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Water-Quality Comparisons in the Greater Mooses Tooth Unit of the National Petroleum Reserve in Alaska, 2010 and 2023



Scientific Investigations Report 2024–5098

U.S. Department of the Interior
U.S. Geological Survey

Cover: Photograph showing the sampling location at Blackfish Creek, taken near Nuiqsut, Alaska, on June 28, 2023.
Back cover: Photograph showing Oil Creek and the Colville Delta drilling pad 5 oil-production facility, taken near Nuiqsut, Alaska, on June 28, 2023.
Photographs by Brent M. Hall, U.S. Geological Survey.

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Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
square kilometer (km^2)	247.1	acre
square kilometer (km^2)	0.3861	square mile (mi^2)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32.$$

Datums

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Supplemental Information

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of chemical constituents in water are given in either milligrams per liter (mg/L) or micrograms per liter (µg/L).

Abbreviations

BLM	Bureau of Land Management
GMT	Greater Mooses Tooth
NPR–A	National Petroleum Reserve in Alaska
UAF	University of Alaska Fairbanks
USGS	U.S. Geological Survey
VOC	volatile organic compound

Water-Quality Comparisons in the Greater Mooses Tooth Unit of the National Petroleum Reserve in Alaska, 2010 and 2023

By Brent M. Hall

Abstract

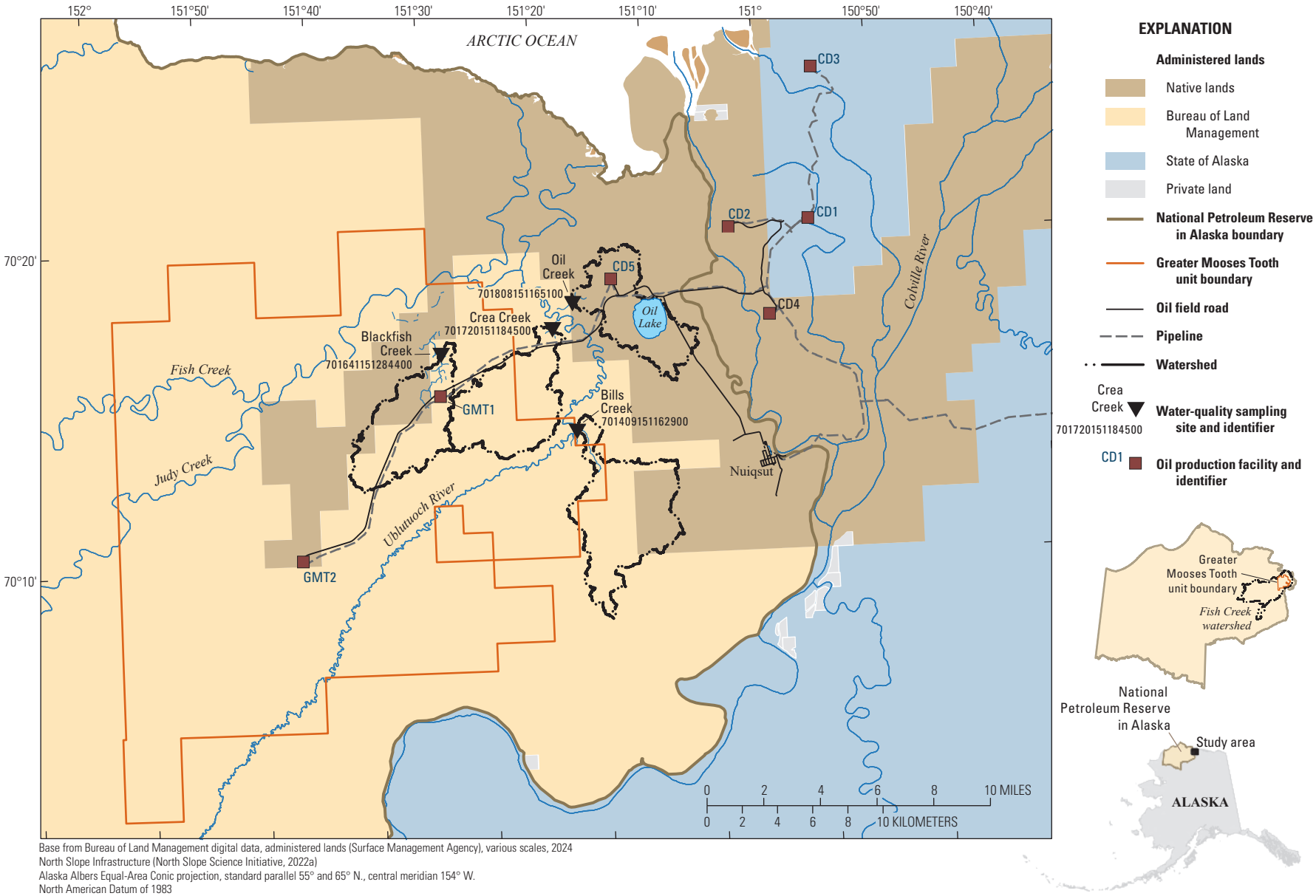
The United States has long held oil reserves in the National Petroleum Reserve in Alaska (NPR–A), but oil production did not begin until 2015. The waters of the NPR–A are generally considered "pristine," but water quality has not been characterized temporally or spatially in a rigorous manner. In 2010 and 2023, the U.S. Geological Survey, in cooperation with the Bureau of Land Management, collected water-quality samples from four small, beaded streams in the NPR–A, three of which currently (2024) have oil and gas infrastructure within their drainage. Samples collected preconstruction and postconstruction were analyzed and compared to determine concentration changes in nutrients, major ions, trace elements, and volatile organic compounds to evaluate the effectiveness of required operating procedures designed to minimize potential effects to water quality from oil and gas activities.

The four small streams in the Greater Mooses Tooth unit of the NPR–A had similar water-quality characteristics in the 2010 and 2023 samples. Most analytes were measured at low concentrations or below the reporting level for both samples. For analytes that were detected, variability between the two samples was generally low and mostly showed lower concentrations in the 2023 samples, possibly partially because of recent rainfall that led to streamflow being much higher at the time of the 2023 sample. Trichloromethane was present in the sample at one site in both years and at a second site in the 2023 sample. All three detections of trichloromethane were within the expected natural background range for the area. The few increases in analyte concentrations in the watersheds with oil and gas facilities were all within the range of predevelopment concentrations or background concentrations for the area.

Introduction

The presence of oil in north-central Alaska has been known since at least 1904 (Carter and others, 1977), and the deposits have been held in reserve by the U.S. Government since 1923 (Bureau of Land Management [BLM], 2024). The Naval Petroleum Reserve No. 4 was created in 1923. In 1976, The Naval Petroleum Reserve No. 4 was renamed the National Petroleum Reserve in Alaska (NPR–A), and the administration was transferred to the BLM (BLM, 2024). Initial approval for oil and gas infrastructure in the NPR–A was given by the BLM in 2004 (BLM, 2004b). After two seasons of construction in 2014 and 2015 on the facility known as Colville Delta drilling pad 5 (CD5), oil production occurred in 2015 within the NPR–A on Alaska Native lands owned by the Kuukpik Corporation (fig. 1; ConocoPhillips Alaska, 2018). Final approval for the first oil and gas production on BLM-managed lands within the NPR–A was given in 2015 within the Greater Mooses Tooth (GMT) unit in the northeast portion of the NPR–A (fig. 1; BLM, 2015). Construction of the oil-production facilities in the GMT (including drill pads, a road, and a pipeline) began in 2017, and oil production started at the first site (GMT1) in 2018 and at the second site (GMT2) in 2021. In 2023 production from the two sites totaled 14,000,000 barrels of oil equivalent per day (ConocoPhillips Company, 2023).

The waters of the NPR–A are generally considered "pristine," and limited testing indicates water quality is unimpaired (BLM, 2023a). This stands in contrast to waters exposed to the potential contamination from oil production. The effects of spills or releases of oil are easy to quantify and locate from their point sources, but it is more difficult to determine the amount or type of contamination if it originates from nonpoint sources such as those integrated by surface runoff into streams. Reviews of published literature suggest that salinity, metals, and organic compounds are typically the primary contaminants of surface water from oil production (Johnston and others, 2019; Lusweti and others, 2022). In the undeveloped areas of the NPR–A, contamination could result in many ways from new roads and facilities including disruptions during construction, erosion of the new material



Base from Bureau of Land Management digital data, administered lands (Surface Management Agency), various scales, 2024
North Slope Infrastructure (North Slope Science Initiative, 2022a)
Alaska Albers Equal-Area Conic projection, standard parallel 55° and 65° N., central meridian 154° W.
North American Datum of 1983

Figure 1. Oil-production facilities and water-quality sampling sites in the National Petroleum Reserve in Alaska, 2010–23. Water-quality site information from U.S. Geological Survey (2024); oil infrastructure information from North Slope Science Initiative (2022b).

used to build the road and pad bases, dust during the summer, changes in hydrology from possible flow-path disruptions or increased flow from spring melting of ice roads, and possible localized alterations to the permafrost freeze/thaw cycle and depth (thermokarsts), which have been shown to affect water quality (Koch and others, 2018b).

Water quality has not been characterized temporally or spatially in a rigorous manner in the NPR–A, but summaries of what is known locally or regionally are provided in permit and management reports by the BLM (2004a, 2012, 2014, 2020, 2023a). Although nutrients and metals have been studied (primarily in lakes) in areas of the Alaskan Arctic, most water-quality assessments have focused on lakes or large rivers (like the Colville River; fig. 1) and have primarily measured physical characteristics such as water temperature, pH, dissolved oxygen, and turbidity (Hobbie, 1984; Koch and others, 2014; Koch and others, 2018a, 2018b; Kurek and others, 2022). During summer (when waterbodies are not frozen), dissolved oxygen is typically near saturation in the cool waters of the tundra. Summer turbidity and sediment in lakes and smaller streams are low, but the water is often colored by naturally occurring dissolved organic material and iron (BLM, 2004a, 2012, 2023a). In the NPR–A, nutrients (phosphorus and nitrogen) and trace elements are generally reported to be low or below the laboratory detection limit (BLM, 2004a, 2012; Koch and others, 2014), with some exceptions for the Colville River during higher summer flows and for areas containing known metal deposits (although none are in the region of the study area). Metals that are present at higher naturally occurring concentrations in at least some areas of the NPR–A include barium, copper, cadmium, iron, lead, and zinc (BLM, 2004a, 2012, 2023a).

Another natural component of water quality along the coast of the Arctic Ocean is the presence of hydrocarbons in the subsurface and in surface waters. Surface oil seeps have been identified at a few locations in NPR–A since the 1940s, including seeps in or near the GMT north of Fish Creek and near Oil Lake (BLM, 2004a, 2012; Payne, 1948). The subsurface peat in this area is reported to have high hydrocarbon content, and the surface waters often show evidence of a sheen or foam (BLM, 2012). Aromatic hydrocarbons have been present in concentrations of 0.1 to 0.2 micrograms per liter (µg/L) in undisturbed surface water near Prudhoe Bay, another oil-production area about 100 kilometers east of the NPR–A (not shown on fig. 1). The BLM (2012) reports that similar naturally occurring background concentrations are expected in the NPR–A.

Purpose and Scope

Development of oil and gas infrastructure in the NPR–A has the potential to alter the hydrology and water-quality characteristics in the area. Discrete water-quality samples were collected by the U.S. Geological Survey (USGS), in cooperation with the BLM, to assess potential effects from recent oil and gas development in this previously undeveloped region. The purpose of this report is to compare changes in sample concentrations of water-quality analytes from 2010 to 2023 in selected streams with established monitoring stations in the northeast region of the NPR–A. This period brackets the construction of the first oil and gas facilities in the NPR–A and allows for a comparison of water-quality characteristics during summer flows predevelopment and postdevelopment. This comparison will inform land managers on the effectiveness of current management practices at mitigating effects to aquatic resources.

Study Area

The NPR–A covers an area of approximately 93,000 square kilometers in north-central Alaska (fig. 1; BLM, 2024). It comprises 5 percent of the State of Alaska—an area larger than Maine. The study area is in the northeastern region of the NPR–A and is located on the tundra near the Arctic Ocean with an arctic climate characterized by long, cold winters and short, cool summers (BLM, 2014). Below freezing temperatures are typical from October to May, with an average annual temperature of around −12 degrees Celsius (BLM, 2020). Smaller streams and lakes less than about 2 meters deep typically freeze completely during the winter (BLM, 2012). Annual precipitation across the coastal region of the NPR–A is normally less than 15 centimeters as rain in the summer and about 75 centimeters of snow (13 centimeters of water equivalent), which can fall in any month of the year (BLM, 2014, 2020). Streamflow is seasonal with near-zero flows during the long winters and is typically dominated by the peak discharge during the spring snowmelt (BLM, 2023a). However, increases in runoff documented for larger rivers (Arp and others, 2020) and smaller beaded streams (Arp and Whitman, 2022) within the Fish Creek watershed indicate a shift toward runoff dominated by rainfall events as opposed to early snowmelt within this region.

The coast along the Arctic Ocean is a generally flat, poorly drained area with little topographic relief that rises slowly from the Arctic Ocean inland towards the foothills and mountains of central Alaska (BLM, 2004a). Periglacial features such as marshes, meandering streams, and thaw lakes (that cover about 20 percent of the area) dominate the coastal region (BLM, 2014). Permafrost underlies the coast of the NPR–A and ranges in thickness from 200 to more than 600 meters (BLM, 2014). The continuous coverage of permafrost acts as a confining layer to infiltration deeper into the subsurface and limits available groundwater to shallow permeable deposits (alluvial aquifers) under larger surface water bodies such as streams and lakes (BLM, 2004a, 2014). During the summer, a thin layer (as much as a meter thick) of soil thaws, supporting vegetation growth while remaining saturated from the poor drainage and lack of infiltration (BLM, 2004a, 2012).

In 2009, prior to development of oil-production facilities in the NPR–A, the BLM and the University of Alaska Fairbanks (UAF) established a hydrologic monitoring network on small streams within the Fish Creek watershed in the area of GMT (fig. 1; table 1; UAF, 2024). Ongoing monitoring of these four sites by BLM and UAF includes water level, streamflow, and water temperature, and a water-quality sample was collected at each site by the USGS in 2010.

The watersheds contributing to the sites range in size from 23 to 29 square kilometers, and three of the four watersheds have had development for oil production, with Bills Creek initially selected as a reference site where no surface development (roads, drill pads, pipeline) was planned, nor has any been constructed, within the watershed. However, a gravel mine adjacent to Bills Creek was recently approved (but was not yet active at the time of the 2023 sampling) as part of a larger oil and gas infrastructure project, referred to as the Willow Development (BLM, 2023b).

In 2019, as oil and gas development continued to expand, BLM and UAF extended the Fish Creek watershed hydrologic monitoring network 20 to 30 kilometers to the southwest into the Willow Development area (not pictured) where, in 2023, development was permitted (BLM, 2023b; UAF, 2024). Although water samples were collected at four streams within the Willow Development in 2023, it is beyond the scope of this report to discuss the sampling results for this area because these samples were collected as a benchmark from which to evaluate potential changes in water-quality conditions postconstruction; however, the data are available (USGS site numbers 700646152112000, 700825152071300, 701008151561200, 701259151583700; USGS, 2024).

Table 1. Water-quality sampling sites, numbers, and selected watershed characteristics in the Greater Mooses Tooth unit of the National Petroleum Reserve in Alaska (U.S. Geological Survey, 2024).

[Drainage areas from University of Alaska Fairbanks (UAF) Fish Creek Watershed Observatory (UAF, 2024). USGS, U.S. Geological Survey; km^2, square kilometer; GMT1, Greater Mooses Tooth drilling pad 1; CD5, Colville Delta drilling pad 5]

Site name	Site short name	USGS site number	Drainage area (km^2)	Selected features within watershed
Bills Creek near Nuiqsut, Alaska	Bills Creek	701409151162900	24.6	No development, background site
Blackfish Creek near Nuiqsut, Alaska	Blackfish Creek	701641151284400	22.9	GMT1 drill pad, road, pipeline
Crea Creek near Nuiqsut, Alaska	Crea Creek	701720151184500	28.9	Road with bridge over creek, pipeline
Oil Creek near Nuiqsut, Alaska	Oil Creek	701808151165100	24.3	CD5 drill pad, road, pipeline, Oil Lake

Methods

Discrete water-quality samples were collected from all four sampling locations in the GMT in the summers of 2010 and 2023. Sampling procedures followed the USGS "National Field Manual for the Collection of Water-Quality Data" (USGS, variously dated) and are briefly described herein. Helicopter transportation to the sampling sites was provided by the BLM, and BLM and UAF staff assisted in sample collection and processing to maintain USGS protocols using two-person sampling crews. Samples were collected to assess stream water concentrations of nutrients, major ions, trace elements, and volatile organic compounds (VOCs). Field parameters were also recorded at the time of sample collection. A field blank sample was collected as quality control to determine any contamination that may have been introduced during collection of the samples. Surrogate standards were also added to the VOC samples at the laboratory to assess the quality of the analysis for impacts resulting from matrix effects of the water, analytical performance, or other potential issues.

Flow-integrated samples were collected using the equal-width interval technique by sampling 10 equally spaced locations across the stream with a depth-integrating sampler (USGS, variously dated). Sampling locations were selected between pools in the beaded streams (streams common in the Arctic with a series of deep pools connected by shallower, often short runs) so water depth was shallow enough for wading and water velocity was high enough to be within the range of proper depth-integrating sampler function. Samples were processed on-site immediately after collection following standard USGS procedures (USGS, variously dated) by compositing the water into a churn and mixing before filling sample bottles inside of a portable sampling chamber for all samples except those for VOCs. VOC samples were collected at the midpoint of the stream by placing the bottles under the surface of the water before removing the cap, filling them, and recapping them without exposing the sample to the atmosphere. Samples were then briefly opened within the processing chamber for the addition of preservation acid. All VOC samples were collected after the helicopter had been gone from the site or the engine had ceased operation for at least 30 minutes. All samples were transported on ice and stored refrigerated until they could be shipped on ice to the USGS National Water Quality Lab in Denver, Colorado, for analysis.

During the cleaning process, there was a variation from standard USGS protocol for sample collection and processing. With the remote location of the field camp, practical transportation limitations on the number of supplies and field equipment, and the undisturbed nature of the watersheds of the sites, the sample bottle and churn were not fully cleaned following USGS protocols for every sample. Fewer clean sample bottles (2) and churns (4) were taken to the field camp than sample locations that were planned (8–4 in GMT and 4 in the Willow Development area). Before previously used equipment was used for another sample it was given several extra rinses with stream water at the site to dilute any residual water from prior use. In addition to the check of field procedures, the field blank sample was collected using a previously used churn to check for sample contamination from the modified cleaning protocol.

With only two sets of samples at the sites (in 2010 and 2023), the ability to do statistical analysis with the results was limited. The magnitude and percentage of change among samples at sites were compared, and a paired t-test (Helsel and others, 2020) was used to assess changes in the sample concentrations for the three sites with development.

Water-Quality Comparisons in the Greater Mooses Tooth Unit of the National Petroleum Reserve in Alaska

Stream conditions and concentrations of selected analytes from the four stream sites in the GMT unit of the NPR–A in 2010 and 2023 are presented in table 2, and all results are available from USGS (2024). Considering the differences in the sampling conditions between 2010 and 2023, the water-quality characteristics of the four streams in the GMT unit of the NPR–A (USGS, 2024) were similar. Sampling occurred during the same time of year (midsummer), but flow conditions were quite different between the two sampling years. The 2023 samples were collected 1 to 2 days after a widespread rain event, and flows in 2023 ranged from 2.8 to 10 times higher than the 2010 flow estimates (USGS, 2024). Observed rains and streamflow responses aligned with increases in summer runoff documented in the area by Arp and Whitman (2022).

Concentrations of analytes previously reported in the NPR–A (BLM, 2012) and of analytes that increased by at least 20 percent or decreased by at least 50 percent between the 2010 and 2023 samples are shown in table 2. Bills Creek was used as the reference site because there was no development within its watershed.

Field parameters showed some variability but had similar water-quality characteristics in 2023 compared to 2010. Water temperatures were similar in 2010 and 2023, pH values were lower for all sites in 2023 by 0.2 to 0.7 units, and specific conductance was lower in 2023 for all sites except Blackfish Creek, where it was slightly higher. Major ions were generally lower at all sites in 2023 than in 2010, except for sodium and magnesium concentrations at Blackfish Creek (mirroring specific conductance), which were slightly higher (less than 10 percent) and within the range of values seen at other sites. Using a paired t-test for the sites with development in their watersheds, the only analyte that showed a statistically significant decrease in concentrations between the 2010 and 2023 samples was potassium (p-value=0.03), but the decrease in concentration was greater at the reference site (Bills Creek)

than any of the other sites. Corresponding to the increases in streamflow, silica concentrations increased at all sites from 2010 to 2023, particularly at Bills Creek (390 percent) and Blackfish Creek (180 percent). Although concentrations of silica increased at all sites sampled in 2023, the maximum reported value in the current study (0.750 milligram per liter [mg/L]; table 2) was well below the mean value of 2.84 mg/L reported for "pristine" freshwater streams (*n*=134) in the western Canadian Arctic (Dean and others, 2016). The increase in silica concentrations between the two sampling events may be attributed to increased runoff and flow from a rainfall event in 2023 (Alaska State Climate Office, 2024). Ultimately, the magnitude of these concentration increases is still within reference conditions reported for other Arctic streams.

Nutrient concentrations in the samples were low to undetectable and were similar among the sampling events. Nitrate concentrations were all lower than the reporting limit in 2023, while phosphorus concentrations increased slightly at all sites compared to 2010. Concentrations of other analyzed forms of nutrients not listed in table 2, including ammonia and orthophosphate, were below the detection limit for all samples in 2010 and 2023. Organic carbon concentrations increased from 2010 to 2023 at three of the four sites, particularly at Blackfish Creek and Bills Creek where the concentrations were at least 50 percent higher than the 2010 sample, possibly because of the increased runoff and flow from the recent rainfall (USGS, 2024). Values of organic carbon were within the range of observed values reported for undisturbed smaller streams across the NPR–A (4 to 16 mg/L; Shaftel and others, 2018) and well below the mean organic carbon value reported from streams in the western Canadian Arctic (23 mg/L; Dean and others, 2016).

Twenty-three trace elements were included in the laboratory analysis for both samples. In 2023, 10 of the trace elements were below the reporting level at all four sampling sites, and all 10 trace elements had concentrations near or below the reporting level in 2010 (USGS, 2024). All trace elements that have been reported as elevated in some areas of the NPR–A (BLM, 2004a, 2012, 2023a) were detected in 2023 in at least one of the four sampled streams (table 2). Most trace elements decreased in 2023 from their 2010 concentrations, likely at least partly because of dilution resulting from the rainfall that led to the higher flows during the 2023 samplings. However, metal concentrations in permafrost environments can be complex based upon the time of year and the seasonal depth and chemical, organic, and mineral compositions of the active layer (thawed permafrost; Skierszkan and others, 2024). Increases greater than 20 percent among samples were measured in boron at Oil Creek, aluminum and nickel at Bills Creek and Blackfish Creek, and molybdenum at Bills Creek. Barium and strontium concentrations decreased about 50 percent at Bills Creek and increased slightly at the other sites. All the trace elements had values within the range of the 2010 samples from samples at Bills Creek except for the higher molybdenum value of 0.311 µg/L at Bills Creek, which was more than three times higher than any other sample but still less than the human health benchmark of 40 µg/L (Ayotte and others, 2011).

VOCs were detected at a concentration just above the reporting level at two sites. The VOC samples were analyzed for 61 different analytes, and all samples at all sites were below the reporting level except trichloromethane (table 2). Trichloromethane was detected at Oil Creek in both samples, and from 2010 to 2023, the concentration decreased from 0.2 to 0.1 µg/L. The 2023 sample at Blackfish Creek also contained trichloromethane at a concentration of 0.1 µg/L. The presence of trichloromethane in the 2010 sample from Oil Creek, the known oil seep near Oil Lake, which is in the Oil Creek watershed (BLM, 2004a; UAF, 2024), and the report of hydrocarbons in surface waters of other northern Alaska oil fields at similar concentrations (BLM, 2012) all suggest the possibility that these positive detections of trichloromethane are from natural sources.

Thirty-three of the chemicals analyzed have drinking water standards as listed on the toxic substances list from the Alaska Department of Environmental Conservation (2022). All were less than 10 percent of the drinking water standard, with most under 1 percent and many below the reporting level (table 3).

The field and laboratory quality control measures were used to ensure the reliability of the sample results. The field blank collected during the 2023 sampling had no detections of nutrients, major ions, or trace elements above the reporting level. Similarly, the 2023 field trip blank collected for VOCs from Blackfish Creek had no results above the reporting level. Three surrogate compounds were added to quality control samples for VOCs (including surrogates for toluene and, in 2010, 1,2-dicholorethane that are regulated in drinking water), and percent recoveries were computed to test for matrix effects. The samples had surrogate recovery percentages ranging from 82 to 133 percent in 2010 and from 86 to 99 percent in 2023. These data indicate that matrix effects that could affect sample concentrations were minimized.

The four small streams in the GMT unit of the NPR–A had similar water-quality characteristics in the 2010 and 2023 samples. Variability between the two sampling periods was generally low and mostly showed decreased concentrations in 2023 relative to 2010. Concentrations in 2023 from the three sites with development within their watershed (Blackfish, Crea, and Oil Creeks) were within the range of those measured either predevelopment in 2010 or at the reference site (Bills Creek) in 2023 except for the nickel and organic carbon results at Blackfish Creek, which were within 25 percent of values from other sites or sample periods. Continued monitoring and sampling of these sites and others in areas of the NPR–A with oil and gas development could provide better understanding of the trends in water quality and effects on the hydrology and water quality in this unique environment.

Table 2. Sites, sample dates, stream conditions, field parameters, and selected results of analytes known to be in regional waters or changing among water-quality sampling periods in the Greater Mooses Tooth unit of the National Petroleum Reserve in Alaska, 2010 and 2023.

[Dates shown as month/day/year. ft^3/s, cubic foot per second; E, estimated; °C, degree Celsius; --, data missing; µS/cm, microsiemens per centimeter; mg/L, milligram per liter; <, less than; SiO_2, silicone dioxide; N, nitrogen; P, phosphorus; µg/L, microgram per liter]

Parameter	Bills Creek		Blackfish Creek		Crea Creek		Oil Creek	
	7/8/2010	6/27/2023	7/8/2010	6/28/2023	7/8/2010	6/28/2023	7/8/2010	6/28/2023
Stream conditions and field parameters								
Discharge (ft^3/s)	E 5.4	15	E 0.64	6.6	E 2.2	7.8[a]	E 2.8	8.7
Water temperature (°C)	10.0	--	16.0	14.7	11.9	13.3	11.7	13.3
Specific conductance (µS/cm at 25 °C)	166	85	100	113	114	103	202	166
pH (standard units)	7.8	7.3	7.9	7.2	7.5	7.1	7.7	7.5
Major ions and nutrients (mg/L) (19 total analytes measured)								
Calcium	22.2	10.9	13.3	12.3	13.0	11.9	20.6	17.6
Potassium	0.66	<0.30	0.55	0.36	0.80	0.62	0.90	0.60
Sodium	5.33	2.99	5.05	5.17	4.76	4.04	11.2	8.82
Chloride	15.3	6.88	15.8	12.3	12.6	10.4	27.5	20.3
Sulfate	0.18	0.09	<0.18	0.09	E 0.15	0.06	<0.18	0.09
Silica, as SiO_2	0.154	0.750	0.202	0.566	0.197	0.249	0.297	0.414
Nitrite, as N	<0.002	<0.001	<0.002	<0.001	<0.002	<0.001	0.002	<0.001
Nitrate, as N	E 0.011	<0.010	<0.016	<0.010	E 0.011	<0.010	E 0.008	<0.010
Phosphorus, as P	E 0.003	0.005	<0.006	0.005	E 0.004	0.005	<0.006	0.005
Organic carbon	6.05	9.07	6.62	11.4	6.25	7.14	6.31	6.25
Trace metals (µg/L) (23 total analytes measured)								
Antimony	0.184	<0.060	0.171	0.073	0.103	<0.060	0.118	0.063
Aluminum	E 2.2	11	E 3.4	9.0	E 2.4	2.0	<3.4	<2
Barium	99.7	48.3	43.0	46.3	54.7	51.2	101	107
Boron	4	<5	3	<5	4	5	3	6
Cobalt	1.11	0.086	2.96	0.187	0.82	0.137	0.94	0.251
Copper	<1.0	2.0	<1.0	1.6	<1.0	0.47	<1.0	<0.40
Iron	121	103	188	160	139	112	99.7	115
Magnesium	3.28	2.06	2.78	3.01	2.75	2.73	4.58	3.81
Molybdenum	0.068	0.311	0.035	<0.050	0.083	<0.050	0.064	0.063
Nickel	1.0	1.4	1.2	1.8	0.99	0.95	0.87	0.88
Strontium	47.2	24.2	28.2	30.9	26.9	27.2	47.8	45.1
Volatile organic compounds (µg/L) (61 total analytes measured)								
Trichloromethane	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	0.2	0.1

[a]Data from University of Alaska Fairbanks, 2024.

Table 3. Alaska water-quality standards for drinking water and the maximum sampled concentrations in the Greater Mooses Tooth unit of the National Petroleum Reserve in Alaska, 2010 and 2023.

[mg/L, milligram per liter; N, nitrogen; E, estimated; µg/L, microgram per liter; <, less than]

Parameter	Water quality criteria[a]	Maximum sampled concentration[b]	Site and sample year
Major ions and nutrients (mg/L)			
Nitrate, as N	10	E0.011	Bills Creek and Crea Creek, 2010
Nitrite, as N	1	0.002	Oil Creek, 2010
Trace metals (µg/L)			
Antimony	6	0.184	Bills Creek, 2010
Arsenic	10	0.44	Oil Creek, 2010
Barium	2,000	107	Oil Creek, 2023
Beryllium	4	<0.012	All sites, 2010
Cadmium	5	<0.030	All sites, 2023
Chromium (total)	100	<0.050	All sites, 2023
Fluoride	4,000	0.09	Oil Creek, 2010
Manganese	300	19.4	Crea Creek, 2010
Selenium	50	0.05	Bills Creek and Crea Creek, 2010
Thallium	2	<0.040	All sites, 2023
Uranium	30	0.069	Bills Creek, 2010
Volatile organic compounds (µg/L)			
Benzene	5	<0.1	All sites, both years
Chlorobenzene	100	<0.1	All sites, both years
1,2-Dichlorobenzene	600	<0.1	All sites, both years
1,4-Dichlorobenzene	75	<0.1	All sites, both years
1,2-Dichloroethane	5	<0.2	All sites, both years
1,1-Dichloroethane	7	<0.1	All sites, both years
cis-1,2-Dichloroethane	70	<0.1	All sites, both years
trans-1,2-Dichlorethane	100	<0.1	All sites, both years
Dichloromethane	5	<0.2	All sites, both years
1,2-Dichloropropane	5	<0.1	All sites, both years
Ethylbenzene	700	<0.1	All sites, both years
Styrene	100	<0.1	All sites, both years
Tetrachloromethane	5	<0.2	All sites, both years
Toluene	1,000	<0.2	All sites, both years
Trihalomethanes	80	0.2	Oil Creek, 2010
1,2,4-Trichlorobenzene	70	<0.2	All sites, both years
1,1,1-Trichloroethane	200	<0.1	All sites, both years
1,1,2-Trichloroethane	5	<0.2	All sites, both years
Vinyl chloride	2	<0.2	All sites, both years
Xylene	10,000	<0.3	All sites, both years

[a]Alaska Department of Environmental Conservation, 2022.

[b]U.S. Geological Survey, 2024.

Summary

For more than a century, the presence of oil in north-central Alaska has been known, and the deposits have been held in reserve by the U.S. government in what is now the National Petroleum Reserve in Alaska (NPR–A). The Bureau of Land Management initially approved oil and gas development in the NPR–A in 2004, but first oil production did not occur until 2015.

The waters of the NPR–A are generally considered "pristine," while contaminants of surface water from oil production in other areas include salinity, metals, and organic compounds. Water quality has not been characterized temporally or spatially in a rigorous manner and has focused mainly on measurements of physical characteristics. Local waters are often colored by dissolved organic material and iron, and nutrients and trace elements are generally low except for areas of known metal deposits. Hydrocarbons are known to be present in the subsurface and in surface waters of northern Alaska. Aromatic hydrocarbons have been detected in concentrations of 0.1 to 0.2 microgram per liter (µg/L) in undisturbed surface water in the Alaskan Arctic.

The purpose of this report was to compare changes in sample concentrations of water-quality analytes from 2010 to 2023 in selected streams located in the northeast region of the NPR–A near the recently established oil and gas production areas. This period bracketed the construction of the first oil-production facilities in the NPR–A and allowed for a comparison of water quality during summer flows predevelopment and postdevelopment.

Prior to development of oil-production facilities in the NPR–A, four hydrologic monitoring sites were established on small streams in the Fish Creek watershed. Ongoing monitoring at the sites includes water level, streamflow, and water temperature. The watersheds contributing to the sites range in size from 23 to 29 square kilometers, and three of the four watersheds have had oil and gas infrastructure development, with one selected as a reference watershed where no surface development (roads, drill pads, pipeline) was planned, nor has any been constructed (as of the 2023 sampling), within the watershed. Discrete water-quality samples were collected by the U.S. Geological Survey in cooperation with the Bureau of Land Management from all four study sites in the Greater Mooses Tooth (GMT) in the summers of 2010 and 2023. Sampling procedures followed the standard U.S. Geological Survey protocols and were collected to assess stream water concentrations of nutrients, major ions, trace elements, and volatile organic compounds.

Considering the differences in the sampling conditions between 2010 and 2023, the water-quality characteristics were similar in the four streams in the GMT unit of the NPR–A. Sampling occurred during the same time of year, but flow conditions were quite different between the two sampling times, with flow elevated because of a widespread rain event over the study area two days prior to sampling in 2023.

Field parameter measurements showed some variability but had similar water-quality characteristics. Nutrient concentrations in the samples were low to undetectable and did not change appreciably among the sampling events. Major ions were generally lower at all sites from 2010 to 2023, whereas silica and organic carbon concentrations generally increased at all sites, possibly because of the increased runoff and flow from the recent rainfall.

Most trace elements decreased in 2023 from their 2010 concentrations, likely at least partly because of dilution resulting from the rainfall-induced higher flows during the 2023 samples. Increases greater than 20 percent among samples were seen in boron at Oil Creek, aluminum and nickel at Bills Creek and Blackfish Creek, and molybdenum at Bills Creek. The 2023 molybdenum concentration at Bills Creek was 0.311 µg/L, which was more than three times higher than any other sample, but still less than the human health benchmark of 40 µg/L. The volatile organic compound trichloromethane was detected at a concentration just above the reporting level at two sites—Oil Creek during both samples and Blackfish Creek in 2023. The presence of trichloromethane in the 2010 sample from Oil Creek, the presence of known oil seeps in the greater area, and the report of hydrocarbons in other Arctic surface waters at similar concentrations all suggest the possibility that these positive detections of trichloromethane are from natural sources.

The four small streams in the GMT unit of the NPR–A had similar water-quality characteristics in the 2010 and 2023 samples. Variability between the two samples was generally low and mostly showed decreases in the 2023 concentrations relative to 2010, and no 2023 concentrations from the three sites with development within the watershed were outside of the range of concentrations seen either predevelopment in 2010 or in the site without development in 2023. Continued monitoring and sampling of these sites and others in areas of the NPR–A with oil and gas development could provide better understanding of the trends in water quality and effects on the hydrology and water quality in this unique environment.

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