figure 4-19. Proposed Koktuli Conservation Area. Figure 1-1 from PLP's November 2020 Compensatory Mitigation Plan (PLP 2020c).



Performance Standards-Not Compliant: No ecological performance standards were submitted. Submitted performance standards are administrative in nature, such as the act of monitoring, the act of enforcement, and the act of documentation of the deed restriction requirements. [33 CFR 332.4(c)(9) and 33 CFR 332.5]

Monitoring-Not Compliant: One monitoring event is proposed. One event is not sufficient to demonstrate that the compensatory mitigation project has met and maintained performance standards. [33 CFR 332.6]

Long-Term Management-Not Compliant: No long-term endowment mechanism was submitted. No supporting information was submitted for cost estimate. Cost estimate did not include items such as capitalization rate, inflationary adjustments, legal defense costs, etc.; therefore, could not determine sufficiency. Long-term manager unclear and unsupported. [33 CFR 332.4(c)(11) and 33 CFR 332.7(d)]

Financial Assurances-Not Compliant: No financial assurances were provided. [33 CFR 332.4(c)(13) and 33 CFR 332.3(n)]

EPA Region 10 shares USACE's concerns regarding the November 2020 CMP. Based on its review of the November 2020 CMP, EPA Region 10 finds that it would not adequately mitigate the adverse effects of the 2020 Mine Plan that are the subject of this proposed determination to an acceptable level. Additional deficiencies identified by EPA Region 10 are as follows:

- **The November 2020 CMP does not qualify as compensatory mitigation under the regulations.** Compensatory mitigation is defined as "the restoration (re-establishment or rehabilitation), establishment (creation), enhancement, and/or in certain circumstances preservation of aquatic resources for the purposes of offsetting unavoidable adverse impacts which remain after all appropriate and practicable avoidance and minimization has been achieved" (40 CFR 230.92). The November 2020 CMP "proposes permittee-responsible mitigation in the form of preservation" (Page 1). For the proposal to qualify as preservation it must meet the regulatory definition and requirements for preservation.

  Preservation is defined at 40 CFR 230.92 as "the removal of a threat to, or preventing the decline of, aquatic resources by an action in or near those aquatic resources." Preservation is only allowed when the resources to be preserved "are under threat of destruction or adverse modification" (40 CFR 230.93(h)(1)(iv)). Though PLP would give up mining claims within the proposed Conservation Area, development of those claims was not included in the FEIS, the CWA Section 404(b)(1) evaluation, or the Public Interest Review for the 2020 Mine Plan, and it was not considered for development under the Expanded Mine Scenario. Further, the State of Alaska's MCO 393, issued in 1984, already precludes mining in the Koktuli River and 100 feet of its banks within the proposed Koktuli Conservation Area (Section 2.2.1). The primary "threat of destruction or adverse modification" for the proposed Conservation Area comes from the destruction and degradation of streams, wetlands, lakes, and ponds upstream of the Conservation Area at the proposed mine site for PLP's 2020 Mine Plan.

  As discussed in Sections 4.2 and 4.3, discharges at the mine site for the 2020 Mine Plan would result in a number of significant secondary effects that would degrade aquatic resources downstream of the mine site, including the aquatic resources proposed for preservation in the Conservation Area. For example, Sections 4.2 and 4.3 describe how aquatic resource losses at the mine site would result in the loss or reduction of water, nutrient, detritus, and macroinvertebrate exports to downstream areas.

The November 2020 CMP would not qualify as preservation because it does not involve "the removal of a threat to, or preventing the decline of, aquatic resources by an action in or near" (40 CFR 230.92) the proposed Conservation Area. Indeed, PLP is seeking credit for "preserving" aquatic resources that the record shows would be permanently degraded by its own mine plan.

- **The November 2020 CMP does not reduce the severity of the impacts that are the subject of this proposed determination.** Preservation does not replace lost ecological functions or area (40 CFR 230.92). As discussed in Sections 4.2 and 4.3.1, discharges from the 2020 Mine Plan would result in significant aquatic resource losses and degradation. This preservation proposal would not adequately mitigate the adverse effects of those losses and degradation to an acceptable level. Moreover, as discussed previously, impacts at the mine site would lead to degradation of the aquatic resources proposed for preservation.[70]
- **The November 2020 CMP does not meet the higher bar for "permanent protection" of preservation sites under the regulations.** The general provisions for site protection in the regulations provide that the "overall compensatory mitigation project must be provided long-term protection through real estate instruments or other available mechanisms" (40 CFR 230.97(a)(1)). However, preservation can only be used in "certain circumstances," including when the resources to be preserved would be "*permanently protected* through an appropriate real estate or other legal instrument" (emphasis added) (40 CFR 230.93(h)(1)(iv)). The November 2020 CMP proposes to protect the site by recording a 99-year deed restriction on state lands. This arrangement is not permanent, and PLP fails to identify a mechanism that would allow it to record a deed restriction over state-owned lands. PLP cannot restrict the uses of state lands and PLP provides no evidence that the State has agreed to do so.

4.3.2.3 Summary Regarding Compensatory Mitigation Measures

As described in Section 4.2, EPA Region 10 finds that discharges of dredged or fill material for the construction and routine operation of the 2020 Mine Plan could result in unacceptable adverse effects on anadromous fishery areas. Region 10 evaluated PLP's two compensatory mitigation plans and neither plan adequately mitigates adverse effects described in this proposed determination to an acceptable level. EPA Region 10 also evaluated additional potential compensation measures for informational purposes. Available information demonstrates that known compensation measures are unlikely to adequately mitigate effects described in this proposed determination to an acceptable level.

[70] This proposed preservation in the Koktuli River watershed would also fail to address any impacts that would occur in the UTC watershed, since those impacts would be in an entirely different river basin (i.e., the Kvichak River).

SECTION 5. PROPOSED DETERMINATION

Section 404(c) of the CWA authorizes EPA to (1) prohibit or withdraw the specification of any defined area as a disposal site and (2) restrict, deny, or withdraw the use of any defined area for specification as a disposal site whenever it determines that the discharge of dredged or fill material into such area will have an unacceptable adverse effect on municipal water supplies, shellfish beds and fishery areas (including spawning and breeding areas), wildlife, or recreational areas (33 USC 1344(c)).

The following proposed determination includes two parts. EPA Region 10 is proposing first to prohibit the specification of a defined area as a disposal site (Section 5.1), and second to restrict the use of a defined area for specification as a disposal site (Section 5.2), because it has reason to believe that certain discharges of dredged or fill material into waters of the United States within these areas could result in unacceptable adverse effects on fishery areas (including spawning and breeding areas).

EPA's prohibition and restriction below reference the Pebble deposit. For the purposes of this proposed determination, EPA Region 10 is describing the "Pebble deposit" by its surficial boundary, which is a rectangular area measuring 2.5 miles north–south by 3.5 miles east–west. As illustrated in Figures ES-5 and ES-6, this area covers:

> The southeast quarter of Section 17, Township 3 South, Range 35 West, Seward Meridian (S003S035W17); the south half of S003S035W14, S003S035W15, and S003S035W16; the east half of S003S035W20; the entirety of S003S035W21, S003S035W22, S003S035W23, S003S035W26, S003S035W27, and S003S035W28; and the east half of S003S035W29, with corners at approximately latitude 59.917 degrees north (59.917 N) and longitude 155.233 degrees west (155.233 W), latitude 59.917 N and longitude 155.333 W, latitude 59.881 N and longitude 155.333 W, and latitude 59.881 N and longitude 155.233 W.

5.1 Proposed Prohibition

The EPA Region 10 Regional Administrator has reason to believe that discharges of dredged or fill material for the construction and routine operation of the mine at the Pebble deposit identified in the 2020 Mine Plan (PLP 2020b) could result in unacceptable adverse effects on anadromous fishery areas in the SFK and NFK watersheds.[71] Based on information in PLP's CWA Section 404 permit application, the FEIS, and the ROD, such discharges would have the following impacts on aquatic resources:

1. The loss of approximately 8.5 miles (13.7 km) of documented anadromous fish streams (Section 4.2.1).

[71] Anadromous fishes are those that hatch in freshwater habitats, migrate to sea for a period of relatively rapid growth, and then return to freshwater habitats to spawn. For the purposes of this proposed determination, "anadromous fishes" refers only to Coho or Silver salmon (*Oncorhynchus kisutch*), Chinook or King salmon (*O. tshawytscha*), Sockeye or Red salmon (*O. nerka*), Chum or Dog salmon (*O. keta*), and Pink or Humpback salmon (*O. gorbuscha*).

2. The loss of approximately 91.2 miles (146.8 km) of additional streams that support anadromous fish streams (Section 4.2.2).

3. The loss of approximately 2,113 acres (8.6 km^2) of wetlands and other waters that support anadromous fish streams (Section 4.2.3).

4. Adverse impacts to at least 29 additional miles (46.7 km) of anadromous fish streams resulting from greater than 20 percent changes in average monthly streamflow (Section 4.2.4).

Sections 4.2.1 through 4.2.4 describe the basis for EPA Region 10's determination that each of the above impacts could, independently, result in unacceptable adverse effects on anadromous fishery areas (including spawning and breeding areas).

Accordingly, the Regional Administrator proposes that EPA prohibit the specification of waters of the United States within the mine site footprint for the 2020 Mine Plan located in the SFK and NFK watersheds (Figure ES-4) (PLP 2020b) as disposal sites for the discharge of dredged or fill material for the construction and routine operation of the 2020 Mine Plan (PLP 2020b, USACE 2020a: Appendix J). The Defined Area for Prohibition is the portion of the mine site footprint for the 2020 Mine Plan within the SFK and NFK watersheds (Figure ES-4) (PLP 2020b). The discharges prohibited in the Defined Area for Prohibition are dredged or fill material for the construction and routine operation of the 2020 Mine Plan.

5.2 Proposed Restriction

Based on the same record, the Regional Administrator has reason to believe that discharges of dredged or fill material associated with future plans to mine the Pebble deposit could result in unacceptable adverse effects on anadromous fishery areas anywhere in the SFK, NFK, and UTC watersheds if the effects of such discharges are similar or greater in nature[72] and magnitude[73] to the adverse effects of the 2020 Mine Plan described in Sections 4.2.1 through 4.2.4.

Accordingly, the Regional Administrator proposes to restrict the use of waters of the United States within the Defined Area for Restriction, as identified in Section 5.2.1, for specification as disposal sites for the discharge of dredged or fill material for the construction and routine operation of any future plan to mine the Pebble deposit that would either individually or collectively result in adverse effects similar or greater in nature and magnitude to those described in Sections 4.2.1 through 4.2.4. Because each of the impacts described in Sections 4.2.1 through 4.2.4 could, independently, result in unacceptable adverse effects on anadromous fishery areas, a proposal that triggers any one of these four unacceptability findings would be subject to the restriction.

[72] *Nature* means "the type or main characteristic of something" (see Cambridge Dictionary available at: https://dictionary.cambridge.org/us/dictionary/english/nature).
[73] *Magnitude* means "the large size or importance of something" (see Cambridge Dictionary available at: https://dictionary.cambridge.org/us/dictionary/english/magnitude).

5.2.1 Defined Area for Restriction

EPA Region 10 has determined that the discharge of dredged or fill material associated with mining the Pebble deposit could result in unacceptable adverse effects on anadromous fishery areas anywhere within the SFK, NFK, and UTC watersheds (Section 4). EPA Region 10 has identified the Defined Area for Restriction by including those areas within the boundaries of the SFK, NFK and UTC watersheds with potential to be a disposal site for the discharge of dredged or fill material associated with mining the Pebble deposit.

The Pebble deposit is wholly located within the SFK, NFK, and UTC watersheds. To identify such areas within the watershed boundaries with potential to be a disposal site, EPA Region 10 identified the location of mine claims in and around the Pebble deposit within the three watersheds. Alaska State law specifically recognizes the opportunity for mineral claims to be converted to leases to use the state's surface land for mining activity, including for a mill site, tailings disposal, or another use necessary for the mineral development, making the surface lands above mineral claims the most likely areas for discharge of dredge or fill material associated with mining.[74] As a result, EPA Region 10 focused on areas within the three watershed boundaries where mine claims are currently held and areas where mine claims are available to represent locations where there is a potential to be a disposal site (ADNR 2022c).

Accordingly, a Defined Area for Restriction that includes areas within the three watershed boundaries where mine claims are currently held and areas where mine claims are available represents locations where there is a potential for the discharge of dredged or fill material associated with mining the Pebble deposit.

The Defined Area for Restriction encompasses certain headwaters of the SFK, NFK, and UTC watersheds. The size of the Defined Area for Restriction is approximately 309 square miles (800 km^2). The description of the Defined Area for Restriction (Figures ES-5 and ES-6) is as follows:

> Beginning in the northeast at the intersection between the Upper Talarik Creek, Newhalen River, and Chulitna River watersheds, at approximately latitude 59.955 degrees north (59.955 N) and longitude 154.994 degrees west (154.994 W), it travels generally westward, along the boundary between the Upper Talarik Creek and Chulitna River watersheds to the intersection between the Upper Talarik Creek, Chulitna River, and Koktuli River watersheds, at approximately latitude 59.972 N and longitude 155.193 W; then generally west along the boundary between the Koktuli River and Chulitna River watersheds to approximately latitude 59.979 N and longitude 155.583 W; then generally southward along the boundary between the North Fork Koktuli River and mainstem Koktuli River watersheds, to the south boundary of Section 11, Township 4 South, Range 38 West, Seward Meridian (S004S038W11), at approximately latitude 59.837 N and longitude 155.774 W; then east along the south section line approximately 0.38 mile to the north-south half-section line at approximately latitude 59.837 N and longitude 155.763 W; then south, approximately 1.5 mile, along the north-south half-section line to the center of S004S038W23 at approximately latitude 59.816 N and longitude 155.763 W; then west along the east-west half-section line, approximately 1.09 mile, to the boundary between the Upper Koktuli River and Middle Koktuli River subwatersheds at approximately latitude 59.816 N and longitude 155.794 W; then generally southwest, approximately 0.46 mile, along the boundary between the Upper Koktuli River and Middle Koktuli River subwatersheds to the west boundary of S004S038W22at approximately latitude 59.812 N and longitude 155.806 W; then south along the section line, approximately 0.26 mile, to the south boundary of

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[74] 11 Alaska Administrative Code 86.600.

S004S038W22, at approximately latitude 59.808 N and longitude 155.806 W; then east along the south section line, approximately 1.0 mile to the east boundary of S004S038W27 at approximately latitude 59.808 N and longitude 155.777 W; then south along the east section line of S004S038W27 and S004S038W34, approximately 2.0 miles, until the south boundary of S004S038W34 at approximately latitude 59.780 N and longitude 155.777 W; then west along the south section line, approximately 0.04 mile, until the boundary between the Koktuli River and Stuyahok River watersheds at approximately latitude 59.780 N and longitude 155.778 W; then generally southeast, approximately 0.59 mile, along the watershed boundary between the Koktuli River and Stuyahok River watersheds until the intersection between the Koktuli River, Stuyahok River, and Kaskanak Creek watersheds at approximately latitude 59.775 N and longitude 155.764 W; then generally east along the boundary between the Koktuli River and Kaskanak Creek watersheds, approximately 4.14 miles, to the north boundary of S005S037W06 at approximately latitude 59.780 N and longitude 155.645 W; then east, approximately 0.09 mile, along the north section line to approximately latitude 59.780 N and longitude 155.642 W; then south along the north-south half-section line, approximately 0.07 mile, to the boundary between the Koktuli River and Kaskanak Creek watersheds at approximately latitude 59.778 N and longitude 155.642 W; then generally eastward, along the watershed boundary until the intersection between the Koktuli River, Kaskanak Creek, and Lower Talarik Creek watersheds at approximately latitude 59.767 N and longitude 155.541 W; then generally eastward, along the boundary between the Koktuli River and Lower Talarik Creek watersheds to the intersection of the Koktuli River, Lower Talarik Creek, and Upper Talarik Creek watersheds at approximately latitude 59.762 N and longitude 155.363 W; then generally southeastward, along the boundary between the Upper Talarik Creek and Lower Talarik Creek watersheds, to the south boundary of S005S036W24, at approximately latitude 59.722 N and longitude 155.329 W; then east along the south section line approximately 0.52 mile to the east section line, at approximately latitude 59.722 N and longitude 155.314 W; then north along the section line 1.0 mile to the south boundary of S005S035W18, at approximately latitude 59.736 N and longitude 155.314 W; then east along the south section line 2.0 miles to the east boundary of S005S035W17, at approximately latitude 59.736 N and longitude 155.259 W; then north along the east section line 1.0 mile to the south boundary of S005S035W09, at approximately latitude 59.751 N and longitude 155.259 W; then east along the south section line 1.0 mile to the east section line, at approximately latitude 59.751 N and longitude 155.230 W; then north along the east section line 1.0 mile to the south boundary of S005S035W03, at approximately latitude 59.765 N and longitude 155.230 W; then east along the south section line 1.0 mile to the east section line, at approximately latitude 59.765 N and longitude 155.202 W; then north along the east section line 1.0 mile to the south boundary of S004ST034W31, at approximately latitude 59.780 N and longitude 155.202 W; then west along the south section line 0.09 mile to the west section line, at approximately latitude 59.780 N and longitude 155.204 W; then north along the west section line 2.0 miles, to the south boundary of S004S034W19, at approximately latitude 59.808 N and longitude 155.204 W; then east along the south section line 1.0 mile to the east section line, at approximately latitude 59.808 N and longitude 155.176 W; then north along the east section line 1.0 mile to the south boundary of section S004S034W17, at approximately latitude 59.823 N and longitude 155.176 W; then east along the south section line 3.0 miles to the east boundary of S004S034W15, at approximately latitude 59.823 N and longitude 155.090 W; then north along the east section line 2.0 miles to the south boundary of S004S034W02, at approximately latitude 59.852 N and longitude 155.090 W; then east along the south section line, approximately 2.64 miles, to the boundary between the Upper Talarik Creek and Newhalen River watersheds, at approximately latitude 59.852 N and longitude 155.014 W; then generally north along the watershed boundary until the east boundary of S003S034W12 at approximately latitude 59.936 N and longitude 155.032 W; then north 1.15 mile along the section line to the south boundary of S002S033W31 at approximately latitude 59.953 N and longitude 155.032 W; then east along the section line 1.23 mile to the boundary between the Upper Talarik Creek and Newhalen River watersheds, at approximately latitude 59.953 N and longitude 154.997 W; then generally north, approximately 0.17 mile, along the watershed boundary to the starting point, at the intersection between the Upper Talarik Creek, Newhalen River, and Chulitna River watersheds (coordinates above).

SECTION 6. OTHER CONCERNS AND CONSIDERATIONS

The basis for EPA Region 10's proposed determination is the unacceptable adverse effects on fishery areas from discharges of dredged or fill material associated with proposed mining at the Pebble deposit, which is discussed in detail in Section 4. This section describes additional concerns and information that, while not the basis for EPA Region 10's proposed determination, are related to discharges of dredged or fill material associated with proposed mining at the Pebble deposit.

6.1 Other Potential CWA Section 404(c) Resources

CWA Section 404(c) authorizes EPA to exercise its discretion to act whenever it determines that the discharge of dredged or fill material will have an unacceptable adverse effect on specific aquatic resources. CWA Section 404(c) provides the following:

> The Administrator is authorized to prohibit the specification (including the withdrawal of specification) of any defined area as a disposal site, and he is authorized to deny or restrict the use of any defined area for specification (including the withdrawal of specification) as a disposal site, whenever he determines, after notice and opportunity for public hearings, **that the discharge of such materials into such area will have an unacceptable adverse effect on municipal water supplies, shellfish beds and fishery areas (including spawning and breeding areas), wildlife, or recreational areas**. Before making such determination, the Administrator shall consult with the Secretary. The Administrator shall set forth in writing and make public his findings and his reasons for making any determination under this subsection. [emphasis added]

Section 4 of this proposed determination considers the adverse effects from the discharge of dredged or fill material on fishery areas. Section 6.1 evaluates the potential for adverse effects on wildlife, recreation, and water supplies.

6.1.1 Wildlife

Unlike most terrestrial ecosystems, the Bristol Bay watershed has undergone little development and remains largely intact. Thus, it still supports its historical complement of species, including large carnivores, such as brown bears, bald eagles, and gray wolves; ungulates such as moose and caribou; and numerous bird species. For example, more than 40 mammal species are thought to regularly occur in the Nushagak and Kvichak River watersheds (Brna and Verbrugge 2013). At least 13 of these species are known, or have the potential based on the presence of suitable habitat, to occur in the SFK, NFK, and UTC watersheds: brown bear, moose, caribou, gray wolf, red fox, river otter, wolverine, arctic ground squirrel, red squirrel, beaver, northern red-backed vole, tundra vole, and snowshoe hare (PLP 2011: Chapter 16). One of two freshwater harbor seal populations in North America is found in Iliamna Lake (Smith et al. 1996).

As many as 134 species of birds occur in the Nushagak and Kvichak River watersheds (Brna and Verbrugge 2013), and at least 37 waterfowl species have been observed in the SFK, NFK, and UTC watersheds, 21 of which have been confirmed as breeders (PLP 2011: Chapter 16). The region's aquatic habitats support migrants and wintering waterfowl, which includes an important staging area for many species, including emperor geese, Pacific brant, and ducks, during spring and fall migrations. Twenty-eight landbird and 14 shorebird species have also been documented in the SFK, NFK, and UTC watersheds (PLP 2011: Chapter 16). The FEIS identifies bird species protected under the Migratory Bird Treaty Act of 1918, the Bald and Golden Eagle Protection Act, and bird species of concern within its mine site analysis area (USACE 2020a: Section 4.23).

Within the Nushagak and Kvichak River watersheds, there are no known breeding or otherwise significant occurrences of any species listed as threatened or endangered under the Endangered Species Act, nor is there any designated critical habitat.

Wildlife present in the SFK, NFK, and UTC watersheds—several of which are essential subsistence species (Section 6.3.1)—would likely be adversely affected by large-scale mining at the Pebble deposit. Direct impacts of mining on wildlife would include, but are not limited to, loss of terrestrial and aquatic habitat, reduced habitat effectiveness (e.g., in otherwise suitable habitats adjacent to the mine area), habitat fragmentation, increased stress and avoidance due to noise pollution, and increased conditioning on human food. Direct copper toxicity to wildlife resulting from mine operations is less of a concern than indirect effects from copper-related reductions in aquatic communities (EPA 2014: Chapter 12).

In addition to direct mine-related effects, wildlife species would also likely be affected indirectly via any reductions in salmon populations. Marine-derived nutrients imported into freshwater systems by spawning salmon provides the foundation for the region's aquatic and terrestrial foodwebs, via both direct consumption of salmon in any of its forms (spawning adults, eggs, carcasses, or juveniles) and nutrient recycling (e.g., transport and distribution of marine derived nutrients from aquatic to terrestrial environmental by wildlife) (Section 3.3.4). Availability and consumption of these salmon-derived resources can have significant benefits for terrestrial mammals and birds, including increases in growth rates, litter sizes, nesting success, and population densities (Brna and Verbrugge 2013). Waterfowl prey on salmon eggs, parr, and smolts and scavenge salmon carcasses. Carcasses are an important food source for bald eagles, water birds, other land birds, other freshwater fishes, and terrestrial mammals. Aquatic invertebrate larvae also benefit from carcasses and are an important food source for water birds and land birds. It is likely that these species would be adversely affected by any mine-related reductions in salmon production.

The FEIS identifies direct and indirect impacts to wildlife that could result at the proposed mine site, including behavioral disturbances, injury and mortality, and habitat changes. Noise and the presence of humans, vehicles, aircraft, and other equipment could result in avoidance of the mine site by wildlife throughout construction, operations, and closure. Mortality of, and injury to, wildlife at the proposed mine site could occur due to vegetation clearing; collisions with vehicles, equipment, and structures; defense of life and property; altered predator and prey relationships; changes in water quality; nest abandonment and/or disturbance; exposure to contaminants; and possible spills. The FEIS estimates the direct loss of 8,390 acres of habitat and the indirect loss of additional habitat surrounding the mine site due to avoidance, which would occur throughout the life of the project and longer in areas that are not restored. Wildlife habitat may also see long-term changes due to the introduction or spread of invasive species, changes in water quality and air quality, and potential spills (USACE 2020a: Section 4.32).

The Expanded Mine Scenario would contribute to cumulative effects of wildlife habitat loss, disturbance, injury, and mortality. The FEIS estimates that 31,541 acres of habitat would be lost at the expanded mine site, as well as additional habitat surrounding the expanded mine site due to avoidance (USACE 2020a: Section 4.23).

The FEIS provides more detailed information not summarized in this proposed determination regarding other potential direct, indirect, and cumulative impacts that may result from the 2020 Mine Plan and the Expanded Mine Scenario, including species-specific information in some cases.

6.1.2 Recreation

Next to commercial salmon fishing and processing, recreation is the largest private economic sector in the Bristol Bay region (EPA 2014: Appendix E) due mainly to the watershed's remote, pristine wilderness setting and abundant natural resources. Key recreational uses include sport fishing, sport hunting, and other tourism/wildlife viewing recreational trips—all of which are directly or indirectly dependent on the intact, salmon-based ecosystems of the region. Direct regional expenditures on these recreational uses, expressed in terms of 2021 dollars,[75] are estimated at more than $210 million (EPA 2014: Table 5-4). Much of these expenditures are by non-residents, highlighting the fact that the recreational value of Bristol Bay watershed is recognized even by people that live a significant distance from the region. Total visitors to the Bristol Bay region are estimated at 40,00 to 50,000 people annually (McKinley Research Group 2021). In 2019, tourism spending in the Bristol Bay region generated $155 million in total economic output and 2,300 jobs in Alaska. Recreation in the region diversifies the region's economy through the use of sustainable resources (McKinley Research Group 2021).

In particular, the abundance of large game fishes makes the region a world-class destination for recreational anglers. The 2005 Bristol Bay Angler Survey confirmed that the freshwater rivers, streams, and lakes of the region are a recreational resource equal or superior in quality to other world-renowned sport fisheries (EPA 2014: Appendix E). In 2009, sport anglers took approximately 29,000 sport-fishing trips to the Bristol Bay region (12,000 trips by people living outside of Alaska, 4,000 trips by Alaskans living outside of the Bristol Bay area, and 13,000 trips by Bristol Bay residents) (EPA 2014: Chapter 5). These sport-fishing activities directly employed over 800 full- and part-time workers. At peak times, 92 businesses and 426 guides have operated in the Nushagak and Kvichak River watersheds alone (EPA 2014: Chapter 5). Approximately 90 lodges and camps operate in the Bristol Bay region, primarily

[75] Values adjusted using Anchorage Consumer Price Index.

focusing on sport fishing and bear viewing. Lodge and camp guests spent an estimated $77 million in 2019 (McKinley Research Group 2021).

Much of the sport fishery in the region is relatively low-impact catch-and-release, although there is some recreational harvest. Sockeye, Chinook, and Coho salmon are the predominant fishes harvested, although Rainbow Trout, Dolly Varden, Arctic Char, Arctic Grayling, Northern Pike, Chum Salmon, Lake Trout, and whitefish are also important recreational species (Dye and Borden 2018). From 2007 to 2017, the total annual recreational harvest in the Bristol Bay Management Area ranged from roughly 42,000 to 59,000 fish (Dye and Borden 2018). In 2017, an estimated 30,282 Rainbow Trout were caught and 241 Rainbow Trout were harvested in the Nushagak, Wood, and Togiak River watershed. The same year, an estimated 114,431 Rainbow Trout were caught and 66 Rainbow Trout were harvested in the Kvichak River watershed (Table 3-12) (Romberg et al. 2021).

Sport fishing in the Bristol Bay region is a large and well-recognized share of recreational use and associated visitor expenditures (Section 3.3.5). In addition, thousands of trips to the region each year are made for sport hunting and wildlife viewing. For example, Lake Clark and Katmai National Parks are nationally significant protected lands and are important visitor destinations. Between 2012 and 2021, Katmai National Park and Preserve attracted an average of 41,139 visitors annually, and Lake Clark National Park and Preserve averaged 15,728 visitors annually (NPS 2022). Rivers within Katmai National Park provide the best locations in North America to view wild brown bears (EPA 2014: Appendix E). The region is also used for recreational water activities, hiking, backpacking, biking, flightseeing, and other activities, especially in Katmai National Park and Preserve and Lake Clark National Park and Preserve (USACE 2020a: Section 4.5).

Sport hunting for caribou, moose, brown bear, and other species also plays a role in the local economy of the Bristol Bay region. In recent years, approximately 1,323 non-residents and 1,319 non-local residents of Alaska traveled to the region to hunt, spending approximately $6,395 (non-residents) and $1,631 (non-local residents) per trip (expressed in 2021 dollars[76]), respectively (EPA 2014: Chapter 5). These hunting activities result in an estimated $10 million per year in direct hunting-related expenditures (values expressed in 2021 dollars[77]) and directly employ over 100 full- and part-time workers (EPA 2014: Chapter 5).

The 2020 Mine Plan would result in the permanent alteration and loss of 8,391 acres of land at the mine site that are currently available for recreation, including the loss of 2,113 acres of wetlands and other waters that support fish and wildlife and attract recreational anglers and hunters (USACE 2020a: Section 4.5). As described in Section 4.2.1.1, the 2020 Mine Plan would permanently remove 8.5 miles (13.7 km) of streams with documented occurrence of Coho and Chinook salmon, disrupting the spawning cycle and displacing spawners. The substantial spatial and temporal extents of stream habitat losses under the 2020 Mine Plan suggest that these losses would reduce the overall capacity and

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[76] Values adjusted using Anchorage Consumer Price Index.
[77] Values adjusted using Anchorage Consumer Price Index.

productivity of Chinook and, particularly, Coho salmon in the NFK watershed. The Nushagak River—to which the SFK and NFK flow—supports the largest Chinook Salmon sport fishery in the United States and, in turn, a network of private and commercial sport-fishing camps overseen by Choggiung, Ltd., the Alaska Native village Corporation for Dillingham, Ekuk, and Portage Creek (NMWC 2007, Choggiung 2014, Dye and Borden 2018). The loss of habitat at the mine site would affect downstream trout habitat, possibly displacing trout and, therefore, anglers (USACE 2020a: Section 4.6). The FEIS acknowledges the potential for economic impacts borne by recreational anglers and affiliated guides and lodges, stating that "affected operators could substitute fishing on different streams, albeit at potentially higher costs to themselves and their consumers" (USACE 2020a: Page 4.6-12).

The FEIS indicates that the mine site itself does not support much recreational use, though construction, operations, and closure of the mine site would affect recreational activities on surrounding lands. Noise and the presence of humans, vehicles, aircraft, and other equipment is likely to result in avoidance of the mine site by wildlife that support recreational uses. Changes to the landscape due to visibility of the mine and night sky light pollution would alter the recreational experience for visitors and potentially displace recreation visitors and activities to other areas. These impacts together would reduce the opportunities for solitude (USACE 2020a: Section 4.6). Further, there exists the possibility of a loss in recreational visitors and activity in areas not impacted by the 2020 Mine Plan resulting from the perceived loss of habitat or fishery quality due to the construction and operations of the mine (Glasgow and Train 2018, English et al. 2019, Glasgow and Train 2019).

The Expanded Mine Scenario, which would extend impacts in the SFK and UTC watersheds, would contribute to cumulative effects similar in nature to those described above but over a larger area. The larger mine footprint would further displace wildlife and increase the amount of disturbance in the NFK and SFK watersheds, reducing opportunities for hunting, fishing, and wildlife viewing (USACE 2020a: Section 4.6).

6.1.3 Public Water Supplies

Alaska Native residents of the Nushagak and Kvichak River watersheds consistently stress the importance of clean water to their way of life, not only in terms of providing habitat for salmon and other fishes but in terms of providing high-quality drinking water (EPA 2014: Appendix D). Drinking water sources in the region include municipal treated water, piped but untreated water, individual wells, and water hauled directly from rivers and lakes (EPA 2014: Appendix D, Table 3).

At this time, it is difficult to determine what, if any, effects routine operations of a mine at the Pebble deposit could have on public water supplies in the Nushagak and Kvichak River watersheds. Private wells are a primary drinking water source for many residents of the Nushagak and Kvichak River watersheds, and communities also rely on groundwater for their public water supply. The extent that surface water influences the quality or quantity of the groundwater source for these wells is unknown. There are also communities in the area that rely on surface water sources, which may be more susceptible to mine-related contamination. Although no communities are currently located in the SFK, NFK, or UTC watersheds (Figure ES-2), residents of nearby communities use these areas for subsistence hunting and fishing and other activities and may drink from surface waters and springs in these watersheds.

Development of a large-scale mine at the Pebble deposit would require a work force of more than 1,700 people during construction and more than 850 people during mine operation (USACE 2020a: Chapter 2). Thus, the mine site would rival Dillingham as the largest population center in the Bristol Bay watershed during construction and would remain the second-largest population center during operation. This population would require sufficient water supplies in the Pebble deposit region, and these supplies would be vulnerable to contamination or degradation resulting from mine development and operation. The 2020 Mine Plan includes installation of groundwater wells on the northern side of the mine site to supply potable water (USACE 2020a: Section 3.18).

Other public water supplies (e.g., at Iliamna, Newhalen, and Pedro Bay) could be affected by construction of and transport along a roadway and/or pipelines connecting the Pebble deposit region to Cook Inlet. The Safe Drinking Water Act requires states and utilities to assess the source water for public water systems, and there CWA provisions designed for protecting source waters from contamination. The ADEC Drinking Water Program has delineated drinking water source protection areas for all public water system sources and includes areas along the proposed transportation corridor, the region surrounding Iliamna Lake, and the adjacent communities. Currently, there are no designated drinking water protection areas for private wells in Newhalen, Iliamna, and other villages along the transportation corridor, nor at the mine site (USACE 2020a: Section 3.18).

6.2 Effects of Spills and Failures

This proposed determination does not consider impacts from potential accidents and failures as a basis for its findings; however, as discussed in this section there is a likelihood that some spills would occur over the life of the mining operation. Failure of major infrastructure—such as, concentrate and tailings pipelines, the water management facilities, or TSF dams—while less likely, could result in severe impacts to aquatic resources in the SFK, NFK, and UTC watersheds.

The FEIS and the BBA evaluated potential impacts of an array of possible accidents and failures that could result in releases and spills of concentrate, tailings, and contaminated water, including their potential effects on fishery areas (EPA 2014, USACE 2020a). This section summarizes the potential impacts of mine area spills on aquatic resources that were evaluated in the FEIS and also summarizes the potential impacts of a tailings dam failure.

6.2.1 Final Environmental Impact Statement Spill and Release Scenarios

The FEIS (Section 4.27) evaluates the spill risk associated with the 2020 Mine Plan, including spills and releases of diesel fuel, natural gas, chemical reagents, copper-gold flotation concentrate, tailings, and untreated contact water. The FEIS includes a detailed analysis of seven hypothetical spill scenarios that would generally have a low probability of occurring, but with potential environmental consequences that could be high. Some of the scenarios considered in the FEIS are vehicle and marine transportation-related and are not mentioned here since this proposed determination focusses on the mine site impacts. The spill scenarios analyzed in the FEIS applicable to the mine site include a spill of concentrate slurry, a bulk tailings release from the tailings delivery pipeline, and a partial breach of the pyritic tailings impoundment that results in a pyritic tailings release. The FEIS evaluates potential environmental impacts of these spill scenarios and uncertainties. A summary of the potential environmental impacts of these scenarios on aquatic resources is provided below.

6.2.1.1 Release of Concentrate Slurry from the Concentrate Pipeline

The copper-gold flotation concentrate that would be produced under the 2020 Mine Plan would be composed of a slurry containing finely ground rock and mineral particles that have been processed from the mined ore to concentrate the economic minerals containing copper and gold. The concentrate particles in the slurry would be potentially acid generating and capable of metal leaching over time, depending on conditions. The concentrate slurry would also contain approximately 45 percent mine contact water, which would have elevated concentrations of metals, including copper, and residual amounts of chemical reagents. Under the 2020 Mine Plan, the concentrate would be transported from the mine site to the port site by a pipeline. The FEIS evaluates the potential impacts due to a release of concentrate slurry from the pipeline. The concentrate slurry release scenario was based on historic spill data and a statistical evaluation of probabilities. The FEIS estimates a concentrate pipeline failure rate of 0.013, which equates to a probability of one or more pipeline failures of 1.3 percent in any given year; 23 percent in 20 years; or 64 percent in 78 years.

The analysis in the FEIS determines that a concentrate slurry spill into flowing waters could have the following impacts on water quality, aquatic resources, and subsistence, commercial, and recreational fisheries users:

- If a concentrate spill occurs to flowing water, the concentrate would be difficult to recover and would be transported downstream. The distance downstream would depend on the amount and location of the release but could extend into Iliamna Lake.
- Concentrate solids would cause a temporary increase in total suspended solids (TSS) and sedimentation to downstream waters.
- Potential impacts to fish from increased TSS and sedimentation include decreased success of incubating salmon eggs; reduced food sources for rearing juvenile salmon; modified habitat; and in extreme cases, mortality to eggs and rearing fish in the immediate area of the spill.
- Contact water contained in the concentrate slurry would result in exceedances of water quality criteria for copper and other metals.
- Sulfide minerals in the concentrate slurry would slowly dissolve in the subaqueous environment over years to decades and result in metal leaching. The dissolved metals in the aqueous phase of the

concentrate slurry could have acute impacts to the aquatic environment that would likely be temporary and localized, but would depend on the size of the release.

- A concentrate spill into flowing water could temporarily displace recreational angling efforts in the vicinity of the spill if the event or cleanup occurred during the open water fishing season.
- A concentrate release would likely cause concerns over contamination for local subsistence users.

6.2.1.2 Tailings Releases

Tailings are the leftover mixture of ground ore and process water following separation of the copper-gold concentrate and molybdenum concentrate. Processing associated with the 2020 Mine Plan would result in the production of two separate tailings waste streams, bulk tailings, and pyritic tailings. Approximately 88 percent of the tailings would be bulk tailings and approximately 12 percent would be pyritic tailings. The bulk tailings would consist of tailings that are primarily non-acid generating. The pyritic tailings would have a high level of potentially acid generating minerals.

The bulk tailings would be transported by pipeline to a bulk TSF. The pyritic tailings would be transported by a pipeline to a pyritic TSF. Table 6-1 lists some of the key features of the TSFs.

Table 6-1. Summary description of Tailings Storage Facilities.

TSF	Design Features
Bulk TSF	• 1.1 billion tons of tailings would be disposed in the bulk TSF. • Tailings would be thickened before disposal in the TSF. • TSF would have a minimal supernatant pool (pond) during operations. • TSF would have two embankments (dams). The main dam would be 13,700 ft long and 545 ft high. The south dam would be 4,900 ft long and 300 ft high. • The main dam would be a flow-through design and would be constructed using the centerline method. • The south dam would be constructed using downstream method and would be lined on the upstream face. • At closure, the TSF would be covered and allowed to dewater with the goal of becoming a stable landform.
Pyritic TSF	• 155 million tons of pyritic tailings and up to 93 million tons of PAG waste rock would be stored in the pyritic TSF. • TSF would have a full water cover during operations. • TSF would have three dams. The south dam would be 4,500 ft long and 215 ft high. The north dam would be 335 ft high and the east dam 225 ft high with combined length of 2,500 ft. • These dams that would be constructed using the downstream method. • Impoundment would be fully lined. • At closure, the pyritic tailings and waste rock would be backfilled into the open pit.

Source: USACE 2020a.

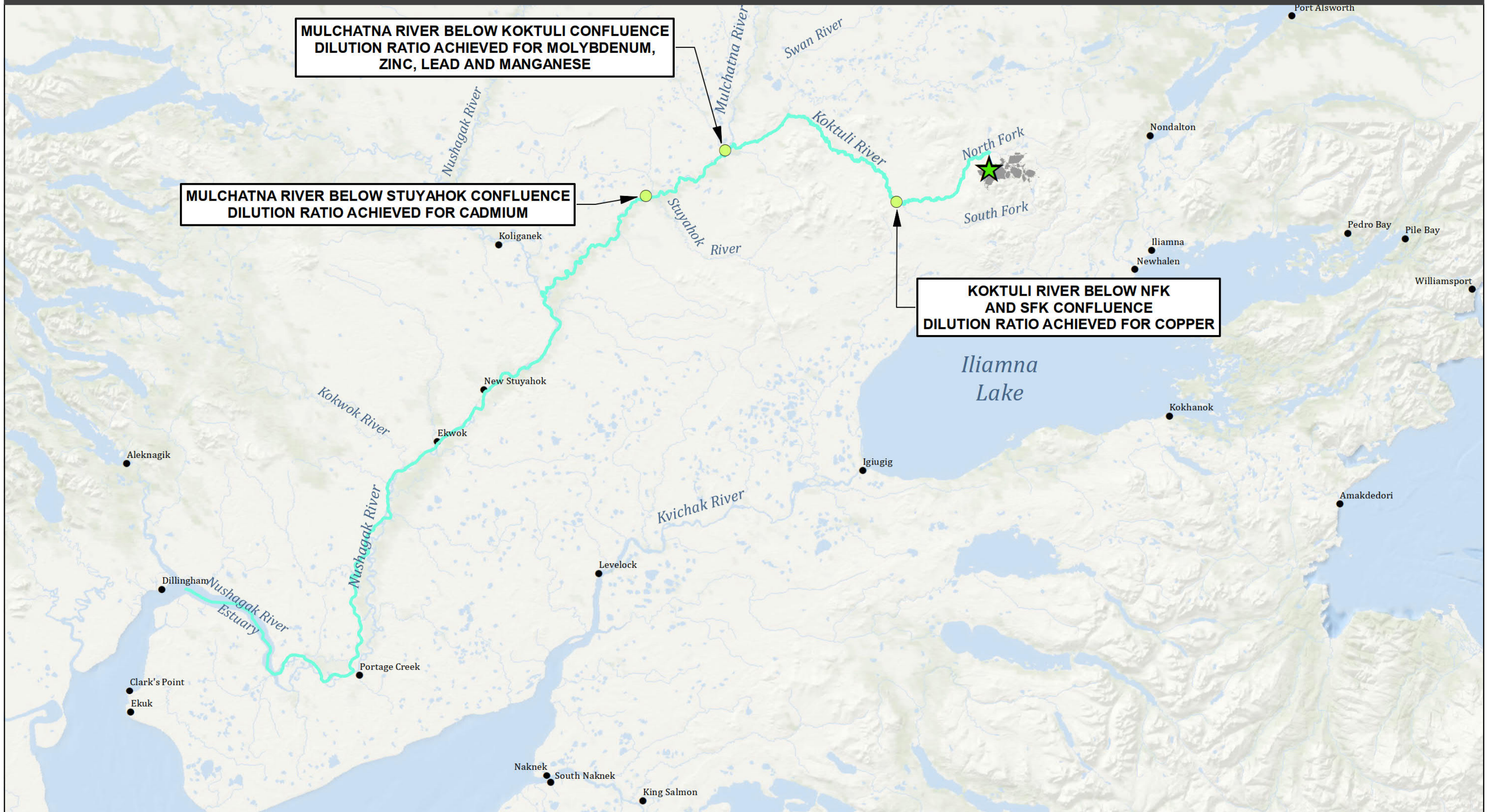
The FEIS evaluates the potential environmental impacts associated with two hypothetical tailings release scenarios, including a release of 1.56 million cubic feet of bulk tailings associated with shearing of the tailings delivery pipelines and a partial breach of the pyritic tailings facility embankment that would result in a release of 185 million cubic feet of tailings and pond water. These scenarios were based on an EIS-Phase Failure Modes Effects Analysis (FMEA) risk assessment that was conducted by USACE. The FEIS determines that tailings releases under these scenarios could result in the following impacts:

- Under both tailings release scenarios, most of the fine tailings particles would be transported downstream, causing elevated TSS in exceedance of water quality criteria (WQC) for approximately

230 miles downstream as far as the Nushagak River Estuary, where the river feeds into Nushagak Bay. Additional TSS would be generated due to ongoing erosion and sedimentation from potential stream destabilization during the release floods and could persist for months to years, depending on the speed and effectiveness of stream reclamation efforts that would control streambed erosion.

- Tailings fluids (contact water used to mix the bulk tailings slurry and pyritic supernatant fluid) would contain concentrations of some metals that exceed WQC. The dissolved metals would be transported downstream and diluted to various degrees, depending on stream flow. Metals with the highest concentrations would continue to exceed WQC for tens of miles downstream. The estimated extent of impacts for the specific scenarios modeled in the FEIS are as follow:
    - Bulk tailings release: Copper concentrations would exceed the most stringent WQC to the Koktuli River below the NFK and SFK confluence, about 23 miles downstream from the mine site. Molybdenum, zinc, lead, and manganese concentrations would exceed the most stringent WQC until the Mulchatna River below the Koktuli River confluence, about 62 miles downstream. Cadmium concentrations would exceed the most stringent WQC until the Mulchatna River below the Stuyahok River confluence, about 78 miles downstream from the mine site.
    - Pyritic tailings release: Copper would remain at levels exceeding the most stringent WQC until the Mulchatna River below the Koktuli River confluence, about 80 miles downstream of the mine site. Zinc, lead, and manganese would remain at levels exceeding the most stringent WQC until the Nushagak River below the Mulchatna River confluence, about 122 miles downstream of the mine site. Cadmium and molybdenum would remain at levels exceeding the most stringent WQC as far downstream as the Nushagak River Estuary, about 230 miles downstream from the mine site. The modeled extent of elevated metals for this scenario is shown in Figure 6-1.
- Fish and other aquatic organisms would be simultaneously affected by the elevated TSS and metals concentrations in the water, leading to potential physical injury, loss of habitat and food, and potentially lethal metals toxicity. In the short term, and immediately downstream of the spill, potentially lethal acute metal toxicity may occur in fish species and other sensitive aquatic species. Over days to weeks in downstream locations, sub-lethal effects, such as impairment of olfaction, behavior, and chemo/mechanosensory responses, may also occur in these receptors, specifically due to copper. Impacts from elevated metals could last for 5 to 6 weeks after the pyritic release scenario, while TSS impacts could last for months to years, depending on the effectiveness of stream restoration efforts.
- Although predicted mercury concentrations in tailings are low, even very low amounts of total mercury could result in bioaccumulation and biomagnification in fishes.
- Commercial fishing could be affected, depending on impacts to fish in the affected drainages. Recreational anglers fishing these waters could experience a temporary reduction in harvest rates or catch per unit effort rates if the sub-lethal effects reduced target species' ability or desire to feed or strike at anglers' lures.

Figure 6-1. Modeled extent of elevated metals downstream of pyritic tailings release. Figure 4.27-4 from the FEIS (USACE 2020a: Section 4.27)



Sources: KP 2018o; PLP 2019-RFI153

US Army Corps of Engineers

10 0 10 20
Miles

Location of Release
Dilution Ratio Achieved
Modeled Rivers
Mine Site

MODELED EXTENT OF ELEVATED METALS DOWNSTREAM OF BULK TAILINGS RELEASE

PEBBLE PROJECT EIS **FIGURE 4.27-4**

- Tailings spills could cause psychosocial stress resulting from community anxiety over a tailings release, particularly in areas of valued subsistence and fishing activities. There could be exposures to potentially hazardous materials, including metals, particularly in the pyritic tailings release. Subsistence users may choose to avoid the area and alter their harvest patterns, due to actual and potential perceptions of subsistence food contamination that extend throughout the area.

In the event of a tailings release, efforts would be made recover tailings. A small release near the mine site could be recoverable. However, once tailings are actively transported downstream full recovery efforts may not be practicable or possible. This issue is discussed further in Section 6.2.2.

6.2.1.3 Untreated Contact Water Release

Untreated contact water is surface water or groundwater that has been in contact with mining infrastructure or mining wastes. Under the 2020 Mine Plan, contact water would be stored in several facilities, including the main WMP, the open pit WMP, and six seepage collection ponds downstream of the TSFs. The main WMP is the largest water storage facility and would include a 750- to 825-acre reservoir contained by a 150-ft-high embankment. According to the FEIS, the main WMP would be among the largest lined water storage reservoirs in the world. The FEIS predicts that contact water would contain elevated levels of several metals in exceedance of WQC. The FEIS evaluates a scenario of a slow release of untreated contact water from the main WMP over a month for a total release of 5.3 million cubic feet into the NFK. The scenario was developed by USACE based on the EIS-Phase FMEA. The FEIS determines that the release could result in the following impacts:

- Untreated contact water released into the downstream drainages would contain elevated levels of aluminum, arsenic, beryllium, cadmium, copper, lead, manganese, mercury, molybdenum, nickel, selenium, silver, and zinc in exceedance of the most stringent aquatic life WQC. The released untreated contact water would be diluted by stream water as it flows downstream, yet some metal concentrations could remain elevated above WQC for up to 45 miles downstream of the mine site; exceedances would last through the duration of the release.
- Impacts to fish from the release of untreated contact water would be similar to those described for elevated metal impacts from the pyritic tailings release scenario. Acute toxicity due to metals would not likely occur; however, prolonged exposure to metal concentrations in slight exceedance of WQC may result in sub-lethal effects.
- Commercial fishing could be affected, depending on impacts to fish in the affected drainages. Recreational anglers fishing these waters could experience a temporary reduction in harvest rates or catch-per-unit effort rates if the sub-lethal effects reduced target species' ability or desire to feed or strike at anglers' lures.
- Subsistence users may choose to avoid the area and alter their harvest patterns. Spills of untreated contact water could cause psychosocial stress, particularly in areas of valued subsistence and fishing activities.

6.2.2 Tailings Dam Failure

While the FEIS assesses impacts of a partial breach of the pyritic TSF, as discussed above, it does not quantify or model the extent of impacts that could be caused by a catastrophic failure of the pyritic or bulk TSF dams. USACE determined that a full breach analysis was not necessary because it determined that the probability that a full breach could occur is very remote based on the tailings management plans and TSF designs.

However, EPA believes there could be uncertainty with this conclusion due to the conceptual nature of the TSF designs, potential future changes to the TSF water balances due to climate change, the possibility that design or operational changes could occur during implementation, and the very long time frames over which the bulk TSF dams would need to be maintained. In addition, the FEIS identifies that there is uncertainty associated with the ability of the bulk tailings to drain sufficiently, which would result in the majority of the tailings remaining in a saturated condition and a higher phreatic surface than assumed in the main dam drainage design. The FEIS identifies that this could be monitored during operations and corrected by changes to designs of future dam raises. The FEIS acknowledges that the common factor in all major TSF failures has been human error, including errors in design, construction, operations, maintenance, and regulatory oversight. FEIS Appendix K4.27 includes a review of recent tailings dam failures including Mount Polley (Canada, 2014), Fundao (Brazil, 2015), Cadia (Australia, 2018), and Feijao (Brazil 2019). Some of these failures have caused severe environmental damage and fatalities.

EPA evaluated potential dam failure scenarios in the BBA. The quantitative aspects of the BBA scenarios are not applicable to the 2020 Mine Plan due to differences in the TSF designs and assumptions. However, some of the general conclusions regarding the potential for severe impacts on aquatic resources if such an event were to occur are still applicable. In addition, the FEIS contains a general discussion of the fate and behavior of released tailings from which a potential range of impacts can be discerned.

Failure of the bulk TSF main dam would result in the release of a thickened tailings slurry into the NFK. The FEIS estimates that a release from the bulk TSF main dam would travel only about 2.2 miles downstream due to the thickened nature of the tailings. However, as noted above, it is possible that the tailings could remain saturated, which would result in more fluidized conditions and would travel further. In addition, the FEIS notes that slumping can occur and that upon entering a flowing stream, tailings particles would become entrained in the water and be carried further downstream. Failure of any of the fluid-filled pyritic TSF dams would result in a flood of water and tailings slurry, which could move far downstream.

Tailings slurry releases can result in the following effects:

- Spilled tailings would bury habitat and streamflow would transport some of the spilled tailings downstream, where further deposition would occur, burying stream substrate and altering habitat.

- Tailings entrained in water would create turbid water conditions and sedimentation downstream. Upstream erosion would also contribute to ongoing downstream turbidity and sedimentation.
- Downstream sedimentation and elevated TSS and turbidity would continue until spilled tailings are recovered, naturally flushed out of the drainage, or incorporated into the bedload. Complete recovery of spilled tailings is not possible, because tailings spilled in flowing water would be widely dispersed. If no tailings were recovered or if the volume of release was extremely high, decades to centuries may be required to naturally flush tailings out of the drainages.
- Metals could leach from unrecovered tailings on a timescale of years to decades. Metals that accumulate in streambed sediments could adversely affect water quality on a timescale of decades.
- The bulk tailings fluid contains antimony, arsenic, beryllium, cadmium, copper, lead, manganese, mercury, molybdenum, selenium, zinc, total dissolved solids, hardness, and sulfate in exceedance of WQC. Water quality characteristics of the pyritic TSF fluids are discussed in Section 6.2.1. Elevated metals and other constituents contained in released tailings process fluids would affect water quality downstream. Released fluids would be diluted by stream water, but streams could fail to meet WQC for many miles downstream. Depending on the volume and the rate of release, the downstream water quality would be in exceedance of WQC for an unknown length of time and an unknown distance before the released fluid is sufficiently diluted below WQC.
- Deposited tailings would severely degrade habitat quality for fishes and the invertebrates they eat due to extensive smothering effects. In addition, based largely on their copper content, deposited tailings would be toxic to benthic macroinvertebrates; existing data concerning toxicity to fishes are less clear.
- The affected streams would provide low-quality spawning and rearing habitat for decades.
- Recovery of suitable substrates via mobilization and transport of tailings would take years to decades and would affect much of the watershed downstream of the failed dam.
- For some years, periods of high streamflow would be expected to suspend sufficient concentrations of tailings to cause avoidance, reduced growth and fecundity, and even death of fishes.
- Loss of NFK fishes downstream of the TSF and additional fish losses in the mainstem Koktuli, Nushagak, and Mulchatna Rivers would be expected to result from these habitat losses.

The extent of habit and fisheries loss due to failure of any of the TSF dams would depend on many factors, including when the breach occurs during the operational life of the facility, the amount of tailings released, the water content of the tailings, the speed and duration of release, seasonality (winter vs spring/summer conditions), and failure mode. However, the extent of impacts would go much further beyond the extent of the bulk TSF pipeline release and pyritic TSF partial breach described in the FEIS and summarized in Section 6.2.1, and the duration of impacts would be much longer. The USACE ROD acknowledges that although the probability of a full dam breach is low, the consequences would be high and catastrophic failure could have severe and irreversible impacts to subsistence, commercial, and recreational fisheries. USACE states "In the event of human error and/or a catastrophic event, the commercial and/or subsistence resources would be irrevocably harmed, and there is no historical scientific information from other catastrophic events to support restoration of the fishery to its pre-impacted state" (USACE 2020b: Page B3-27).

6.3 Other Tribal Concerns

EPA's policy is to consult on a government-to-government basis with federally recognized tribal governments whenever EPA actions and decisions may affect tribal interests, consistent with Executive Order 13175, *Consultation and Coordination with Indian Tribal Governments*.[78] Consultation is a process of meaningful communication and coordination between EPA and tribal officials. Separately, pursuant to Public Law 108-199, 118 Stat. 452, as amended by Public Law 108-447, 118 Stat. 3267, EPA is required to consult and engage with Alaska Native Corporations on the same basis as tribes under Executive Order 13175.[79]

Throughout development of the BBA (EPA 2014: Chapter 1), the 2014 Proposed Determination, and the 2017 proposal to withdraw the 2014 Proposed Determination, EPA Region 10 provided opportunities for consultation and coordination with federally recognized tribal governments, as well as consultation and engagement with Alaska Native Corporations. On all actions, EPA invited all 31 Bristol Bay tribal governments and all 26 Alaska Native Corporations in Bristol Bay to participate.

On January 27, 2022, EPA Region 10 sent letters inviting consultation to all 31 tribal governments located in the Bristol Bay watershed. Separately, it also invited consultation with 5 Alaska Native Corporations and offered engagement to 21 Alaska Native Corporations with lands in the Bristol Bay watershed. EPA Region 10 hosted two informational webinars for tribal governments and one informational webinar for Alaska Native Corporations to review the CWA Section 404(c) process and answer questions. EPA Region 10 will continue to provide opportunities for tribal consultation and coordination and consultation and engagement with Alaska Native Corporations going forward.

This section describes additional concerns and information that may affect tribal interests regarding potential effects of discharges of dredged or fill material associated with mining of the Pebble deposit on subsistence use, traditional ecological knowledge (TEK), and environmental justice.

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[78] In May 2011, EPA issued the *EPA Policy on Consultation and Coordination with Indian Tribes*, which established national guidelines and institutional controls for consultation. In October 2012, EPA Region 10 issued the EPA Region 10 Tribal Consultation and Coordination Procedures, which established regional procedures for the consultation process. On January 26, 2021, President Biden issued the Presidential Memorandum, *Tribal Consultation and Strengthening Nation-to-Nation Relationships*, which charges each federal agency to engage in regular, meaningful, and robust consultation and to implement the policies directed in Executive Order 13175.

[79] As described in EPA's *Guiding Principles for Consulting with Alaska Native Claims Settlement Act Corporations* (EPA 2021), it is EPA's practice to consult with Alaska Native Corporations on a regulatory action that has a substantial direct effect on an Alaska Native Corporation and imposes substantial direct compliance costs and to notify Alaska Native Corporations of impending agency actions that may be outside of the scope of consultation.

6.3.1 Subsistence Use and Potential Mining Impacts

The use and importance of subsistence fisheries in the Nushagak and Kvichak River watersheds and the SFK, NFK, and UTC watersheds are discussed in detail in Section 3.3.6. Although salmon and other fish provide the largest portion of subsistence harvests for Bristol Bay communities, non-fish resources make up a significant portion of subsistence use (Table 6-2). On average, non-fish resources, such as moose, caribou, waterfowl, plants, and other organisms represent just over 30 percent of subsistence harvests by local communities (Table 6-2). The relative importance of non-fish subsistence resources varies throughout the Bristol Bay watershed, and per capita subsistence harvest of non-fish resources exceeds fish harvests in two communities (Table 6-2).

Table 6-2. Harvest of subsistence resources for communities in the Nushagak and Kvichak River watersheds.

Community	Year	Total Harvest (pounds) [a]	Estimated Per Capita Harvest (pounds)		
			All Resources [c]	Fish	Non-Fish Resources
Aleknagik	2008	51,738	296	169	127
Dillingham	2010	486,533	212	138	74
Ekwok	1987	77,268	793	524	269
Igiugig	2005	22,310	541	264	277
Iliamna	2004	34,160	469	404	65
Kokhanok	2005	107,644	680	549	131
Koliganek	2005	134,779	898	655	243
Levelock	2005	17,871	527	192	335
New Stuyahok	2005	163,927	389	216	173
Newhalen	2004	86,607	692	534	158
Nondalton	2004	58,686	357	253	104
Pedro Bay	2004	21,026	305	265	40
Port Alsworth	2004	14,489	133	101	32

Notes:

[a] Total harvest values represent usable weight and include fishes, land mammals, freshwater seals, beluga, other marine mammals, plant-based foods, birds or eggs, and marine invertebrates.

Sources: Schichnes and Chythlook 1991 (Ekwok), Fall et al. 2006 (Iliamna, Newhalen, Nondalton, Pedro Bay, and Port Alsworth); Krieg et al. 2009 (Igiugig, Kokhanok, Koliganek, Levelock, New Stuyahok); Holen et al. 2012 (Aleknagik); Evans et al. 2013 (Dillingham).

Numerous studies on TEK have been completed for the Nushagak and Kvichak River watersheds.[80] These studies provide extensive information from villages in the watersheds, including primary and secondary subsistence species, subsistence use areas and critical habitat, subsistence practices, and observed changes in abundance and timings for subsistence species (Boraas and Knott 2013). For example, the *Nushagak River Watershed Traditional Use Area Conservation Plan* identifies that the species most integral to subsistence were all five species of Pacific salmon, whitefish, winter freshwater fish, moose, caribou, waterfowl, and edible and medicinal plants. The plan also identified probable threats to the watershed and identified as one of its strategic actions "prevent[ing] habitat damage that

[80] Boraas and Knott (2013) summarized additional studies in Appendix D of the BBA (EPA 2014).

could result from mining" (NMWC 2007: Page 3). Section 6.3.2 provides more information about the role of TEK in the Bristol Bay watershed.

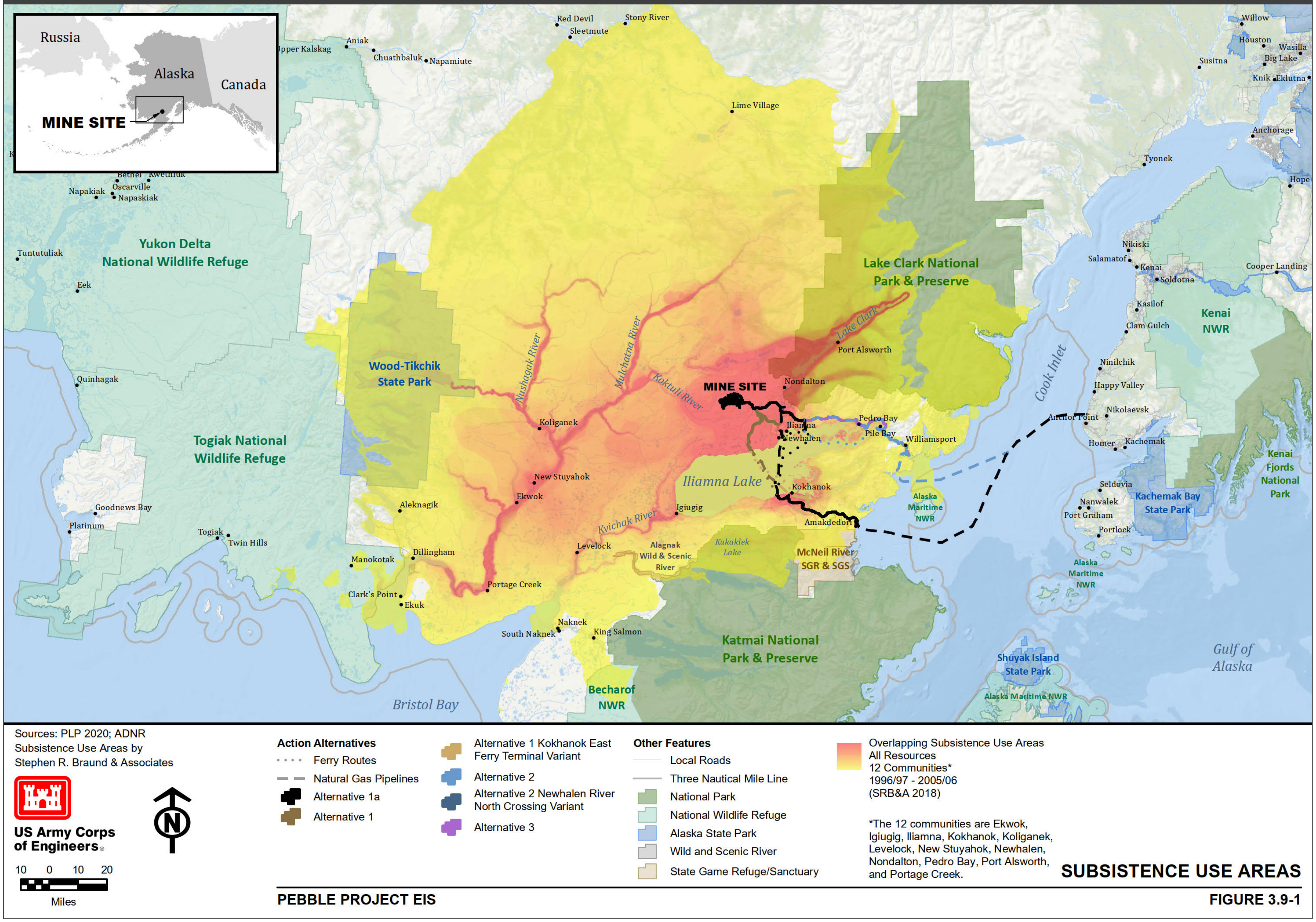
Figure 6-2 highlights areas of subsistence use for fish, wildlife, and waterfowl in the Nushagak and Kvichak River watersheds as identified in the FEIS (USACE 2020a: Table 3.9-1). Subsistence use patterns do not follow watershed boundaries, and communities outside the Nushagak and Kvichak River watersheds also rely on these areas for subsistence resources. For example, Clark's Point subsistence use areas for caribou and moose overlap with the Nushagak and Kvichak River watersheds; South Naknek, Naknek, and King Salmon subsistence use areas for waterfowl, moose, and berry picking, as well as caribou search areas, overlap both watersheds, particularly the Kvichak (Holen et al. 2011). Subsistence data are coarse and incomplete, and it is likely that subsistence activities occur outside the areas identified in Figure 6-2. In addition, Figure 6-2 indicates only use, not abundance or harvest.

In Section 4, EPA Region 10 considers potential effects of discharges of dredged or fill material associated with mining of the Pebble deposit at the levels derived from the 2020 Mine Plan on the region's fishery resources. All subsistence resources could be directly affected by discharges associated with the identified mining activities, for example, via habitat destruction or modification of habitat use by different subsistence species. In addition, non-salmon subsistence resources could be indirectly affected by any adverse effects on salmon fisheries that result from discharges associated with the mine; as explained in Section 3.3.6.1, the loss or reduction of salmon populations would have repercussions on the productivity of the region's ecosystems.

Any effects on fish—particularly salmon—and other subsistence resources that result from discharges associated with the mine could have significant adverse effects on the Bristol Bay communities that rely on these subsistence foods (EPA 2014: Chapter 12). Given the nutritional and cultural importance of salmon and other subsistence foods to Alaska Native populations, these communities would be especially vulnerable to impacts to subsistence resources; however, non-Alaska Native populations in the region also rely heavily on subsistence resources.

As discussed in EPA (2014) and Section 4 above, routine development and operation of a large-scale mine at the Pebble deposit would likely affect salmon and other important fish resources in the Nushagak and Kvichak River watersheds. The FEIS confirms that the 2020 Mine Plan would result in adverse impacts to the availability of and access to subsistence resources (USACE 2020a: Section 4.9). Although no subsistence salmon fisheries are documented directly in the 2020 proposed mine site, subsistence use of the mine area is high and centers on hunting caribou and moose and trapping small mammals (PLP 2011: Chapter 23). Tribal Elders have expressed concerns about ongoing mine exploration activities directly affecting wildlife resources, especially the caribou herd range (EPA 2014: Appendix D). Tribal members and subsistence hunters have anecdotally reported to EPA that noise during the exploration phase of the Pebble deposit has already disturbed moose populations and altered caribou migration patterns (EPA 2018).

Figure 6-2. Subsistence use intensity for salmon, other fishes, wildlife, and waterfowl within the Nushagak and Kvichak River watersheds. (USACE 2020a: Section 3.9)



Negative impacts to downstream fisheries from headwater disturbance (Section 4) could affect subsistence fish resources beyond the mine footprint. Those residents using the upper reaches of the SFK, NFK, and UTC rivers downstream of the mine footprint for subsistence harvests would be most affected. Access to subsistence resources is also important. A reduction in downstream seasonal water levels caused by mine-related withdrawals during and after mine operation could pose obstacles for subsistence users who depend on water for transportation to fishing, hunting, gathering, or other culturally important areas.

Changes in subsistence resources may affect the health, welfare, and cultural stability of Alaska Native populations in several ways (EPA 2014: Appendix D):

- The traditional diet is heavily dependent on wild foods. If fewer subsistence resources were available, diets would move from highly nutritious wild foods to increased reliance on purchased processed foods.
- Social networks are highly dependent on procuring and sharing wild food resources, so the current social support system would be degraded.
- The transmission of cultural values, language learning, and family cohesion would be affected because meaningful family-based work takes place in fish camps and similar settings for traditional ways of life.
- Values and belief systems are represented by interaction with the natural world through salmon practices, clean water practices, and symbolic rituals. Thus, core beliefs would be challenged by a loss of salmon resources, potentially resulting in a breakdown of cultural values, mental health degradation, and behavioral disorders.
- The region exhibits a high degree of cultural uniformity tied to shared traditional and customary practices, so significant change could provoke increased tension and discord both between villages and among village residents.

Dietary transition away from subsistence foods in rural Alaska carries a high risk of increased consumption of processed simple carbohydrates and saturated fats, which has occurred in urban communities that have low availability and high cost of fresh produce, fruits, and whole grains (Kuhnlein et al. 2001, Bersamin et al. 2006). Available alternative food sources may not be economically obtainable and are not as healthful. Section 3 describes the replacement value of subsistence salmon. Compounding the detrimental shift to a less healthful diet, the physical benefits of engaging in a subsistence lifestyle also would be reduced (EPA 2014: Appendix D).

The magnitude of human health and cultural effects related to potential decreases in resources would depend on the magnitude of these reductions. A small reduction in salmon quality or quantity may not have significant impacts on subsistence food resources, human health, or cultural and social organization. However, a significant reduction in salmon quality or quantity would significantly negatively affect these salmon-based cultures. Ultimately, the magnitude of overall impacts would depend on many factors, including the location and temporal scale of effects, cultural resilience, the degree and consequences of cultural adaptation, and the availability of alternative subsistence resources.

However, even a negligible reduction in salmon quantity or quality related to mining activities could decrease use of salmon resources, based on the perception of subtle changes in the salmon resource. Interviews with tribal Elders and culture bearers indicate that perceptions of subtle changes to salmon quality are essential to subsistence users, even if there are no measurable changes in the quality and quantity of salmon (EPA 2014: Appendix D). In addition to actual exposure to environmental contamination, the perception of exposure to contamination is linked to known health consequences, including stress and anxiety about the safety of subsistence foods and avoidance of subsistence food sources (Joyce 2008, CEAA 2010, Loring et al. 2010, USACE 2020a: Section 4.9).

The 2020 Mine Plan would likely adversely affect access to subsistence harvest areas, as well as the availability, abundance, and quality of subsistence resources, due to impacts on fishery areas (Section 4.2) and wildlife (Section 6.1.1). These impacts would endure long beyond mine closure, though with diminishing intensity following closure, unless there are any impoundment failures creating mine waste releases. The FEIS confirms reduced availability of subsistence resources due to habitat loss, disturbance, displacement, and contamination from fugitive dust deposition. The FEIS also states that the reduction of available harvest areas would result in increased costs and time for traveling to alternative harvest areas (USACE 2020a: Section 4.9). However, this assumes that subsistence users would adapt to changes in harvest areas. EPA Region 10 recognizes that subsistence users may not adapt to these changes due to the ability, capacity, or cultural willingness to access alternate areas and make dietary substitutions across all sectors of the population. Increased economic opportunity and income could enable subsistence users to afford necessary subsistence technologies, but could also reduce time available for subsistence practices, thereby decreasing harvest yields and subsistence sharing in communities (USACE 2020a: Section 4.9).

Further, the FEIS confirms that long-term sociocultural impacts to subsistence users and communities could occur due to the adverse impacts to resource abundance, availability, quality, and access due to the 2020 Mine Plan. These sociocultural impacts could result in adverse effects on community health and well-being, cultural identity and continuity, traditional knowledge transfer, language, spirituality, and social relations (USACE 2020a: Section 4.9).

6.3.2 Traditional Ecological Knowledge

In November 2021, the White House issued a memo, *Indigenous Traditional Ecological Knowledge and Federal Decision Making,* regarding the federal government's commitment to incorporate indigenous traditional ecological knowledge[81] (ITEK) into its decision-making and scientific inquiry where appropriate. As defined by the White House memo:

> ITEK is a body of observations, oral and written knowledge, practices, and beliefs that promote environmental sustainability and the responsible stewardship of natural resources through relationships between humans and environmental systems. It is applied to phenomena across biological, physical, cultural and spiritual systems. ITEK has evolved over millennia, continues to evolve, and includes insights based on evidence acquired through direct contact with the environment and long-term experiences, as well as extensive observations, lessons, and skills passed from generation to generation. ITEK is owned by Indigenous people—including, but not limited to, Tribal Nations, Native Americans, Alaska Natives, and Native Hawaiians.

In the Nushagak and Kvichak watersheds, home primarily to the Yup'ik and Dena'ina, indigenous peoples have been harvesting wild resources for at least 12,000 years and harvesting salmon for at least 4,000 years. Salmon and other subsistence resources continue to make up the large majority of the diet in the Nushagak and Kvichak River watersheds. For millennia, the Yup'ik and Dena'ina peoples and their predecessors have depended on the ecosystems that support salmon and other wild resources, and for millennia these ecosystems have remained relatively pristine (Section 3). Traditional subsistence management practices have proven to be sustainable in the Bristol Bay watershed (Boraas and Knott 2013).

The Yup'ik and Dena'ina cultures are inseparably connected to wild salmon and subsistence resources, with one Bristol Bay resident stating that salmon "defines who we are" (Boraas and Knott 2013: Page 1). Parents, grandparents, and Elders transfer knowledge about fish-harvesting practices and the environment to younger generations through demonstration and supervision (Boraas and Knott 2013, USACE 2020a: Section 4.9). The transmission of cultural values, language learning, and family cohesion often takes place in fish camps and similar settings for traditional ways of life (Boraas and Knott 2013). Social mechanisms, such as rituals, folklore, and language, all serve to encode and transmit TEK (Berkes et al. 2000). For instance, the Dena'ina words to indicate direction are based on the concept of upstream or downstream rather than cardinal direction (Boraas and Knott 2013).

Subsistence users in the Bristol Bay watershed are uniquely positioned to track important subsistence metrics, including primary and secondary subsistence species, subsistence use areas and critical habitat, subsistence practices, and observed changes in abundance and timings for subsistence species (Boraas and Knott 2013). Historically, TEK was primarily used in western science to compare and confirm the presence of species documented by indigenous peoples against those documented by western scientists (Knott 1988). More recently, western scientists have begun to include the larger body of TEK into their research, including to inform land and species management plans (Boraas and Knott 2013). The Alaska Department of Fish and Game, for instance, has begun to incorporate some TEK into subsistence reports and databases for the Bristol Bay and Alaska Peninsula region, identifying information, such as

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[81] There are many terms and definitions used to refer to the concept of traditional ecological knowledge, such as "cultural knowledge," "indigenous knowledge," and "native science." The White House memo refers to this concept as "indigenous traditional ecological knowledge" or "ITEK." The FEIS refers to this concept as "traditional knowledge." This proposed determination uses the term "traditional ecological knowledge" or "TEK" consistent with the BBA.

taxonomy, subsistence use, harvest areas, and changes to local salmon stocks (Kenner 2003, ADF&G 2020).

Traditional management of wild resources, especially salmon, incorporates a deep recognition of the connection between communities and ecosystems (Boraas and Knott 2013, Berkes et al. 2000). Incorporating TEK into fisheries management can promote more equitable fishing opportunities for communities (Atlas et al. 2021). This is apparent in interviews with Alaska Native Bristol Bay residents, with one resident stating “when the fish first come up here we don’t put our nets out here before a bunch of them go by for the people who live at the end of the river up in Nondalton and all those guys… We just kind of watch the salmon go by for the people who live upstream from us” (Boraas and Knott 2013: Page 100).

TEK is incorporated more substantially in watershed- and community-level reports in the region. The Nushagak-Mulchatna Watershed Conservation Plan (NMWC 2007) conducted interviews with watershed Elders, residents, and others to develop maps of critical subsistence resources and habitats, identify traditional use areas, and document subsistence species. These data were used to inform a conservation plan for the watershed, which included identification of probable threats and strategic actions. The *K’ezghlegh: Nondalton Traditional Ecological Knowledge of Freshwater Fish* study (Stickman et al. 2003) documented TEK regarding subsistence salmon and other freshwater fish harvest through interviews with Nondalton residents. Residents provided observed changes in salmon run strength and timing, salmon appearance, environment, and the impacts of human activities on salmon and other freshwater fishes. TEK can enhance understanding of the spatial patterns of subsistence species, facilitate planning for long-term monitoring, improve management practices, track climate and environmental change, and contribute to local-capacity building for research (Berkes et al. 2000, USFWS 2011, Woll et al. 2013, Atlas et al. 2021).

TEK is inherently connected to the millennia-long subsistence way of life in Bristol Bay. The subsistence lifestyle enables Alaska Native Bristol Bay residents to continue to develop, evolve, and pass down their knowledge of the ecosystems supporting subsistence resources. As described in Section 6.3.1 and the FEIS, the 2020 Mine Plan could adversely affect participation in subsistence activities due to impacts to subsistence resource availability, abundance, and quality; changes in the perception of subsistence resource quality; personal comfort harvesting near mining facilities; and time available due to alternative, cash-paying employment. As described in the FEIS, changes such as these could have a “compounding effect on the subsistence way of life” by decreasing the transmission of TEK to younger generations (USACE 2020a: Page 4.9-12). Further, retention of TEK for traditional subsistence harvest areas and resources could be lost as subsistence users adapt to alternative areas and resources (USACE 2020a: Section 4.9).

6.3.3 Environmental Justice

In discussing environmental justice issues, it is useful to consider the following terms, as defined by EPA:

- *Environmental justice* is defined as the fair treatment and meaningful involvement of all people, regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies.
- *Fair treatment* means that no group of people should bear a disproportionate burden of environmental harms and risks, including those resulting from negative environmental consequences of industrial, governmental, and commercial operations or programs and policies.
- *Meaningful involvement* means that potentially affected community members have an appropriate opportunity to participate in decisions about a proposed activity that will affect their environment and/or health; the public's contribution can influence EPA's decisions; the concerns of all participants involved will be considered in the decision-making process; and the decision-makers seek out and facilitate the involvement of those potentially affected.

Executive Order 12898, titled *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, and its accompanying presidential memorandum establish executive branch policy on environmental justice. To the greatest extent practicable and permitted by law, Section 1-101 of the Executive Order directs each federal agency, as defined in the Executive Order, to make environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority and low-income populations.

Furthermore, Section 4-401 of the Executive Order states the following about subsistence consumption of fish and wildlife:

> In order to assist in identifying the need for ensuring protection of populations with differential patterns of subsistence consumption of fish and wildlife, Federal agencies, whenever practicable and appropriate, shall collect, maintain, and analyze information on the consumption patterns of populations who principally rely on fish and/or wildlife for subsistence. Federal agencies shall communicate to the public the risks of those consumption patterns.

In implementing the Executive Order, EPA considers whether there would be "disproportionately high and adverse human health or environmental effects" from its regulatory action and ensures meaningful involvement of potentially affected minority or low-income communities. The scope of the inquiry for any environmental justice analysis by EPA is directly tied to the scope of EPA's potential regulatory action. Because a CWA Section 404(c) action has the potential to affect human health and the environment of minority or low-income populations, including tribal populations, EPA evaluates environmental justice concerns when undertaking an action pursuant to its authorities under CWA Section 404(c).

Though not addressed in Executive Order 12898, the issues and concerns shared with EPA by federally recognized tribal governments during consultation meetings will be considered in the environmental justice analysis because of related issues and concerns among Alaska Native communities regarding safety of subsistence foods and cultural impacts, including the sustainability of the subsistence way of life. Consultation is discussed further in Section 6.3.4.

The Bristol Bay communities of the Nushagak and Kvichak River watersheds are predominantly Alaska Native, primarily Yup'ik and Dena'ina (EPA 2014: Chapter 5). Although there are other Bristol Bay communities that are concerned with potential impacts to fishery resources and, consequently, their way of life, EPA Region 10 focused on communities who practice subsistence within the SFK, NFK, and UTC watersheds for this environmental justice analysis.

As described in Section 2, EPA Region 10 has conducted extensive community outreach throughout its engagement in the Bristol Bay watershed. Public hearings or meetings were held in May and June 2012, August 2012, August 2014, and October 2017, in which community members expressed concerns about the potential impacts of large-scale mining on Alaska Natives' subsistence way of life. Community members expressed concern about adverse environmental and cultural aspects of the project. They also expressed concerns about job loss, the sustainability of villages (e.g., schools closing because enrollment drops as parents make tough choices to go where jobs are available), potential tax revenue, Alaska Native Corporation economic opportunities, and the State of Alaska's concerns regarding economic opportunities for the citizens of Alaska.

Traditional and more modern spiritual practices place salmon in a position of respect and importance, as exemplified by the First Salmon Ceremony and the Great Blessing of the Waters. The salmon harvest provides a basis for many important cultural and social practices and values, including sharing resources, fish camp, gender and age roles, and the perception of wealth. Although a small minority of tribal Elders and culture bearers interviewed expressed a desire to increase market economy opportunities (including large-scale mining), most equated wealth with stored and shared subsistence foods. In interviews conducted for the BBA (Appendix D), the Yup'ik and Dena'ina communities of the Nushagak and Kvichak River watersheds consistently define a "wealthy person" as one with food in the freezer, a large extended family, and the freedom to pursue a subsistence way of life in the manner of their ancestors, Further, interviews of residents in the Nushagak and Kvichak River watersheds described subsistence as a year-round, full-time occupation. However, subsistence is not captured in labor statistics because it is not based on wages or a salary (EPA 2014: Appendix D).

The Alaska Native community also depends in part on the regional economy, which is primarily driven by commercial salmon fishing and tourism. The commercial fishing and recreation-based market economies provide seasonal employment for many residents, giving them both the income to purchase goods and services needed for subsistence and the time to participate year-round in subsistence activities. The fishing industry provides half of all jobs in the region, followed by government (32 percent), recreation (15 percent), and mineral exploration (3 percent) (EPA 2014: Appendix E). It is estimated that local Bristol Bay residents held one-third of all jobs and earned almost $78 million (28 percent) of the total income traceable to the Bristol Bay watershed's salmon ecosystems in 2009 (EPA 2014: Appendix E).

The Bristol Bay Regional Vision Project convened over 50 meetings in 26 communities in 2011 to create a guidance document for communities, regional organizations, and all entities that have an interest in the Bristol Bay region. Their final report stated that the residents of the Bristol Bay watershed want "excellent schools, safe and healthy families, local jobs, access to subsistence resources, and a strong voice in determining the future direction of the region" (Bristol Bay Vision 2011: Page 1). Several common themes emerged during this process, which were similar to themes reflected in public comments EPA received during development of the BBA.

- Family, connection to the land and water, and subsistence activities are the most important parts of people's lives, today and in the future.
- Maintaining a subsistence focus by teaching children how to engage in subsistence activities and encouraging good stewardship practices is important.
- People welcome sustainable economic development that is based largely on renewable resources. Any large development must not threaten land or waters.
- True economic development will require a regionally coordinated approach to reduce energy costs, provide business training, and ensure long-term fish stock protection.
- There should be joint planning meetings among tribes, local governments, and Corporations to create community-wide agreement on initiatives or projects.

Development of the Pebble Mine would result in employment opportunities in the region, primarily for those communities nearest the mine site (Nondalton, Iliamna, and Newhalen), leading to increased revenues and year-round job opportunities throughout the lifespan of the mine, though these jobs could vary based on economic conditions and business decisions. Increased revenue in the region may lead to investments in infrastructure and services, and provide revenue needed for subsistence hunters and anglers to purchase subsistence-related technology and equipment (USACE 2020a: Section 4.9). However, as described in Section 6.3.1, increased employment may also reduce the time available for subsistence activities, including the transfer of TEK and practices to family members, potentially decreasing harvest yields (USACE 2020a: Section 4.9). Social networks in the Bristol Bay region are highly dependent on procuring and sharing wild food resources, especially for cash-poor households who are unable to fish or hunt, such as Elders, single parents, or people with disabilities (ADF&G 2018). A reduction in subsistence harvests for harvesting households could result in long-term decreased sharing and trading with other households in the community (USACE 2020a: Section 4.9).

As discussed in Sections 3.3.6 and 6.3.1, subsistence foods make up a substantial proportion of the human diet in the Nushagak and Kvichak River watersheds, and likely contribute a disproportionately high amount of protein and certain nutrients.[82] EPA Region 10 acknowledges that human health within

[82] The BBA did not evaluate threats to human health due to physical exposure to discharged pollutants or consumption of exposed organisms, because these effects were outside the scope of the assessment (EPA 2014: Chapter 2).

the communities near the Pebble deposit is directly related to the subsistence way of life practiced by many residents of these communities. Additionally, EPA Region 10 recognizes that subsistence use areas and related subsistence activities provide not only food but also support important cultural and social connections within the region's communities. If a significant adverse impact on the Nushagak and Kvichak River watersheds were to occur, the Alaska Native community reliant on these areas for food supply and cultural and social connections could experience disproportionately high and adverse effects.

6.4 Consideration of Potential Costs

EPA's consideration of these issues can be found in the document titled *Consideration of Potential Costs Regarding the Clean Water Act Section 404(c) Proposed Determination for the Pebble Deposit Area, Southwest Alaska* (EPA 2022).

SECTION 7. SOLICITATION OF COMMENTS

EPA Region 10 is soliciting comments on this proposed determination. Please see http://www.epa.gov/bristolbay for information about how to submit comments on the proposed determination. EPA Region 10 is soliciting comments on all matters and issues discussed in the proposed determination, including but not limited to the following:

1. Comments regarding whether the EPA Region 10 Regional Administrator should withdraw the proposed determination or prepare a recommended determination for review by the Assistant Administrator for the Office of Water.
2. Comments regarding any corrective action that could be taken to reduce adverse impacts on aquatic resources from discharges of dredged or fill material associated with mining the Pebble deposit.
3. Comments on the likely adverse effects on fishery areas and other ecological resources that would be directly or indirectly affected by discharges of dredged or fill material associated with mining the Pebble deposit (including the SFK, NFK, and UTC and downstream reaches of the Nushagak and Kvichak Rivers).
4. Comments regarding wildlife species that could be affected if discharges of dredged or fill material associated with mining the Pebble deposit were to occur.
5. Comments regarding recreational uses that could be affected if discharges of dredged or fill material associated with mining the Pebble deposit were to occur.
6. Comments regarding drinking water supplies (including public water supplies and private sources of drinking water such as streams or wells) that could be affected if discharges of dredged or fill material associated with mining the Pebble deposit were to occur.
7. Comments on the potential for mitigation to be successful in reducing the impacts on aquatic resources from discharges of dredged or fill material associated with mining the Pebble deposit.
8. Comments regarding the approach used to delineate the Defined Area for Prohibition and the Defined Area for Restriction and whether there are other factors or approaches EPA Region 10 should consider in delineating these areas.
9. Comments regarding whether the discharge of dredged or fill material associated with mining the Pebble deposit should be prohibited, prohibited/restricted as proposed, prohibited/restricted in another manner, or not prohibited/restricted at all. In particular, EPA Region 10 is seeking comment on whether environmental effects associated with the discharge of dredged or fill material from mining the Pebble deposit in amounts other than those proposed in the 2020 Mine Plan (1.3 billion tons of ore over 20 years) could provide a basis for alternative or additional restrictions.

10. Comments on whether and how EPA Region 10's proposed action under CWA Section 404(c) should consider discharges of dredged or fill materials beyond those associated with the mine site and include discharges associated with the construction of other mine infrastructure (e.g., port, pipelines, transportation corridors).

11. Comments on EPA Region 10's consideration of the USACE administrative record, which contains documents pertaining to the USACE Pebble Mine permit decision. EPA Region 10 included in the docket for this proposed determination all portions of the voluminous administrative record for the USACE Pebble Mine permit decision that are relevant to EPA's decision-making and that EPA considered in its decision to issue this proposed determination. EPA Region 10 is soliciting comments that identify any other documents from the USACE administrative record that EPA should consider in its decision-making for this CWA Section 404(c) review process.

12. Comments on how EPA Region 10 considered costs, including whether all appropriate costs have been considered.

13. Comments regarding updated or additional information related to TEK and/or subsistence use in the Nushagak and Kvichak River watersheds.

Any interested persons may submit written comments on the proposed determination. All relevant data, studies, or informal observations are appropriate. The Regional Administrator will fully consider all such comments as he decides whether to withdraw the proposed determination or forward to EPA Headquarters a recommended determination to prohibit/restrict the use of certain waters in the SFK, NFK, and UTC watersheds in southwest Alaska as disposal sites for the discharge of dredged or fill material associated with mining the Pebble deposit.

Dated: 5/25/22

CASEY SIXKILLER
Digitally signed by CASEY SIXKILLER
Date: 2022.05.25 17:26:06 -07'00'

Casey Sixkiller
Regional Administrator
EPA Region 10

SECTION 8: REFERENCES

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APPENDIX A. SUMMARY OF KEY CHANGES FROM THE 2014 PROPOSED DETERMINATION

This appendix summarizes key changes from the U.S. Environmental Protection Agency (EPA) Region 10's 2014 Proposed Determination, including revisions to (1) incorporate the adverse effects associated with the discharge of dredged or fill material for the construction and routine operation of the mine plan proposed by the Pebble Limited Partnership (PLP) in its 2020 Clean Water Act (CWA) Section 404 permit application (2020 Mine Plan); (2) update the scope of the proposed determination; and (3) reflect consideration of additional information that has become available since EPA issued the 2014 Proposed Determination.

A.1 Adverse Effects of Discharges from Construction and Routine Operation of the 2020 Mine Plan

The 2014 Proposed Determination was based on an evaluation of the adverse impacts associated with a mine scenario assessed in the 2014 *Assessment of Potential Mining Impacts on Salmon Ecosystems of Bristol Bay, Alaska* (Bristol Bay Assessment or BBA) (EPA 2014) that envisioned mining approximately 0.25 billion tons of ore at the Pebble deposit over 20 years. This mine scenario drew on preliminary mine plans submitted by Northern Dynasty Minerals (NDM) to the U.S. Securities and Exchange Commission (SEC) (Ghaffari et al. 2011, SEC 2011), consultation with experts, and baseline data collected by NDM/PLP. Thus, EPA's assessment of that mine scenario provided a solid scientific and technical foundation for the 2014 Proposed Determination and the BBA continues to support EPA's findings.

PLP's 2020 Mine Plan proposes to mine substantially more ore than what was evaluated in the BBA and the 2014 Proposed Determination, approximately 1.3 billion tons of ore over 20 years. The 2020 Mine Plan is also based on new assumptions, higher resolution aquatic resource mapping, and more sophisticated modeling. Given the evolution of the scientific and technical record associated with a proposed mine at the Pebble deposit, EPA has developed a revised proposed determination (i.e., this 2022 Proposed Determination), which focuses on adverse effects resulting from discharges of dredged or fill material associated with the 2020 Mine Plan.

A.2 Scope of the Proposed Determination

The 2014 Proposed Determination proposed to establish restrictions on discharges of dredged or fill material into waters of the United States associated with mining the Pebble deposit within a potential defined area. These restrictions would have been applicable in an area that covered 268 square miles (693 km^2) across the headwater portions of the South Fork Koktuli River (SFK), North Fork Koktuli River (NFK), and Upper Talarik Creek (UTC) watersheds. The extent of this area included the areas within these watersheds where mine claims were owned by NDM subsidiaries at that time. This area was thought at the time to best represent locations where the discharge of dredged or fill material associated with mining the Pebble deposit and, therefore, any resulting unacceptable adverse effects on fishery areas, would be likely to occur.

This revised proposed determination changes the 404(c) approach in several ways. First, this revised proposed determination proposes to prohibit the specification of waters of the United States within the mine site footprint for the 2020 Mine Plan located in the SFK and NFK watersheds as disposal sites for the discharge of dredged or fill material for the construction and routine operation of the 2020 Mine Plan. The prohibition applies to waters within the mine site footprint for the 2020 Mine Plan in the SFK and NFK watersheds, i.e., the Defined Area for Prohibition (Figure ES-4 and Figure A-1) (PLP 2020).

In addition, this revised proposed determination proposes to restrict the use of certain waters of the United States within the SFK, NFK, and UTC watersheds for specification as disposal sites for the discharge of dredged or fill material for the construction and routine operation of any future plan to mine the Pebble deposit that would either individually or collectively result in adverse effects similar or greater in nature and magnitude to those associated with the 2020 Mine Plan. The restriction would apply to an area that encompasses certain headwaters of the SFK, NFK, and UTC watersheds and includes approximately 309 square miles (800 km^2), i.e., the Defined Area for Restriction (Figures ES-5 and ES-6, and Figure A-1).

Because EPA recognizes that the ownership status of mine claims could change over time, EPA now believes that both currently held claims and areas where mine claims are available in the SFK, NFK, and UTC watersheds better represent locations that have the potential to be disposal sites associated with mining the Pebble deposit. Thus, the Defined Area for Restriction is based on areas within the three watershed boundaries where mine claims are currently held and areas where mine claims are available (ADNR 2022).

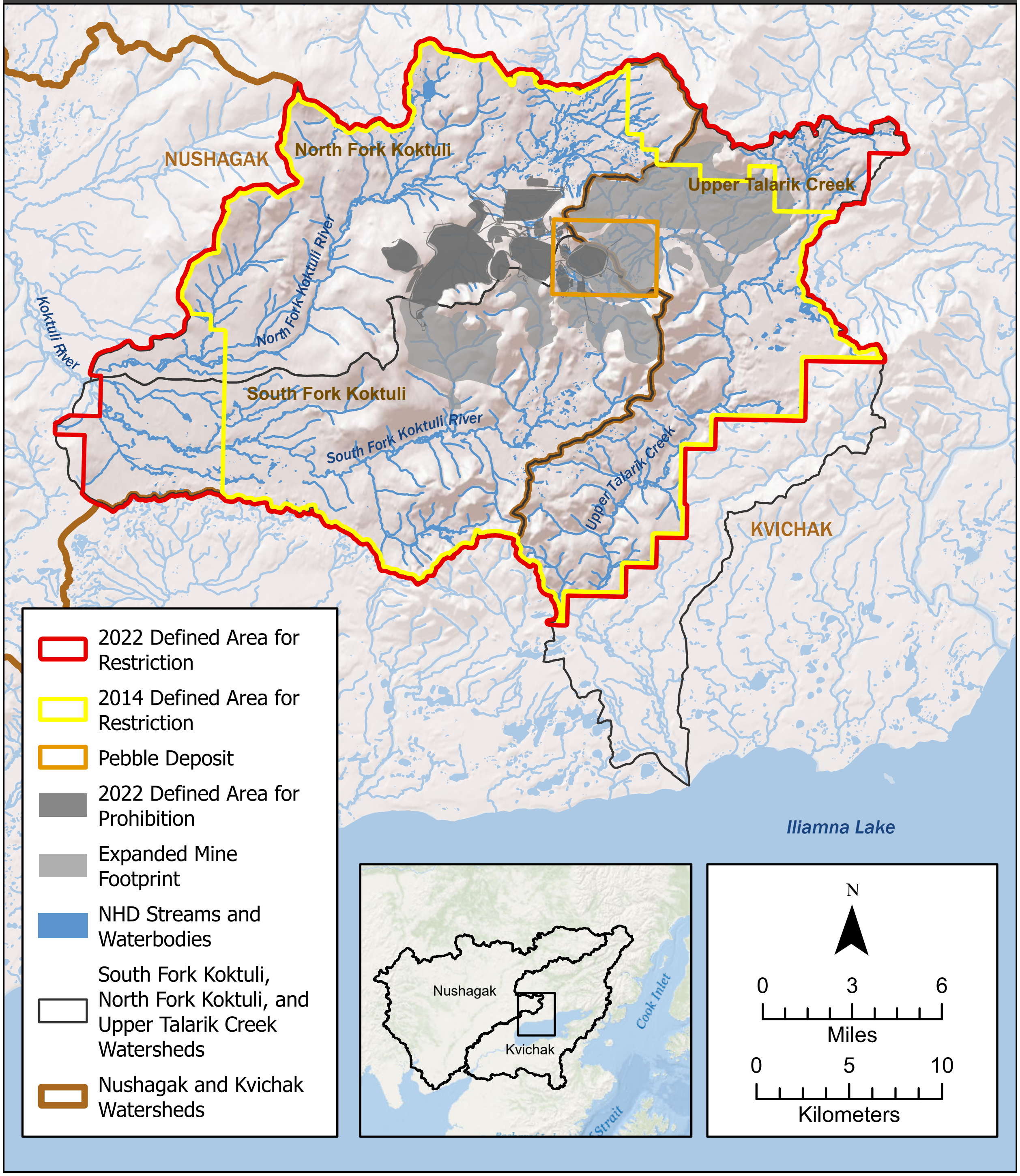
A.3 Information Available Since Issuance of the 2014 Proposed Determination

Since EPA Region 10 issued the 2014 Proposed Determination, new information has become available that is relevant to evaluating the potential effects of the discharge of dredged or fill material for the construction and routine operation of a mine at the Pebble deposit. EPA has revised all sections of the proposed determination, where appropriate, to reflect its considerations of such new information, including the following:

- More than 670,000 public comments submitted to EPA Region 10 in response to the 2014 Proposed Determination.[1]
- PLP's CWA Section 404 permit application, including the 2020 Mine Plan (PLP 2020).
- The U.S. Army Corps of Engineers' (USACE) FEIS evaluating the 2020 Mine Plan, including the FEIS appendices, technical support documents, and references (USACE 2020a).
- EPA Region 10's and the U.S. Fish and Wildlife Service's 12-week coordination process with USACE in Spring 2020 to evaluate PLP's proposed project for compliance with the CWA Section 404(b)(1) Guidelines.
- USACE's Record of Decision (ROD) denying PLP's CWA Section 404 permit application for the 2020 Mine Plan, including ROD-supporting documents (USACE 2020b).
- NDM's Pebble Project Preliminary Economic Assessment dated September 9, 2021 (Kalanchey et al. 2021).
- Updated data regarding fishery resources in the Bristol Bay watershed (see Section 8 of the revised proposed determination for citations).
- New scientific and technical publications (see Section 8 of the revised proposed determination for citations).

[1] Copies of these comments can be found in the docket for the 2014 Proposed Determination at www.regulations.gov, see docket ID No. EPA-R10-OW-2014-0505.

Figure A-1. Changes to the proposed defined areas from 2014 to 2022.



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APPENDIX B: ADDITIONAL INFORMATION RELATED TO THE ASSESSMENT OF AQUATIC HABITATS AND FISH

Appendix B provides additional supporting information related to aquatic habitats within and downstream of the mine site in the South Fork Koktuli River (SFK), North Fork Koktuli River (NFK), and Upper Talarik Creek (UTC) watersheds, their role in supporting fish populations, and how changes to these resources were assessed in the Final Environmental Impact Statement (FEIS) (USACE 2020). As discussed in detail in Section 4, the impacts to aquatic resources that are predicted to occur from the 2020 Mine Plan could result in significant loss of or damage to fishery areas in the SFK and NFK watersheds. This appendix explores additional issues related to two key points: (1) in many cases, the FEIS states that impacts would not result in significant adverse effects on aquatic resources, conclusions that often are not supported by the evidence provided in the FEIS; and (2) the predicted impacts reported in the FEIS likely underestimate the actual impacts that the 2020 Mine Plan would have on the region's aquatic resources.

B.1 Quality, Importance, and Productivity of Lost Habitats for Fish Life Stages, Species, and Communities

This section provides an overview of the U.S. Environmental Protection Agency's (EPA's) approach and assumptions for assessing habitat quality and fish use when determining the "quality" of the stream habitats affected by the 2020 Mine Plan and the "importance" or "value" of that lost habitat and altered functions for fish populations. It discusses why EPA believes that the available evidence does not support the conclusion that aquatic habitats lost or affected by the 2020 Mine Plan are of low quality, importance, or value.

B.1.1 Assessing Habitat Quality

In the FEIS, the relative quality of aquatic habitats that would be lost to the 2020 Mine Plan and their influence on downstream waters are assumed to be low, resulting in the conclusion that loss of these habitats would be inconsequential for fish populations (USACE 2020: Section 4.24). This conclusion is not supported by the available information about these aquatic habitats (including information provided in the FEIS), or the current science surrounding the importance of headwater systems (Section 3.2.4, USACE 2020: Sections 4.16 and 4.24), their contributions to the spatial and temporal availability of aquatic resources (Section 3.3.3, USACE 2020: Sections 4.16 and 4.24), and the spatial and temporal scales at which those aquatic resources vary.

The headwater streams draining the mine site were found to have low nutrient and dissolved organic carbon (DOC) concentrations (PLP 2018a: Appendix 9.1A), but these values do not suggest a low capacity to support biological productivity. Nutrient and DOC concentrations in downstream reaches and the mainstem Koktuli River generally are similar to those at the mine site (PLP 2018a: Appendix 9.1A). These mainstem habitats are productive salmon habitat, which highlights that nutrient and DOC concentrations are not the only or even most relevant indicators of biological productivity in this region.

According to the FEIS, streams that would be lost to the 2020 Mine Plan "…tend to have higher gradients, fewer off-channel and overwintering habitats, lower proportions of spawning gravels, and less woody debris…" (USACE 2020: Page 3.24-5) than downstream channels. In general, channels with gradients less than 3 percent most frequently meet the substrate and hydraulic conditions required by stream-spawning salmon (Montgomery and Buffington 1997, Montgomery et al. 1999). Many streams draining the mine site, particularly the smallest ones, do have gradients exceeding 3 percent (USACE 2020: Table 3.24-2). However, the anadromous fish stream losses under the 2020 Mine Plan (Table 4-1) are dominated by reaches with gradients less than 3 percent (USACE 2020: Table 3.24-2). Furthermore, the largest stream lengths affected would be in NFK tributaries 1.190 and 1.200, both of which were found to have suitable spawning substrates (USACE 2020: Table 3.24-2). No data on off-channel habitats, woody debris, or overwintering habitats are reported for these streams, although off-channel habitats were quantified at mainstem sites (USACE 2020: Section 3.24, Table 3-10). This comparison between mainstem and tributary habitats also misrepresents the relationship between them. Mainstems and tributaries perform overlapping, but not duplicative, roles – mainstem spawning habitats are productive because the headwaters that support them are currently undisturbed.

The FEIS states,

> Based on project baseline surveys, the streams directly impacted in the mine site are not considered major contributors of marine-derived nutrients (MDN) from spawning salmon relative to downstream portions of the river network, making terrestrial nutrient sources relatively more important. This can be attributed to the comparatively small numbers of spawning fish, high flushing flows in the fall after spawning has occurred, and the lack of large woody debris or pool habitats for carcass retention (USACE 2020: Page 4.24-21).

As discussed in greater detail below (Sections B.1.2 and B.2.2), the project baseline surveys looked at highly variable spawning densities over only 4 or 5 years (PLP 2018a: Chapter 15, Tables 15-14 through 15-17). These surveys thus provide a poor estimate of the temporal variation in spawning densities that has been observed in the region and may be expected over the time scales capturing the life of the mine and its attendant impacts (Rogers et al. 2013). In addition, the methods used to assess spawner abundance only provide minimum estimates (Section B.1.2) of the abundance of spawners within—and thus the amount of marine-derived nutrients (MDN) they contribute to—a given reach.

The FEIS concludes, "There are abundant small headwater streams in the Koktuli River drainage that would be unaffected by mine site development, and would continue to provide downstream inputs important for stream productivity" (USACE 2020: Page 4.24-21). Although that statement is true, the FEIS also indicates that approximately 20 percent of available stream habitat in the Headwaters Koktuli watershed (i.e., the SFK and NFK watersheds) and 12 percent of available stream habitat in the larger Koktuli River watershed would be lost to the 2020 Mine Plan (USACE 2020: Section 4.24). At both spatial scales, these impacts represent a considerable loss of upstream habitats that would necessarily affect downstream transport of energy and nutrients. Although the effects of these losses would be increasingly dampened as one moves farther downstream in the river network, reaches immediately downstream of the lost habitats would experience a complete loss of inputs from upstream habitats, which would necessarily affect their downstream transport of energy and nutrients. Thus, impacts to a specific downstream reach result not only from direct loss of headwater habitats under the 2020 Mine Plan, but also from how those direct losses cascade downstream through intervening reaches that are also affected by those direct losses.

B.1.2 Assessing Fish Distribution and Abundance

The SFK, NFK, and UTC are relatively well-sampled streams, compared with other streams in the region, due to Pebble Limited Partnership's (PLP)'s efforts to collect environmental baseline data in areas draining the Pebble deposit area (PLP 2011, 2018). However, accurately and comprehensively assessing fish distribution and abundance in stream and wetland habitats in the larger SFK, NFK, and UTC watersheds, as well as at the mine site area, is difficult. Because the region is inaccessible by road and subject to a challenging and variable climate, sampling occurs on intermittent site visits during periods when the region and its aquatic habitats are accessible and effective fish sampling is possible. Given these logistical challenges, it is reasonable to conclude that the currently available data provide an incomplete description of the full seasonal distribution and abundance of fish species and life-history stages in the region and are likely to be underestimates.

This underestimation of fish distributions is true not only of the data reported by PLP (2011, 2018), but also of the Anadromous Waters Catalog (AWC) (Giefer and Blossom 2021) and the Alaska Freshwater Fish Inventory (AFFI) (ADF&G 2022a). These databases do not characterize all potential fish-bearing streams, due largely to the impossibility of sampling all streams in Alaska. The AWC and the AFFI are not comprehensive, meaning that not all streams have been sampled; those that have not been sampled cannot be assumed to be non-fish bearing streams. The AWC website states that the database "…lists almost 20,000 streams, rivers, or lakes around the state which have been specified as being important for the spawning, rearing or migration of anadromous fish. However, based upon thorough surveys of a few drainages it is believed that this number represents a fraction of the streams, river, and lakes actually used by anadromous species" (ADF&G 2022b). This is particularly true in habitats outside of the mine site area, many of which have never been sampled. However, even within the footprint of the 2020 Mine Plan, the FEIS indicates that the majority of mapped streams have not been sampled for fish (USACE 2020: Section 4.24, Figure 4.24-1). Similarly, life stage–specific designations in the AWC likely represent underestimates, given the challenges inherent in surveying all streams (not to mention other aquatic habitats) that may support life-stage use throughout the year.

The methods used to assess fish distribution and abundance have included several sampling techniques, including snorkeling, electrofishing, seining, angling, and visual observation (aerial and on-the-ground). These methods have limitations. Aerial surveys of spawning salmon only account for a portion of the spawning populations, and estimates based on these surveys should be considered minimum counts

(Jones et al. 2007, Morstad et al. 2009). Many of these methods, as applied, appear to lack quantitative estimates of capture efficiency: for example, PLP (2011) acknowledges that many of the methods used "were not conducive to estimate catch-per-unit-effort (CPUE)" (PLP 2011: Chapter 15). As a result, estimates of abundance or density with confidence bounds cannot be derived, and these methods are most useful for estimating presence of species and life-history stages. These estimates are necessarily minimum estimates of distribution and abundance because fish species may use certain habitats at times of the year other than when sampling has been conducted to date.

B.1.3 Assessing Habitat Importance or Value

The importance of individual streams and wetlands is not fully captured by fish presence. Stream and river fish depend on the interconnected suite of watershed processes that shape physical habitat, structure the flow of energy through the system, provide the trophic basis for growth, and regulate the chemical, physical, and biological conditions experienced by fish and other aquatic life. As discussed in Section 3.2.4, headwater streams and wetlands and their associated functions are crucial contributors to the quality of downstream waters inhabited by fish, even if those habitats do not themselves contain fish (Cummins and Wilzbach 2005).

Where fish are observed in headwater streams and wetlands, density is not always a reliable indicator of habitat quality or productive potential. PLP has undertaken a significant effort to assess fish populations in the SFK, NFK, and UTC watersheds, and the resulting data provide useful baseline information. However, these data are insufficient to conclude that aquatic habitats with no or low fish densities are unimportant for supporting and maintaining fishery resources over the lifespan of potential impacts under the 2020 Mine Plan.

Productivity for Pacific salmon, sometimes defined as the ratio of recruits or offspring per spawner, varies over space and time (Rogers and Schindler 2008). Based on evidence that the components watersheds and associated marine waters yield large quantities of salmon biomass annually, the Bristol Bay watershed is highly productive. Watersheds with a high capacity to support salmon production will not always contain high densities of fish at all given times and locations, for numerous reasons (Warren 1971, Van Horne 1983). This may be particularly true for anadromous salmonids and other mobile fish species (e.g., Northern Pike) that use an array of habitats to complete their life cycles. For these species, local abundances may be influenced by population dynamics that occurred elsewhere, during an earlier life stage.

Salmon populations may cycle at decadal to centennial scales (Rogers et al. 2013), and locations of high salmon productivity in the region shift in time and space (Brennan et al. 2019). Some aquatic habitats are seasonally important: salmon may be absent at certain times of the year, but present in high abundances at other times. Some aquatic habitats may have no or low abundances of salmon in some years, but high abundances in other years, allowing populations to respond to changing environmental conditions across habitats (Section 3.3.3). This variability is illustrated by annual differences in aerial counts of salmon spawners in the SFK, NFK, and UTC mainstems between 2004 and 2008 (PLP 2018a: Table 3-7). Highest index spawner counts differed substantially across species and years, with no consistent pattern across sites: for example, the maximum highest index spawner count for Chinook Salmon occurred in 2004 in the SFK but in 2005 in the NFK (Table 3-7). These data show how variable counts are over a 5-year period; there is no reason to believe that this 5-year period fully captures variability over longer time scales. These same patterns of spatial and temporal variability also apply to other fish species, macroinvertebrates, and other components of the food web essential for ecosystem function. Given these considerations and the spatial and temporal limitations of the available data, it is impossible to conclude with any certainty that the aquatic habitats lost to the 2020 Mine Plan are not and would not be important to salmon over the life of the mine and beyond.

B.1.4 Summary

PLP (2011, 2018) presents results of the most extensive fish-sampling regime that currently has been conducted in the SFK, NFK, and UTC watersheds. Limitations of the sampling regime mean that these data still provide an incomplete description of—and likely underestimate—actual seasonal fish distributions and abundances in the region. Aquatic habitats at the mine site will vary in importance across species and life stages, both seasonally and annually (see Section B.2.2). Given these factors, EPA cautions against making conclusions that certain habitats are not important based solely on the numbers of fish observed under PLP's sampling regime. It is not valid to conclude that aquatic habitats with no or low observed fish abundances under the sampling regime conducted to date are somehow unimportant as, or in maintaining, fishery areas. The measure of value, importance, or significance of a given habitat includes not just the fish found there at a specific point in time, but also the fish that have used those habitats in the past, those that will use those habitats in the future, and the larger watershed functions to which that habitat contributes. Because these considerations are impossible to predict with precision, a precautionary approach that maintains habitat structure and function is warranted. The headwater streams and wetlands affected by the 2020 Mine Plan can in fact be very important for fish, both directly by providing fish habitat at particular times (i.e., in specific years or seasons, or for specific life stages) and indirectly by provisioning and regulating downstream fish habitats (Section 3.2.4). As a result, these habitats are integral parts of their immensely productive watersheds.

B.2 Spatial and Temporal Scales and Variability

This section examines the importance of (1) considering the spatial and temporal scales at which potential effects of the 2020 Mine Plan on aquatic resources are evaluated, and (2) sufficiently capturing and considering spatial and temporal variability in environmental parameters and aquatic resources when evaluating those effects.

B.2.1 Spatial and Temporal Scales Used in Assessment of the 2020 Mine Plan

When conducting an assessment, defining and selecting appropriate spatial and temporal scales for the analysis are essential. Assessments and models evaluate the system of inquiry at specific spatial and temporal scales, which may be explicitly or implicitly determined. The selection of appropriate scales of inquiry is critical, as it must be appropriate to capture biologically and ecologically meaningful patterns and processes (Levin 1992).

In evaluating potential effects of the 2020 Mine Plan on fish populations, an appropriate spatial scale would capture the extents of adult spawning, juvenile rearing and seasonal movement, and migration as potentially affected by changes in chemical, physical, or biological conditions or processes at and downstream of the mine site. For mine site development and operations, this spatial scale would include all waters under the mine footprint and extend downstream as far as effects could be measured or reasonably expected to have ecological consequences. For example, the spatial scale might be determined by the downstream extent that key constituents were altered for chemical changes and fluvial geomorphic processes for physical changes; salmon, due to their mobile and migratory nature, would link these spatial domains through movements over their life cycles.

This selection of appropriate scale is important because assessment of whether “measurable impacts” occur is scale dependent. If an assessment selects a large-enough spatial or temporal scale, relative to the assessed area, when evaluating impacts, those impacts will diminish as a function of increasing scale. Thus, assessment of effects should be conducted at spatial and temporal scales that are most relevant to the resources being evaluated (EPA 2019).

This scale-dependence is illustrated clearly in the FEIS, which concludes that “impacts to Bristol Bay salmon are not expected to be measurable” (USACE 2020: Page 4.24-7). This statement presupposes that the only scale at which impacts matter is the entire Bristol Bay watershed—that is, only impacts at the level of the entire Bristol Bay salmon population are important. Reporting conclusions about impacts at this regional scale results in impacts appearing to be less severe. The direct loss of 99.7 miles of streams within the initial 2020 Mine Plan footprint is reported as “…about 20 percent of available habitat in the Headwaters Koktuli drainage [i.e., the SFK and NFK watersheds], 12 percent of available habitat in the larger Koktuli River drainage, and 0.3 percent of available stream and river habitat in the Nushagak watershed” (USACE 2020: Page 4.24-8). Basing conclusions on effects at the largest spatial extent suggests that individual habitats and the fish they support are similar and interchangeable throughout the Nushagak watershed, which evidence suggests is not the case (Section 3.3.3).

Ninety-four percent of the 2020 Mine Plan’s impacts to streams, wetlands, and other aquatic resources would occur in the Koktuli River watershed. The miles of streams and acres of wetlands and other waters that would be lost reflect local conditions and provide habitat to specific fish communities that are part of a portfolio of local populations (Section 3.3.3). Thus, the FEIS conclusion does not disclose impacts at the smaller, more relevant and appropriate scale where impacts would be measurable. Loss of any genetically distinct populations in the Koktuli River watersheds would constitute a measurable, adverse effect, in addition to any effects these losses may have at the entire Bristol Bay watershed scale via the portfolio effect (Section 3.3.3).

Selection of appropriate temporal scales is also important. For example, the FEIS presents streamflows in terms of average monthly changes (USACE 2020: Section 4.16, Table 4.16-3). Although hydrologists consider monthly flows to be a critical component of a stream’s hydrograph, evaluating impacts of streamflow changes at this temporal scale does not address key ecological considerations relevant to fish. A stream's annual hydrograph can be characterized by monthly averages, the annual extremes of low and high flows, and short-duration flow pulses (Richter et al. 1996). A stream's hydrograph may also be characterized by components that include baseflow, frequent floods, seasonal timing of flows, and annual variation in flow. In all cases, the magnitude, timing, duration, frequency, and rate of change of streamflows are important in characterizing the hydrograph (Poff et al. 1997).

The life histories and behaviors of aquatic organisms are attuned to streamflow cues and may be affected by daily (and even sub-daily) variations in streamflow that affect physical and ecological processes (Bevelhimer et al. 2015, Freeman et al. 2022). The use of monthly averages precludes analyzing individual streamflow components and masks the severity of impacts, because percent changes to daily flows would be more variable than changes to monthly averages. However, such daily flow information is not reported or analyzed in the FEIS. Evaluating streamflow changes using monthly averages provides only a minimum estimate of the actual streamflow changes likely to result from the 2020 Mine Plan. The same is true for changes in water temperature, which the FEIS also presents as monthly averages grouped by winter and summer months (USACE 2020: Section 4.24, Table 4.24-3). The FEIS acknowledges that the potential for daily temperature variations beyond the monthly ranges exists, but without any supporting evidence states that the monthly ranges are representative of potential temperature changes (USACE 2020: Section 4.24).

B.2.2 Spatial and Temporal Variability in Assessment of the 2020 Mine Plan

Streams and rivers are dynamic, highly variable systems. Oversimplification of this variability, or failure to account for rare, but disproportionately influential, spatial features or temporal events, can lead to faulty conclusions. In streams and rivers, infrequent but extreme flow events (i.e., floods or droughts) can strongly shape ecology. The timing and duration of ecologically important flow events, for example, can be difficult to predict, but can profoundly affect both physical habitat structure and population dynamics (Poff et al. 1997, Freeman et al. 2022). Similarly, uncommon or infrequent habitat features can be disproportionately important; examples include shelters or refuges from episodic conditions that may be briefly limiting but can serve as "bottlenecks," constraining the abundance of future life stages.

To fully consider this variability in an assessment of potential impacts, all components of these aquatic systems (i.e., chemical, physical, and biological) should be sampled over spatial and temporal extents that capture the full range of variability in each component. In addition, connectivity between headwater streams and wetlands and downstream waters is dynamic, shifting on both short-term and long-term time frames in response to changing environmental conditions (Fritz et al. 2018). As a result, a complete accounting of how headwaters affect downstream waters should consider aggregate physical, chemical, and biological connections over multiple years to decades (Fritz et al. 2018, Schofield et al. 2018).

A significant amount of baseline environmental data has been collected in the SFK, NFK, and UTC watersheds, primarily between 2004 and 2008 (PLP 2011, 2018). These data highlight the natural variability of these systems, in terms of biological communities, streamflow, water chemistry, and myriad other factors, across both sites and sampling dates (e.g., see discussion of adult salmon spawner counts in Section B.1.3). There is no reason to expect that these data fully capture how much these factors vary over longer time scales and more finely resolved spatial scales, which means that FEIS conclusions about the long-term impacts to aquatic resources resulting from the 2020 Mine Plan based on these data should be viewed as minimum estimates.

For example, fish populations can be highly dynamic in time and space, limiting the ability of short-term, spatially unbalanced sampling designs to adequately characterize population dynamics that may be important for long-term persistence (Davis and Schindler 2021). The baseline data on fish abundance and distribution used in the FEIS were not collected over sufficient spatial and temporal scales to fully establish the bounds of the natural spatial and temporal variability of fish populations in the region, for all species and life stages, to adequately support the FEIS conclusions about impacts to fishes.

B.3 Evaluating Mine Impacts to Streamflow

This section examines how changes in streamflow resulting from operation of the 2020 Mine Plan were assessed.

B.3.1 Overview of Streamflow Assessment Methods

The impact of the 2020 Mine Plan on streamflow in the SFK, NFK, and UTC was estimated using an end-of-mine watershed model that incorporates inputs from three primary components: a baseline watershed model, a groundwater flow model, and a mine-site water-balance model (PLP 2019b: RFI 109g). Streamflow changes are reported in terms of changes in average monthly streamflow between baseline and end-of-mine, assuming 50-percent exceedance probability discharge of treated water, based on 76 synthetic monthly average flows (USACE 2020: Section 4.16 and Appendix K4.16).

B.3.2 Evaluating the Streamflow Assessment Methods

There are several potential issues related to how the FEIS evaluated changes in downstream flows under the 2020 Mine Plan, many of which were identified by EPA (2019).

- The baseline watershed model was configured and calibrated prior to development of the groundwater model (MODFLOW) and was not updated to include any additional geologic or water table elevation data collected and used in the groundwater model.
- Within the mine site boundary, streamflow changes due to well pumping and groundwater table depression are not considered. Losses associated with the mine are conveyed downstream only as decreases in influent stream flow; effects of groundwater drawdown on downstream flows are not considered. Losses associated with drawdown of less than 3 feet (ft) are not accounted for in either the streamflow loss analysis or the streamflow change analysis. For example, NFK100C1 is not included in the streamflow change analysis (NFK Reach D), but its contributing watershed is affected by groundwater drawdown.

- The majority of surface water and groundwater flows within the mine site boundary are assumed to be captured, contained, and released via mine infrastructure. The proposed operations transform the naturally varying and unregulated surface water and groundwater flows in the headwaters into uniform, regulated process-water discharges to surface waters. The altered variability in streamflows within and between the SFK, NFK, and UTC watersheds is not described or characterized.
- Percentage differences between baseline and end-of-mine conditions are computed based on monthly averages; thus, they do not represent the full magnitude of potential daily fluctuations. Fish do not experience average monthly flows; rather, they experience the dynamic continuum of flows occurring over much shorter time periods (i.e., daily or even sub-daily). The use of average monthly streamflow is a relatively insensitive measure of potential impacts to fishes and other aquatic resources. If average monthly streamflows differ from baseline conditions, aquatic resources are likely to be altered; if average monthly streamflows do not differ from baseline conditions, it does not necessarily mean that streamflow patterns on shorter time scales—and, thus, aquatic resources—will not be affected.
- The method used estimated streamflow change at multiple nodes and extended changes in streamflow from the downstream node to the upstream node. This method underestimates impacts, because streamflow changes would generally be greater at upstream nodes, closer to the mine site.
- In the streamflow change analysis, wastewater treatment plant (WTP) discharge is a fixed annual volume representing "50-percent exceedance probability" that is distributed in fixed percentages across months according to habitat suitability criteria developed in the Physical Habitat Simulation System (PHABSIM) model (PLP 2019a: RFI 109f). This value is representative of the median streamflow condition (USACE 2020: Appendix K4.24); managing to the median serves to dampen variability in the system (Section B.2.2). In addition, the 50-percent exceedance probability was derived under a limited set of hydraulic conductivity scenarios (USACE 2020: Section 4.16, Appendix K4.16).
- The volume of groundwater pumping and the extent of groundwater table drawdown are likely underestimated for several reasons. In the groundwater model, pit dewatering well depths ranged up to 200 ft, which is approximately 1,450 ft less than the maximum pit depth; dewatering from mine site facilities other than the pit also was not considered. Furthermore, water table drawdown was not evaluated downstream of the mine site boundary (PLP 2019b: RFI 109g). Groundwater loss estimates from the pit assumed a zero groundwater flow condition at surface water divides, which does not seem to be substantiated by the stratigraphic data. As a result, more dewatering likely would be required than was included in the groundwater model.
- In evaluating mine impacts, hydraulic conductivity scenarios with the highest impact on streamflow were not considered in the streamflow analysis, and hydraulic conductivity scenarios were not applied beyond the mine site area. A fixed groundwater pumping rate was selected for each of the

hydraulic conductivity scenarios, despite the fact that groundwater pumping demand, and thus effects on baseflows, would vary with rainfall and temperature.

- Climate variability was not captured in the streamflow analysis, because the 50-percent exceedance probability water-discharge rate and the average annual pit-dewatering pumping rate were used in the streamflow analysis.
- Wet, dry, and average climate conditions were selected based on total precipitation in the final year of a 20-year series selected across the 76-year synthetic climate record. There was no verification that the 20-year period leading up to the final year was wetter or drier than average, although antecedent conditions are important in determining streamflows. The 20-year average annual precipitation across these three realizations only ranged from 54 to 55 inches (USACE 2020: Section 4.16). These wet, dry, and average climate conditions were used to design the water management plan, but were not used to analyze streamflow changes.

Based on these concerns, it is likely that the streamflow change analysis generally underestimates the extent to which streamflow in the SFK and NFK watersheds would be affected by mine operations resulting from the 2020 Mine Plan, in terms of both percentage change in streamflow, length of affected streams, and changes in streamflow variability. Even this underestimate of streamflow changes represents an unacceptable adverse effect on fishery areas in the SFK and NFK watersheds (Section 4.2.4).

B.4 Evaluating Mine Impacts to Fish Habitat

Assessment of streamflow and fish habitat changes under the 2020 Mine Plan are closely related, given the fish habitat assessment methods used in the FEIS. This section considers potential issues associated with how the FEIS evaluated fish habitat changes and how those issues affect conclusions about impacts of the 2020 Mine Plan.

B.4.1 Overview of Fish Habitat Assessment Methods Used to Evaluate the 2020 Mine Plan

The FEIS relied on the PHABSIM modeling approach, which is part of the Instream Flow Incremental Methodology developed by the U.S. Fish and Wildlife Service (Bovee et al. 1998) to model changes in fish habitat in response to changes in streamflow. In the FEIS fish habitat analysis, PHABSIM was used to predict effects of streamflow changes on the amount of available habitat for multiple fish species and life stages. There are two basic components of a PHABSIM model: (1) the hydraulic representation of the stream at a stream transect; and (2) the habitat simulations at a stream transect using defined hydraulic parameters (i.e., water depth and velocity and, for some life stages, substrate). Habitat suitability curves (HSCs) for different fish species and life stages are used to calculate weighted usable habitat area for a stream segment represented by the transect.

In addition, the HABSYN program developed by R2 Resource Consultants was used to expand the standard transect-based component of PHABSIM to unsampled habitat areas (USACE 2020: Appendix K4.24, PLP 2018b: RFI 048). To our knowledge, the HABSYN model has never been validated or documented in the scientific literature, and the basic premise of extending sampled transect data to unsampled habitats was not evaluated in the FEIS.

Together, PHABSIM and HABSYN models were used to estimate total acres of fish habitat—by species, life stage, and reach—for wet, average, and dry climate conditions during pre-mine (baseline), end-of-mine, and post-closure phases of mine development. The following sections focus on potential issues associated with the modeling of fish habitat changes under the 2020 Mine Plan, as reported in the FEIS (USACE 2020: Section 4.24, Appendix K4.24). Many of these issues were also identified in EPA (2019).

B.4.2 Evaluating the Use of PHABSIM Models to Estimate Fish Habitat Changes under the 2020 Mine Plan

PHABSIM is a one-dimensional physical model that has been used for decades to model habitat and manage streamflows for fish populations, including salmon. However, PHABSIM has several limitations that have long been acknowledged (e.g., Anderson et al. 2006, Railsback 2016), which should be addressed during application and considered in interpreting results when PHABSIM is used. The FEIS did not consider many of these issues in its fish habitat analysis; as a result, its estimates of changes to fish habitat resulting from the 2020 Mine Plan likely underestimate the extent of those changes. This section explores specific assumptions and limitations of how PHABSIM models were implemented in the FEIS (USACE 2020: Section 4.24, Appendix K4.24), as well as factors that were omitted from fish habitat analyses.

B.4.2.1 Assumption that Streamflow Equals Fish Habitat

The FEIS bases its conclusions about changes in the availability of fish habitat under the 2020 Mine Plan on PHABSIM modeling (USACE 2020: Section 4.24, Appendix K4.24), which, as implemented in the FEIS, assumes that water depth and velocity are the only determinants of fish habitat. This assumption cannot defensibly be made unless (1) field data and analysis show that water depth and velocity are related to fish habitat in the region, and (2) there is a comprehensive evaluation of the other factors that determine fish habitat that potentially would be affected by the 2020 Mine Plan (e.g., water temperature, ice cover, groundwater exchange).

Importantly, the FEIS and its supporting documents did not establish that relationships between discharge (water depth and velocity) and fish habitat exist in the SFK, NFK, and UTC. This is of particular concern because these watersheds are groundwater-driven systems. When the assumption that habitat use primarily is structured by surface water hydraulics is not valid, hydraulic habitat modeling methods such as PHABSIM are not appropriate (Waddle 2001). Field data demonstrate that fish occurrence in areas of differing water depths and velocities changed with streamflow and over time (PLP 2011: Appendix 15.1C). These data demonstrate variability in fish habitat use among survey years, an indication that the underlying PHABSIM assumptions are not valid.

Once the assumption is made that habitat can be reduced to discharge (as does the PHABSIM model used in the FEIS), the amount of habitat can be predicted over time based on streamflow variability. As stated above, the relationship between streamflow variability and fish habitat was assumed to be a function of water depth and velocity in the FEIS. The PHABSIM analysis did not account for or consider other ecologically relevant fish habitat parameters, such as groundwater exchange, substrate, water temperature, water chemistry, cover, and habitat complexity (e.g., wetlands, off-channel habitats). Water depth and velocity are important determinants of fish habitat, but they are only two variables interacting with a suite of other factors that determine overall fish habitat suitability.

PHABSIM models are not appropriate as the sole means to evaluate habitat for fish species that key into specific habitat variables unrelated to water depth and velocity. For example, the SFK, NFK, and UTC watersheds experience complex interactions between surface water and groundwater, with repercussions for fish habitat. Spawning Sockeye Salmon (*Oncorhynchus nerka*) and Coho Salmon (*O. kisutch*) select habitats based on groundwater upwelling and downwelling, respectively; changes in these habitat determinants are not reflected in the PHABSIM analysis. In addition, the PHABSIM analysis did not consider how disruption of surface water flows, groundwater pathways, and aquifer characteristics would alter water temperatures and thermal patterns within the NFK, SFK, and UTC watersheds.

The alteration of water temperatures is a concern because fish are at risk from changes in the heterogeneity and spatial distribution of thermal patterns, which drive their metabolic energetics. Fish populations rely on groundwater–surface water connectivity, which has a strong influence on stream thermal regimes throughout the Nushagak and Kvichak River watersheds and provides a moderating influence against both summer and winter temperature extremes (Woody and Higman 2011). Coho Salmon may move considerable distances over short time periods in response to food resources and temperature to enhance growth and survival (Armstrong et al. 2013). The PHABSIM analysis also does not account for the benefits of complex stream features resulting from off-channel habitats (e.g., side channels, sloughs) or other habitats, such as islands or tributary junctions. These can be important features for fish populations: for example, tributary junctions are biological hotspots, and off-channel habitats are often the most important factors in salmonid distribution (e.g., Swales and Levings 1989, Benda et al. 2004).

By considering only water depth and velocity, the PHABSIM analysis simplifies and homogenizes the complexity of fish habitat into combinations of only water depth and velocity. This simplified approach provides only a coarse assessment of suitable fish habitat and predicted impacts resulting from the 2020 Mine Plan, which likely underestimates actual changes to fish habitat that result from changes to the full suite of variables determining available fish habitat that potentially would be affected under the 2020 Mine Plan.

B.4.2.2 Data Collection Issues

The approach taken to develop valid fish-habitat associations typically involves mapping defined, representative, hierarchical habitats; conducting fish surveys at sites both used and unused by fish across the full seasonal distribution (i.e., spring, summer, fall, and winter) of all fish species and life stages (including incubation, emergence, and fry); and then selecting study sites for analysis. Data collection efforts to support fish habitat modeling in the FEIS did not follow this approach and do not appear to be structured or consistently implemented to inform the PHABSIM model in a meaningful way. As a result, there are several issues of concern regarding the data used in the fish habitat analysis, in terms of both data-collection methods and data completeness; some examples are discussed below.

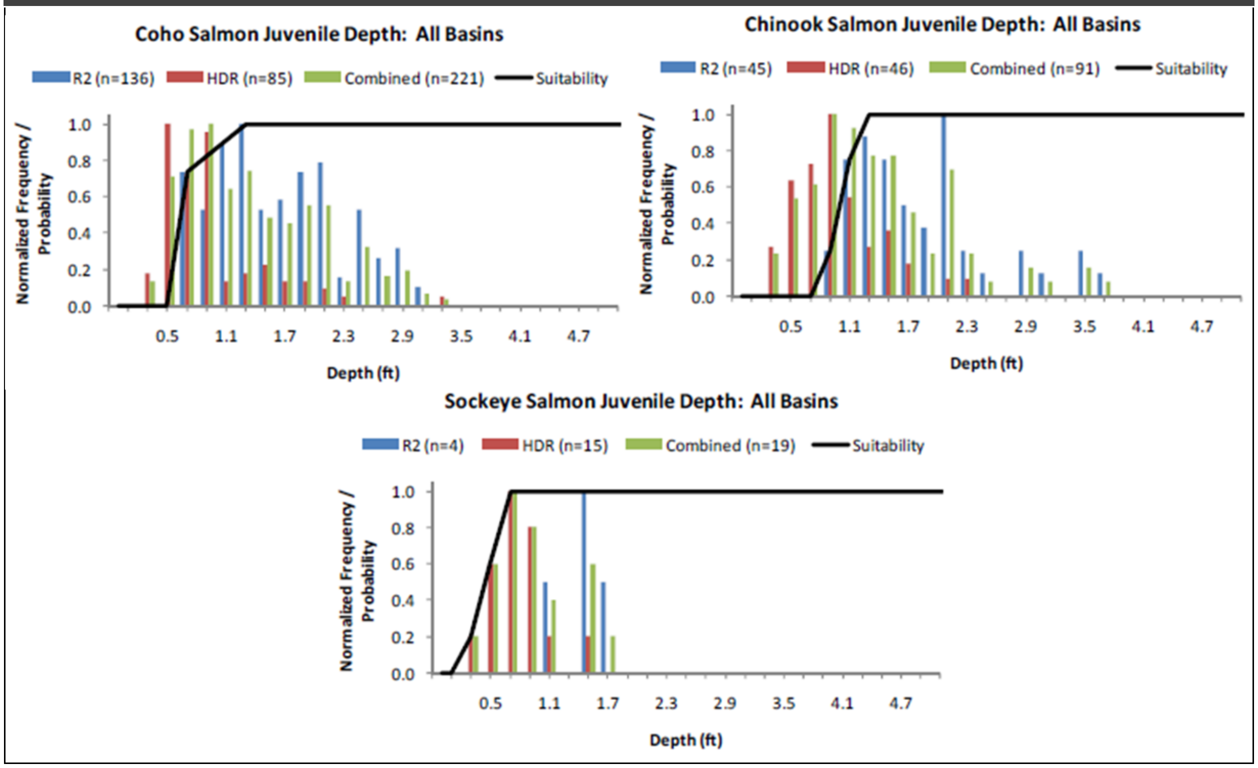
Additional environmental baseline data relevant to fish habitat use were collected, but these data were not used in the habitat impact analysis. For example, data on off-channel habitats are reported in PLP (2011, 2018) (see Table 3-10) but are not used in analyses related to fish habitat. The SFK, NFK, and UTC are modeled as single-channel systems in the PHABSIM analysis, despite the frequent occurrence of riparian wetland complexes, floodplains, beaver ponds, and other off-channel habitats throughout the area (Table 3-10; PLP 2011, 2018: Chapter 15). For example, up to 70 percent of the mainstem SFK downstream of Frying Pan Lake appears to be bordered by off-channel habitats (USACE 2020: Section 3.24). This complexity is not captured in the instream habitat classification, despite its prevalence and importance for different life stages of salmon and other fish species (e.g., Coho Salmon).

The streamflow data used to generate wet year, average water year, and dry year climate conditions represented in the PHABSIM analysis were based on daily stream gage data measured between January 2005 and December 2014. The 76-year synthetic climate record was used to predict effects of the 2020 Mine Plan on streamflow and was applied to the daily observed 2005–2014 times series. Thus, the streamflow data used to predict habitat changes likely do not accurately capture the full extent of streamflow variability at the mine site over longer time periods (see Section B.2.2 for additional discussion of spatial and temporal variability of data).

B.4.2.3 Habitat Suitability Curves

Biology is incorporated into PHABSIM through the use of HSCs. The underlying premise of HSCs is that more fish will occur in more suitable habitats; thus, HSCs look at occurrence of a given fish species and life stage relative to a single habitat variable (e.g., water depth or velocity) (Naman et al. 2020). The univariate nature of HSCs greatly oversimplifies the concept of habitat suitability for fishes (Section B.4.2.1). In addition, HSCs developed for evaluation of fish habitat impacts resulting from the 2020 Mine Plan do not reflect field data collected at the mine site (Figure B1). PLP (2011: Appendix 15.1C) reported that the HSCs generally track the shape of the normalized observed data histograms, with the exception of maximum depth. However, they concluded that maximum depth is not a limiting factor for fish habitat use; thus, HSCs used in the fish habitat analysis do not include a descending limb for depth (Figure B-1). This is an indication that appropriate steps described by developers of PHABSIM and HSCs (Bovee 1986) were not taken to validate the ecological relevance of depth before applying a model that forces a relationship with depth. The HSCs assume that more water means better fish habitat, and fish will use deeper water if it is available. This assumption is problematic, given that the field data actually demonstrate decreased habitat use for juvenile Coho, Sockeye, and Chinook (*O. tshawytscha*) salmon with increasing depth (Figure B-1). For example, Figure B-1 shows that as water depth increased above approximately 2.1 ft, the probability that juvenile Coho and Chinook salmon would be found decreased, with no juveniles of either species found at water depths above roughly 3.7 ft.

Figure B-1. Sample habitat suitability curves used in the PHABSIM fish habitat modeling. Models are for juvenile Coho, Chinook, and Sockeye salmon and water depth. From PLP 2011: Appendix 15.1C.



Railsback (2016) considers univariate HSC curves obsolete and suggests that they introduce considerable error to habitat modeling. Modern multivariate resource selection models or HSCs based on bioenergetic models (which relate habitat conditions to net energy gain by fish) can address some of these limitations and provide a better fit to observed fish habitat-use data (Naman et al. 2019, Naman et al. 2020). Particularly for drift-feeding fish, like salmonids, univariate HSCs may introduce systematic bias related to factors such as density-dependent territoriality and failure to consider water-velocity effects on prey availability (Rosenfeld and Naman 2021).

In addition, HSCs were not developed (or not included in the PHABSIM analysis) for all relevant life stages. For example, the fry life stage (salmonids less than 50 millimeters [mm]) was not included in the PHABSIM analysis; according to RFI 147, they were excluded because they occupy low velocity areas with cover and the "habitat needs of fry are generally met with flows much lower than those for other life stages" (PLP 2019c: RFI 147). This document also states that fry habitat generally is not limiting, although no support for this statement is provided (PLP 2019c: RFI 147). Hardy et al. (2006) discuss the importance of evaluating fry response to streamflow changes and present an approach for evaluating fry habitat availability. No HSCs were developed for the egg-incubation stage; in fact, impacts to the egg incubation stage were not considered in any assessment of impacts resulting from the 2020 Mine Plan. Potential impacts to these life stages could include scouring of redds and egg mortality with increased streamflows, and loss of water-temperature buffering, waste removal, and aeration during the incubation stage due to changes in groundwater exchange.

B.4.3 Evaluating Results and Conclusions of PHABSIM Modeling Related to Fish Habitat

The PHABSIM models used in the FEIS provide an oversimplification of fish habitat changes under the 2020 Mine Plan that does not account for the inherent complexity of aquatic habitats in the SFK, NFK, and UTC watersheds. As a result, the magnitude of fish habitat changes identified in the FEIS likely is an underestimate of actual effects of the project. It should be noted, however, that even this underestimate represents unacceptable adverse effect on fishery areas in the SFK and NFK watersheds (Section 4.2).

Specific issues related to how the FEIS evaluated changes in fish habitat under the 2020 Mine Plan include the following.

- The FEIS describes predicted changes in streamflow with and without the addition of treated water, but only evaluates predicted changes in suitable spawning and rearing habitat with treated water discharges (USACE 2020: Sections 4.16 and 4.24).
- Based on PHABSIM flow modeling, Figure K4.24.1 (USACE 2020: Appendix K4.24) depicts that most habitat units would not decrease under the 2020 Mine Plan, which is not supported. Because this figure only includes information about mainstem channels and omits tributaries and off-channel habitats, it does not present a complete depiction of potential effects of the 2020 Mine Plan.
- Based on average monthly streamflow, normal streamflow fluctuations would be altered substantially in the SFK and NFK: in total, a combined 29 miles of the SFK and NFK are predicted to experience changes in average monthly flows greater than 20 percent during mine operations (USACE 2020: Section 4.16). The FEIS refers to average monthly streamflow changes, which dampen variability and do not reflect changes to daily, seasonal, or even annual fluctuations (Section B.3.2). NFK Reaches A, B, and C would experience a greater than 20 percent increase in streamflow during April; NFK Reach C could see a 105-percent increase in April and a 20-percent decrease in June despite “optimization” of treated water discharges (see below). SFK Reach E would see a 52-percent decrease in average monthly streamflow in April, whereas SFK Reach D would see a 110-percent increase. The FEIS did not assess changes to suitable fish habitat in these SFK reaches. The portion of SFK Reach E above Frying Pan Lake (and stream gage SK100G) is specified as rearing habitat for Coho Salmon; Frying Pan Lake and portions of the SFK down to stream gage SK100F are used for rearing by both Coho and Sockeye salmon (USACE 2020: Section 3.24, Giefer and Blossom 2021).
- NFK Tributary 1.190 would be dewatered due to construction of the bulk tailings storage facility and seepage-collection system. The FEIS reports a 100-percent flow loss for this tributary (USACE 2020: Section 4.16). SFK Tributary 1.190 is predicted to experience a maximum change in the average monthly flow of 19 percent during operations, whereas SFK Tributary 1.24 is predicted to

experience a maximum change of 98 percent (USACE 2020: Section 4.16). A total of 9.2 miles of anadromous habitat have been documented within these two SFK tributaries. The use of monthly averages downplays the extent of impacts to the hydrograph and the aquatic life that is adapted to and relies on it. The body of published scientific literature on the functional consequences of hydrograph alteration is extensive (e.g., Poff et al. 1997, Freeman et al. 2022), but the FEIS does not address the predicted flow changes directly. The FEIS instead presents summaries of monthly changes to "suitable fish habitat" as defined within the PHABSIM model. Flow changes that alter monthly averages by more than 100 percent are viewed only through the lens of the PHABSIM model and are predicted to increase available habitat, notwithstanding the elimination of nearly 100 miles of streams. There is no distinction made in the FEIS between flows that create and maintain habitat (e.g., channel-maintenance flows) and those that affect habitat utilization.

- The FEIS states that treated discharges would be "optimized to benefit priority species and life stages for each month and stream" (USACE 2020: Section 4.24, Table 4.24-2). EPA has concerns that the goal of habitat optimization would not come to fruition. These concerns are due in part to limitations of the flow-habitat model development and application, and because an aquatic resource monitoring plan (ARMP) has not been developed for the project (USACE 2020: Table 5-2).[1,2] The Monitoring Summary provided by PLP states that monitoring of surface-water flow and quality is proposed to be conducted downstream of water-discharge points on a quarterly basis and would focus on streamflow and fish presence surveys (PLP 2019e: RFI 135). Because streamflow monitoring was not described as being used for real-time WTP discharge decisions, the optimization approach appears to be pre-planned, based on numerous assumptions that would not reflect the natural hydrologic regime. The FEIS does not indicate that adaptive management would be applied to ensure that habitat optimization is achieved or consider how differences across species and life stages would result in adverse effects for species other than each month's priority species and life stage.

These and other issues support the contention that application of the PHABSIM flow-routing model to evaluate fish habitat changes under the 2020 Mine Plan is flawed for two key reasons: (1) it does not consider habitat complexity, which is a critical component of the extremely complex aquatic system that exists in the SFK, NFK, and UTC watersheds; and (2) it does not integrate losses resulting from critical habitat components other than water depth and velocity, such as water temperature, groundwater

[1] The FEIS states, "An ARMP would be developed for the project. The ARMP would be developed in consultation with the ADF&G and ADNR as part of the plans of operation during state permitting" (USACE 2020: Section 5, Table 5-2).

[2] The FEIS states, "The project's water management strategy is based on the managed release of surplus water to maximize downstream fish habitat in areas impacted by flow reductions resulting from mine construction. Details are available in the PHABSIM modeling reports (PLP 2019-RFI 147 and PLP 2019-RFI 149 [R2 Resource Consultants 2019a]), the watershed modeling reports (PLP 2019-RFI 109f), and the Water Balance and Water Quality Model Report (PLP 2019-RFI 021g), which collectively outline the project's water management strategy" (USACE 2020: Section 5, Table 5-2).

interactions, and off-channel habitats. Cumulatively, the results of the analysis thus underestimate the project effects and its consequences for fish and fish habitat.

B.4.4 Summary

The fish habitat assessment included in the FEIS relies heavily on the PHABSIM modeling approach. Because the PHABSIM model only considers water depth and velocity, the FEIS necessarily provides an overly simplistic characterization of fish habitat. EPA (2019) highlighted the value of conducting a comprehensive analysis of the suite of environmental drivers associated with distributions and abundances of the fish species and life stages found throughout the SFK, NFK, and UTC watersheds. The FEIS acknowledges that PHABSIM does not account for other factors affecting fish habitat and ultimately fish survival and that losses of headwater streams and wetlands and changes to streamflows, groundwater inputs, water chemistry, and water temperature would occur under the 2020 Mine Plan (USACE 2020: Appendix K4.24)—all of which are likely to affect fish habitat use, as well as other components of these aquatic resources. However, the integrated effect that these changes are predicted to have on fish habitat has not been assessed adequately. As a result, the FEIS likely underestimates both direct and indirect effects on fish habitat under the 2020 Mine Plan, and its conclusion of no "measurable impact" on fish populations is not supported by the evidence, particularly at spatial scales relevant to the 2020 Mine Plan (i.e., the SFK, NFK, and UTC watersheds; see Section B.2.1). Even this underestimate of fish habitat changes resulting from the 2020 Mine Plan represents unacceptable adverse effect on fishery areas in the SFK and NFK watersheds (Section 4.2).

B.5 Other Effects on Aquatic Resources

The prohibitions and restrictions included in this proposed determination focus on direct losses of aquatic habitats and losses of the ecological subsidies that these habitats provide to downstream waters (Sections 4.2.1 through 4.2.3), as well as additional secondary effects caused by streamflow alterations (Section 4.2.4). This section considers other key impacts that development of the 2020 Mine Plan would have on aquatic habitats and fish populations in the SFK, NFK, and UTC.

B.5.1 Water Quality Effects

The FEIS states that adaptive management strategies would be employed at the WTPs to address water quality issues prior to discharging to the environment, including adding further treatment, as needed (USACE 2020: Section 4.18). However, the FEIS also acknowledges that "over the life of the mine, it is possible that [Alaska Pollutant Discharge Elimination System] permit conditions may be exceeded for various reasons (e.g., treatment process upset, record-keeping errors) as has happened at other Alaska mines" (USACE 2020: Page 4.18-13,). It is likely that the predicted water quality of effluents is overly optimistic (Sobolewski 2020), further suggesting that water quality impacts are underestimated in the FEIS.

Despite acknowledgement of the potential for water quality exceedances, Section 4.24 of the FEIS states that treated water discharges are expected to result in "no noticeable changes" in water chemistry and only slight increases in water temperature immediately below discharge points (USACE 2020). This misrepresents the information presented in Section 4.18 of the FEIS, which indicates that treated water discharges would substantially increase concentrations of 11 constituents (e.g., chloride, sulfate, calcium, magnesium, sodium, nitrate-N, ammonia, hardness) in receiving waters relative to baseline concentrations (USACE 2020). For example, chloride concentrations in the NFK are predicted to increase by 1,620 percent; nitrate-N and ammonia are predicted to be 30 times and 12 times higher than baseline concentrations, respectively; total dissolved solids are predicted to be nine times higher than baseline concentrations in UTC, and approximately 12 times higher than baseline concentrations in the SFK and NFK.

Section 4.18 of the FEIS does not identify environmental consequences from these predicted changes in water chemistry, and Section 4.24 of the FEIS suggests that there would be no impacts to fishes because point-source discharges are not expected to exceed water quality criteria. However, FEIS modeling indicates that discharges from WTP #1 during operations would exceed the standard for ammonia; it is also possible that the treated water discharges would result in seasonal exceedances of the turbidity standard (USACE 2020: Section 4.18).

In addition to water quality changes resulting from treated water releases, there is also the potential for accidents and spills to affect water quality. Although the FEIS acknowledges the potential for acute toxicity and sublethal effects on fish, conclusions regarding impacts to fishes from potential spills appear to be based on the potential for direct habitat loss. For example, regarding the modeled pyritic tailings release scenario, the FEIS states that "[c]admium and molybdenum would remain at levels exceeding the most stringent [water quality criteria] as far downstream as the Nushagak River Estuary, approximately 230 miles downstream from the mine site" and "[t]hese metals would remain at elevated levels above WQC [water quality criteria] for several weeks..." (USACE 2020: Page 4.27-139). The FEIS concludes that:

> [t]he low-level use of the habitat that would be impacted (based on densities of juvenile Chinook and coho salmon captured in these habitats) and the low numbers of coho spawning near the confluence of Tributary SFK 1.240 with the SFK, indicates drainage-wide or generational impacts to populations of salmon from direct habitat losses associated with the scenario would not be expected" (USACE 2020: Page 4.27-144).

As discussed earlier, the FEIS does not appear to address impacts to aquatic resources from the elevated metal concentrations, which would also affect fish populations.

The proposed mine also would likely alter water chemistry via land runoff and fugitive dust, and the FEIS likely underestimates these impacts. For example, the volume of material that would potentially leach metals to the environment is likely underestimated due to the use of a non-conservative neutralization potential/acid-generating potential ratio to characterize materials (USACE 2020: Section 3.18), as well as the application of a large temperature correction that is not representative of field conditions (USACE 2020: Appendix K3.18). The modeling of impacts from fugitive dust underreports the area affected and does not account for watershed loading or the effects of seasonal flushes to surface waters, such as during snowmelt (USACE 2020: Appendix K4.18). Watershed loading and "first flush" effects are also relevant to the transport of leached metals to surface waters. The FEIS also does not take into consideration the likely effect of sulfate loading from the treated water discharges on mercury methylation and subsequent bioaccumulation in fish and other aquatic organisms.

Predicted changes in average stream water temperature in winter and summer months are presented in Table 4.24-3 of the FEIS (USACE 2020: Section 4.24). Temperature is predicted to increase by up to 2.8°C within the NFK during winter months. The influence of temperature on fish bioenergetics is well understood, and the FEIS acknowledges the potential for impacts to eggs and alevins in spawning gravels (USACE 2020: Section 4.24). Impacts would occur through increased metabolism, growth, and changes in emergence timing that may increase juvenile mortality (Section 3.2.1).

Water quality in the SFK, NFK, and UTC are predicted to change downstream of the mine under the 2020 Mine Plan, due to the loss of upstream aquatic habitats, changes in surface water and groundwater flows, and the release of treated water discharges. These changes would create water quality conditions that would differ from the current conditions to which fish communities are in the region are adapted. These changes would alter fish habitat and the ecological cues that influence the timing of fish migration, spawning, incubation, emergence, rearing, and outmigration with likely negative consequences. Because the FEIS does not consider these effects, it underestimates potential impacts of the 2020 Mine Plan to the region's aquatic resources.

B.5.2 Multiple, Cumulative Effects

Under the 2020 Mine Plan, aquatic resources in the SFK, NFK, and UTC watersheds would experience a suite of co-occurring and interacting changes, including losses of headwater streams and wetlands; changes in streamflow regime due to changes in surface water and groundwater hydrology and treated water discharges; and changes in water temperature and water chemistry. However, the FEIS estimates effects of the 2020 Mine Plan by considering each impact independently—that is, by assuming each effect would act in isolation, typically without consideration of how multiple effects acting simultaneously would impact aquatic resources. This issue is evident across multiple contexts, as follows.

- Effects on species, and life stages within species, are considered independently, without consideration of how "optimization" of water discharges for priority species and life stages at certain times of year would affect other species and life stages (USACE 2020: Section 4.24).
- Effects in different sections of the stream channel are considered independently, without consideration of how changes in upstream portions may influence effects in downstream portions and vice versa (e.g., by affecting upstream movement).
- Effects of different stressors (e.g., changes in flow, temperature, water quality, and sedimentation) are considered independently, without consideration of how simultaneous exposure to multiple stressors, which also affect each other, would alter aquatic resources.

As a result, the FEIS likely underestimates how multiple, co-occurring changes associated with the 2020 Mine Plan would cumulatively affect the region's aquatic habitats and fish populations. The impacts reported in the FEIS likely represent a minimum estimate of how aquatic resources would be affected under the 2020 Mine Plan. This underestimation of cumulative impacts compounds the numerous underestimates of single-factor impacts throughout the FEIS. For example, based only on modeled streamflow impacts, RFI 149 concludes that there would be a loss of more than 10 percent of Chinook Salmon spawning habitat in the Koktuli River (PLP 2019d: RFI 149), a major producer of Chinook Salmon within the Nushagak River. For reasons discussed in Sections B.3 and B.4, this value likely underestimates streamflow impacts to Chinook Salmon populations; this value also fails to account for other co-occurring contributors to Chinook Salmon population impacts that would result from the 2020 Mine Plan, such as changes in water temperature, water chemistry, and downstream transport of energy and materials from headwater streams and wetlands. Although all aquatic resources in and downstream of the mine site would be affected by a suite of co-occurring (and likely interacting) changes to chemical, physical, and biological conditions, the impact of each change is only evaluated as if it would be acting in isolation.

B.6 Climate Change and Potential Mine Impacts to Aquatic Habitats and Fish

The ecosystems that support Pacific salmon species, in Alaska and elsewhere, are experiencing rapid changes due to a changing climate (Markon et al. 2018, Jones et al. 2020, von Biela et al. 2022). Alaska is warming faster than any other state (Markon et al. 2018). Across the entire Bristol Bay watershed, average temperature is projected to increase by approximately 4°C by the end of the century, with winter temperature projected to experience the highest increases (EPA 2014: Table 3-5, Figure 3-16). Similar patterns are projected in the Nushagak and Kvichak River watersheds (EPA 2014: Table 3-5). By the end of the century, precipitation is projected to increase roughly 30 percent across the Bristol Bay watershed, for a total increase of approximately 250 mm annually (EPA 2014: Table 3-6, Figure 3-17). In the Nushagak and Kvichak River watersheds, precipitation is projected to increase roughly 30 percent as well, for a total increase of approximately 270 mm of precipitation annually (EPA 2014: Table 3-6). At both spatial scales, increases in precipitation are expected to occur in all four seasons (EPA 2014: Table 3-6). Based on evapotranspiration calculations, annual water surpluses of 144 mm and 165 mm are projected for the Bristol Bay watershed and the Nushagak and Kvichak River watersheds, respectively (EPA 2014: Table 3-7, Figure 3-18).

These projected changes in temperature and precipitation are likely to have repercussions for both water management at the proposed mine and the surrounding aquatic resources. For example, increases in temperature are likely to affect evapotranspiration and exacerbate thermal stress. If water temperatures increase and cold-water species cannot find optimal conditions of groundwater exchange, incubating eggs may fail to develop or develop too rapidly, resulting in egg emergence out of sync with the availability of food resources (Cushing 1990, McCracken 2021). Increases in precipitation, as well as changes in the seasonality of precipitation, snowpack, and the timing of snowmelt, would likely affect streamflow regimes. High-intensity rainfalls may contribute to increased scouring and sedimentation of stream channels. Stream types at the mine site are highly susceptible to scour and erosion and could be destabilized significantly by streamflow or sediment regime changes (Brekken et al. 2022).

Wobus et al. (2015) incorporated climate change scenarios into an integrated hydrologic model for the upper Nushagak and Kvichak River watersheds. These simulations projected changes in water temperature, average winter streamflows, and dates of peak streamflows by 2100 (Wobus et al. 2015). Ultimately, these projected increases in temperature and changes in hydrology could affect salmon populations in multiple ways, such as alteration of spawning and rearing habitats, changes in fry emergence and growth patterns, and direct thermal stress (Tang et al. 1987, Beer and Anderson 2001, Bryant 2009, Wobus et al. 2015).

Despite these expected climate changes in Bristol Bay region, many of the models USACE (2020) used to evaluate potential impacts of the 2020 Mine Plan were parameterized based on past environmental conditions. For example, the mine site water-balance model included in the FEIS incorporated climate variability by using the 76-year average monthly synthetic temperature and precipitation record (USACE 2020: Section 3.16). EPA (2019) recommended that the FEIS consider how projected changes in the type (e.g., snow versus rain) and timing of precipitation could affect impacts to aquatic resources under the 2020 Mine Plan, but no future climate scenarios were included in the FEIS analysis of streamflow changes under the 2020 Mine Plan. It is not clear that past variability in temperature and precipitation will adequately capture future variability. As a result, these models may fail to adequately characterize mine impacts in ecosystems experiencing an altered climate (Sergeant et al. in press).

A thorough evaluation of impacts under the 2020 Mine Plan should consider future climate scenarios, particularly in terms of water treatment and management and potential effects on aquatic habitats and salmon populations. A key feature of salmon populations in the Bristol Bay watershed is their genetic diversity (i.e., the portfolio effect), which serves as an overall buffer for the entire population (Section 3.3.3). Different sub-populations may be more productive in different years, which affords the entire population stability under variable conditions year to year. If this variability increases over time due to changes in temperature and precipitation patterns, this portfolio effect becomes increasingly important in providing the genetic diversity to potentially allow for adaptation; thus, affecting or destroying genetically diverse populations may have a larger than expected effect on the overall Bristol Bay fishery under future climate conditions.

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May 2022

APPENDIX C

TECHNICAL EVALUATION OF POTENTIAL COMPENSATORY MITIGATION MEASURES

U.S. Environmental Protection Agency
Region 10
Seattle, WA

CONTENTS

Acronyms and Abbreviations

BBA	Bristol Bay Assessment
CWA	Clean Water Act
DA	Department of the Army
EBD	Environmental Baseline Document
EPA	Environmental Protection Agency
FEIS	Final Environmental Impact Statement
MOA	Memorandum of Agreement
NFK	North Fork Koktuli River
NOAA	National Oceanic and Atmospheric Administration
PLP	Pebble Limited Partnership
ROD	Record of Decision
SFK	South Fork Koktuli River
TDS	total dissolved solids
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geologic Survey
UTC	Upper Talarik Creek
WTP	wastewater treatment plant

EXECUTIVE SUMMARY

Compensatory mitigation refers to the restoration, establishment, enhancement, and/or in certain circumstances preservation of wetlands, streams, or other aquatic resources. Compensatory mitigation regulations jointly promulgated by the U.S. Environmental Protection Agency (EPA) and the U.S. Army Corps of Engineers (USACE) state that "the fundamental objective of compensatory mitigation is to offset environmental losses resulting from unavoidable impacts to waters of the United States authorized by [Clean Water Act (CWA) Section 404 permits issued by USACE]" (40 CFR 230.93(a)(1)). Compensatory mitigation enters the analysis only after a proposed project design has incorporated all appropriate and practicable means to avoid and minimize adverse impacts on aquatic resources (40 Code of Federal Regulations [CFR] 230.91(c)).

The Pebble Limited Partnership (PLP) has proposed to develop the Pebble copper-gold-molybdenum porphyry deposit as a surface mine in the Bristol Bay watershed in southwest Alaska (i.e., the 2020 Mine Plan) (PLP 2020b). In its 2022 *Proposed Determination of the U.S. Environmental Protection Agency Region 10 Pursuant to Section 404(c) of the Clean Water Act: Pebble Deposit Area, Southwest Alaska*, EPA Region 10 finds that the estimated loss and degradation of wetlands, streams, and other aquatic resources resulting from the discharge of dredged or fill material for the construction and routine operation of the 2020 Mine Plan could have unacceptable adverse effects on fishery areas.

During development and finalization of the Bristol Bay Assessment (BBA) (EPA 2014) between 2011 and 2014 and review of an earlier 404(c) proposed determination regarding the Pebble deposit published in 2014, PLP and other commenters suggested an array of measures as having the potential to compensate for the nature and magnitude of adverse impacts on wetlands, streams, and fish from the discharge of dredged or fill material associated with mining the Pebble deposit.

This appendix provides a detailed technical evaluation of each of these measures, for informational purposes. Available information demonstrates that known compensation measures are unlikely to adequately mitigate effects described in this proposed determination to an acceptable level.

SECTION 1. COMPENSATORY MITIGATION BACKGROUND

Compensatory mitigation is defined as the restoration, establishment, enhancement, and/or, in certain circumstances, preservation of wetlands, streams, or other aquatic resources conducted specifically for the purpose of offsetting unavoidable authorized impacts to these types of resources (40 Code of Federal Regulations [CFR] 230.92, Hough and Robertson 2009). According to compensatory mitigation regulations jointly promulgated by the U.S. Environmental Protection Agency (EPA) and the U.S. Army Corps of Engineers (USACE), "the fundamental objective of compensatory mitigation is to offset environmental losses resulting from unavoidable impacts to waters of the United States authorized by [Clean Water Act (CWA) Section 404 permits issued by USACE]" (40 CFR 230.93(a)(1)).

Section 404 permitting requirements for compensatory mitigation are based on what is "practicable and capable of compensating for the aquatic resource functions that will be lost as a result of the permitted activity" (40 CFR 230.93(a)(1)). In determining what type of compensatory mitigation will be "environmentally preferable," USACE "must assess the likelihood for ecological success and sustainability, the location of the compensation site relative to the impact site and their significance within the watershed, and the costs of the compensatory mitigation project" (40 CFR 230.93(a)(1)). Furthermore, compensatory mitigation requirements must be commensurate with the amount and type of impact associated with a particular Section 404 permit (40 CFR 230.93(a)(1)).

1.1 Location, Type, and Amount of Compensation

Regulations regarding compensatory mitigation require the use of a watershed approach to "establish compensatory mitigation requirements in [Department of the Army] permits to the extent appropriate and practicable" (40 CFR 230.93(c)(1)). Under these regulations, the watershed approach to compensatory mitigation site selection and planning is an analytical process for making compensatory mitigation decisions that support the sustainability or improvement of aquatic resources in a watershed. It involves consideration of watershed needs and how locations and types of compensatory mitigation projects address those needs (40 CFR 230.92). The regulations specifically state that compensatory mitigation generally should occur within the same watershed as the impact site and in a location where it is most likely to successfully replace lost functions and services (40 CFR 230.93(b)(1)). The goal of this watershed approach is to "maintain and improve the quality and quantity of aquatic resources within watersheds through strategic selection of compensatory mitigation sites" (40 CFR 230.93(c)(1)).

The regulations emphasize using existing watershed plans to inform compensatory mitigation decisions when such plans are determined to be appropriate for use in this context (40 CFR 230.93(c)(1)). Where appropriate plans do not exist, the regulations describe the types of considerations and information that should be used to support a watershed approach to compensation decision-making. Central to the watershed approach is consideration of how the types and locations of potential compensatory mitigation projects would sustain aquatic resource functions in the watershed. To achieve that goal, the regulations emphasize that mitigation projects should, where practicable, replace the suite of functions typically provided by the affected aquatic resource, rather than focus on specific individual functions (40 CFR 230.93(c)(2)). For this purpose, "watershed" means an "area that drains to a common waterway, such as a stream, lake, estuary, wetland, or ultimately the ocean" (40 CFR 230.92). Although there is flexibility in defining geographic scale, the watershed "should not be larger than is appropriate to ensure that the aquatic resources provided through compensation activities will effectively compensate for adverse environmental impacts resulting from [permitted] activities" (40 CFR 230.93(c)(4)).

With regard to type, in-kind mitigation (i.e., involving resources similar to those being impacted) is generally preferable to out-of-kind mitigation, because it is most likely to compensate for functions lost at the impact site (40 CFR 230.93(e)(1)). Furthermore, the regulations recognize that, for difficult-to-replace resources such as bogs, fens, springs, and streams, in-kind "rehabilitation, enhancement, or preservation" should be the compensation of choice, given the greater likelihood of success of those types of mitigation (40 CFR 230.93(e)(3)).

The amount of compensatory mitigation required must be, to the extent practicable, "sufficient to replace lost aquatic resource functions" (40 CFR 230.93(f)(1)), as determined through the use of a functional or condition assessment. If an applicable assessment methodology is not available, the regulations require a minimum one-to-one acreage or linear foot compensation ratio (40 CFR 230.93(f)(1)). Certain circumstances require higher ratios, even in the absence of an assessment methodology (e.g., use of preservation, lower likelihood of success, differences in functionality between the impact site and compensation project, difficulty of restoring lost functions, and the distance between the impact and compensation sites) (40 CFR 230.93(f)(2)).

1.2 Compensatory Mitigation Guidance for Alaska

In addition to the federal regulations regarding compensatory mitigation, EPA and the DA have also developed compensatory mitigation guidance applicable specifically to Alaska in a 2018 Memorandum of Agreement (MOA) (EPA and DA 2018).[1] The 2018 MOA provides guidance regarding flexibilities that exist in the mitigation requirements for CWA Section 404 permits, and how those flexibilities can be applied in Alaska given the abundance of wetlands and unique circumstances involved with Section 404 permitting in the state. Accordingly, the 2018 MOA recognizes that restoring, enhancing, or establishing wetlands for compensatory mitigation may not be practicable due to limited availability of sites and/or technical or logistical limitations. It also recognizes that compensatory mitigation options over a larger

[1] This MOA updates and replaces the EPA and DA Memoranda entitled *Clarification of the Clean Water Act Section 404 Memorandum of Agreement on Mitigation*, dated January 24, 1992, and *Statements on the Mitigation Sequence and No Net Loss of Wetlands in Alaska*, dated May 13, 1994.

watershed scale may be appropriate given that compensation options are frequently limited at a smaller watershed scale.

The 2018 MOA also identifies when compensatory mitigation may be required to ensure that an activity requiring a Section 404 permit complies with the CWA Section 404(b)(1) Guidelines (40 CFR Part 230.91(c)(2)). The 2018 MOA provides the following examples.

- Compensatory mitigation may be required to ensure that discharges do not cause or contribute to a violation of water quality standards or jeopardize a threatened or endangered species or result in the destruction or adverse modification of critical habitat under the Endangered Species Act (40 CFR Part 230.10(b)).
- Compensatory mitigation may be required to ensure that discharges do not cause or contribute to significant degradation (40 CFR Part 230.10(c)).
- The Section 404(b)(1) Guidelines also require compensatory mitigation measures when appropriate and practicable (40 CFR Parts 230.10(d), 230.12, 230.91, and 230.93(a)(1)).

The 2018 MOA also notes that during the Section 404(b)(1) Guidelines compliance analysis, USACE may determine that a Section 404 permit for a proposed discharge cannot be issued because of a lack of appropriate and practicable compensatory mitigation options (40 CFR Part 230.91(c)(3)).

It is important to remember that decisions regarding the appropriate type, amount, and location of compensatory mitigation are made on a case-by-case basis and depend on a number of factors, including the type, amount, and location of aquatic resources being impacted.

SECTION 2. IMPORTANT ECOLOGICAL FUNCTIONS AND SERVICES PROVIDED BY AFFECTED STREAMS AND WETLANDS

2.1 Aquatic Resources Affected at the Proposed Mine Site

As discussed in Section 2 of the proposed determination, the Pebble Limited Partnership (PLP) has proposed to develop the Pebble copper-gold-molybdenum porphyry deposit as a surface mine in the Bristol Bay watershed in southwest Alaska. The project (i.e., the 2020 Mine Plan) consists of four primary components: the mine site, the port, the transportation corridor including concentrate and water return pipelines, and the natural gas pipeline and fiber optic cable (PLP 2020b).[2]

As discussed in Section 4 of the proposed determination, USACE's Final Environmental Impact Statement (FEIS) and Record of Decision (ROD) for the project estimate that the discharge of dredged or fill material at the mine site would result in the permanent loss of approximately 2,113 acres of wetlands and other waters and 99.7 miles of streams. Included in these permanent stream losses are approximately 8.5 miles of documented anadromous fish streams (USACE 2020a and 2020b).[3] Section 4 of the proposed determination also discusses how discharges of dredged or fill material for the construction and routine operation of the 2020 Mine Plan would adversely affect approximately 29 miles of anadromous fish streams resulting from greater than 20 percent changes in average monthly streamflow. In the proposed determination, EPA Region 10 finds that discharges of dredged or fill material for the construction and routine operation of the 2020 Mine Plan could have unacceptable adverse effects on anadromous fishery areas.

2.2 Importance of Affected Aquatic Resources

Section 3 of the proposed determination provides a detailed description of the importance of the region's ecological resources. As discussed in Section 3 of the proposed determination, because of its climate, geology, hydrology, pristine environment, and other characteristics, the Bristol Bay watershed is home to abundant, diverse, and productive aquatic habitats (proposed determination: Figure ES-1). These streams, rivers, wetlands, lakes, and ponds support world-class commercial, subsistence, and

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[2] EPA did not evaluate the ancillary project components along the transportation corridor or at the Diamond Point port; therefore, this proposed determination does not address them.

[3] Anadromous fishes are those that hatch in freshwater habitats, migrate to sea for a period of relatively rapid growth, and then return to freshwater habitats to spawn. For the purposes of this proposed determination, "anadromous fishes" refers only to Coho or Silver salmon (*Oncorhynchus kisutch*), Chinook or King salmon (*O. tshawytscha*), Sockeye or Red salmon (*O. nerka*), Chum or Dog salmon (*O. keta*), and Pink or Humpback salmon (*O. gorbuscha*). Impact values cited here come from the ROD, which provides updates to the impact values provided in the FEIS.

recreational fisheries for multiple species of Pacific salmon, as well as numerous other fish species valued as subsistence and recreational resources (proposed determination: Section 3.3).

The productivity and diversity of the watershed's aquatic habitats are closely tied to the productivity and diversity of its fisheries. The waters of the South Fork Koktuli River (SFK), North Fork Koktuli River (NFK), and Upper Talarik Creek (UTC) watersheds are important for maintaining the integrity, productivity, and sustainability of the region's salmon and non-salmon fishery resources (proposed determination: Sections 3.2 and 3.3). The Pebble deposit overlies portions of the SFK, NFK, and UTC watersheds, and these areas would be most directly affected by mine development at the Pebble deposit.

Streams and lakes in the SFK, NFK, and UTC watersheds are ideal for maintaining high levels of fish production, with clean, cold water, gravel substrates, and abundant areas of groundwater upwelling. These conditions create preferred salmon spawning habitat and provide favorable conditions for egg incubation and survival. Figure 4-3 of the proposed determination illustrates reported distributions for all five species of Pacific salmon (Coho [*Oncorhynchus kisutch*], Chinook [*O. tshawytscha*], Sockeye [*O. nerka*], Chum [*O. keta*], and Pink [*O. gorbuscha*]) in these three watersheds. Streams and lakes in the SFK, NFK, and UTC watersheds also provide high-quality habitat for fishes, such as Rainbow Trout (*O. mykiss*), Dolly Varden (*Salvelinus malma*), Arctic Grayling (*Thymallus arcticus*), and Northern Pike (*Esox lucius*). Wetlands provide essential off-channel habitats that protect young Coho Salmon and other species, as well as provide spawning areas for Northern Pike. All of these species move throughout the region's freshwater habitats during their life cycles, and all are fished—commercially, for subsistence use, and recreationally—in downstream waters. Thus, the intact headwater-to-larger river systems found in the SFK, NFK, and UTC watersheds, with their associated wetlands, help sustain the overall productivity of these fishery areas (proposed determination: Sections 3.2 and 3.3).

Not only do the streams, wetlands, and ponds of the SFK, NFK, and UTC watersheds directly provide habitat for salmon and other fishes, they also provide critical support for downstream habitats. By contributing water, organic matter, and macroinvertebrates to downstream systems, these headwater areas help maintain downstream habitats and fuel their fish productivity. Together, these functions—direct provision of high-quality habitat and indirect provision of other resources to downstream habitats—help support the valuable fisheries of the Bristol Bay watershed (proposed determination: Section 3.2).

This support is vital in Coho, Chinook, and Sockeye salmon fisheries. Chinook Salmon are the rarest of the North American Pacific salmon species but are a critical subsistence resource, particularly along the Nushagak River. The SFK, NFK, and UTC watersheds support discrete populations of Sockeye Salmon that are genetically programmed to return to specific localized reaches or habitats to spawn; they likely do the same for Coho and Chinook salmon (proposed determination: Section 3.3.3). This portfolio of multiple small populations is essential for maintaining the genetic diversity and, thus, the stability and productivity of the region's overall salmon stocks (i.e., the portfolio effect) (proposed determination: Section 3.3.3).

2.3 Identifying the Appropriate Watershed Scale for Compensatory Mitigation

As previously noted, the regulations regarding compensatory mitigation specifically state that compensatory mitigation generally should occur within the same watershed as the impact site and in a location where it is most likely to successfully replace lost functions and services (40 CFR 230.93(b)(1)).

For the impacts of the mine site associated with the 2020 Mine Plan, ecological functions and services would be most directly affected in the SFK, NFK, and UTC watersheds. 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 these locations 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), Yocom and Bernard 2013). An important consideration is that salmon populations in these watersheds possess unique adaptations to local environmental conditions, as suggested by recent research in the region (Olsen et al. 2003, Ramstad et al. 2010, Quinn et al. 2012, Dann et al. 2012, Shedd et al. 2016, Brennan et al. 2019). Accordingly, maintenance of local biocomplexity (i.e., salmon genetic, behavioral, and phenotypic variation) and the environmental template upon which biocomplexity develops will be important for sustaining resilience of these populations (Hilborn et al. 2003, Schindler et al. 2010, Griffiths et al. 2014, Brennan et al. 2019). Thus, the most appropriate spatial scale and context for compensation would be within the local watersheds where impacts on salmon populations occur.

If there are no practicable or appropriate opportunities to provide compensation in these watersheds, exploring options in adjoining watersheds may be appropriate. However, defining the watershed scale too broadly would likely fail to ensure that wetland, stream, and associated fish losses in the SFK, NFK, and UTC watersheds would be addressed, because compensation in a different watershed(s) would not reduce the severity of the impacts to aquatic resources in the affected watersheds. Similarly, compensation in different watersheds would not address impacts to the subsistence fishery where users depend on a specific temporal and spatial distribution of fish to ensure nutritional needs and cultural values are maintained (EPA 2014: Chapter 12).

SECTION 3. REVIEW OF ADDITIONAL POTENTIAL COMPENSATORY MITIGATION MEASURES

During development and finalization of the Bristol Bay Assessment (BBA) between 2011 and 2014 and review of an earlier 404(c) proposed determination regarding the Pebble deposit published in 2014, PLP and other commenters suggested an array of measures as having the potential to compensate for the nature and magnitude of adverse impacts on wetlands, streams, and fish from the discharge of dredged or fill material associated with mining the Pebble deposit. This section provides a technical evaluation of the likely efficacy, applicability, and sustainability of these additional measures in reducing the unavoidable aquatic resource impacts estimated for the 2020 Mine Plan to an acceptable level. Since mitigation bank and in-lieu fee program options are not available, all of these additional measures would involve permittee-responsible compensatory mitigation.[4]

3.1 Permittee-Responsible Compensatory Mitigation

3.1.1 Compensation Measures Suggested within the SFK, NFK, and UTC Watersheds

This section discusses specific suggestions for potential compensation measures within the SFK, NFK, and UTC watersheds that were provided in the public and peer review comments on the BBA and 2014 Proposed Determination.

3.1.1.1 Increase Habitat Connectivity

Several commenters recommended actions to increase connectivity between aquatic habitats, which are discussed in this section. Connectivity among aquatic habitats within stream networks is an important attribute influencing the ability of mobile aquatic taxa to utilize the diversity and extent of habitats within those networks. Within riverine floodplain systems, a complex array of habitats can develop that express varying degrees of surface and sub-surface water connectivity to main channels (Stanford and Ward 1993). In the study area, off-channel floodplain habitats can include side channels (both inlet and outlet connections to main channel), various types of single-connection habitats including alcoves and

[4] Mitigation banks and in-lieu fee programs are other mechanisms for satisfying compensatory mitigation requirements that rely on third-party providers (40 CFR 230.92). Should a mitigation bank or in-lieu fee sponsor pursue the establishment of mitigation bank or in-lieu fee program sites to address impacts of the nature and magnitude estimated for the 2020 Mine Plan, they would encounter the same challenges described in Section 3 of this appendix. Permittee-responsible mitigation means an aquatic resource restoration, establishment, enhancement, and/or preservation activity undertaken by the permittee to provide compensatory mitigation for which the permittee retains full responsibility (40 CFR 230.92).

percolation channels, and pools and ponds with no surface connection to the main channel during certain flow conditions (PLP 2011: Appendix 15.1D). Beavers (*Castor canadensis*) can be very important modifiers and creators of habitat in these off-channel systems (Pollock et al. 2003, Rosell et al. 2005). As a result of their morphology and variable hydrology, the degree of surface-water connectivity and the ability of fish to move among floodplain habitats changes with surface water levels. Connectivity for fish movement at larger spatial scales within watersheds is influenced by barriers to longitudinal movements and migrations. Examples include dams and waterfalls.

Efforts to manage or enhance connectivity within aquatic systems have primarily focused on watersheds altered by human activities, where land uses and water utilization have led to aquatic habitat fragmentation. Specific activities to increase habitat connectivity within human-dominated stream-wetland systems may include the following.

- Improving access around real or perceived barriers to migration (including dams constructed by humans or beavers).
- Removing or retrofitting of road culverts.
- Excavating and engineering of channels to connect isolated wetlands and ponds to main channels.
- Reconnection of historic floodplains via levee removal or other channel engineering.

Within watersheds minimally affected by human activity, efforts to increase connectivity may include creation of passage around barrier waterfalls to expand the availability of habitat for species like Pacific salmon. Removal of human-created dams do not offer any opportunities for habitat improvement or expansion in the Nushagak or Kvichak River watersheds because they are absent, so they are not discussed further. As stated earlier, this is primarily a roadless area, so road stream crossing retrofits presently offer few if any opportunities for habitat improvement or expansion within the SFK, NFK, and UTC watersheds, but exist elsewhere in the larger Nushagak and Kvichak River watersheds and are discussed in Section 3.1. Here, beaver dam removal and engineered connections to variably connected floodplain habitats, and habitats upstream of barrier waterfalls are discussed. For each of these measures, the potential applicability, suitability, and effectiveness as mitigation tools within the SFK, NFK, and UTC watersheds are addressed.

3.1.1.1.1 Remove Beaver Dams

Two commenters suggested the removal of beaver dams as part of a potential compensation strategy that included beaver management. Presumably, the rationale for this recommendation is that beaver dams can block fish passage, limiting fish access to otherwise suitable habitat, thus, the removal of beaver dams could increase the amount of available fish habitat. This rationale is based on early research that led to the common fish management practice of removing beaver dams to protect certain fish populations like trout (Salyer 1934, Reid 1952, *in* Pollock et al. 2004). However, more recent research has documented numerous benefits of beaver ponds to fish populations and habitat (Murphy et al. 1989, Pollock et al. 2003). For example, Bustard and Narver (1975) found that a series of beaver ponds on Vancouver Island had a survival rate for overwintering juvenile Coho Salmon that was twice as high as the 35 percent estimated for the entire stream. Pollock et al. (2004) estimated a 61 percent reduction in summer habitat capacity relative to historical levels, largely due to the loss of beaver ponds, for Coho Salmon in one Washington watershed.

A recent review by Larsen et al. (2021) describes the extensive and complex ways in which beavers modify stream ecosystems. Increases in habitat complexity and availability of ponded and productive floodplain habitats associated with beaver activity can result in positive impacts on Sockeye, Coho, and Chinook salmon, as well as Dolly Varden, Rainbow Trout, and Steelhead (Kemp et al. 2012). Using meta-analysis and weight-of-evidence methodology, Kemp et al. (2012) showed that most (71.4 percent) negative effects cited, such as low dissolved oxygen and impediment to fish movement, lack supportive data and are speculative in nature, whereas the majority (51.1 percent) of positive impacts cited are quantitative in nature and well supported by data. In addition to increased invertebrate (i.e., food) production and habitat heterogeneity, the study cited the importance of beaver ponds as rearing habitat due to the increased cover and protection that higher levels of woody material and overall structural diversity provide. Other studies from the Pacific Northwest (Nickelson et al. 1992, Collen and Gibson 2001) and Alaska (Lang et al. 2006) have identified beaver ponds as excellent salmon rearing habitat because they have high macrophyte cover, low flow velocity, and increased temperatures, and they trap organic materials and nutrients. DeVries et al. (2012) describe a stream restoration approach that attempts to mimic and facilitate beaver dam creation and the numerous positive benefits for stream habitat and riparian enhancement. Studies in Oregon have shown that salmon abundance is positively related to pool size, especially during low flow conditions (Reeves et al. 2011), and beaver ponds provide particularly large pools. During winter, beaver ponds typically retain liquid water below the frozen surface, providing refugia for species that overwinter in streams and off-channel habitats (Nickelson et al. 1992, Cunjak 1996).

Beaver dams generally do not constitute significant barriers to salmonid migration, even though their semi-permeability may temporarily limit fish movement during periods of low stream flow (Rupp 1954, Gard 1961, Pollock et al. 2003). Even when beaver dams impede fish movements, the effects are typically temporary with higher flows from storm events ultimately overtopping them or blowing them out (Leidholt-Bruner et al. 1992, Kemp et al. 2012). Even the temporary effect may be limited, when seasonal rainfall is at least average (Snodgrass and Meffe 1998, Kemp et al. 2012). Adding to the body of evidence, Pacific salmon and other migratory fish species commonly occur above beaver dams, including above beaver dams in the study area (PLP 2011: Appendix 15.1D). Other surveys have documented both adult and juvenile Sockeye Salmon, Steelhead, Cutthroat Trout, and char upstream of beaver dams (Swales et al. 1988, Murphy et al. 1989, Pollock et al. 2003).

Beavers preferentially colonize headwater streams and off-channel habitats (Collen and Gibson 2001, Pollock et al. 2003). An October 2005 aerial survey of active beaver dams in the mine site area mapped

113 active beaver colonies (PLP 2011). PLP's Environmental Baseline Document (EBD) highlights the significant role that beaver ponds are currently providing for Pacific salmon in this area:

> [W]hile beaver ponds were relatively scarce in the mainstem UT [UTC], the off-channel habitat study revealed a preponderance of beaver ponds in the off-channel habitats. As in the SFK watershed, beaver ponds accounted for more than 90 percent of the off-channel habitat surveyed. Beaver ponds in the UT provided habitat for adult spawning and juvenile overwintering for Pacific salmon. The water temperature in beaver ponds in the UT was slightly warmer than in other habitat types and thus, beaver ponds may represent a more productive habitat as compared to other mainstem channel habitat types. (PLP 2011)

The current body of literature describing the effects of beaver dams on salmonid species reports more positive associations between beaver dam activity and salmonids than negative associations (Kemp et al. 2012). Hence, removal of beaver dams as a means of compensatory mitigation could lead to a net negative impact on salmonid abundance, growth, and productivity. Moreover, because the mine footprint would eliminate or block several streams with active beaver colonies in the headwaters of the NFK, the benefits provided by those habitats would be part of the suite of functions that compensatory mitigation should aim to offset.

3.1.1.1.2 Connect Off-channel Habitats and Habitat Above Impassable Waterfalls

Off-channel habitats can provide important low-velocity rearing habitats for juvenile salmon and other native fishes. Floodplain-complex habitats including beaver ponds, side channels, oxbow channels, and alcoves can contribute significantly to juvenile salmonid rearing capacity (e.g., Beechie et al. 1994, Ogston et al. 2015). Such habitats are a common feature of unmodified alluvial river corridors. These habitats may express varying degrees of surface-water connectivity to main channels that depend on streamflow stage and natural channel dynamics in unmodified rivers. Off-channel habitats may become isolated from the main channel during certain streamflow conditions due to channel migration or avulsion, and in highly dynamic channels, connectivity may change frequently during bed-mobilizing events (Stanford and Ward 1993). This shifting mosaic of depositional and erosional habitats within the floodplain creates a diverse hydraulic and geomorphic setting, contributing to biocomplexity (Amoros and Bornette 2002). In river systems modified by human activity, isolation or elimination of off-channel habitats has had severe impacts on salmon productivity (e.g., Beechie et al. 1994), and re-connection and re-creation of off-channel habitats are now common tools for increasing juvenile salmonid habitat capacity in those systems (Morley et al. 2005, Roni et al. 2006, Ogston et al. 2015).

Waterfalls or high-gradient stream reaches can prevent fish from accessing upstream habitats, due to velocity barriers or drops that exceed passage capabilities of fish (Reiser et al. 2006). Waters upstream of barriers may be devoid of all fish life or may contain resident fish species including genetically distinct populations (e.g., Whiteley et al. 2010). Engineered passageways for fish around waterfalls have been used to create access to upstream lakes or stream systems for fish, such as salmon. However, the response of resident fish species to barrier removal and the colonization success of species from downstream habitats may be context dependent and difficult to predict (Kiffney et al. 2009, Pess et al. 2014). Salmon population responses to a fishway in southeast Alaska depended on the species, and the ecological effects of fish passage on the upstream lake system and watershed are not fully understood (Bryant et al. 1999). Burger et al. (2000) provide a well-documented history of colonization of Sockeye Salmon in Frazer Lake, Alaska, above a historically impassable waterfall following passage installation and planting of salmon eggs, fry, and adults above the barrier. Their study documents how differing donor populations, each with different life-history characteristics, contributed differently toward the establishment of populations in the newly accessible habitats (Burger et al. 2000). This study highlights the importance of genetics and life history adaptations of source populations to colonization success.

Creating connectivity between parts of the river network that are naturally disconnected can have adverse ecological effects, including impacts on resident vertebrate and invertebrate communities, as well as disruptions to ecosystem processes. Introduction of fish to fishless areas can lead to altered predator–prey interactions, food web changes, changes in algal production, nutrient cycling, and meta-population dynamics of other vertebrate species (Section 3.1.2.5). For example, previous studies on the introduction of trout species to montane, wilderness lakes have shown that introducing fish to fishless lakes can have substantial impacts on nutrient cycles (Knapp et al. 2001). The risk of disruption to the functions of naturally fishless aquatic ecosystems should be fully evaluated before these approaches are used for the sole purpose of creating new fish habitat area.

The importance of spatial habitat configuration to stream salmonid ecology has been recognized by a wide variety of systems (reviewed by Flitcroft et al. 2019). For example, Rosenfeld and co-authors (Rosenfeld et al. 2008, Rosenfeld and Raeburn 2009) conducted a variety of experiments and monitoring activities within a re-connected river meander in coastal British Columbia to explore the relationship of salmon productivity to habitat features. Their work highlights the importance of habitat configuration. In their study, spacing of pools (foraging habitats for fish) and riffles (source areas for invertebrate prey) was an important factor influencing growth rates of juvenile Coho Salmon. Given the high diversity of channel conditions within floodplain habitats in the SFK, NFK, and UTC watersheds (PLP 2011), it is likely that fish responses to increased connectivity would be highly variable.

Rosenfeld et al. (2008) point out the importance of considering the full suite of factors that influence habitat capacity and productivity when designing restoration or enhancement projects. For instance, attempting to optimize habitat structure for one species may adversely affect species with differing habitat preferences, as demonstrated by Morley et al. (2005) who found differential responses of juvenile Steelhead and juvenile Coho Salmon to conditions in constructed and natural off-channel habitats. Predator–prey relationships also need to be considered. Increased connectivity of off-channel habitats has been proposed as a strategy for enhancing Northern Pike production in northern Canada (Cott 2004). How increased connectivity in the project area would influence trophic relationships among Northern Pike and salmonids is unknown, although introduced Northern Pike in other areas of Alaska have the potential to reduce local abundances of salmonids via predation (Sepulveda et al. 2013). Bryant et al. (1999) in their study of the effects of improved passage at a waterfall concluded that the effects on food webs, trophic relationships, and genetics among resident and newly colonizing species were largely unknown. Rosenfeld and Raeburn (2009) emphasize the high degree of uncertainty associated with channel design for enhanced fish productivity, stating the following:

> …despite the enormous quantity of research on stream rearing salmonids and their habitat associations, stream ecologists still lack a definitive understanding of the relationship between channel structure, prey production and habitat capacity for drift-feeding fishes. (Rosenfeld and Raeburn 2009: Page 581)

Several commenters proposed that enhanced or increased connectivity of off-channel habitats or habitats above waterfalls could provide fish access to the currently underutilized or inaccessible habitat. This comment presumes that currently disconnected habitats would provide suitable mitigation sites. Based on the above, multiple criteria would have to be met, and numerous assumptions would have to be validated for these sites to qualify as effective mitigation sites. Given the examples of the challenges of connectivity management, use of fishways at waterfalls, and engineered connections to off-channel habitats there is a great deal of uncertainty regarding the efficacy and sustainability of such techniques as compensatory mitigation in the affected watersheds. Further, there also appears to be a lack of opportunities to implement such techniques. When evaluating what compensation measures could reduce the severity of the adverse effects estimated for the 2020 Mine Plan in the Koktuli River watershed,[5] PLP ruled out all other potential measures aside from preservation stating that "[r]estoration, establishment, or enhancement projects within the identified watershed are not plentiful enough in size or scale to mitigate for the identified acreage of direct and indirect impacts to be mitigated" (PLP 2020c).

3.1.1.2 Increase Habitat Quality

EPA received comments about enhancing habitat quality. Addition of large structural elements, such as wood and boulders to streams, has been a common stream habitat rehabilitation approach in locations where stream habitats have been extensively simplified by mining, logging, and associated timber transportation, or other disturbances (Roni et al. 2008). The goals of large-structure additions are typically to create increased hydraulic and structural complexity and improve local-scale habitat conditions for fish in streams that are otherwise lacking in rearing or spawning microhabitats. Properly engineered structural additions to channels can increase hydraulic diversity, habitat complexity, and retention of substrates and organic materials in channels. However, benefits for fish can be highly variable and context-dependent (Roni 2019) and can be difficult to quantify (Richer et al. 2022, Rogers et al. 2022). The unpredictability of beneficial biotic responses to stream structural enhancements is at odds with perceptions by managers whose evaluations tend to be overtly positive—but usually based on qualitative opinion rather than scientific observation (Jähnig et al. 2011). In addition, improperly sited or engineered structural additions can fail to achieve desired effects or have adverse, unanticipated consequences (e.g., via structural failure or scour and fill of sensitive non-target habitats (Frissell and Nawa 1992), highlighting the need for appropriate design (Kondolf et al. 2007).

[5] The most severe impacts of the 2020 Mine Plan are concentrated in the SFK and NFK watersheds, which are a part of the Koktuli River watershed.

Commenters proposed that the quality of stream habitats in the project area could be enhanced by increasing habitat complexity through the addition of boulders or large wood to existing off-channel habitats. Off-channel habitats can provide important low-velocity rearing habitats for juvenile salmon and other native fishes. Floodplain-complex habitats including beaver ponds, side channels, oxbow channels, and alcoves provide hydraulic diversity that can be important for fishes in variable flows (Amoros and Bornette 2002, Rosenfeld et al. 2008). Beavers are a major player in the creation and maintenance of these habitats in the study area (PLP 2011: Appendix 15.1D), as has been noted elsewhere (Pollock et al. 2003, Rosell et al. 2005). Off-channel habitats also provide important foraging environments, and can be thermally diverse, offering opportunities for thermoregulation or enhanced bioenergetic efficiency (Giannico and Hinch 2003). Off-channel habitats are relatively frequent and locally abundant in area streams and rivers, particularly in lower-gradient, unconstrained valley settings and at tributary confluences (e.g., PLP 2011: Figure 15.1-15). PLP's EBD, Appendix 15.1D (PLP 2011) contains an assessment of the natural fluvial processes creating and maintaining off-channel habitats and their quality, quantity, and function in the SFK, NFK, and UTC watersheds, including mechanisms of connectivity to the mainstem channels. The EBD (PLP 2011) provides background information that is useful for evaluating the potential effectiveness of off-channel habitat modification.

Commenters proposed that off-channel habitats could also be improved by engineered modifications to the depth, shoreline development ratio, and configuration of off-channel habitats to create better overwintering habitat for juvenile salmon. The degree to which existing habitats could be enhanced to improve survival of juvenile salmon as proposed by commenters, will depend on several considerations, including an evaluation of factors known to influence the utilization, survival, and growth within these habitats. These considerations are discussed below.

Off-channel habitats surveyed by PLP and other investigators reveal that patterns of occupancy and density are high but variable among off-channel habitats (PLP 2011: Appendix 15.1D). Some of the highest densities observed were within off-channel habitats, such as side channels and alcoves, but some "isolated" pools held fish (PLP 2011: Appendix 15.1D). This variability could reflect variation in suitability, access, or other characteristics of individual off-channel habitats. Juvenile salmonids require a diverse suite of resources to meet habitat requirements—cover and visual isolation provided by habitat complexity is one such resource. However, other critical resources include food, space, and suitable temperatures and water chemistry (Quinn 2005). Habitat configuration within constructed side-channel habitats can also strongly influence density, size, and growth of juvenile salmonids (Rosenfeld and Raeburn 2009). Giannico and Hinch (2003) in experimental treatments in side channels in British Columbia found that wood additions were beneficial to Coho Salmon growth and survival in surface–water-fed side channels, but not in groundwater-fed channels. They attributed this effect to differences in foraging strategy and bioenergetics of the juvenile Coho Salmon overwintering in the channels. Additions of wood had no effect, or even possibly a detrimental effect, on Coho Salmon survival in groundwater-fed side channels. These findings highlight the importance of understanding the ecology, bioenergetics, and behavior of the species and life histories present within habitats that may be quite diverse with regard to hydrology and geomorphology.

It is not clear from current data that adding complexity would address any limiting factor within existing off-channel habitats, or that additions of boulders and wood would enhance salmonid abundance or survival. Placement of structures (e.g., boulders, large wood) within stream channels could also have potential adverse consequences, including unanticipated shifts in hydraulic conditions that lead to bank erosion or loss of other desirable habitat features. Sustainability of off-channel habitat modifications is also in question. As stated in the EBD, off-channel habitats are a product of a dynamic floodplain environment and ". . . are continually being created and destroyed" (PLP 2011: Appendix 15.1D; page 2). Maintenance of engineered structures or altered morphologies of such habitats over the long term would be a challenging task (Tullos et al. 2021). Observations from the EBD suggest that beavers are already providing desired complexity:

> . . . habitat mapping from this off-channel study shows that the beaver ponds contain extensive and diverse habitats and dominate the active valley floor" and "…these off-channel habitats provide a critical habitat component of freshwater rearing of Coho Salmon, and to a lesser extent, other anadromous and resident species. (PLP 2011: Appendix 15.1D: Page 14)

3.1.1.3 Increase Habitat Quantity

EPA received comments about increasing habitat quantity. The creation of spawning channels and off-channel habitats has been proposed as a means to compensate for lost salmon spawning and rearing areas. The intent of a constructed spawning channel is to simulate a natural salmon stream by regulating flow, gravel size, and spawner density (Hilborn 1992). Off-channel habitats may be enlarged or modified to alter habitat conditions and capacities for rearing juvenile salmonids. Examples include the many spawning channels (Bonnell 1991) and off-channel habitats (Cooperman 2006) enhanced or created in British Columbia and off-channel ponds rehabilitated by the City of Seattle (Hall and Wissmar 2004).

Off-channel spawning and rearing habitats can be advantageous to salmon populations by providing diverse hydraulic and habitat characteristics. Redds constructed in these habitats may be less susceptible to scour compared to main channel habitats due to flow stability provided by their hyporheic or groundwater sources (Hall and Wissmar 2004). Moderated thermal regimes can provide benefits for growth and survival for overwintering juveniles (Giannico and Hinch 2003). Morley et al. (2005) compared 11 constructed off-channel habitats to naturally occurring paired reference side channels and found that both natural and constructed off-channel habitats supported high densities of juvenile salmonids in both winter and summer. Although numerous studies have documented short-term or localized benefits of constructed off-channel habitats, ascertaining population-level effects is much more difficult (Ogston et al. 2015). Any additional fry produced by spawning channels (if successful) would require additional suitable habitat for juvenile rearing and subsequent life stages in order to have a net positive effect on populations. In a notable study, Ogston et al. (2015) tracked production of Coho Salmon smolts from rehabilitated floodplain habitats that had been extensively modified by logging and observed a significant population-level increase in smolts. Hilborn (1992) indicates that success, measured by increased production of adult fish from such channels, is unpredictable and generally unmonitored. A notable exception is the study by Sheng et al. (1990), which documented 2- to 8-fold increases in recruitment of Coho Salmon spawner production from groundwater-fed off-channel habitats. Sheng et al. (1990) stated that effectiveness would be greatest in systems that currently lack adequate overwinter refuges. As with any rehabilitation strategy, population responses will depend on whether factors actually limiting production are addressed (Gibeau et al. 2020). Additional research and monitoring would be important to quantify factors currently limiting production within project area watersheds.

Replacing destroyed salmon habitats with new constructed channels is also not a simple task. Factors for consideration in designing and implementing off-channel habitat development are outlined in Lister and Finnigan (1997), and include evaluation of species and life stages present, current habitat conditions, and factors limiting capacity or productivity (Roni et al. 2008). Research indicates that channels fed by hyporheic flow or groundwater may be most effective for creating suitable spawning and rearing habitats (Lister and Finnigan 1997). Near-stream excavation and compaction associated with channel construction can alter groundwater flowpaths, so designing projects to protect current function and groundwater connectivity is important.

Numerous researchers have emphasized that replacing lost habitats is not merely a process of providing habitat structure (Lake et al. 2007). Effective replacement of function also requires establishment of appropriate food web structure and productivity to support the food supply for fish—in essence, an entire ecosystem, including a full suite of organisms such as bacteria, algae, and invertebrates—needs to be in place for a constructed channel to begin to perform some of the same functions of a destroyed stream (Palmer et al. 2010, Bellmore et al. 2017). Quigley and Harper (2006b), in a review of stream rehabilitation projects, concluded “the ability to replicate ecosystem function is clearly limited.”

There is some history of using constructed spawning channels to mitigate for the impacts of various development projects on fish, based on the premise that they would provide additional spawning habitat and produce more fry, which would presumably result in more adult fish returning (Hilborn 1992). Off-channel rearing habitats have also been used to create additional overwintering habitats in Pacific Northwest rivers (Roni et al. 2006), and spawning channels have also been shown to provide suitable overwintering habitats for juvenile Coho Salmon (Sheng et al. 1990). Reliance on spawning channels for fishery enhancement may also introduce unintended adverse consequences. Enhancement of Sockeye Salmon via use of spawning channels in British Columbia’s Skeena River has been accompanied by the erosion of local diversity and homogenization of life history traits, leading to possible losses in the spatial availability of salmon harvests to indigenous fisheries and local ecosystems (Price et al. 2021). Constructed spawning channels, particularly those dependent on surface flow, may also require annual maintenance and cleaning (Hilborn 1992), and salmon using them can be prone to disease outbreaks (Mulcahy et al. 1982). Off-channel habitats to mainstems are also extremely difficult to engineer in a way that can self-sustain in the face of a dynamic fluvial environment. Alluvial channels frequently shift (Amoros and Bornette 2002), and beavers are highly effective ecosystem engineers whose activities are constantly re-arranging floodplain channels and creating new dams (Pollock et al. 2003), including within engineered channels and culverts (Cooperman 2006).

In light of their uncertain track record, it does not appear that constructed spawning channels and engineered connections of off-channel habitats would provide reliable and sustainable fish habitat in the Bristol Bay region.

3.1.1.4 Manage Water Quantity

Two commenters suggested a variety of techniques to manipulate water quantities within the SFK, NFK, and UTC watersheds to improve fish productivity. Possible techniques for accomplishing this include flow management, flow augmentation, and flow pump-back.

3.1.1.4.1 Direct Excess On-site Water

Commenters suggested that fish habitat productivity could be improved through careful water management at the mine site, including the storage and strategic delivery of excess water to streams and aquifers to maintain or enhance flow and/or thermal regimes in the receiving streams. Delivering such flows via groundwater (i.e., by using wastewater treatment plant (WTP) discharges to "recharge and surcharge groundwater aquifers") was identified as a preferred approach; commenters argued doing so would both render the measure less prone to operational anomalies at the WTP and better mimic current natural flow patterns, thereby attenuating potential adverse effects related to discharge volume and temperature. Ideally, flow, temperature, and habitat modeling would inform the design and operation of flow management to optimize species and habitat benefits, for example, by providing water at specific times to locations where low flow currently limits fish productivity.

Manipulation of surface flows at another mine in Alaska—Red Dog, in the northwest part of the state—has resulted in an increase in fish (Arctic Grayling and Dolly Varden) use of the downstream creek (Weber-Scannell 2005, Ott 2004). The circumstances at Red Dog, however, differ from those in the SFK, NFK, and UTC area. As described in Weber-Scannell (2005), the near complete absence of fish in Red Dog Creek prior to implementation of the water management techniques was the direct result of water quality, not quantity, as the stream periodically experienced toxic levels of metals that occurred naturally as it flowed through and downslope of the exposed ore body. Furthermore, the Red Dog water management system primarily involves point-to-point diversion or transfer of surface, rather than groundwater, both around the ore body and from tributaries upstream of the mine. Utilization of managed aquifer surcharge or recharge to manage streamflows (e.g., Van Kirk et al. 2020) involves significant complexities that may require spatially distributed numerical modeling and would still be subject to considerable uncertainty (Ronayne et al. 2017), particularly in hydrologically complex areas like the Pebble deposit site.

Given that most streams in the area support multiple salmonid species and life stages, with differing habitat needs at different times, designing and managing a water delivery system to overcome limiting factors for one or more species without adversely affecting others would be a significant challenge. Given the complexity of the surface-groundwater connectivity in the watersheds draining the Pebble deposit, ensuring that discharges to groundwater actually reached the target habitat at the intended time would, perhaps, be the most difficult task. Quigley and Harper (2006b), in a review of stream rehabilitation projects, concluded "the ability to replicate ecosystem function is clearly limited."

This challenge could be easier to overcome where habitat limitations occurred only as a result of mine development, assuming pre-project modeling and verification accurately identified groundwater flow paths to those areas. It is important to note, however, that even if such actions appeared to be feasible, they likely would be required to avoid or minimize the adverse impacts of flow reduction due to mine development, rather than to compensate for unavoidable habitat losses.

If it were an overall enhancement to pre-existing habitat, using WTP discharges to groundwater to address natural limitation factors could be a form of compensatory mitigation. For example, PLP (2011) points out that productivity may be limited by the existence of "losing" reaches along the SFK mainstem and intermittent or ephemeral tributaries to both the SFK and NFK. Altering the natural flow regimes at such sites, however, could have unintended consequences on the local ecosystem and species assemblages (Poff et al. 1997). Moreover, "enhancing" these habitats through a WTP-sourced groundwater flow delivery system would be even more challenging than managing flow to avoid or minimize impacts to already productive habitat, because it would require "improving" the natural flow delivery system that currently results in the periodic drying or low flows. Given that aquifer recharge for streamflow management is a highly experimental approach to enhancing fish productivity, particularly in a natural stream system there is a great deal of uncertainty regarding the efficacy and sustainability of this technique as compensatory mitigation in the affected watersheds.

3.1.1.4.2 Augment Flows

Another means suggested for maintaining or increasing habitat productivity downstream of the mine site is to increase flow volume into specific streams by creating new sources of surface flow or groundwater recharge, specifically from impoundments or ice fields. EPA Region 10 is unaware of any documented successful compensatory mitigation efforts to create impoundments or ice fields for the benefit of salmonids. If there were potential locations for impoundments to manage flow in stream reaches identified as having "sub-optimal" flow, logistical and environmental issues decrease the likely efficacy and sustainability of such an approach. Manipulating streamflows in particular watersheds would require diverting water from other basins or capturing water during peak flows for subsequent release at other times, with the concomitant engineering, construction, and maintenance challenges. Doing so would create additional adverse impacts from the construction of infrastructure and would be subject to modeling and perpetual management sufficient to ensure that water withdrawals from the "donor" watershed or from other times of the year would not adversely affect fish habitat and populations in the donor watershed or the watershed's downstream waters. These concerns are in addition to those commonly associated with impoundments, such as alteration of flow, thermal, and sediment transport regimes.

Creating ice fields to increase the total volume of water available to a stream would also require water diversion, with the same challenges and concerns related to building and maintaining system infrastructure and reducing water volumes in the source watershed. Using ice fields to change the timing of water availability would create issues related to managing the melt to produce stream flow at the intended time (i.e., late summer or late winter low-flow periods). Moreover, because aquatic organisms supported by a particular water body typically have evolved specific life history, behavioral, and morphological traits consistent with the characteristics of that water body's natural flow regime, local populations are inherently vulnerable to flow modification (Lytle and Poff 2004). Any use of ice fields would face the potentially substantial challenges of the effects of climate change on ice production and preservation. Given the logistical and environmental issues associated with this technique and the lack of evidence of its use to benefit salmonids, it does not appear to be an effective or sustainable approach to compensatory mitigation in the affected watersheds.

3.1.1.4.3 Pump Water Upstream

Another option suggested for making flow in some stream reaches more persistent is to pump groundwater or surface water from a down-gradient site upstream to either a direct release point or a recharge area. This technique has been used for fish habitat restoration at sites in the continental United States, for example, the Umatilla River in Oregon (Bronson and Duke 2005), the Lower Owens River in California (LADWP 2013), and Muddy Creek in Colorado (GrandRiver Consulting 2008, AECOM et al. 2012). However, EPA Region 10 is unaware of any documentation addressing its efficacy in increasing salmonid productivity.

Even if potential source sites with sufficient water could be identified, this technique would require substantial disturbance and additional environmental impacts associated with the construction of tens of kilometers of water pipeline, power infrastructure, and access, along with maintenance of those facilities in perpetuity. It would also entail active management to ensure that releases occur at appropriate times to increase the persistence of flow in target streams without otherwise adversely affecting their hydrographs or habitat. Such management would be another aspect of the approach that would be perpetual. In total, this technique would involve a great deal of uncertainty with regard to both efficacy and sustainability, making it a questionable mechanism for providing compensatory mitigation.

3.1.1.5 Manipulate Water Quality

Two commenters suggested that alteration of stream water chemistry would improve fish production in the SFK, NFK, and UTC. They suggested increasing two groups of water chemistry parameters: basic parameters such as alkalinity, hardness, and total dissolved solids, and nutrients such as nitrogen (N) and phosphorous (P). This argument suggests that low concentrations of basic parameters or nutrients limit algae production, thus, limiting aquatic macroinvertebrate production and habitat complexity. This, in turn, can reduce overall fish production, reduce individual fish growth rates, or result in fish movements away from low production areas.

3.1.1.5.1 Increase Levels of Alkalinity, Hardness, and Total Dissolved Solids

PLP suggested in its 2014 comments that current levels of alkalinity, hardness, and total dissolved solids (TDS) in the SFK, NFK, and UTC are suboptimal for fish production and could be manipulated to improve fish production. PLP proposes "that streams with higher concentrations of total alkalinity, hardness, and total dissolved solids, assuming no nutrient limitations due to low concentration of nitrogen or phosphorus, produce a higher biomass per unit area than areas with lower concentrations" (PLP 2014, Exhibit 6). However, PLP does not propose any actual mechanisms for fish habitat compensation via increases in alkalinity, hardness, or TDS nor does it state its basis for assuming that N and P are not limiting.

PLP proposed increasing levels of alkalinity, hardness, and TDS in streams as a compensation proposal in its comments on the draft BBA (NDM 2013, Attachment D). In these comments, PLP refers to a number of field studies of streams. The cited studies of stream manipulations that raise alkalinity, hardness, or TDS are studies of the mitigation of acid mine drainage or of streams acidified by acid deposition (Gunn and Keller 1984, Hasselrot and Hultberg 1984, Rosseland and Skogheim 1984, Zurbuch 1984, Gagen et al. 1989, Lacroix 1992, Clayton et al. 1998, McClurg et al. 2007). The addition of limestone or dolomite often increases the production of acidic streams, and alkalinity, hardness, and TDS also increase, but the coincidence is not necessarily causal. It is more likely that the improvement is due to reduced acidity or reduced dissolved metal concentrations, not to increased alkalinity, hardness, or TDS per se. Other studies address the differences in the natural ability of streams to buffer natural or anthropogenic acids. Streams with acidic inputs and high buffering capacity may have higher productivity, as well as high alkalinity, hardness, and TDS. Other studies cited were not explicitly acidified sites, but it was not clear what role, if any, alkalinity, hardness, or TDS played in reported differences in productivity among those streams. Some of the studies are confounded by differences in habitat, macronutrients, or other factors. Others suffer from pseudo-replication or low replication.

Further, PLP's comments (NDM 2013, Attachment D) do not support that such measures would be effective. For example, it cites Scarnecchia and Bergersen (1987) as supporting the importance of alkalinity, hardness, and TDS at the Pebble site (NDM 2013, Attachment D, Section 3.4.2.1). However, Scarnecchia and Bergersen concluded the opposite. They found that most of the variance in productivity and biomass was associated with elevation and the three chemical parameters were correlated with elevation: "The overall weakness (despite statistical significance) of the correlations of chemical factors with production suggested to us that physical factors strongly influence production in these streams. Elevation, percentage of zero-velocity stations, and substrate diversity were the three most effective combinations of variables for explaining variation in production."

Given the lack of a mechanism by which any of the three aggregated parameters would increase productivity in the absence of acidity or high metal concentrations and inherent problems in the studies, the causal nature of the reported field relationships is questionable. In any case, their relevance to compensatory mitigation of the Pebble site has not been demonstrated.

The potential for unintended adverse consequences if alkalinity, hardness, or TDS are raised without an understanding of the mechanisms of action and of the chemistry and biology of the receiving streams is illustrated by studies that show impairment of stream communities in response to elevating one or more of those parameters. In particular, the addition of limestone or dolomite to streams to mitigate acid drainage and the filling of valleys with carbonaceous rock from mining have raised hardness, alkalinity and TDS/conductivity, which have been shown to cause adverse and persistent effects on stream invertebrate and fish communities (Weber-Scannell and Duffy 2007, Pond et al. 2008, Bernhardt and Palmer 2011, Cormier et al. 2013a, Cormier et al. 2013b, Hopkins et al. 2013, Hitt and Chambers 2014, Morris et al. 2019).

3.1.1.5.2 Increase Levels of Nitrogen and/or Phosphorus

Commenters have also suggested that water quality could be manipulated by altering stream water chemistry to increase levels of N and P where they are individually or co-limiting.

The commenters make recommendations about how to consider these factors when developing mitigation in the SFK, NFK, and UTC. They suggest that the spatial distribution could focus on existing or newly created side channels, sloughs, beaver ponds, alcoves, or, if necessary, the main channels at 10-km intervals. They suggest several possible temporal distribution options, such as adding the nutrients only during the growing season, potentially earlier, or all winter in open-water locations where biological production continues year-round. They further indicate that the key considerations are access cost and maintenance requirements. The commenters note that there are several types of nutrient delivery methods: liquid fertilizer, slow-release fertilizer, and nutrient analogs (which are essentially slow-release pellets of processed fish).

As support for their conclusion that lake and stream fertilization represent “demonstrably successful mitigation techniques” for the SFK, NFK, and UTC, the commenters cite papers summarizing experiments and case studies, as well as references to several management programs in the United States, Canada, and northern Europe. These studies have examined the use of increased levels of inorganic N and P, or fish carcasses, to improve ecosystem productivity and/or fish production.

The commenters assert that current levels of N and P in the SFK, NFK, and UTC are suboptimal for fish production stating that benefits of fertilizing oligotrophic waters to stimulate fish production have been demonstrated in many venues. Although numerous studies show an effect at one or more trophic levels in response to fertilization, these studies are insufficient for drawing conclusions regarding the long-term effectiveness of nutrient application to streams in the SFK, NFK, and UTC watersheds because they lack scientific controls or have not been replicated, do not account for potential confounding factors, were conducted in very different ecosystems, and/or only evaluated short-term effects. These differences are discussed in the following paragraphs.

Commenters provided examples of experiments and studies aimed at increasing primary productivity and theoretically salmon productivity. These studies assume that nutrients are the limiting factor preventing increased salmon productivity, but that is not necessarily the case (Collins et al 2015).

Paleolimnetic studies in Alaska indicate nutrient inputs are not always tied to higher primary productivity or salmon productivity (Chen et al. 2011). Wipfli and Baxter (2010) found that most fish consume food from external or very distant sources, including from marine systems borne by adult salmon, from fishless headwaters that transport prey to downstream fish, and from riparian vegetation and associated habitats. An increase in food via nutrients may not overcome other limiting factors, such as habitat availability or interspecies competition.

Most studies on stream and lake fertilization to increase productivity are short term in duration and conducted in ecosystems with important differences from Bristol Bay (e.g., Perrin et al. 1987, Raastad et al. 1993, Wipfli et al. 1998, Slaney et al. 2003). Many of the studies have been conducted in lakes (e.g., Bradford et al. 2000, Kyle 1994), which have different ecosystem dynamics from streams. Furthermore, factors that limit populations in one habitat or time period may be different than in another (Collins et al. 2015). Almost all of the stream studies are conducted in locations where salmon populations have been negatively affected; therefore, the increased production is aimed at restoration, not enhancement, of an existing healthy population.

Most studies are conducted between one and five years in duration, and a spike in productivity has been seen in a number of these short-term studies. For example, the studies conducted at the Keogh and Salmon Rivers (Ward et al. 2003, Slaney et al. 2003) examined the effect of nutrient supplement in the form of salmon carcasses and inorganic N and P, respectively, in two coastal river systems for a period of three years. Additionally, most studies quantify responses at the individual level, which may not translate to an increase at the population level (Collins et al. 2015).

While a short-term spike in productivity is common, long-term studies call into question whether the trend will be sustained over longer periods. Several papers cite results from the early years of the longest-running study on stream fertilization located in the pristine Kuparuk River on the North Slope of Alaska. This study raises concerns about using fertilization other than as an interim restorative measure. While commenters cite a study capturing the increased size and growth rates of Arctic Grayling during the first seven years of the study (Deegan and Peterson 1992), a subsequent paper documenting conditions after 16 years found that persistent increased levels of N and P can result in dramatic ecosystem shifts (Slavik et al. 2004). This long-term ecological research on the North Slope of Alaska examined the effect of P input into P-limited streams, finding an increase in production for some species at all trophic levels over the first few years. These results are similar to the studies finding improved fish productivity in predominantly degraded systems cited extensively by commenters. However, after approximately eight years of fertilization, a dramatic rise in moss (photos A and B) changed ecosystem structure, affecting food and shelter availability (Slavik et al. 2004). Despite higher insect biomass in the fertilized area during this period, there were no significant differences in fish growth rates between the fertilized reach and the reference reach. The decrease in fish productivity was thought to result from the effects of moss on preferred insect prey (Slavik et al. 2004, Gough et al. 2016). Following cessation of nutrient enrichment, it took eight years of recovery to approach reference levels, after storms had scoured most remnant moss in the recovering reach, demonstrating that even at low concentrations, sustained nutrient enrichment can have "dramatic and persistent consequences" (Benstead et al. 2007).

Photos showing the difference in bottom coverage between the diatom state (Photo A, left) and the fertilized moss state (Photo B, right). Used with permission (Slavik et al. 2004).

Slavik et al. (2004) conclude that "[a]dditional long-term whole stream fertilization studies are needed to better understand the delayed stream ecosystem responses to nutrient enrichment. Even studies of two to eight years in duration may be poor predictors of the long-term responses to added nutrients." This conclusion is echoed in the most recent (2019) *Long Term Ecological Research Network Decadal Review Self Study* (Groffman et al. 2019), which is a collection of papers reflecting study and experimentation at diverse sites ranging from arctic and alpine tundra to grasslands, forests, streams, wetlands, and lakes. In the paper addressing nutrient supply effects on ecosystems, the authors state, "Long term observations and experiments at LTER sites have shown that short term patterns may have little bearing on the ultimate direction and magnitude of nutrient effects, which can play out over many decades" (Groffman et al. 2019: Page 23). The risks of long-term fertilization would also play out in the context of global climate change, which is predicted to cause a release of phosphorous into streams from melting permafrost (Hobbie et al. 1999), adding yet another layer to the unknowns.

In another study, long-term nutrient enrichment produced an unanticipated trophic decoupling whereby enrichment continued to stimulate primary consumer production without a similar increase in predator fish (Davis et al. 2010). The majority of the increased ecosystem productivity was confined to lower trophic levels because the long-term enrichment primarily stimulated primary consumers that were relatively resistant to predation. Based on these results, the authors concluded that "even in ecosystems where energy flow is predicted to be relatively efficient, nutrient enrichment may still increase the production of non-target taxa (e.g., predator or grazer resistant prey), decrease the production of higher trophic levels, or lead to unintended consequences that may compromise the productivity of freshwater ecosystems" (Davis et al. 2010).

These unanticipated results raise important questions about the potential consequences of long-term nutrient supplementations. They also underscore the unpredictability of nutrient additions on the food web, and the greater likelihood of unintended consequences as the effects ripple through complex interactions between species. These implications are relevant considerations for potential long-term mitigation, which would be necessary for the SFK, NFK, and UTC. If long-term nutrient addition were to cause an ecosystem shift at lower trophic levels in the SFK, NFK, and UTC, effects on higher trophic levels including the productivity of salmon and other target fish species are unknown.

Studies examining the relationship between salmon carcasses and productivity at various trophic levels are another active area of investigation. Some research provides evidence that carcasses are superior to inorganic nutrient amendments for sustaining and restoring stream productivity, including fish production, potentially because inorganic nutrients lack biochemicals and macromolecules that are utilized directly by consumers (Wipfli et al. 2010, Martin et al. 2010, Heintz et al. 2010). Others have found the effects of carcasses can be transient, localized, and variable with no increase in fish growth (Cram et al. 2011). Few studies have documented the long-term impacts of carcass addition, and there are many remaining gaps in understanding the efficacy of this method of potentially improving salmon productivity. In addition, a number of authors express concern about the potential for the spread of toxins and pathogens when carcasses are used as the supplemental nutrient source (Compton et al. 2006).

Authors of many of these studies state that the application of their results are relevant and appropriate for salmonid restoration in streams or lakes with depressed numbers (e.g., Larkin and Slaney 2011). The authors do not describe their results as informing methods to manipulate existing unaltered wild systems to further augment salmon production. Although some commenters draw heavily from Ashley and Stockner (2003) to support their recommendation to use this as a method of mitigation in the SFK, NFK, and UTC watersheds, the authors of that study state the following:

> The goal of stream and lake enrichment is to rebuild salmonid escapement to historical levels via temporary supplementations of limiting nutrients using organic and/or inorganic formulations. Stream and lake enrichment should not be used as a 'techno-fix' to perpetuate the existing mismanagement of salmonids when there is any possibility of re-establishing self-sustaining wild populations through harvest reductions and restoration of salmonid habitat. Therefore, fertilization should be viewed as an interim restorative measure that is most effective if all components of ecosystem recovery and key external factors (e.g. overfishing) are cooperatively achieved and coordinated. This paper reviews some of the technical and more applied aspects of stream, river, and lake enrichment as currently practiced in British Columbia and elsewhere. As a caveat, the discussion assumes that salmonid stock status of candidate lakes and streams has been quantified and classified as significantly depressed and that additional limiting factors (e.g. habitat/water quality and quantity) have been addressed and/or incorporated into an integrated basin or lake restoration plan. (Ashley and Stockner 2003: Page 246)

There are still many gaps in understanding the role of nutrients in fish productivity, so there is much that is not known about whether nutrient addition can be a successful method to increase fish productivity especially in the long term. Furthermore, much of the existing literature on which commenters base their assertions rests on several untested assumptions (Collins et al. 2015).

Setting aside questions of scientific efficacy and applicability, there are also numerous practical challenges inherent in nutrient addition as a potential mitigation method. Conducting a long-term management protocol in remote waterways subject to extreme weather changes necessarily requires careful monitoring of water chemistry, as well as other ecosystem parameters and precise application of nutrients, which calls into question the sustainability of altering stream water chemistry to improve the fish production.

At this time, there are no scientific studies showing how an increase in nutrients resulting in increased salmon productivity can be reliably achieved on a long-term basis in the SFK, NFK, and UTC watersheds or the larger Bristol Bay ecosystem without risk to the region's existing robust populations. Just as for the addition of non-nutrients, such as limestone, manipulating stream chemistry in this largely unaltered ecosystem through the addition of N and P would be a challenging and difficult experiment with many negative outcomes being possible.

3.1.2 Other Potential Compensation Measures Suggested within the Nushagak and Kvichak River Watersheds

As noted above, if practicable or appropriate opportunities to provide compensation within the SFK, NFK, or UTC watersheds are non-existent or limited, it may be appropriate in certain circumstances to explore options in adjoining watersheds. For example, there are a few scattered degraded sites in more distant portions of the Nushagak and Kvichak River watersheds that could potentially benefit from restoration or enhancement. This section discusses specific suggestions for other potential compensation measures within the Nushagak and Kvichak River watersheds that were provided in the public and peer review comments on the BBA and in response to the 2014 Proposed Determination.

3.1.2.1 Remediate Old Mine Sites

The U.S. Geological Survey identifies four small mine sites within the Nushagak and Kvichak River watersheds: Red Top (in the Wood River drainage), Bonanza Creek (a Mulchatna River tributary), Synneva or Scynneva Creek (a Bonanza Creek tributary), and Portage Creek (in the Lake Clark drainage) (USGS 2008, 2012). These sites could provide opportunities for performing ecological restoration or enhancement. However, due to their relatively small size and distant location, it is unlikely that these sites could provide sufficient restored or enhanced acreage or ecological function to reduce the adverse effects of the 2020 Mine Plan to an acceptable level. Further, some mitigation measures have already occurred at these mines; for example, there have been some remediation activities at Red Top mine, although traces of mercury and diesel-range organics remain in soils (BLM 2000). Resolution of liability and contamination issues at these old mines would be necessary before they could serve as compensatory mitigation sites for other projects. In its comments on the 2014 Proposed Determination, PLP rejected this as a potential compensation measure, in part, due to concerns regarding the resolution of these kinds of liability issues (PLP 2014: Exhibit 2).

3.1.2.2 Remove Roads

Another potential type of restoration within the Nushagak and Kvichak River watersheds is the removal of existing or abandoned roads. As described in detail in EPA 2014, Appendix G, roads have persistent, multifaceted impacts on ecosystems and can strongly affect water quality and fish habitat. Common long-term impacts from roads include (1) permanent loss of natural habitat; (2) increased surface runoff and reduced groundwater flow; (3) channelization or structural simplification of streams and hydrologic connectivity; (4) persistent changes in the chemical composition of water and soil; (5) disruption of movements of animals, including fishes and other freshwater species; (6) aerial transport of pollutants via road dust; and (7) disruption of near-surface groundwater processes, including interception or re-routing of hyporheic flows, and conversion of subsurface slope groundwater to surface flows (Trombulak and Frissell 2000, Forman 2004). Road removal, thus, could facilitate not only the reestablishment of former wetlands and stream channels, but also the enhancement of nearby aquatic resources currently degraded by the road(s).

Commenters did not offer specific suggestions for potential road-removal sites. As EPA 2014 Appendix G highlights, the Nushagak and Kvichak River watersheds are almost entirely roadless areas (EPA 2014, Appendix G, Figure 1). Further, it is unlikely that local communities would support removal of any segments of the few existing roads in the watersheds. Thus, it appears there are very few, if any, viable opportunities to provide environmental benefits through road removal.

3.1.2.3 Retrofit Road Stream Crossings

Another potential type of enhancement within the Nushagak and Kvichak River watersheds is to retrofit existing road stream crossings to improve fish passage through these human-made features. Stream crossings can adversely affect spawning, rearing (Sheer and Steel 2006, Davis and Davis 2011), and refuge habitats (Price et al. 2010), as well as reduce genetic diversity (Wofford et al. 2005, Neville et al. 2009). These changes can, in turn, reduce long-term sustainability of salmon populations (Hilborn et al. 2003, Schindler et al. 2010). Blockage or inhibition of fish passage is a well-documented problem commonly associated with declines in salmon and other fish populations in many regions of the United States (Nehlsen et al. 1991, Bates et al. 2003), including Alaska (ADF&G 2022).

Removing and replacing crossings that serve as barriers to fishes could improve fish passage and re-open currently inaccessible habitat. However, as noted in Section 3.1.2.2, the Nushagak and Kvichak River watersheds are almost entirely roadless areas and, thus, likely offer few, if any, viable opportunities to provide the extent of environmental benefits necessary to reduce the adverse effects of the 2020 Mine Plan to an acceptable level. Further, prior to concluding that any effort to retrofit existing stream crossings would be appropriate compensatory mitigation, it would first be necessary to determine that no other party has responsibility for the maintenance of fish passage at those stream crossings (e.g., through the terms or conditions of a Section 404 permit that authorized the crossing). After initially proposing this as a potential compensation measure, in its comments on the 2014 Proposed Determination, PLP rejected this measure due to “the long term liability involved as PLP would be responsible for effectiveness in perpetuity, possible requiring monitoring and maintenance (including repair and replacement)” (PLP 2014: Exhibit 2).

3.1.2.4 Construct Hatcheries

One commenter referenced the potential use of hatcheries as a compensation measure. Such a proposal could be very problematic, particularly in the Bristol Bay watershed, where the current salmon population is entirely wild. There are several concerns over the introduction of hatchery-produced salmon to the Bristol Bay watershed.

Many of the potential risks associated with fish hatcheries concern reductions in fitness, growth, health, and productivity that result from decreases in genetic diversity when hatchery-reared stocks hybridize with wild salmon populations. Hatchery-raised salmon have lower genetic diversity than wild salmon (Christie et al. 2011, Yu et al. 2012). Consequently, when hatchery-raised salmon hybridize with wild salmon, the result can be a more genetically homogenous population, leading to decreases in genetic fitness (Waples 1991). In some cases, wild populations can become genetically swamped by hatchery stocks. Zhivitovsky et al. (2012) found evidence of such swamping in a wild Chum Salmon population in Kurilskiy Bay, Russia, during a two-year period of high rates of escaped hatchery fish. This genetic homogenization is of concern because hatchery-raised fish stocks are considered less genetically "fit" and, therefore, could increase the risk of collapse of salmon fisheries. This concern is supported by Araki et al. (2008); a review of 14 studies that suggests that nonlocal hatchery stocks reproduce very poorly in the wild. The authors of this review also found that wild stocks reproduce better than both hatchery stocks and wild, local fish spawned and reared in hatcheries.

Hatchery fish can also compete directly for food and resources with wild salmon populations in both freshwater and marine environments (Rand et al. 2012a). Ruggerone et al. (2012) examined the effect that Asian hatchery Chum Salmon have had on wild Chum Salmon in Norton Sound, Alaska, since the early 1980s. They found that an increase in adult hatchery Chum Salmon abundance from 10 million to 80 million adult fish led to a 72 percent reduction in the abundance of the wild Chum Salmon population. They also found smaller adult length-at-age, delayed age-at-maturation, and reduced productivity were all associated with greater production of Asian hatchery Chum since 1965 (Ruggerone et al. 2012). In addition to this competition for resources, hatchery-raised subyearling salmon can also prey upon wild subyearling salmon, which tend to be smaller in size (Naman and Sharpe 2012).

Despite extensive efforts to restore federally listed Pacific Northwest salmon populations, these salmon remain imperiled, and hatchery fish stocks may be a contributing stressor (Kostow 2009). Given the exceptional productivity of the wild Bristol Bay salmon population, hatcheries would likely pose greater ecological risks than benefits to this unique and valuable wild salmon population.

3.1.2.5 Stock Fish

Comments also mentioned stocking fish. Because many of the fish used in fish stocking originate in hatcheries, fish stocking raises many of the same concerns as hatcheries and, thus, would also be a problematic form of compensatory mitigation for the Bristol Bay region. Although stocking has been a common practice in other regions, even in previously fishless habitats (e.g., Red Dog Mine, Alaska), a large body of literature describes widespread adverse impacts of such management decisions. Fish stocking throughout western North America and worldwide has affected other fish (Knapp et al. 2001, Townsend 2003), nutrient cycling (Schindler et al. 2001, Eby et al. 2006, Johnson et al. 2010), primary production (Townsend 2003, Cucherousset and Olden 2011), aquatic macroinvertebrates (Dunham et al. 2004, Pope et al. 2009, Cucherousset and Olden 2011), amphibians (Pilliod and Peterson 2001, Finlay and Vredenberg 2007), and terrestrial species (Epanchin et al. 2010). Although fish stocking has provided limited benefits in certain circumstances, it would appear from the growing body of literature that the ecological costs of fish stocking far outweigh any potential benefits.

3.2 Other Suggested Measures

Commenters also suggested that payments to organizations that support salmon sustainability or investing in various public education, outreach, or research activities designed to promote salmon sustainability could constitute potential compensatory mitigation for impacts on fish and other aquatic resources. Although these initiatives can provide benefits in other contexts, compensatory mitigation for impacts authorized under Section 404 of the CWA can only be provided through purchasing credits from an approved mitigation bank or in-lieu fee program or conducting permittee-responsible compensatory mitigation projects (40 CFR 230.92). One commenter also suggested reducing commercial fishery harvests to compensate for fish losses due to large-scale mining; however, such a measure would also be inconsistent with the definition of compensatory mitigation (40 CFR 230.92).

In its comments on the 2014 Proposed Determination, PLP (2014, Exhibit 2) provides a list of compensation measures that it was not recommending, specifically culvert replacement, contaminated site clean-up, landfill rehabilitation or replacement, and clean-up and restoration of legacy wells. In deciding not to recommend these measures in 2014, PLP notes that "[t]he task to evaluate mitigation actions in the Bristol Bay region included all opportunities available" and that the feasibility of these opportunities was identified as "very expensive, high-risk, low compensatory credit return" and that "[g]enerally, the main limitation to these permittee-responsible mitigation projects is a lack of opportunity for restoration, establishment, and/or enhancement of wetlands within the Bristol Bay region." PLP goes on to state that "[o]ther limitations to these permittee-responsible mitigation projects include liability, cost, monitoring responsibilities in perpetuity, and the lack of infrastructure within the Bristol Bay region to access existing opportunities" (PLP 2014: Exhibit 2).

SECTION 4. EFFECTIVENESS OF COMPENSATION MEASURES AT OFFSETTING IMPACTS ON FISH HABITAT

In North America, 73 percent of fish extinctions are linked to habitat alterations (Miller et al. 1989). Although extensive efforts have been undertaken to create or improve salmon habitat and prevent fishery losses, all U.S. Atlantic salmon populations are endangered (NOAA 2022), 40 percent of Pacific salmon in the lower 48 states are extirpated from historical habitats (NRC 1996), and one-third of remaining populations are threatened or endangered with extinction (Nehlsen et al. 1991, Slaney et al. 1996, Gustafson et al. 2007). Coho and Chinook salmon are the two rarest of North America's five species of Pacific salmon (Healey 1991) and have the greatest number of population extinctions among the five species of Pacific salmon (Nehlsen et al. 1991, Augerot 2005). Approximately one-third of Sockeye Salmon population diversity assessed by Rand et al. (2012b) was considered at risk of extinction or extinct. Of remaining populations categorized as of "least concern," Bristol Bay Sockeye Salmon likely represent the most abundant, diverse Sockeye Salmon populations left in the United States.

Since 1990, a billion dollars has been spent annually on stream and watershed restoration in the United States (Bernhardt et al. 2005). More than 60 percent of the projects completed during this period were associated with salmon and trout habitat restoration efforts in the Pacific Northwest and California (Katz et al. 2007). Despite the proliferation of projects and the significant funds being expended on these efforts, debate continues over the effectiveness of various fish habitat restoration techniques and the cumulative impact of multiple, poorly coordinated restoration actions at watershed or regional scales (Reeves et al. 1991, Chapman 1996, Roni et al. 2002, Kondolf et al. 2008). However, in the Columbia River Basin where billions of dollars have been spent on salmon and steelhead recovery efforts, a 2013 report indicates that some stream rehabilitation techniques, such as fish passage improvements, in-stream wood and rock structures, livestock grazing controls, connection or construction of off-channel habitat, and flow augmentation appear to be leading to fish habitat improvements in this basin where logging, grazing, channelization, irrigation, development of urban areas, and construction and operation of dams have led to extensive historic fish habitat loss and degradation (BPA 2013).

A 2014 review of 434 stream restoration, enhancement, and creation projects conducted to offset impacts to Appalachian streams from surface coal mining authorized by CWA Section 404 permits highlights the uncertain outcomes of stream mitigation projects (Palmer and Hondula 2014). Palmer and Hondula (2014) found that even after five years of monitoring, 97 percent of projects reported suboptimal or marginal habitat; they conclude that stream mitigation projects "are not meeting the objectives of the Clean Water Act to replace lost or degraded streams ecosystems and their functions."

In general, independent evaluations of the effectiveness of fish habitat compensation projects are rare (Harper and Quigley[6] 2005b, Quigley and Harper 2006a, Quigley and Harper 2006b), and consequently the long-term success rates and efficacy of such projects are not well known (DFO 1997, Lister and Bengeyfield 1998, Lange et al. 2001, Quigley and Harper 2006a). A 2008 review of stream habitat rehabilitation studies published worldwide found that "[d]espite locating 345 studies on effectiveness of stream rehabilitation, firm conclusions about many specific techniques were difficult to make because of the limited information provided on physical habitat, water quality, and biota and because of the short duration and limited scope of most published evaluations" (Roni et al. 2005, Roni et al. 2008). Despite these shortcomings, Roni et al. (2008) did find that some techniques, specifically, reconnection of isolated habitats, floodplain rehabilitation, and instream habitat improvement, were proven to be effective under numerous circumstances for improving habitat and increasing local fish abundance.

In its 2014 comments, PLP relies heavily on the findings of Roni et al. (2008) and BPA (2013) to support the following positions.

- The effectiveness of the stream rehabilitation techniques PLP had proposed at that time for use at the Pebble site is unequivocal and "settled science."
- These stream rehabilitation techniques should be expected to effectively rehabilitate streams permanently lost or degraded by mining at the Pebble deposit.
- These stream rehabilitation techniques should also be expected to result in demonstrable improvements in fish habitats in unaltered/undegraded streams that are currently part of an ecosystem that supports some of the world's most productive wild salmon runs.

While PLP ultimately did not propose any of these measures during the CWA Section 404 permit review process (PLP 2020a, 2020c), its application of the findings of Roni et al. (2008) and BPA (2013) is inaccurate or oversimplified for the following reasons.

- **Type of restoration is different.** The effectiveness of the stream rehabilitation techniques reviewed in these papers is not settled science, and the success of these approaches is highly variable and context-dependent (Roni 2019); can be difficult to quantify (Richer et al. 2022, Rogers et al. 2022); and must address the suite of factors influencing fish populations (water quality, connectivity, hydrology, sediment, etc.).
- **Impact is different.** A large majority of the stream rehabilitation studies reviewed in these papers were conducted in moderate climates, for streams that had been impacted by forestry,

[6] Dr. Jason Quigley, a scientist employed in 2014 by a company working to advance a mine at the Pebble deposit, sent EPA Region 10 a letter dated April 28, 2014, indicating his concern that the BBA cited his work in a manner that is "not fully accurate." EPA notes that the findings and conclusions of Dr. Quigley's earlier studies referenced by the BBA are taken directly from Dr. Quigley's studies. Further, EPA clearly notes in this section that Quigley's earlier studies highlight the need for improvements in compensation science, as well as institutional approaches, such as better project planning, monitoring, and maintenance. Dr. Quigley's letter also notes that compensation success has improved since his earlier studies; however, no examples of such documented success are included in his letter.

agriculture, roads, or human activities other than mining. The papers were not a review of rehabilitation of streams impacted by mining. Where reviews of mined stream mitigation success have occurred in Appalachia, monitoring revealed that 97 percent of the projects reported suboptimal or marginal habitat (Palmer and Hondula 2014). These papers do not support use of these techniques to rehabilitate streams permanently lost or degraded by mining at the Pebble deposit.

- **Magnitude of restoration is likely not enough.** There is little evidence that unaltered and high-functioning habitats such as those in the affected watersheds can be made substantially better. Roni and Beechie (2012) observed that when and where positive responses to restoration have been observed, it has primarily been in systems where habitat had been greatly simplified due to land clearing, road building, channelization, or other human activities (e.g., Ogston et al. 2015). Furthermore, with the exception of downstream barrier removal (e.g., Pess et al. 2012) or barrier modification, EPA Region 10 is aware of no instances where restoration approaches yielded significant improvements in fish populations in highly functional watersheds with minimal human modification. These papers do not support the position that existing unaltered/undegraded fish habitats could somehow be improved by use of these techniques.
- **Population response is not demonstrated.** Even in watersheds where significant habitat rehabilitation efforts have been undertaken, a corresponding salmon response at the population scale has been elusive (Bennett et al. 2016).
- **It is preferable to protect than to restore.** Many authors have stated that based on lessons learned regarding the difficulty of restoring fish habitat once it has been degraded, priority should always be given to protecting existing high-quality habitat because it is much more effective and efficient to protect than to restore (Beechie et al. 2008).

In Canada, the Department of Fisheries and Oceans evaluated the efficacy of fish habitat compensation projects in achieving the conservation goal of no net loss (Harper and Quigley 2005a, Harper and Quigley 2005b, Quigley and Harper 2006a, Quigley and Harper 2006b). Quigley and Harper (2006a) showed that 67 percent of compensation projects resulted in net losses to fish habitat, 2 percent resulted in no net loss, and only 31 percent achieved a net gain in habitat area. Quigley and Harper (2006a) concluded that habitat compensation in Canada was, at best, only slowing the rate of fish habitat loss. Quigley and Harper (2006b) showed that 63 percent of projects resulted in net losses to aquatic habitat productivity, 25 percent achieved no net loss, and only 12 percent provided net gains in aquatic habitat productivity. Quigley and Harper (2006b) concluded “the ability to replicate ecosystem function is clearly limited.”

Quigley and Harper (2006b) and Quigley et al. (2006) highlight the need for improvements in compensation science, as well as institutional approaches, such as better project planning, monitoring, and maintenance. However, they also recognize that, based on decades of experience in wetland replacement projects, simply achieving compliance with all regulatory requirements does not ensure that ecological functions are replaced (NRC 2001, Sudol and Ambrose 2002, Ambrose and Lee 2004, Kihslinger 2008). Findings from Quigley and Harper (2006a and 2006b) are echoed in a 2016 study of marsh and riparian habitat compensation projects constructed within the Fraser River Estuary from 1983 to 2011; this study found that only 33 percent of compensation sites were meeting biological and functional goals, even after many decades (Lievesley et al. 2016).

Although there are clearly opportunities to improve the performance of fish habitat compensation projects, Quigley and Harper (2006b) caution the following:

> It is important to acknowledge that it is simply not possible to compensate for some habitats. Therefore, the option to compensate for HADDs [*harmful alteration, disruption or destruction to fish habitat*] may not be viable for some development proposals demanding careful exploration of alternative options including redesign, relocation, or rejection.

SECTION 5. CONCLUSIONS

PLP and other commenters suggested an array of measures over the past decade as having the potential to compensate for adverse impacts on wetlands, streams, and fishes from the discharge of dredged or fill material associated with mining the Pebble deposit. EPA Region 10 evaluated these measures for informational purposes. Available information demonstrates that known compensation measures are unlikely to adequately mitigate effects described in this proposed determination to an acceptable level.

SECTION 6. REFERENCES

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