# EPA’s Recommended Determination for Bristol Bay:
# Solid Scientific Backing for the Threat of Mining to
# Bristol Bay’s Pristine Waters and Salmon Population

EPA closely reviewed the Pebble Final Environmental Impact Statement (EIS) and associated technical documents and reports developed by PLP and Army Corps consultants during the EIS and Clean Water Act consultation processes. As the following excerpts from EPA’s Recommended Determination show, the agency has appropriately determined that (1) Bristol Bay is a unique resource warranting protections from the threat of the proposed Pebble Mine and (2) the best available science, including the information developed during the EIS process, shows that unacceptable adverse effects would result from the construction and operation of the proposed Pebble Mine. These excerpts also counter PLP's characterization of the EIS that the proposed mine can be "developed without harm to the Bristol Bay fishery."

Notably, in response to the Recommended Determination and an EPA request, Pebble Limited Partnership declined to provide EPA with any corrective action to prevent unacceptable adverse effects on anadromous fishery areas from discharges of dredged or fill material associated with developing the Pebble deposit.

## Bristol Bay is a unique resource warranting protections from the threat of the proposed Pebble Mine

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| “Bristol Bay is home to the largest Sockeye Salmon fishery in the world. … More than half of the Bristol Bay watershed’s Sockeye Salmon harvest comes from the Nushagak and Kvichak River watersheds.” | view excerpt<br>(RD, p. 3-53) |
| “the number of Sockeye Salmon that returned to Bristol Bay in 2022 (79.0 million) … is roughly 20 million more than the number of individuals of all Pacific salmon species that historically returned to Washington, Oregon, and California before these rivers were dammed.” | view excerpt<br>(RD, p. 3-63) |
| “The Bristol Bay watershed contains intact, connected, and heterogeneous 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.” | view excerpt<br>(RD, p. 3-64) |
| “Alaska Native cultures in the region represent one of the last intact salmon-based cultures in the world.” | view excerpt<br>(RD, p. 3-55) |
| “The salmon-dependent diet of Alaska Natives benefits their physical and mental well-being in multiple ways … the cost of replacing subsistence salmon in diets, even with lower-quality protein sources, is likely to be significant.” | view excerpt<br>(RD, pp. 3-59, 60) |
| “[I]n 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.” | view excerpt<br>(RD, p. 3-54) |
| The Bristol Bay watershed [] 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. … Sport fishing in the Bristol Bay watershed accounts for approximately $66.58 million expenditures, expressed in 2020 dollars.” | view excerpt<br>(RD, pp. 3-60, 61) |

January 24, 2023

## EPA’s review of the Final EIS and the best available science shows unacceptable adverse effects would result from the construction and operation of the proposed Pebble Mine

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| “EPA Region 10 has reviewed the available information, including the relevant portions of the USACE permitting record, and this information supports the findings reported in this recommended determination.” | view excerpt<br>(RD, p. 2-23) |
| “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 miles (147 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 2,108 acres (8.5 km$^2$) of wetlands and other waters in the SFK and NFK watersheds that support anadromous fish streams.” | view excerpt<br>(RD, p. ES-12) |
| “[I]n 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 [] the impacts reported in the FEIS likely underestimate or underpredict the actual impacts that the 2020 Mine Plan would have on aquatic resources in the SFK, NFK, and UTC watersheds.” | view excerpt<br>(RD, p. B-1) |
| “[T]he FEIS evaluation of fish habitat changes did not represent an accurate and thorough assessment of likely impacts.” | view excerpt<br>(RD, p. B-16) |
| “The FEIS concludes that loss of stream habitats under the 2020 Mine Plan would be inconsequential for fish populations []. This conclusion appears to be based on an assumption that the relative quality of these habitats is low and they have minimal influence on downstream waters. These assumptions and conclusions are not supported by the available information about these habitats (including information provided in the FEIS), or the current science surrounding the importance of headwater systems….” | view excerpt<br>(RD, p. B-1) |
| “The FEIS acknowledges that [its modeling] 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 []—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 was not assessed adequately to conclude in the FEIS that there will be no effects on fish habitat, abundance, and productivity. 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….” | view excerpt<br>(RD, p. B-22) |
| “FEIS conclusions about the quality of streams that would be lost under the 2020 Mine Plan, relative to downstream mainstem habitats, are not supported by evidence presented in the FEIS.” | view excerpt<br>(RD, p. B-2) |
| “[T]he 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 watershed 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.” | view excerpt<br>(RD, p. B-7) |
| “[The] approach [relied on in the FEIS] likely underestimates actual changes to fish habitat that would be likely to result from changes to the full suite of variables determining available fish habitat.” | view excerpt<br>(RD, p. B-18) |

Click to view the complete Recommended Determination on EPA’s website.

December 2022

Excerpts from

# RECOMMENDED 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

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

## The Recommended Determination

EPA Region 10 completed its review of the extensive administrative record, including all public comments, and has determined that the discharge of dredged or fill material associated with mining at the Pebble deposit would be likely to result in unacceptable adverse effects on anadromous fishery areas. Section 4 of this recommended 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 miles (147 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 2,108 acres (8.5 $km^2$) of wetlands and other waters in the SFK and NFK watersheds that support anadromous fish streams.

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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 approximately 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 and "no other wild salmon fishery in the world exists in conjunction with an active mine of this size" (USACE 2020a: Page 4.6-9).

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 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,

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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.

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 has determined the discharge of dredged or fill material for the construction and routine operation of the 2020 Mine Plan would be likely to 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 eliminated streams, wetlands, and other waters; and the resulting erosion of habitat complexity and biocomplexity within the SFK and NFK watersheds, both of which are key to the abundance and stability of salmon populations within these watersheds. EPA Region 10 has also determined that discharges of dredged or fill material associated with the development of the Pebble deposit anywhere at the mine site that would result in the same or greater levels of loss or streamflow changes as the 2020 Mine Plan also would be likely to have unacceptable adverse effects on anadromous fishery areas, because such discharges would involve the same aquatic resources characterized as part of the evaluation of the 2020 Mine Plan. These conclusions support the recommended prohibition described in Section 5.1 of this recommended determination.

Further, EPA Region 10 has determined 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 would be likely to 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 ecological importance of anadromous habitat throughout the SFK, NFK, and UTC watersheds; how aquatic habitats across these three watersheds function similarly to support productive anadromous fishery areas; 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 habitat complexity and biocomplexity within the SFK, NFK, and UTC watersheds, both of which are key to the abundance and stability of salmon populations within these watersheds. This conclusion supports the recommended restriction described in Section 5.2 of this recommended determination.

Based on the foregoing, the EPA Region 10 Regional Administrator determined that the appropriate next step in this CWA Section 404(c) review process is to transmit this recommended determination, along with the administrative record, to EPA's Assistant Administrator for Water for review and final action.

### 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

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[30] Information regarding the proposed determination can be found in the docket for this effort at www.regulations.gov, see docket ID No. EPA-R10-OW-2022-0418.

appeal is ongoing, and USACE has not stated when its review will be completed. EPA's use of its 404(c) authority is independent from USACE's timing and actions of a permit denial. Furthermore, in this recommended determination, EPA Region 10 has concluded that each of the impacts on aquatic resources identified in Sections 4.2.1 through 4.2.4 would be likely to, 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).[31]

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. The statement is also a statement of policy that 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 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:

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[31] See footnote 27 in Section 2.

> 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,[32] including the relevant portions of the USACE permitting record, and this information supports the findings reported in this recommended determination.

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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

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[32] 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).

of the anadromous fishery areas at issue and, therefore, promotes regulatory certainty for all stakeholders. If EPA acts now, based on an extensive and carefully considered record, EPA, USACE, and the regulated community can also avoid unnecessary expenditure of resources. 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[33] that propose to discharge dredged or fill material associated with mining the Pebble deposit in the SFK, NFK, or UTC watersheds that would be likely to result in effects that are the same as, or similar or greater in nature and magnitude to the effects of the 2020 Mine Plan. Ultimately, recommending the prohibition and restriction now provides the most effective, transparent, and predictable protection of valuable anadromous fishery areas in the SFK, NFK, and UTC watersheds against unacceptable adverse effects.

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[33] USACE's denial of PLP's permit application does not address any other plan to mine the Pebble deposit that would have adverse effects the same as, or 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 (Woody 2018). 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 was 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. Given the connected and spatially nested structure of watersheds (EPA 2015), the migratory nature of many of the region's fish populations, and the importance of evaluating fish-habitat relationships across spatial scales (Bryant and Woodsmith 2009, Jackson and Fahrig 2015, Hale et al. 2019), these ecological resources are considered at multiple geographic scales.

The Pebble deposit is located in the Bristol Bay watershed, 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.[34] 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 each of these watersheds provide habitat for five species of Pacific salmon and numerous other fish species. Each of these headwater watersheds also supports fish habitats and populations in larger downstream systems via contributions of water, organisms, organic matter, and other resources.

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[34] 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).

## 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 2022d). 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 commercial 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 2021b). In 2021, 66.1 million Sockeye Salmon returned to Bristol Bay (ADF&G 2021b); this number increased by almost 20 percent in 2022, to 79.0 million—the largest inshore Sockeye Salmon run ever recorded in the region (ADF&G 2022e). 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).

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**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[43] 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).

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**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.

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[43] 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).

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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).[44]

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).

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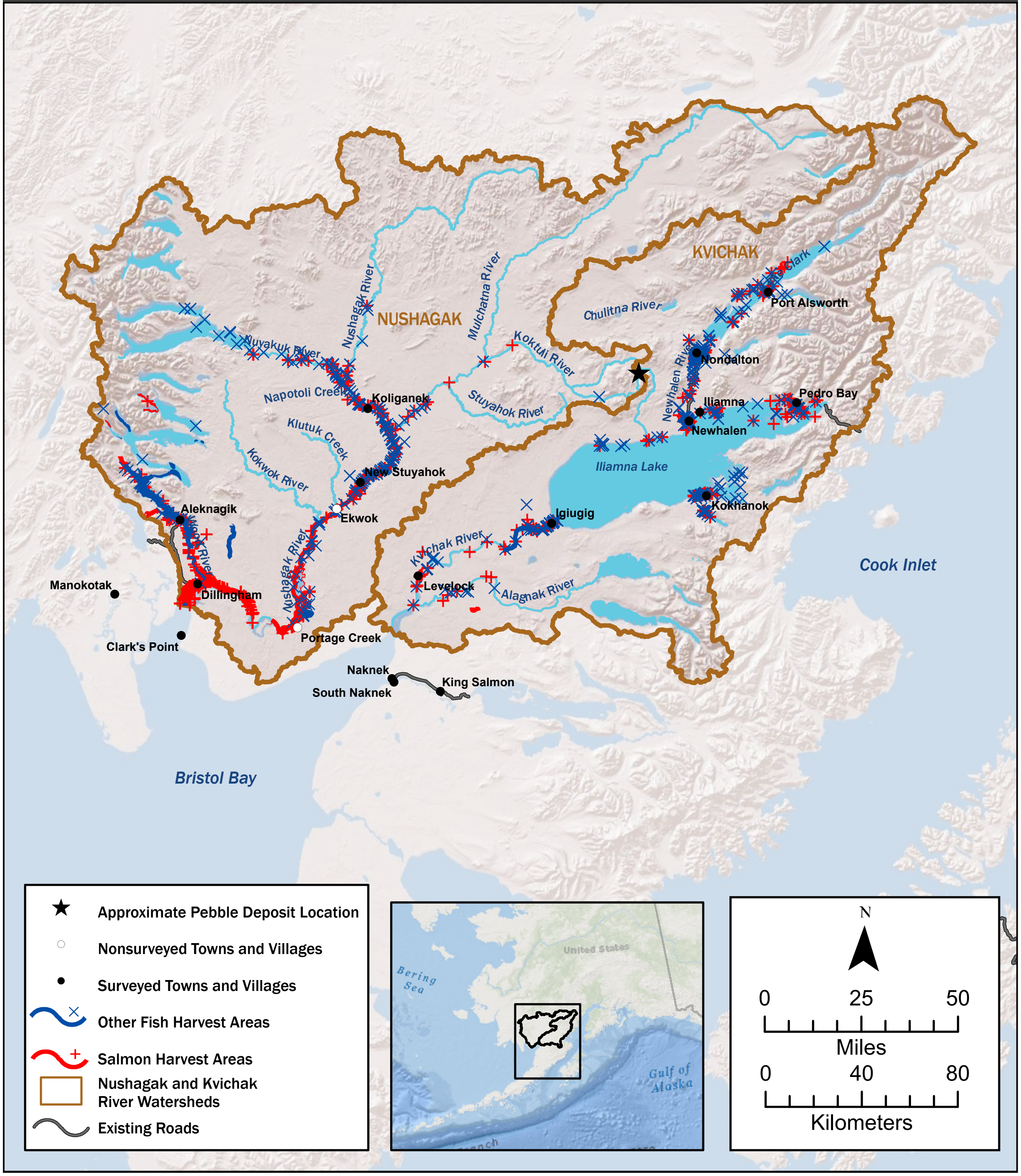
[44] For comparison, an average American consumes roughly 2,000 pounds of food per year.

**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, Steelhead (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 the 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

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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).

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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).

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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. Popular areas for recreational fishing in the Nushagak and Kvichak River watersheds.** Areas were digitized from previously published maps (Dye et al. 2006). Areas for recreational Rainbow Trout fishing are also distributed throughout the watersheds.

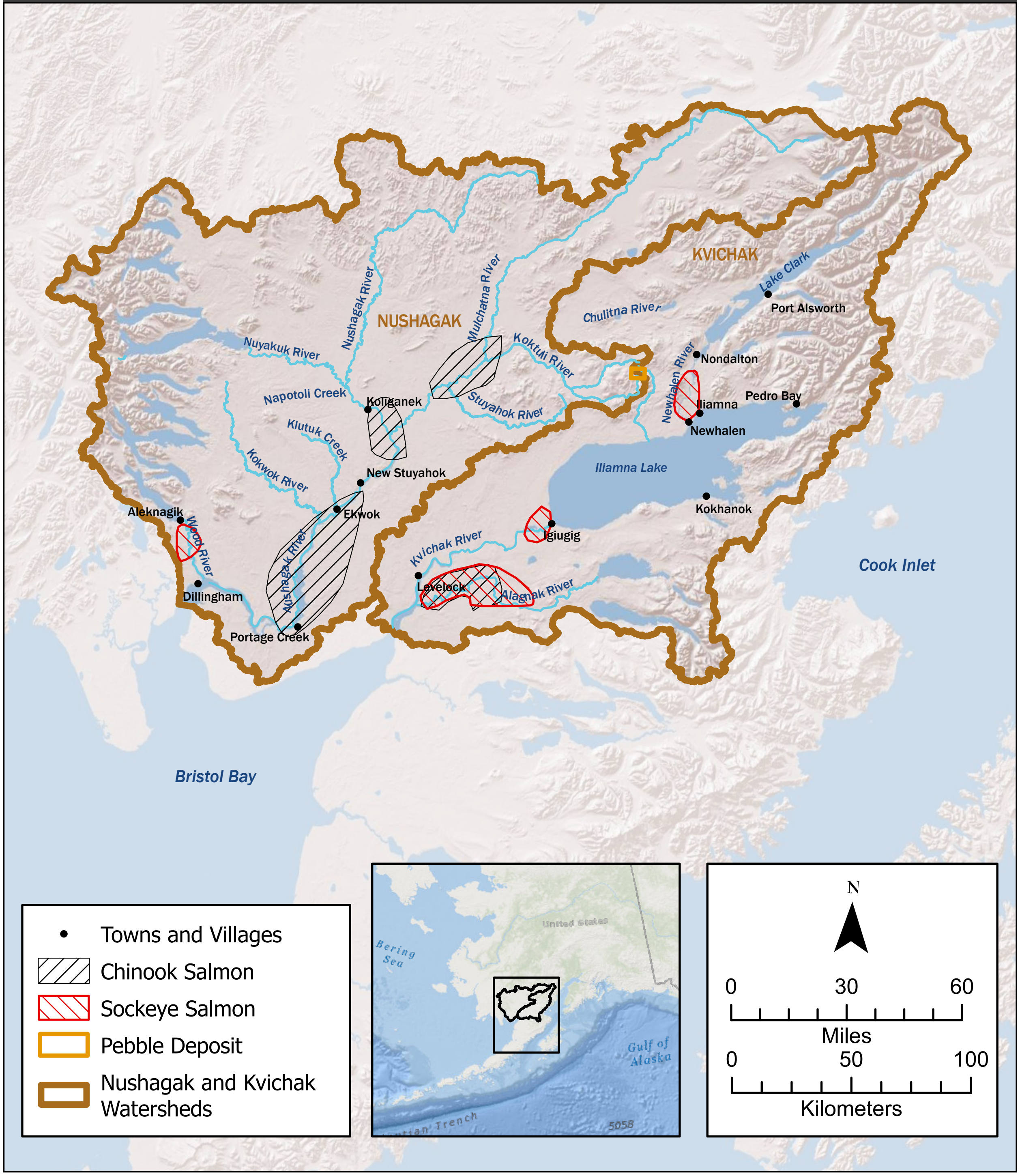

**Table 3-18. Estimated annual sport harvest and catch of fishes in the Kvichak River watershed and the Nushagak, Wood, and Togiak River watersheds, 2008–2017.** Estimated annual sport harvest is presented as the range between the minimum and maximum estimated annual harvest over the 2008–2017 period; 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. Recent Sockeye Salmon returns to Bristol Bay highlight the region's productivity relative to other watersheds in the United States: the number of Sockeye Salmon that returned to Bristol Bay in 2022 (79.0 million)—more than 60 percent of which returned to the Nushagak and Naknek-Kvichak River watersheds—is roughly 20 million more than the number of individuals of all Pacific salmon species that historically returned to Washington, Oregon, and California before these rivers were dammed (Gresh et al. 2000, ADF&G 2022e). 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).

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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). Many watersheds that have historically supported large salmon runs, such as the Fraser River in Canada, are affected by multiple types of urban and industrial development, resulting in habitat loss and degradation and declines in salmon runs (O'Neal and Woody 2011, EPA 2014: Box 8-4). 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, and heterogeneous 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).

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## 3.4 Summary

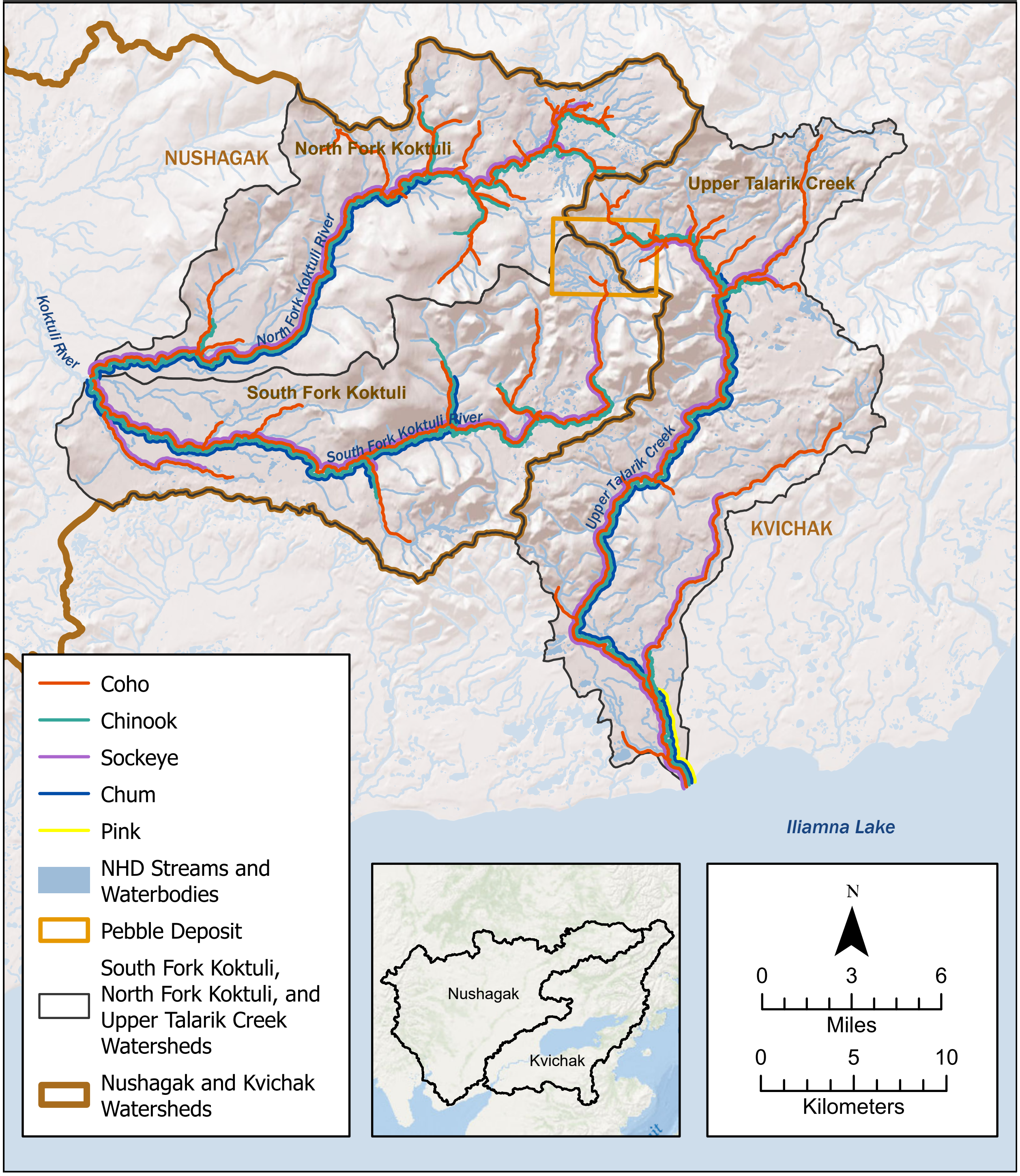
Because of its climate, geology, hydrology, pristine environment, and other characteristics, the Bristol Bay watershed is home to abundant, diverse, high-quality aquatic habitats. These streams, rivers, wetlands, lakes, and ponds support world-class subsistence, commercial, and recreational fisheries for multiple species of Pacific salmon, as well as numerous other fish species valued as subsistence and recreational resources. 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, Nesbitt and Moore 2016, USACE 2020a: Section 3.7), the watershed also has global cultural significance.

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, and Pacific salmon species and life stages have been documented to occur, often in high numbers, throughout the three watersheds (Figure 3-18). They also provide high-quality habitat for fishes, such as Rainbow Trout, Dolly Varden, Arctic Grayling, and Northern Pike. Wetlands and other off-channel areas provide essential 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.

**Figure 3-18. Streams, rivers, lakes and documented salmon use in the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek watersheds near the Pebble deposit.** Species distributions are based on the Anadromous Waters Catalog (Giefer and Graziano 2022).



# APPENDIX B

# ADDITIONAL INFORMATION RELATED TO THE ASSESSMENT OF AQUATIC HABITATS AND FISHES

# APPENDIX B. ADDITIONAL INFORMATION RELATED TO THE ASSESSMENT OF AQUATIC HABITATS AND FISHES

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 and their role in supporting fish populations. As discussed in detail in Section 4, the impacts on aquatic resources that are predicted to occur from the 2020 Mine Plan, based on the available data (e.g., PLP 2011, PLP 2018a) and analyses reported in the Final Environmental Impact Statement (FEIS) (USACE 2020), would likely result in significant loss of or damage to fishery areas in the SFK and NFK watersheds. This appendix addresses 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 impacts reported in the FEIS likely underestimate or underpredict the actual impacts that the 2020 Mine Plan would have on aquatic resources in the SFK, NFK, and UTC watersheds.

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## B.1 Quality, Importance, and Productivity of Lost Habitats for Fish Life Stages, Species, and Communities

As detailed in Sections 3 and 4 of this recommended determination, the evidence presented in the FEIS supports the U.S. Environmental Protection Agency's (EPA's) conclusion that aquatic habitats lost or degraded by the 2020 Mine Plan are of high quality, importance, and value as fishery areas. This section provides an overview of EPA's approach and assumptions for assessing habitat quality and fish use when determining the "quality" of the stream habitats degraded by the 2020 Mine Plan and the "importance" or "value" of that lost habitat and altered functions for fish populations.

### B.1.1 Assessing Stream Habitat Quality

The FEIS concludes that loss of stream habitats under the 2020 Mine Plan would be inconsequential for fish populations (USACE 2020: Section 4.24). This conclusion appears to be based on an assumption that the relative quality of these habitats is low and they have minimal influence on downstream waters. These assumptions and conclusions are not supported by the available information about these 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.

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### B.1.1.1 Quality of Lost Stream Habitats

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, NFK tributaries 1.190 and 1.200, are documented in the FEIS as having gradients less than 3 percent and suitable spawning substrates (USACE 2020: Table 3.24-2). No data on off-channel habitats, woody debris, or overwintering habitats are reported for these tributaries, although off-channel habitats were quantified at mainstem sites (USACE 2020: Section 3.24, Table 3-10). As a result, FEIS conclusions about the quality of streams that would be lost under the 2020 Mine Plan, relative to downstream mainstem habitats, are not supported by evidence presented in the FEIS. This comparison between mainstem and tributary habitats also misrepresents the relationship between these habitats. Mainstems and tributaries perform overlapping, but not duplicative, roles—mainstem spawning habitats are productive because the headwaters that support them are currently undeveloped and undisturbed.

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### B.1.1.2 Downstream Effects of Lost Stream Habitats

Losses of stream habitats under the 2020 Mine Plan also will affect downstream waters, due to reduced inputs from lost upstream reaches. According to the FEIS,

> 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 four or five spawning seasons (PLP 2018a: Chapter 15, Tables 15-14 through 15-17). For this reason, these surveys 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 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 it is true that there are headwater streams that would remain unaffected and continue to provide downstream inputs, there would still be a loss of inputs from 91 miles of streams that support downstream anadromous habitats. The FEIS 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).[1] At both spatial scales, these impacts represent a considerable and unacceptable 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, 2018a). 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 only during periods when the region and its aquatic habitats are accessible and effective fish sampling is possible. For example, fish sampling efforts were not conducted during the winter, resulting in a lack of fish distribution and abundance information in overwintering areas. Given these logistical challenges, the currently available data provide an incomplete description of the full seasonal distribution and abundance of fish species and life-history stages across the region's high diversity and density of aquatic habitats. Because habitat use by fishes is highly variable in space and time, and because all habitats in the region have not been sampled for all species and life stages, in all seasons, over multiple years, it is reasonable to conclude that the data provide an underestimate of the distribution and abundance of fish species and life stages within these habitats.

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[1] EPA acknowledges that water resources have not been consistently mapped throughout these watersheds (USACE 2020a: Page 4.24-8), which affects these percentage estimates. Nonetheless, the 2020 Mine Plan would result in the permanent loss of nearly 100 miles of headwater streams.

This likely underestimation of fish distributions is true not only of the data reported by PLP (2011, 2018a), but also of the Anadromous Waters Catalog (AWC) (Giefer and Graziano 2022) and the Alaska Freshwater Fish Inventory (AFFI) (ADF&G 2022a). These databases do not characterize all potential fish-bearing streams due to the large number of and lack of access to streams in Alaska. The AWC and the AFFI are not comprehensive, meaning that not all streams have been sampled and those that have not been sampled cannot be assumed to be non-fish bearing streams. The AWC website acknowledges this limitation, stating 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). 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 that may support life-stage use throughout the year. These same challenges—and thus likely underestimation of habitat use—also pertain to other aquatic habitat types (e.g., wetlands and other off-channel habitats).

Moreover, 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). All of 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, these methods are most useful for estimating presence of species and life-history stages, and any estimates of distribution and abundance derived from such methods are necessarily minimums 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 fishes 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 fishes 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 fishes, even if those habitats do not themselves contain fish (Cummins and Wilzbach 2005).

Where fishes 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 (PLP 2011, 2018a), 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 component watersheds and associated marine waters yield large quantities of salmon biomass annually, the Bristol Bay watershed—including the SFK, NFK, and UTC watersheds—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 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 present in high abundances at certain times of the year, and absent at other times. Some aquatic habitats may have no or low abundances of salmon in some years, but high abundances in other years, reflecting how populations 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. Over longer time scales, this variability is even greater. Available data for total inshore Sockeye Salmon runs in Bristol Bay illustrate this point. Between 2004 and 2008, the period during which most of the fish abundance and distribution data reported in the FEIS were collected, Bristol Bay's total inshore run of Sockeye Salmon ranged from 39.4 million to 44.8 million fish (Tiernan et al. 2021). In 2022, the total inshore run of Sockeye Salmon was 79.0 million fish (ADF&G 2022c)—a roughly 100 percent increase from 2004 through 2008 values. This significant increase in Bristol Bay's Sockeye Salmon runs over the past decade is not captured in the fish abundance and distribution data used to estimate impacts in the FEIS.

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 Pacific salmon over the life of the mine and beyond.

### B.1.4 Summary

PLP (2011, 2018a) presents results of the most extensive fish-sampling regime that currently has been conducted in the SFK, NFK, and UTC watersheds. These data show that streams in these watersheds, including those that will be lost under the 2020 Mine Plan, provide spawning and rearing habitat for multiple Pacific salmon species. However, limitations of the sampling regime mean that these data provide an incomplete description of—and likely underestimate—actual seasonal fish distributions and abundances in the region. Aquatic habitats at the mine site and in downstream mainstem reaches, including lateral floodplain habitats, 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. The quality of a given aquatic habitat as a fishery area does not depend solely on fish abundance within that habitat, particularly when fish abundance is assessed infrequently and over limited time scales. Many other factors, including the contributions that habitat makes to the quality and maintenance of downstream reaches, determine the importance of aquatic habitat as fishery areas. 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 unimportant 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. The headwater streams and wetlands that would be impacted by the 2020 Mine Plan are, in fact, very important for Pacific salmon and other fishes, 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 scales of inquiry is critical, as they 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 that fluvial geomorphic processes were altered for physical changes. Pacific salmon, due to their mobile and migratory nature, use habitats across these spatial scales over the course of their life cycles.

This selection of appropriate scale is important because assessment of whether "measurable impacts" occur is scale dependent. For example, if an assessment considers a large-enough spatial scale, relative to the assessed area, when evaluating impacts, the relative magnitude of those impacts will diminish as a function of increasing scale (although the absolute magnitude of those impacts remains unchanged). If an assessment considers a short enough temporal scale, relative to the life histories of the species affected and the time frames over which habitat use by species and life stages vary, when evaluating impacts, it may fail to detect what over longer time periods becomes irreparable harm to those habitats and populations (Schindler and Hilborn 2015). 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, relatively. 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 relative effects at the largest spatial extent suggests that individual habitats and the fishes they support are similar and interchangeable throughout the Nushagak River watershed, and evidence suggests that is not the case (Section 3.3.3). It also does not change the fact that 99.7 miles of streams in the SFK, NFK, and UTC watersheds would be lost under the 2020 Mine Plan footprint, an amount of loss that would be likely to have an unacceptable adverse effect on fishery areas in these watersheds (Section 4.2.1).

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 of multiple Pacific salmon and other fish species (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 watershed 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).

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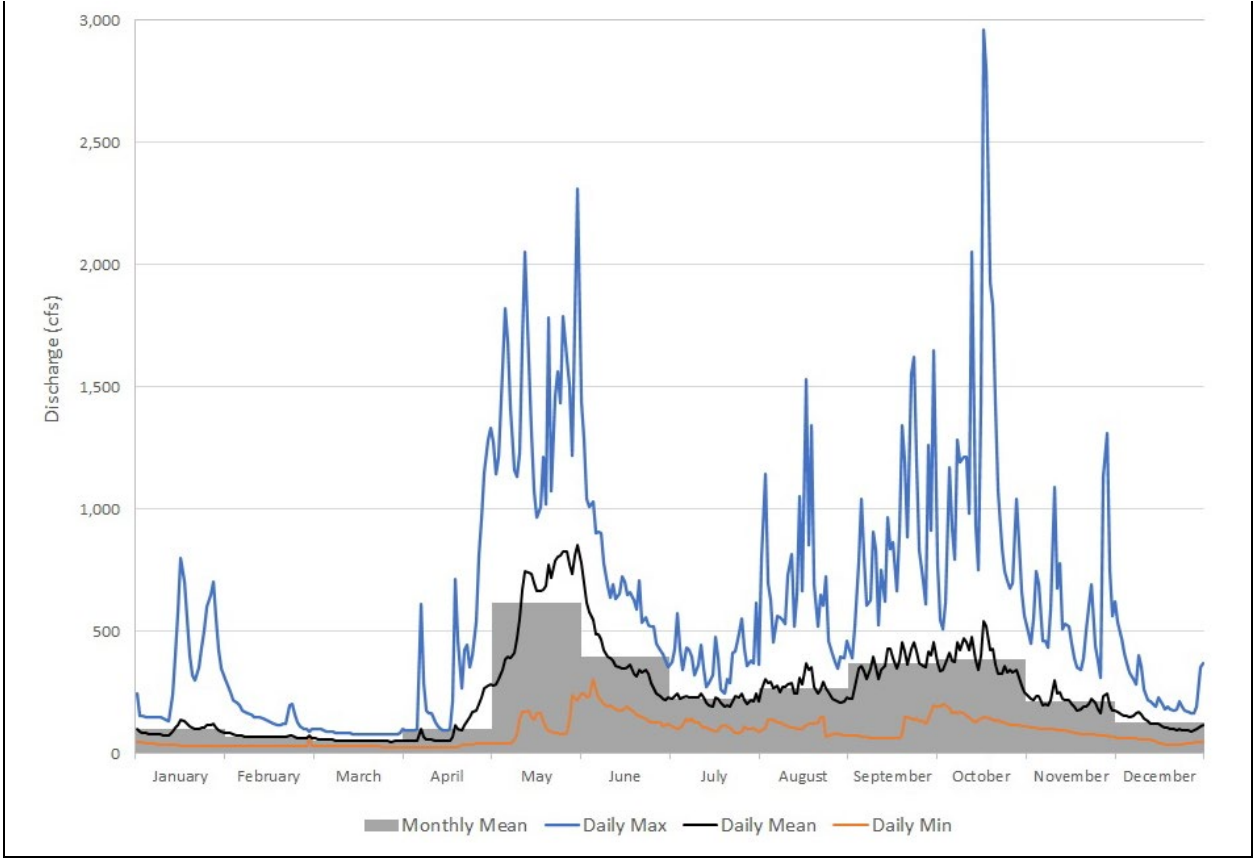
Selection of appropriate temporal scales is also important for evaluating impacts to fishes and their habitats. For example, the FEIS presents streamflows and estimates of streamflow change in terms of average monthly flows (USACE 2020: Section 4.16, Table 4.16-3). Although hydrologists consider average monthly flows to be a meaningful measure of a stream's hydrograph, evaluating impacts of streamflow changes at a monthly temporal scale does not address key ecological considerations relevant to fishes. 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, George et al. 2021). A stream's hydrograph may also be characterized by components that include baseflow, frequent floods, seasonal timing of flows, and interannual variation in flow. In all cases, the magnitude, timing, duration, frequency, and rate of change of streamflows are important in characterizing the natural hydrograph (Poff et al. 1997).

The life histories and behaviors of aquatic organisms are attuned to streamflow cues at different timescales 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 without consideration of daily and interannual variation ignores impacts of predicted flow changes on other important streamflow components. Evaluating streamflow changes using only average monthly flows masks the severity of impacts, because percent changes in daily flows are more variable than changes to monthly averages. This dampening of variability is clearly illustrated by comparing average daily to average monthly flows (Figure B-1): during both low flow and high flow periods, average monthly streamflow does not capture the range of flows that occur in the system. 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 states, without any supporting evidence, that the monthly ranges are representative of potential temperature changes (USACE 2020: Section 4.24).

**Figure B-1. Average monthly versus minimum, average, and maximum daily streamflow in the North Fork Koktuli River.** Averages are based on data at site NK100A (USGS Gage #15302250), from 2004-2015 (USGS 2022).



## 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. For example, shelters or refuges from environmental conditions that may be briefly limiting can serve as “bottlenecks,” constraining the abundance of future life stages; for Pacific salmon, critical “bottleneck” habitats can include off-channel habitats and beaver ponds (Pollock et al. 2004).

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). 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, 2018a). These data demonstrate 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, primarily collected over a 5-year period nearly 15 years ago, fully capture how much these factors vary over longer time scales and more finely resolved spatial scales. The nearly 100 percent increase in Bristol Bay's total inshore Sockeye Salmon run in 2022 (ADF&G 2022c), relative to runs between 2004 and 2008 (Tiernan et al. 2021), provides just one example of the variability in environmental conditions that has not been captured in the FEIS and, thus, not considered in its evaluation of impacts of the 2020 Mine Plan.

Streamflow data provide another illustration of this point. Accurate quantification of streamflow metrics requires data collected over sufficient areas and time periods to account for spatial and temporal variability (George et al. 2021). Multiple studies have shown that streamflow data collected over a limited number of years are associated with high levels of uncertainty (Kennard et al. 2010, Goguen et al. 2020). For example, Goguen et al. (2020) evaluated the variability of flow metrics calculated with data collected over different time periods. They found that uncertainty or variability (measured as coefficient of variation) in monthly flow metrics was 30 percent when metrics were calculated over 5 years but decreased rapidly when metrics were calculated over 15 or more years (Goguen et al. 2020).

The high natural variability of these systems also makes FEIS claims that impacts of the 2020 Mine Plan would not be significant because they "would be expected to fall within the range of natural variability" (e.g., USACE 2020: Page 4.24-46) meaningless. This is easily illustrated by considering streamflow variability in Figure B-1. Between 2004 and 2015, average daily streamflow at NK100A, the downstream-most site on the NFK mainstem considered in the FEIS, ranged from roughly 0 to 3,000 cfs; in May alone, average daily streamflow ranged from 40 to more than 2,000 cfs (Figure B-1). Streamflow changes that occur within this range of "natural variability" could still have significant impacts on aquatic resources if they are occurring more or less frequently than under natural, undisturbed conditions.

Like streamflow, 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 primarily collected between 2004 and 2008, and many sites were not sampled in multiple seasons across multiple years; thus, data were not collected over sufficient spatial and temporal scales to fully characterize 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. Based on 57 years of continuous monitoring data, Davis and Schindler (2021) conclude that long-term assessments are needed to fully understand the contributions of individual populations. The FEIS assessment of fish abundance and habitat use relies on data collected over a much shorter time period. As a result, FEIS conclusions about the long-term impacts on aquatic resources resulting from the 2020 Mine Plan based on these data should be viewed as minimum estimates—and, as detailed in Section 4.2, even these minimum estimates constitute an unacceptable adverse effect on fishery areas.

## B.3 FEIS Assessment of Streamflow Changes

The models and methods used in the FEIS to estimate streamflow changes in the SFK, NFK, and UTC watersheds associated with the 2020 Mine Plan have several shortcomings. This section summarizes the FEIS conclusions regarding streamflow and identifies several issues with those conclusions or the underlying methods, many of which EPA expressed throughout the EIS development process (e.g., EPA 2019).

The FEIS presents impacts of the 2020 Mine Plan that were estimated using an end-of-mine watershed model that incorporated inputs from three primary components: a baseline watershed model, a groundwater flow model, and a mine-site water-balance model (PLP 2019a: RFI 109g). Streamflow changes are reported in terms of changes in average monthly streamflow between baseline (i.e., under natural conditions) and end-of-mine, assuming discharge of treated water in an "average climate year" (i.e., at a 50-percent exceedance probability), based on 76 synthetic monthly average flows (USACE 2020: Section 4.16 and Appendix K4.16) calculated from runoff estimates derived from long-term precipitation and temperature data at a site roughly 17 miles from the mine site. The FEIS states that water would be strategically discharged from wastewater treatment plants (WTPs) to benefit a priority fish species (Chinook Salmon, Coho Salmon Sockeye Salmon, Rainbow Trout, or Arctic Grayling) and life stage (spawning or juvenile rearing) selected for each month in each watershed (USACE 2020: Table 4.24-2).

As detailed in Section 4.2.4, downstream flow changes associated with the 2020 Mine Plan, as reported in the FEIS (USACE 2020: Section 4.16), would exceed 20 percent of average monthly flows in at least 29 miles of documented anadromous fish streams. Reaches of the SFK and NFK closest to the mine site would experience greater changes in average monthly streamflow than reaches farther downstream (USACE 2020: Section 4.16). NFK Tributary 1.190 would be dewatered entirely—that is, experience a 100-percent loss of flow—due to construction of the bulk tailings storage facility and seepage-collection system (USACE 2020: Section 4.16). SFK Tributary 1.190 is predicted to experience a maximum change in 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.

Significant streamflow alterations also would extend down the NFK and SFK mainstems. For example, 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. These alterations are predicted to occur despite attempts to "optimize" the discharge of treated water to benefit priority fish species and life stages. SFK Reach E would see a 52-percent decrease in average monthly streamflow in April, whereas SFK Reach D would see a 109-percent increase (USACE 2020: Table 4.16-3) due to WTP discharges. According to the FEIS, the extent of impacts on streamflow could extend to just below the confluence of the SFK and NFK (USACE 2020: Page 4.16-2),[2] meaning that up to 61 miles of the SFK and NFK mainstems could experience "discernible" streamflow alterations. This level of change from natural streamflows represents an unacceptable adverse effect on fishery areas in the SFK and NFK watersheds (Section 4.2.4).

Despite the importance of natural flow regimes as a "master variable" determining the structure and function of stream and river ecosystems (Bunn and Arthington 2002, Lytle and Poff 2004, Poff and Zimmerman 2010, Sofi et al. 2020, Tonkin et al. 2021), the FEIS fails to evaluate the myriad ways that anticipated streamflow changes would affect these systems. The FEIS also likely underestimates the actual extent to which streamflow in the SFK, NFK, and UTC watersheds would be affected by mine operations resulting from the 2020 Mine Plan, in terms of percentage change in streamflow, length of affected streams, and changes in streamflow variability. This underestimation of streamflow changes in the FEIS results from several issues.

The following sections highlight three specific areas of concern in the FEIS assessment of streamflow changes: the failure to consider ecological impacts of streamflow changes; the use of average monthly streamflows to assess impacts; and the failure to sufficiently consider interactions between surface waters and groundwater.

## B.3.1 Impacts of Streamflow Changes

The natural flow regime is a critical component of streams and rivers and their hydrologically connected aquatic habitats because water flow directly or indirectly affects all other physical, chemical, and biological components of these systems (Bunn and Arthington 2002, Lytle and Poff 2004, Poff and Zimmerman 2010, Sofi et al. 2020, Tonkin et al. 2021). The body of published scientific literature on the functional consequences of hydrograph alteration is extensive (e.g., Poff et al. 1997, Tonkin et al. 2021, Freeman et al. 2022). Despite its importance, the FEIS does not address the numerous effects of predicted flow changes directly. There is no explanation of how streamflow changes associated with the 2020 Mine Plan would affect natural flow patterns and variability, nor consideration of how these

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[2] 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 2020: Section 4.24).

changes would alter physical habitat, water quality, and the full suite of organisms adapted to natural flows in these systems (Section B.5.2).

The FEIS instead uses estimates of streamflow change solely to inform its fish habitat modeling, presenting summaries of monthly changes to "suitable fish habitat" as defined in the PHABSIM model (Section B.4). 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 and the myriad effects the loss of these flows and their ecological subsidies would have on downstream reaches. 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. As a result, the FEIS presents an extremely simplified assessment of how streamflow changes will affect mainstem and tributary reaches of the SFK, NFK, and UTC watersheds. As detailed in Section 4.2.4, even this simplified assessment shows that streamflow alterations associated with the 2020 Mine Plan would constitute an unacceptable adverse effect on fishery areas, and the actual ecological impact of these changes would likely be more extensive than estimated in the FEIS.

Furthermore, stream lengths in which flow regimes would be significantly altered from natural conditions are not quantified or discussed in the FEIS. The FEIS states that flow changes may extend to reaches just below the confluence of the SFK and NFK mainstems (USACE 2020: Page 4.16-2), but the FEIS does not mention that there are 61 miles combined in the SFK and NFK mainstems before reaching that confluence. Additionally, the distance between locations at which streamflow information was collected and modeled limits the ability to accurately predict the extent of streamflow impacts. For example, WTP discharges to Frying Pan Lake would increase outflows to the SFK up to 109 percent above average monthly flows. However, it is unclear how far downstream these flow increases would extend because the next downstream gage at which streamflow information was estimated (i.e., SFK Reach C) is located 11.7 river miles downstream. At that point, streamflow changes were estimated at less than 5 percent below baseline average monthly flow (USACE 2020: Table 4.16-3).[3] The actual extent of streamflow changes in the SFK most likely extends some distance downstream of Frying Pan Lake, but the FEIS does not provide an estimate of that distance.

## B.3.2 Use of Average Monthly Flows and Climate Conditions

The FEIS presents streamflows and estimates of streamflow change in terms of average monthly flows (USACE 2020: Section 4.16, Table 4.16-3). Percentage flow differences between baseline and end-of-mine conditions are computed based on monthly averages, which as discussed below provide a relatively coarse measure of potential impacts to fishes and other aquatic resources. Even at this coarse level of assessment, greater than 20 percent changes in average monthly flows are predicted during at least 1 month per year in at least 29 miles of documented anadromous fish streams.

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[3] The next downstream location for which streamflow data are presented in FEIS Table 4.16-3 is SFK Reach C, which is based on streamflow at gage SK100C (PLP 2019b: RFI 109f), 11.7 river miles (18.9 km) downstream of SK100F (PLP 2020d: RFI 161).

In reality, the use of average monthly flows to evaluate impacts of the 2020 Mine Plan likely underestimates downstream flow changes that would have meaningful ecological effects. Average monthly flows do not capture ecologically important aspects of the natural hydrograph (Section B.2) or represent the full magnitude of potential daily flow fluctuations. As a result, the use of monthly averages downplays the extent of impacts on the natural hydrograph and the aquatic life that is adapted to and relies on it. 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 flows). As discussed in Section B.2.1, evaluation of streamflow changes using only average monthly flows masks the severity of impacts, because percent changes in average monthly flows are less variable than changes in daily flows (Figure B-1). 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.

In the FEIS analysis of streamflow changes, WTP discharges would be preplanned for each month based on modeling and a set of assumptions. Monthly WTP discharges would be the amount needed to “optimize” downstream habitat for specific anadromous fish species and life stages assuming that the historic monthly average streamflow was to occur (i.e., given an “average climatic year,” or 50 percent exceedance probability). However, the only monitoring proposed by PLP appears to be quarterly streamflow and fish presence surveys (PLP 2019c: RFI 135), indicating that water discharges were never proposed to be altered in response to current climatic conditions. Managing water discharges based on average long-term streamflows would dampen variability in the system (Section B.2.2). The proposed discharges would transform the naturally varying and unregulated surface water and groundwater flows in the headwaters into uniform, regulated process-water discharges to surface waters. The loss of this streamflow variability, which is critical to the structure and function of these ecosystems (Poff et al. 1997, Bunn and Arthington 2002, Freeman et al. 2022), is not described or characterized in the FEIS.

Despite these shortcomings, the streamflow change estimates documented in the FEIS provide a reasonable minimum approximation of the streamflow impacts expected to result from the 2020 Mine Plan. Even these minimum estimates of changes in average monthly flows, over the stream lengths documented in the FEIS, would affect the physical, chemical, and biological characteristics of these streams and constitute an unacceptable adverse effect on fishery areas.

### B.3.3 Interactions between Groundwater and Surface Waters

As discussed in Section 3.2.1, surface waters and groundwater in the SFK, NFK, and UTC watersheds are highly connected and interact in complex ways (USACE 2020: Section 3.17). These interactions influence streamflow patterns—and thus aquatic resources—in both space and time. The FEIS provides limited characterization or simulation of the coupled surface water-groundwater interactions critical to maintaining the region’s aquatic ecosystems (Wobus and Prucha 2020). As a result, the FEIS underestimates the extent of groundwater impacts likely to occur under the 2020 Mine Plan and, thus, potential effects on downstream flows. Examples of the failure of the FEIS to adequately consider groundwater impacts and interactions with surface waters are included below.

- The baseline watershed model and the groundwater flow model used to assess streamflow changes were not integrated, and instead they were developed and operated independently (Wobus and Prucha 2020). The baseline watershed model was configured and calibrated prior to development of the refined groundwater model (MODFLOW). Together, these points indicate that estimates of streamflow change in the FEIS did not represent a comprehensive, integrated assessment of how changes in both surface waters and groundwater would affect streamflows under the 2020 Mine Plan.
- A review of the model calibration shows the groundwater model overestimates groundwater elevation in the NFK headwaters area and underestimates NFK streamflow downstream of the headwaters, which may be an indication of poor model calibration (PLP 2019d: RFI 109d). MODFLOW simulations resulted in groundwater elevations that were up to 35 feet deeper than observed water table elevations (e.g., Figure 6-10 in PLP [2019d]), suggesting poor model calibration and the need to expand the alluvial aquifer in the headwaters of the NFK to properly account for groundwater and surface water observations.
- Within and across the mine site boundary, streamflow changes due to well pumping and groundwater table depression were not well characterized. Streamflow losses during mine operation were only characterized by conditions at the end-of-mine (e.g., 20 years). Changes in shallow groundwater conditions and associated stream losses within and across the mine site boundary were not rigorously accounted for when estimating streamflow impacts, as indicated by the significant differences between MODFLOW's simulated groundwater elevations and observed groundwater elevations (discussed above). Impacts on gaining reaches downstream of the mine, attributed to groundwater sources under pre-mine conditions in the FEIS, were not considered.
- The majority of surface water and groundwater flows within the mine site boundary were assumed to be captured, contained, and released via WTP discharge to surface waters. There was no assessment of impacts associated with the loss of groundwater recharge at the mine site, which provides baseflow contributions to discharge under low flow conditions (including under surficial ice) and stabilizes water temperatures under low and transitional flow conditions.

As these examples illustrate, the FEIS likely underestimates the impacts of groundwater pumping and processing demands, the extent of groundwater drawdown both within and across watersheds, and, thus, the influence these groundwater-related factors would have on downstream flow changes associated with the 2020 Mine Plan.

## B.4 FEIS Assessment of Fish Habitat Changes

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. The issues raised here do not affect EPA's conclusion that the habitat losses (i.e., losses of anadromous fish streams, additional streams, and wetlands and other waters) or streamflow changes predicted to occur under the 2020 Mine Plan each constitute an unacceptable adverse effect on fishery areas. Rather, these issues highlight concerns that the FEIS evaluation of fish habitat changes did not represent an accurate and thorough assessment of likely impacts.

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### B.4.1 Overview of Fish Habitat Assessment Methods

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 EPA's knowledge, the HABSYN model has never been validated or documented in the scientific literature. The basic premise of extending sampled transect data to unsampled habitats was not evaluated, but was assumed in the FEIS to be valid for assessing fish habitat in unsampled areas.

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 previously identified in EPA (2019) and NMFS (2020).

### B.4.2 Use of PHABSIM Models to Estimate Fish Habitat Changes

PHABSIM is a one-dimensional physical model that has been used for decades to model habitat and manage streamflows for fish populations, including salmon. Because PHABSIM is a method that does not have a direct relationship to fish population biology (Waddle 2001), it has several limitations that have long been acknowledged (e.g., Anderson et al. 2006, Railsback 2016) and 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 determining fish habitat that would potentially be affected by the 2020 Mine Plan.

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)—that is, a consistent relationship between water depth and velocity and fish habitat use was not observed. These data demonstrate variability in fish habitat use among survey years, an indication that the underlying PHABSIM assumptions are not valid.

The PHABSIM model used in the FEIS incorrectly assumed that habitat can be reduced to discharge. Even if this assumption were valid—as discussed above, it was not—the PHABSIM analysis also failed to 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 and other off-channel habitats). While water depth and velocity are important determinants of fish habitat, 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 were not reflected in the PHABSIM analysis; in general, the utility of PHABSIM approaches may be extremely limited in areas such as the SFK, NFK, and UTC watersheds, with extensive and complex surface water-groundwater interactions (NMFS 2020).

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 SFK, NFK, and UTC watersheds. The alteration of water temperatures is a concern because fishes are at risk from disruption of 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 one-dimensional 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. As a result, this approach likely underestimates actual changes to fish habitat that would be likely to result from changes to the full suite of variables determining available fish habitat.

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### 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 (e.g., Rosenfeld 2003). 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. Data on off-channel habitats are reported in PLP (2011, 2018a) (see Table 3-10) but were not used in analyses related to fish habitat. The SFK, NFK, and UTC were 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 (especially Coho Salmon) and other fish species.

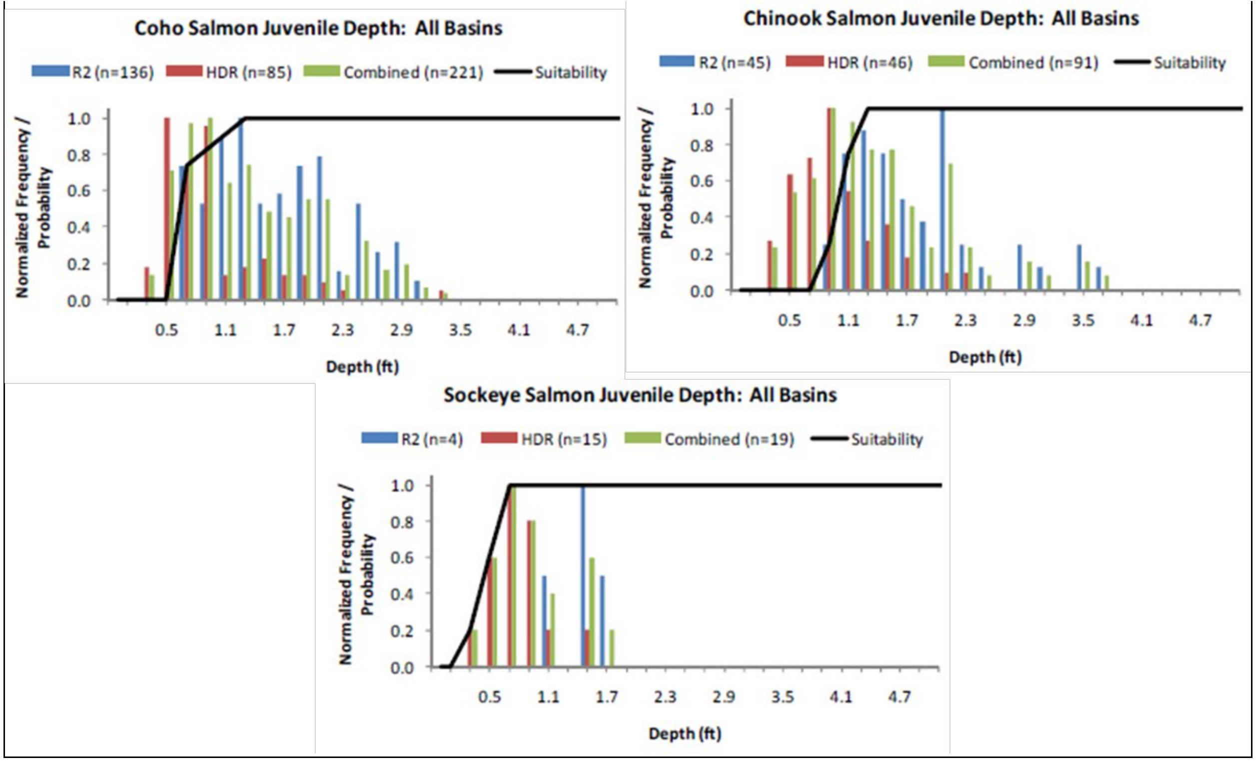
### B.4.2.3 Habitat Suitability Curves

Biology is attempted to be 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). Generally speaking, 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 B-2). 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-2). 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 that fish will use deeper water if it is available. This assumption is problematic as applied in the FEIS, given that the field data actually demonstrate decreased habitat use by juvenile Coho, Sockeye, and Chinook (*O. tshawytscha*) salmon with increasing depth (Figure B-2). For example, Figure B-2 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.

Railsback (2016) considers univariate HSCs 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 fishes) 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 fishes 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).

**Figure B-2. 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.



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 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 2019e: RFI 147). This document also states that fry habitat generally is not limiting, although no support for this statement is provided (PLP 2019e: 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. Early salmonid life stages (i.e., eggs and alevins) are particularly susceptible to adverse effects associated with changes in flow (Warren et al. 2015). Potential impacts to these life stages include scouring of redds and egg mortality with increased streamflows, freezing and desiccation with decreased streamflows, and loss of water-temperature buffering, waste removal, and aeration during the incubation stage due to changes in groundwater exchange. These early developmental stages are also when imprinting to natal waters begins; flow changes that alter the physical and chemical signatures of the water during these stages may impair imprinting and, thus, adult homing capabilities. Failure to evaluate impacts of the 2020 Mine Plan on these important life stages represents a significant omission in the FEIS.

### B.4.3 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. However, even this underestimate represents an unacceptable adverse effect on fishery areas in the SFK and NFK watersheds (Section 4.2).

Examples of specific issues related to FEIS conclusions about fish habitat changes associated with the 2020 Mine Plan are provided below.

- 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. 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. Exclusion of these non-mainstem habitats—which are critical habitats for many fish species and life stages—from estimates of fish habitat changes under 2020 Mine Plan results in a significant underestimate of impacts.
- As detailed in Section B.3, adjacent mainstem reaches of the SFK are predicted to experience both large decreases (52 percent) and increases (110 percent) in average monthly streamflows in April. The FEIS did not assess changes to suitable fish habitat in these SFK reaches, despite their documented use by juvenile salmon. 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 Graziano 2022).
- 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). Specific details about how discharges would be managed and monitored are not provided, and 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, in addition to limitations of the planned streamflow monitoring program. 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 is 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 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 and does not account for complex interactions between surface waters and groundwater, the FEIS necessarily provides an overly simplistic characterization of fish habitat. EPA (2019) and NMFS (2020) 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 was not assessed adequately to conclude in the FEIS that there will be no effects on fish habitat, abundance, and productivity. 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 the underestimate of fish habitat changes resulting from the 2020 Mine Plan documented in the FEIS represents unacceptable adverse effect on fishery areas in the SFK and NFK watersheds (Section 4.2).

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## B.5 Other Effects on Aquatic Resources

The prohibition and restriction included in this recommended 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). These impacts, as evaluated in the FEIS, would result in unacceptable adverse effects on fishery areas in the SFK, NFK, and UTC watersheds and are the basis for the proposed prohibition and restriction detailed in Section 5. However, the impacts underpinning this prohibition and restriction are only a subset of the many ecological effects likely to result from implementation of the 2020 Mine Plan. 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 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: Section 4.18). For example, chloride loads in the NFK are predicted to increase by 1,620 percent (USACE 2020: Page 4.18-19); nitrate-nitrite and ammonia are predicted to be 30 times and 12 times higher than baseline concentrations, respectively (USACE 2020: Tables K3.18-7 and K4.18-13); total dissolved solids are predicted to be more than three times higher than baseline concentrations in UTC, and approximately 12 times higher than baseline concentrations in the NFK (USACE 2020: Tables K3.18-7, K3.18-9, and K4.18-13).

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). Furthermore, fishes and other aquatic organisms are adapted to the naturally occurring water chemistry in the SFK, NFK, and UTC headwaters, and the ambient concentrations of many water chemistry parameters in these systems are much lower than existing water quality criteria (O'Neal 2020). For this reason, water chemistry changes that do not exceed water quality criteria but that significantly alter natural conditions may adversely affect aquatic biota.

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). Even small increases in water temperature can affect salmon development, growth, and timing of life-history events such as emergence and migration (e.g., Beacham and Murray 1990, McCullough 1999, Fuhrman et al. 2018, Adelfio et al. 2019, Sparks et al. 2019).

Water quality in the SFK, NFK, and UTC are predicted to change downstream of the mine site 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 baseline conditions to which fish communities (as well as other organisms) 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 further 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. Even considered in isolation, impacts on aquatic habitats documented in the FEIS constitute an unacceptable adverse effect on fishery areas (Section 4.2); a more holistic evaluation of how the full suite of changes expected to result from the 2020 Mine Plan would likely only increase the extent and magnitude of these impacts. This failure to consider multiple, cumulative effects is evident across multiple contexts, as the following examples below demonstrate.

- Effects on species, and life stages within species, are considered independently. There is no 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). Similarly, there is no consideration of how the direct effects of the 2020 Mine Plan on one life stage within a species will indirectly influence subsequent life stages (Marra et al. 2015), in addition to any direct effects those life stages experience.
- Effects on fishes are considered only in terms of changes to fish habitat, despite that fact that fishes also will be affected by impacts on lower trophic levels (e.g., macroinvertebrates, algae), which may be particularly sensitive to changes in physical and chemical characteristics likely to occur under the 2020 Mine Plan.
- 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. 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 (Hodgson et al. 2019), the impact of each change is only evaluated as if it would be acting in isolation. 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 2019f: RFI 149), a major producer of Chinook Salmon within the Nushagak River and within the state of Alaska. 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.

## 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 temperatures 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 (i.e., calculations of the total amount of water moving from the land surface to the atmosphere via evaporation and transpiration), 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 air temperature are likely to affect evapotranspiration and exacerbate thermal stress, increasing the probability of high severity wildfires (Lader et al. 2017). The combined effects of increased air temperature, altered timing and type of precipitation, and vegetation changes likely will lead to altered stream temperature regimes, with implications for fish metabolism and timing of key life history events. For example, 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. In precipitation driven streams, Adelfio et al. (2019) reported shifts in modeled incubation timing by Coho Salmon by up to 3 months during years with warmer winters. Given that substantially warmer winters are projected to be increasingly common in Alaska in the near future (Lader et al. 2017), these life history shifts may become increasingly common. Such shifts in timing can result in egg emergence that is out of sync with the availability of food resources (Cushing 1990, McCracken 2021), as well as other asynchronizations across salmon life histories. These life history shifts may disrupt the adaptation of salmon life stages to local environmental conditions, particularly if altered timing of key life history events such as emergence, migration, or seasonal movements is no longer synched to favorable conditions for salmonid growth and survival. These changes can lead to adverse impacts on resilience of Pacific salmon populations (Crozier et al. 2008).

Such increases in temperature (and associated adverse ecological effects) can occur during the winter, and at temperatures well below the State of Alaska's critical temperature threshold for spawning or egg incubation (13°C; ADEC 2020). Thermal effects on fry size and emergence timing can interact with streamflow to adversely affect juvenile salmon survival. 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, projected to increase in frequency with climate change (Lader et al. 2017), may contribute to increased scouring and sedimentation of stream channels. Increased exposure to earlier or larger peak streamflows can displace incubating eggs or newly emerged salmon fry, contributing to mortality. 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 the Bristol Bay region, many of the models used in the FEIS 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. Schindler and Hilborn (2015) stated that "…we should expect that the future is not likely to be a simple extrapolation of the recent past." Predictions of future habitat based on conditions in the recent past—or even current conditions—are of limited utility (Moore and Schindler 2022). As a result, models like those used in the FEIS may fail to adequately characterize mine impacts in ecosystems experiencing an altered future climate (Sergeant et al. 2022).

A thorough evaluation of potential 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. Even without this evaluation, the impacts on aquatic habitats documented in the FEIS constitute an unacceptable adverse effect on fishery areas (Section 4.2); consideration of how future climate conditions would affect these impacts would not change this unacceptability finding, but would give a more complete assessment of likely effects associated with the 2020 Mine Plan. A key feature of salmon populations in the Bristol Bay watershed is their genetic and life history 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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