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Water Resources of the Colville River Special Area, National Petroleum Reserve-Alaska

By Jon Kostohrys, Kristine Kosnik, and Ethan Scott

Cover Photo
The Colville River flows on the northern slope of the Brooks Range in northern Alaska.

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Abstract

In July 2000, the BLM began a systematic inventory of the water resources of the Colville River Special Area, as recommended by the Record of Decision for the Northeast National Petroleum Reserve-Alaska Integrated Activity Plan/Environmental Impact Statement. Six lakes and seventeen river sites were surveyed to provide baseline limnological and hydrological information for the Special Area. Field crews measured streamflow, surveyed channel geometry, and collected water quality samples. Drainage basins and their physical characteristics were determined using Geographic Information System analysis. A hydrologic basin map was produced. Flood frequency relationships and bankfull discharge were estimated using computer models. The basin characteristics, streamflow data, channel geometry, and water quality information will be used to characterize those areas subject to future management plans and mitigate potential disturbances in site-specific environmental analyses.

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INTRODUCTION

The Colville River Special Area (CRSA) was designated by the Secretary of Interior in 1977 to assure maximum protection of its subsistence, wildlife, recreational, and other identified values, such as the unique bluff and riparian habitats associated with the Colville River and its tributaries. The CRSA is located within the National Petroleum Reserve – Alaska and about one-third of it is within the Northeast NPR-A Planning Area (Figure 1). In October 1998, the Bureau of Land Management (BLM) issued a Record of Decision (ROD) regarding the Northeast National Petroleum Reserve-Alaska Integrated Activity Plan/Environmental Impact Statement (IAP/EIS). The ROD stated that in developing a management plan for the CRSA, the BLM will determine the status of the various resources, including water resources, within the CRSA. In addition, the inventory and monitoring recommendations, described in Appendix A of the IAP/EIS, state that in order to minimize undue and unnecessary degradation to water resources in the Northeast NPR-A Planning Area and adjacent watersheds, hydrology and limnology should be correlated to critical aquatic habitat areas for fisheries and waterfowl. For more information on the ROD, IAP/EIS, and history of the CRSA, the reader is referred to USDI 1998a and USDI 1998b.

To meet the requirements of the ROD and the IAP/EIS, hydrologic and limnologic field surveys, consisting of stream channel geometry and water quality sampling, were initiated. While some preliminary work was done in 1999 in conjunction with a survey of the Northeast Planning Area (Kostohrys et al. 2000), the surveys for the CRSA began in 2000 and continued in 2001, 2002, and 2003. A geographic information system (GIS) was used to delineate drainage basins for each stream channel reference site and to determine the physical characteristics of each contributing area. Drainage basin characteristics were used in a statewide regression model to determine flood frequency relationships. Field survey parameters were input into a slope-conveyance model to compute bankfull discharge estimates. The purpose of this paper is to document and disseminate the results.

Description of Study Area

The CRSA is located in northern Alaska on the north slope of the Books Range. The Special Area covers the central portion of the foothills and the coastal plain just south of the Beaufort Sea (Figure 1). In general, the designated Special Area forms a corridor along much of the Colville River, excepting portions of the headwaters and the delta area near the mouth. The lower reaches of the tributary streams are also included within the designated area, and two of them, the Kikiakrorak and Kogosukruk Rivers, also include portions of their headwaters. Physiography and climate are the dominant factors influencing the water resources.

Physiography

As defined by Wahrhaftig (1965), the CRSA contains two primary physiographic regions: the Arctic Coastal Plain, which comprises the northern-most portion of the area, and the Arctic Foothills of the Brooks Range, which includes the majority of the area.

Ice-rich marine sediments underlie the Arctic Coastal Plain, the result of numerous marine transgressions and recessions (Sellmann et al. 1975). Permafrost, perennially frozen ground, is virtually continuous throughout the planning area. Permafrost prevents infiltration of surface water, forms a largely saturated active (thawed) soil layer, and isolates the much deeper ground water of the area (Sloan 1987). Disturbance and thaw settlement of the perennially frozen, ice-rich sand and silt have created a mosaic of lakes, ponds, and interconnected streams (beaded drainages). The thaw lake cycle (Sellman et al. 1975) creates a continuously changing landscape as lakes form, expand, and drain in response to disturbance of the permafrost terrain. The limited relief of the coastal plain also results in low-gradient, meandering and braided streams, as well as shallow-water tracks, surface flow unconfined by channels, that can convey significant discharge in these areas (Hinzman et al. 1993). Portions of the coastal plain are underlain by low, undulating sand dunes. These relic Pleistocene eolian dunes are generally stabilized by vegetation, though numerous active blowouts along bluffs bordering streams and lakes indicate that this terrain is easily disturbed and subject to renewed erosion (Carter and Galloway 1979). Tussock grass is the most abundant type of vegetation in the poorly drained soils.

The Arctic Foothills of the Brooks Range form the southern and western portion of the planning area. The foothills begin as a band of low hills, approximated by the 500-foot elevation contour, adjacent to the coastal plain. These hills terminate on the steeper slopes of the Brooks Range. The foothills north of the Colville River are termed the northern foothills, and tend towards longer, flat-topped ridges, while those to the south are often more rugged, isolated hills. Lakes are rarer, river valleys narrower, and streams generally of steeper gradient than those on the coastal plain. The rolling hills and mesa-like tablelands are a sharp contrast to the mosaic of lakes and wetlands to the north. Ice-rich permafrost soils and tussock vegetation are still abundant, but steeper valleys, ridges, and higher hilltop soils often contain well-drained sand and gravel, with occasional exposures of weathered bedrock. Many of the foothills rivers are incised within their meanders, confined by bedrock walls that erode into scenic bluffs and cliffs. Other valleys contain thick riparian stands of head-high willow and alder. These cliffs and riparian zones are an important habitat for raptors and other migratory birds.

Climate

The climate of the area has been divided into three zones, Arctic Coastal, Arctic Inland and Arctic Foothills (Zhang et al., 1996). All three zones have short, moderately warm summers and long, very cold winters. Temperature ranges are extreme, with the winter lows often down to -60°F and summer highs to near 90°F. Annual precipitation varies from over 12 inches in the foothills to less than 8 inches along the coast. About half of the annual precipitation falls as snow. The snowpack is highly variable due to the extreme winter winds that scour snow from exposed ridges and hilltops and form deep drifts along protected side slopes and valley bottoms. The deepest snowpack tends to be in the northern foothills and decreases northward to the coast (Sloan 1987). Summer precipitation is usually light, but heavy rainstorms do occur, most often during July or August in the inland and foothills areas, especially the higher foothills near the Brooks Range, south of the Colville River. While no precipitation data was collected during the field surveys, about a half an inch of rainfall was observed at the base camp at Ivotuk during one thunderstorm in July 2001. Another storm caused a significant rise on the Nuka River later that same week.

METHODS

GIS Analysis of Basin Characteristics

The delineation of a drainage basin for each stream channel reference site was necessary to determine basin characteristics used in hydrologic computer models. Development and analysis of the drainage basins were performed using terrain and hydrologic modeling routines available in Arc/Info Geographic Information System (GIS) software. Once delineated, a basin's drainage area, perimeter, mean elevation, percent of lake area, and percent of forested area were calculated (approximated) using GIS. The following is a technical discussion of the use of GIS in delineating and characterizing the drainage basins in the CRSA.

Terrain Modeling: A 60-meter resolution digital elevation model (DEM) of the entire study area was produced by merging 144 USGS 15-minute series DEMs. Errors in the USGS DEMs due to sampling and rounding effects often create hydrologic sinks. These sinks interfere with hydrologic analyses performed in a GIS, and filling them is a standard practice prior to using DEMs for hydrologic analyses. Filling sinks is an iterative process involving five steps:

1. Determine the direction of flow for each grid cell in the DEM.
2. Locate all sinks in the DEM.
3. Find the contributing area to each sink.
4. Find the depth of each sink.
5. Fill the sinks to the level of the lowest neighboring grid cell.

The process is repeated until there are no remaining sinks. Arc/Info's GRID module provides pre-written routines to facilitate each of these steps. Filling sinks creates two new data prod-

Map 1

back of map

map 2

back of Map2

ucts: a “hydrologically corrected” digital terrain model (DTM) and a flow direction model (a corresponding grid in which the cell values represent the direction of flow for each grid cell in DTM). These are both used in the hydrologic modeling process.

Hydrologic modeling: The flow direction grid was used to create a flow accumulation model (a grid in which the cell values represent the total number of cells that drain into each grid cell). A threshold was applied to the flow accumulation grid to determine which grid cells represented stream channels. In this exercise, choosing all grid cells with a flow accumulation of 500 or more produced a reasonable approximation of streams in the study area.

The next step was to identify the outflow or pour points for the drainage basins that were to be delineated. Here, each reference site represented a basin outflow, or pour point, location. The stream channel reference site locations were determined in the field using global positioning system receivers. From this data a grid of the pour point locations was created. Then each point was adjusted to the nearest grid cell that was within 300 meters of its actual location and coincident with a stream channel represented by the terrain model, as determined above.

Using a pre-written routine in Arc/Info, the flow direction grid was used to determine groups of cells that drain to the same pour point. This provided an initial approximation of the contributing areas to each pour point. The perimeter of each contributing area was plotted over Digital Raster Graphics (DRGs) of USGS 15-minute topographic quadrangles. Errors in the basin perimeters were identified by the hydrologist using these plots and orthophoto quadrangles derived from National Technical Systems. The basin perimeters were then manually edited to produce perimeters for the

Figure 3. *The Colville River Special Area begins upstream of the Nuka River, where steep bluffs confine the river.*

area contributing exclusively to each pour point site. The immediate contributing area to each pour point was combined with the contributing areas for all upstream basins to produce a perimeter for the total contributing basin to each pour point. The perimeters were stored as polygons in a GIS database. The area and perimeter of each polygon was automatically generated in the polygon attribute table.

Terrain description: Each basin was converted to a raster data set at the same resolution as the DTM. Descriptive statistics (mean, minimum, maximum) about the population of DTM cells that fell within each basin were generated and stored in a database table.

Lake area determination: All lakes contained in the USGS 15-minute Digital Line Graph (DLG) files were extracted into a separate GIS database. The union of each basin with the lakes was calculated. This, in effect, added the basin ID number to the polygon attribute table record for each lake that fell within the basin. The area was summed for all lakes with the same basin ID number to determine the total area of lakes within each basin.

Determination of forested area: Pixels representing tall shrub or low shrub were extracted from a land-cover classification produced from Landsat Thematic Mapper and SPOT XS satellite imagery (Ducks Unlimited, Inc. 1998) and were used as an approximation of the forested portion of the study area. The tall and low shrub pixels were extracted into a separate data set. This produced a grid representing the forested portion of the study area. The raster version of each basin was combined with the forested area grid to produce an attribute table containing the number of 30 m by 30 m forested pixels falling within the basin. This was used to calculate the total forested area within each basin.

Hydrology

Data collection methods used to define a series of stream channel reference sites were similar to the hydraulic geometry surveys of Emmett (1972) and reconnaissance hydrologic surveys of Childers et al. (1979) in their pioneering investigations in northern Alaska. The initial survey sites were located on topographic maps prior to each summer field season. Sites within or near the Colville River Special Area were selected to provide a range of stream types and drainage basins representative of the planning area. Since logistics prohibited flying a boat to the remote Colville River and the larger tributaries, survey sites were restricted to stream reaches where water depths were shallow enough to measure cross sections with chest waders. This limitation meant that the tributary streams were sampled in greater frequency than the Colville River. Because of this limitation, USGS data for the Colville and Etivluk Rivers (Childers et al. 1979) were used to supplement some of the analysis. Two sites, the lower Kogosukruk and Kikiakrorak Rivers, were established in 2000 in conjunction with other surveys in the Northeast planning area. These were revisited in 2001 when the additional fifteen sites in the Special Area were surveyed. A few sites were resurveyed in 2002. A total of seventeen sites were visited in the three years and all were surveyed sufficiently for channel morphology analysis (Table 1).

At each site, cross-sectional discharge (streamflow) measurements were made using a Price AA current meter to measure water velocity and a top-setting wading rod and tag line for depth and width, respectively (Rantz et al. 1982). The stream banks, high-water marks and water surface profiles were surveyed using a surveyor's level and stadia rod (Benson and Dalrymple 1967). Water samples and photographs of the channel and surrounding areas were taken. The roughness coefficients (n values), used in the slope-conveyance model, were selected according to the criteria discussed by Barnes (1967). The bankfull channel determination followed the active floodplain definition of Leopold and Skibitzke (1967).

A water level versus discharge rating was then developed by utilizing the direct discharge measurement to verify parameters used in the computer-generated streamflow (slope-conveyance) model (Dalrymple and Benson 1967). Information determined at each cross-section included instantaneous discharge, elevation of the current year's flood marks, and bankfull channel characteristics. Bankfull geometry relationships for width, depth, and discharge were then analyzed following the regression methods used in Emmett (1972). After the stream channel reference site locations were entered into a GIS

Table 1. Colville River Special Area rivers and lakes surveyed beginning in July 2000.

Site No.	Survey Site	Latitude	Longitude	Origin of Basin	Channel Type
Rivers					
1	Colville River above Kiligwa River	69° 00.96'	158° 37.74'	Brooks Range	Meandering
2	Nuka River	68° 58.49'	158° 58.89'	Brooks Range	Incised Meanders
3	Kiligwa River	68° 58.65'	158° 25.61'	Brooks Range	Incised Meanders
4	Kuna River	68° 52.28'	157° 38.90'	Brooks Range	Meandering
5	Blankenship Creek	68° 45.15'	156° 37.73'	Foothills	Meandering
6	Ipnavik River above Medial Creek	68° 46.53'	156° 35.09'	Brooks Range	Meandering
7	Etivluk River above East Fork	68° 41.73'	156° 14.29'	Brooks Range	Meandering
8	East Fork Etivluk River	68° 48.45'	156° 03.83'	Brooks Range	Braided
9	Lookout River	69° 02.35'	156° 35.35'	Foothills	Meandering
10	Awuna River above Lookout River	69° 03.81'	156° 33.87'	Foothills	Incised Meanders
11	Awuna River near the Mouth	69° 01.35'	155° 44.63'	Foothills	Incised Meanders
12	Maybe Creek	69° 14.85'	153° 59.00'	Foothills	Meandering
13	Prince Creek	69° 19.30'	152° 30.84'	Foothills	Meandering
14	Upper Kikiakrorak River	69° 39.90'	152° 36.40'	Foothills	Meandering
15	Upper Kogosukruk River	69° 35.74'	152° 10.06'	Foothills	Incised Meanders
16	Lower Kikiakrorak River	69° 53.31'	151° 45.86'	Foothills	Meandering
17	Lower Kogosukruk River	69° 48.95'	151° 37.75'	Foothills	Incised Meanders
Lakes					
1	Liberator Lake Outlet	68° 53.21'	158° 21.75'	Foothills	NA
2	Lookout Lake Outlet	68° 56.70'	157° 08.50'	Foothills	NA
3	Smith Mountain Lake Outlet	68° 45.18'	156° 26.74'	Foothills	NA
4	Puddin Lake	69° 18.22'	153° 27.72'	Foothills	NA
5	Prince Lake	69° 16.42'	152° 41.81'	Foothills	NA
6	Dogbone Lake Outlet	69v 36.04'	152° 01.26'	Foothills	NA

database and the basin characteristics determined, the two-year recurrence interval discharge was computed from the regional estimator equations listed in Curran et al. (2003) to compare to the bankfull discharge.

Water Quality

Six lakes and seventeen river sites were sampled in the two years of field surveys to provide baseline limnological information. During each trip, water quality readings were taken with portable, single-parameter meters, which recorded water temperature, specific conductance, pH, and turbidity. Additional water samples were also collected from some rivers and lakes, stored in coolers, and then transported to Fairbanks for an independent laboratory determination of major anions and cations. The dissolved oxygen and hydrogen isotope analysis was performed by Arizona State University. All samples were collected from either the main portion of flow in the river or lake outlet, or by wading out into the deeper portion of the lake basin if no outfall could be found.

RESULTS AND DISCUSSION

GIS Analysis of Drainage Basin Characteristics

A hydrologic basin map generated from the GIS analysis is shown in Figure 2. The basin characteristics data generated from this analysis are listed in Table 2. Lake sampling sites in the CRSA area are also shown in Figure 2.

Hydrology

Table 3 contains bankfull channel geometry and discharge data at the surveyed sites. Appendix A has a brief description of the stream reach at each survey site and graphs of the cross-sectional data used for the hydraulic mod-

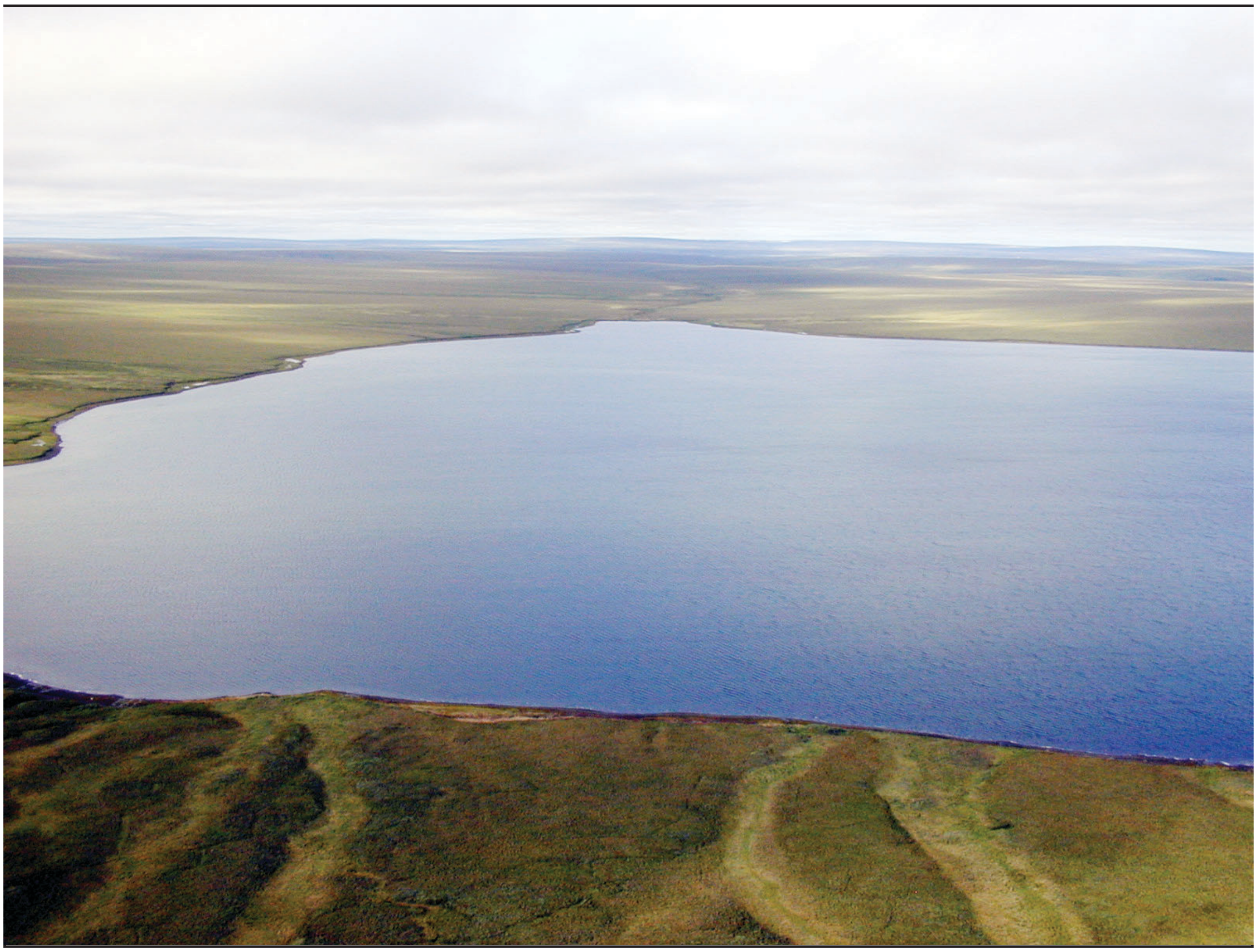

Figure 4. *While not as common as on the coastal plain, large lakes such as Liberator Lake are found within the Colville River Special Area.*

Figure 5. *The lower portion of the Colville River Special Area has bluffs at the mouths of the Kogosukruk and Kikiakrorak Rivers.*

els. Table 4 lists the regression relationships for bankfull discharge, width, and depth as a function of drainage area. While the bankfull discharge and width relationships appear to be reasonably accurate, the relationship of bankfull depth to drainage area was not. The variation in the respective bankfull discharges might at first seem large. However, the diverse nature of some of the watersheds, especially their basin areas, mean elevations, and the lake and shrub percentages, as listed in Table 2, would imply very disparate runoff characteristics. Since Childers (1979) surveyed two sites within the planning area, data from these were also analyzed with the current data set. The regressions, utilizing the additional sites (also listed in Table 4), show a higher correlation and lower standard error that those computed with just the BLM data alone. While Childers et al. (1979) also noted large differences in bankfull discharge and peak runoff rates, such that they were unable to determine any clear relationships to drainage basin physiography or climate, more recent work in NPR-A has correlated some basin characteristics to bankfull discharge (Kostohrys et al. 2000).

Table 3 lists the 2-year and 100-year flood frequency discharges computed from the USGS regional estimator equations (Curran et al. 2003) and the basin characteristics in Table 2. While Leopold (1994) and others state unequivocally that the bankfull discharge "has a recurrence interval that averages 1.5 years," Williams (1978), in an analysis of 233 stream sites, found that the bankfull discharge does not have a common recurrence frequency. The field-surveyed bankfull discharges, listed in Table 3, were almost all greater than the calculated two-year recurrence interval flood. The BLM data for the larger rivers not only had the highest bankfull discharge, but also the longest return period. Smith (1979) noted a long

Table 2. Drainage basin characteristics from GIS analysis

Site No.	Stream Survey Site	Drainage Area (Sq. mi.)	Mean Basin Elevation (ft)	Area of Lakes & Ponds (sq mi)	Area of Lakes and Ponds (%)	Area of Shrub Cover (sq mi)	Area of Shrub Cover (%)
1	Colville River above Kiligwa River	1,273	2,064	3.4	0.4%	63.6	5.0%
2	Nuka River	499	2,198	0.4	0.9%	16.6	3.3%
3	Kiligwa River	534	2,099	0.7	0.1%	30.7	5.7%
4	Kuna River	653	1,987	1.2	0.2%	39.9	6.1%
5	Blankenship Creek	46	1,626	0.0	0.0%	1.9	4.0%
6	Ipnavik River above Medial Creek	533	2,032	0.6	0.1%	17.5	3.3%
7	Etivluk River above East Fork	1,309	2,470	8.3	0.6%	21.6	1.6%
8	East Fork Etivluk River	601	2,386	1.7	0.3%	46.1	7.7%
9	Lookout River	288	1,087	0.7	0.2%	5.8	2.0%
10	Awuna River above Lookout River	907	1,122	2.2	0.2%	18.0	2.0%
11	Awuna River near the Mouth	1,515	1,105	2.9	0.9%	30.5	2.0%
13	Maybe Creek	172	661	0.2	0.1%	38.5	22.4%
14	Prince Creek	225	714	2.0	0.9%	12.3	5.4%
15	Upper Kikiakrorak River	79	564	0.1	0.2%	3.4	4.3%
16	Upper Kogosukruk River	191	530	0.9	0.5%	8.9	4.7%
17	Lower Kikiakrorak River	354	350	25.4	9.2%	4.4	1.3%
18	Lower Kogosukruk River	519	439	6.3	1.9%	26.4	5.1%

Table 3. Bankfull channel characteristics and flood frequency of streams in the Colville River Special Area

Stream Channel Survey Site	Discharge (cfs)	Runoff (cfsm)	Maximum Depth (ft)	Width (ft)	Area (sq.ft)	Average Velocity (fps)	Average Depth (ft)	Two-Year Flood (Q_2)	Hundred-Year Flood (Q_{100})
Colville River above Kiligwa River	50,000	39.27	20.0	408	6,440	7.8	15.8	16,500	41,400
Nuka River	15,000	30.06	11.7	229	1,950	7.7	8.5	7,100	18,900
Kiligwa River near Brady	18,800	35.22	11.6	328	2,360	8.0	7.2	7,600	20,000
Kuna River	20,500	31.38	11.2	459	3,400	6.0	7.4	9,100	2,400
Blankenship Creek	1,600	34.9	4.8	155	457	3.5	3.0	850	2,600
Ipnavik River above Medial Creek	14,500	27.21	8.7	295	1,950	7.4	6.6	7,600	20,000
Etivluk River above East Fork	22,000	16.81	11.0	347	3,080	7.1	8.9	16,900	42,300
East Fork Etivluk River	10,500	17.47	7.0	692	2,640	4.0	3.8	8,400	22,100
Lookout River	5,500	19.09	9.9	155	1,140	4.8	7.4	4,400	11,900
Awuna River above Lookout River	28,000	30.86	17.4	279	3,620	7.7	13.0	12,200	31,200
Awuna River near the Mouth	33,500	22.11	21.0	438	6,070	5.5	13.9	19,200	47,900
Maybe Creek	2,500	14.57	7.4	135	683	3.7	5.1	2,800	7,700
Prince Creek	3,000	13.33	4.6	169	542	5.5	3.2	3,500	9,700
Upper Kikiakrorak River	2,500	31.68	7.2	73	383	6.5	5.2	1,400	4,000
Upper Kogosukruk River	4,500	23.51	8.0	132	812	5.6	6.1	3,000	8,500
Lower Kikiakrorak River	7,500	21.21	10.0	356	2,330	3.2	6.5	5,300	14,200
Lower Kogosukruk River	15,000	28.89	14.8	251	2,600	5.8	10.4	7,400	19,500

Table 4. Bankfull discharge and width regressions based on field survey and GIS data

Gage Site	Parameters			
	m	b	r^2	se
Bankfull Discharge	1.001	3.203	0.900	0.333
Bankfull Discharge*	1.017	3.137	0.945	0.359
Bankfull Width	0.468	2.716	0.624	0.362
Bankfull Width*	0.556	2.232	0.815	0.389
Bankfull Depth	0.383	-0.355	0.591	0.318
Bankfull Depth*	0.293	0.135	0.583	0.364

* Includes additional data from Childers, et al (1979)

m - Slope of regression line

b - Y-intercept of regression line

r^2 - Coefficient of determination

se - Standard error

return period for the bankfull discharge on 25 rivers that had significant ice flows. He concluded that channel enlargement occurred due to the scouring power of the ice-laden flow. While the flood recurrence values used here are approximations derived from the statewide regressions, they still indicate that the relationship of the bankfull discharge to a specific recurrence interval flood, while uncertain, has been traditionally underestimated in the Arctic. The effects of ice, snow, and permafrost during peak runoff may have considerable impact to the stream channel and floodplain, so these factors should be carefully evaluated in any land use or development plan.

Water Quality

The results of each year's water quality field surveys are listed in Appendix B. With the addition of the 2002 and 2003 data, there is a limited amount of information with which to assess seasonal or annual changes, as well as the differences related to the basin physiography. Tables 5 and 6 summarize the data where multiple sampling was done. Of the sites surveyed more than once, none showed any significant differences. Work done by others (Kling et al. 1992) related the water quality differences surveyed along a transect between Atigun Pass in the Brooks Range to Prudhoe Bay on the Beaufort Sea to the presence of continuous permafrost, the geological differences in the parent material, and the proximity to the sea.

In general, the waters in the CRSA are pristine, and the parameters recorded during the trips reflect this. Lake and river pH were similar; all were neutral to slightly alkaline, with a range of 6.7 to 8.5. The waters are dilute, with specific conductances ranging from .011-.220 mS cm^{-1}. Lake and river temperatures in July averaged 12.5˚C. In general, the warmest waters were those that flowed from the foothills north of the Colville River, while those rivers that drained the Brooks Range had the coolest water. Turbidity ranged from less than 1 NTU in some of the western most rivers and lakes, to over 50 NTU in some of the shallower lakes where wind had stirred up bottom sediments. Values for total hardness, an expression of ionic strength of primarily calcium and magnesium ions, were relatively low. This is probably due to presence of continuous permafrost, which limits ground water infiltration, so that the waters are almost totally derived from snowmelt runoff (Sloan 1987). The notable exception is Blankenship Creek (Figure 6) where the presence of a large overflow icing (aufeis) in July, low water temperature, and relatively high specific conductance indicates a year-round, continuously flowing groundwater spring. Sloan (1987) noted that icings invariably form downstream from springs due to the extremely low winter temperatures on the North Slope. A similar aufeis field was observed on a tributary stream in the headwaters of the East Fork of the Etivluk River, just outside of the NPR-A.

The oxygen and hydrogen isotope values, listed in Table 7, were generally more negative than those collected during 1999 in the Northeast NPR-A (Figure 7). This is expected, since the more inland waters of the Special Area would be expected to be depleted in heavier isotopes, as compared to the isotopically heavier waters of the coastal regions of NPR-A. For a more complete of discussion of the isotopes of oxygen and hydrogen in water, as well as a description of the Northeast NPR-A sample locations, the reader is referred to the water quality discussion in Kostohrys et al. (2000).

Though no fish sampling was attempted, Arctic grayling were observed in pools of the upper Kikiakrorak and Kogosukruk rivers. The Alaska Department of Fish and Game has collected baseline fisheries data on most of the streams in the Special Area. Researchers found grayling in all of the streams inventoried, whitefish and burbot in many, and Arctic char and lake trout in the lower Colville River (Bendock et al. 1979).

RECOMMENDATIONS

Hydrology

The data and statistical calculations presented here should be considered preliminary. Direct measurements of peak flow during spring break up would provide more reliable flood estimates than computer-generated discharges. Installing stream-level recorders, (automated data loggers with pressure transducers), during ice break up, combined with streamflow measurements, would then provide a complete record of the flood events that ac-

Table 5. Summary of field determined discharge and water quality values for all years sampled

Rivers	Number of samples	Discharge (cfs)		Water Temperature (°C)		Conductance(ms/cm)		pH		Turbidity (NTU)	
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Colville River above Kiligwa River	3	515	ND	2.6	9.0	0.137	0.168	7.8	8.2	4.9	45
Nuka River	3	673	ND	2.2	13.0	0.088	0.171	7.9	8.1	2.2	15
Kiligwa River near Brady	3	492	ND	2.6	9.0	0.164	0.195	7.8	8.0	2.3	75
Kuna River	2	488	ND	8.3	8.5	0.114	0.153	7.7	8.0	2.2	66
Blankenship Creek	2	18	84	5.8	6.8	0.115	0.135	7.4	7.5	1.9	ND
Ipnavik River above Medial Creek	2	344	992	7.7	9.0	0.128	0.135	7.4	7.9	1.5	7.8
Etivluk River above East Fork	2	762	ND	7.8	9.0	0.049	0.064	7.2	7.8	3.0	51
Maybe Creek	3	8	ND	2.0	18.0	0.053	0.079	7.5	7.5	1.0	2.2
Prince Creek	3	22	341	5.3	16.0	0.055	0.096	7.3	7.5	1.0	3.2
Upper Kikiakrorak River	3	9	160	3.9	14.0	0.102	0.143	7.6	8.0	1.0	2.6
Upper Kogosukruk River*	4	13	306	5.9	16.6	0.042	0.138	7.8	8.0	7.6	16
Lower Kikiakrorak River	4	58	385	3.6	16.8	0.123	0.157	7.8	8.3	3.5	24
Lower Kogosukruk River	4	48	415	6.9	16.3	0.146	0.151	7.8	8.1	0.8	7.6
Lakes											
Dog Bone Lake Outlet	3	<1	1.2	6.9	16.5	0.025	0.028	6.9	7.1	0.0	0.8
Liberator Lake Outlet	2	8.6	13	3.4	12.0	0.036	0.068	7.8	7.8	0.5	28.8

*Originally sampled in 1999
ND - not determined

Table 6. Summary of laboratory-determined water quality values for all years sampled

Rivers	Number of samplesMin	Calcium (mg/L)		Magnesium (mg/L)		Iron (mg/L)		Silicon (mg/L)		Hardness (Total)	
		Max	Min	Max	Min	Max	Min	Max	Min	Max	
Colville River above Kiligwa River	3	18.0	22.0	3.9	6.0	0.04	2.00	0.96	3.30	61	80
Nuka River	3	17.0	24.0	3.5	5.5	0.05	0.09	1.00	2.20	57	83
Kiligwa River near Brady	3	20.0	22.0	5.9	7.3	0.05	3.90	1.20	4.60	79	80
Kuna River	2	14.0	17.0	4.4	5.7	0.04	3.70	1.30	4.30	58	61
Ipnavik River above Medial Creek	2	15.0	17.0	4.3	5.7	<MRL	0.04	1.40	1.70	55	66
Etivluk River above East Fork	2	7.0	9.1	4.4	4.9	0.04	4.40	1.00	5.20	38	41
Prince Creek	3	3.7	12.0	0.5	2.9	0.06	0.25	0.10	3.50	28	42
Upper Kikiakrorak River	2	14.0	15.0	2.8	3.4	0.20	0.30	1.80	2.90	49	50
Upper Kogosukruk River	3	6.3	21.0	2.4	3.9	0.33	0.60	1.10	3.06	26	68
Lower Kikiakrorak River	3	14.0	23.0	2.9	4.5	0.15	1.00	1.59	3.10	66	86
Lower Kogosukruk River	2	20.0	27.0	2.9	4.5	0.15	0.96	1.59	3.20	66	86
Lakes											
Liberator Lake Outlet	2	6.3	6.3	2.1	2.4	0.10	0.62	0.13	1.15	24	26

<MDL - less than method detection limit

Figure 6. *Blankenship Creek, with the presence of a large overflow icing (aufeis), indicates a ground water source.*

count for 70% or more of the annual discharge (Sloan 1987). Collecting five or more years of peak-flow data at selected sites would provide a reliable database as well as allow computation of flood-recurrence statistics that meet state and federal guidelines (Alaska DNR 1984, Childers 1970). Surveying more stream reaches for hydraulic geometry relationships would increase the reliability of the channel geometry regression equations, providing a more accurate environmental evaluation for permitted activities. Critical fisheries and aquatic wildlife habitat needs to be identified within the special area, so that these areas can be referenced in future environmental analyses.

GIS Analysis of Drainage Basin Characteristics

The use of GIS was inefficient in this project, largely due to limitations in available data, hardware, and software. The currently available digital elevation models do not provide adequate resolution to capture the necessary terrain details on the North Slope of Alaska. Because of this, an inordinate amount of time was spent manually editing the GIS-derived basins for this project. The National Elevation Dataset (NED) in production by USGS is likely to provide some improvement when it becomes available. Remote sensing techniques using Synthetic Aperture Radar (SAR) can be also used to provide higher resolution and higher accuracy DEMs, but at a higher cost than the NED data set.

Water Quality

Sampling over the course of the summer for several years would not only provide baseline data, but also allow the determinations of seasonal and annual patterns of change in the lakes and rivers as well as an insight into mechanisms controlling these changes. Fisheries inventories to determine locations of overwintering, spawning, and rearing areas would provide insight into identifying these areas of critical aquatic habitat.

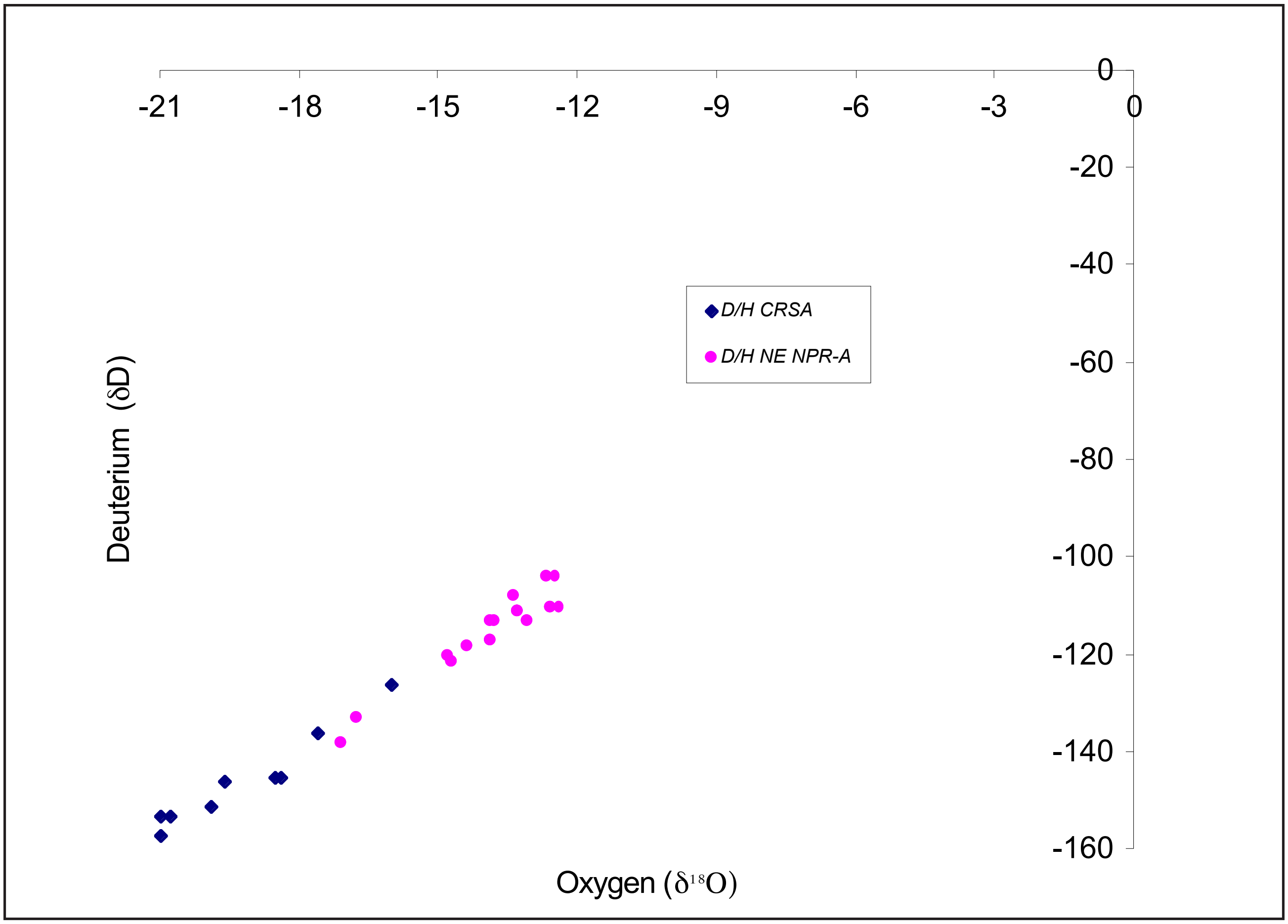

Figure 7. *Plot of Colville River Special Area and NE NPR-A water samples analyzed for oxygen and hydrogen isotopes.*

Table 7. 2001 CRSA water samples analyzed for oxygen isotope ^{18}O and deuterium

Sample site	Date sampled	^{18}O	D
Nuka River near the mouth	14-Jul	-21.0	-153
Ipnavik River above Medial Creek	10-Jul	-20.8	-153
Etivluk River above East Fork	11-Jul	-21.1	-157
Awuna River near the mouth	13-Jul	-19.6	-146
Liberator Lake Outlet	12-Jul	-18.5	-145
Lookout Lake Outlet	9-Jul	-18.4	-145
Smith Mountain Lake Outlet	12-Jul	-19.9	-151
Puddin Lake	16-Jul	-17.6	-136
Prince Lake	16-Jul	-16.0	-126
Analytical Precision	(1 sigma)	0.08	0.9

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Figure A-8. Looking downstream at the survey site on the Colville River above the Kiligwa River. The Colville supports grayling and whitefish in this reach, according to the Alaska Dept. of Fish and Game.

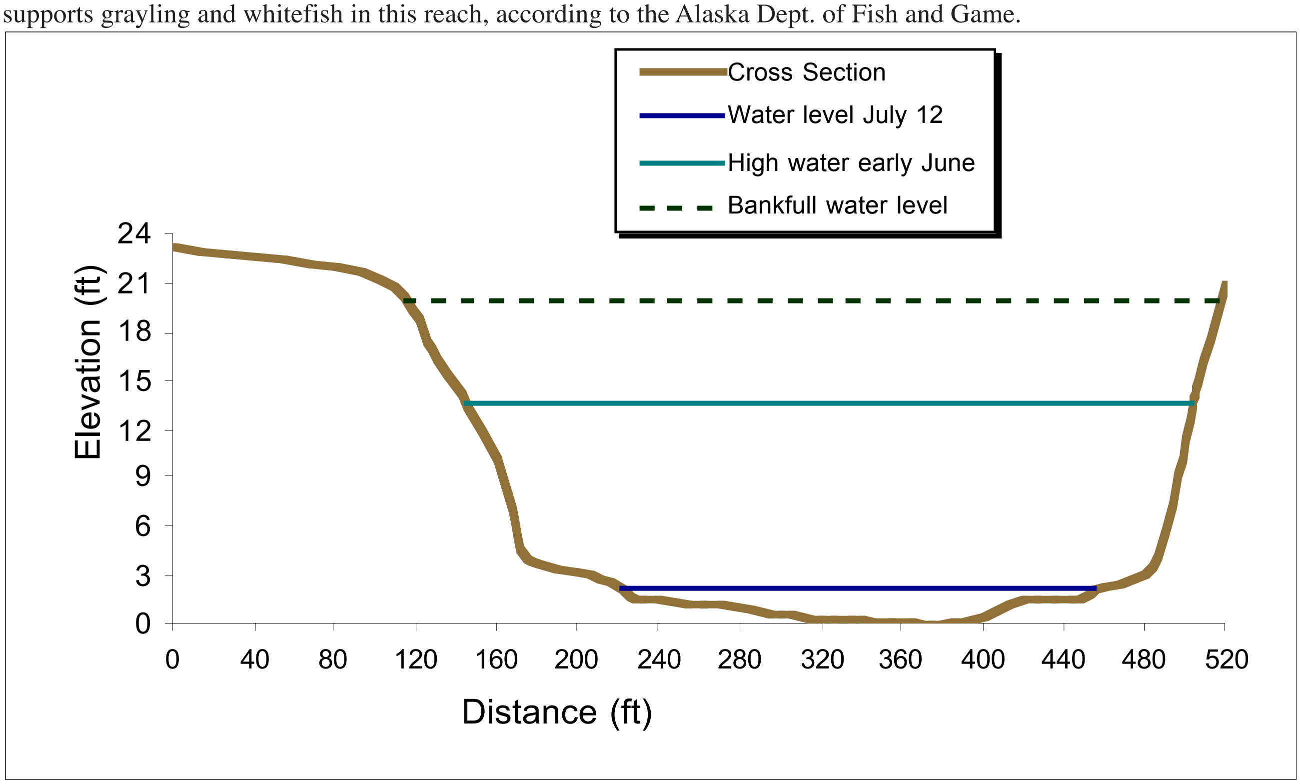

Figure A-9. Channel cross section for the Colville River above the Kiligwa River.

Figure A-10. Looking downstream at the survey site on the Nuka river. The pool-riffle channel and vegetation provide excellent aquatic habitat, according to the Alaska Dept. of Fish and Game.

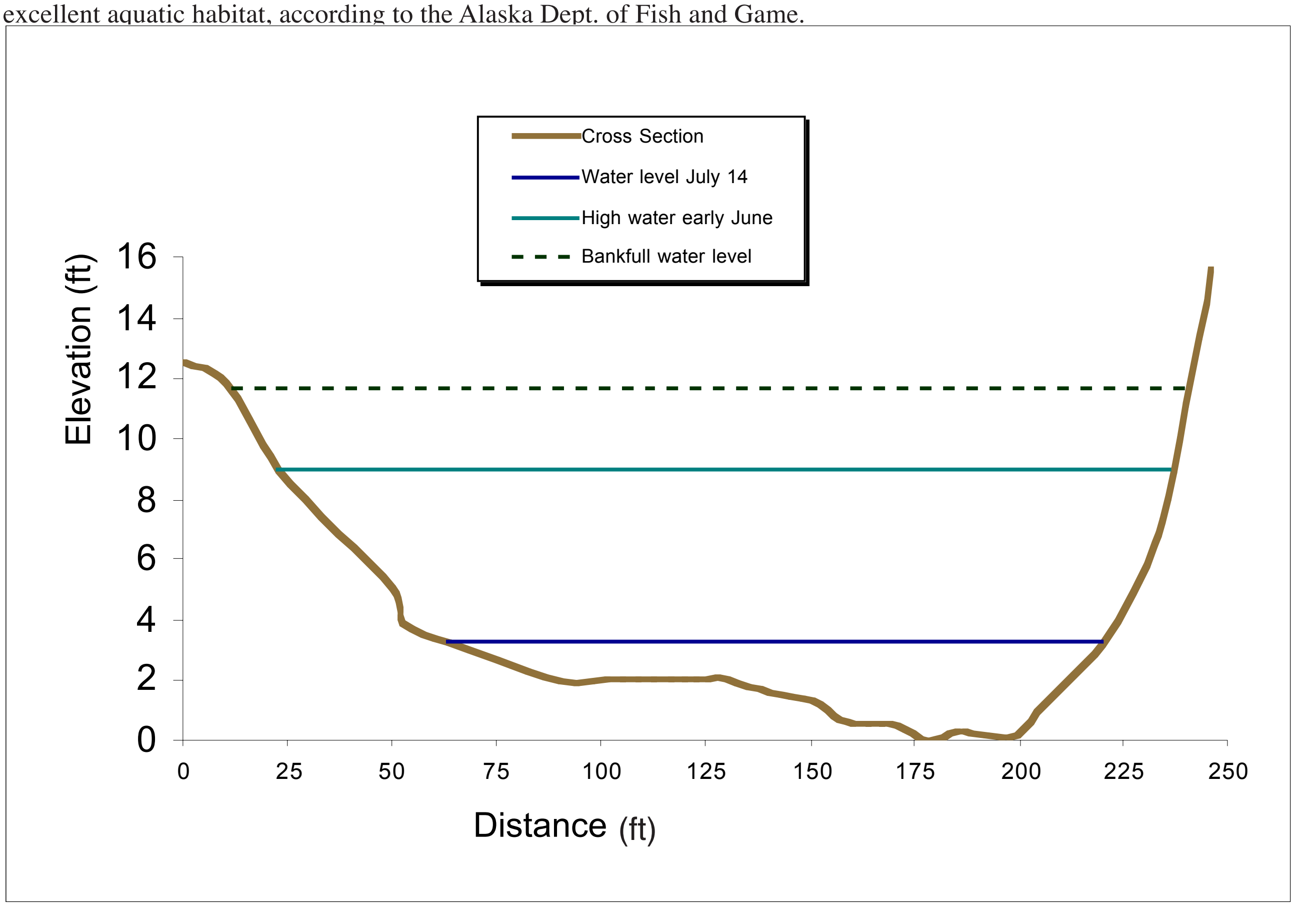

Figure A-11. Channel cross section for the Nuka River.

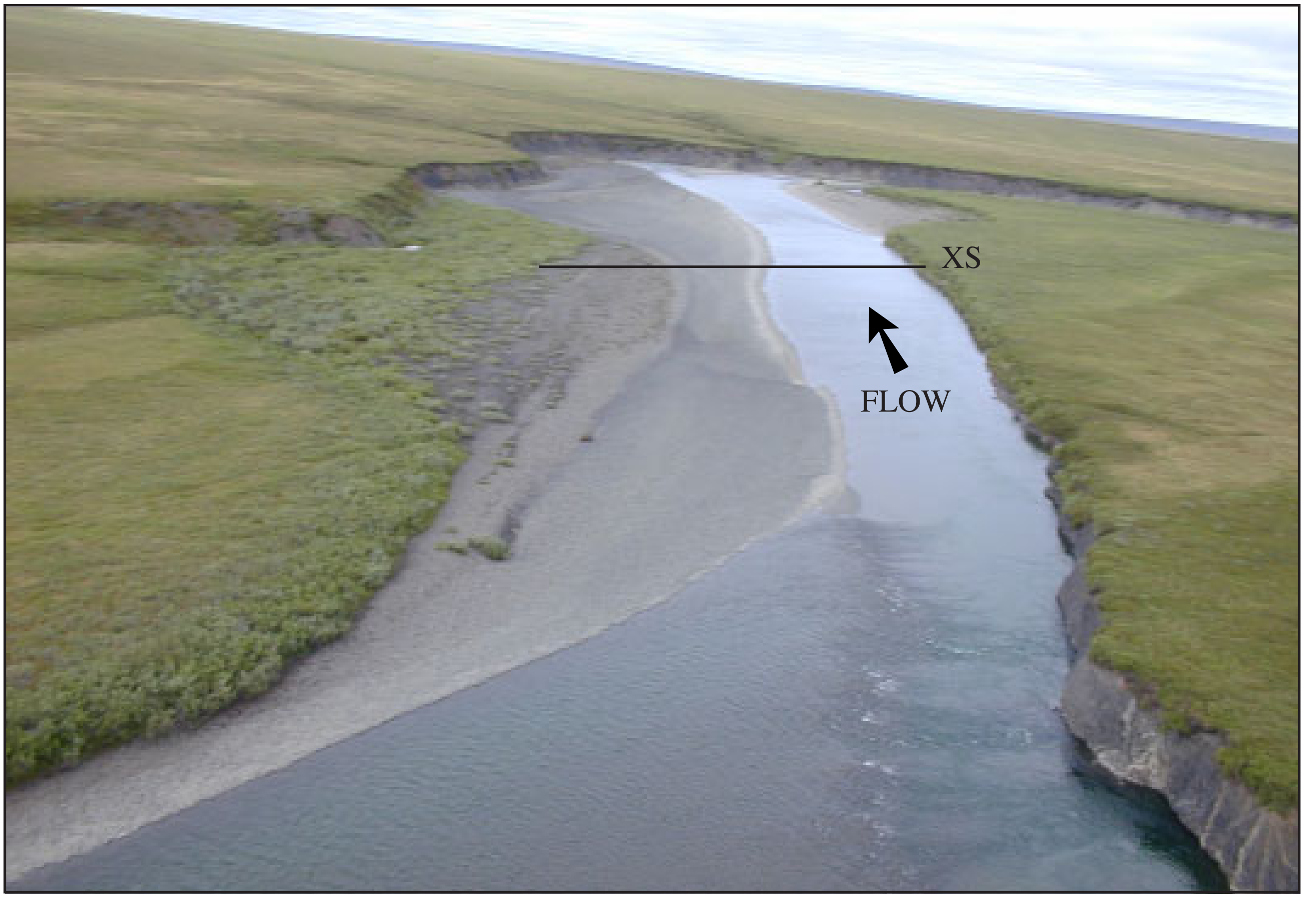

Figure A-12. Looking downstream at the survey site on the Kiligwa River. The Kiligwa supports arctic grayling, according to the Alaska Dept. of Fish and Game.

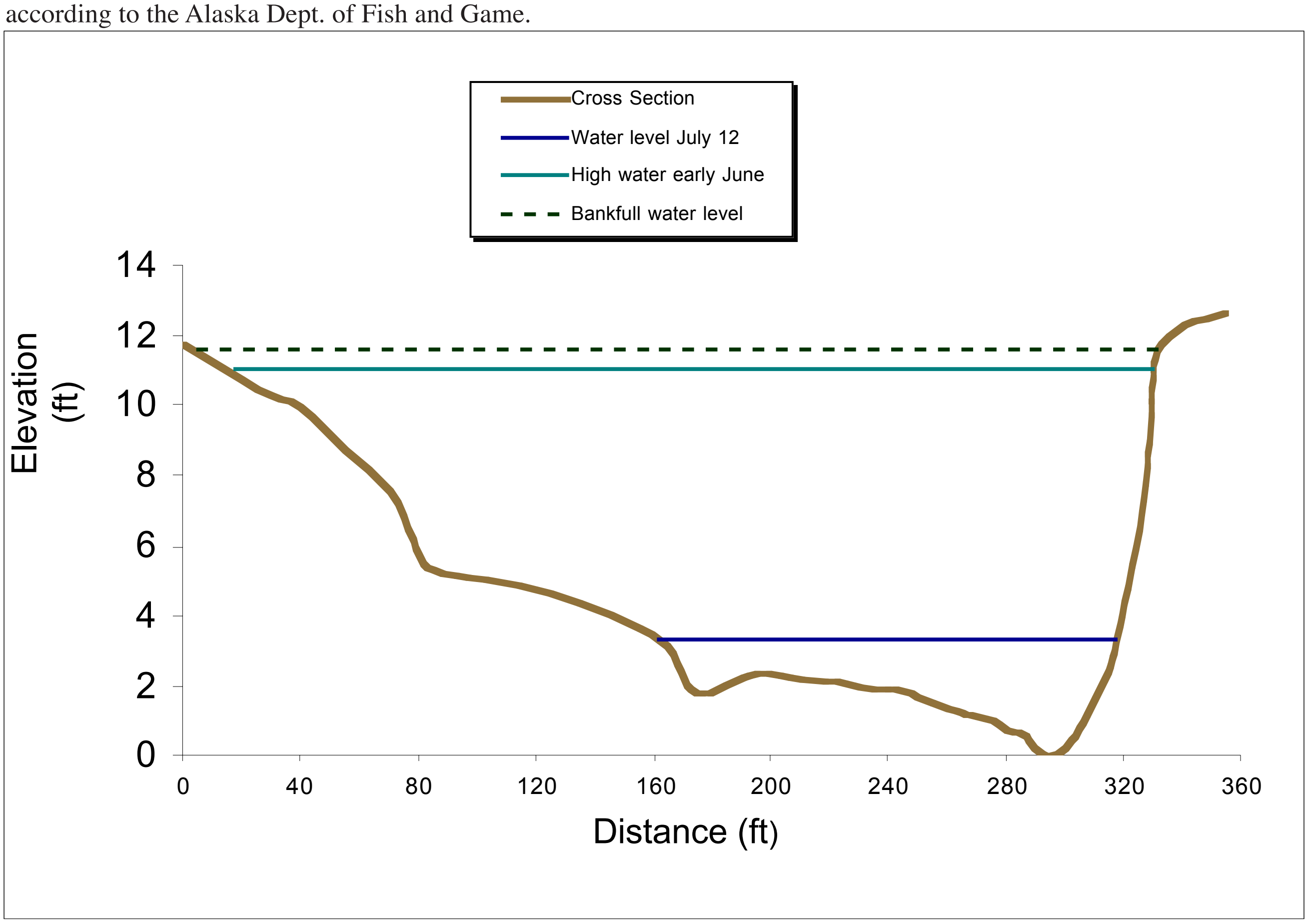

Figure A-13. Channel cross section for the Kiligwa River.

Figure A-14. Looking downstream at the survey site on the Kuna River. The stream bank vegetation and pool-riffle channel formations provide abundant aquatic habitat, according to the Alaska Dept. of Fish and Game..

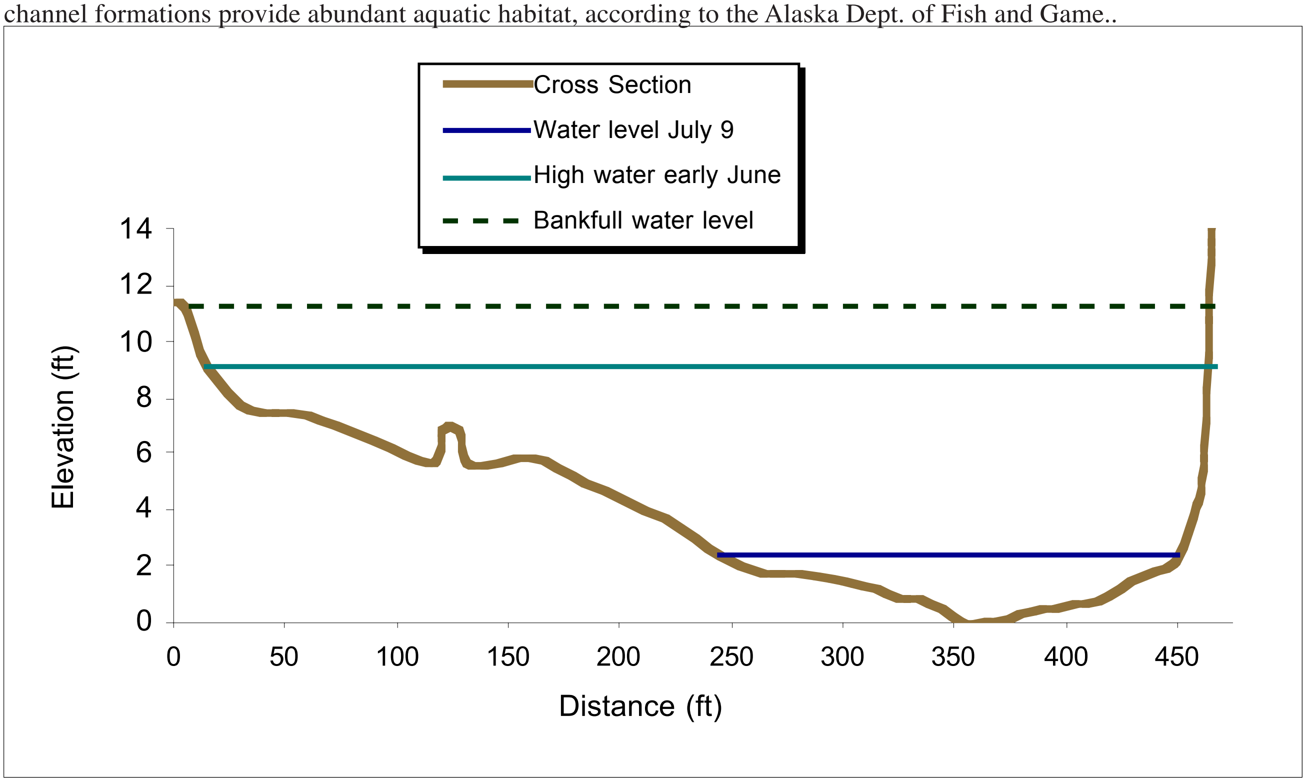

Figure A-15. Channel cross section for the Kuna River.

Figure A-16. Channel cross section for Blankenship Creek. The remnant ice fields indicate a groundwater spring system in the basin.

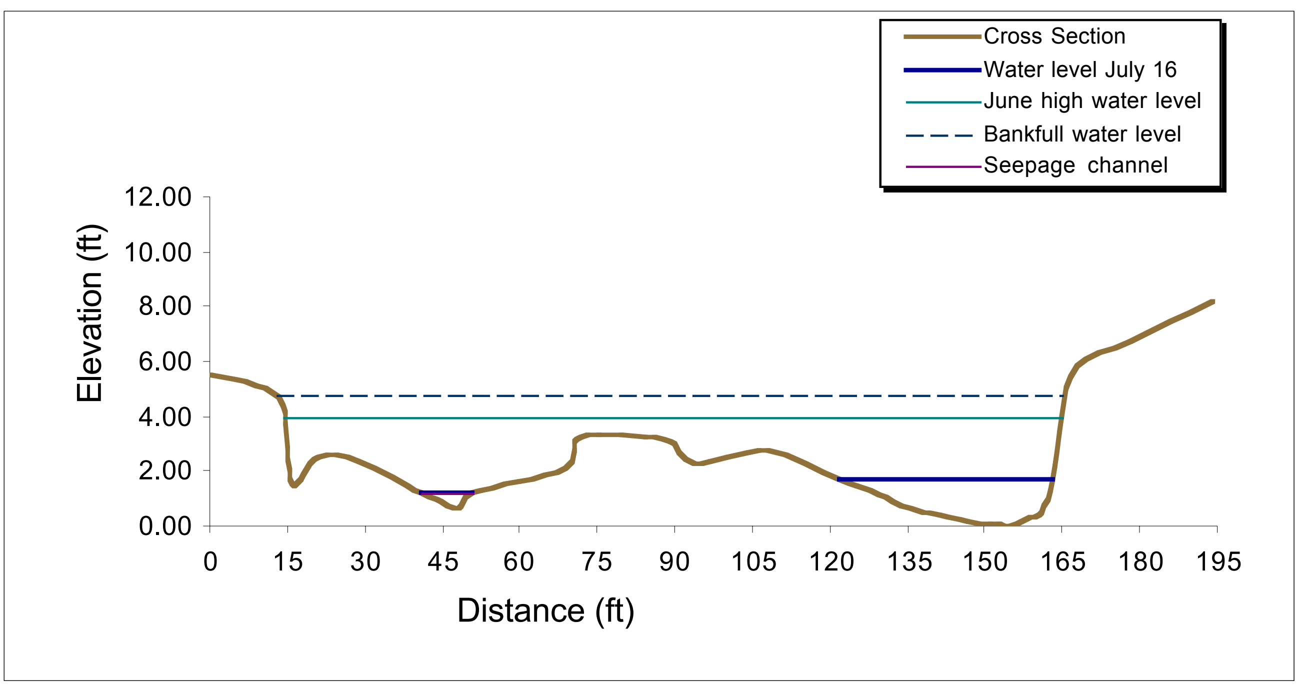

Figure A-17. Cross section of Blankenship Creek.

Figure A-18. Looking downstream at the survey site on the Ipnavik River. The Ipnavik supports arctic grayling, according to the Alaska Dept. of Fish and Game.

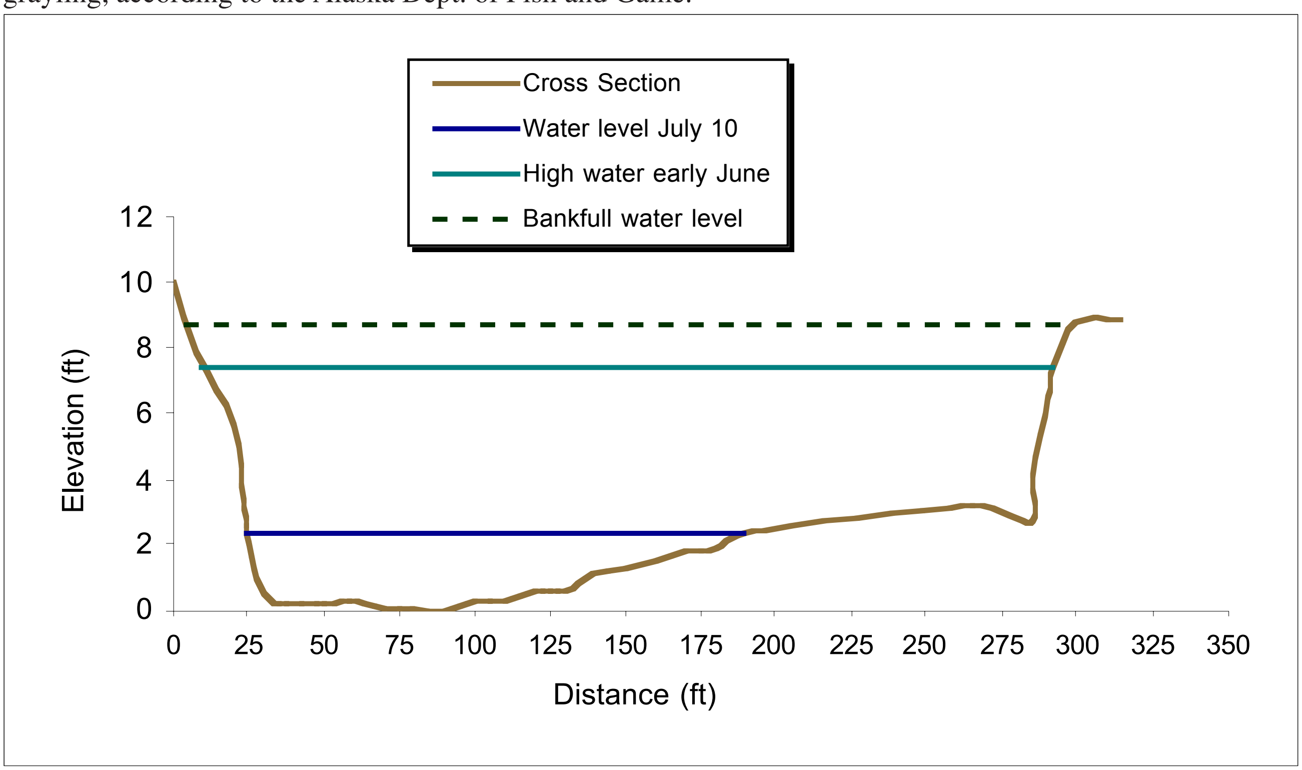

Figure A-19. Channel cross section for the Ipnavik River.

Figure A-20. Looking upstream at the survey site on the Etivluk River above the East Fork. The Etivluk River supports a wide range of anadromous fish, including salmon, according to the Alaska Dept. of Fish and Game.

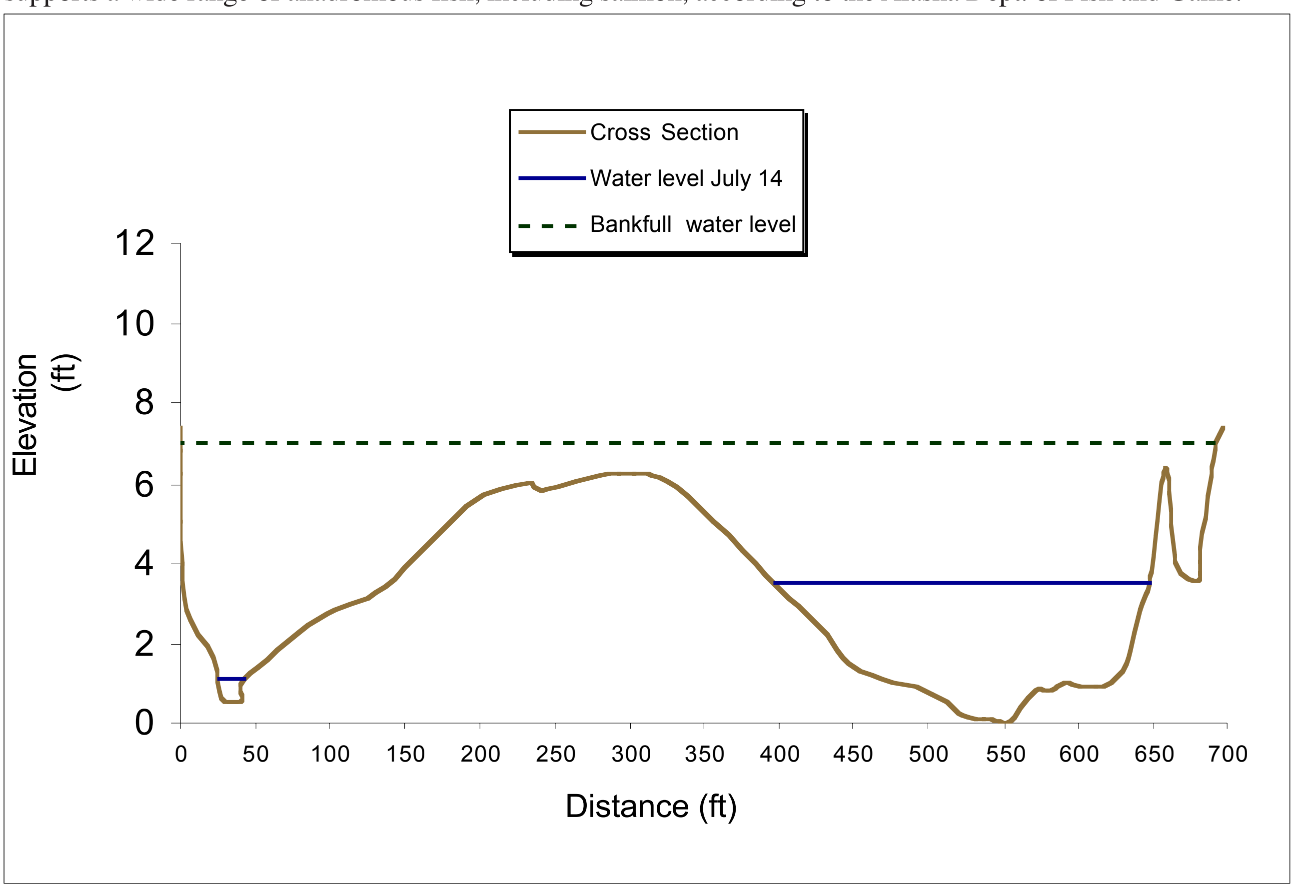

Figure A-21. Channel cross section for the East Fork Etivluk River.

Figure A-22. Looking upstream at the survey site on the Etivluk River. The Etivluk is a braided stream for most of its course.

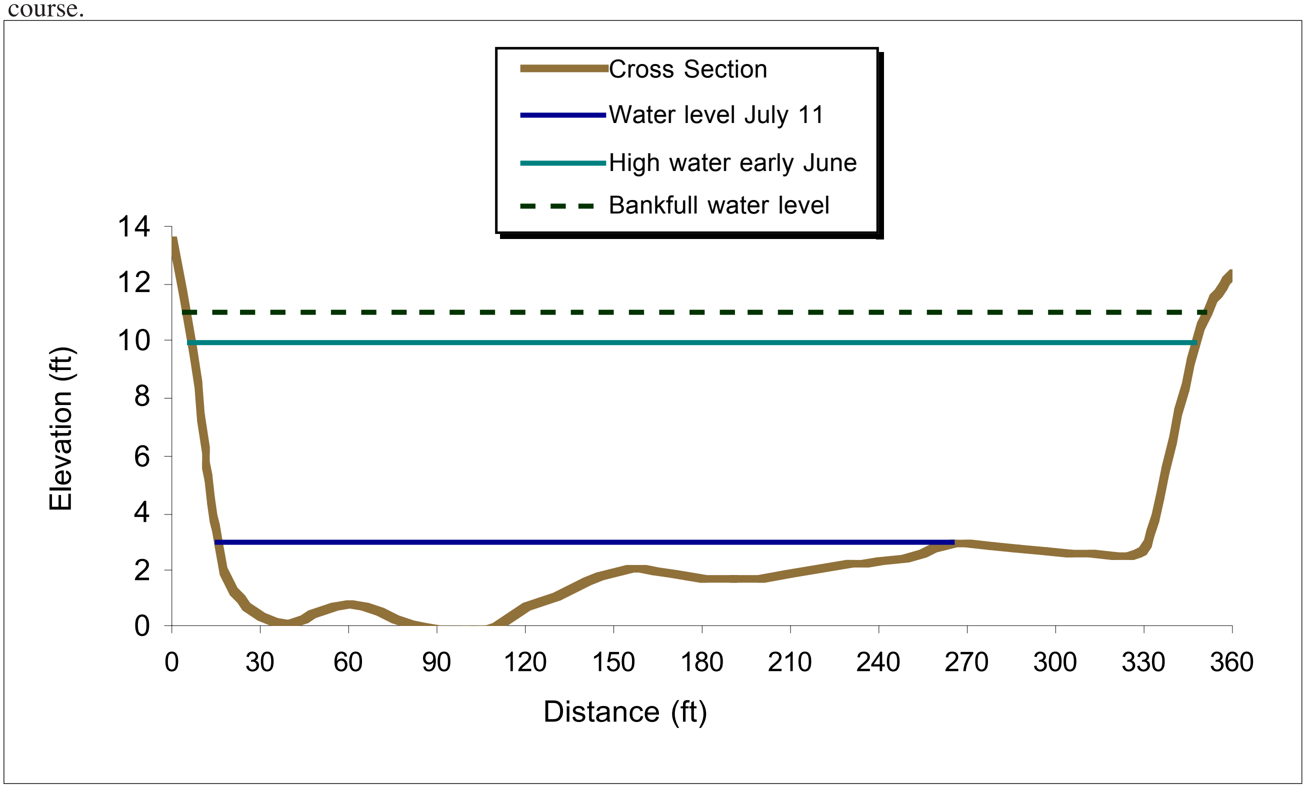

Figure A-23. Channel cross section for the Etivluk River above East Fork.

Figure A-24. Looking downstream at the survey site on the Lookout River near the mouth. The Awuna River is in the background, just beyond the ridgeline.

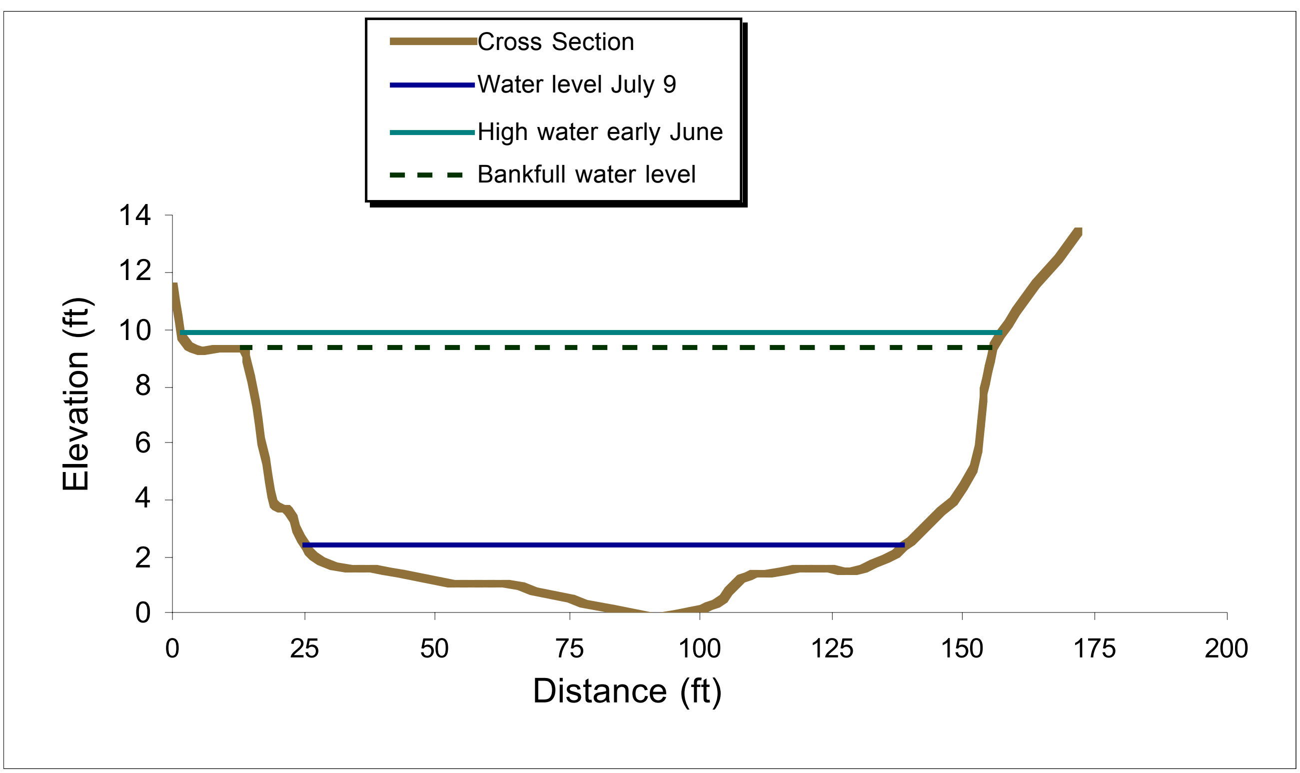

Figure A-25. Channel cross section for the Lookout River.

Figure A-26. Looking upstream at the survey site on the Awuna River above the Lookout River. The Awuna was studied as a Wild and Scenic River, but not nominated, due to low water that limited floating.

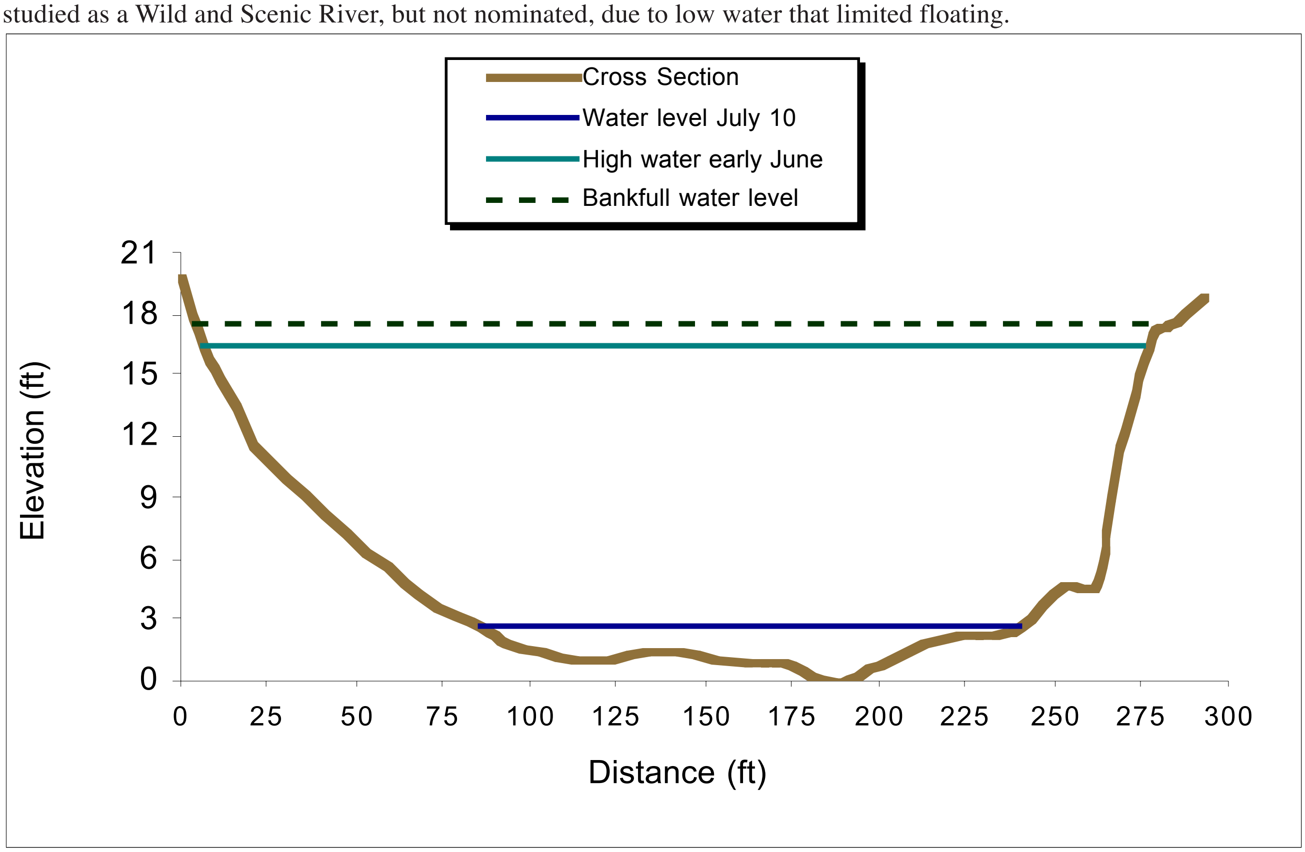

Figure A-27. Channel cross section for the Awuna River above the Lookout River.

Figure A-28. Looking upstream at the survey site on the Awuna River near the mouth. The lower Awuna supports grayling and whitefish, according to the Alaska Dept. of Fish and Game.

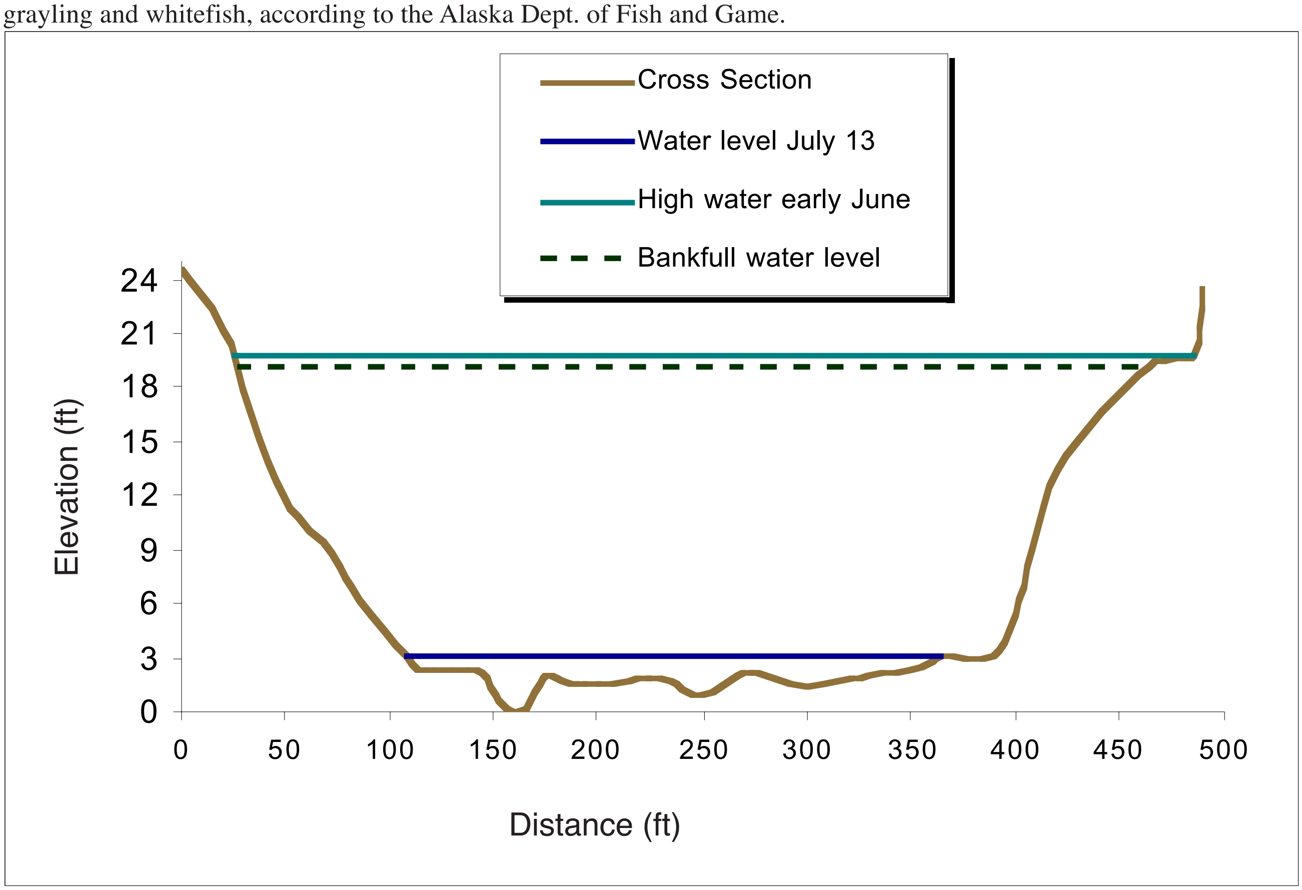

Figure A-29. Channel cross section for the Awuna River near the mouth.

Figure A-30. Looking downstream at the survey site on Maybe Creek. The Ikpikpuk River is formed at the confluence of Maybe Creek and the Kigalik River.

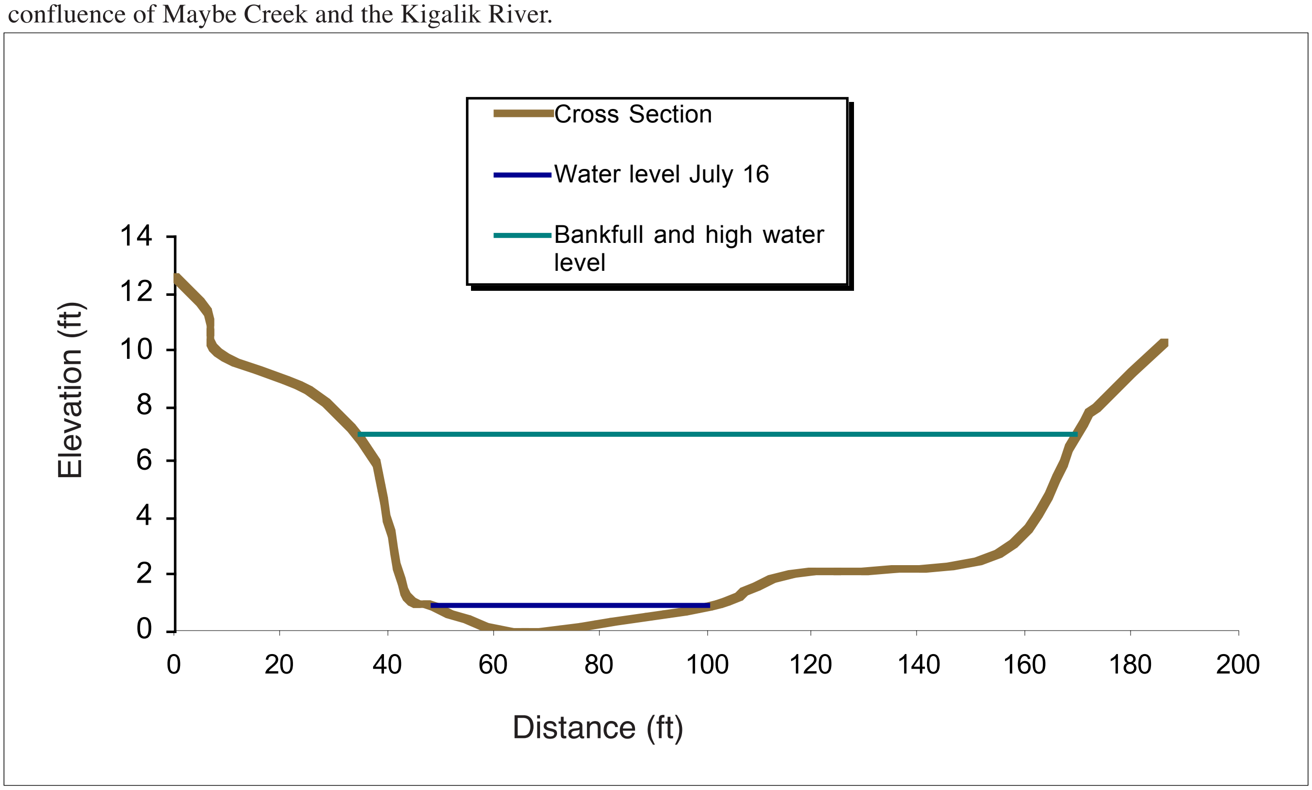

Figure A-31. Channel cross section for Maybe Creek.

Figure A-32. Looking downstream at the survey site on Prince Creek. The channel has excellent aquatic habitat, which supports arctic grayling, according to the Alaska Dept. of Fish and Game.

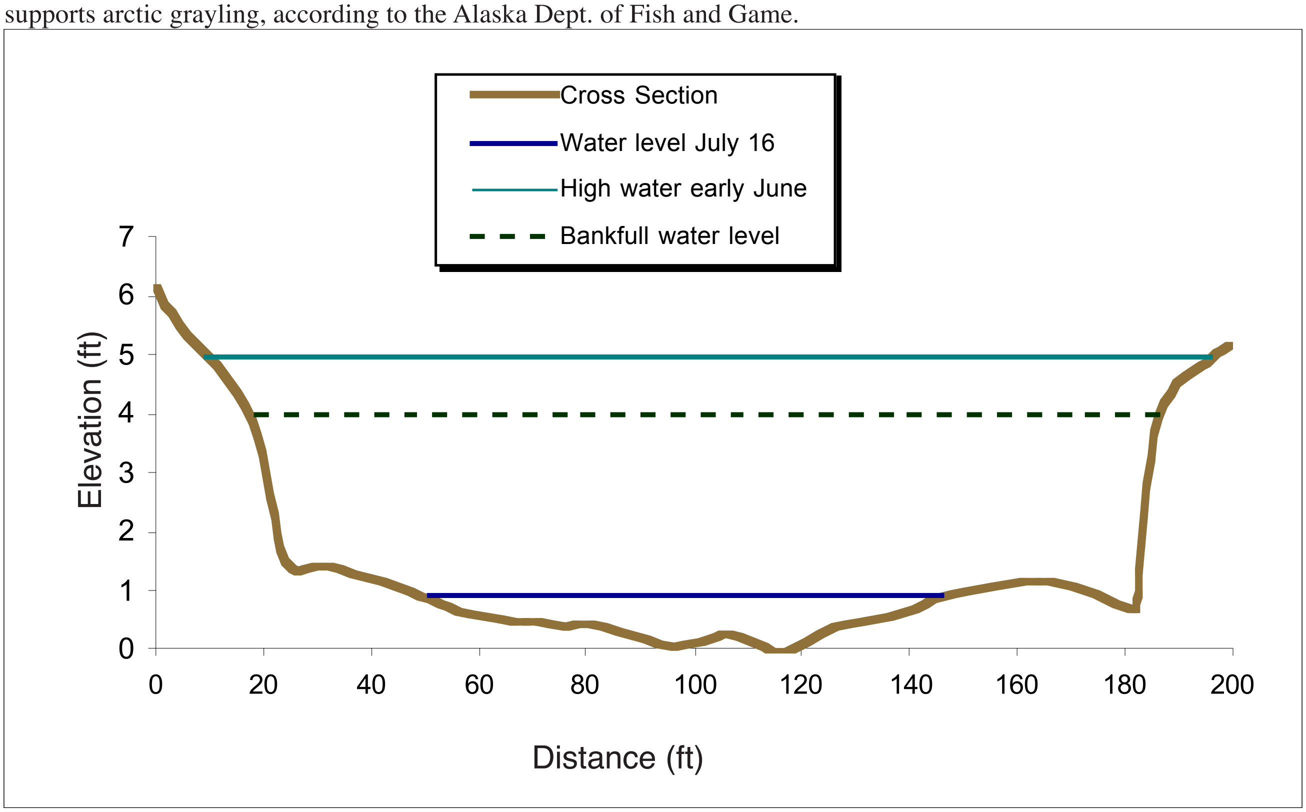

Figure A-33. Channel cross section for Prince Creek.

Figure A-34. Looking downstream at the survey site on the upper Kikiakrorak River. The deep channel pools and bank vegetation provide excellent aquatic habitat, according to the Alaska Dept. of Fish and Game.

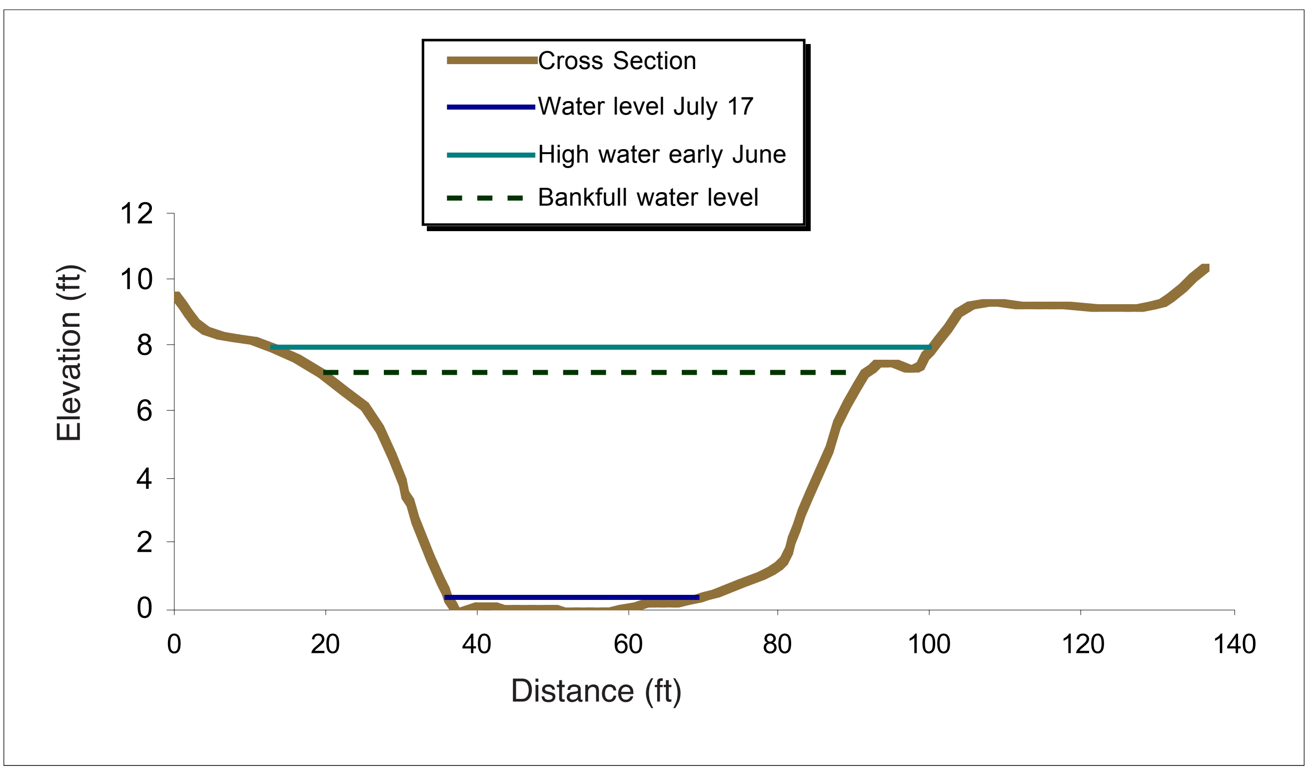

Figure A-35. Channel cross section for the upper Kikiakrorak River.

Figure A-36. Looking downstream at the survey site on the upper Kogosukruk River. The bluffs along the Kogosukruk support raptors and other avian species, according to the Alaska Dept. of Fish and Game.

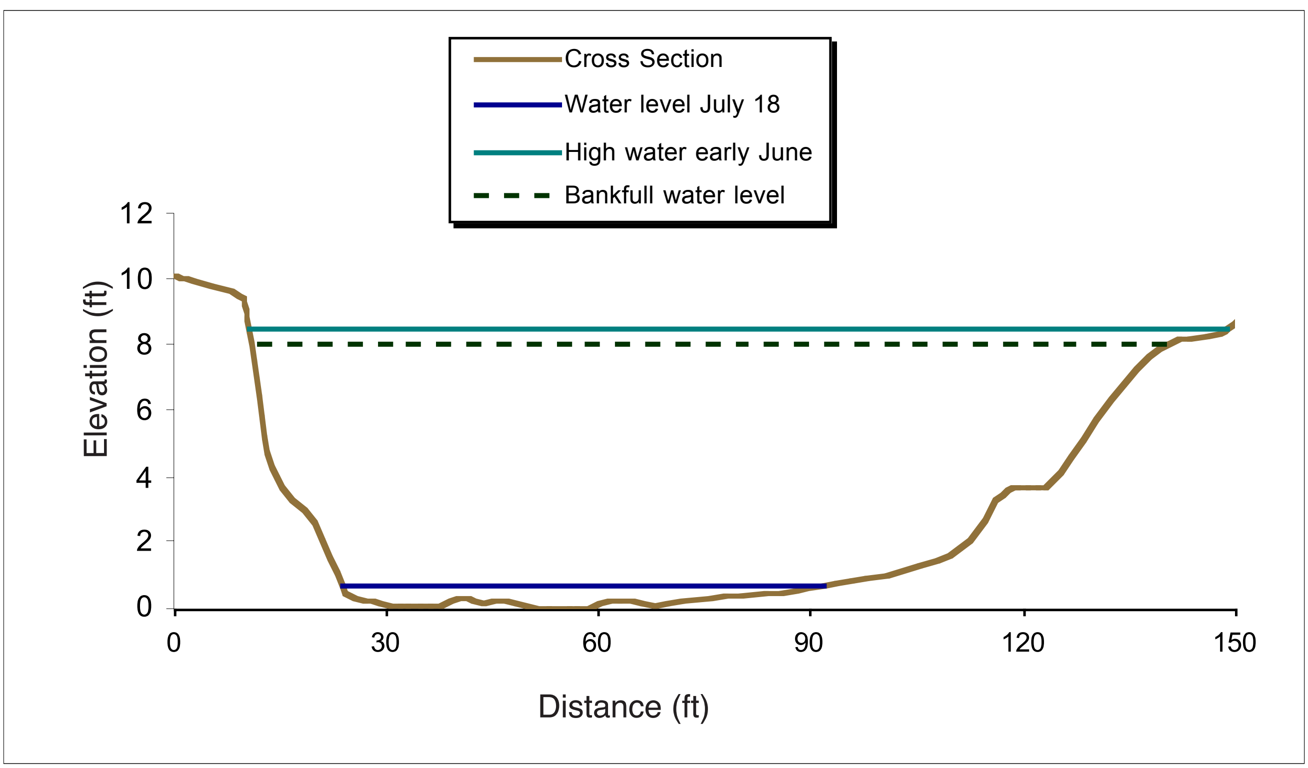

Figure A-37. Channel cross section for the upper Kogosukruk River.

Figure A-38. Looking downstream at the survey site on the lower Kikiakrorak River. The bluffs along the Kikiakrorak support raptors and other avian species, according to the Alaska Dept. of Fish and Game.

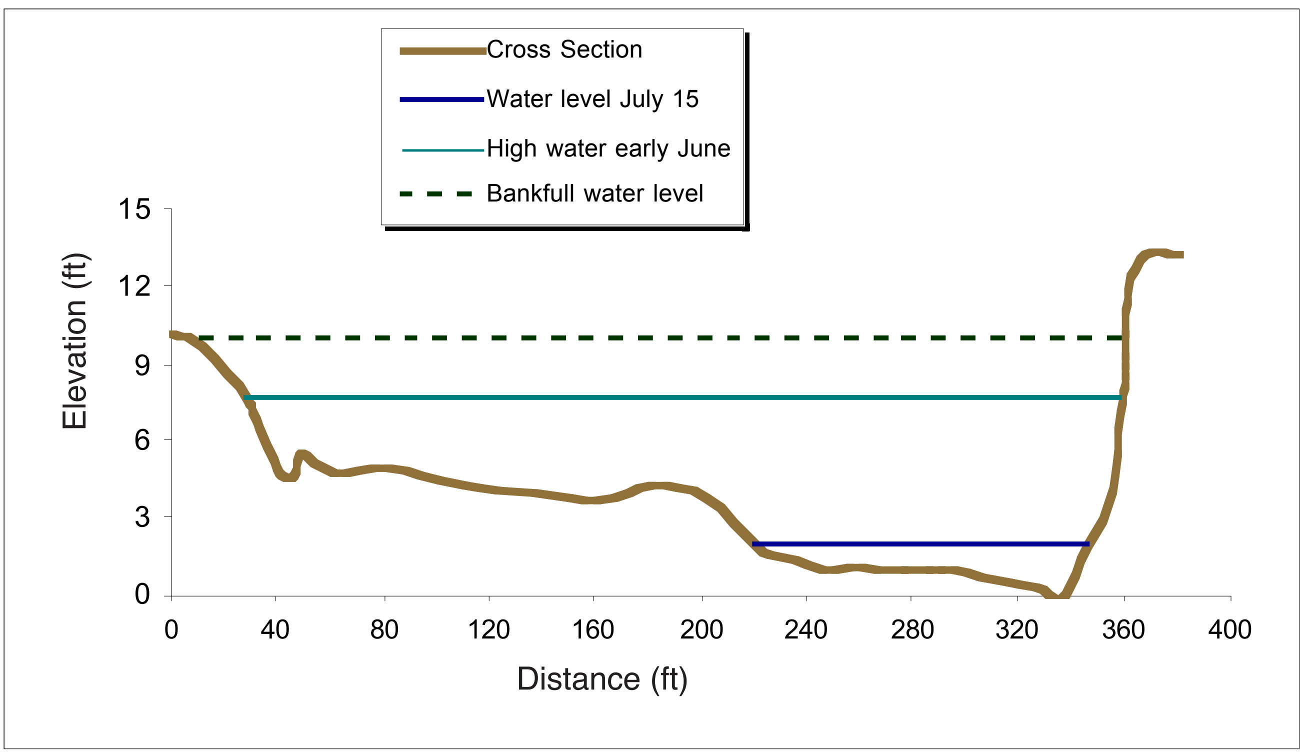

Figure A-39. Channel cross section for the lower Kikiakrorak River.

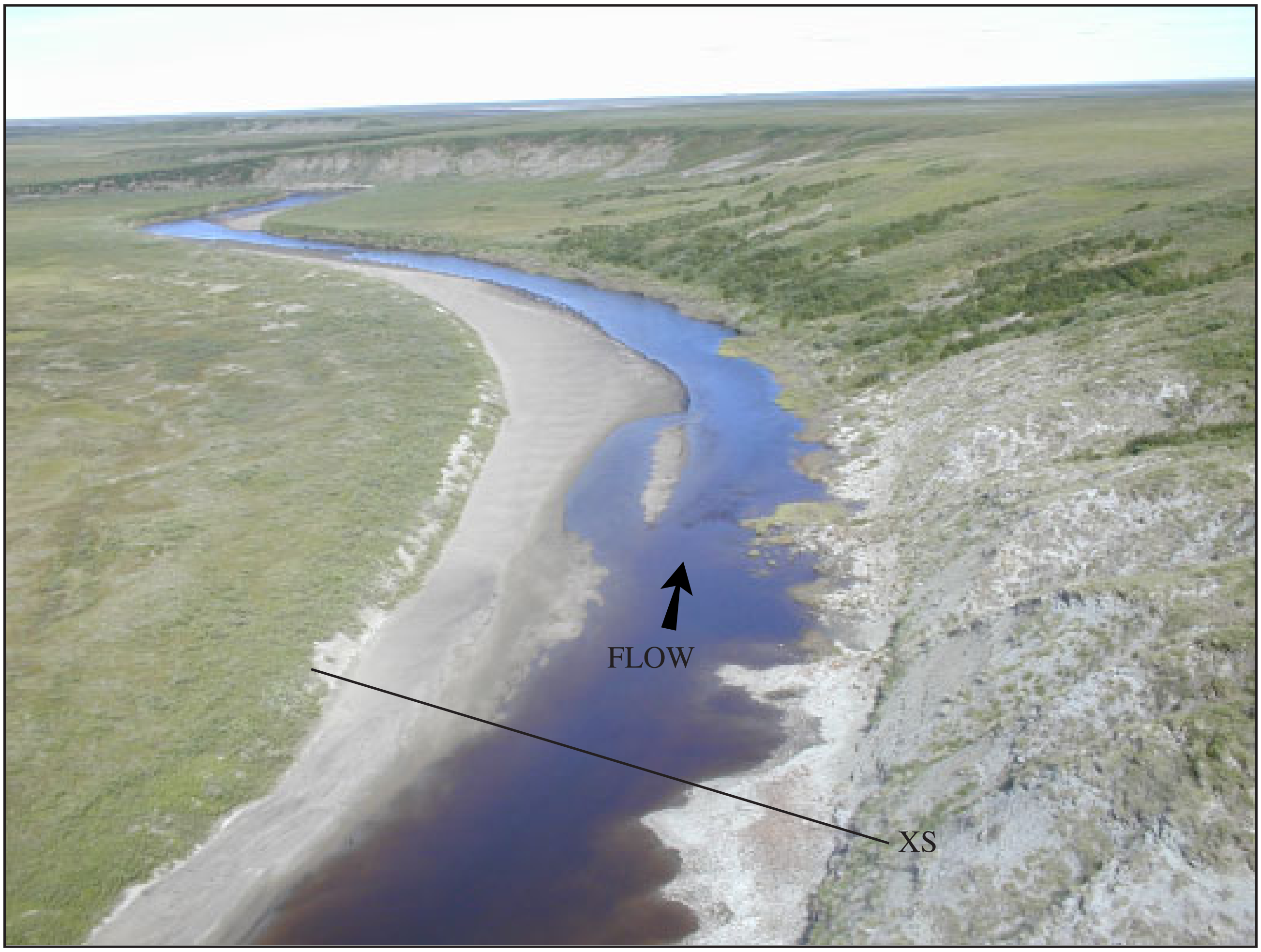

Figure A-40. Looking downstream at the survey site on the lower Kogosukruk River. The bluffs along the Kogosukruk support raptors and other avian species, according to the Alaska Dept. of Fish and Game.

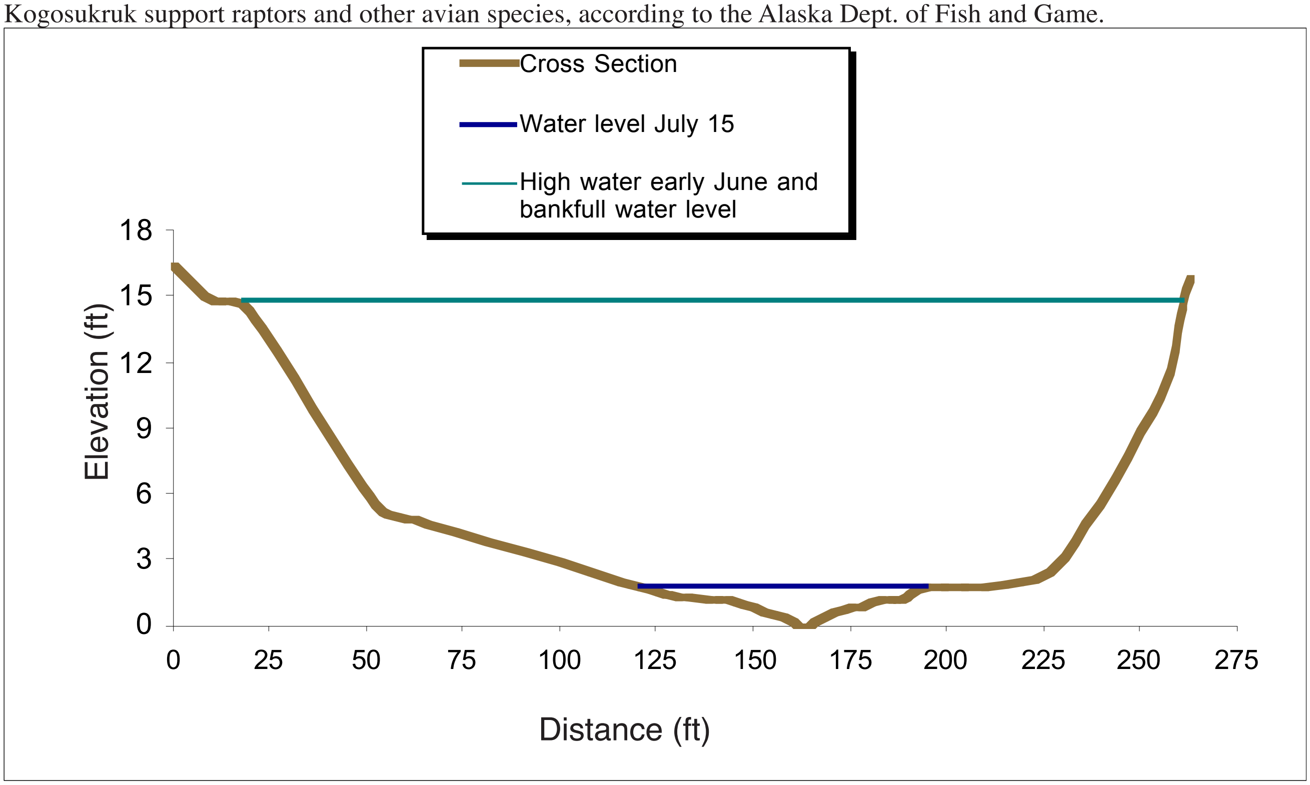

Figure A-41. Channel cross section for the lower Kogosukruk River.

Appendix B Water Quality Data

Table 1B. Field-determined discharge and water quality values for July 2000.

Stream Site	Date Sampled	Discharge cfs	Temperature (°C)	Conductance (ms/cm)	pH	Turbidity NTU	Hardness (Total)
Lower Kikiakrorak River	15	63	16.8	0.157	8.3	3.5	79
Lower Kogosukruk River	15	68	15.9	0.148	8.0	2.5	82

Table 2B. Laboratory analysis of water quality samples taken July 2000.

Site	Date Sampled	Calcium mg/L	Iron mg/L	Magnesium mg/L	Potassium mg/L	Silicon mg/L	Nitrate-N mg/L
Lower Kikiakrorak River	15	24	0.15	4.5	0.9	2.20	<RL
Lower Kogosukruk River	15	27	0.21	3.6	0.8	1.30	<RL

<RL - less than reporting limit

Table 3B. Summary of field-determined discharge and water quality values for July 2001.

Stream Site	Date	Discharge cfs	Water Temp.(°C)	Conductance (ms/cm)	pH	Turbidity NTU	Air Temp.(°C)
Nuka River	14	673	13.0	0.088	8.1	3.5	20.0
Colville River above Kiligwa River	12	515	9.0	0.168	8.2	ND	8.0
Kiligwa River near Brady	12	492	9.0	0.193	8.0	ND	8.0
Kuna River	9	488	8.5	0.153	8.0	2.2	8.0
Lookout River	9	211	11.5	0.051	7.6	14.0	7.0
Blankenship Creek	10	18	5.8	0.135	7.5	ND	7.0
Ipnavik River above Medial Creek	10	344	9.0	0.135	7.9	1.5	7.0
Awuna River above Lookout River	10	427	11.0	0.055	7.7	2.0	8.0
Etivluk River above East Fork	11	762	9.0	0.049	7.8	3.0	7.0
East Fork Etivluk River	14	943	12.0	0.111	7.8	5.0	11.0
Awuna River near the Mouth	13	437	11.5	0.056	7.7	2.0	15.0
Maybe Creek	16	8.0	18.0	0.079	7.5	1.0	18.0
Prince Creek	16	22	16.0	0.096	7.5	1.0	24.0
Upper Kikiakrorak River	17	9.0	16.0	0.143	8.0	1.0	14.0
Upper Kogosukruk River	18	13	16.6	0.138	7.8	ND	19.0
Lower Kikiakrorak River	18	58	15.0	0.156	8.2	ND	13.0
Lower Kogosukruk River	18	48	16.3	0.151	8.1	ND	11.0
Lookout Lake Outlet	9	1.0	13.8	0.011	6.7	3.5	ND
Liberator Lake Outlet	12	13	12.0	0.036	7.8	0.5	ND
Smith Mountain Lake Outlet	12	3e	12.0	0.066	7.8	52.8	ND
Puddin Lake	16	ND	13.7	0.036	7.4	1.5	20.0
Prince Lake	16	ND	17.3	0.220	8.5	3.5	24.0

e - estimated
ND - not determined

Table 4B. Laboratory analysis of water quality samples taken in July 2001.

Stream Site	Date Sampled	Calcium mg/L	Iron mg/L	Magnesium mg/L	Potassium mg/L	Silicon mg/L	Hardness (Total)
Nuka River	14	17.0	0.05	3.5	0.39	1.00	57
Colville River above Kiligwa River	12	18.0	0.04	3.9	0.43	0.96	61
Kiligwa River near Brady	12	22.0	0.05	5.9	0.41	1.20	79
Kuna River	9	17.0	0.04	4.4	0.57	1.30	61
Lookout River	9	5.6	0.45	2.2	0.21	1.50	23
Ipnavik River above Medial Creek	10	15.0	0.04	4.3	0.36	1.40	55
Awuna River above Lookout River	10	5.7	0.50	2.9	<DL	1.40	26
Etivluk River above East Fork	11	9.1	0.06	4.4	0.22	1.00	41
East Fork Etivluk River	14	14.0	0.04	4.6	0.50	1.30	54
Awuna River near the Mouth	13	6.3	0.43	3.2	<DL	1.60	29
Prince Creek	16	12.0	0.06	2.9	1.20	2.20	42
Upper Kogosukruk River	18	21.0	0.33	3.9	1.10	3.00	68
Liberator Lake Outlet	12	6.3	0.10	2.1	0.70	0.13	24
Smith Mountain Lake Outlet	12	6.0	1.70	2.1	0.95	1.10	24
	Mean	12.5	0.28	3.6	0.59	1.36	46
	Max	22.0	1.70	5.9	1.20	3.00	79
	Min	5.6	0.04	2.1	0.21	0.13	23

<DL - less than detection limit

Table 5B. Summary of field determined discharge and water quality values for 2002

Stream Site	Date	Discharge cfs	Water Temp.(°C)	Conductance (ms/cm)	pH	Turbidity NTU	Dissolved Oxygen mg/L	Alkalinity (HCO3) mg/L	Hardness (Total)	Air Temp.(°C)
Colville River above Kiligwa River	Sep.10	ND	2.6	0.137	7.9	4.9	11.9	51.0	70	5.0
Nuka River	Sep.10	770	2.2	0.162	7.9	2.2	11.9	52.8	67	3.3
Kiligwa River near Brady	Sep.10	779	2.6	0.195	7.8	2.3	12.3	37.8	84	6.1
Maybe Creek	Aug. 24	131	4.9	0.053	7.5	2.2	11.0	19.2	26	10.0
Prince Creek	July 13	157	13.0	0.059	7.4	2.5	7.0	25.8	30	12.8
Upper Kikiakrorak River	Aug. 24	72	7.2	0.105	7.7	1.6	10.6	41.2	50	10.0
Upper Kogosukruk River	Aug. 24	124	7.5	0.126	7.9	7.6	10.8	57.8	61	10.0
Lower Kikiakrorak River	July 13	157	11.3	0.123	7.8	8.0	7.5	54.8	66	13.9
Lower Kogosukruk River	Aug. 20	415	16.3	0.151	8.1	ND	3.5	ND	ND	11.0
Dogbone Lake Outlet	July 10	1.2	14.1	0.027	7.1	0.8	8.4	9.8	12	18.3
Liberator Lake Outlet	Sep. 10	8.6	3.4	0.068	7.8	28.8	12.2	25.0	26	7.2
	Mean	261	7.7	0.110	7.7	6.1	9.7	37.5	49	9.8
	Max	779	16.3	0.195	8.1	28.8	12.3	57.8	84	18.3
	Min	1.2	2.2	0.027	7.1	0.8	3.5	9.8	12	3.3

ND - not determined
e - estimated

Table 6B. Laboratory analysis of water quality samples taken in 2002.

Stream Site	Date	Calcium mg/L	Iron mg/L	Magnesium mg/L	Potassium mg/L	Silicon mg/L	Manganese mg/L	Sodium mg/L	Chlorine mg/L	Sulfate mg/L
Colville River above Kiligwa River	10-Sep	18.80	0.38	5.53	0.5	1.86	0.01	2.62	<MDL	ND
Nuka River	10-Sep	18.43	0.09	5.15	0.6	1.64	0.02	2.59	0.1	ND
Kiligwa River near Brady	10-Sep	22.12	0.13	7.08	0.5	1.77	0.02	3.52	0.1	ND
Maybe Creek	24-Aug	7.06	0.29	2.05	0.3	2.17	0.01	1.49	<MDL	4.9
Prince Creek	13-July	8.79	0.25	2.03	0.4	1.78	ND	1.42	<MDL	ND
Upper Kikiakrorak River	24-Aug	15.32	0.19	2.75	0.8	2.93	0.01	2.86	0.4	4.9
Upper Kogosukruk River	24-Aug	18.52	0.40	3.49	0.7	3.06	0.01	3.30	0.6	5.7
Lower Kikiakrorak River	13-July	21.76	0.96	2.88	0.7	1.59	ND	2.42	1.7	ND
Dogbone Lake Outlet	10-July	3.73	0.13	0.54	0.1	0.06	ND	0.84	1.3	ND
Liberator Lake Outlet	10-Sep	6.27	0.62	2.41	0.7	1.15	0.03	4.09	0.3	ND
	Mean	14.08	0.34	3.39	0.6	1.80	0.01	2.52	0.6	5.2
	Max	22.12	0.96	7.08	0.8	3.06	0.03	4.09	1.7	5.7
	Min	3.73	0.09	0.54	0.3	0.06	0.01	0.84	0.1	4.9

ND - not determined
<MDL - less than method detection limit

Table7B. Summary of field determined discharge and water quality values for 2003.

Stream Site	Date	Discharge cfs	Water Temp. (°C)	Conductance (ms/cm)	pH	Turbidity NTU	Dissolved Oxygen mg/L
Ipnavik River	14-Aug	992	7.7	0.128	7.4	7.8	ND
Blankenship Creek	14-Aug	84	6.8	0.115	7.4	1.9	ND
Etivluk River	14-Aug	ND	7.8	0.064	7.2	51	ND
Kuna River	15-Aug	ND	8.3	0.114	7.7	66	ND
Kiligwa River	15-Aug	ND	7.8	0.164	7.9	75	ND
Colville River	15-Aug	ND	8.4	0.161	7.8	45	ND
Nuka River	15-Aug	ND	8.6	0.171	7.9	15	ND
Lower Kogosukruk River	4-Sep	189	6.9	0.151	8.0	7.6	12.0
Dogbone Lake Outlet	4-Sep	<1	6.9	0.028	6.9	ND	11.0
Upper Kogosukruk River	4-Sep	306	5.9	0.121	7.8	16	12.1
Lower Kikiakrorak River	6-Sep	385	3.6	0.146	8.0	24	12.7
Upper Kikiakrorak River	6-Sep	160	3.9	0.102	7.6	2.6	12.6
Prince Creek	6-Sep	341	5.3	0.055	7.3	3.2	12.4
Maybe Creek	4-Jun	ND	2.0	ND	ND	15	ND

ND - not determined

Table 8B. Laboratory analysis of water quality samples taken in 2003.

Stream Site	Date	Calcium mg/L	Iron mg/L	Magnesium mg/L	Potassium mg/L	Silicon mg/L	Manganese mg/L	Sodium mg/L	Chloride mg/L	Hardness (Total)
Ipnavik River	14-Aug	17.0	<MRL	5.7	<MRL	1.7	<MRL	2.5	<MRL	66
Blankenship Creek	14-Aug	16.0	0.2	5.6	<MRL	1.9	0.01	1.8	<MRL	63
Etivluk River	14-Aug	7.0	4.4	4.9	0.5	5.2	0.17	0.7	<MRL	38
Kuna River	15-Aug	14.0	3.7	5.7	0.9	4.3	0.12	2.6	<MRL	58
Kiligwa River	15-Aug	20.0	3.9	7.3	1.1	4.6	0.14	3.2	<MRL	80
Colville River	15-Aug	22.0	2.0	6.0	0.9	3.3	0.05	3.5	<MRL	80
Nuka River	15-Aug	24.0	0.9	5.5	0.4	2.2	0.02	3.6	<MRL	83
Lower Kogosukruk River	4-Sep	20.0	0.4	3.8	0.7	3.2	ND	4.9	1.4	66
Upper Kogosukruk River	4-Sep	17.0	0.6	3.3	0.7	4.2	3.60	<MRL	0.3	56
Lower Kikiakrorak River	6-Sep	23.0	1.0	3.2	1.0	3.1		3.3	2.2	71
Upper Kikiakrorak River	6-Sep	15.0	0.2	2.8	0.5	3.4		2.4	<MRL	49

<MDL - less than method detection limit