
By Angela Matz, Terry Doyle, Elaine Snyder-Conn, and Dana Seagars

Fairbanks Fish and Wildlife Field Office
U.S. Fish and Wildlife Service
Fairbanks, AK
June 2005
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Acknowledgments

Thanks to all who helped on this project, especially the late Steve Breezer, Manager at Tetlin National Wildlife Refuge, who foresaw the need and garnered the initial support for establishing a contaminants baseline monitoring program for the Refuge, along with Howard Metzsker and Everett Robinson. Steve Breezer, David Cox, Terry Doyle, Jamie La Galley, Hank Timm, Elaine Snyder-Conn, and Ron Warbelow participated in the field data collection. Patrick Sousa, Keith Mueller, Bud Johnson, Hank Timm, Philip Johnson, Jordan Stout, and Deborah Rocque graciously reviewed this technical report.
Introduction

The Tetlin National Wildlife Refuge (Tetlin NWR) encompasses 924,000 acres of federal, selected and conveyed lands (Fig. 1). It is bordered on the north by the Alaska Highway, on the east by the Canadian border, on the south by the Wrangell-St. Elias National Park and Preserve (Wrangell - St. Elias NPP), and on the west by the Tetlin Reserve (previously known as the Tetlin Indian Reservation). Identified special values of the Tetlin NWR include the sand dunes of the Tanana Valley, the subsistence way of life for residents of the area, wetland habitats for waterfowl and other bird species, fish and wildlife resources, cultural resources, and opportunities for public education about natural and cultural resources afforded by the proximity of the Alaska Highway. The Refuge landscape consists primarily of climax black spruce forest interspersed with thousands of wetlands and large areas of tussock peatland. These habitats support 13 fish, 192 bird, 44 mammal, and one amphibian species.

Congress established the Tetlin NWR in 1980 when it enacted the Alaska National Interest Lands Conservation Act (ANILCA). Refuge purposes defined within ANILCA include, “to conserve fish and wildlife populations and habitats in their natural diversity including, but not limited to, waterfowl, raptors and other migratory birds, furbearers, moose, caribou, salmon, and Dolly Varden,” and “to ensure, to the maximum extent practicable...water quality and necessary water quantity within the refuge.” This study addresses conservation of fish and wildlife habitat and water quality within the Refuge by establishing baseline data for, and examining potential mining impacts on, water quality and metals\(^1\) concentrations in water, sediments, and fish tissue.

Biological Resources

Thirteen fish species have been documented on Tetlin NWR, and the Refuge has appropriate habitat for others (U.S. Fish and Wildlife Service 1990). Chinook (Oncorhynchus tshawytscha) and coho salmon (O. keta), were reported by subsistence users to have been historically present on the refuge; however, no salmon are known to occur in Refuge waters today. Species of particular relevance to this study include: arctic grayling (Thymallus arcticus), northern pike (Esox lucius), humpback whitefish (Coregonus pidschian), burbot (Lota lota), and longnose sucker (Catostomus catostomus). Tetlin NWR contains important sport and subsistence fisheries for burbot, arctic grayling, northern pike, and several species of whitefish. Within the Yukon River drainage only six spawning areas have been identified for humpback whitefish and two of these are located on the Tetlin NWR. Additional information about the fish and fisheries of the Tetlin NWR is contained in the refuge's Fishery Management Plan (U.S. Fish and Wildlife Service 1990).

\(^1\) In this report “metals" includes the metalloids antimony, arsenic, boron, and selenium.
Figure 1. Sample sites for water quality and metals sampling on Tetlin NWR, Alaska, 1987-1992.
The rivers, adjoining lakes, and numerous connected wetlands provide habitat for one of the most dense and productive concentrations of nesting waterfowl in Alaska, with approximately 25,000 ducklings produced each year, including lesser scaup (*Aythya affinis*), American wigeon (*Anas americana*), green-winged teal (*Anas crecca*), bufflehead (*Bucephala albeola*), ring-necked duck (*Aythya collaris*), white-winged scoter (*Melanitta fusca*), mallard (*Anas platyrhynchos*), northern pintail (*Anas acuta*), canvasback (*Aythya valisineria*), and common (*Bucephala clangula*) and Barrow's (*B. islandica*) goldeneye. Tetlin NWR supports an expanding population of trumpeter swans (*Cygnus buccinator*), a nationally significant species. On the major swan migration route, several thousand swans stage on the refuge each fall and the summer population exceeds 1,200. Thirty-two osprey (*Pandion haliaetus*), 64 bald eagle (*Haliaeetus leucocephalus*), and 13 peregrine falcon (*Falco peregrinus anatum*) pairs occupied nests on and adjacent to the refuge in 2003 (Timm et al. 2004), and the refuge is part of a major spring and fall migratory corridor for these and other raptors. Birds regularly found on the refuge but rare elsewhere in interior Alaska include the American coot (*Fulica americana*), sora (*Porzana carolina*), and blue-winged teal (*Anas discors*).

Other refuge resources include approximately 60 wolves (*Canis lupus*), 500 moose (*Alces alces*), more than 45,000 caribou (*Rangifer tarandus*) from three distinct herds, lynx (*Lynx canadensis*), grizzly bear (*Ursus arctos*), black bear (*Ursus americanus*), several species of furbearers (Mustelidae), and wood frogs (*Rana sylvatica*).

**Water Resources**

Water is an extremely important resource on the Tetlin NWR. Fish and wildlife production is greatest in the lowland complexes of ponds, marshes, and streams of the northern portion of the refuge. The rivers and major streams on and off the refuge influence water levels and nutrient richness in these wetland areas. Although most of the tributary streams have maximum discharge during spring run-off, the major glacial rivers experience maximum discharge in late summer when glacial melt is increased by high temperatures. Glacial rivers in the Tanana basin generally remain high through August due to rain and melting of glacial ice, with some flooding potential. Minimum discharges occur from mid to late winter when subsurface water from the major rivers provides the majority of flow. Many of the small tributary streams are completely frozen at this time. In summer, both the Chisana and the Nabsesna drainages carry large loads of sediment (up to 2000 mg/L). In winter the streams are relatively clear of glacial sediment. There are few known pollution sources on the refuge and most river waters contain natural minerals in moderate amounts (total dissolved solids of 75-200 mg/L). The Chisana and Nabsesna rivers have fairly hard water, normal pH, relatively high levels of calcium and magnesium, and some waters have a high iron content (0.71 mg/L in one lake in the northwest corner of the refuge) (U.S. Fish and Wildlife Service 1990).

This study focused on Tetlin NWR's three primary watersheds, the Nabsesna, Chisana, and Tanana rivers, and their major tributaries. The Nabsesna River watershed includes regions flowing into the Nabsesna River, Cheslina River, and Lick and Alder creeks. The Nabsesna River
is a large glacial stream (watershed over 5,500 km²) originating from the Nabesna Glacier in the Wrangell Mountains. The stream has a 0.8% gradient from its origin in the Wrangell-St.Elias NPP for a distance of about 33 km to the refuge's southern boundary, and a 0.16% gradient from the refuge boundary to Northway. Water is turbid in spring, summer, and fall but clears in winter. The Cheslina River originates in the Mentasta Mountains in the southwest corner of the refuge, and meanders northeast to join the Nabesna River midway between the refuge boundary and Northway.

The Chisana River watershed includes those regions flowing into the Chisana River and Desper, Gardiner, Mirror, Moose, Scottie, Stuver, Yellow Water, and Wellesley creeks. These creeks originate from off-refuge watersheds located in Canada (Mirror, Scottie, Yellow Water), on state and private lands north of the Alaska Highway (Gardiner, Desper), on federal lands south of the refuge within Wrangell - St. Elias NPP (Stuver), or within the refuge (Moose). The Chisana River originates at the base of the Chisana Glacier in the Nutzotin Mountains and flows northeast about 64 km through the Wrangell - St. Elias NPP to the refuge boundary. The river flows another 81 km toward Northway where it joins the Nabesna to form the Tanana River. The river substrate within the refuge is variable with sand, gravel, and cobble in riffle areas and sand-silt in pool areas. Stream banks are unstable with riparian vegetation of poplar or aspen (Populus spp.), spruce (Picea spp.), birch (Betula spp.), willow (Salix spp.) and alder (Alnus spp.). Large slip areas, with mature trees in various stages of inundation, are quite common. The Chisana is highly turbid during the open water season but clears during the winter.

Gardiner Creek is a spring-bog stream draining an area of over 777 km² northeast of the Alaska Highway. Riparian vegetation is primarily spruce, birch, and aspen. The stream substrate is composed of silt and sand but also has riffle areas of gravel and cobble. This creek has organically stained water, 6.6-7.5 pH, open-water conductivity of 40-93 µmhos/cm in winter, and dissolved oxygen (DO) near saturation during open water.

Desper Creek is a spring-bog stream originating east of the Alaska Highway at Island Lake. It flows into Scottie Creek about 6.5 km below the highway. Spruce, birch, alder, and willow grow at the top of steep stream banks and there is an abundance of aquatic vegetation. A culvert crossing the Alaskan Highway restricts fish upstream movement during low flows. The stream has a width of 5-10 m, humic-stained water, 6.5-7.0 pH, 75 µmhos/cm conductivity and DO at saturation during open water. During winter, it freezes to the bottom or has shallow, anoxic, water under the ice.

Scottie Creek is a low gradient, spring-bog creek originating in a lake area northeast of the Alaska Highway. It flows through a portion of Canada and re-enters the United States about 32 km south of the source lake. The stream channel is 15-20 m wide and 1.2-3.0 m deep with streamside vegetation of spruce, alder, and willow, and a mud substrate. Water quality during the open water period is excellent, indicated by 6.8-7.0 pH, 60 (open water) to 130 (winter) µmhos/cm conductivity and DO near saturation (open water) to < 2 ppm (winter).
Yellow Water Creek is a small side tributary of Scottie Creek approximately 16 km north of the refuge boundary. In 1987, an active placer mining operation immediately across the Yukon/Alaska border discharged effluent directly into the stream. Turbidity was pronounced during this operation and sedimentation occurred in several lakes immediately downstream. This mine was still in operation in 2000. Yellow Water Creek drains into the refuge via Scottie Creek.

Mirror Creek is a clear spring stream that originates in Canada and flows almost due west 19 km through the southern portion of the refuge to the Chisana River. The stream averages 10.6 m wide with variable depth (0.6-3.6 m) and a sand and gravel substrate. Streamside vegetation is spruce, willow, and alder. The stream has clear water, 7.5-8.0 pH, 170 to 250 µmhos/cm conductivity, and 6-8 ppm DO.

Moose Creek is a spring-bog stream originating in the Black Hills and flows northeast to the Chisana River roughly 5 km above the Tanana confluence. The stream averages 10-20 m width and 0.5-1.0 m depth, with a mud substrate. Streamside vegetation is spruce, alder, willow, cottonwood (Populus spp.), sedge (Carex spp.), and horsetail (Equisetum spp.) with rooted aquatics of bur-reed (Sparganium spp.), pond weed (Potamogeton spp.), and water milfoil (Myriophyllum spp.). Floating duckweed (Lemna minor) is also present on many sections of the stream. During summer months, the water is tannin-stained with 8.5-9.0 pH, 150-195 µmhos/cm conductivity, and 4-9 ppm surface DO.

The upper Tanana River watershed is made up of regions flowing into the Tanana River, Bitters Creek, Beaver Creek, and the Kalutna River. The Tanana River originates at the confluence of the Chisana and Nabesna rivers; its aquatic habitats, fish, sediments, and water quality are similar to those rivers.

Threats to Refuge Resources

Section 304(g)(2E) of ANILCA mandates identification and description of problems that may adversely affect refuge fishery resources and wildlife populations. On the Tetlin NWR, potential problems include development of extensive inholdings and adjacent private lands, and mining to extract abundant mineral resources existing both within the refuge and on adjacent lands (U.S. Fish and Wildlife Service 1987). In particular, placer gold or other types of mining on inholdings, or across the international or refuge borders, could affect water quality, fish and wildlife populations and their habitats within the refuge.

Placer mining for gold and other heavy metals grew dramatically in Alaska since the early 1970's when Federal restrictions on gold prices were lifted. As of 2004, there were no active mining claims on Tetlin NWR, but mining prospects on allotments within and near the refuge boundaries are currently being investigated. There are no large metal mines currently operating in the Yukon Territories, Canada (http://mmsd1.mms.nrcan.gc.ca/mmsd/producers/default_e.asp, accessed 6 June 2005), but a large-scale hydraulic mine on a tributary of Scottie Creek, one of
the most productive drainages for waterfowl breeding on the Refuge, was active as late as 2000 (B. Johnson, pers. comm.). Several mining operations also exist in the Chisana River and Scottie Creek drainages bordering the refuge. There are three active placer mines in Wrangell-Saint Elias NPP that could potentially affect Tetlin NWR; Bonanza Creek, the Nabsenca River, and the White River. Future placer mining is expected in the mineral-rich Nutzotin and Mentasta mountains along the southwestern and southern boundaries of the refuge, and near the village of Northway, as the economy, regulations, or extraction processes change. In particular, the Road Metal prospect near Northway has considerable development potential (http://www.dggs.dnr.state.ak.us/scan1/ic/text/IC48.PDF, accessed 6 June 2005).

Placer operations destroy river habitats by the direct removal or relocation of substrate, downstream deposition of sediment loads, and mobilization of toxic metals. Large amounts of overburden are removed in the placer mining process to extract gold from ancient alluvia; this often disturbs active stream beds. Placer mining can also cause channelization, changing pool-and-riffle reaches into long, straight chutes of water unsuitable for spawning habitat. Such physical changes can cause even an uncontaminated stream to be relatively sterile. Unless it is treated ("recycled"), water used to sort the gold from the lighter materials and other uncontrolled surface and groundwater discharges at the mine site result in sediment-rich effluent. Sediment-rich mine effluent, transported in suspension and as bedload, causes highly turbid water and blankets the stream bottom with a layer of fines unsuitable for benthic aquatic life and fish spawning (Bjerklie and LaPerriere 1985; Wagener and LaPerriere 1985; LaPerriere et al. 1985; Van Nieuwenhyse and LaPerriere 1986; Lloyd 1987; Lloyd et al. 1987). In addition, mining activities may mobilize toxic metals such as arsenic, cadmium, copper, lead, mercury, and zinc, thus making them more available for biological uptake (LaPerriere et al. 1985). Studies typically show higher total and dissolved metal concentrations in water from non-rehabilitated or actively mined watersheds compared to unmined, with copper, zinc, lead and arsenic commonly found in association with placer mining (Madison 1981, LaPerriere et al. 1985) in interior Alaska. Other toxic metals that may be mobilized by placer mining include mercury, antimony, aluminum, cadmium, chromium, iron, manganese, nickel, selenium, and silver.

Plant, invertebrate, and fish abundance and productivity decline in streams with placer impacts (Cordone and Kelley 1961; Wagener and LaPerriere 1985; Van Nieuwenhyse and LaPerriere 1986; Lloyd et al. 1987). Many metals, especially copper, zinc, and mercury, are more bioavailable in waters with low alkalinity and low hardness, such as those on the Tetlin NWR. Copper and zinc in water and sediment may concentrate in fish and can result in increased susceptibility to disease (U.S. Environmental Protection Agency 1985a). Arctic grayling in mined streams exhibited higher metal concentrations and greater propensity for liver and cellular abnormalities compared to fish from control streams (West 1982; West and Deschu 1984). Copper-containing water from mined streams was acutely toxic to early life stages of fish, with arctic grayling from Alaska being more sensitive than Montana arctic grayling or other species tested (Buhl and Hamilton 1990). Mercury, absorbed through the gills and skin into the bloodstream, concentrates in the muscles for long-term storage (U.S. Environmental Protection Agency 1985b), and can affect spawning success and therefore productivity. Mercury at high
concentrations in fish tissue is also a potential concern for human consumers, especially subsistence users in Alaska who eat large amounts of fish.

**Study Objectives**

In response to historic and proposed mining activities, this study was initiated to establish baseline water quality and heavy metal concentrations in water, sediments, and fish from drainages with mining potential or history in Tetlin NWR.

The study objectives were to: 1) Establish permanent monitoring sites, in historic or proposed mined and reference drainages, on the major streams and rivers of the Tetlin NWR and determine baseline water quality and trace metal concentrations in water, sediment, and fish at these sites; and 2) Evaluate the effects of metal concentrations for each site, based on mining status and underlying geology as indexed by source (glacial or clear water), on Refuge resources including fish, invertebrates, and their habitats.

**Methods**

**Study Area**

The study area included numerous drainages within Tetlin NWR, located in eastern Alaska (Fig. 1). Sample sites are described in Table 1.

<table>
<thead>
<tr>
<th>Site Name (Number)</th>
<th>Year</th>
<th>Description</th>
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<tbody>
<tr>
<td>Nabesna River (1)</td>
<td>1987</td>
<td>On the south Refuge boundary, east side of main channel immediately upstream of high cliff face in T. 9 N, R. 16 E, Sec. 20, NE 1/4, Copper River Meridian (CRM), 62° 32' 53&quot;N, 142° 26' 58&quot; W</td>
</tr>
<tr>
<td></td>
<td>1989</td>
<td>East side of east channel, approximately 0.6 km west of Jimmy Brown Lake in T. 8 N, R. 15 E, Sec. 10, SE 1/4, CRM, 62° 29' 00&quot;N, 142° 35' 42&quot;W</td>
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<td></td>
<td>1992</td>
<td>South end of small island in main channel, approx. 0.5 km north of 1987 site in T. 9 N, R. 16 E, Sec. 17, SE 1/4, CRM, 62° 33' 00&quot;N, 142° 26' 54&quot; W (GPS)</td>
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<tr>
<td>Stuver Creek (2)</td>
<td>1987</td>
<td>On the south Refuge boundary, east bank directly across from the mouth of Ellis Creek in T. 9 N, R. 19 E, Sec. 34, SE 1/4, CRM, 62° 30' 58&quot;N, 141° 49' 07&quot; W (GPS)</td>
</tr>
<tr>
<td>Site Name (Number)</td>
<td>Year</td>
<td>Description</td>
</tr>
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<td>-------------------------</td>
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<tr>
<td>Chisana River (4)</td>
<td>1987</td>
<td>On the south Refuge boundary, west bank directly opposite Hill 2290 in T. 9 N, R. 21E, Sec. 32, NW 1/4,</td>
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<td></td>
<td>1989</td>
<td>CRM, 62°31’20&quot;N, 141° 30' 48&quot; W (GPS)</td>
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<td></td>
<td>1992</td>
<td></td>
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<tr>
<td>Mirror Creek (5)</td>
<td>1987</td>
<td>On the Canadian border, south bank immediately below large tributary stream in T. 9 N, R. 23 E, Sec. 36, NE 1/4,</td>
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<td></td>
<td>1988</td>
<td>CRM, 62° 31' 11&quot;N, 141° 00' 12&quot; W</td>
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<td></td>
<td>1989</td>
<td>T. 9 N, R. 23 E, Sec. 22, SW 1/4, CRM, 62 ° 32' 36&quot;N, 141° 04' 42&quot; W.</td>
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<td></td>
<td>1992</td>
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<tr>
<td>Scottie Creek (6)</td>
<td>1987</td>
<td>On the north bank about 200 yards downstream from the Alaska Highway Bridge in, T. 10 N, R. 23 E, Sec. 24, NW</td>
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<tr>
<td></td>
<td>1989</td>
<td>1/4, CRM, 62° 38' 21&quot;N, 141° 01' 45&quot; W</td>
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<td></td>
<td>1992</td>
<td></td>
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<tr>
<td>Desper Creek (7)</td>
<td>1987</td>
<td>On the Alaska highway at boat ramp on south bank of creek immediately below the highway in T. 10 N, R. 23 E,</td>
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<td></td>
<td>1989</td>
<td>Sec. 11, SW 1/4, CRM, 62° 39' 45&quot;N, 141° 03' 36&quot; W.</td>
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<td>1992</td>
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<tr>
<td>Gardiner Creek (8)</td>
<td>1987</td>
<td>On the Alaska highway immediately below wayside pullout on east bank of creek, south of the highway in T.</td>
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<td></td>
<td>1989</td>
<td>12 N, R. 21 E, Sec. 3, NW 1/4, CRM, 62° 51' 15&quot;N, 141° 27' 29&quot; W.</td>
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<td></td>
<td>1992</td>
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<td>Moose Creek (9)</td>
<td>1987</td>
<td>On the south bank about 50 yards upstream from the confluence with Chisana River in T. 14 N, R. 19 E, Sec. 9,</td>
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<td></td>
<td>1989</td>
<td>NE 1/4, CRM, 63° 00' 44&quot;N, 141° 48' 57&quot; W</td>
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<td></td>
<td>1992</td>
<td>Three miles upstream from the confluence of the Chisana River, about 1/4 mile upstream of Fish Camp Creek in T.</td>
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<td>Yellow Water Creek (10)</td>
<td>1988</td>
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<td>1992</td>
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<tr>
<td>S. Cheslina River (11)</td>
<td>1987</td>
<td>On the west bank immediately upstream at junction with Wolf Den Creek in T. 11 N, R. 16 E, Sec. 23, SE 1/4,</td>
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<td></td>
<td>1992</td>
<td>CRM, 62° 42' 52&quot;N, 142° 20' 56&quot; W (GPS)</td>
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<td></td>
<td>1989</td>
<td>On the south bank, in T. 11 N, R. 16 E, Sec. 24, SE 1/4, CRM, 62° 43' 00&quot;N, 142° 19' 00&quot; W.</td>
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### Sample Collection

Not all sample matrices were collected at all sites in all years (Table 2). Water samples were collected for analysis of water quality variables for most sites in most years (1987-1989, 1992). Sediment and water samples were collected for metals analysis for most sites in all study years. Fish tissue samples for metals analysis were collected when and where fish could be caught.

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**Table 2.** Sites (numbers referenced in Table 1) for baseline water quality and contaminant data collection in Tetlin National Wildlife Refuge, Alaska, 1987-92. Not all data were collected at all sites in all years.

<table>
<thead>
<tr>
<th>Site Name (Number)</th>
<th>Year</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N. Cheslina River (12)</td>
<td>1987</td>
<td>On the west bank approximately one half mile below the cabins at the mouth of Fern Creek overflow near the site where a hillside comes close to the west bank in T. 11 N, R. 17 E, Sec. 19, NE 1/4, CRM, 62° 43' 37&quot;N, 142° 17' 18&quot; W (GPS)</td>
</tr>
<tr>
<td></td>
<td>1989</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1992</td>
<td></td>
</tr>
<tr>
<td>Tanana River (13)</td>
<td>1987</td>
<td>On the south bank immediately upstream of the junction with the Kalutna River in T. 16 N, R. 16 E, Sec. 22, NE 1/4, CRM, 63° 09' 33&quot;N, 142° 21' 02&quot; W (GPS)</td>
</tr>
<tr>
<td></td>
<td>1989</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1992</td>
<td></td>
</tr>
</tbody>
</table>

---

**Metals in Water**

<table>
<thead>
<tr>
<th>Year</th>
<th>Water Quality</th>
<th>Total</th>
<th>Total</th>
<th>Dissolved</th>
<th>Metals in Sediment</th>
<th>Metals in Fish</th>
</tr>
</thead>
<tbody>
<tr>
<td>1987</td>
<td>1-9, 11-13</td>
<td>1-9, 11-13</td>
<td>1</td>
<td>9, 11</td>
<td>13</td>
<td>1, 6-9, 13</td>
</tr>
<tr>
<td>1988</td>
<td>5, 10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>1989</td>
<td>1-9, 11-13</td>
<td>none</td>
<td>1</td>
<td>9, 11</td>
<td>6-9, 13</td>
<td></td>
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<tr>
<td>1992</td>
<td>1-13</td>
<td>1-8, 10-13</td>
<td>1-8, 10-14</td>
<td>1-13</td>
<td>5-9, 13</td>
<td></td>
</tr>
</tbody>
</table>

**Water Quality:** Water quality data were collected during one or more sample periods in September, 1987 and 1989, May 1988, and August, 1992. Triplicate 500 mL grab samples were collected from just below the surface in 1987, 1988, 1989 (except 1 L samples for total settleable solids), and 1992 (except 1 L samples for total suspended and total settleable solids). Bottles were completely filled to minimize gaseous exchange. Each bottle was labeled immediately prior to collection and placed in a cooler with ice or snow for transport to a field laboratory for analysis.

In all years, pH, total alkalinity, total hardness, conductivity, turbidity, suspended solids, and settleable solids were measured, plus DO in 1988. Water pH was measured with either a VWR portable digital pH meter (1987 - 1989) or a Hach One digital pH meter (1992), both equipped
with a combination electrode and automatic temperature compensation. Prior to each measurement series, two-buffer calibrations were performed using buffers that bracketed the sample pH. Hardness and alkalinity were determined with a Hach digital titrator and Hach standards. Conductivity was measured with a Hach DREL/5 conductivity meter with automatic temperature compensation to 25°C, calibrated prior to each measurement series with Hach standards.

Turbidity was measured using a Hach Portable Turbidity Meter Model 16800, calibrated with Gelex secondary standards for 1, 10, and 100 nephelometric turbidity units (NTU). Total suspended solids (TSS) samples were sent to a commercial laboratory (Northern Testing Laboratories, Fairbanks, AK). Total settleable solids were measured using the Imhoff Cone Method for 1 L samples (APHA et al. 1989). If settleable solids did not exceed 0.1 mL/L, "trace" or <0.3 was recorded.

**Metals in Water:** Surface grab samples were collected in triplicate (except for 1989 with one bottle per site, except site 6 where samples were collected in triplicate) just below the water surface in 250 ml or 500 ml (1992) precleaned bottles. Bottles were completely filled to minimize gaseous exchange. Each bottle was labeled immediately prior to collection and placed in a cooler with ice or snow for transport to a field laboratory for preparation for total, recoverable, and dissolved metals analysis.

Dissolved metals samples were filtered in the field laboratory using 0.8-μm prefilters and 0.45 μm cellulose acetate syringe filters with Luerlock fittings (approximately 250 ml). Samples for total metals, total recoverable metals, and dissolved metals analysis were acidified in the field to a pH <2 with 1-2 mL concentrated pure nitric acid (HNO₃) (Ultrix). In 1987 and 1989 replicate water samples for total metals and total recoverable metals were collected at each site in a single previously unused 500-mL acid-precleaned high-density polyethylene bottles (I-Chem) and split in the laboratory; in 1988 all replicates were collected and remained in separate bottles. In 1988, dissolved metals samples (n=3) could not be filtered in the field due to excessive suspended solids, so were allowed to settle for 72 hours, filtered as above (final volume approximately 120 mL), then acidified.

Total metals were analyzed after a vigorous acid digestion and included all metal molecules in the sample; recoverable metals were analyzed after a weak acid digestion and included free and particulate-bound but not silicate-bound molecules, and dissolved metals were analyzed on an unacidified but filtered sample. All three analyses were done because of their usefulness in a variety of toxicity comparisons; for example, dissolved metals represent only completely bioavailable metals.

**Sediment:** Three samples were collected from shore at each site, except in 1989 only one sample was collected at sites 1-5 and 7-13. Samples were collected in areas of fine silt with a stainless steel strainer, mixed in a plastic bucket, and placed in acid cleaned 500 mL I-Chem polyethylene bottles with teflon-lined lids. Sample bottles were labeled immediately prior to collection,
placed in a cooler with ice or snow for transport, and stored frozen.

**Fish:** Fish were collected by angling or experimental monofilament gillnet (mesh sizes varied from 1/4 inch to 1-1/2 inch) depending on the site and stream conditions. Target fish species included Arctic grayling and northern pike; however, humpback whitefish, burbot, and longnose sucker were also caught and analyzed. Fish were stripped from the net or taken from the line and placed in plastic garbage bags; then individually wrapped in plastic bags or plastic wrap. Fish samples were weighed (g), and total and fork lengths measured (mm). Liver, kidney, and muscle samples were extracted with stainless steel instruments from fish longer than approximately 400 mm; smaller fish were bagged and analyzed as whole samples. Tissues were extracted either in the laboratory in (1987, 1988) or in the field (1989, 1992). Sample bottles were labeled immediately prior to collection, placed in a cooler with ice or snow for transport, and stored frozen.

All samples were shipped from the field in coolers filled with ice or snow. Sediments and fish tissues were frozen as soon as possible, stored frozen, and shipped to the analytical laboratory via overnight mail on blue or dry ice. A “catalog” or list of samples was prepared and approved prior to sample shipment. This contained a regional identifier for the sample batch, study objectives, instructions to the laboratory on analyses requested and detection limits, and a tabulated summary for each sample including species, tissue type, collection location, collection date, weight, and other variables.

**Chemical Analysis**

Except where noted, aluminum (Al), antimony (Sb), arsenic (As), boron (B), barium (Ba), beryllium (Be), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), mercury (Hg), magnesium (Mg), manganese (Mn), molybdenum (Mo), nickel (Ni), lead (Pb), selenium (Se), silver (Ag), tin (Sn), strontium (Sr), thallium (Tl), vanadium (V) and zinc (Zn) were analyzed. Mercury was analyzed by cold vapor atomic absorption (AA) spectrometry. Arsenic and Se in water were analyzed by graphite furnace AA and by hydride generation/graphite furnace AA in sediments and tissue. All other metals were analyzed by inductively coupled plasma (ICP) spectrometry. Three different laboratories were used over the four sampling years because of differing availability (although use of different laboratories would no longer be tolerated because of the high probability of data quality differences).

1987 and 1992: Metals in water, sediments, and fish were analyzed by Environmental Trace Substances Research Center, University of Missouri (Columbia, MO). Sediment samples were mixed and large fish tissue samples were ground in a meat grinder. Sample aliquots were weighed, freeze-dried (Labcono Freeze Dryer 8), weighed and further homogenized (Spex Industries, Inc. Model 8000 mixer/mill with tungsten-carbide vial and balls), then slowly acid-digested in 100 mL glass beakers with sub-boiled nitric (HNO3), perchloric (HClO4), and hydrochloric (HCl) acids. Analysis instruments and methods included: Graphite furnace AA (either a Perkin-Elmer Model 3030B with HGA-500 graphite furnace or a Perkin-Elmer Model
5100 Seeman with HGA-600 graphite furnace); hydride generation/graphic furnace AA (Perkin-Elmer MHS-1 hydride generation accessory mounted on either a Perkin-Elmer 603 AA or 3030(B) AA); cold vapor AA (Perkin-Elmer Model 403 AA); and ICP (Jarrell-Ash Model 1100) according to Standard Methods (APHA et al. 1989).

1988: Metals in water, sediments, and fish were analyzed by Versar, Inc. (Springfield, VA). Arsenic and selenium in water, and in tissue and sediments were analyzed by AA following Kopp and McKee (1983) and Krynitsky (1987), respectively. For tissues, mercury digestion and analysis followed the wet ash mercury procedure used by Patuxent Analytical Control Facility in 1988; for water and sediments, mercury analysis used cold vapor AA. The graphite furnace AA digestates were analyzed using a Zeeman background correction. ICP analysis for all other samples followed Mavrodineanu (1977) or Kopp and McKee (1983).

1989: Metals in water, sediments, and fish were analyzed by Hazleton Laboratories America, Inc. (Madison, WI). Arsenic and selenium was determined by graphite furnace AA, with tissue samples digested with nitric acid in a microwave digester and sediment and water samples digested with nitric acid and hydrogen peroxide. Prior to cold vapor AA (with a MHS-20 hydride generation unit) for mercury analysis, water samples were digested with sulphuric acid, potassium permanganate, and potassium persulfate, and tissue and sediment samples were digested with a mixture of sulfuric and nitric acid and reduced with sodium borohydride. Analysis for all other elements was by ICP spectroscopy after nitric acid digestion, reduction, and filtration.

Quality Assurance/Quality Control (QA/QC): Laboratory quality assurance/quality control (QA/QC) procedures included duplicate (split) samples, spiked samples, standard reference materials (SRMs), and blanks. Data were considered acceptable if they had relative percent difference (RPD) of duplicate analyses ≤20%, spike recovery of 80 - 120%, SRM within ±20% of the certified mean, and mean blank ≤15% of the mean duplicate value or < the Limit of Detection (LOD). Analyte/matrix combinations that did not pass these QA/QC criteria, or that were deemed unsound by the reporting laboratory, were not presented, summarized, or used.

Data Analysis

Discrepancies among catalogs from different laboratories required resolution prior to presenting or analyzing data. First, detection limits often varied among years, so upon combination any data less than highest reasonable detection limit were considered non-detections. Second, total recoverable metals concentrations (from filtered water) were sometimes greater than total metals concentrations (from unfiltered samples); the same was true for dissolved and total recoverable concentrations. These were resolved by a case-by-case evaluation and removal of the affected data. Third, not every matrix was sampled at each site every year, and many data did not meet QA/QC criteria. This resulted in many data gaps and inadequate data for statistical comparisons

2 No reference for this procedure was found.
between mined and unmined drainages, so these comparisons had to be made graphically. However, statistical comparisons could be made between glacial (Nabesna River, Chisana River, Moose Creek, and Tanana River) and clearwater (Stuver Creek, Alder Creek, Mirror Creek, Scottie Creek, Desper Creek, Gardiner Creek, Yellow Water Creek, S. Cheslina River, and N. Cheslina River) streams, since even normal sediment loading can affect both water quality and metals concentrations. For these comparisons, Multivariate Analysis of Variance (MANOVA) tested differences in metals detected in 100% of samples, using a backwards stepwise model resulting in the most parsimonious significant model. In this analysis, individual metals are determined to be significantly different between groups if they are included in a significant multivariate model (Wilks' lambda multivariate statistic $P < 0.05$) and have a univariate $P$ (from the $F$ statistic) $< 0.15$. Non-parametric Kruskal-Wallis rank sum testing was used for metals detected less frequently but in at least 50% of samples, with alpha = 0.05. Concentrations of the more toxic metals were also compared to water quality standards and toxicity thresholds.

**Results and Discussion**

**Glacial and Clearwater Streams**

There were significant differences in metal concentrations between glacial and clear streams in abiotic matrices. In sediments ($P = 0.034$), Cr, Cu, and Mg were all greater in glacial streams (univariate $P = 0.101$, 0.019, and 0.125, respectively), and Zn was lower (univariate $P = 0.026$). Arsenic, Ba, Sr, and V were also greater in sediments from glacial streams, although the differences were not significant in the multivariate model (all univariate $P > 0.15$). In water, total Fe, Mg, and Sr concentrations were greater in glacial streams, significantly so for Fe and Mg ($P = 0.009$; univariate $P = 0.001$, 0.007, 0.447, respectively). Although not detected in all water samples, total Ba, Mn, and Zn were also significantly greater in glacial streams ($P = 0.025$, $<0.001$, and $<0.001$, respectively). Significant differences between glacial and clearwater streams indicate that future sampling needs to take the stream type into account when designing new studies or comparing new data to the baseline data presented here.

However, northern pike (the only fish species with enough samples to compare statistically) from glacial streams did not have different metal concentrations compared to those from clear streams (liver, $P = 0.397$; muscle, $P = 0.444$). Northern pike are considered resident, but migrate on an annual basis between deep overwintering areas and shallow spring spawning areas, which can be quite distant (Morrow 1980). With the notable exception of mercury, most metals do not biomagnify (concentrate up the food chain).

**Mined and Unmined Drainages**

A statistical comparison of metals in mined compared to unmined drainages was not feasible, because of the unbalanced experimental design ($n=2$ mined drainages, Scottie and Yellow Water Creeks, and $n=11$ mined drainages), poor data quality, and lack of data on underlying geology in
each drainage. Graphical comparison between mined and unmined drainages showed no consistent pattern, except that Ba, Mn, and Cr appeared substantially greater in sediments from the mined sites (Fig. 2). Of the metals previously associated with interior Alaska placer mining (Cu, Zn, Pb, and As; Madison 1981, LaPerriere et al. 1985), Zn and As concentrations appeared slightly greater in sediments from mined sites, Cu concentrations appeared lower (Fig. 2), and Pb was not measured or detected in enough samples to make a comparison. In water, total Fe concentrations appeared greater in mined compared to unmined sites (although with high variability), but total Sr and B concentrations appeared lower (Fig. 3). Few conclusions can be drawn from these data regarding the effects of mining on metals concentrations in sediment and water metals concentrations at the time these samples were taken. However, these data still serve as useful baseline data for Scottie Creek and Yellow Water Creek for assessment of future mining impacts.

Effect Levels in Water

Measurements at some sites exceeded 2003 Alaska Water Quality Criteria (WQC) for protection of aquatic life.3 Comparisons are not exact because WQC are based on multiple measurements over a short time (days), compared with the sampling over years in this study. Further, the WQC themselves are often not specific to Alaska, a region with highly mineralized soils and therefore relatively high “background” concentrations of minerals in water, to which invertebrate communities may be adapted (Oswood et al. 1990). Some WQC also require additional parameters for interpretation, such as hardness and ammonia (NH₃). Nevertheless, they provide an estimate of the potential toxicity of waters to aquatic life, especially if measured concentrations greatly exceed the WQC.

Arsenic (As), Cr, Ni, and Se did not exceed their WQC. Aluminum (Al), Cd, and Zn WQC were exceeded by some samples, especially the highly turbid glacial sites on the Nabesna, Chisana, and Tanana rivers for all of the contaminants for most years (Table 3). The Hg WQC was exceeded at most sites (Table 3).

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3 Aquatic Life Freshwater Acute Criteria, from Alaska Water Quality Standards, 18 AAC 70.020(b), are based on a one-hour average of total recoverable metals. Criteria are hardness-dependent for cadmium, copper, lead, and zinc.
Fig. 2. Mean (+ SE) metals concentrations in sediments from streams with a history of mining (■, n=2) compared to those without (□, n=11) in Tetlin National Wildlife Refuge, Alaska, 1987-92.
Fig. 3. Mean (+ SE) metals concentrations in water from streams with a history of mining (■, n=2) compared to those without (□, n=11) in Tetlin National Wildlife Refuge, Alaska, 1987-92.
Table 3. Streams in which dissolved aluminum (Al), cadmium (Cd), mercury (Hg), and zinc (Zn) in water exceeded 2003 Alaska Water Quality Aquatic Life Freshwater Acute Criteria, Tetlin National Wildlife Refuge, Alaska, 1988-92.

<table>
<thead>
<tr>
<th>Site</th>
<th>Al</th>
<th>Cd</th>
<th>Hg</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glacial streams</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nabesna River</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Chisana River</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Tanana River</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Moose Creek</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clear streams</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stuver Creek</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yellow Water Creek</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scottie Creek</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All other sites</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

Effect Levels in Sediments

Sediment standards for the protection of aquatic life have not been promulgated for the state of Alaska. However, sediment data can be compared to Screening Quick Reference Tables (SQuiRTs), thresholds developed by the National Oceanic and Atmospheric Administration (NOAA). These are probabilistic toxicity estimates based on large compilations of published effect data on microorganisms and benthic communities. The threshold should be interpreted with some caution in Alaska because benthic biota may be adapted to mineralized soils. Nevertheless, SQuiRT thresholds are useful, especially if measured concentrations are much greater. Threshold levels of greatest concern are upper effects thresholds (UET), followed by probable effects level (PEL), then threshold effects level (TEL) for most organisms and specifically *Hyallela azteca* (TEL-HA). Specific thresholds and caveats for their use are available online (http://response.restoration.noaa.gov/cpr/sediment/sediment.html, accessed 6 June 2005).

Metal concentrations often exceeded the SQuiRTs, in both glacial and clear streams, although the greatest exceedances were in glacial streams for Ba and Cr (Table 4). Individual sites may also have had exceedances for metals that were not detected in every sample (and are therefore not reported in this general discussion). While these comparisons are not precise, the overall pattern indicates that streams on Tetlin NWR drain highly mineralized watersheds. While background metal concentrations on Tetlin NWR may be considered toxic to some biota, there may also be some degree of adaptation to the high metals for others (e.g. Oswood et al. 1990).
Table 4. Stream types, thresholds, and metals with concentrations in exceedance in streams on Tetlin National Wildlife Refuge, Alaska, 1987-92.

<table>
<thead>
<tr>
<th>Stream Type</th>
<th>Greatest SQuiRT(^1) Level Exceeded</th>
<th>Metal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glacial</td>
<td>Background</td>
<td>As, Fe, Mn, V, Zn</td>
</tr>
<tr>
<td></td>
<td>Threshold Effects Level – <em>H. azteca</em></td>
<td>Al, Sr</td>
</tr>
<tr>
<td></td>
<td>Threshold Effects Level</td>
<td>Cu</td>
</tr>
<tr>
<td></td>
<td>Upper Effect Threshold</td>
<td>Ba, Cr</td>
</tr>
<tr>
<td>Clear</td>
<td>Background</td>
<td>As, Ba, Fe, Mn, V, Zn</td>
</tr>
<tr>
<td></td>
<td>Threshold Effects Level – <em>H. azteca</em></td>
<td>Al, Sr</td>
</tr>
<tr>
<td></td>
<td>Threshold Effects Level</td>
<td>Cr, Cu</td>
</tr>
</tbody>
</table>

\(^1\) Screening Quick Reference Tables (SQuiRTs), thresholds developed by the National Oceanic and Atmospheric Administration (NOAA); see explanation in text. Thresholds have not been developed for B and Mg.

**Effect Levels in Fish**

Most metals in fish were at relatively low concentrations, including mercury concentrations, which were all below those that caused mortality or behavioral changes in a variety of adult fish species, including salmonids and northern pike (at 3-20 ppm wet weight; various refs. cited in Wiener and Spry 1996). Very few fish samples exceeded the Food and Drug Administration (FDA) action level of 1 ppm wet weight for methyl-mercury in edible tissues. However, these data are now more than a decade old. As with other arctic organisms, mercury may have increased during the intervening years and should be measured again, especially in northern pike, before current conclusions regarding effects can be made.

**Conclusions**

This study established water quality and metals concentrations in water, sediments, and fish, for glacial and clearwater streams within Tetlin NWR. The study sites, all on the major drainages of Tetlin NWR, have been established for use in future monitoring, although erosion and channel changes may necessitate slight changes in location. Future sampling may be conducted to determine impacts of development or other phenomena that introduce pollution to the Refuge, such as atmospheric deposition of mercury. While there weren’t enough data to test whether differences existed between mined and unmined drainages, and consequently the effects of placer mining, others evaluations were made. In particular, some metals in water and sediments, especially in glacial streams, exceeded toxicity thresholds (with the caveat that native aquatic biota may be adapted to highly mineralized Alaskan waters). Additionally, if active mining were to occur in the Scottie Creek or Yellow Water Creek drainages, these are useful pre-impact baseline data (especially if combined with more recent pre-impact sampling to account for atmospheric deposition since 1992).
Mercury in fish is of particular concern. It is toxic to organisms at many trophic levels, including fish and their consumers. In the years since these data were collected, mercury has emerged as one of the few persistent contaminants that is increasing, rather than decreasing, in arctic biota, and is of special concern in species used for subsistence. While the measured concentrations in fish in this study were low, these data cannot be used to illustrate current conditions. Queries regarding the effects of mercury on fish populations and their suitability as subsistence foods should be answered with current data, which would account for potential increases over time.

**Literature Cited**


West, R. L. and N. A. Deschu. 1984. Kantishna Hills heavy metals investigations, Denali


Table A-1. Quality assurance/quality control (QA/QC) evaluation for metals in sediments from Tetlin National Wildlife Refuge, AK, 1987-92. For each year and analyte, the lower limit of detection (LOD) (ppm, dw) is given if QA/QC criteria were met; the highest of these was used as the overall LOD for that analyte and matrix. Other entries include: Not analyzed (NA); rejection due to poor duplicate precision (DUP); rejection due to poor standard reference material recovery (SRM); rejection due to poor spike recovery (SPIKE); and rejection by analytical laboratory due to methodological problems (LAB).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum (Al)</td>
<td>SRM</td>
<td>50.0</td>
<td>SRM</td>
<td>10.0</td>
</tr>
<tr>
<td>Antimony (Sb)</td>
<td>NA</td>
<td>LAB</td>
<td>13.4</td>
<td>NA</td>
</tr>
<tr>
<td>Arsenic (As)</td>
<td>1.00</td>
<td>SRM</td>
<td>0.27</td>
<td>SRM</td>
</tr>
<tr>
<td>Boron (B)</td>
<td>SPIKE</td>
<td>NA</td>
<td>6.72</td>
<td>NA</td>
</tr>
<tr>
<td>Barium (Ba)</td>
<td>0.10</td>
<td>0.50</td>
<td>SRM</td>
<td>0.40</td>
</tr>
<tr>
<td>Beryllium (Be)</td>
<td>0.10</td>
<td>0.10</td>
<td>0.67</td>
<td>0.40</td>
</tr>
<tr>
<td>Cadmium (Cd)</td>
<td>0.80</td>
<td>SRM</td>
<td>0.67</td>
<td>0.80</td>
</tr>
<tr>
<td>Chromium (Cr)</td>
<td>2.00</td>
<td>1.00</td>
<td>SRM</td>
<td>4.00</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>0.40</td>
<td>0.50</td>
<td>3.36</td>
<td>0.80</td>
</tr>
<tr>
<td>Iron (Fe)</td>
<td>40.0</td>
<td>10.0</td>
<td>13.4</td>
<td>6.00</td>
</tr>
<tr>
<td>Mercury (Hg)</td>
<td>0.02</td>
<td>0.10</td>
<td>0.067</td>
<td>0.01</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>4.00</td>
<td>20.0</td>
<td>SRM</td>
<td>0.50</td>
</tr>
<tr>
<td>Manganese (Mn)</td>
<td>0.90</td>
<td>0.50</td>
<td>1.69</td>
<td>0.80</td>
</tr>
<tr>
<td>Molybdenum (Mo)</td>
<td>4.00</td>
<td>1.00</td>
<td>6.72</td>
<td>4.00</td>
</tr>
<tr>
<td>Nickel (Ni)</td>
<td>2.00</td>
<td>2.00</td>
<td>DUP</td>
<td>4.00</td>
</tr>
<tr>
<td>Lead (Pb)</td>
<td>5.00</td>
<td>5.00</td>
<td>4.03</td>
<td>20.0</td>
</tr>
<tr>
<td>Selenium (Se)</td>
<td>SRM</td>
<td>SRM</td>
<td>0.27</td>
<td>0.10</td>
</tr>
<tr>
<td>Silver (Ag)</td>
<td>2.00</td>
<td>1.00</td>
<td>6.72</td>
<td>NA</td>
</tr>
<tr>
<td>Strontium (Sr)</td>
<td>0.10</td>
<td>NA</td>
<td>1.34</td>
<td>0.40</td>
</tr>
<tr>
<td>Tin (Sn)</td>
<td>NA</td>
<td>10.0</td>
<td>6.72</td>
<td>NA</td>
</tr>
<tr>
<td>Thallium (Tl)</td>
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Table A-2. Quality assurance/quality control (QA/QC) evaluation for total metals in water from Tetlin National Wildlife Refuge, AK, 1987-92. For each year and analyte, the lower limit of detection (LOD) (ppm, dw) is given if QA/QC criteria were met; the highest of these was used as the overall LOD for that analyte and matrix. Other entries include: Not analyzed (NA); rejection due to poor duplicate precision (DUP); rejection due to poor standard reference material recovery (SRM); rejection due to poor spike recovery (SPIKE); and rejection by analytical laboratory due to methodological problems (LAB).

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<td>0.025</td>
<td>NA</td>
</tr>
<tr>
<td>Beryllium (Be)</td>
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Table A-3. Quality assurance/quality control (QA/QC) evaluation for recoverable metals in water from Tetlin National Wildlife Refuge, AK, 1987-92. For each year and analyte, the lower limit of detection (LOD) (ppm, dw) is given if QA/QC criteria were met; the highest of these was used as the overall LOD for that analyte and matrix. Other entries include: Not analyzed (NA); rejection due to poor duplicate precision (DUP); rejection due to poor standard reference material recovery (SRM); rejection due to poor spike recovery (SPIKE); and rejection by analytical laboratory due to methodological problems (LAB).

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<td>NA</td>
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<td>SRM</td>
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<td>NA</td>
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<td>0.015</td>
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<td>SRM</td>
</tr>
<tr>
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<td>SRM</td>
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<td>0.002</td>
</tr>
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<td>NA</td>
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</tr>
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<td>NA</td>
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</tr>
<tr>
<td>Nickel (Ni)</td>
<td>RECOV &gt; TOTAL&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>NA</td>
<td>0.002</td>
</tr>
<tr>
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<td>DUPS, SRM</td>
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<td>NA</td>
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<tr>
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<sup>a</sup> Recoverable values in water greater than total values in water.
Table A-4. Quality assurance/quality control (QA/QC) evaluation for dissolved metals in water from Tetlin National Wildlife Refuge, AK, 1987-92. For each year and analyte, the lower limit of detection (LOD) (ppm, dw) is given if QA/QC criteria were met; the highest of these was used as the overall LOD for that analyte and matrix. Other entries include: Not analyzed (NA); rejection due to poor duplicate precision (DUP); rejection due to poor standard reference material recovery (SRM); rejection due to poor spike recovery (SPIKE); and rejection by analytical laboratory due to methodological problems (LAB).

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<td>SRM</td>
</tr>
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<td>SRM</td>
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<td>0.001</td>
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<td>0.003</td>
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</tr>
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<td>0.002</td>
</tr>
<tr>
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<td>0.013</td>
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</tr>
<tr>
<td>Iron (Fe)</td>
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<td>DUP</td>
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<td>0.03</td>
</tr>
<tr>
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<td>0.0002</td>
<td>0.0004</td>
<td>0.0003</td>
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<td>DISS &gt; RECOV</td>
</tr>
<tr>
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<td>0.01</td>
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<tr>
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<td>NA</td>
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<td>0.01</td>
</tr>
<tr>
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<td>0.01</td>
<td>0.02</td>
<td>0.001</td>
</tr>
<tr>
<td>Lead (Pb)</td>
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<td>0.015</td>
<td>DISS &gt; RECOV</td>
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<td>0.0025</td>
<td>0.001</td>
<td>0.0005</td>
</tr>
<tr>
<td>Silver (Ag)</td>
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<td>NA</td>
<td>0.025</td>
<td>NA</td>
</tr>
<tr>
<td>Strontium (Sr)</td>
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<td>NA</td>
<td>0.005</td>
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</tr>
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<td>NA</td>
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<tr>
<td>Vanadium (V)</td>
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<td>NA</td>
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<td>0.003</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>DUP</td>
<td>SRM</td>
<td>SPIKE</td>
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<sup>A</sup> Dissolved values in water greater than total values in water.

<sup>B</sup> Dissolved values in water greater than recoverable values in water.
Table A-5. Quality assurance/quality control (QA/QC) evaluation for metals in fish tissues (whole fish, muscle and liver) from Tetlin National Wildlife Refuge, AK, 1987-92. For each year and analyte, the lower limit of detection (LOD) (ppm, dw) is given if QA/QC criteria were met; the highest of these was used as the overall LOD for that analyte and matrix. Other entries include: Not analyzed (NA); rejection due to poor duplicate precision (DUP); rejection due to poor standard reference material recovery (SRM); rejection due to poor spike recovery (SPIKE); and rejection by analytical laboratory due to methodological problems (LAB).

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<td>LAB</td>
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<td>Tin (Sn)</td>
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Appendix B, Table B-1. Summary statistics for metal concentrations (ppm, dw) in sediment collected from Tetlin National Wildlife Refuge, AK, 1987-1992. Shown are number of samples per site (N) that met QA/QC criteria, and summary statistics. When a portion of the data were below the detection limit, the minimum is given as “nd” (non-detect), and the median was calculated rather than the mean and standard deviation (SD). No statistics were calculated when all data were below the detection limit. Antimony, molybdenum, silver, and thallium are not included as they were detected in few or no samples.

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<th>Be</th>
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<th>Cr</th>
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<th>Fe</th>
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## Appendix B, Table B-1. Metals in sediments (cont.)

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|                    |           |     |      |      |     |     |     |     |     |     |     |     |
| S. Cheslina River  | Minimum   | 75200 | 7.6  | 13.17 | 93 | nd  | nd  | 43  | 40  | 42297 | nd  |
|                    | Maximum   | 76800 | 28.7 |       | 788 | 5.0 | 77  | 69  | 44900 | 0.15 |
|                    | Median    | 75600 | 8.4  |       | 402 | 2.2 | 58  | 47  | 43900 | 0.06 |
|                    | Mean      | 75867 | 13.3 |       | 426 |     | 59  | 54  | 43671 |     |
|                    | SD        | 833  | 10.3 |      | 360 |     | 16  | 11  | 885  |     |
|                    |           | 3    | 4    | 1    | 6  | 7   | 7   | 6   | 7   | 7   | 7   |
|                    | Minimum   | 70800 | 7.1  | 8.95 | 76 | nd  | nd  | 39  | 43  | 40500 | nd  |
|                    | Maximum   | 76400 | 29.8 |       | 819 | 5.3 | 97  | 66  | 47225 | 0.07 |
|                    | Median    | 75300 | 8.0  |       | 413 | 2.2 | 0.8 | 55  | 51  | 43500 | 0.05 |
|                    | Mean      | 74167 | 13.2 |       | 418 |     | 58  | 54  | 43718 |     |
|                    | SD        | 2967 | 11.1 |      | 362 |     | 18  | 9   | 1968 |     |
|                    |           | 3    | 4    | 1    | 6  | 7   | 7   | 6   | 7   | 7   | 7   |
|                    | Minimum   | 75400 | 3.7  | 10.85 | 136 | nd  | nd  | 21  | 40  | 24500 | nd  |
|                    | Maximum   | 76900 | 22.6 |       | 555 | 3.8 | 120 | 81  | 46500 |     |
|                    | Median    | 75600 | 4.4  |       | 354 | 1.9 | 64  | 61  | 29200 |     |
|                    | Mean      | 75967 | 8.8  |       | 348 |     | 68  | 61  | 35285 |     |
|                    | SD        | 814  | 9.2  |      | 216 |     | 47  | 15  | 9439 |     |
|                    |           | 3    | 4    | no data | 6 | 7   | 7   | 6   | 7   | 7   | 7   |
|                    | Minimum   | 73900 | 3.7  |       | 716 | 2   | nd  | 83  | 41  | 42100 | nd  |
|                    | Maximum   | 75700 | 8.0  |       | 823 | 2   |     | 100 | 46  | 45100 |     |
|                    | Median    | 74500 | 4.4  |       | 808 | 2   |     | 84  | 46  | 44400 |     |
|                    | Mean      | 74700 | 8.8  |       | 782 | 2   |     | 89  | 44  | 43867 |     |
|                    | SD        | 917  | 9.2  |      | 58  |     | 10  | 3   | 1570 |     |

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Appendix C. Summary statistics for metal concentrations in water collected from Tetlin National Wildlife Refuge, AK, 1987-92. Shown are number of samples per site (N) that met QA/QC criteria, and summary statistics. When a portion of the data were below the detection limit, the minimum is given as “nd” (non-detect), and the median was calculated rather than the mean and standard deviation (SD). No statistics were calculated when all data were below the detection limit.

Table C-1. Summary statistics for total metal concentrations (mg/L) in water collected from Tetlin National Wildlife Refuge, AK, 1987-1992. Antimony, beryllium, mercury, molybdenum, silver, thallium, and tin were detected in few or no samples. No samples were collected from Yellow Water Creek.

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Table C-2. Summary statistics for dissolved metal concentrations (mg/L) in water collected from Tetlin National Wildlife Refuge, AK, 1987-1992. No data were available for boron. Antimony, beryllium, copper, mercury, molybdenum, nickel, lead, silver, thallium, tin, and vanadium were detected in few or no samples.

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Appendix D: Summary statistics for metal concentrations in fish collected from Tetlin National Wildlife Refuge, AK, 1987-92. Shown are number of samples per site (N) that met QA/QC criteria, and site summary statistics. When a portion of the data were below the detection limit, the minimum is given as “nd” (non-detect), and the median was calculated rather than the mean and standard deviation (SD). No statistics were calculated when all data were below the detection limit.

Table D-1. Summary statistics for metal concentrations (ppm, dw) in whole fish collected in Tetlin National Wildlife Refuge, 1987-92. Beryllium, boron, cadmium, chromium, nickel, lead, and silver were detected in few or no samples.

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Table D-3. Summary statistics for metal concentrations (ppm, dw) in fish livers collected in Tetlin National Wildlife Refuge, 1987-92. Boron, barium, beryllium, chromium, nickel, lead, silver, and thallium were detected in few or no samples.

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