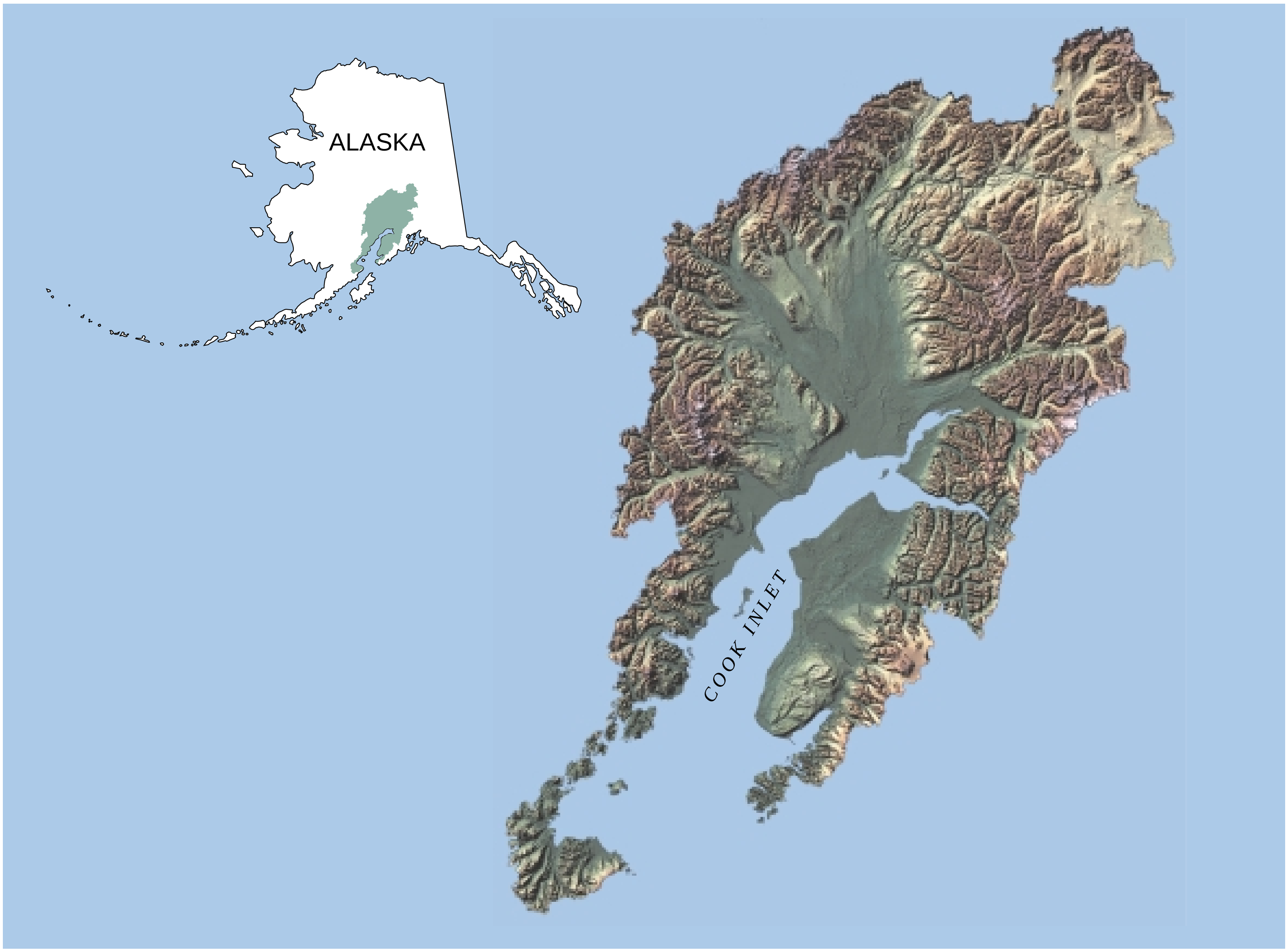
Selected Organic Compounds and Trace Elements in Streambed Sediments and Fish Tissues, Cook Inlet Basin, Alaska

Water-Resources Investigations Report 00-4004

National Water-Quality Assessment Program



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

Selected Organic Compounds and Trace Elements in Streambed Sediments and Fish Tissues, Cook Inlet Basin, Alaska

By Steven A. Frenzel

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 00-4004

Prepared as part of the

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Anchorage, Alaska
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U.S. DEPARTMENT OF THE INTERIOR
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FOREWORD

The mission of the U.S. Geological Survey (USGS) is to assess the quantity and quality of the earth resources of the Nation and to provide information that will assist resource managers and policymakers at Federal, State, and local levels in making sound decisions. Assessment of water-quality conditions and trends is an important part of this overall mission.

One of the greatest challenges faced by water-resources scientists is acquiring reliable information that will guide the use and protection of the Nation's water resources. That challenge is being addressed by Federal, State, interstate, and local water-resource agencies and by many academic institutions. These organizations are collecting water-quality data for a host of purposes that include: compliance with permits and water-supply standards; development of remediation plans for specific contamination problems; operational decisions on industrial, wastewater, or water-supply facilities; and research on factors that affect water quality. An additional need for water-quality information is to provide a basis on which regional- and national-level policy decisions can be based. Wise decisions must be based on sound information. As a society we need to know whether certain types of water-quality problems are isolated or ubiquitous, whether there are significant differences in conditions among regions, whether the conditions are changing over time, and why these conditions change from place to place and over time. The information can be used to help determine the efficacy of existing water-quality policies and to help analysts determine the need for and likely consequences of new policies.

To address these needs, the U.S. Congress appropriated funds in 1986 for the USGS to begin a pilot program in seven project areas to develop and refine the National Water-Quality Assessment (NAWQA) Program. In 1991, the USGS began full implementation of the program. The NAWQA Program builds upon an existing base of water-quality studies of the USGS, as well as those of other Federal, State, and local agencies. The objectives of the NAWQA Program are to:

- Describe current water-quality conditions for a large part of the Nation's freshwater streams, rivers, and aquifers.
- Describe how water quality is changing over time.
- Improve understanding of the primary natural and human factors that affect water-quality conditions.

This information will help support the development and evaluation of management, regulatory, and monitoring decisions by other Federal, State, and local agencies to protect, use, and enhance water resources.

The goals of the NAWQA Program are being achieved through ongoing and proposed investigations of 60 of the Nation's most important river basins and aquifer systems, which are referred to as study units. These study units are distributed throughout the Nation and cover a diversity of hydrogeologic settings. More than two-thirds of the Nation's freshwater use occurs within the 60 study units and more than two-thirds of the people served by public water-supply systems live within their boundaries.

National synthesis of data analysis, based on aggregation of comparable information obtained from the study units, is a major component of the program. This effort focuses on selected water-quality topics using nationally consistent information. Comparative studies will explain differences and similarities in observed water-quality conditions among study areas and will identify changes and trends and their causes. The first topics addressed by the national synthesis are pesticides, nutrients, volatile organic compounds, and aquatic biology. Discussions on these and other water-quality topics will be published in periodic summaries of the quality of the Nation's ground and surface water as the information becomes available.

This report is an element of the comprehensive body of information developed as part of the NAWQA Program. The program depends heavily on the advice, cooperation, and information from many Federal, State, interstate, Tribal, and local agencies and the public. The assistance and suggestions of all are greatly appreciated.

Robert M. Hirsch

Robert M. Hirsch
Chief Hydrologist

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CONVERSION FACTORS, ABBREVIATIONS, MAP NUMBERS, AND VERTICAL DATUM

Multiply	by	To obtain
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mi (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
cubic foot per second (ft^3/s)	0.02832	cubic meter per second

Abbreviations:

Certain biological measurements used in this report are given only in metric units:
mL, milliliter
mm, millimeter
µm, micrometer
g, gram
µg/g, microgram per gram
µg/kg, microgram per kilogram

Map Numbering System:

The map numbers of sampling sites on the tables and figures in this report generally follow the map numbering system for stream-gaging stations in the NAWQA environmental setting report (Brabets and others, 1999). Because data in this streambed sediment/fish tissue report were not collected at all of the stream-gaging stations numbered in the environmental setting report, this report contains gaps in the map numbers.

Vertical Datum:

In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929—A geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Selected Organic Compounds and Trace Elements in Streambed Sediments and Fish Tissues, Cook Inlet Basin, Alaska

by Steven A. Frenzel

ABSTRACT

Organochlorines, semivolatile organic compounds (SVOCs), and trace elements were investigated in streambed sediments and fish tissues at selected sites in the Cook Inlet Basin, Alaska, during 1998. At most sites, SVOCs and organochlorine compounds were either not detected or detected at very low concentrations. Chester Creek at Arctic Boulevard at Anchorage, which was the only site sampled with a significant degree of development in the watershed, had elevated levels of many SVOCs in streambed sediment. Coring of sediments from two ponds on Chester Creek confirmed the presence of elevated concentrations of a variety of organic compounds. Moose Creek, a stream with extensive coal deposits in its watershed, had low concentrations of numerous SVOCs in streambed sediment. Three sites located in national parks or in a national wildlife refuge had no detectable concentrations of SVOCs.

Trace elements were analyzed in both streambed sediments and tissues of slimy sculpin. The two media provided similar evidence for elevated concentrations of cadmium, lead, and zinc at Chester Creek. In this study, "probable effect levels "(PELs) were determined from sediments finer than 0.063 millimeters, where concentrations tend to be greatest. Arsenic and chromium concentrations exceeded the PEL at eight and six sites respectively. Zinc exceeded the PEL at one site. Cadmium and copper concentrations were smaller than the PEL at all sites. Mercury concentrations in streambed sediments from the Deshka River were near the PEL, and selenium concentrations at that site also appear to be elevated above background levels. At half the sites where slimy sculpin were sampled, selenium concentrations were at levels that may cause adverse effects in some species.

INTRODUCTION

Background

Streambed sediments and fish tissues are analyzed for concentrations of organic compounds and trace elements as part of the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program. The primary objectives of the NAWQA Program are to (1) describe the current status of the Nation's water quality, (2) describe water-quality trends, and (3) increase understanding about the natural and human factors that affect water quality. Data from each of about 60 study units are compiled at a national level so that particular constituents of regional or national concern may be identified (Gilliom and others, 1998).

Streambed sediments and fish tissues were analyzed because many compounds of interest tend to concentrate in these media relative to water and because sediments and tissues represent long-term exposure to the environment. Organochlorines were detected less frequently in streambed sediments than in fish tissues during the study of the 20 initial NAWQA study units (Gilliom and others, 1998). Several of the compounds analyzed, such as the organochlorine pesticide DDT, have been banned for use in the United States but persist in the environment. Lipophilic compounds, such as the organochlorines, tend to bioaccumulate in a food chain with possible adverse effects on the reproductive success at the top trophic levels. However, organochlorine concentrations in fish tissues show a generally decreasing trend at sites across the country and the one site in the Cook Inlet Basin sampled in 1973 for the National Contaminant Biomonitoring Program had undetectable organochlorine concentrations in fish (Schmitt and others, 1990). To reduce costs per site for the Cook Inlet Basin study, organochlorines generally were analyzed in fish tissues and not in streambed sediments.

Distribution of synthetic organic compounds in the environment has been shown to be related to land uses that included significant areas of agricultural or urban land (Munn and Gruber, 1997; Dennehy and others, 1998; Land and others, 1998). In the Cook Inlet Basin, agricultural and urban land uses each account for less than one percent of the total area (Frenzel, 1997). Yet organochlorines have been detected in remote arctic environments far from areas of possible use (Wilson and others, 1995). Semivolatile organic compounds (SVOCs)—polycyclic aromatic hydrocarbons (PAHs), for example—result from anthropogenic sources such as incomplete combustion of fossil fuels and wood, or from natural sources such as wetlands, oil, and coal deposits (Lopes and others, 1998).

Trace elements are derived from natural sources, but may be redistributed in the environment by human activities such as mining and urbanization. Some trace elements are essential micronutrients, yet at elevated concentrations may be harmful to organisms exposed to them. For example, elevated levels of selenium in irrigation return flows have been tied to abnormal development of birds and elevated levels of cadmium are deleterious to egg survival in salmonids (U.S. Department of the Interior, 1998).

Purpose and Scope

This report describes the occurrence of organochlorines, SVOCs, and trace elements in streambed sediments and fish tissues at 15 sites in the Cook Inlet Basin in southcentral Alaska, during 1998 (fig. 1; table 1). Organochlorines were analyzed in streambed sediments at six sites and in fish tissues at 12 sites. SVOCs were analyzed in streambed sediments at all 15 sites. Trace elements were analyzed in streambed sediments at 14 sites and in fish tissues at 12 sites. About half of the sites were located along the road system, but seven sites were located in more remote areas including three national parks.

The map numbers of sampling sites on the tables and figures in this report generally follow the map-numbering system for streamgaging stations in the NAWQA environmental setting report (Brabets and others, 1999). Because data for streambed sediments and fish tissue were not collected at all of the streamgaging stations numbered in the environmental setting report, this report contains gaps in the map numbers (appendix 1).

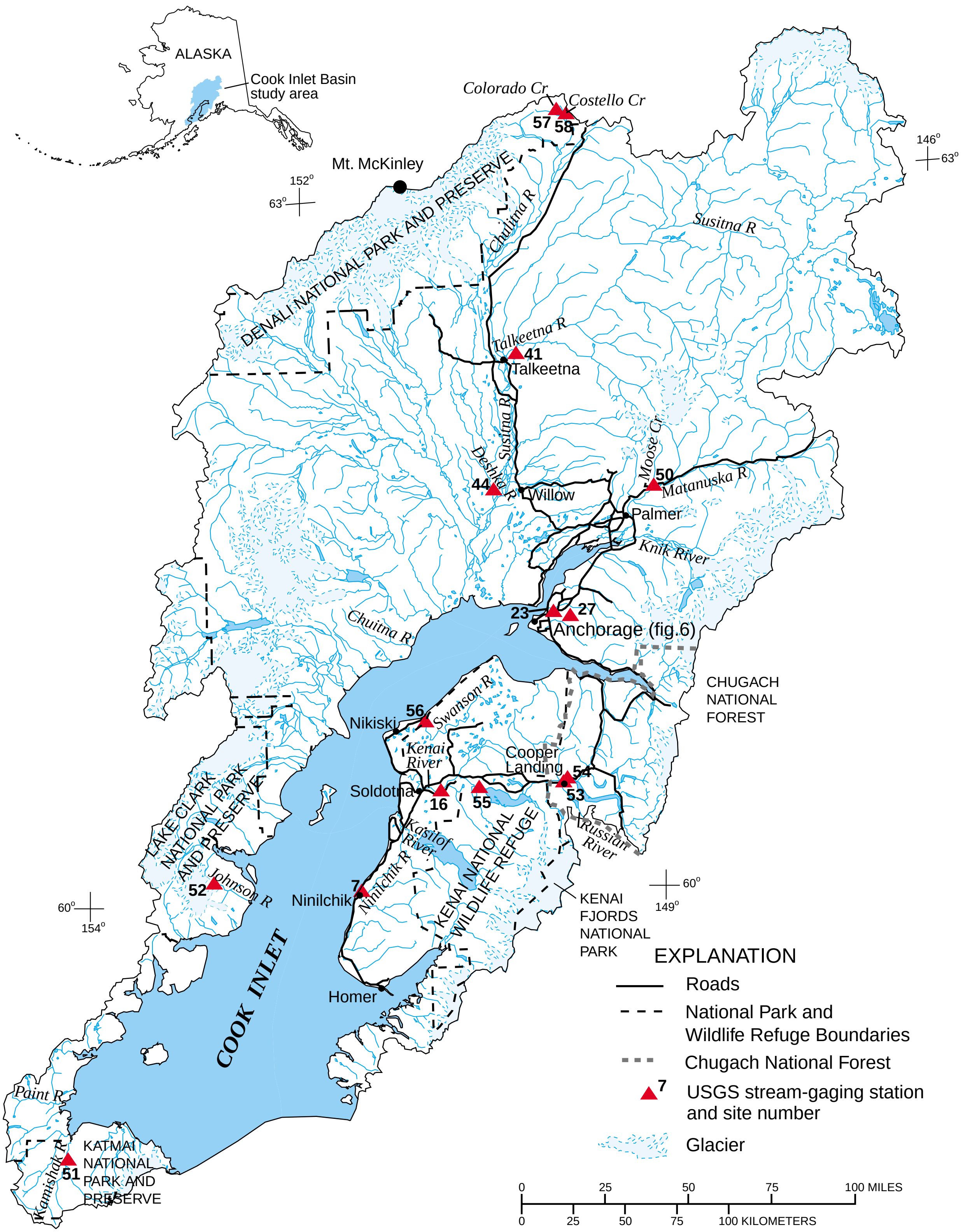

Figure 1. Location of streambed-sediment and fish-tissue sampling sites, Cook Inlet Basin, Alaska. (See table 1 for types of samples collected at each site.)

Table 1. Streambed-sediment and fish tissue sampling sites in the Cook Inlet Basin, Alaska

[mi^2, square mile; OC-sed, organochlorines in streambed sediments < 2 mm; OC-fish, organochlorines in whole slimy sculpin; SVOC, semivolatile organic compounds in streambed sediments < 2 mm; TE-sed, trace elements in streambed sediments <0.063 mm; TE-fish, trace elements in whole slimy sculpin]

Map No. (fig. 1)	Site name	USGS Station No.	Latitude Longitude	Drainage area (mi^2)	Type of samples collected	Remarks
7	Ninilchik River at Ninilchik	15241600	60°02'56" 151°39'48"	[a]131	OC-fish, SVOC, TE-sed, TE-fish	Lowland drainage; timber harvesting
16	Kenai River at Soldotna	15266300	60°28'39" 151°04'46"	[a]1,951	OC-fish, SVOC, TE-sed, TE-fish	Records since 1965; recreational use
23	South Fork Campbell Creek near Anchorage	15274000	61°09'57" 149°46'15"	[a]29.4	OC-fish, SVOC, TE-sed, TE-fish	Reference for urban area
27	Chester Creek at Arctic Blvd. at Anchorage	15275100	61°12'19" 149°53'43"	[a]27.3	OC-fish, SVOC, TE-sed, TE-fish	Urban area
41	Talkeetna River near Talkeetna	15292700	62°20'49" 150°01'01"	[a]1,996	OC-fish, OC-sed, SVOC, TE-sed, TE-fish	Records since 1964; undeveloped basin
44	Deshka River near Willow	15294100	61°46'05" 150°20'13"	[a]591	OC-fish, SVOC, TE-sed, TE-fish	Lowland drainage; undeveloped
50	Moose Creek near Palmer	15283700	61°41'00" 149°02'36"	[a]47.3	OC-fish, SVOC, TE-sed, TE-fish	Coal deposits upstream
51	Kamishak River near Kamishak	5857501541011	58°57'50" 154°10'11"	[a]275	OC-sed, SVOC, TE-sed, TE-fish	Katmai National Park and Preserve
52	Johnson River above Lateral Glacier near Tuxedni Bay	15294700	60°05'41 152°54'38"	[a]24.8	OC-sed, SVOC, TE-sed	Lake Clark National Park and Preserve
53	Kenai River below Russian River near Cooper Landing	15266010	60°29'07" 150°00'35"	828	OC-fish, OC-sed, SVOC, TE-sed, TE-fish	Kenai National Wildlife Refuge
54	Kenai River at Jim's Landing near Cooper Landing	15266020	60°28'55" 150°06'36"	841	OC-fish, OC-sed, SVOC, TE-sed, TE-fish	Kenai National Wildlife Refuge
55	Kenai River below Skilak Lake Outlet near Sterling	15266110	60°28'00" 150°35'56"	[a]1,206	OC-fish, SVOC, TE-sed, TE-fish	Reference for recreational use
56	Swanson River near Kenai	15267160	60°47'15" 151°00'30"	[a]280	OC-fish, SVOC	Oil and gas fields upstream
57	Colorado Creek near Colorado	6316291493520	63°16'29" 149°35'20"	10.6	OC-sed, SVOC, TE-sed	Denali National Park and Preserve
58	Costello Creek near Colorado	6310181493237	63°16'18" 149°32'37"	23.2	OC-fish, SVOC, TE-sed, TE-fish	Denali National Park and Preserve

[a]Drainage area revised from previously published values; new values computed using Geographic Information System (GIS) tools

DESCRIPTION OF STUDY AREA

The 39,325 square-mile Cook Inlet Basin is largely undeveloped. Population in 1996 was about 347,000, concentrated in the Municipality of Anchorage (254,000), Matanuska-Susitna Borough (51,000), and the Kenai Peninsula Borough (42,000) (Glass, 1999). The low population density also equates to few industries present; only two facilities in the Cook Inlet Basin are listed in the Toxics Release Inventory for Alaska (U.S. Environmental Protection Agency, 1999). However, one of these facilities near Nikiski (fig. 1) has had aerial releases of ammonia in the 10 years ending in 1997 from as much as 205 million pounds in 1988 to 3 million pounds in 1997 (U.S. Environmental Protection Agency, 1999).

The State of Alaska and the Federal government manage the vast majority of land in the Cook Inlet Basin (fig. 2). State-owned land accounts for 51 percent of the total area. Federal lands account for 44 percent of the basin and include parts of four national parks, the Chugach National Forest, and the Kenai National Wildlife Refuge (KNWR) (fig. 1) (Brabets and others, 1999). Lake Clark and Katmai National Parks and Preserves are located on the western side of Cook Inlet and are accessed by aircraft. Denali National Park and Preserve, located in the northern part of the study unit is a popular ecotourism destination accessible by road. However, the areas of Denali National Park and Preserve that drain to Cook Inlet are not road accessible. Only a small part of the Harding Icefield in Kenai Fjords National Park is within the Cook Inlet Basin boundaries. The KNWR is one of two National Wildlife Refuges in Alaska with road access. In spite of being relatively accessible, more than 70 percent of the refuge is designated as wilderness. The proximity of KNWR to population centers in Alaska makes it a popular recreational destination.

A wide range of physiographic conditions exists in the Cook Inlet Basin. Altitude ranges from sea level to 20,320 ft at Mount McKinley; this altitude range has a large effect on climate and vegetation. Mean annual precipitation ranges from about 20 in. in the lowland areas of Anchorage to 240 in. in the mountains bordering the basin (Brabets and others, 1999). The combination of high latitudes, high altitudes, and high precipitation results in glaciers, snow, and ice that cover 17 percent of the basin. Six ecoregions (fig. 3) are present in the basin and roughly correspond to the altitude and precipitation patterns. The Alaska Range ecoregion covers nearly half of the Cook Inlet Basin, but is largely inaccessible. A poorly developed road system provides access to some areas of four other ecoregions, but is mostly restricted to the Cook Inlet and Pacific Coastal Mountains ecoregions. Combined, those two ecoregions represent 44 percent of the basin. Sites sampled during this study represent four of the ecoregions in the Cook Inlet Basin (table 2). Detailed descriptions of the physical characteristics of the basin are given by Brabets and others (1999).

Glaciers have a profound effect on water quality, but their effects can be moderated by the presence of large lakes that trap sediment (Brabets and others, 1999). Seven sites sampled in the Cook Inlet Basin have glaciers in their headwaters (fig. 1). Of those sites, only the Kenai River has large lakes that serve as efficient sediment traps. Water at the Johnson River sampling site is greatly influenced by glaciers a short distance upstream. The Talkeetna and Kamishak Rivers also have glaciers present in their headwaters.

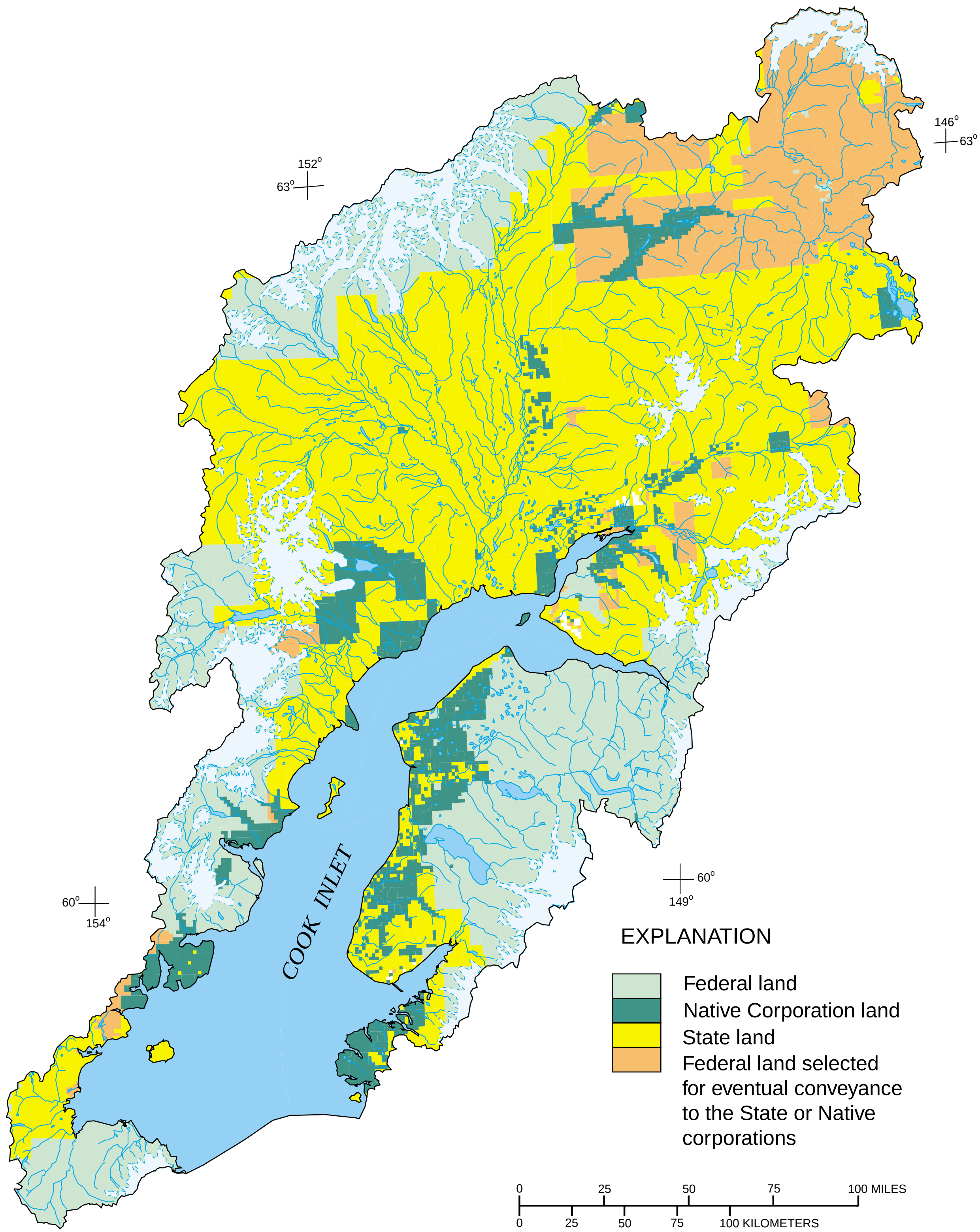

Figure 2. Land ownership in the Cook Inlet Basin, Alaska.

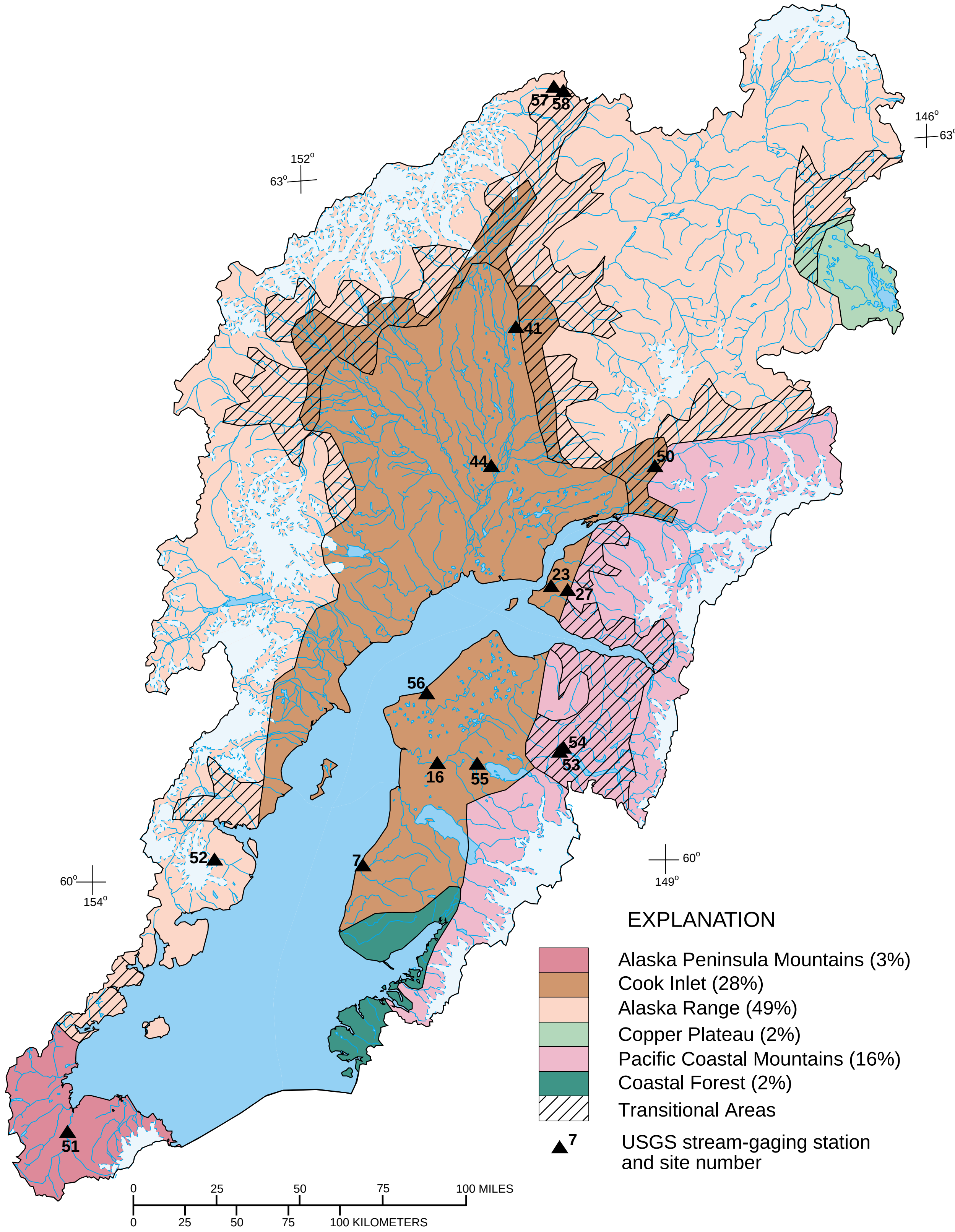

Figure 3. Ecoregions in the Cook Inlet Basin, Alaska (modified from Gallant and others, 1995).

Table 2. Ecoregions and vegetation classes for sites in the Cook Inlet Basin
[Data from Alaska Geospatial Data Clearinghouse (1998)]

Map No. (fig. 3)	Site name	Dominant ecoregion (percent of total area)	Vegetation class (percent of total area)	
			Dominant	Sub-dominant
7	Ninilchik River near Ninilchik	Cook Inlet (100)	Closed spruce forest (73)	Closed mixed forest (21)
16	Kenai River at Soldotna	Pacific Coastal Mtns (66)	Tall shrub (18)	Closed mixed forest (18)
23	South Fork Campbell Creek near Anchorage	Pacific Coastal Mtns (95)	Alpine tundra (35)	Closed spruce forest (25)
27	Chester Creek at Arctic Blvd. at Anchorage	Cook Inlet (70)	Closed spruce forest (27)	Closed mixed forest (23)
41	Talkeetna River near Talkeetna	Alaska Range (92)	Tall shrub (38)	Alpine tundra (27)
44	Deshka River near Willow	Cook Inlet (100)	Closed broadleaf & closed mixed forest (75)	Closed mixed forest (18)
50	Moose Creek near Palmer	Cook Inlet (60)	Alpine tundra (35)	Closed broadleaf & closed mixed forest (32)
51	Kamishak River near Kamishak	Alaska Peninsula Mtns (100)	Alpine tundra (49)	Tall shrub (46)
52	Johnson River above Lateral Glacier near Tuxedni Bay	Alaska Range (100)	Alpine tundra (57)	Glaciers (42)
53	Kenai River below Russian River near Cooper Landing	Pacific Coastal Mtns (100)	Tall shrub (33)	Alpine tundra (23)
54	Kenai River at Jim's Landing near Cooper Landing	Pacific Coastal Mtns (100)	Tall shrub (32)	Alpine tundra (23)
55	Kenai River below Skilak Lake Outlet	Pacific Coastal Mtns (88)	Tall shrub (25)	Alpine tundra (18)
56	Swanson River near Kenai	Cook Inlet (100)	Closed mixed forest (45)	Low shrub/lichen tundra (17)
57	Colorado Creek near Colorado	Alaska Range (100)	Alpine tundra (69)	Tall shrub (31)
58	Costello Creek near Colorado	Alaska Range (100)	Alpine tundra (53)	Tall shrub (30)

Few long-term streamflow monitoring stations exist in the Cook Inlet Basin, so determining whether normal streamflow existed during sampling from May through August 1998 was problematic. The Kenai River at Soldotna and the Talkeetna River near Talkeetna have been monitored since the mid-1960's (fig. 4). Ship Creek near Anchorage and the Little Susitna River near Palmer are two smaller streams that were not sampled, but also have long streamflow records (fig. 4). The interquartile range of streamflow shown in blue on figure 4 represents the central 50 percent of data for each day. The interquartile range is unaffected by the magnitudes of extremes such as rare floods. To improve the clarity of the figures, the interquartile range was plotted with a 5-day moving average. By comparing this distribution of daily flows for the period of record through 1997 to the 1998 streamflows, it was concluded that 1998 was a year of normal streamflow in the basin.

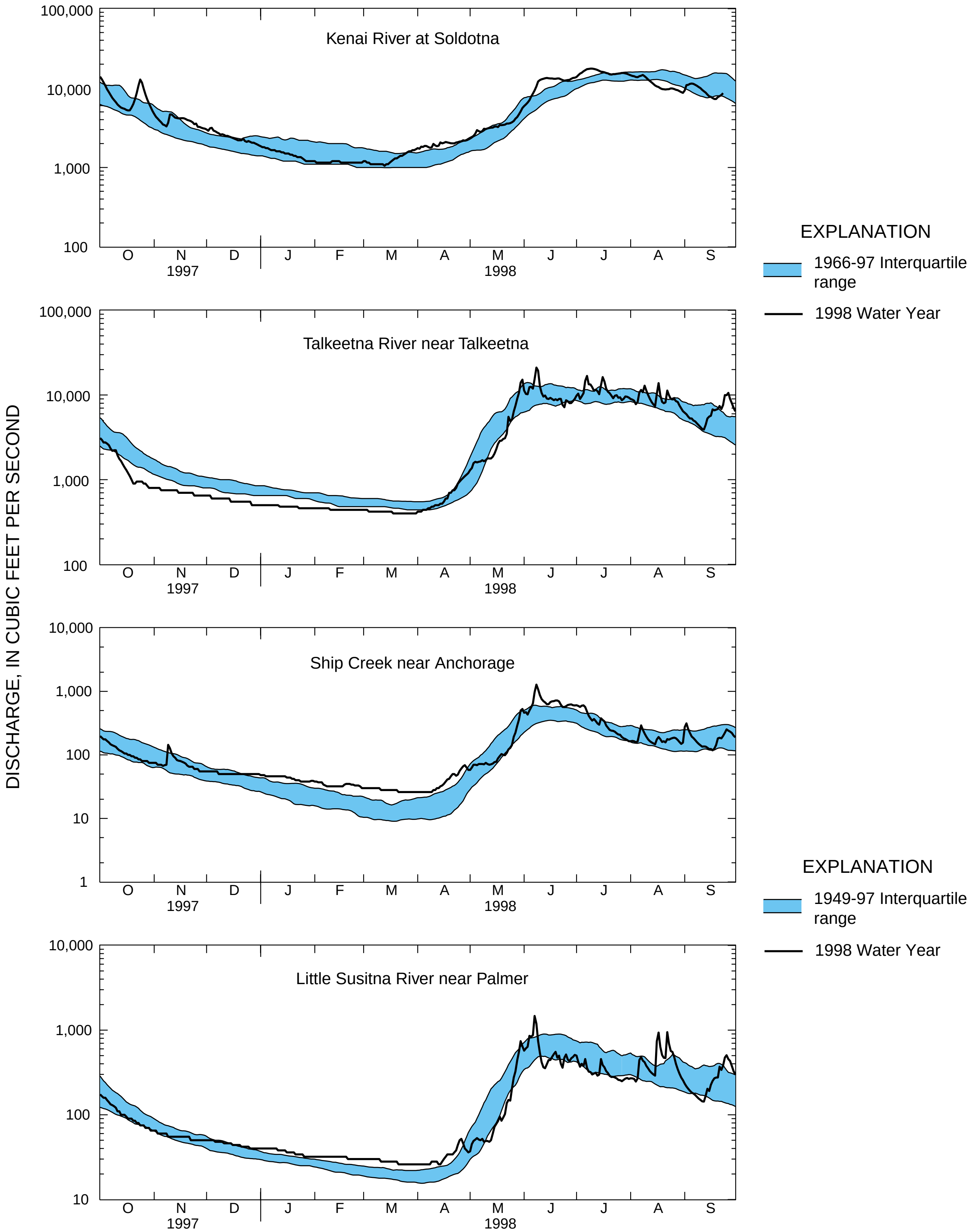

Figure 4. Comparison of 1998 streamflow to normal streamflow for four rivers in the Cook Inlet Basin, Alaska.

METHODS

Streambed Sediment Sampling

Streambed sediments were sampled from several depositional areas at each site (fig. 5). Sediments were collected from the surface of the streambed using Teflon tubes or Teflon coated spoons and composited in glass bowls (Shelton and Capel, 1994). Three types of samples were obtained from this composite: a sample for SVOCs (and organochlorines when necessary) was passed through a 2-mm stainless-steel sieve; a sample for particle-size analysis also was passed through the 2-mm sieve; and a sample for trace elements was passed through a 0.063-mm Nylon sieve. Up to 250 mL of stream water was used for sieving the trace-element sample. Samples for SVOCs and trace elements were chilled after sieving. Water included in the trace-element sample was decanted after very fine-grained sediments had settled.

Sediment samples also were collected for a national study of historical trends in water quality. Those samples were collected from two ponds on Chester Creek in Anchorage (sites A and B, fig. 6) and the streambed of a tributary to Chester Creek upstream from the area of development (site C, fig. 6). The sample-collection method at the pond sites differed from that used in streams. At the pond sites, a coring device was used and compositing was not done so that discrete layers of the core could be analyzed separately.

Figure 5. Streambed-sediment samples being collected from a depositional area.

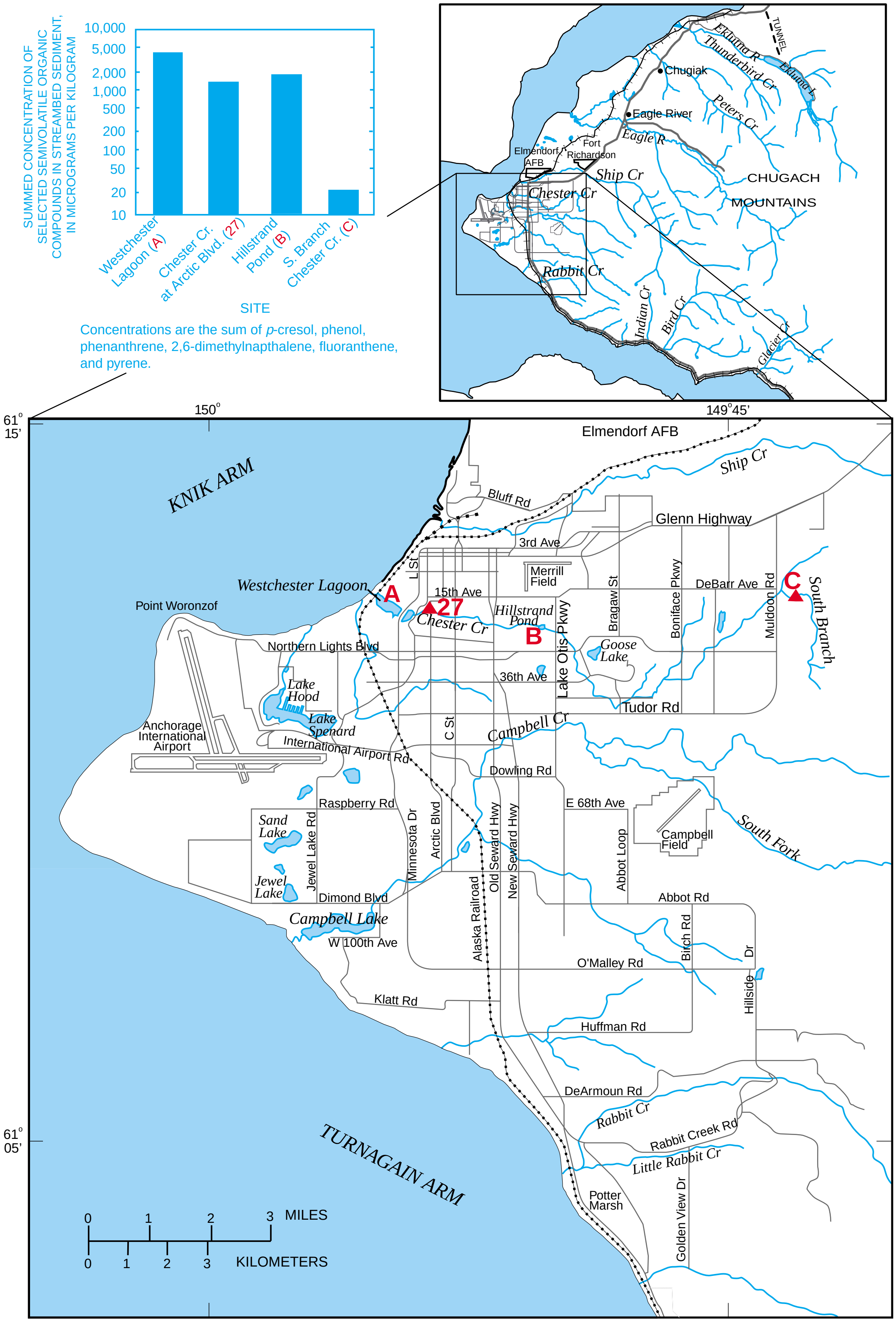

Figure 6. Location of sampling sites in the Anchorage area and summed concentration of selected semivolatile organic compounds in streambed sediments.

Fish Tissue Sampling

Slimy sculpin, *Cottus cognatus* (fig. 7), was chosen as the most appropriate species for tissue analysis in the Cook Inlet Basin. This species is nonmigratory and a bottom-feeding omnivore, which are characteristics necessary for interpretation of results (Crawford and Luoma, 1993). Guidelines from Crawford and Luoma recommend analysis of whole fish for organic compounds and analysis of fish livers for trace elements. Because adult slimy sculpin are small, whole fish were used for analysis of both organic compounds and trace elements. Whole sculpin were used for trace-element samples in both the Willamette River Basin NAWQA study (Wentz and others, 1998) and the Puget Sound Basin NAWQA study (MacCoy and Black, 1998).

Fish typically were collected using a backpack electrofishing unit and a seine (fig. 8). The seine would be set across a riffle and the electrofishing would begin about 20 ft upstream and work down toward the seine. Sculpin captured on the seine were placed in a bucket of stream water until sufficient numbers had been collected to constitute a sample. Fish tissue samples were composites of a number of individuals to achieve desired minimum weight of 30 g. The fewest number of individuals making up a composite sample was four fish and the largest number was 20 fish. At two sites, no sculpin were collected. At a third site, most individual sculpin were much smaller than were collected elsewhere, so only enough comparably sized sculpins were available for a trace-element sample and no organics in fish tissue data were collected at that site.

Figure 7. Slimy sculpin collected from a Cook Inlet Basin site.

Figure 8. Electrofishing technique used to collect fish samples.

Each fish in the composite sample was weighed and measured. Fish used for an organics sample were wrapped in aluminum foil and then placed in a plastic bag, whereas fish used for trace element samples were double bagged in plastic. Composited samples were immediately placed on dry ice, or for sites located in Anchorage, placed on wet ice and taken to a freezer at the USGS office. At the three sites without adequate numbers of sculpin, streambed sediments were analyzed for organochlorines as well as SVOCs (table 1). At three other sites, organochlorines were analyzed in both streambed sediments and fish tissues.

Analytical Methods

Streambed samples were analyzed for organic compounds at the USGS National Water-Quality Laboratory (NWQL) in Arvada, Colo. Details of laboratory methods related to the analysis of SVOCs in streambed sediments are described by Furlong and others (1996). The analytical results for constituents are expressed as *concentration* when they exceed a minimum reporting limit (MRL), *detected* when they are detected but are less than the MRL, and *not detected* when they are less than the method detection limit. Streambed samples were analyzed for trace elements at the USGS Branch of Geochemistry Laboratory in Denver, Colo. Arbogast (1990) describes laboratory procedures followed for processing streambed samples for trace element analysis. Trace elements in streambed sediments were analyzed following a total digestion procedure. As such, these data may be more useful for differentiating source areas of sediments than for detecting anthropogenic effects, or for determining bioaccumulation in fish.

Whole sculpin were analyzed for organochlorines at the NWQL according to procedures described by Leiker and others (1995). Whole sculpin also were analyzed for trace elements at the NWQL using methods described by Hoffman (1996). The NWQL employs rigorous quality assurance procedures in all of its analytical procedures (Pirkey and Glodt, 1998).

Analytical results of SVOCs in streambed sediments collected during the first 20 NAWQA studies were found to have some laboratory contamination (Gilliom and others, 1998). At the NWQL, contamination of the following five SVOCs is unavoidable (E.T. Furlong, USGS, written commun., 1998): *bis*(2-Ethylhexyl) phthalate, di-*n*-butyl phthalate, butylbenzyl phthalate, phenol, and diethyl phthalate. Analyses of these compounds in samples from the Cook Inlet Basin were corrected by subtracting the 95th percentile concentration in laboratory blank samples from the measured concentrations (Gilliom and others, 1998).

STANDARDS AND GUIDELINES

Guidelines for the protection of aquatic life have been established by the U.S. Environmental Protection Agency (1996) for only 10 specific SVOCs in streambed sediments. Two additional SVOCs in streambed sediments have guidelines proposed by the Canadian Council of Ministers of the Environment (1999). These guidelines, as well as data from 198 NAWQA sites (Gilliom and others, 1998) were used to evaluate streambed sediment results from the Cook Inlet Basin. Gilliom and others (1998) developed a ranking system (table 3) by using three categories of SVOCs (PAHs, phenols, and phthalates). Each site was scored by its ratio to the national median concentrations (in micrograms per kilogram, dry weight) as follows:

- PAHS 104
- Phenols 73
- Phthalates 20

Table 3. Guidelines for ranking sites based on semivolatile organic compounds in streambed sediment

[From Gilliom and others, 1998]

Rank (1, lowest; 4, highest)	Percentile	Water-quality score (ratio to national median)
1	≤25	≤0.45
2	>25-50	>0.45-1.58
3	>50-75	>1.58-5.43
4	>75	>5.43

If a site had a ratio to the national median values for the three categories of SVOCs of less than 0.45, it ranked among the lowest 25 percent of sites nationally. If a site had a ratio to the national median values for the three categories of SVOCs of greater than 5.43, it ranked among the highest 25 percent of sites nationally. A comparison with previous NAWQA data only provides a relative ranking of sites in Cook Inlet Basin. NAWQA sites are not selected randomly; therefore, a similar analysis with a larger population of water bodies in the country might result in a different evaluation.

Organochlorines were analyzed in both streambed sediment and whole slimy sculpin samples. However, only the guidelines for the protection of fish-eating wildlife were used for comparison (Newell and others, 1987).

Trace-element concentrations in streambed sediments were compared with those of previous NAWQA studies in the same manner as was used for comparisons of SVOC data; however, the values separating the quartiles differ from those used for SVOCs. Gilliom and others (1998) determined the following national median concentrations (in micrograms per grams, dry weight):

- Arsenic: 6.35
- Cadmium: 0.4
- Chromium: 62
- Copper: 26
- Lead: 24.3
- Mercury 0.06
- Nickel: 25
- Selenium 0.7
- Zinc 110

Background levels of trace elements in streambed sediments also were determined using a technique described by Deacon and Stephens (1998). The technique involves plotting the cumulative frequency of observed concentrations for a particular element and determining where the slope of a best fit line changes abruptly. The point at which the slope changes is considered the background concentration. If no substantial slope change is observed, then samples are considered to represent natural conditions.

The Canadian Council of Ministers of the Environment (1999) has established guidelines for some trace elements in unsieved streambed sediment. These guidelines use two assessment values: a lower value, called the “interim freshwater sediment quality guideline” (ISQG), is the concentration below which adverse effects to aquatic organisms are expected to occur rarely. The upper value, called the “probable effect level” (PEL), is the concentration above which adverse effects are expected to occur frequently. Because trace-element samples for the NAWQA program are from sediments finer than 0.063 mm where concentrations tend to be greatest, comparisons with the Canadian guidelines may overestimate the effects on aquatic organisms (Deacon and Stephens, 1998). However, the PEL may be useful for comparative purposes when applied to the finer than 0.063-mm size fraction sediment samples analyzed for this study.

RESULTS

Discussion of results generally is restricted to organic compounds as a group and a subset of trace elements. Streambed sediments were analyzed for 32 organochlorine pesticides and PCBs at six sites (table 1) and only a single compound was detected at reportable concentrations. Organochlorine pesticides and polychlorinated biphenyls (PCBs) were detected in just three samples of slimy sculpin from a total of 12 samples analyzed (table 1). Twenty-eight compounds were analyzed and four were detected. SVOCs were rarely detected in streambed sediments of the 15 sites sampled in the Cook Inlet Basin (table 4). A total of 78 SVOCs were analyzed and 23 were detected at concentrations greater than the 50 µg/kg MRL, 19 compounds were detected at concentrations less than the MRL. Thirty-six SVOCs were never detected (appendix 2). No individual organic compounds were consistently detected at concentrations greater than the MRL. No SVOCs in the Cook Inlet Basin streambed sediment samples were measured at concentrations exceeding any aquatic-life criteria described by Gilliom and others (1998). Chester Creek at Arctic Boulevard in Anchorage had the greatest number of SVOC detections (23) in streambed sediment (table 4), of which 16 were greater than the minimum reporting level. With the exception of the two pond sites in the Chester Creek basin, concentrations also tended to be highest at Chester Creek compared with other stream sites (table 5). Thirteen of the 23 SVOCs with concentrations greater than 50 µg/kg were found only at Chester Creek. Most of those concentrations were estimated because the values were outside of the instrument calibration range. This was the only site sampled whose drainage was largely developed.

Arsenic concentrations in streambed sediments finer than 0.063 mm exceeded the PEL at eight sites. Chromium concentrations in streambed sediments exceeded the PEL at six sites. Cadmium, lead, and zinc concentrations were above background levels in streambed sediments at Chester Creek. Selenium concentrations in slimy sculpin ranged from 1.4 to 8.5 µg/g, dry weight. Six sites had selenium concentrations in the slimy sculpin samples at concentrations that may cause adverse effects in some species (U.S. Department of the Interior, 1998).

Table 4. Detection frequency for organochlorine compounds in whole slimy sculpin and semivolatile organic compounds in streambed sediments

[Ranking is in comparison with 198 NAWQA sites summarized by Gilliom and others (1998) based on summed concentrations of PAHs, phenols, and phthalates; a rank of 1 places the site with the lowest 25 percent of sites nationally, a rank of 4 places the site with the highest 25 percent of sites; NC, sample not collected]

Map No. (fig. 1)	Site name	Mean weight of slimy sculpin in composite sample (grams)	Lipid in slimy sculpin (percent)	Number of organochlorine compounds detected in whole slimy sculpin	Number of semivolatile organic compounds detected in streambed sediments	Rank for summed SVOC concentration
7	Ninilchik River	5.1	4.8	0	1	1
16	Kenai River at Soldotna	2.9	2.6	0	9	1
23	South Fork Campbell Creek	6.0	2.8	1	1	1
27	Chester Creek	4.3	2.8	1	23	4
41	Talkeetna River	3.0	4.6	1	0	1
44	Deshka River	2.8	4.2	0	9	2
50	Moose Creek	3.6	5.3	0	14	3
51	Kamishak River	3.6	NC	NC	0	1
52	Johnson River	NC	NC	NC	0	1
53	Kenai River below Russian River	3.1	3.1	0	0	1
54	Kenai River at Jim’s Landing	7.2	4.7	0	3	3
55	Kenai River below Skilak Lake Outlet	2.4	4.6	0	2	1
56	Swanson River	2.1	8.1	0	2	3
57	Colorado Creek	NC	NC	NC	10	1
58	Costello Creek	9.4	5.1	0	7	1

Table 5. Concentrations of semivolatile organic compounds and total PCBs exceeding minimum reporting limits in streambed and pond sediments

[See figures 1 and 6 for site locations; minimum reporting limit 50 micrograms per kilograms (µg/kg) for streambed samples and 5 µg/kg for pond samples; concentration in µg/kg dry weight; NA, not analyzed; --, not detected, or detected at concentration less than the minimum reporting limit; Westchester Lagoon and Hillstrand Pond data shown only for compounds reportable at other sites, from Peter VanMetre, USGS, written commun., 1999]

Map No.	Site name	PAHs					
		1,6-Dimethyl-napthalene	1-Methyl-9H-fluorene	1-Methyl-phenanthrene	2,6-Dimethyl-napthalene	9,10-Anathraquinone	Benz[*a*]-anthracene
7	Ninilchik River	--	--	--	--	--	--
27	Chester Creek	--	--	--	58	[a]150	[a]130
44	Deshka River	--	62	--	--	--	
50	Moose Creek	150	--	60	70	--	--
A	Westchester Lagoon (0-3 cm)	67	42	153	292	NA	[b]392
B	Hillstrand Pond (0-2 cm)	36	32	41	173	NA	109

Map No.	Site name	Benzo[*a*]-pyrene	Benzo[*b*]-fluoranthene	Benzo[*ghi*]-perylene	Benzo[*k*]-fluoranthene	Chrysene	Dibenzo-thiophene
27	Chester Creek	[a]200	[a]240	[a]180	[a]190	[a]150	--
A	Westchester Lagoon (0-3 cm)	379	673	[a]332	429	850	NA
B	Hillstrand Pond (0-2 cm)	107	212	[a]107	140	306	NA

Map No.	Site name	Fluoranthene	Indeno[1,2,3-*cd*]pyrene	Naphthalene	Phenanthrene	Pyrene	Total PCBs
7	Ninilchik River	--	--	--	--	--	NA
27	Chester Creek	[a]420	[a]150	--	220	[a]410	NA
44	Deshka River	--	--	--	--	--	NA
50	Moose Creek	--	--	80	70	--	NA
54	Kenai River at Jim's Landing	--	--	--	--	--	--
56	Swanson River	--	--	--	--	--	NA
A	Westchester Lagoon (0-3 cm)	1670	302	44	[b]781	[b]1550	147
B	Hillstrand Pond (0-2 cm)	261	82	23	178	327	46

Map No.	Site name	Phenols			Phthalates		
		4-Nitrophenol	Phenol	*p*-Cresol	bis(2-ethyl-hexyl)phthalate	Dibutyl-phthalate	Dioctyl-phthalate
7	Ninilchik River	--	--	410	--	--	--
27	Chester Creek	--	--	55	[c]2,200	[a,c]86	[a]290
44	Deshka River	[a]86	130	--	--	--	--
54	Kenai River at Jim's Landing	--	55	650	--	--	--
56	Swanson River	--	--	1,200	--	--	--
A	Westchester Lagoon (0-3 cm)	NA	282	284	NA	NA	NA
B	Hillstrand Pond (0-2 cm)	NA	552	531	NA	NA	NA

[a]Estimated value outside of instrument calibration range
[b]Value exceeds Canadian sediment quality guidelines for the protection of aquatic life (Canadian Council of Ministers of the Environment (1999)
[c]Concentration reduced by amount of laboratory contamination described by Gilliom and others (1998)

For quality assurance purposes, triplicate samples of slimy sculpin were collected at Chester Creek and were analyzed for organochlorines. Results for the three samples showed that PCBs were the only compound detected, but concentrations, surrogate recovery, fish size, and percent lipids varied (table 6). At Johnson River, duplicate streambed sediment samples were collected for analysis of trace elements. Concentrations of each element discussed in this report were within 8 percent between the two samples.

Table 6. Quality-assurance data for organochlorines in whole slimy sculpin, Chester Creek at Arctic Blvd., May 13, 1998
[µg/kg, microgram per kilogram]

Mean weight (grams)	Lipids (percent)	PCB concentration (µg/kg) (wet weight)	Surrogate recovery (percent)
4.3	2.80	79	80
10.0	4.25	115	72
8.1	3.95	142	124

The complete data set for all analyses is expected to be available on the Cook Inlet Basin NAWQA web page during 2000 at *http://ak.water.usgs.gov/Projects/Nawqa/*.

DISCUSSION OF ORGANIC COMPOUND DATA

Streambed Sediment

At six sites (Kenai River below Russian River and at Jim's Landing, Talkeetna River, Johnson River, Kamishak River, and Colorado Creek), organochlorines were analyzed in streambed sediment samples, either in place of a fish tissue sample or to supplement the fish tissue sample. The only detectable concentrations of organochlorines were from streambed sediments collected at the Talkeetna River (table 7). Three of 32 compounds were detected, although only hexachlorobenzene was above the MRL. The two compounds detected below the MRL were dieldrin and *p,p'*-DDE. Organochlorine compounds that were not detected in any sample from the Cook Inlet Basin are listed in appendix 2.

No streambed sediment samples collected in the Cook Inlet Basin contained a SVOC that exceeds a criterion for the protection of aquatic life. However, core samples from Westchester Lagoon (0-3 cm stratum) and Hillstrand Pond (0-2 cm stratum) (sites A and B, fig. 6) exceeded suggested criteria for protection of aquatic life for benz[*a*]anthracene, phenanthrene, and pyrene (table 5). Four sites

Table 7. Organochlorine compounds detected in streambed sediments and whole fish
[Concentrations in micrograms per kilogram, wet weight; D, detected below minimum reporting limit of 1.0 µg/kg; --, less than method detection limit]

Site	Streambed sediment			Fish tissue				Mean weight of fish (grams)	Lipid (percent)
	Dieldrin	Hexachlorobenzene	*p,p'*-DDE	Hexachlorobenzene	PCBs	*p,p'*-DDE	*p,p'*-DDT		
South Fork Campbell Creek	--	--	--	--	--	9.0	6.1	6.0	2.8
Chester Creek	--	--	--	--	79	--	--	4.3	2.8
Talkeetna River	D	13	D	5.7	--	--	--	3.0	4.6

had sufficiently large concentrations of at least one SVOC to rank them with the upper 50 percent of NAWQA sites sampled for SVOCs during 1992-95 (Gilliom and others, 1998) (table 4). A score of more than 5.43 times the sum of national median concentrations of PAHs, phenols, and phthalates places a site among the upper 25 percent of sites in terms of SVOCs contamination. Chester Creek scored nearly 50 times the national median for PAHs, phenols, and phthalates. Chester Creek had reportable concentrations of several PAHs, but was scored with the upper 25 percent of sites largely because of a *bis*(2-ethylhexyl)phthalate concentration of 2,200 µg/kg (table 5). Lopes and others (1998) reported median, mean, and standard deviation for *bis*(2-ethylhexyl)phthalate from 431 samples to be 180, 620, and 1,600 µg/kg, respectively.

Several layers from cores collected at Hillstrand Pond upstream from the Chester Creek stream sampling location at Arctic Boulevard, and at Westchester Lagoon downstream from the sampling site, confirmed results obtained at the stream site. Although phthalates were not analyzed from the core samples, phenols and PAHs were larger than national median values from streambed sediments. PAH concentrations were particularly large at the Westchester Lagoon site where the top two layers were 8,880 µg/kg (0-3 cm) and 9,710 µg/kg (3-6 cm) for the summed PAHs identified by Gilliom and others (1998) (Peter VanMetre, USGS, written commun., 1999). The streambed sample from the South Branch Chester Creek (site C, fig. 6) upstream from development, collected in conjunction with the coring, had very low levels of SVOCs. Concentrations generally increased in the downstream direction from the South Branch Chester Creek to Westchester Lagoon (fig. 6), indicating that surface runoff and land use, rather than atmospheric deposition or natural sources, were more likely responsible for SVOCs distribution in the Chester Creek basin.

Several SVOCs were detected in streambed sediment at Moose Creek, Kenai River at Soldotna, Deshka River, and the two sites in Denali National Park and Preserve; few, if any, detectable SVOCs were detected at the remaining sites (table 4). The drainage of Moose Creek includes an extensive coal deposit that may be the source for SVOCs in that basin. Small concentrations of SVOCs were detected at remote sites such as the Deshka River, an undeveloped basin draining vast areas of wetlands (fig. 9), and at Costello and Colorado Creeks in Denali National Park and Preserve, which largely drain tundra (table 2). Isolated coal deposits are know to exist in the part of Denali National Park and Preserve where Costello and Colorado Creeks are located.

Although the Kenai River is largely undeveloped upstream from the city of Soldotna, a corridor along the river downstream from Skilak Lake has become increasingly developed. This localized development may explain the low-level detections of SVOCs at the Soldotna site. The Kenai River at Soldotna site (located in the city of Soldotna) is along a mid-channel island less than 0.25 mi downstream from a highway bridge. Samples were collected from this site in early May, before the annual influx of recreationalists, minimizing seasonal influences from highway and boat traffic. Sport fishing for Kenai River salmon has grown rapidly; in 1997 an estimated 321,000 angler-days were expended on the Kenai River (Barry Stranton, Alaska Department of Fish and Game, oral commun., 1998). Peak use coincides with the peak of sockeye and chinook salmon returns from late June through July.

SVOCs generally were less than MRLs at the sites not mentioned above. No SVOCs were detected at four sites, including those in Katmai and Lake Clark National Parks and one site in the Kenai National Wildlife Refuge (table 4).

One compound, *p*-cresol, was measured at concentrations exceeding the MRL at four stream sites and the two ponds (table 5). Swan-

Figure 9. Deshka River in a vast area of wetlands and mixed forests.

son River had a *p*-cresol concentration of 1,200 µg/kg. That concentration is much greater than the median *p*-cresol concentration of 53 µg/kg (mean concentration and standard deviation of 210 and 460 µg/kg) from 370 samples described by Lopes and others (1998). This phenol compound was detected at 58 percent of other NAWQA sites in 1992-95 (Lopes and others, 1998) including rural areas such as the Upper Snake River Basin (detected in 79 percent of samples; Clark and others, 1998) and the Red River of the North Basin (detected in 64 percent of the samples; Stoner and others, 1998). Phenols in general, and specifically *p*-cresol, were found to be widespread among streambed-sediment samples collected by the NAWQA program from 1992-95, and did not differ significantly among urban and reference sites, suggesting possible natural sources (Lopes and others, 1998). Sediments collected from the Kenai River at Jim's Landing had moderately elevated levels of *p*-cresol (table 5). Samples at the Jim's Landing site were collected from a backwater area.

The number of SVOCs detected in streambed samples from the Cook Inlet Basin can be compared with those of other NAWQA study units that represent areas of both low and high population density (table 8; fig. 10). Study units with low population densities tend to have fewer commonly occurring SVOCs than do study units with higher population densities. Although NAWQA sampling sites are not selected randomly, neither are they selected to address questions of population density. It appears that—at the study unit scale—areas of greater human population and the associated transportation and energy production infrastructure tend to have greater numbers of SVOCs in streambed sediments. Lopes and others (1998) found that at the basin scale, the correlation between population density and total PAHs and phthalates was weak, but statistically significant.

Table 8. Comparison of population densities and SVOC detections among selected NAWQA study units

Study unit	Population density (number per square mile)	Number of SVOCs detected in at least 50 percent of samples[1]
Cook Inlet Basin: Alaska	8	3
Upper Snake River Basin: Idaho and Wyoming[2]	11	2
Red River of the North Basin: Minnesota, North and South Dakota[3]	14	6
Ozark Plateaus: Arkansas, Kansas, Missouri, and Oklahoma[4]	48	1
South Platte River Basin: Colorado, Nebraska, and Wyoming[5]	99	11
Western Lake Michigan Drainages: Wisconsin and Michigan[6]	122	11
Georgia–Florida Coastal Plain: Georgia and Florida[7]	145	8
White River Basin: Indiana[8]	185	14
Lower Susquehanna River Basin: Pennsylvania and Maryland[9]	201	28
Connecticut, Housatonic, and Thames River Basins: Connecticut, Massachusetts, New Hampshire, New York, and Vermont[10]	285	27
Potomac River Basin: Maryland, Pennsylvania, Virginia, West Virginia, and District of Columbia[11]	314	35

[1]Excluding compounds subject to laboratory contamination
[2]Clark and others, 1998
[3]Stoner and others, 1998
[4]Peterson and others, 1998
[5]Dennehy and others, 1998
[6]Peters and others, 1998
[7]Berndt and others, 1998
[8]Fenelon, 1998
[9]Lindsey and others, 1998
[10]Garabedian and others, 1998
[11]Ator and others, 1998

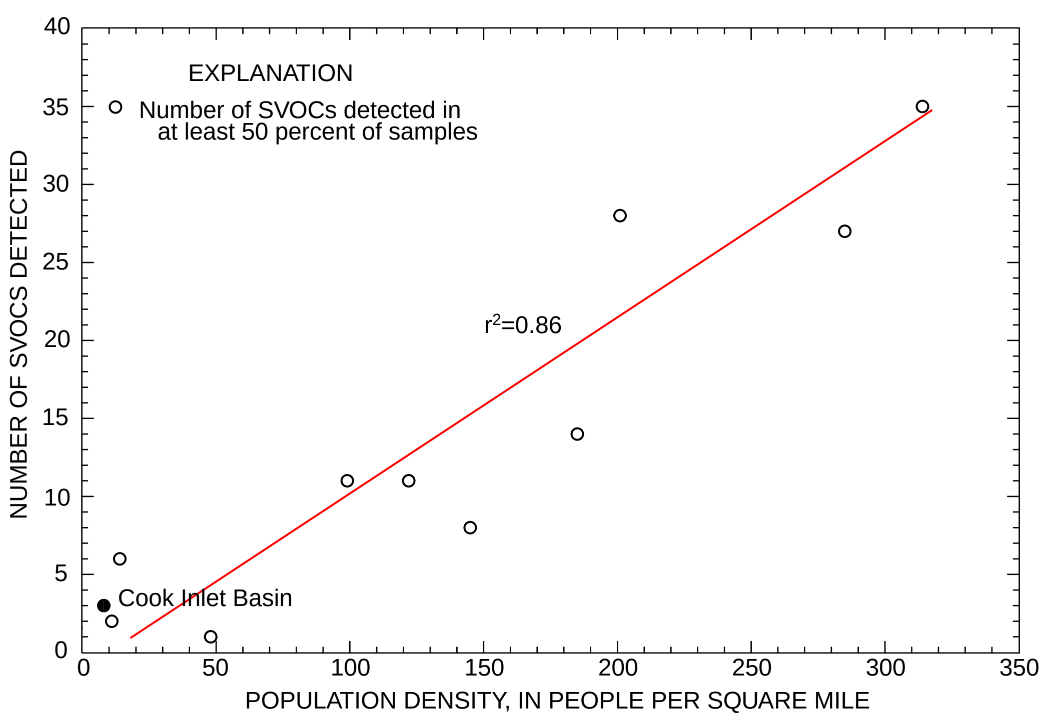

Figure 10. Comparison of population density and SVOC detections among selected NAWQA study units.

Fish Tissue

Four of a possible 28 organochlorine compounds were detected, each in only one sample of whole slimy sculpin collected at 12 sites. Concentrations of those detected organochlorines did not exceed guidelines for the protection of fish-eating wildlife (Newell and others, 1987). Hexachlorobenzene was detected in slimy sculpin at the Talkeetna River at a concentration of 5.7 µg/kg (table 7). Two DDT compounds, *p,p'*-DDE and *p,p'*-DDT, were detected in slimy sculpin collected from South Fork Campbell Creek. PCBs were detected at one site, Chester Creek. Quality assurance samples confirmed the presence of PCBs in slimy sculpin at Chester Creek.

DISCUSSION OF TRACE ELEMENT DATA

Many of the 44 trace elements analyzed in streambed sediment samples were present at sites in the Cook Inlet Basin. Neither bismuth nor gold was detected in either a streambed sediment or a fish tissue sample (appendix 2). Nineteen of 22 trace elements were detected in at least one sample of slimy sculpin. Antimony, beryllium, and uranium were never detected in tissue samples. In this report, the discussion is restricted to those trace elements potentially toxic to aquatic organisms: arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, and zinc.

Streambed Sediment

Four trace elements—arsenic, chromium, copper, and nickel—appear to be at naturally large concentrations in the Cook Inlet Basin (table 9, fig. 11). Arsenic concentrations in sediments finer than 0.063 mm exceeded the PEL developed for unsieved sediment samples at Ninilchik River, Chester Creek, South Fork Campbell Creek, Moose Creek, Kenai River below Russian River and at Soldotna, Colorado Creek, and Costello Creek. All sites except the Talkeetna River site had arsenic concentrations exceeding the national median concentration of 6.35 µg/g. Chromium concentrations in sediments finer than 0.063 mm exceeded the PEL developed for unsieved sediment samples at Chester Creek, Deshka River, Kenai River below Russian River and at Jim's Landing, Colorado Creek, and Costello Creek. Chromium concentrations were smaller than the national median value of 62 µg/g only at the Ninilchik and Talkeetna Rivers. Copper concentrations tended to be between the ISQG and PEL at most sites and were smaller than the national median concentration of 26 µg/g only at the Ninilchik River. Nickel concentrations were smaller than the national median value only at the Ninilchik, Talkeetna, and Johnson Rivers. The ISQG do not include data for nickel.

Four trace elements—cadmium, lead, selenium, and zinc—show a significant break in slope in the cumulative frequency curve indicating a break between background levels and elevated concentrations (fig. 12). Cadmium, lead, and zinc exceed background concentrations for the Cook Inlet Basin only at Chester Creek. Relative to NAWQA sites sampled from 1992 to 1995, most sites from the Cook Inlet Basin ranked within the upper 50 percent (greater concentrations) using the scoring criteria for trace elements from Gilliom and others (1998) (table 9). The Deshka River, South Fork Campbell Creek, Colorado Creek, and Costello Creek, which are essentially undeveloped basins, ranked within the upper 25 percent of sites indicating that surficial rocks and soils naturally contribute trace elements to streambed sediments. Only the Talkeetna River ranked with the lowest 25 percent of NAWQA sites sampled from 1992 to 1995. Brabets and others (1999) describe the geology of the Cook Inlet Basin at a broad scale. More detailed information is available only for selected areas. These results indicate that the Cook Inlet Basin contains more expansive areas of mineralized rock and soils than were sampled in NAWQA study units from 1992 to 1995.

Table 9. Trace-element concentrations in streambed sediments and scores relative to national median values

[Score is each element divided by the appropriate national median value and the summed value divided by 9. Rank is by quartiles, with 1 as the lowest 25 percent of sites and 4 as the highest 25 percent of sites nationally; scores ≤0.85 are rank 1, scores >0.85-1.07 are rank 2, scores >1.07-1.57 are rank 3, scores >1.57 are rank 4. Background level for arsenic, chromium, copper, mercury, and nickel could not be determined]

Map No. (fig. 1)	Site name	Trace element (microgram per gram, dry weight)									Organic carbon (percent)	Score	Rank
		Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Zinc			
7	Ninilchik River	[a]30	0.2	50	15	8	0.05	20	0.4	74	3.57	1.05	2
16	Kenai River at Soldotna	[a]23	0.3	84	36	15	0.03	42	0.3	85	0.91	1.22	3
23	South Fork Campbell Creek	[a]32	0.5	78	73	14	0.03	34	0.4	110	2.85	1.59	4
27	Chester Creek	[a]23	[b]1.2	[a]120	60	[b]90	0.18	64	0.8	[a,b]600	6.96	2.97	4
41	Talkeetna River	5.2	<0.1	38	27	7	0.04	18	0.1	53	0.16	0.46	1
44	Deshka River	9.8	0.5	[a]110	84	13	0.46	46	[b]2.6	100	8.42	2.49	4
50	Moose Creek	[a]23	0.3	84	74	16	0.2	40	0.5	120	1.52	1.44	3
51	Kamishak River	8.9	0.1	78	38	7	0.04	29	0.4	93	0.58	0.87	2
52	Johnson River	16	0.24	66	75	3.9	0.13	17	0.27	127	0.05	1.30	3
53	Kenai River below Russian River	[a]17	0.3	[a]110	46	16	0.07	52	0.3	110	1.51	1.36	3
54	Kenai River at Jim's Landing	11	0.3	[a]110	45	17	0.09	54	0.7	110	2.61	1.37	3
55	Kenai River below Skilak Lake Outlet	9.3	0.2	82	41	13	0.07	42	0.2	80	0.72	1.02	3
57	Colorado Creek	[a]44	0.47	[a]215	59	15	0.18	131	0.73	154	0.52	2.78	4
58	Costello Creek	[a]23	0.27	[a]174	64	16	0.23	98	0.72	144	0.46	2.22	4
National median value[c]		**6.35**	**0.4**	**62**	**26**	**24**	**0.06**	**25**	**0.7**	**110**			

[a]Concentration is at or greater than PEL, which is determined for bulk sediment samples
[b]Sample is above background level
[c]National median values from Gilliom and others (1998)

Chester Creek contained streambed sediments that exceeded the PEL or were greater than the Cook Inlet Basin background levels for five of the nine trace elements discussed in this report. Chester Creek was the only site where cadmium (1.2 µg/kg), lead (90 µg/kg), or zinc (600 µg/kg) exceeded those backgrounds (table 9). Brabets (1987) sampled lead and zinc in streambed sediments from the Chester Creek basin as part of a water-quality study focused on urban runoff. In that study, lead concentrations of 230 µg/g and zinc concentrations of 400 µg/g were observed upstream from the Arctic Boulevard site. At Arctic Boulevard, lead and zinc concentrations in Chester Creek decreased to 80 and 40 µg/g (Brabets, 1987). This indicates substantial input of lead and zinc to Chester Creek upstream from Arctic Boulevard prior to Brabets' study, and either dilution or dispersion of the more contaminated sediments in a downstream direction.

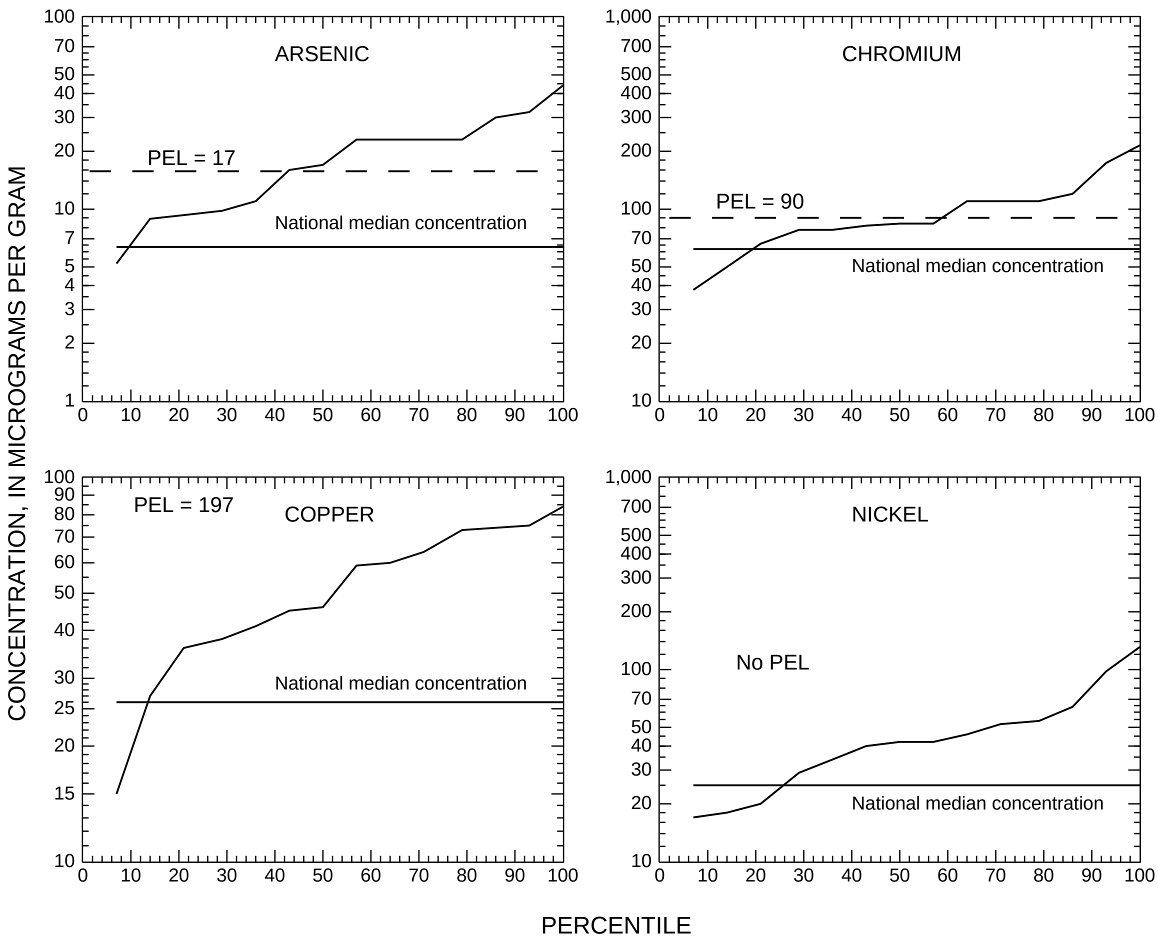

Figure 11. Concentrations of arsenic, chromium, copper, and nickel in streambed sediments with comparison to probable effect level (PEL) and national median concentrations determined by Gilliom and others (1998).

Streambed sediment from the Deshka River contained mercury and selenium at concentrations of 0.46 and 2.6 µg/g, respectively, that were substantially greater than at other sites sampled in the Cook Inlet Basin and much greater than the median from the 198 NAWQA samples collected from 1992-95 (table 9). Mercury concentrations in the finer than 0.063-mm streambed sediments were near the PEL of 0.486 µg/g for unsieved sediments (Canadian Council of Ministers of the Environment, 1999). Although a ISQG or PEL has not been established for selenium, an aquatic hazard assessment for selenium developed by Lemly (1995) classifies selenium concentrations of 1 µg/g as “no identifiable hazard level” and a concentration of 4 µg/g as “high hazard level.” Copper concentrations in streambed sediments from the Deshka River were the highest (84 µg/g) in the Cook Inlet Basin.

Colorado and Costello Creeks in Denali National Park and Preserve tended to have some of the highest natural trace-element concentrations in the Cook Inlet Basin. A streambed sediment sample from Colorado Creek

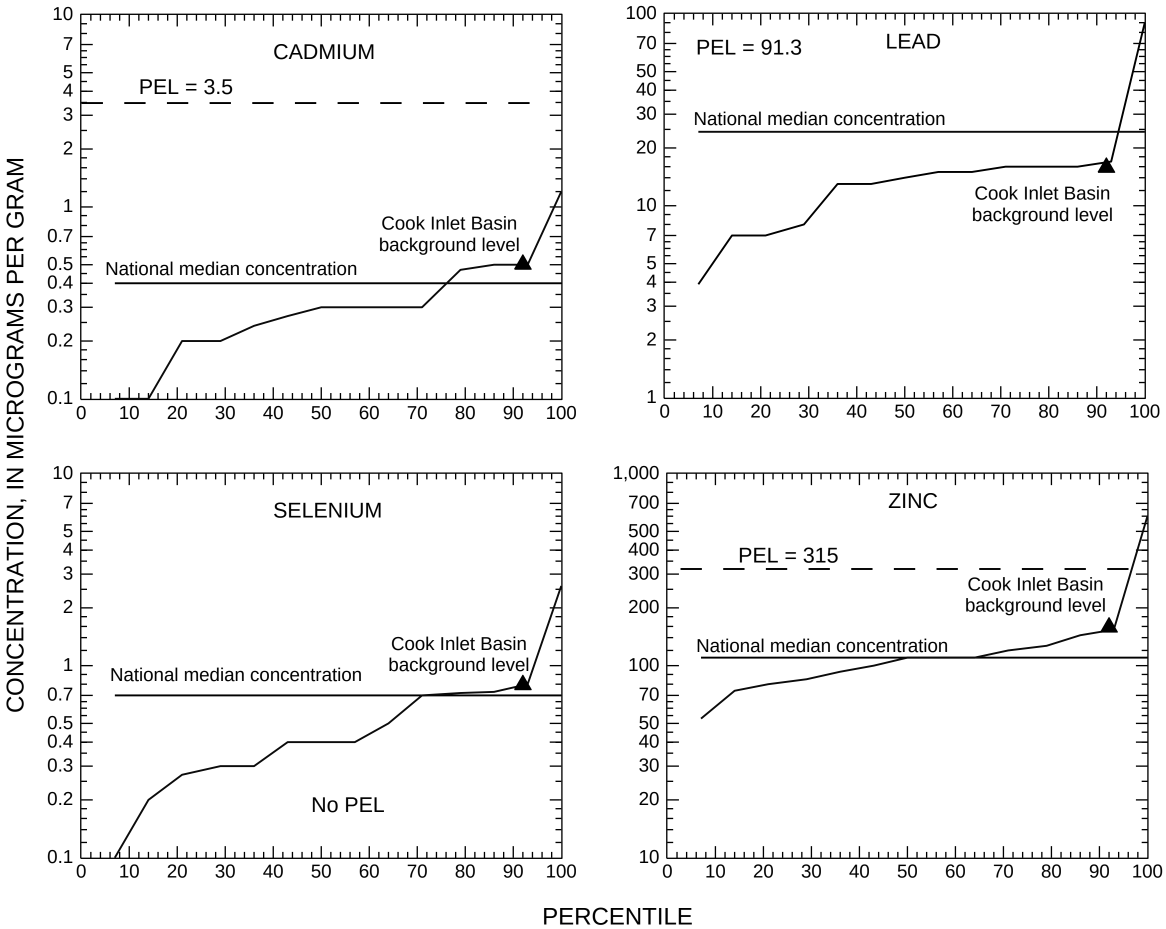

Figure 12. Concentrations of cadmium, lead, selenium, and zinc in streambed sediments and background levels for the Cook Inlet Basin with comparison to PEL and national median concentrations determined by Gilliom and others (1998).

contained the highest concentration of arsenic, chromium, and nickel, and, along with a sample from Costello Creek, exceeded the PEL for arsenic and chromium (table 9). Only Chester Creek exceeded Colorado Creek in cadmium and zinc concentrations, and only the Deshka River exceeded Colorado Creek in selenium concentration. Mercury concentrations at the Denali National Park and Preserve sites were higher than those typically observed in NAWQA samples from 1992 to 1995 (Gilliom and others, 1998), but did not exceed the backgrounds established for this report. Colorado and Costello Creeks appear to drain a part of Denali National Park and Preserve that is highly mineralized and contributed trace elements to streambed sediments to a greater degree than was found elsewhere in the Cook Inlet Basin.

The Talkeetna River, Kamishak River, Johnson River, and Kenai River below Skilak Lake outlet were below PELs and background levels for all trace elements discussed in this report (table 9). All of those sites are remote, not accessible by the road system, and only the Kenai River below Skilak Lake outlet has developed roads in the basin. An infrequently used gravel landing strip is located just above the sampled reach on Johnson River and exploratory gold mining currently exists in the Johnson River watershed. Although Johnson River had copper concentrations of 75 µg/g, the second highest in the Cook Inlet Basin, overall trace-element concentrations in streambed sediments do not appear to be elevated in that basin.

Fish Tissue

Trace elements in whole slimy sculpin samples showed a similar pattern of concentrations as did the streambed sediment data. Lead and zinc concentrations were highest at Chester Creek (table 10). Arsenic, chromium, copper, selenium, and zinc showed consistently higher concentrations in slimy sculpin from the Cook Inlet Basin than were observed in sculpin samples from both urban and reference sites in the Puget Sound NAWQA study (MacCoy and Black, 1998) (table 10).

Table 10. Trace element concentrations in whole slimy sculpin

[Concentration in micrograms per gram dry weight; median values shown for data from whole sculpin at nine urban sites and five forest or reference sites in the Puget Sound NAWQA study (MacCoy and Black, 1998); ND, not determined]

Map No. (fig. 1)	Site name	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Selenium	ZInc
7	Ninilchik River	0.9	<0.2	2.8	3.1	<0.2	0.15	0.6	1.4	91.2
16	Kenai River at Soldotna	1.3	<0.2	2.7	0.7	<0.2	0.20	0.7	3.8	108
23	South Fork Campbell Creek	0.5	<0.2	1.7	0.9	<0.2	0.21	1.3	6.3	81.2
27	Chester Creek	0.9	0.3	3.0	3.5	1.3	0.10	1.1	3.0	162
41	Talkeetna River	0.5	<0.2	1.7	2.1	<0.2	0.08	0.3	4.4	92.9
44	Deshka River	1.5	<0.2	3.5	4.3	0.3	0.11	0.6	2.0	144
50	Moose Creek	0.8	<0.2	1.9	3.0	<0.2	0.16	0.5	5.8	82.5
51	Kamishak River	0.4	<0.2	1.7	2.6	<0.2	0.09	0.5	5.2	74.4
52	Johnson River	— No fish collected —								
53	Kenai River below Russian River	0.8	<0.2	1.9	4.6	0.3	0.12	1.0	3.0	95.6
54	Kenai River at Jim's Landing	0.7	<0.2	2.0	3.2	0.4	0.14	0.9	2.8	88.0
55	Kenai River below Skilak Lake Outlet	1.0	<0.2	1.4	1.4	<0.2	0.15	0.6	4.7	83.5
57	Colorado Creek	— No fish collected —								
58	Costello Creek	1.2	0.4	2.8	4.6	<0.3	0.08	1.5	8.5	123
Ratio to concentration in streambed sediments		0.06	ND	0.03	0.07	ND	2.35	0.02	12.0	0.98
Puget Sound urban sites		0.5	<0.2	1.3	2.0	<0.2	0.25	1.0	1.5	59.1
Puget Sound forest and reference sites		0.3	<0.2	1.6	2.1	<0.2	0.14	1.5	4.2	62.4

Of the trace elements discussed in this report, only selenium concentrations in slimy sculpin appear to be at levels of potential concern. Typical selenium concentrations at background sites are less than 2 µg/g (U.S. Department of the Interior, 1998), whereas selenium concentrations exceeded 4 µg/g at 6 of the 12 sites where slimy sculpin were sampled in the Cook Inlet Basin. Lemly (1996) suggested that selenium concentrations greater than 4 µg/g in whole fish produce adverse effects on some species. Whole-body selenium concentrations of 4 to 6 µg/g were estimated as the threshold for reproductive impairment in sensitive species such as salmon (U.S. Department of the Interior, 1998). Slimy sculpin may bioaccumulate selenium to a greater degree than do salmonids; however, sampling of additional species may be warranted to assess selenium toxicity in the Cook Inlet Basin.

Mercury Pilot Study

Additional mercury samples were collected as part of a pilot study involving NAWQA studies from across the country (Krabbenhoft and others, 1999). Partitioning of inorganic mercury and methyl mercury in unsieved streambed sediment, fish tissue, and water was examined in a variety of environmental settings. Five sites were sampled in the Cook Inlet Basin (table 11). The Deshka River, however, provides an interesting contrast to other sites in terms of the percentage of mercury in sediments that is composed of the more toxic methyl mercury. Methyl mercury production has been shown to be positively influenced by wetlands density (St. Louis and others, 1994). In comparison to the national data set, the percentage of methyl mercury in Deshka River sediments is among the highest of the sites sampled during the pilot study (Krabben-

Table 11. Mercury partitioning at five sites in the Cook Inlet Basin
[µg/g, microgram per gram; µg/L, microgram per liter; mg/L, milligram per liter; data from Krabbenhoft and others, 1999; NC, not collected]

Map No. (fig. 1)	Site name	Concentration in bed sediment (µg/g dry weight)		Ratio of methyl mercury to inorganic mercury	Concentration in whole fish (µg/g dry weight)	Concentration in water			
		Inorganic mercury	Methyl mercury		Inorganic mercury	Inorganic mercury (µg/L)	Methyl mercury (µg/L)	Total organic carbon (mg/L)	Sulfate (mg/L)
23	South Fork Campbell Creek	0.200	0.00067	0.0034	[a]0.292 [b]0.429	0.00250	0.00002	1.6	9.3
27	Chester Creek	0.109	0.00038	0.0035	[a]0.152	0.00296	0.00002	3.8	28
44	Deshka River	0.021	0.00510	0.2429	[a]0.246	NC	NC	8.4	0.2
52	Johnson River	0.050	0.00001	0.0002	NC	0.00978	0.00002	0.7	6.1
58	Costello Creek	0.169	0.00004	0.0002	[b]0.101	0.00497	0.00002	0.7	41

[a]Slimy sculpin
[b]Dolly Varden

hoft and others, 1999). This site also had one of the greatest percentages of wetlands in its drainage.

Differences in concentrations between unsieved sediments and sediments finer than 0.063 mm are worth noting. The Deshka River had inorganic mercury concentrations of 0.02 µg/g in the unsieved sediment sample (table 11), but had concentrations an order of magnitude greater in the sieved sample (0.46 µg/g) (table 9). Conversely, at the South Fork Campbell Creek site, inorganic mercury concentrations were 0.20 µg/g in the unsieved sediment sample (table 11) and 0.03 µg/g in the sieved sample (table 9).

SUMMARY AND CONCLUSIONS

Organochlorines, SVOCs, and trace elements were investigated in streambed sediments and fish tissues at selected sites in the Cook Inlet Basin, Alaska during 1998. Although about half of the sites were along the road system, seven sites were in more remote areas including three national parks.

Streambed sediments at six sites were analyzed for 32 organochlorine pesticides and PCBs and only a single compound—hexachlorobenzene at the Talkeetna River—was detected at reportable concentrations. Where detected, organochlorine concentrations were well below levels considered toxic.

Organochlorine pesticides and PCBs were detected in just three samples of slimy sculpin from a total of 12 samples analyzed. Samples from South Fork Campbell Creek near Anchorage contained *p,p*'-DDE and *p,p*'-DDT concentrations of 9.0 and 6.1 µg/kg. Hexachlorobenzene concentrations of 5.7 µg/kg were measured in slimy sculpin from the Talkeetna River. Total PCBs were measured at 79 µg/kg in the slimy sculpin sample from Chester Creek in Anchorage.

SVOCs in streambed sediments were rarely measured in concentrations exceeding MRLs of 50 µg/kg at the 15 sites sampled in the Cook Inlet Basin. No SVOCs were detected at South Fork Campbell Creek, Talkeetna River, Kamishak River, Johnson River, and Kenai River below Russian River. Three or fewer SVOCs with concentrations greater than the MRL were detected at seven sites. Chester Creek in Anchorage had the greatest number of SVOCs detected at 23, 16 of which were greater than 50 µg/kg. Concentrations also tended to be highest at Chester Creek, which was the only site sampled whose drainage was largely developed. Coring of two ponds on Chester Creek confirmed the presence of elevated concentrations of a variety of organic compounds.

Four trace elements—arsenic, chromium, copper, and nickel—appear to be at naturally large concentrations in the Cook Inlet Basin. All but one site, the Talkeetna River, had arsenic concentrations exceeding a national median concentration of 6.35 µg/g. Chromium concentrations were smaller than a national median value of 62 µg/g only at the Ninilchik and Talkeetna Rivers. Arsenic and chromium concentrations in streambed sediment samples exceeded the PEL at eight and six sites, respectively. Copper concentrations were smaller than a national median concentration of 26 µg/g only at the Ninilchik River. Nickel concentrations were smaller than a national median value only at the Ninilchik, Talkeetna, and Johnson Rivers. Cadmium, lead, selenium, and zinc were detected at one site each with concentrations substantially elevated above background levels. Cadmium, lead, and zinc concentrations were elevated in slimy sculpin as well as in streambed sediments in Chester Creek. Elevated trace-element concentrations in Chester Creek are probably related to the degree of development in the watershed. Selenium was elevated at the Deshka River, a remote, undeveloped basin draining vast areas of wetlands. Selenium concentrations in slimy sculpin were above a national background level at most sites, and at more than half the sites, were at levels that may cause adverse effects in some species. Elevated trace elements in undeveloped watersheds are most likely due to highly mineralized rock exposed to hydrologic processes.

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APPENDIX 1

Cook Inlet NAWQA Map Numbering System

The map numbers of sampling sites on the tables and figures in this report generally follow the map numbering system for stream-gaging stations in the NAWQA environmental setting report (Brabets and others, 1999). Because data for streambed sediments and fish tissue were not collected at all of the stream-gaging stations in the environmental setting report, this report contains gaps in the map numbers. The following list contains all the map numbers that had been assigned to stream water-quality sites in the NAWQA Program at the time of the study described in this report. Additional sites will be added in the future.

Cook Inlet NAWQA Map Numbering System

[Shaded sites are those that are included in this report]

Map No.	USGS station No.	Name
1	15238820	Barabara Creek near Seldovia
2	15239500	Fritz Creek near Homer
3	15239000	Bradley River near Homer
4	15239050	Middle Fork Bradley River near Homer
5	15239900	Anchor River near Anchor Point
6	15240000	Anchor River at Anchor Point
7	**15241600**	**Ninilchik River at Ninilchik**
8	15242000	Kasilof River near Kasilof
9	15244000	Ptarmigan Creek at Lawing
10	15246000	Grant Creek near Moose Pass
11	15248000	Trail River near Lawing
12	15254000	Crescent Creek near Cooper Landing
13	15258000	Kenai River at Cooper Landing
14	15260000	Cooper Creek near Cooper Landing
15	15264000	Russian River near Cooper Landing
16	**15266300**	**Kenai River at Soldotna**
17	15266500	Beaver Creek near Kenai
18	15267900	Resurrection Creek near Hope
19	15271000	Sixmile Creek near Hope
20	15272280	Portage River at Lake Outlet near Whittier
21	15272550	Glacier Creek at Girdwood
22	152739009	South Fork Campbell Creek at Canyon Mouth near Anchorage
23	**15274000**	**South Fork Campbell Creek near Anchorage**
24	15274300	North Fork Campbell Creek near Anchorage
25	15274600	Campbell Creek near Spenard
26	15275000	Chester Creek at Anchorage

Cook Inlet NAWQA Map Numbering System (Continued)

[Shaded sites are those that are included in this report]

Map No.	USGS station No.	Name
27	**15275100**	**Chester Creek at Arctic Boulevard at Anchorage**
28	15276000	Ship Creek near Anchorage
29	15276570	Ship Creek below Power Plant at Elmendorf Air Force Base
30	15277100	Eagle River at Eagle River
31	15277410	Peters Creek near Birchwood
32	15281000	Knik River near Palmer
33	15282000	Caribou Creek near Sutton
34	15284000	Matanuska River at Palmer
35	15290000	Little Susitna River near Palmer
36	15291000	Susitna River near Denali
37	15291200	Maclaren River near Paxson
38	15291500	Susitna River near Cantwell
39	15292000	Susitna River at Gold Creek
40	15292400	Chulitna River near Talkeetna
41	**15292700**	**Talkeetna River near Talkeetna**
42	15294005	Willow Creek near Willow
43	15274010	Deception Creek near Willow
44	**15294100**	**Deshka River near Willow**
45	15294300	Skwentna River near Skwentna
46	15294350	Susitna River at Susitna Station
47	15294410	Capps Creek below North Capps Creek near Tyonek
48	15294450	Chuitna River near Tyonek
49	15294500	Chakachatna River near Tyonek
50	**15283700**	**Moose Creek near Palmer**
51	**5857501541011**	**Kamishak River near Kamishak**
52	**15294700**	**Johnson River above Lateral Glacier near Tuxedni Bay**
53	**15266010**	**Kenai River below Russian River near Cooper Landing**
54	**15266020**	**Kenai River at Jim’s Landing near Cooper Landing**
55	**15266110**	**Kenai River below Skilak Lake Outlet**
56	**15267160**	**Swanson River near Kenai**
57	**6316291493520**	**Colorado Creek near Colorado**
58	**6310181493237**	**Costello Creek near Colorado**

APPENDIX 2

Organochlorine compounds, semivolatile organic compounds, and trace elements not detected in any sample of streambed sediments or fish tissues

Organochlorine Compounds, Semivolatile Organic Compounds, and Trace Elements Not Detected in Any Sample of Streambed Sediments or Fish Tissues

Organochlorines Not Detected

Aldrin	Endrin	Oxychlordane
cis-Chlordane	Heptachlor	Pentachloroanisole
trans-Chlordane	Heptachlor epoxide	*cis*-Permethrin
Chloroneb	Isodrin	*trans*-Permethrin
Dacthal	Lindane	Toxaphene
o,p'-DDD	*o,p'*-Methoxychlor	α-HCH
o,p'-DDE	*p,p'*-Methoxychlor	β-HCH
o,p'-DDT	Mirex	δ-HCH
p,p'-DDD	*cis*-Nonachlor	
α-Endosulfan	*trans*-Nonachlor	

Semivolatile Organic Compounds Not Detected

1,2,4-Trichlorobenzene	2-Nitrophenol	N-Nitrosodiphenylamine
1,2-Dichlorobenzene	4,6-Dinitro-2-methylphenol	Nitrobenzene
1,3-Dichlorobenzene	4-Bromophenylphenylether	Pentachloroanisole
1,4-Dichlorobenzene	4-Chlorophenylphenylether	Pentachloronitrobenzene
1-Methylpyrene	Acenaphthene	Pentachlorophenol
2,3,5,6-Tetramethylphenol	Acenaphthylene	Phenanthridine
2,4,6-Trimethylphenol	Azobenzene	Quinoline
2,4-Dichlorophenol	Dibenz[*a,h*]anthracene	*bis*(2-Chloroethoxy)methane
2,4-Dinitrophenol	Dimethyl phthalate	*bis*(2-Chloroethyl)ether
2,4-Dinitrotoluene	Hexachlorobutadiene	*bis*(2-Chloroisopropyl) ether
2,6-Dinitrotoluene	Hexachlorocyclopentadiene	
2-Chloronaphthalene	Hexachloroethane	
2-Chlorophenol	Isophorone	

Trace Elements Not Detected

Bismuth
Gold