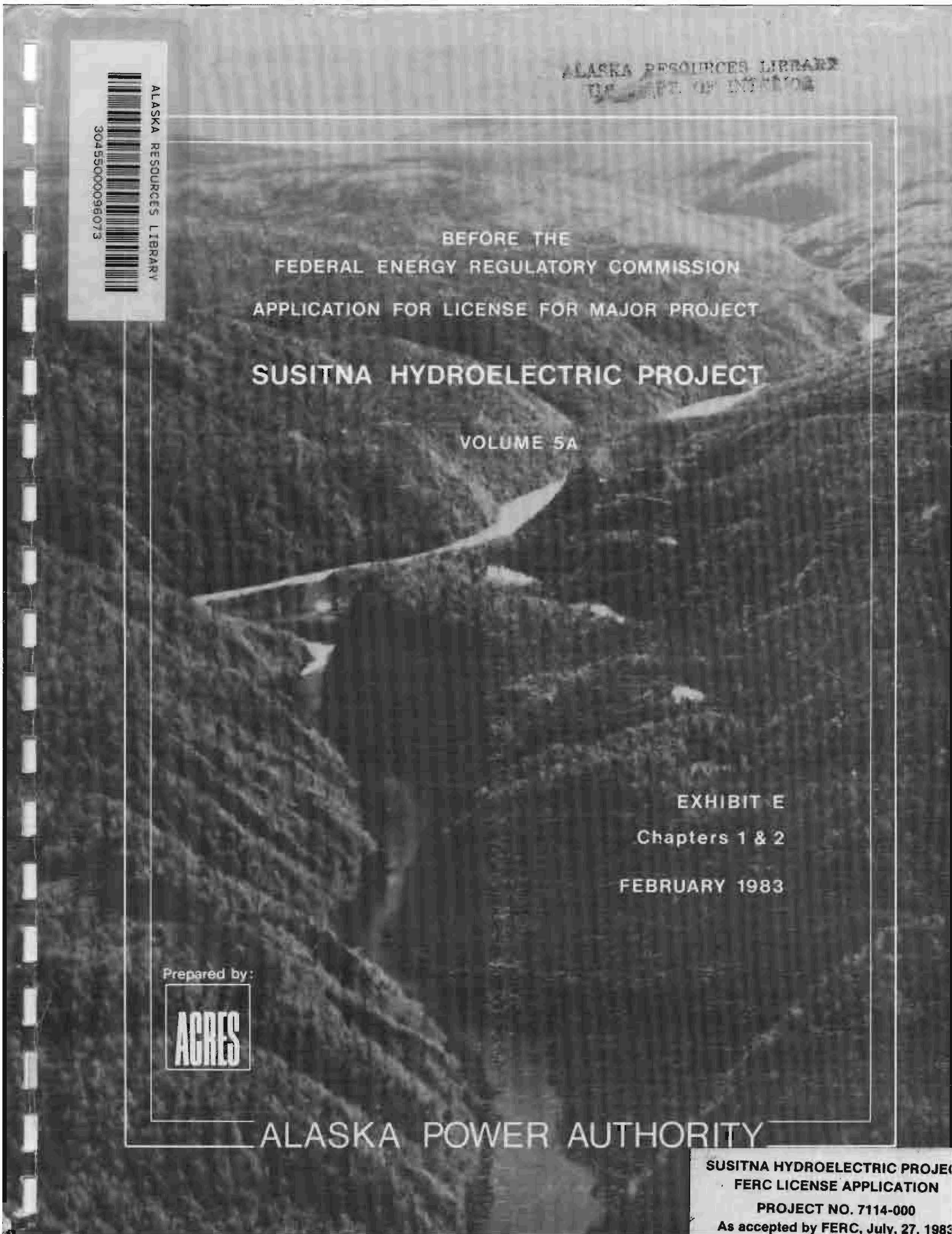


BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION

APPLICATION FOR LICENSE FOR MAJOR PROJECT

SUSITNA HYDROELECTRIC PROJECT

VOLUME 5A

EXHIBIT E

Chapters 1 & 2

FEBRUARY 1983

Prepared by:

ACRES

ALASKA POWER AUTHORITY

ARLIS

Alaska Resources
Library & Information Services
Anchorage, Alaska

BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION

APPLICATION FOR LICENSE FOR MAJOR PROJECT

SUSITNA HYDROELECTRIC PROJECT

VOLUME 5A

EXHIBIT E

Chapters 1 & 2

FEBRUARY 1983

Prepared by:

ACRES

ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

VOLUME 5

EXHIBIT E CHAPTER 1

GENERAL DESCRIPTION OF THE LOCALE

SUSITNA HYDROELECTRIC PROJECT

VOLUME 5

EXHIBIT E CHAPTER 1

GENERAL DESCRIPTION OF THE LOCALE

TABLE OF CONTENTS

Page

LIST OF FIGURES

1 - GENERAL DESCRIPTION OF THE LOCALE

1.1 - General Setting

The location of the proposed Susitna Hydroelectric Project is within the east-to-west-flowing section of the Susitna River approximately 140 miles (230 km) north-northeast of Anchorage, Alaska, and 110 miles (180 km) south-southwest of Fairbanks, Alaska (Figure E.1.1). Two proposed dams would generate electrical power for the railbelt region of Alaska; that is, the corridor surrounding the Alaska Railroad from Seward and Anchorage to Fairbanks. The two proposed damsites, Watana and Devil Canyon, are 152 (246 km) and 184 (300 km) river miles upstream from the river's mouth at Cook Inlet. The nearest settlements (Gold Creek, Canyon, Chulitna) are along the Alaska Railroad, approximately 12 miles (18 km) from Devil Canyon.

The project site is within the south-central region of Alaska. This region is geographically bounded by the Alaska Range to the north and west, the Wrangell Mountains to the east, and the Chugach Mountains and the Gulf of Alaska to the south. Topography is varied and includes rugged, mountainous terrain; plateaus; and broad river valleys.

Mount McKinley, the state's single most significant geographical feature, is located on the region's northwest border. Denali National Park, Denali State Park, and the diversity of landscapes and resources offer a wide variety of recreational opportunities. Spruce-hemlock and spruce-hardwood forests, wetlands, and tundra are the predominant vegetative types. A wide variety of wildlife and fish species are present, including moose, caribou, bear, and salmon.

Approximately 50 percent of Alaska's population lives in south-central Alaska. Anchorage is the state's largest city with a civilian population in 1980 of 174,400. Fairbanks, north of the present site and outside south-central Alaska, is the state's second largest urban center with a population of 30,000. The region's economy is based on support services, commercial fishing, mining, forestry, petroleum, and tourism.

South-central Alaska contains the most highly developed transportation system in the state interconnected by paved highways and gravel secondary roads. An extensive airport system ranging from the international level to gravel strips and water bodies permit plane access into more remote areas. The Alaska Railroad and ferry systems also serve large portions of the region.

Air quality in the region is good. All areas outside Anchorage and Fairbanks meet all the National Ambient Air Quality Standards. Thus, the area is classified as attainment, and any facility which exceeded threshold levels for pollutant emissions would be subject to the requirements of the Prevention of Significant Deterioration program under the Clean Air Act.

1.2 - Susitna Basin

1.2.1 - Physiography and Topography

The 19,400-square-mile (50,440 km^2) Susitna River basin is bordered by the Alaska Range to the north, the Chulitna and Talkeetna Mountains to the west and south, and the northern Talkeetna plateau and Gulkana uplands to the east. This area is largely within the Coastal Trough province of south-central Alaska, a belt of lowlands extending the length of the Pacific Mountain System and interrupted by the Talkeetna, Clearwater, and Wrangell Mountains.

The basin has distinct and diverse combinations of landforms and waterforms. The deep V-shaped canyon of the Susitna River and tributary valleys the Talkeetna Mountains, and upland plateau to the east are the dominant topographic forms. Elevations in the basin range from approximately 700 feet (210 meters) to over 6000 feet (1800 meters). Distinctive landforms include tundra highlands, active and post-glacial valleys, and numerous lakes.

In the vicinity of the proposed impoundments (Figure E.1.2), the river cuts a narrow, steep-walled gorge up to 1000 feet (300 meters) deep through the Clarence Lake Upland and Fog Lakes Upland, areas of broad, rounded summits 3000 to 4200 feet (900 to 1260 meters) in elevation. Between these uplands, the gorge cuts through an extension of the Talkeetna Mountains, where rugged peaks are 6900 feet (2070 meters) high. Downstream from its confluence with the Chulitna and Talkeetna rivers, near Talkeetna, the Susitna traverses the Cook Inlet-Susitna Lowland, a relatively flat region generally less than 500 feet (150 meters) in elevation. A portion of the proposed transmission facilities, between Healy and Fairbanks, would follow the narrow valley of the Nenana River through the northern foothills of the Alaska Range, traverse the Tanana-Kuskokwim Lowland in a flat region generally less than 650 feet (200 meters) in elevation (the Tanana Flats), and then parallel a ridge on the edge of the Yukon-Tanana Upland.

1.2.2 - Geology and Soils

The regional geology of the Susitna Basin area has been extensively studied and is documented. The upper Susitna Basin lies within what is geologically called the Talkeetna Mountains area. This area is geologically complex and has a history of at least three periods of major tectonic deformation. The oldest rocks exposed in the region are volcanic flows and limestones which were formed 250 to 300 million years before present (m.y.b.p.) and which are overlain by sandstones and shales dated approximately 150 to 200 m.y.b.p. A tectonic event approximately 135 to 180 m.y.b.p. resulted in the intrusion of large diorite and granite plutons, which caused intense thermal metamorphism. This was followed by marine deposition of silts and clays. The argillites and phyllites which predominate at Devil Canyon were formed from the silts and clays during faulting and folding of the Talkeetna Mountains area in the Late Cretaceous period (65 to 100 m.y.b.p.). As a result of this faulting and uplift, the eastern portion of the area was elevated and the oldest volcanics and sediments were thrust over the younger metamorphics and sediments. The major area of deformation during this period of activity was southeast of Devil Canyon and included the Watana area. The Talkeetna Thrust Fault, a well-known tectonic feature which has been identified in the literature, trends northwest through this region. This fault was one of the major mechanisms of this overthrusting from southeast to northwest. The Devil Canyon area was probably deformed and subjected to tectonic stress during the same period, but no major deformations are evident at the site.

The diorite pluton that forms the bedrock of the Watana site was intruded into sediments and volcanics about 65 m.y.b.p. The andesite and basalt flows near the site have intruded the pluton. During the Tertiary period (20 to 40 m.y.b.p.) the area surrounding the sites was again uplifted by as much as 3000 feet (900 meters). Since then, widespread erosion has removed much of the older sedimentary and volcanic rocks. During the last several million years, at least two alpine glaciations have carved the Talkeetna Mountains into the ridges, peaks, and broad glacial plateaus seen today. Postglacial uplift has induced downcutting of streams and rivers, resulting in the deep, V-shaped canyons that are evident today, particularly at the Vee and Devil Canyon damsites. This erosion is believed to be still occurring, and virtually all streams and rivers in the region are considered to be actively downcutting. This continuing erosion has removed much of the glacial debris at high elevations, but very little alluvial deposition has occurred.

The resulting landscape consists of barren bedrock mountains, glacial till-covered plains, and exposed bedrock cliffs in canyons and along streams. Climatic conditions have retarded the development of topsoil. Soils are typical of those formed in cold, wet climates and have developed from glacial till and outwash. They include the acidic, saturated, peaty soils of poorly drained areas; the acidic, relatively infertile soils of the forests; and raw gravels and sands along the river. The upper basin is generally underlain by discontinuous permafrost.

1.2 - Susitna Basin

1.2.3 - Hydrology

The entire drainage area of the Susitna River is about 19,400 square miles (50,440 km^2), of which the basin above Gold Creek comprises approximately 6160 square miles (16,016 km^2) (Figures E.1.3 and E.1.4). Three glaciers in the Alaska Range feed forks of the Susitna River and flow southward for about 18 miles (29 km) before joining to form the mainstem of the Susitna River. The river flows an additional 55 miles (88 km) southward through a broad valley, where much of the coarse sediment from the glaciers settles out. The river then flows westward about 96 miles through a narrow valley with the constrictions in the Devil Creek and Devil Canyon areas creating violent rapids. Numerous small, steep-gradient, clear-water tributaries flow to the Susitna in this reach of the river. Several of these tributaries cascade over waterfalls as they enter the gorge. As the Susitna curves south past Gold Creek, 12 miles (19 km) downstream from Devil Canyon, its gradient gradually decreases. The river is joined about 40 miles (64 km) beyond Gold Creek in the vicinity of Talkeetna by two major rivers, the Chulitna and Talkeetna. From this confluence, the Susitna flows south through braided channels about 97 miles (155 km) until it empties into Cook Inlet near Anchorage, approximately 318 miles (509 km) from its source.

(a) Flows

The Susitna River is typical of unregulated northern glacial rivers with high, turbid summer flow and low, clear winter flow. Runoff from snowmelt and rainfall in the spring causes a rapid increase in flow in May from the low discharges experienced throughout the winter. Peak annual floods usually occur during this period. Approximately 80 percent of the annual flow occurs between May and September. At Gold Creek, average flows approach 6000 cubic feet per second (cfs) in October, the start of the water year. The flow rapidly decreases in November and December as the river freezes. Low flows of about 1000 cfs occur in March and April. At breakup, flows are over 13,000 cfs in May and peak at about 27,700 cfs in June. Flows gradually decrease to 24,000 cfs in July, 22,000 cfs in August, and 13,000 cfs in September.

Associated with the higher spring flows is a 100-fold increase in sediment transport which persists throughout the summer. The large, suspended sediment concentration in the June-to-September time period causes the river to be highly turbid. Glacial silt contributes most of the turbidity of the river when the glaciers begin to melt in late spring.

Rainfall-related floods often occur in August and early September, but generally these floods are not as severe as the spring snowmelt floods.

As the weather begins to cool in the fall, the glacial melt rate decreases and the flows in the river gradually decrease correspondingly. Because most of the river suspended sediment is caused by glacial melt, the river also begins to clear. Freeze up normally begins in October and continues to progress up river through early December. The river breakup generally begins in late April or early May near the mouth and progresses upstream with breakup at the damsite occurring in mid-May.

(b) Water Quality

The Susitna River is a fast-flowing, cold-water glacial stream of the calcium bicarbonate type containing soft to moderately hard water during breakup in summer, and moderately hard water in the winter. Nutrient concentrations (namely, nitrate and orthophosphate) exist in low-to-moderate concentrations. Dissolved oxygen concentrations typically remain high, averaging about 12 mg/l during the summer and 13 mg/l during winter. Percentage saturation of dissolved oxygen generally exceeds 80 percent and averages near 100 percent in the summer. Winter saturation levels decline slightly from the summer levels. Typically, pH values range between 7 and 8 and exhibit a wider range in the summer compared to the winter. During summer, pH occasionally drops below 7, which is attributed to organic acids in the tundra runoff. True color, also resulting from tundra runoff, displays a wider range during summer than winter. Values have been measured as high as 40 color units in the vicinity of the damsites. Temperature remains at or near 0°C during winter, and the summer maximum is 14°C. Alkalinity concentrations, with bicarbonate as the dominant anion, are low-to-moderate during summer and moderate-to-high during winter. The buffering capacity of the river is relatively low on occasion.

The concentrations of many trace elements monitored in the river were low or within the range characteristics of natural waters. However, the concentrations of some trace elements exceeded water quality guidelines for the protection of freshwater aquatic organisms. These concentrations are the result of natural processes because, with the exception of some placer mining activities, there are no man-induced sources of these elements in the Susitna River Basin.

Concentrations of organic pesticides and herbicides, uranium, and gross alpha radioactivity were either less than their respective detection limits or were below levels considered to be potentially harmful to aquatic organisms.

1.2 - Susitna Basin

1.2.4 - Climate

As in most of Alaska, winters are long, summers are short, and there is considerable variation in daylight between these seasons. Higher elevations in the upper basin are characterized by a continental climate typical of interior Alaska. The lower floodplain falls within a zone of transition between maritime and continental climatic influences. From the upper to the lower basin, the climate becomes progressively wetter, with increased cloudiness and more moderate temperatures.

At Talkeetna, which is representative of the lower basin, average annual precipitation is about 28 inches, of which 68 percent falls between May and October, and annual snowfall is about 106 inches. Monthly average temperatures range from 9°F (-13°C) in December and January to 58°F (14°C) in July.

1.2.5 - Vegetation

The Susitna Basin occurs within an ecoregion classified as the Alaska Range Province of the Subarctic Division. The major vegetation types in the upper basin are low mixed shrub, woodland and open black spruce, sedge-grass tundra, mat and cushion tundra, and birch shrub. These vegetation types are typical of vast areas of interior Alaska and northern Canada, where plants exhibit slow or stunted growth in response to cold, wet, and short growing seasons. Deciduous and mixed conifer-deciduous forests occur at lower elevations in the upper basin, primarily along the Susitna River, but comprise less than three percent of the upper basin area. These forest types have more robust growth characteristics than the vegetation types at higher elevations and are more comparable to vegetation types occurring on the floodplain farther downstream.

The floodplain of the lower river is characterized by mature and decadent balsam poplar forests, birch-spruce forest, alder thickets, and willow-balsam poplar shrub communities. The willow-balsam poplar shrub and alder communities are the earliest to establish on new gravel bars, followed by balsam poplar forests and, eventually, by birch-spruce forest.

Each of the transmission corridors crosses several vegetation types. The Healy-to-Fairbanks transmission corridor includes ridges, wetlands, and rolling hills with areas of open spruce forests, open deciduous forests, mixed forests, shrublands, and wet tundra. The Willow-to-Anchorage transmission corridor passes through closed birch forests, mixed conifer-deciduous forest, wet sedge grass marshes, and open and closed spruce stands. The Willow-to-Healy transmission corridor traverses a wide variety of vegetation types, from closed spruce-hardwood forests in the south to tundra and shrubland in the north.

1.2 - Susitna Basin

1.2.6 - Wildlife

Big game in the upper basin include caribou, moose, brown bear, black bear, wolf, and Dall sheep. Caribou migrate through much of the open country in the upper basin, and important calving grounds are present outside the impoundment zone. Moose are fairly common in the vicinity of the proposed project, but high quality habitat is rather limited. Moose also frequent the floodplain of the lower river, especially in winter. Brown bear occur throughout the project vicinity, while black bear are largely confined to the forested habitat along the river; populations of both species are healthy and productive. Several wolf packs have been noted using the area. Dall sheep generally inhabit areas higher than 3000 feet (910 meters) in elevation.

Furbearer species of the upper basin include red fox, wolverine, pine marten, mink, river otter, short-tailed weasel, least weasel, lynx, muskrat, and beaver. Beavers become increasingly more evident farther downstream. Sixteen species of small mammals that are characteristic of interior Alaska are known to occur in the upper basin.

Bird populations of the upper basin are typical of interior Alaska but sparse in comparison to those of more temperate regions. Generally, the forest and woodland habitats support higher densities of birds than do other habitats. In regional perspective, ponds and lakes in the vicinity of the proposed impoundments support relatively few waterbirds. Ravens and raptors, including bald and golden eagles, are conspicuous in the upper basin. Bald eagles also nest along the lower river. No known peregrine falcon nests exist in or near the reservoir area, although one nest exists near the northern leg of the transmission corridor. This nest has not been known to be active since the early 1960s.

1.2.7 - Fish

Fishery resources in the Susitna River comprise a major portion of the Cook Inlet commercial salmon harvest and provide sport fishing for Anchorage and the surrounding areas.

Anadromous fish in the Susitna basin include all five species of Pacific salmon: pink (humpback); chum (dog); coho (silver); sockeye (red); and chinook (king) salmon. The Susitna River is a migrational corridor, spawning area, and juvenile rearing area for the five species of salmon from its point of discharge into Cook Inlet to Devil Canyon, where salmon appear to be prevented from moving upstream by the water velocity at high flow. Spawning occurs primarily in the tributaries, sloughs, and side channels; limited spawning occurs in the mainstem. Preliminary data indicate that the majority of the 1981 Susitna River escapement of sockeye, pink, chum, and coho salmon spawned above the Yentna River confluence and below Curry Station. Data also show that sloughs between Devil Canyon and Talkeetna provide spawning habitat for pink, sockeye, and chum salmon. Field data show that juvenile chinook and coho salmon occur throughout the lower river, concentrating at slough and mainstem habitat during winter and at tributary mouths during summer.

Grayling abound in the clear-water tributaries of the upper basin; these populations are relatively unexploited. Grayling as well as lake trout also inhabit many lakes. The mainstem Susitna has populations of burbot and round whitefish, often associated with the mouths of clear-water tributaries. Dolly Varden, humpback whitefish, sculpin, sticklebacks, and long-nosed suckers have also been found in the drainage. Rainbow trout, like the anadromous species, have not been found above Devil Canyon.

1.2.8 - Land Use

Because of limited access, the project area in the upper basin has retained a wilderness character. There are no roads to the project vicinity, but there are several off-road vehicle and sled trails. Although rough, dirt landing strips for light planes are not uncommon, floatplanes provide the principal means of access via the many lakes in the upper basin.

Perhaps the most significant land use over the past three decades has been the study of hydropower potential of the Susitna River. The area is also used by hunters, white-water enthusiasts, fishermen, trappers, and miners. Raft float trips are taken from the Denali Highway on the Susitna or Tyone Rivers down to either Vee or Devil Canyons. Both guided and non-guided hunting occur within the project area, particularly near Stephan, Fog, Clarence, Watana, Deadman, Tsusena, and Big Lakes. A few wilderness recreation lodges and private cabins, single and in small clusters, are scattered throughout the basin, especially on the larger lakes.

Most of the lands in the project area and on the south side of the river have been selected by the Natives under the Alaska Native Claims Settlement Act. Lands to the north are generally federal and are managed by the Bureau of Land Management. The state has selected some lands on the north side of the river, and there are many small, scattered private holdings in the upper basin. The U.S. Department of the Interior has preserved part of the area within the project impoundment zones as a Power Site Classification (No. 443).

Mineral exploration and mining have been limited in the immediate project area. Mining in the upper Susitna River Basin has been low in claims density and characterized by intermittent activity since the 1930s.

1.2 - Susitna Basin

The transmission corridors outside the dam and impoundment areas (Willow to Anchorage and Healy to Fairbanks) traverse lands with a somewhat higher degree of use. Most of the land within the corridors, however, is undeveloped.

Wetlands cover large portions of the Upper Susitna River Basin, including riparian zones along the mainstem Susitna, sloughs and tributary streams, and numerous lakes and ponds on upland plateaus. In addition, extensive areas of wet sedge-grass tundra are classified as wetlands by the U.S. Army Corps of Engineers for purposes of Section 404 permitting. The U.S. Soil Conservation Service has determined that there are no prime farmlands, rangelands, or forests within the upper Susitna Basin.

1.2.9 - Recreation

The large diversity of landscapes and resources in south-central Alaska offer a wide variety of outdoor recreational opportunities. The region's largest and most popular attraction is the Denali National Park and Preserve. Adjacent to this park is Denali State Park, one of 53 state parks in the south-central region of Alaska. Other state parks in the vicinity include Nancy Lake State Park, 70 miles (112 km) from Anchorage, and Chugach State Park, 10 miles (16 km) east of Anchorage. All of the above parks offer facilities for hiking, camping, fishing, and picnicking. Other government land near the project area includes the Susitna Flats State Game Refuge and the Chugach National Forest.

North of the Susitna project site, the U.S. Bureau of Land Management maintains the 4.4-million-acre Denali Planning Block. The bureau maintains several small campgrounds and picnic areas, boat launches, and a canoe trail.

Numerous private facilities in the region provide additional formal and informal recreation opportunities. These include remote lodges, cabins, restaurants, airstrips, and flying and boat services.

GLOSSARY

Alluvial deposition - fine grained material left by rivers

Anadromous fish - fish that ascend freshwater rivers from the ocean in order to breed

Argillites - a compact rock derived from either mudstone or shale

Conifer - forest containing both evergreen trees (pine, spruce, etc.) and those that lose their leaves on an annual basis

Diorite plutons - igneous rocks formed at considerable depth intermediate in composition between acidic and basic rocks

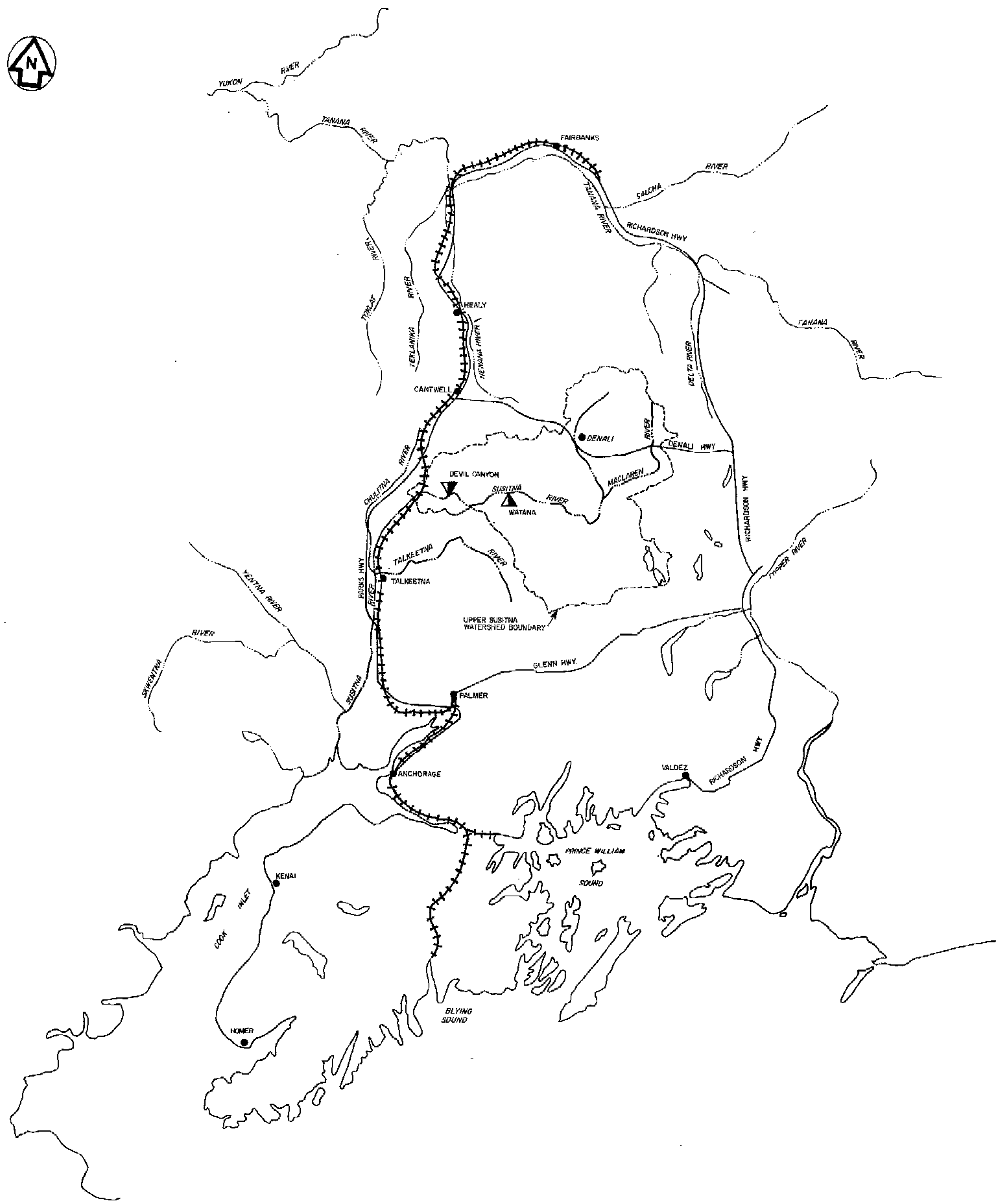
Escapement - the process by which adult anadromous fish migrate from the ocean to their freshwater spawning sites

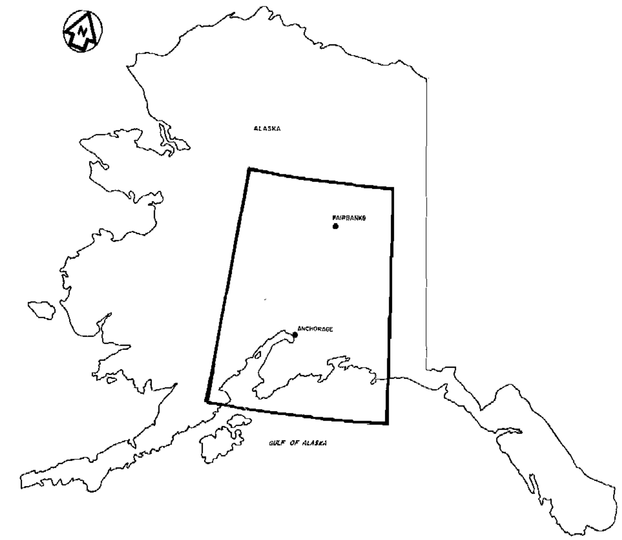
Igneous - formed by solidification from a molten or partially molten state

Phyllites - an argillaceous rock commonly formed by regional metamorphism and intermediate in grade between slate and mica schist

Schist - a medium or coarse-grained metamorphic rock with subparallel orientation of the mica material

Tectonic - pertaining to rock structure and external forms resulting from the deformation of the earth's crust





LOCATION MAP

LEGEND:

- PRIMARY PAVED UNDIVIDED HIGHWAY
- RAILROAD
- WATERWAY
- DAMSITES

SCALE 0 20 40 MILES

LOCATION OF THE PROPOSED SUSITNA HYDROELECTRIC PROJECT

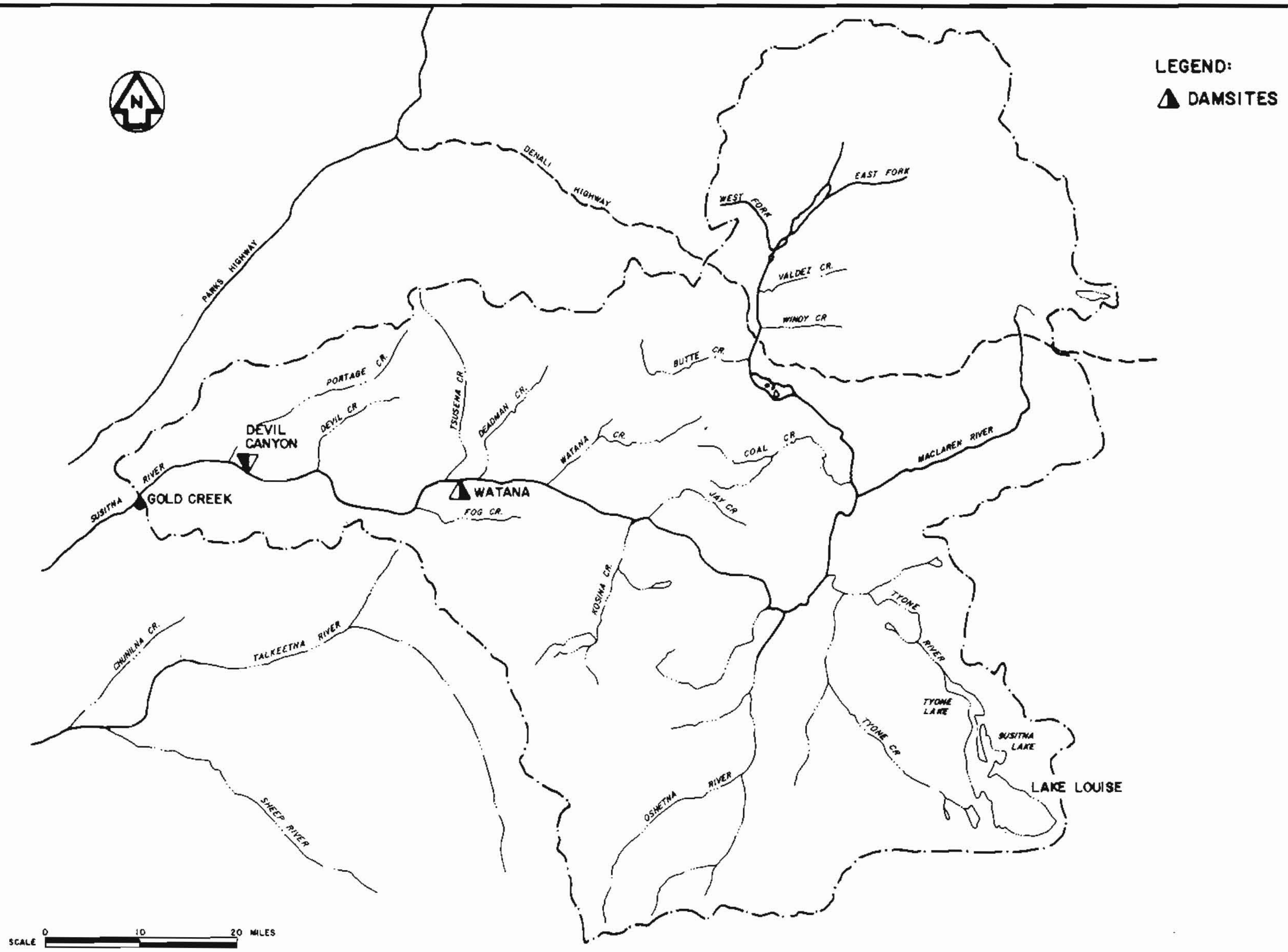
FIGURE E.1.1

WATANA, VIEW UPSTREAM

DEVIL CANYON, VIEW UPSTREAM

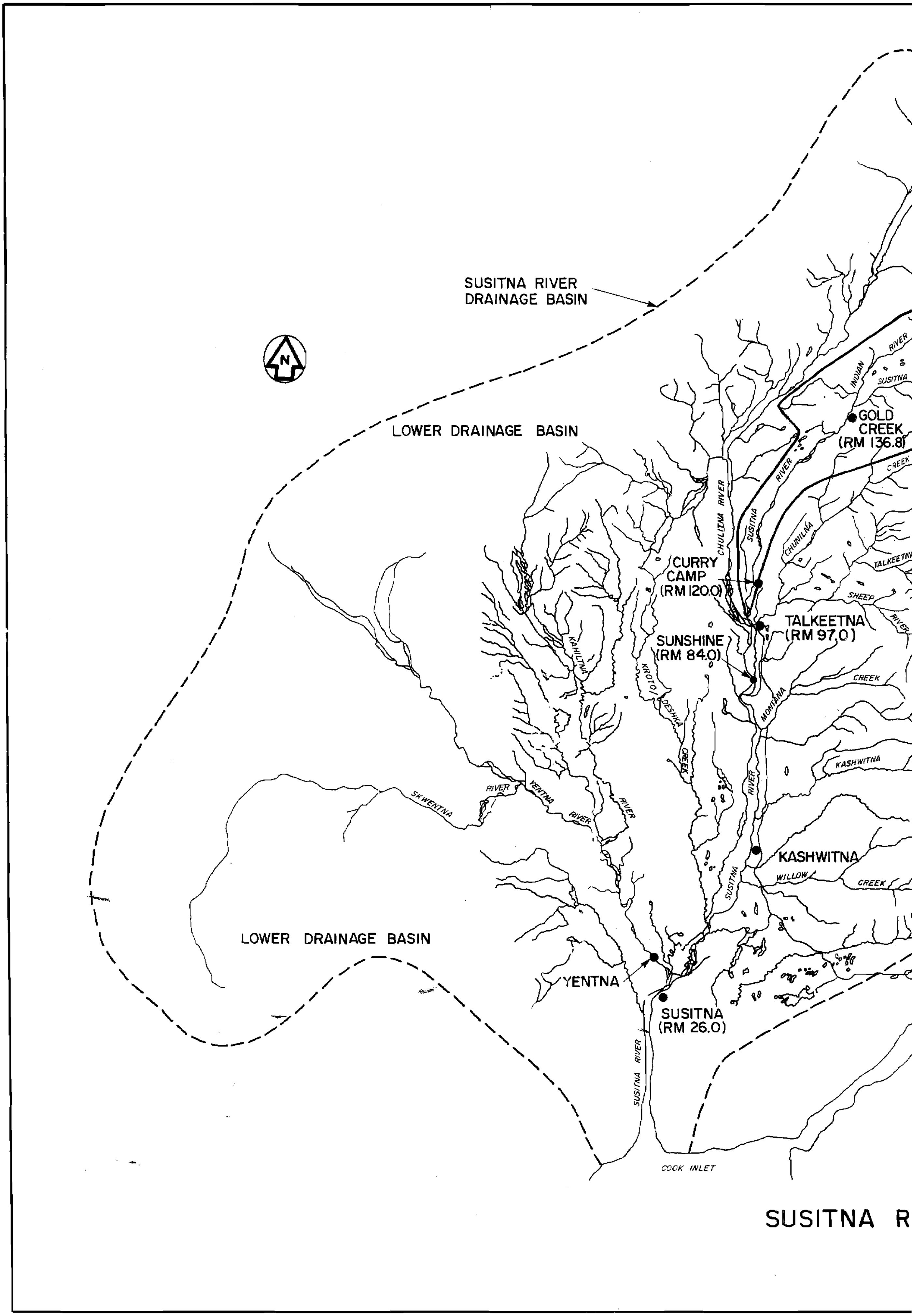
VICINITIES OF THE PROPOSED
DAM SITES, SUSITNA HYDROELECTRIC PROJECT

FIGURE E.1.2



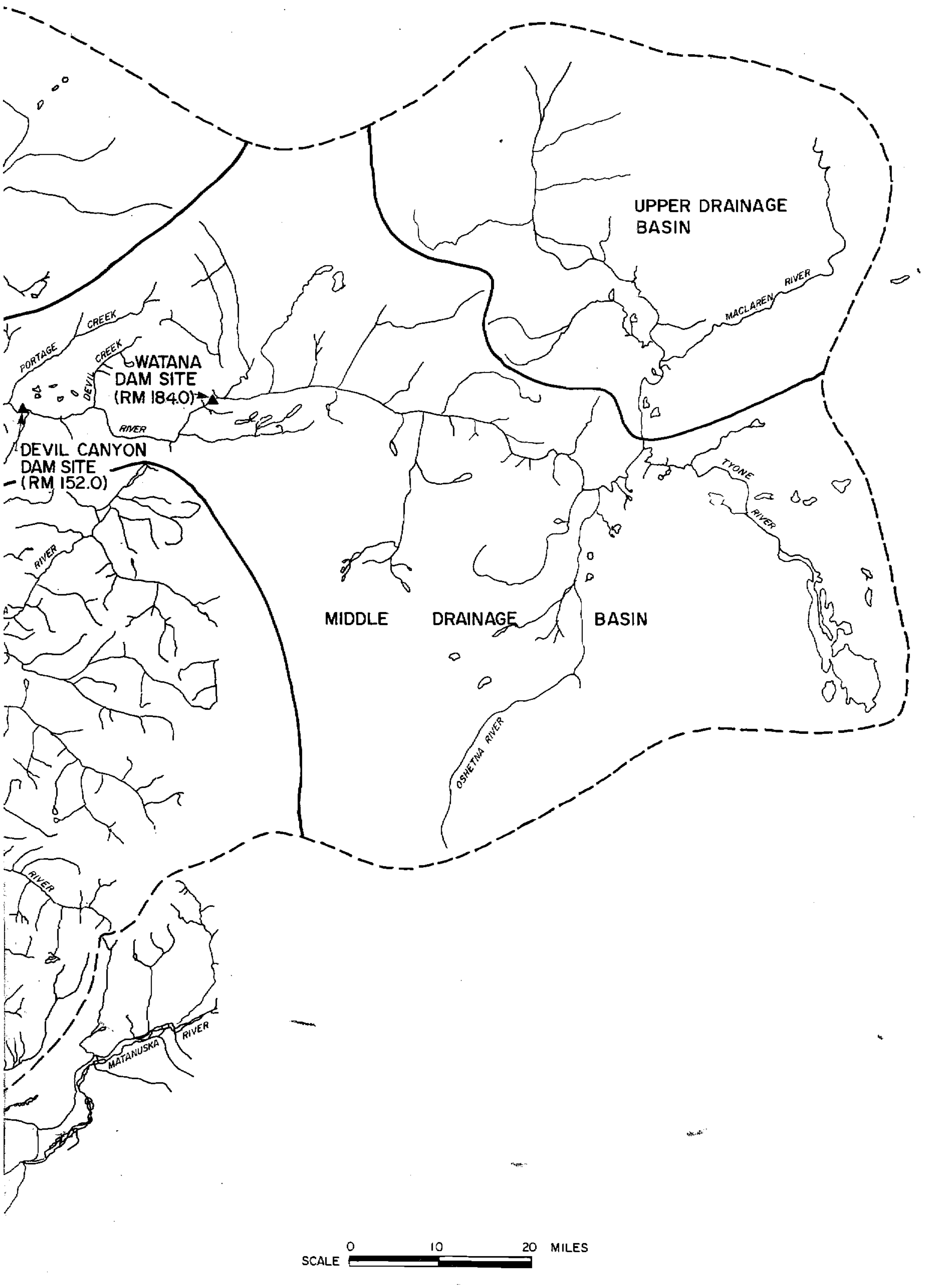
SUSITNA RIVER BASIN UPSTREAM OF GOLD CREEK

FIGURE E.1.3



SUSITNA RIVER
DRAINAGE BASIN
N
LOWER DRAINAGE BASIN
LOWER DRAINAGE BASIN
GOLD
CREEK
(RM 136.8)
CURRY
CAMP
(RM 120.0)
TALKEETNA
(RM 97.0)
SUNSHINE
(RM 84.0)
KASHWITNA
YENTNA
SUSITNA
(RM 26.0)
INDIAN
RIVER
SUSITNA
CREEK
RIVER
SUSITNA
CHULITNA RIVER
CHUNILNA
TALKEETNA
SHEEP
RIVER
CREEK
KAHILTNA
KROTO
DESHKA
CREEK
MONTANA
RIVER
KASHWITNA
SKWENTNA
RIVER
YENTNA
RIVER
RIVER
WILLOW
CREEK
SUSITNA
SUSITNA RIVER
COOK INLET

SUSITNA R



IVER DRAINAGE BASIN

FIGURE E 1.4

SUSITNA HYDROELECTRIC PROJECT
VOLUME 5A
EXHIBIT E CHAPTER 2
WATER USE AND QUALITY

SUSITNA HYDROELECTRIC PROJECT

VOLUME 5A

EXHIBIT E CHAPTER 2

WATER USE AND QUALITY

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PHOTOGRAPHS

1 - INTRODUCTION

The Report on Water Use and Quality is divided into six sections:

1 - Introduction;
2 - Baseline Conditions;
3 - Project Operation and Flow Selection;
4 - Project Impacts;
5 - Agency Concerns and Recommendations; and
6 - Mitigative, Enhancement, and Protective Measures.

Within the sections on baseline conditions and project impacts, emphasis is placed on river morphology, flows, water quality parameters, ground water conditions and instream flow uses. The importance of flows and instream flow uses cannot be overstressed. For this reason, mean flows, flood flows, low flows and flow variability are discussed in detail.

The primary focus of the water quality discussion is on those parameters determined most critical for the maintenance of habitat for fish populations and other aquatic organisms. Detailed discussions are presented on water temperature, ice, suspended sediments turbidity, dissolved oxygen, total dissolved gas supersaturation and nutrients. These parameters have previously been identified as areas of greatest concern.

Mainstem surface water-slough ground water interaction downstream from Devil Canyon is important to successful salmonid spawning in the sloughs and is discussed.

The primary instream flow uses of the Susitna are for fish, wildlife and riparian vegetation. Since these are discussed in Chapter 3, they are only briefly discussed in this Chapter. Other instream flow uses including navigation and transportation, recreation, waste assimilative capacity, and freshwater recruitment to Cook Inlet estuary are discussed. Since minimal out-of-river use is made of the water, limited discussions have been presented on this topic.

In the section on Project Operation and Flow Selection, the characteristics of the Watana and Devil Canyon reservoirs are described and the alternative operating flow scenarios are discussed. The rationale for the selected operational flow regime is presented.

Project impacts have been separated by development. Impacts associated with each development are presented in the following chronological order: construction, impoundment, and operation.

The agency concerns and recommendations that were received during the ongoing consultation process have been addressed. Section 5 of this chapter highlights the major concerns. Detailed responses to individual comments are addressed in Chapter 11 of Exhibit E.

1 - Introduction

The mitigation plans incorporate the engineering and construction measures necessary to minimize potential impacts, given the economic and engineering constraints.

2 - BASELINE DESCRIPTION

The entire drainage area of the Susitna River is about 19,400 square miles, of which the drainage area above Gold Creek comprises approximately 6160 square miles (Figure E.2.1). Three glaciers in the Alaska Range feed forks of the Susitna River, which flow southward for about 18 miles (30 km) and then join to form the Susitna River. The river flows an additional 55 miles (90 km) southward through a broad valley where much of the coarse sediment from the glaciers settles out. The river then flows westward about 96 miles (154 km) through a narrow valley, with constrictions at the Devil Creek and Devil Canyon areas creating violent rapids. Numerous small, steep gradient, clear-water tributaries flow into the Susitna in this reach of the river. Several of these tributaries cascade over waterfalls as they enter the gorge. As the Susitna curves south past Gold Creek, 13 miles (21 km) downstream from the mouth of Devil Canyon, its gradient gradually decreases. The river is joined about 40 miles (64 km) beyond Gold Creek in the vicinity of Talkeetna by two major tributaries, the Chulitna and Talkeetna Rivers. From this confluence, the Susitna flows south through braided channels for 97 miles (156 km) until it empties into Cook Inlet near Anchorage, approximately 318 miles (512 km) from its source.

For ease of discussion, the watershed has been divided into three drainage basins. The upper drainage basin extends from the glacial headwaters of the Susitna River to the confluence of the Tyone River. The middle basin extends downstream from this point to Talkeetna and contains the Watana and Devil Canyon damsites. The middle reach is where the major project-related impacts will occur. The lower basin is defined as the drainage basin from Talkeetna to Cook Inlet. The approximate boundaries of the three basins are shown in Figure E.2.1.

The Susitna River is typical of unregulated northern glacial rivers with high, turbid summer flow and low, clear winter flow. Runoff from snow melt and rainfall in the spring causes a rapid increase in flow in May from the low discharges experienced throughout the winter. Peak annual floods usually occur in June.

Associated with the higher spring flows is a 100 fold increase in sediment transport which persists throughout the summer. Between June and September, the large suspended sediment concentration causes the river to be highly turbid. Glacial silt, released by the glaciers when they begin to melt in late spring or re-entrained from the river banks by high flows, is responsible for much of the turbidity.

Rainfall-related floods often occur in August and early September, but generally these floods are not as severe as the spring (May-June) snowmelt floods.

As the weather begins to cool in the fall, the glacial melt rate decreases and the flow in the river correspondingly decreases. Because most of the suspended sediment is caused by glacial outwash, the river also begins to clear. Freezeup normally begins in October and continues through early December, progressing upstream from one natural lodgement point in the river to the next upstream lodgement point. Freezeup generally begins at the upper basin lodgement points first. The river breakup generally begins in late April or early May near the mouth, and progresses upstream with breakup at the damsites occurring in mid-May.

2.1 - Susitna River Morphology

2.1.1 - Mainstem

The Susitna River originates in the glaciers of the southern slopes of the central Alaskan Range, flowing 318 miles (512 km) from Susitna Glacier to the river's mouth at Cook Inlet. Throughout its course, the Susitna River is characterized by several reach types. These are defined and illustrated in Figures E.2.2 through E.2.5.

(a) Morphological Characteristics Upstream of Devil Canyon

The headwaters of the Susitna River and the major upper basin tributaries are characterized by broad, braided, gravel floodplains below the glaciers, with several melt-streams exiting from beneath the glaciers before they combine further downstream. The West Fork Susitna River joins the main river about 18 miles (29 km) below Susitna Glacier. Below the West Fork confluence, the Susitna River develops a split-channel configuration with numerous islands. The river is generally constrained by low bluffs for about 55 miles (89 km). The Maclaren River, a significant glacial tributary, and the non-glacial Tyone River, which drains Lake Louise and the swampy lowlands of the southeastern upper basin, both enter the Susitna River from the east.

Below the confluence with the Tyone River, the Susitna River flows west for 96 miles (154 km) through steep-walled canyons before reaching the mouth of Devil Canyon. The reach contains the Watana and Devil Canyon damsites at River Mile (RM) 184.4 and 151.6, respectively. River gradients are high, averaging nearly 14 feet per mile (4 m per km) in the 54 mile (87 km) reach upstream of the Watana damsite wherein the Watana reservoir will be located. Downstream from Watana to Devil Creek, the river gradient is approximately 10.4 feet per mile (3.2 m per km) as illustrated in the profile contained in Figure E.2.6. In the 12 mile (19 km) reach between Devil Creek and Devil Canyon, the river gradient averages 31 feet per mile (9.5 m per km).

This 96 mile-long (154 km) reach is primarily a single channel with intermittent islands. Cross sections presented in the Hydraulic and Ice Studies Report (R&M 1982b) illustrate the single channel configuration. Bed material mainly consists of large gravel cobbles. The mouth of Devil Canyon, at RM 149 forms the lower limit of this reach.

(b) Morphological Characteristics Downstream from Devil Canyon

Between Devil Canyon and the mouth at Cook Inlet, the river has been subdivided into nine separate reaches (R&M 1982d). These reaches are identified in Table E.2.1, together with the average slopes and predominant channel patterns. The thalweg profiles between Portage Creek and Talkeetna and between Sunshine and Cook Inlet are shown in Figures E.2.7, E.2.8, and E.2.9. Figure E.2.10 illustrates the cross section at RM 129.7 near Sherman. Additional cross section data are contained in the Hydraulic and Ice Studies Report (R&M 1982b). Aerial photographs of the Susitna River between Portage Creek and Talkeetna are presented in Figures E.2.11 through E.2.20. The nine reaches are discussed below.

(i) RM 149 to RM 144

Through this reach, the Susitna flows predominately in a single channel confined by valley walls. At locations where the valley bottom widens, deposition of gravel and cobble has formed mid-channel or side-channel bars. Occasionally, a vegetated island or fragmentary floodplain has formed with elevations above normal flood levels, and has become vegetated. Presence of cobbles and boulders in the bed material aids in stabilization of the channel geometry.

(ii) RM 144 to RM 139

A broadening of the valley bottom through this reach has allowed the river to develop a split channel with intermittent, well-vegetated islands. A correlation exists between bankfull stage and mean-annual flood. Where the main channel impinges on valley walls or terraces, a cobble armor layer has developed with a top elevation at roughly bankfull flood stage. At RM 144, a periglacial alluvial fan of coarse sediments confines the river to a single channel.

(iii) RM 139 to RM 129.5

This river reach is characterized by a well-defined split channel configuration. Vegetated islands separate the main channel from side channels. Side channels occur frequently in the alluvial floodplain and are inundated only at flows above 15,000 to 20,000 cfs. There is a good correlation between bankfull stage and the mean annual flood.

Where the main channel impinges valley walls or terraces, a cobble armor layer has developed with a top elevation at roughly bankfull flood stage. The main channel bed has been frequently observed to be well armored.

Primary tributaries include Indian River, Gold Creek and Fourth of July Creek. Each has formed an alluvial fan extending into the valley bottom, constricting the Susitna to a single channel. Each constriction has established a hydraulic control point that regulates water surface profiles and associated hydraulic parameters at varying discharges.

(iv) RM 129.5 to RM 119

River patterns through this reach are similar to those in the previous reach. Prominent characteristics between Sherman and Curry include the main channel flowing against the west valley wall and the east floodplain having several side channels and sloughs. The alluvial fan at Curry constricts the Susitna to a single channel and terminates the above patterns. A fair correlation exists between bankfull stage and mean annual flood through this reach. Comparison of 1950 and 1980 aerial photographs reveal occasional local changes in banklines and island morphology.

The west valley wall is generally nonerodible and has occasional bedrock outcrops. The resistant boundary on one side of the main channel has generally forced a uniform channel configuration with a well armored perimeter. The west valley wall is relatively straight and uniform except at RM 128 and 125.5. At these locations, bedrock outcrops deflect the main channel to the east side of the floodplain.

(v) RM 119 to RM 104

Through this reach the river is predominantly a very stable, single incised channel with a few islands. The channel banks are well armored with cobbles and boulders, as is the bed. Several large boulders occur intermittently along the main channel and are believed to have been transported down the valley during glacial ice movement. They provide local obstruction to flow and navigation, but do not have a significant impact on channel morphology.

(vi) RM 104 to RM 95

At the confluence of the Susitna, Chulitna and Talkeetna Rivers, there is a dramatic change in the Susitna from a split channel to a braided channel. Emergence from confined mountainous basins into the unconfined lowland basin has enabled the river systems to develop laterally. Ample bedload transport and a gradient decrease also assist in establishing the braided pattern.

The glacial tributaries of the Chulitna River are much closer to the confluence than the Susitna glacial tributaries. As the Chulitna River emerges from an incised canyon 20 miles (32 km) upstream of the confluence, the river transforms into a braided pattern with moderate vegetation growth on the intermediate gravel bars. At about a midpoint between the canyon and the confluence, the Chulitna exhibits a highly braided pattern with no vegetation on intermediate gravel bars, which is evidence of recent lateral instability. This pattern continues beyond the confluence, giving the impression that the Susitna is tributary to the dominant Chulitna River. The split channel Talkeetna River is a tributary to the dominant braided pattern.

Terraces generally bound the broad floodplain, but provide little control over channel morphology. General floodplain instability results from the three-river system striving to balance out the combined flow and sediment regime.

(vii) RM 95 to 61

Downstream from the three-river confluence, the Susitna continues its braided pattern, with multiple channels interlaced through a sparsely vegetated floodplain.

2.1 - Susitna River Morphology

The channel network consists of the main channel, usually one or two subchannels, and a number of minor channels. The main channel meanders irregularly through the wide gravel floodplain and intermittently flows against the vegetated floodplain. It has the ability to easily migrate laterally within the active gravel floodplain, as the main channel is simply reworking the gravel that the system previously deposited. When the main channel flows against vegetated bank lines, erosion is retarded due to the vegetation and/or bank materials that are more resistant to erosion. Flow in the main channel usually persists throughout the entire year.

Subchannels are usually positioned near or against the vegetated floodplain and are generally on the opposite side of the floodplain from the main channel. The subchannels normally bifurcate from the main channel when it crosses over to the opposite side of the floodplain and terminate where the main channel meanders back across the floodplain and intercepts them. The subchannels have smaller geometric dimensions than the main channel, and their thalweg is generally about 5 feet (1.5 m) higher. Their flow regime is dependent on the main channel stage and hydraulic flow controls the point of bifurcation. Flow may or may not persist throughout the year.

Minor channels are relatively shallow, wide channels that traverse the gravel floodplains and complete the interlaced braided pattern. These channels are very unstable and generally short-lived.

The main channel and subchannels are intermittently controlled laterally where they flow against terraces. Since the active floodplain is very wide, the presence of terraces has little significance except for determining the general orientation of the river system. An exception occurs where the terraces constrict the river to a single channel at the Parks Highway bridge. Minor channels react to both of the larger channels' behaviors.

(viii) RM 61 to RM 42

Downstream from the Kashwitna River confluence, the Susitna River branches into multiple channels separated by islands with established vegetation. This reach of the river is known as the Delta Islands because it resembles the distributary channel network common with large river deltas. The multiple channels are forced together by terraces just upstream of Kroto Creek (Deshka River).

Through this reach, the very broad floodplain and channel network can be divided into three categories:

- Western braided channels;
- Eastern split channels; and
- Intermediate meandering channels.

The western braided channel network is considered to be the main portion of this very complex river system. Although not substantiated by river surveys, it appears to constitute the largest flow area and lowest thalweg elevation. The reason for this is that the western braided channels constitute the shortest distance between the point of bifurcation to the confluence of the Delta Island channels. Therefore it has the steepest gradient and highest potential energy for conveyance of water and sediment.

(ix) RM 42 to RM 0

Downstream from the Delta Islands, the Susitna River gradient decreases as it approaches Cook Inlet (Figure E.2.9). The river tends toward a split channel configuration as it adjusts to the lower energy slope. There are short reaches where a tendency to braid emerges. Downstream of RM 20, the river branches out into delta distributary channels.

Terraces constrict the floodplain near the Kroto Creek confluence and at Susitna Station. Further downstream, the terraces have little or no influence on the river.

The Yentna River joins the Susitna at RM 28 and is a major contributor of flow and sediment.

Tides in Cook Inlet rise above 30 feet (9 m) and therefore control the water surface profile and to some degree the sediment regime of the lower river. A river elevation of 30 feet (9 m) exists near RM 20 which corresponds to the location where the Susitna begins to branch out into its delta channels.

2.1.2 - Sloughs

Sloughsare spring-fed, overflow channels that exist along the edge of the floodplain, separated from the river by well-vegetated bars. An exposed alluvial berm often separates the head of the sloughs from the mainstem or side-channel flow. The controlling streambank elevations at the upstream end of the sloughs are less than the mainstem water surface elevations during median and high flow periods. At intermediate and low flows, the sloughs convey clear water from small tributaries and upwelling ground water (ADF&G 1982a).

Differences between mainstem water surface elevations and the streambed elevation of the sloughs are notably greater at the upstream entrance to the sloughs than at the mouth of the sloughs. The gradients within the sloughs are typically greater than the adjacent mainstem because of their shorter path length from the upstream end to the downstream end, than along the mainstem. The upstream end of the sloughs generally has a higher gradient than the lower end. This is evidenced in Figure E.2.21, which illustrates the thalweg profile of a typical slough.

The sloughs vary in length from 2,000 to 6,000 feet (610 to 1829 m). Cross-sections of sloughs are typically rectangular with flat bottoms as illustrated in Figure E.2.22. At the head of the sloughs, substrates are dominated by boulders and cobbles [8 to 14 inch (20 to 36 cm) diameter]. Progressing downstream towards the slough mouth, substrate particles reduce in size with gravels and sands predominating (Figure E.2.21). Beavers frequently inhabit the sloughs. Active and abandoned dams are visible. Vegetation commonly covers the banks to the water's edge with bank cutting and slumping occurring during spring break-up flows and high summer flows.

The importance of the sloughs as salmon spawning habitat is discussed in detail in Chapter 3.

2.2 - Susitna River Water Quantity

2.2.1 - Mean Monthly and Annual Flows

Continuous historical streamflow records of various record length (7 to 32 years through water year (WY) 1981) exist for gaging stations on the Susitna River and its tributaries. USGS gages are located at Denali, Cantwell (Vee Canyon), Gold Creek and Susitna Station on the Susitna River; on the Maclaren River near Paxson; at Chulitna Station on the Chulitna River; at Talkeetna on the Talkeetna River; and at Skwentna on the Skwentna River.

2.2 - Susitna River Water Quantity

In 1980 a USGS gaging station was installed on the Yentna River and in 1981 a USGS gaging station was installed at Sunshine on the Susitna River. Statistics on river mile, drainage area and years of record are shown in Table E.2.2, and a summary of the maximum, mean and minimum monthly flows for the respective periods of record are shown in Table E.2.3. Because of the short duration of the stream flow records at Sunshine and on the Yentna, summaries for these two stations have not been included. The station locations are illustrated in Figure E.2.1.

With the exception of the Yentna station, complete 30 year streamflow data sets for each USGS stream gaging station illustrated in Table E.2.2, were generated through a correlation analysis, whereby missing mean monthly flows were estimated (Acres 1982b). The analysis was based on the program FILLIN developed by the Texas Water Development Board (1970). The procedure adopted is a multisite regression technique which analyzes monthly time series data and fills in missing portions in the incomplete records. The program evaluates statistical parameters which characterize the data set (i.e., seasonal means, seasonal standard deviations, lag-one auto-correlation coefficients and multi-site spatial correlation coefficients) and creates a filled-in data set in which these statistical parameters are preserved. For the analysis, all streamflow data up to September 1979 were used (30 years of data at Gold Creek). Recorded data for water years 1980 and 1981 have been subsequently added to provide 32 years of record. The resultant maximum, mean and minimum monthly and annual flows for the 32 years of record are presented in Table E.2.4.

Using an annual volume frequency analysis, the 1969 drought was determined to have a recurrence interval of approximately 1:1000 years, as illustrated in Figure E.2.23. This was considered too extreme an event for an energy simulation analysis and was modified accordingly to a once in 30 year event based on the long term average, monthly flow distribution. (For a more detailed discussion refer to Section 3.3 pre-project flows). A summary of the resulting 32-year modified hydrology for Gold Creek, Sunshine, and Susitna Station is presented in Table E.2.5.

Mean monthly flows at the Watana and Devil Canyon damsites were estimated using a linear drainage area-flow relationship between the Gold Creek and Cantwell (Vee Canyon) gage sites. The resultant maximum, mean, and minimum monthly and annual flows are also presented in Tables E.2.4 and E.2.5.

Monthly flows for each month of the 32-year modified record for Watana, Devil Canyon, Gold Creek, Sunshine and Susitna Station are presented in Tables E.2.6 through E.2.10.

2.2 - Susitna River Water Quantity

Comparison of mean annual flows in Table E.2.4 indicates that 39 percent of the streamflow at Gold Creek originates above the Denali and Maclaren gages. It is in this catchment that the glaciers which contribute to the flow at Gold Creek are located.

The Susitna River above Gold Creek contributes 19 percent of the mean annual flow measured at Susitna Station near Cook Inlet. The Chulitna, and Talkeetna Rivers contribute 20 and 10 percent of the mean annual Susitna Station flow respectively. The Yentna provides 40 percent of the flow, with the remaining 11 percent originating in miscellaneous tributaries.

The variation between summer mean monthly flows and winter mean monthly flows is greater than a 10 to 1 ratio at all stations. This large seasonal difference is due to the characteristics of a glacial river system. Glacial melt, snow melt, and rainfall provide the majority of the annual river flow during the summer. At Gold Creek, for example, 88 percent of the annual streamflow volume occurs during the months of May through September.

A comparison of the maximum and minimum monthly flows for May through September indicates a high flow variability at all stations from year to year.

(a) Effect of Glaciers on Mean Annual Flow

The glaciated portions of the Susitna River Basin above Gold Creek play a significant role in the hydrology of the area. Located on the southern slopes of the Alaska Range, the glaciated regions receive the greatest amount of snow and rainfall in the basin. During the summer months, these regions contribute significant amounts of snow and glacial melt. The glaciers, covering about 290 square miles (750 square kilometers), act as reservoirs that produce most of the water in the basin above Gold Creek during drought periods. The drainage area upstream of the Denali and Maclaren gages comprises 19.9 percent of the basin above Gold Creek, yet contributes 39 percent of the average annual flow at Gold Creek (47 percent of the flow at Watana). Stated another way, the area upstream of the Denali and Maclaren gages contributes 3.1 cubic feet per second (cfs) per square mile, and the area downstream to Gold Creek contributes 1.2 cfs per square mile. In the record drought year of 1969, the proportion of flow at Gold Creek contributed from upstream of the Denali and Maclaren gages increased to 53.4 percent.

There is strong evidence from East Fork Glacier, a small glacier of 13.6 square miles (35.2 square kilometers), that glacier wasting has contributed to the runoff at Gold Creek since 1949 (R&M 1982a; R&M 1981b). However, the magnitude of the runoff from glacier wasting has not been well documented. Potentially significant errors exist in the ice loss estimate at East Fork Glacier due to the lack of adequate survey control. Consequently, errors of 60 feet (18 m) may exist in the estimate of 163 feet (50 m) of surface altitude loss.

Extrapolation of results from East Fork Glacier to the other 275 square miles (712 square km) (or 95 percent) of the glaciers in the basin is speculative at best. Glaciers react differently to changes in climate. Gulkana Glacier, 43 miles (69 km) to the east of East Fork Glacier, wasted at a rate of 1.1 feet (0.3 m) per year from 1966 to 1977, compared to the estimated rate of 5.3 feet (1.6 m) per year from 1949 to 1980 for East Fork Glacier. In the Washington Cascades, North Klawatti Glacier lost about 27 feet (8 m) of ice between 1947 and 1961, while adjacent Klawatti Glacier gained 19 feet or 6 m (Meier 1966).

Even though there is evidence that the glaciers have been wasting since 1949, there is little data available to determine what the impact of wasting has been on the recorded flow at Gold Creek or what will occur in the future. Large glaciers, such as those in the Susitna Basin, take decades to attain equilibrium after a change in climate. The Susitna glaciers may have reached their most recent maximum extent during the "Little Ice Age" which occurred in the early 1800's and may still be responding to the change in climate since then (Harrison personal communication). If the estimated rate of glacier wasting of East Fork Glacier were also applied to Susitna and West Fork Glaciers, almost 36 percent of the recorded streamflow (990 cfs) at Denali and 22 percent (220 cfs) at Maclaren would have been from glacier melt. That is, 12.5 percent of the annual flow at Gold Creek and 15 percent of the annual flow at Watana would be from glacier wasting. These values should be considered as high estimates.

Using the above estimate of glacier wasting, the contribution in the drainage area upstream of the Denali and Maclaren gages would be 2.1 cfs per square mile without the contribution from glacier wasting.

It is difficult to predict future trends. If the glaciers were to stop wasting due to, perhaps, a climate change, there could be implications in hydrological changes throughout the basin. On the other hand, the wasting of the glaciers could easily continue over the life of the project. There is no way to judge whether wasting will continue into the future; hence, no mechanism presently exists for analyzing what will occur during the life of the project.

2.2.2 - Floods

The most common causes of floods in the Susitna River Basin are snow melt or a combination of snow melt and rainfall over a large area. This type of flood occurs between May and July with the majority occurring in June. Floods attributable to heavy rains have occurred in August and September. These floods are augmented by snow melt from higher elevations and glacial runoff.

Examples of flood hydrographs can be seen in the daily discharges for 1964, 1967, and 1970 for Cantwell, Watana, and Gold Creek which are illustrated in Figures E.2.24, E.2.25 and E.2.26. The daily flow at Watana has been approximated using the linear drainage area-flow relationship between Cantwell and Gold Creek that was used to determine Watana average monthly flows. Figure E.2.24 shows the largest snow melt flood on record at Gold Creek. The 1967 spring flood hydrograph shown in Figure E.2.25 has a daily peak equal to the mean annual daily flood peak. In addition, the summer daily flood peak of 76,000 cfs is the second largest flood peak at Gold Creek on record. Figure E.2.26 (WY 1970) illustrates a low flow spring flood hydrograph.

The maximum recorded instantaneous flood peaks for Denali, Cantwell, Gold Creek, and Maclaren, recorded by the USGS, are presented in Table E.2.11. Instantaneous peak flood frequency curves for individual stations are illustrated in Figures E.2.27 to E.2.33. Distribution statistics are presented in Table E.2.12 (R&M 1981f). In the majority of cases the three parameter log-normal distribution provides the best fit to the data. Consequently, the three parameter log-normal distribution has been selected to model peak flows due to its simple construction and adequacy in modeling the sample data parameters.

A regional flood frequency analysis was conducted using the recorded floods in the Susitna River and other Cook Inlet tributaries (R&M 1981f). The resulting dimensionless regional frequency curve is depicted in Figure E.2.34. A stepwise multiple linear regression computer program was used to relate the mean annual instantaneous peak flow to the physiographic and climatic characteristics of the drainage basins. The mean annual instantaneous peak flows for the Watana and Devil Canyon damsites were computed to be 40,800 cfs and 45,900 cfs respectively. The regional flood frequency curve was compared to the station frequency curve at Gold Creek (Table E.2.13). Because the Gold Creek single station frequency curve yielded more conservative flood peaks (i.e. larger), it was used to estimate flood peaks at the Watana and Devil Canyon damsites for floods other than the mean annual flood. The ratio of a particular recurrence interval flood at Gold Creek to the mean annual flood at Gold Creek was multiplied by the mean annual flood at Watana or Devil Canyon to obtain the flood for the given recurrence interval. For example, the ratio of the 1:10,000-year flood to mean annual flood at Gold Creek is 3.84. With the use of this factor, the 1:10,000-year floods at Watana and Devil Canyon were computed to be 157,000 cfs and 176,000 cfs respectively. The flood frequency curves for Watana and Devil Canyon are presented in Figures E.2.35 and E.2.36.

Dimensionless flood hydrographs for the Susitna River at Gold Creek were developed for the May - July snow melt floods and the August - October rainfall floods using the five largest Gold Creek floods occurring in each period (R&M 1981f). Flood hydrographs for the 100, 500, and 10,000 year flood events were constructed using the appropriate flood peak and the dimensionless hydrograph. Hydrographs for the May - July and August - October flood periods are illustrated in Figures E.2.37 and E.2.38 respectively.

Probable maximum flood (PMF) studies were conducted for both the Watana and Devil Canyon damsites for use in the design of project spillways and related facilities (Acres 1982b). The PMF floods were determined by using the SSARR watershed model developed by the Portland District, U.S. Army Corps of Engineers (1975) and are based on Susitna Basin climatic data and hydrology. The probable maximum precipitation was derived from a maximization study of historical storms. The studies indicate that the PMF peak at the Watana damsite is 326,000 cfs.

2.2.3 - Flow Variability

The variability of flow in a river system is important to all instream flow uses. To illustrate the variability of flow in the Susitna River, monthly and annual flow duration curves showing the proportion of time that the discharge equals or exceeds a given value were developed for the four mainstem Susitna River gaging stations (Denali, Cantwell, Gold Creek and Susitna Station) and three major tributaries (Maclaren, Chulitna, and Talkeetna Rivers) (R&M 1982f). These curves, based on mean daily flows, are illustrated in Figures E.2.39 through E.2.42.

The shape of the monthly and annual flow duration curves is similar for each of the stations and is indicative of flow from northern glacial rivers (R&M 1982f). Streamflow is low in the winter months, with little variation in flow and no unusual peaks. Ground water contributions are the primary source of the small but relatively constant winter flows. Flow begins to increase slightly in April as breakup approaches. Peak flows in May are an order of magnitude greater than in April. Flow in May also shows the greatest variation for any month, as low flows may continue into May before the high snow melt/breakup flows occur. June has the highest peaks and the highest median flow for the middle and upper basin stations. The months of July and August have relatively flat flow duration curves. This situation is indicative of rivers with strong base flow characteristics, as is the case on the Susitna with its contributions from snow and glacial melt during the summer. More variability of flow is evident in September and October as cooler weather becomes more prevalent accompanied by a decrease in glacial melt and hence discharge.

From the flow duration curve for Gold Creek (Figure E.2.39), it can be seen that flows at Gold Creek are less than 20,000 cfs from October through April. As a result of the spring breakup in May, flows of 20,000 cfs are exceeded 30 percent of the time. During June and July, the percent of time Gold Creek flows exceed 20,000 cfs increases to 80 percent. This percentage decreases to 65 percent in August and further decreases to only about 15 percent in September. On an annual basis, a flow of 20,000 cfs is exceeded 20 percent of the time.

The 1-day, 3-day, 7-day and 15-day high and the 1-day, 3-day, 7-day and 14-day low flow values were determined for each month of the year for the period of record at Gold Creek and from May through October for the periods of record at the Chulitna River near Talkeetna, the Talkeetna River near Talkeetna and the Susitna River at Susitna Station (R&M 1982f). The high and low flow values are presented for Gold Creek in the form of frequency curves in Figures E.2.43 through E.2.62. May exhibits substantial variability. Both low winter flows and high breakup flows usually occur during May and thus significant changes occur from year to year. June exhibits more variability than July. Flow variability increases again in the August through October period. Heavy rainstorms often occur in August, with 28 percent of the annual floods occurring in this month. Flow variability in the winter months is reduced considerably reflecting the low base flow.

The daily hydrographs for 1964, 1967, and 1970 shown in Figures E.2.24, E.2.25 and E.2.26 illustrate the daily variability of the Susitna River at Gold Creek and Cantwell. The years 1964, 1967, and 1970 represent wet, average and dry hydrological years on an annual flow basis.

2.2.4 - Water Levels

(a) Mainstem

Water surface elevations for various Watana discharges in the reach between Deadman Creek (RM 186.8) and Devil Creek (RM 162.1) are listed in Table E.2.14. The elevations were determined with the use of the HEC-2 computer program "Water Surface Profiles", developed by the U.S. Army Corps of Engineers. The water surface elevations at the discharge of 42,200 cfs would be similar to those of the mean annual flood of 40,800 cfs. The water levels for an 8100 cfs discharge, which is similar to the winter operational flow at Watana, are shown in Figure E.2.6.

The HEC-2 program was also used to predict water levels for the reach between Devil Canyon and Talkeetna. The water surface elevations are presented in Table E.2.15. The water levels presented for the Gold Creek flow of 52,000 cfs would be slightly higher than those associated with the mean annual flood of 49,500 cfs. Water levels for a flow of 13,400 cfs at Gold Creek, which is similar to the project operational flow at Gold Creek during August and early September, are illustrated in Figures E.2.7 and E.2.8.

In addition to the water levels presented in Table E.2.15 for the selected flow cases, the HEC-2 program was used to determine water levels for the 1:100 year flood and the PMF in the reach between Devil Canyon and Talkeetna. The 1:100 year flood plain boundary is illustrated in Figures E.2.12 through E.2.20. The water surface profile associated with the 1:100-year flood and the PMF water surface profile are presented in Figures E.2.7 and E.2.8.

With the use of the data in Table E.2.15 and the corresponding thalweg elevations, water depths were determined at the river cross section locations in the Devil Canyon to Talkeetna reach. This information is shown in Figures E.2.63 and E.2.64.

(b) Sloughs

The water surface elevation of the mainstem generally causes a backwater effect at the mouth of the sloughs[1/]. The backwater effects in slough 9, resulting from several mainstem Susitna discharges is shown in Figure E.2.65. The backwater profiles were determined using the stage-discharge relationship shown in Figure E.2.66 and the HEC-2 program. The stage-discharge curve was obtained from 1982 field data.

[1/] The relationships between mainstem flows and hydraulic characteristics of three sloughs upstream of Talkeetna and one slough down stream of Talkeetna are presented in Appendix E.2.A to Chapter 2 of Exhibit E.

Upstream of the backwater effects, the sloughs function like small stream systems conveying water from local runoff and ground water upwelling during low flow periods and mainstem water during high flow periods when the upstream end of the slough is overtopped by the mainstem flow.

2.3 - Susitna River Water Quality

As previously described in Section 2, the Susitna River is characterized by large seasonal fluctuations in discharge. These flow variations, along with the glacial origins of the river, essentially dictate the water quality of the river.

Water quality data collected by the U.S. Geological Survey (USGS) and R&M Consultants (R&M), have been compiled for the mainstem Susitna River from monitoring stations located at Denali, Cantwell (Vee Canyon), Gold Creek, Sunshine, and Susitna Station. In addition, data from the tributary Chulitna and Talkeetna Rivers, have also been compiled. Water quality monitoring station information is presented in Table E.2.2. Locations of the respective stations are depicted in Figure E.2.1.

Water quality data were compiled according to season: breakup, summer and winter. Breakup is usually short and extends from the time ice begins to move down river until the recession of spring runoff. However, it was often difficult to assess the termination of spring runoff so for the purpose of this report, breakup water quality data were considered to be data collected during the month of May. The summer data period was considered to extend from the end of breakup (June 1) until the water temperature dropped to essentially 0°C (32°F). Winter data were compiled from the end of summer to the beginning of breakup (May 1). In the event that no water temperature data were available to delineate the termination of summer and the onset of the winter period, October 15 was utilized as the cutoff. The water quality parameters measured, and the respective detection limits of the methods used to analyze the samples, are provided in Table E.2.16. Water quality was evaluated using criteria and guidelines set forth in the following references:

- ADEC. 1979. Water Quality Standards. Alaska Department of Environmental Conservation, Juneau, Alaska.

- EPA. 1976. Quality Criteria for Water. U.S. Environmental Protection Agency, Washington, D.C.

- McNeely, R.N., V.P. Neimanism and K. Dwyer. 1979. Water Quality Sourcebook--A Guide to Water Quality Parameters. Environment Canada, Inland Waters Directorate, Water Quality Branch Ottawa, Canada.

2.3 - Susitna River Water Quality

- Sittig, M. 1981. Handbook of Toxic and Hazardous Chemicals. Noyes Publications, Park Ridge, New Jersey.

- EPA. 1980. Water Quality Criteria Documents: Availability. Environmental Protection Agency, Federal Register, 45, 79318-79379.

The criteria used for each parameter were chosen based on a priority system. The Alaska Department of Environmental Consideration's Water Quality Standards (1979) were the first choice, followed by criteria presented in EPA's Quality Criteria for Water (1976). If a criterion expressed as a specific concentration was not presented in either of these references, the other references were used.

A second priority system was necessary for selecting the criteria used for each parameter. This was required because the various references cite levels of parameters that provide for the protection of water quality for specific uses, such as (1) the propagation of fish and other aquatic organisms; (2) water supply for drinking and food preparation, (3) industrial processes and/or agriculture; and (4) water recreation. Given the limited direct human use of the river, the first priority was to present the criteria that apply to the protection of freshwater aquatic organisms. The second priority was to present levels of parameters that are acceptable for water supply and the third priority was to present other guidelines if available. Criteria and guideline values are provided in Table E.2.16 and in each of the individual water quality data summary figures to be discussed later in this document.

Although the Susitna River is a pristine area, 22 parameters exceeded their respective criteria. These parameters, the location and the season during which the criteria were exceeded, and the respective source of the criteria limits, are identified in Table E.2.17. In addition, reasons for establishment of the criteria levels are provided in the individual water quality data summary figures.

Note that water quality standards apply to man-induced alterations and constitute the degree of degradation which may not be exceeded. Because there are no industries except for placer mining operations, no significant agricultural areas, and no major cities adjacent to the Susitna, Talkeetna, and Chulitna Rivers, the measured levels of these parameters are considered to be natural conditions. In addition, the Susitna River basin supports diverse populations of fish and other aquatic life. Consequently, it was concluded that the parameters exceeding their criteria probably do not have significant adverse effects on aquatic organisms. As such, limited additional discussions will be given to criteria exceedance.

2.3 - Susitna River Water Quality

In the following sections, breakup data will generally not be discussed since the limited amount of data available normally indicate transition values between winter and summer extremes. Breakup data are provided in the water quality data summary figures. When available, summer and winter data are briefly highlighted at one monitoring station in each of the three Susitna River reaches (i.e., upper, middle, and lower). Typically the three monitoring stations discussed are Denali, Gold Creek, and Susitna Station. Levels of water quality parameters discussed in the following sections are extracted from updated information in R&M (1982g) unless otherwise noted.

2.3.1 - Water Temperature

(a) Mainstem

Generally during winter (October through April), the entire mainstem Susitna River is at or near 0°C (32°F). However, there are a number of small discontinuous areas with ground water inflow at a temperature of approximately 2°C (35.6°F). As spring breakup occurs the water temperature begins to rise, with the downstream reaches of the river warming first.

During summer (June through September), glacial melt is near 0°C (32°F), when it leaves the glaciers, but as it flows across the wide gravel floodplains downstream from the glaciers, the water begins to warm. As the water winds its way downstream to the Watana damsite, temperatures are as high as 14°C (57.2°F). Further downstream there is additional warming but, temperatures are cooler at some locations due to the effect of tributary inflow. Maximum recorded temperatures at Gold Creek and Susitna Station are 15°C (59°F) and 16.5°C (61.7°F), respectively. In August, temperatures begin to drop, reaching 0°C (32°F), in late September or October.

The seasonal temperature variation on a daily average basis for the Susitna River at Denali and Vee Canyon during 1980, and for Denali and Watana during 1981 are displayed in Figures E.2.67 and E.2.68. Weekly averages for Watana during 1981 are shown in Figure E.2.69. The shaded area in this figure is indicative of the range of temperatures measured on a mean daily basis. The temperature variations for eight summer days at Denali, Vee Canyon and Susitna Station are compared in Figure E.2.70.

The recorded variations in water temperatures at seven USGS gaging stations are displayed in Figure E.2.71. The data in this figure represent discrete measurements recorded by the

USGS and thus, do not reflect the continuously recording thermographs located at Denali, Vee Canyon, Gold Creek, Chulitna or Sunshine. Because of the influence of the Gold Creek tributary inflow on the location of the Gold Creek thermograph prior to 1982, and since all seven stations did not have continuous recording equipment, the USGS discrete measurements were used to provide both accuracy and consistency in this figure.

Additional data on water temperature are available in the annual reports of the USGS (Surface Water Records for Alaska; Water Resources Data for Alaska), the Alaska Department of Fish and Game (ADF&G), Susitna Hydroelectric Project data reports (Aquatic Habitat and Instream Flow Project - 1981, and Aquatic Studies Program - 1982a), and in R&M Consultants reports (Water Quality Annual Reports - 1981h, 1981i).

(b) Sloughs

The sloughs downstream of Devil Canyon have a temperature regime that differs from the mainstem. During the winter of 1982, intergravel and surface water temperatures were measured in sloughs 8A, 9, 11, 19, 20 and 21, the locations of which are illustrated in Figure E.2.72. The measurements indicated that intergravel temperatures were relatively constant at each location through February and March but exhibited some variability from one location to another. At most stations intergravel temperatures were within the 2-3°C (35.6-37.4°F) range. Slough surface temperatures showed more variability at each location and were generally lower than intergravel temperatures during February and March (Trihey 1982c).

During the spring and summer periods of high flow, when the heads of most sloughs are overtopped, slough water temperatures correspond closely to mainstem temperatures. However, when flow at the heads of the sloughs is cut off, spring and summer slough temperatures tend to differ from mainstem temperatures.

Figure E.2.73 compares weekly diel surface water temperature variations during September, 1981 in Slough 21 with the mainstem Susitna River at Portage Creek (ADF&G 1982a). The slough temperatures show a marked diurnal variation caused by increased solar warming of the shallow slough water during the day and subsequent long wave back radiation at night. Thermograph measurements taken in slough 21 during the summer of 1981 illustrated a diurnal temperature fluctuation ranging from 4.5 - 8.5°C (40.1-47.3°F) at the water surface with a constant intergravel water temperature of 3°C (37.4°F). Mainstem water temperatures are more constant because of the buffering capability offered by the large volume of the river and the extensive mixing that occurs.

(c) Tributaries

The tributaries to the Susitna River generally exhibit cooler water temperatures than does the mainstem. Continuous water temperatures have been monitored by both the USGS and ADF&G in the Chulitna and Talkeetna Rivers near Talkeetna, and by ADF&G in Portage, Tsusena, Watana, Kosina, and Goose Creeks, and the Indian and Oshetna Rivers.

The 1982 mean daily temperature records for Indian River and Portage Creek are compared in Figure E.2.74 (ADF&G 1982c). Portage Creek was consistently cooler than Indian River by 0.7 to 1.9°C (1.3-3.4°F). The flatter terrain in the lower reaches of the Indian River valley is apparently more conducive to solar and convective heating than the steep-walled canyon of Portage Creek. Figure E.2.74 also presents water temperature data from the mainstem Susitna for the same period, showing the consistently warmer temperatures in the mainstem. There are noticeable diurnal fluctuations in the tributary temperatures, though not as extreme as in the sloughs.

The major tributaries joining the Susitna at Talkeetna show uniform variation in temperature from the mainstem as illustrated in Figure E.2.75. Compared to the Susitna River, the Talkeetna River temperature is 1-3°C (1.8-5.4°F) cooler on an average daily basis. The Chulitna River, being closer to its glacial headwaters, is from 0 to 2°C (0 to 3.6°F) cooler than the Talkeetna River, and has less diurnal fluctuation.

Winter stream temperatures are usually very close to 0°C (32°F), as all the tributaries become ice covered. Ground water inflow at some locations creates local conditions above freezing, but the overall temperature regime is dominated by the extremely cold ambient air temperatures.

2.3.2 - Ice

(a) Freezeup

Air temperatures in the Susitna basin increase from the headwaters to the lower reaches. While this temperature gradient is partially due to the two-degree latitudinal span of the river, for the most part it is due to the 3,300-foot (1000-m) elevation difference between the lower and upper basins, and the climate-moderating effect of Cook Inlet on the lower river reaches. The gradient results in a period (late October - early November) during which the air temperatures in the lower basin are above freezing, while upper basin temperatures are subfreezing.

Frazil ice (Photograph E.2.1) forms in the upper segment of the river first in October, due to the initial cold temperatures of glacial melt and the earlier cold ambient air temperatures. Additional frazil ice is generated in the fast-flowing rapids between Vee Canyon and Devil Canyon. The frazil ice generation normally continues for a period of 3-5 weeks before a solid ice cover forms in the river downstream of Devil Canyon.

The frazil-ice pans and floes jam at natural lodgement points, which usually are constrictions with low velocity. One such lodgement point is illustrated in Photograph E.2.2. Border ice formation along the river banks also serves to restrict the channel to allow the ice cover closures, or bridgings to form.

From the natural lodgement points, the ice cover progresses in an upstream direction as additional ice is supplied from further upriver. However, before the ice cover can progress upstream, a leading edge stability criterion must first be satisfied. This translates to a velocity at the upstream end of the ice front that is sufficiently low to allow the flowing ice to affix itself to the ice front, causing an upstream progression of the ice front. If the velocities upstream of the ice front are too high (i.e. leading edge stability criterion not satisfied), the ice flowing downstream will be pulled underneath the ice front and deposited downstream on the under side of the established cover. In reaches where the velocity permits ice deposition, a thickening of the ice cover will occur. The thickening ice cover constricts the flow downstream of the ice front by increasing the resistance and thus creating a backwater effect. The velocity upstream of the ice front is thereby reduced until the leading edge stability criterion is satisfied. Experience has shown that in the thickening process, the maximum velocity attained underneath the ice deposits is about three feet per second.

During freezeup, the upstream progression of the ice front on the Susitna River often raises water levels by 2 to 4 feet (0.6 to 1.2 m), but higher stages have also been observed. Figure E.2.76 illustrates the open water rating curve for cross section 9 at RM 103.2 and the observed increase in stage as the ice front progressed upstream of this location in December 1980. Once the ice cover has consolidated, the rating curve will be approximately parallel with the open water discharge as indicated by the hypothetical ice cover rating curve. However, the water level increase in a particular reach of the river is dependent upon the prevailing discharge at which the ice cover was formed in that reach.

The variability in discharge at freezeup, and hence water level increase, coupled with the varying berm elevations at the upstream ends of sloughs results in some sloughs being overtopped during freezeup, other sloughs occasionally being overtopped, and still others not being overtopped. For example, Photograph E.2.3 shows the flow through slough 9 during the 1982 freezeup and photographs E.2.4 through E.2.8 illustrate the increased water level and flow through slough 8A during the same freezeup. It is estimated that slough 8A was overtopped with a discharge of 150 cfs.

The Susitna River is the primary contributor of ice to the river system below Talkeetna, contributing 70-80 percent of the ice load in the Susitna-Chulitna-Talkeetna Rivers (R&M 1982d). Ice formation on the Chulitna and Talkeetna Rivers normally commences several weeks after freezeup on the middle and upper Susitna River.

(b) Winter Ice Conditions

Once the solid ice cover forms, open leads still occur in areas of high-velocity or ground water upwelling. These leads shrink during cold weather and are the last areas in the main channel to be completely covered by ice. Ice thickness increases throughout the winter. The ice cover averages over 4 feet (1.2 m) thick by breakup (R&M 1982d), but thicknesses of over 10 feet (3 m) have been recorded near Vee Canyon.

Some of the side-channels and sloughs above Talkeetna have open leads during winter due to ground water upwelling. Table E.2.18 is a preliminary compilation of open leads that were observed during mid-winter 1982, (Trihey personal communication 1982). They are illustrated in Figures E.2.12 through E.2.20. All open leads identified in Table E.2.18 are believed to be thermally induced from ground water upwelling. Winter ground water temperatures, generally varying between 2°C and 4°C (35.6 and 39.2°F), contribute enough heat to prevent the ice cover from forming (Trihey 1982a). These areas are often salmonid egg incubation areas.

(c) Breakup

The onset of warmer air temperatures occurs in the lower basin several weeks earlier than in the middle and upper basins due to the temperature gradient previously noted. The low-elevation snowpack melts first, causing the river discharge to increase. The rising water level puts pressure on the ice, causing fractures to develop in the ice cover. The severity of breakup is dependent on the snow melt rate, the depth of the snowpack and the amount of rainfall, if it occurs. A light snowpack and warm spring temperatures result in a gradual increase in river discharge. During these conditions, strong forces on the ice cover do not occur to initiate ice movement, resulting in a mild breakup as occurred in 1981 (R&M 1981e). Conversely, a heavy snowpack and cool air temperatures into late spring, followed by a sudden increase in air temperatures may result in a rapid rise in water level. The rapid water level increase initiates ice movement and when coupled with ice left in a strong condition due to the cooler early spring temperatures, can lead to numerous and possibly severe ice jams which may result in flooding and erosion, as occurred in 1982 (R&M 1982h). Local velocities during severe ice jams may reach 10 fps.

These breakup floods result in high flows through the sidechannels and sloughs in the reach above Talkeetna. The flooding and erosion during breakup are believed to be the primary factors influencing river morphology in the reach between Devil Canyon and Talkeetna (R&M 1982d). The following is an excerpt from the Winter 1981-82, Ice Observations Report (R&M 1982h). "By May 7 even minimum daily temperatures averaged 4°C (39.2°F) and ice movement began. Jams occurred in most of the areas described in 1981 but with greater consequences, ranging from scarring and denuding of vegetation to flooding and washing away railroad ties from under the tracks. In several areas below Talkeetna, massive amounts of soil were removed from cutbacks, jeopardizing at least one residence."

2.3.3 - Bedload and Suspended Sediments

(a) Bedload

Bedload data were collected in 1981 and 1982 in the Susitna, Chulitna, and Talkeetna Rivers by the USGS. Data were collected monthly in 1981 during July, August, and September and weekly for June-August 1982 with two samples in

September. The 1981 data, presented in Table E.2.19, indicates that the Chulitna River is the primary contributor of bedload at the confluence. Preliminary results from 1982 bedload measurements confirm this. Susitna River bedload above the confluence was about 80,000 tons (72,730 tonnes) during 1982, whereas bedload in the Chulitna River was 1,200,000 tons (1,090,900 tonnes). That is, the Chulitna River has an estimated bedload volume 15 times greater than the Susitna River near the confluence.

Gravel-bed streams such as the Susitna River are essentially inactive most of the time (Parker 1980). The surface bed material must be moved in order for the bed to be mobilized. Parker indicates that the conditions necessary for mobilization of a gravel bed typically occur for only several days or weeks during the year associated with the high flow periods. The gravel pavement is maintained between transport events.

The stability of a particle resting on the bed or channel bank is a function of stream velocity, depth of flow, the angle of inclined surface on which it rests and its geometric and sedimentation characteristics (Stevens and Simons 1971). However, the interaction of the above factors is quite complex, and obtaining data for all parameters is often impractical under natural conditions. In order to determine at what flow rates the various reaches of the Susitna River above Talkeetna would be stable, an engineering approach to the design of stable alluvial channels was used.

Two major variables affecting channel stability are velocity and shear stress. Determining the shear stress is quite difficult. Consequently, velocity is often used as the most important factor in assessing stable alluvial channels. Various techniques have been developed which estimate the maximum channel velocity so that no scouring occurs for values of velocity equal to or less than the maximum velocity. However, the maximum permissible velocity varies with the sediment carrying characteristics of the channel. Fortier and Scobey (1926) recognized this problem, and introduced an increase in their listed values of maximum permissible velocities when water was transporting colloidal silt.

Various engineering formulas for maximum permissible velocity were presented by Simons and Senturk (1977). The formula selected for analysis was that derived by Neill (1967). Neill's formula uses data readily available for the Susitna River, and gives results in the same range as Fortier and Scobey's. The formula as presented by Neill is:

$$\frac{U^2}{\rho s/\rho - gD} = 2.5 \left[\frac{D}{d}\right]^{-0.20}$$

Where:

U = maximum permissible velocity, ft/sec
ρ = density of water, lb/ft^3
ρs = density of sediment, lb/ft^3 (assumed to be 165 lb/ft^3)
g = gravitational constant, 32 ft/sec^2
D = bed material diameter, ft
d = average depth of flow, ft

The above stability criterion was developed for use on uniform bed material or on the median (D_{50}) size in mixed bed material with moderate size dispersion. Neill (1968) later indicated that the bed material mixture remained fairly stable until the D_{50} size became mobile, at which time general movement of the bed would occur. The stability criteria was designed to use vertically-averaged local velocities (mean column velocities), thus identifying bed stability on only a short segment of the river cross-sectional width. However, only average velocity at each cross section is available for the Susitna River. The results from the equation would thus indicate when bed movement across the entire cross-section is imminent. Bedload normally does not move uniformly across the width of a river, but is concentrated in a relatively narrow band. Therefore, the results of this analysis are not strictly accurate, but do provide an adequate indicator of bed movement occurrence.

In order to estimate the D_{50} size of bed material which would be at the point of movement at a particular cross section for a given flow rate, the above formula was rearranged so that bed material diameter was the unknown value. The average velocity and average depth were obtained from runs of the HEC-2 model for different flow rates. The formula in its rearranged version is:

$$D = \frac{U^{2.5}}{465.43d^{0.25}}$$

Using the above formula and hydraulic parameters obtained from runs of HEC-2, estimates were made of the median material size at the point of movement for flow rates of 9,700; 17,000; 34,500; and 52,000 cfs. The median bed material size at the point of movement for selected cross sections is described in Figure E.2.77. Additional information on bed material movement can be found in the River Morphology Report (R&M 1982d). Included in Figure E.2.77 are the bed material size distribution in the reach described. To assist in classifying the size range of sediment which is being moved, a sediment grade scale is included in the bed movement figure.

By comparing the bed material movement curves to the bed material size distribution, predictions can be made of the effect of reducing the streamflow, i.e., reducing the mean annual flood at Gold Creek. Once the median bed material size is moved, general movement of the bed would occur. In general, bed material size ranges from coarse gravel to cobble throughout most of the river. Some movement of the median bed material size (from the grid samples) could occur above 35,000 cfs throughout much of the river, although these samples were primarily taken along the upper shore. It is believed that an armor layer consisting of cobbles and boulders exists throughout most of the river (R&M 1982d).

(b) Suspended Sediments

The Susitna River and many of its major tributaries are glacial rivers which experience extreme fluctuations in suspended sediment concentrations as the result of both glacial melt and runoff from rainfall or snow melt. The West Fork, Susitna, East Fork, and Maclaren Glaciers are the primary sources of suspended sediment in the river.

Commencing with spring breakup, suspended sediment concentrations begin to rise from their average winter levels of approximately 10 mg/l. During the summer, values as high as 5690 mg/l have been recorded at Denali, the gaging station nearest the glacially-fed headwaters. In the reach downstream from the mouth of the Maclaren River to the Chulitna River, there are no significant glacial sediment sources. Hence, concentrations decrease due to both the settling of the coarser sediments and dilution by the inflow from several clear-water tributaries. However, at high flows when erosion is more prevalent, the tributaries can become significant suspended sediment contributors. Maximum summer concentrations of 2620 mg/l have been observed at Gold Creek. Table E.2.20 illustrates the suspended sediment concentrations at Gold Creek observed from May to September in WY 1952.

2.3 - Susitna River Water Quality

Immediately downstream from Talkeetna, concentrations are increased because of the contribution of the sediment-laden Chulitna River which has 28 percent of its drainage area covered by year round ice. Maximum values of 3510 mg/l have been recorded downstream at the Sunshine monitoring station. Downstream from Talkeetna, the Yentna River is the only other major glacial river entering the Susitna River. Other sediment sources in the Susitna River include bank erosion, talus slides, and resuspension of sediments. Resuspension of sediments from sand and gravel bars, as river flows increase, can be a significant source of sediment, especially in the wide, braided portions of the river. When the flows decrease, the sediments are redeposited on bars downstream.

A summary of suspended sediment concentrations is presented in Figure E.2.78. Table E.2.21 illustrates suspended sediment data collected at Chase (RM 103), at Sunshine (RM 83), on the Chulitna River, and on the Talkeetna River during the summer of 1982.

The 1982 suspended sediment data presented in Table E.2.21, indicates that the suspended sediment load for the Susitna River above the confluence was 3,700,000 tons (3,363,600 tonnes) while the suspended sediment load for the Chulitna River was 7,100,000 tons (6,454,500 tonnes). That is, the suspended load in the Chulitna River was approximately twice that of the Susitna River above the confluence.

Suspended sediment discharge has been shown to increase with river discharge (R&M 1982c). This relationship is illustrated for four middle and upper Susitna gaging stations in Figure E.2.79. Table E.2.22 shows the increase in suspended sediment discharge at Gold Creek with the river discharge of WY 1953.

Estimates of the average annual suspended sediment load for three locations on the middle and upper Susitna River are provided in the following table (R&M 1982c).

Gaging Station	Average Annual Suspended Sediment Load (Tons/Year)	(Tonnes/ Year)
Susitna River at Denali	2,965,000	2,695,500
Susitna River near Cantwell	6,898,000	6,270,900
Susitna River at Gold Creek	7,731,000	7,028,200

The suspended sediment load entering the proposed Watana reservoir from the Susitna River is assumed to be that at the gaging site for the Susitna River near Cantwell, or 6,898,000 tons/year (6,210,900 tonnes/year) (R&M 1982c).

A suspended sediment size analysis for four upper and middle Susitna River monitoring stations is presented in Figure E.2.80. This analysis indicates that between 20 and 25 percent of the suspended sediment is less than 4 microns (.004 millimeters or 0.157 mils) in diameter.

2.3.4 - Turbidity

(a) Mainstem

The Susitna River is typically clear during the winter months with turbidity values at or near zero. Turbidity values measured by the USGS in January and April 1982 were 1.1 Nephelometric Turbidity Units (NTU) or less at Gold Creek, Sunshine, and Susitna Station. Turbidity increases as snow melt and breakup commence. Peak turbidity values occur during summer when glacial input is greatest.

As presented in Table E.2.21, during 1982, measurements of up to 720 and 728 NTU were recorded at Vee Canyon and Chase, respectively. At the USGS gaging station on the glacially-fed Chulitna River, a value of 1920 NTU was observed. In contrast, the maximum recorded value on the Talkeetna River, with its minimal glacial input, was 272 NTU. Downstream on the Susitna River, turbidity values decrease, with maximums of 1056 and 790 NTU measured at Sunshine and Susitna Station, respectively.

A summary of the turbidity data is presented in Figure E.2.81. Figure E.2.82 shows the relationship between suspended sediment concentration and turbidity as measured on the Susitna River at Cantwell, Gold Creek, and Chase (Peratrovich, Nottingham and Drage 1982).

(b) Sloughs

Turbidity values for sloughs 8A, 9, 16B, 19, and 21 were measured by ADF&G during June, July, and September 1981 (ADF&G 1981). June measurements were taken on June 23, 24, and 25 at a Gold Creek discharge of approximatley 17,000 cfs. No sloughs were overtopped with mainstem flow and turbidity in all the sloughs was less than 1 NTU. The corresponding turbidity at Gold Creek was 100 NTU.

During the July measurements, Gold Creek flow was in excess of 35,000 cfs and the upstream ends of sloughs 8A, 9, 16B and 21 were overtopped. However, slough 19 was not. Turbidity values in the overtopped sloughs were 130, 130, 43, and 150 NTU, respectively. Turbidity in slough 19 was 2.5 NTU and turbidity at Gold Creek was 170 NTU.

September measurements were taken with a Gold Creek discharge of about 8500 cfs. Maximum slough turbidity was 1.1 NTU and the turbidity of Gold Creek was 5.5 NTU.

These data indicate that sloughs are generally clear with low turbidity until the upstream ends are overtopped. During overtopping, slough turbidities reflect mainstem values. Even with overtopping, some sloughs maintained lower turbidity due to the dilution effect of ground water or tributary inflow.

2.3.5 - Vertical Illumination

In general, vertical illumination through the water column varies directly with turbidity and hence follows the same temporal and spatial patterns described above. Although no quantitive assessment was conducted, summer vertical illumination is generally a few inches. During winter months, the river bottom can be seen in areas without-ice cover, since the river is exceptionally clear. However, vertical illumination under an ice cover is inhibited especially when the ice is not clear or when a snow cover is present.

2.3.6 - Dissolved Gases

(a) Dissolved Oxygen

Dissolved oxygen (D.O.) concentrations generally remain high throughout the drainage basin. Winter values average 11.6 to 13.9 mg/l, while average summer concentrations are between 11.5 and 12.0 mg/l. These average concentrations equate to summer saturation levels between 97-105 percent. Winter saturation levels decline slightly from summer levels, averaging 98 percent at Gold Creek and 80 percent at Susitna Station.

Figures E.2.83 and E.2.84 contain additional dissolved oxygen data.

(b) Total Dissolved Gas Concentration

Total dissolved gas (nitrogen) concentrations were monitored in the vicinity of Devil Canyon during 1981 and 1982. Limited 1981 data revealed saturated conditions of approximately 100 percent above the Devil Creek rapids. However, downstream concentrations immediately above and below the

Devil Canyon damsite were measured in the supersaturated range of 105-117 percent, respectively (Schmidt 1981).

From August 8, to October 6, 1982, a continuous recording tensionmeter was installed immediately downstream of Devil Canyon. As noted in Figure E.2.85, the data reveals a linear relationship between dissolved gas concentration and discharge at Gold Creek. Gas concentrations ranged from 106 to 115 percent for discharges from 11,700 to 32,500 cfs (ADF&G 1983). Computations have yielded decay rates which suggest variations in the rate of decay of supersaturation with discharge, distance downstream, and channel slope and morphology characteristics (ADF&G 1983; and Peratrovich, Nottingham and Drage 1983).

Alaska water quality statutes allow a maximum dissolved gas concentration of no higher than 110 percent.

2.3.7 - Nutrients

Of the four major nutrients: carbon, silica, nitrogen and phosphorus; the limiting nutrient in the Susitna River is phosphorus (Peterson and Nichols 1982). Although total phosphorous concentrations regularly exceed established criteria (Figure E.2.86), the majority of this nutrient is in a form not available for use by the microflora.

Studies of glacial lakes in Alaska (ADF&G 1982b) and Canada (St. John et al. 1976) indicate that over 50 percent of the total phosphorus concentration in the lakes studied was in the biologically inactive particulate form (Peterson and Nichols 1982).

The bio-available phosphorous, namely orthophosphates, are 0.1 mg/l or less throughout the drainage basin. Although one measurement at Vee Canyon was 0.49 mg/l, this value was disregarded since it was considered unrealistic (R&M 1982g). Data is depicted in Figure E.2.87.

Nitrate nitrogen concentrations exist in low to moderate concentrations (<0.9 mg/l) in the Susitna River. Gold Creek summer levels vary between 0.02 mg/l and 0.86 mg/l. During winter, the range of variability is reduced with the concentration varying between 0.05 and 0.34 mg/l. Maximum recorded concentrations in the watershed of 1.2 mg/l are from the Talkeetna River monitoring station during the summer. Nitrate data for six gaging stations are illustrated in Figure E.2.88.

2.3.8 - Other Parameters

(a) Total Dissolved Solids

Total dissolved solids (TDS), or dissolved salts as they are often referrd to, are higher during the winter low-flow periods than during summer. The TDS concentrations generally decrease in a downstream direction.

At Gold Creek, TDS winter values are 100-188 mg/l, while summer concentrations are between 55 and 140 mg/l. Downstream, measurements at Susitna Station range from 109-139 mg/l during winter, and between 56 and 114 mg/l in the summer. Figure E.2.89 presents the data collected.

Salinity data for Cook Inlet are presented in Section 2.6.7.

(b) Specific Conductance (Conductivity)

Conductivity values, which generally show an excellent correlation with TDS concentrations provided salinity contents are reasonably low (Cole 1975), are also higher during the winter and lower during the summer. In the upstream reaches of the Susitna, conductivity values are generally higher than downstream values.

At Denali, values range from 351-467 umhos/cm in the winter to 121-226 umhos/cm in the summer. Gold Creek conductivities vary from 84-300 umhos in the winter to 75-227 umhos/cm in the summer. Specific conductance levels at Susitna Station range from 182-225 umhos/cm during winter to 90-160 umhos/cm during summer. Figure E.2.90 provides the conductivity data for the seven USGS gaging stations.

(c) Significant Ions

Concentrations of the seven significant ions; namely bicarbonate, sulfate, chloride, and the dissolved fractions of calcium, magnesium, sodium and potassium; which comprise a major portion of the total dissolved solids, are generally low to moderate, with summer concentrations lower than winter values. The ranges of concentrations recorded upstream of the project at Denali and Vee Canyon, and downstream of the project at Gold Creek, Sunshine and Susitna Station are compared in Table E.2.23. The ranges of anion and cation concentrations at each monitoring station are presented in Figures E.2.91 to E.2.96. Data on bicarbonate are presented in the discussion of Total Alkalinity.

(d) Total Hardness

Waters of the Susitna River are moderately hard in the winter, and soft to moderately hard during breakup and summer. In addition, there is a general trend towards softer water in the downstream direction.

Total hardness, measured as the sum of the calcium and magnesium hardness and reported in terms of $CaCO_3$, ranges from 60-121 mg/l at Gold Creek during winter to 31-107 mg/l in the summer. At Susitna Station, values are 73-96 mg/l and 44-66 mg/l during the winter and summer, respectively. Figure E.2.97 presents the available data.

(e) pH

Average pH values tend to be slightly alkaline with averages ranging between 6.9 and 7.7. Maximum pH levels occasionally exceed 8.0, while a value as low as 6.0 has also been recorded. Low pH levels are common in Alaskan streams and are attributable to the acidic tundra runoff.

At Denali, pH variations between 7.1 and 7.6 occur during winter, while the summer fluctuation is 7.2 to 7.9. Winter pH levels at the Gold Creek station are between 7.0 and 8.1. The range of summer values is 6.5 to 7.9. Figure E.2.98 displays the pH data for the seven stations.

(f) Total Alkalinity

Total alkalinity concentrations, with bicarbonate typically the only form of alkalinity present, exhibit moderate to high levels during winter and low to moderate levels during summer. In addition, upstream concentrations are generally higher than downstream concentrations.

Concentrations at Denali during winter are 112-161 mg/l, and 42-75 mg/l during summer. At Gold Creek, winter values range between 46 and 88 mg/l, while summer concentrations are in the range of 23-87 mg/l. In the lower river at Susitna Station, winter concentrations are 60-75 mg/l, and summer levels are 36-57 mg/l.

Figure E.2.99 provides total alkalinity data in the form of $CaCO_3$.

(g) Free Carbon Dioxide

Free carbon dioxide (CO_2) in combination with carbonic acid and the previously discussed bicarbonates (alkalinity) constitute the total inorganic carbon components present in the Susitna River.

In the upper basin, summer measurements of free CO_2 at Denali yield values that range from 1.5 to 5.2 mg/l. Winter data indicates levels from 5.5 mg/l to 25 mg/l.

At Gold Creek, the summer and winter ranges are virtually identical. Minimum values are 1.1 mg/l during summer, and 1.2 mg/l during winter. Maximum concentrations are 20 mg/l during both seasons.

In the lower river basin at the Susitna Station, summer data indicate a variability between 0.6 and 8 mg/l. Winter data range from a minimum of 1.8 mg/l to a maximum of 17 mg/l.

Free CO_2 data are illustrated in Figure E.2.100.

(h) Total Organic Carbon

Total organic carbon (TOC) varies with the composition of the organic matter present (McNeely et al 1979).

At Gold Creek, summer TOC levels vary from 1.4 to 3.8 mg/l. Winter concentrations range from 1.0 mg/l to 5.5 mg/l. Downstream at Susitna Station, TOC ranges between 2.7 and 11.0 mg/l and 0.4 and 4.0 mg/l, during summer and winter, respectively.

Criterion for TOC has been suggested by McNeely et al. (1979) as 3.0 mg/l, since water with lower levels have been observed to be relatively clean. However, as is evidenced above, streams and rivers in Alaska receiving tundra runoff frequently exceed this criterion (R&M 1982g).

A summary of the TOC data is presented in Figure E.2.101.

(i) Chemical Oxygen Demand

Chemical oxygen demand (COD) data are limited to observations at Vee Canyon and Gold Creek. Summer concentrations at Vee Canyon range between 8 and 39 mg/l. Winter values are 6-13 mg/l. Below the proposed reservoirs, at the Gold Creek monitoring station, summer levels vary from 1.3-24 mg/l, while winter concentrations are in the range of 2-16 mg/l.

The available COD data are presented in Figure E.2.102.

(j) True Color

True color, measured in platinum cobalt units, typically displays a wider range during summer than winter. This phenomenon is attributable to organic acids (especially tannin) characteristically present in the summer tundra runoff.

Data gathered at Denali, with its dominant glacial origins, ranged between 0 and 5 units and 0 and 10 units, during winter and summer, respectively. However, color levels at Gold Creek, with its significant tundra runoff, vary between 0 and 40 color units during winter and 0 to 110 units in summer. Although they are extremely high, it is not uncommon for color levels in Alaska to reach 100 units for streams receiving tundra runoff (R&M 1982g).

Figure E.2.103 displays the data collected.

(k) Metals

The concentrations of many metals monitored in the river were low or within the range characteristic of natural waters. In addition, 15 parameters were below detectable limits when both the dissolved (d) fraction and the total recoverable (t) quantities are counted. For antimony, boron, gold, platinum, tin, radium, and zirconium, both (d) and (t) were below detection limits. The dissolved fraction of molybdenum was also not detectable.

The concentrations of some trace elements, however, exceeded water quality guidelines for the protection of freshwater organisms (Table E.2.17). These concentrations are the result of natural processes, since with the exception of some placer mining activities, there are no man-induced sources of these elements in the Susitna River basin. Metals which exceeded criteria include both dissolved and total recoverable aluminum, cadmium, copper, manganese, mercury, and zinc. In addition, the dissolved fraction of bismuth, and the total recoverable quantities of iron, lead, and nickel also exceeded criteria.

Figures E.2.104 through E.2.119 summarize the data for those metals that exceeded criteria. Information pertaining to metals, that did not surpass established or suggested guidelines are presented by R&M (1982g).

2.3 - Susitna River Water Quality

(l) Chlorophyll-a

Chlorophyll-a, as a measure of algal biomass, is low due to the poor light transmissivity of the sediment laden waters. The only chlorophyll-a data available for the Susitna River were collected at the Susitna Station gage. Values up to 1.2 mg/m^3 (chlorophyll-a periphyton uncorrected) were recorded. However, when the chromospectropic technique was used, values ranged from 0.004 to 0.029 mg/m^3 for three samples in 1976 and 1977. All recorded values from 1978 through 1980 were less than detectable limits when analyzed using the chromographic fluorometer technique.

As previously noted, no data on chlorophyll-a are available for the upper basin. However, with the high suspended sediment concentrations and turbidity values, it is expected that chlorophylla values are low.

(m) Bacteria

No data are available for bacteria in the upper and middle river basins. However, because of the glacial origins of the river and the absence of domestic, agricultural, and industrial development in the watershed, bacteria levels are expected to be low.

Limited data on bacterial indicators are available from the lower river basin, namely for the Talkeetna River since 1972, and from the Susitna River at Susitna Station since 1975. Indicator organisms monitored include total coliforms, fecal coliforms, and fecal streptococci.

Total coliform counts were generally low, with the three samples at Susitna Station and 70 percent of the samples on the Talkeetna River registering less than 20 colonies per 100 ml. Occasional high values have been recorded during summer months, with a maximum value of 130 colonies per 100 ml.

Fecal coliforms were also low, usually registering less than 20 colonies per 100 ml. The maximum recorded summer values were 92 and 91 colonies per 100 ml in the Talkeetna and Susitna Rivers, respectively.

Fecal streptococci data also display the same pattern; low values in winter months, with occasional high counts during the summer months.

All recorded values are believed to reflect natural variation within the river, as there are no significant human influences throughout the Susitna River basin that would affect bacterial counts.

(n) Miscellaneous

Concentrations of organic pesticides and herbicides, uranium, and gross alpha radioactivity were either less than their respective detection limits or were below levels considered to be potentially harmful. No significant sources of these parameters are known to exist in the drainage basin, with the exception of herbicides (amitrole, 2-4, D, bromicil and Garlon) used along the railroad right-of-way. Since no pesticides, herbicides, or radioactive materials will be used during the construction, filling or operation of the project, no further discussions will be pursued.

2.3.9 - Water Quality Summary

The Susitna River is a fast flowing, cold water river with glacial origins and large seasonal flow variations that greatly influence its character. During winter, river temperatures remain at or near 0°C (32°F) throughout the mainstem. Localized areas, especially sloughs, experience ground water upwelling which maintains winter temperatures slightly above freezing. Maximum summer mainstem temperatures at Gold Creek reach 15.0°C (59.0°F). Ice formation commonly begins during October in the upper reaches of the river. Breakup usually occurs in the project area during May. Suspended sediment concentrations and turbidity levels experience extreme seasonal fluctuations as the result of glacial melt, snow melt and rainfall. Suspended sediment measurements up to 5690 mg/l have been documented at Denali.

Dissolved oxygen concentrations are high throughout the basin with winter values near 13 mg/l. Summer measurements average near 12 mg/l. Dissolved oxygen saturation in the middle and upper basin averages near 100 percent. Total dissolved gas concentrations exceed criteria levels below the Devil Canyon rapids with supersaturated values up to 117 percent recorded.

Nutrient concentrations, namely nitrates and orthophosphates, exist in low to moderate concentrations throughout the basin.

Total dissolved solids (TDS) concentrations are higher during the winter low-flow periods than during summer. Correspondingly, conductivity values are also higher during the winter, and lower during summer. Concentrations of the seven significant ions are generally low to moderate with lower levels during summer. The

Susitna is moderately hard during winter and soft to moderately hard during breakup and summer. Typically, pH values range between 7 and 8, although values often fall below 7 due to the organic nature of tundra runoff. Total alkalinity concentrations are moderate to high during winter, and low to moderate during summer.

Total organic carbon and true color both exceed their respective criteria because of the influence of tundra runoff.

The concentrations of many trace elements monitored in the river were low or within the range characteristic of natural waters. However, the concentrations of some trace elements exceeded water quality guidelines for the protection of freshwater aquatic organisms. These concentrations are the result of natural processes since there are no man-induced sources of these elements in the Susitna River basin, with the exception of some placer mining activities.

Chlorophyll-a measurements are low as a result of the poor light transmissivity of the sediment-laden waters. Bacterial indicators exhibit generally low concentrations.

Concentrations of organic pesticides and herbicides, uranium, and gross alpha radioactivity were either less than their respective detection limits or were below levels considered to be potentially harmful to aquatic organisms.

2.4 - Baseline Ground Water Conditions

2.4.1 - Description of Water Table and Artesian Conditions

The landscape of the upper and middle basin consists of relatively barren bedrock mountains with exposed bedrock cliffs in canyons and along streams, and areas of unconsolidated sediments (outwash, till, alluvium) with low relief, particularly in the valleys. The arctic climate has retarded development of topsoil. Unconfined aquifers exist in the unconsolidated sediments, however there are no water table data in these areas except in the relict channel at Watana and the south abutment at Devil Canyon. Winter low flows in the Susitna River and its major tributaries are fed primarily from ground water storage in these unconfined aquifers. The bedrock within the basin is comprised of crystalline and metamorphic rocks. No significant bedrock aquifers have been identified or are anticipated.

Below Talkeetna, the broad plain between the Talkeetna Mountains and the Alaska Range generally has higher ground water yields, with the unconfined aquifers immediately adjacent to the Susitna

River having the highest yields. Potential ground water yields along the river are 100-1000 gallons per minute (gpm) (379-3795 liters per minute), whereas upstream of Talkeetna, the ground water yields adjacent to the river are 20-50 gpm (76-189 liters per minute) (Freethey and Scully 1980).

2.4.2 - Hydraulic Connection of Ground Water and Surface Water

Much of the ground water in the system is stored in unconfined aquifers in the valley bottoms and in alluvial fans along the slopes. Consequently, there is a direct connection between the ground water and surface water. Confined aquifers may exist within some of the unconsolidated sediments, but no data are available as to their extent.

2.4.3 - Locations of Springs, Wells, and Artesian Flows

Due to the wilderness character of the basin, there are no data on the location of springs, wells, and artesian flows other than within the sloughs. Winter aufeis buildups have been observed between Vee Canyon and Fog Creek, indicating the presence of ground water discharges. Ground water is the main source of flow during winter months, when precipitation falls as snow and there is no glacial melt. It is believed that much of this water comes from the unconfined aquifers (Freethey and Scully 1980).

2.4.4 - Hydraulic Connection of Mainstem and Sloughs

The sloughs downstream from Devil Canyon are used by salmonid species for spawning, and provide valuable rearing habitat for anadromous and resident fish. Ground water upwelling within the sloughs provides appropriate conditions for egg incubation.

Ground water studies at Sloughs 8A and 9 indicate that there is a hydraulic connection between the mainstem Susitna River and the sloughs. Ground water observation well measurements demonstrate that the ground water upwelling in the sloughs is caused by ground water flow from the uplands and from the mainstem Susitna. The higher permeability of the valley bottom sediments (sand- gravel-cobble-alluvium), compared with the till mantle and bedrock of the valley sides, indicated that the mainstem Susitna River is the major source of ground water inflow in the sloughs. This is illustrated in Figures E.2.120 and E.2.121. The contours indicate a flow direction along the valley and laterally towards the sloughs. Preliminary estimates of the travel time of the ground water from the mainstem to the sloughs indicate a time on the order of six months to a year or more.

Changes in water levels in observation wells in response to a 3.1 foot change in the mainstem stage during the September 14 to 22, 1982 hydrograph event varied from 2.8 feet to 1.7 feet (0.85 to 0.52 m) at distances of 50 feet (15 m) and 1200 feet (366 m), respectively, from the river bank1/.

1/ See Appendix E.2.A for a description of groundwater levels and mainstem discharges.

Preliminary investigations show that ground water upwelling temperatures in sloughs reflect the long-term average water temperature of the Susitna River, which is approximately 3°C (37.4°F). These conclusions are based upon the investigations that have been undertaken to determine the mechanisms controlling slough upwelling. Drilling and soil sampling, installation of observation wells, monitoring of ground water levels and temperatures, analysis of field data, and numerical and analytical modeling of the ground water have been performed. The results indicate that hydrodynamic dispersion and heat exchange between the ground water and soil are the dominant mechanisms responsible for the near constant upwelling temperatures. Annual ground water temperatures within the range 3 ± 1.5°C (37.4 ± 2.7°F) are calculated for ground water travel distances greater than 100 feet (30 m) from the mainstem, based on best estimates for the controlling parameters (Acres 1983).

The dominant parameter in the analysis is the hydraulic conductivity of the alluvial sediments. However, hydraulic conductivity is spatially variable. Values an order of magnitude, higher or lower than the best estimate used in the calculations are quite possible. The sensitivity of temperature fluctuations to an order of magnitude increase in hydraulic conductivity has been examined. This indicates that temperatures within the range 3±1.5°C (37.4 ± 2.7°F) would occur at distances greater than 24,000 feet (7317 m) along a flow line. The flow line lengths between the mainstem and the sloughs are typically 1000 to 4000 feet (305 to 1220 m). Thus, the dispersion and heat exchange mechanisms appear capable of significant damping of the seasonal mainstem temperature fluctuations even for hydraulic conductivities significantly higher than have been calculated from available field data.

A technique for measuring upwelling water flows has been developed. However, sufficient measurements have not yet been taken to determine the magnitude and spatial variation of ground water flow. Gaging of flows in Slough 9 has been undertaken and these data indicate that the ground water component was 0.74 and 1.00 cfs on the two occasions measured. This represented 36 and 61 percent of the total flow at the downstream end of the slough.

2.5 - Existing Lakes, Reservoirs, and Streams

2.5.1 - Lakes and Reservoirs

There are no reservoirs on the Susitna River or on any of the tributaries flowing into either the Watana or Devil Canyon reservoirs. A few small lakes at and upstream of the damsites will be affected by the project. No lakes downstream of the reservoirs will be directly impacted by project construction, impoundment, or operation. However, secondary impacts resulting from increased access from the access road or transmission line maintenance road could occur. The major lakes and lake complexes potentially affected are listed in Table E.2.24, along with the potential impacts.

The normal maximum operating level of 2185 feet (666 m) in the Watana reservoir will lead to the inundation of a number of lakes, none of which are named on USGS topographic maps. Most of these are small tundra lakes and are located along the Susitna River between RM 191 and RM 197 near the mouth of Watana Creek. The largest of these lakes is Sally Lake. It is situated at geographic location S/32N/07E/29. Surface area of this lake is 63 acres (25 ha). It has a maximum depth of 27 feet (8 m) and a mean depth of 11.6 feet (3.5 m). The shoreline length is 10,500 feet (3200 m). The water surface elevation is approximately at elevation 2050 feet (625 m). The area-capacity curves for Sally Lake are illustrated in Figure E.2.122.

There are 27 lakes less than 5 acres (2 ha) in surface area and one between 5 and 10 acres (2 and 4 ha), all on the north side of the river between RM 191 and RM 197. In addition, a small lake (less than 5 acres [2 ha]) lies on the south shore of the Susitna at RM 195.5 and another of about 10 acres (4 ha) in area lies on the north side of the river at RM 204. Most of these lakes appear to be perched, but five are either connected by small streams to Watana Creek or empty directly into the Susitna River mainstem.

A small lake (2.5 acres or 1 ha) lies on the south abutment near the Devil Canyon damsite at RM 151.3, at approximately elevation 1400 feet (427 m). No other lakes exist within the proposed Devil Canyon reservoir.

2.5.2 - Streams

Numerous streams in each reservoir will be completely or partially inundated during project filling and operation. The streams to be inundated within the respective reservoirs and appearing on the 1:63,360 scale USGS maps, are illustrated in Figures E.2.123 and E.2.124 and listed in Tables E.2.25 and E.2.26. Provided in these tables are the map name of each stream, Susitna River mile locations, the existing elevation of the stream mouths, the average stream gradient of the reach to be inundated and the length of the stream to be inundated. Elevations of 2190 feet (668 m) and 1455 feet (444 m) were used for these determinations for the Watana and Devil Canyon reservoirs, respectively.

Within the Watana reservoir, there are two sloughs located at approximately RM 212. Near Jay Creek, there are two sloughs, one just upstream (RM 208.7) and the other just downstream (RM 208.0) from the mouth of Jay Creek. Additional sloughs are located at RM 205.7, RM 200.9 and just downstream of Watana Creek at RM 193.6. Within Devil Canyon reservoir, there are ten sloughs at RM 180.1, 179.1, 177.0, 173.9, 172.2, 172.0, 171.5, 171.5, 169.5, and 168.0, which will be totally inundated. The locations of the sloughs to be inundated are also shown on Figures E.2.123 and E.2.124.

Aside from the streams to be inundated by the two project impoundments, there are several tributaries downstream of the project which may be affected by changes in the Susitna River flow regime. Since post-project summer stages in the Susitna will be several feet lower than pre-project levels, some of the creeks may either degrade to the lower elevation or remain perched above the river. Analyses were done on 19 streams between Devil Canyon and Talkeenta which were determined to be important for fishery reasons or for maintenance of existing bridge crossings by the Alaska Railroad (R&M 1982f). These streams are listed in Table E.2.27, with their river mile locations and the reason for concern.

2.6 - Existing Instream Flow Uses

Instream flow uses are uses made of water in the river channel as opposed to water withdrawn from the river. Instream flow uses include hydroelectric power generation; commercial or recreational navigation; waste assimilation; downstream water rights; water requirements for riparian vegetation, fisheries and wildlife habitat; recreation; freshwater recruitment to estuaries; and water required to maintain the desirable aesthetic characteristics of the river itself. Existing instream flow uses on the Susitna River involve all of these uses except hydroelectric power operation.

2.6.1 - Downstream Water Rights

In 1966, "The Alaska Water Use Act" was established. This legislation, which was amended in 1979, authorized the Alaska Department of Natural Resources (ADNR) to determine and adjudicate water rights for use of the state's water resources (ADNR 1981).

Existing water rights users at that time were eligible for "grandfather rights" and were required to formalize their interests as of April 1968. Currently, the statutory procedure for formalization of water rights requires the filing of an Application for Water Rights with the Commissioner of the ADNR. After issuance of a permit and subsequent to the beneficial utilization of the water as noted in the permit, ADNR personnel may elect to conduct a field investigation. Provided the ADNR concur that the water rights have been perfected, a Certificate of Appropriation is then issued. This certificate provides legal rights against conflicting users of the water who do not have water rights or are junior in priority (ADNR 1981).

Existing surface and ground water rights in the Susitna River basin were investigated by Dwight (1981). To facilitate this search, the basin was divided into 18 township grids (Figure E.2.125). The investigation noted that the only significant surface water rights exist in the headwaters of the Willow Creek (18.3 cfs) and Kahiltna (125 cfs) township grids where placer mining operations occur on a seasonal basis (Table E.2.28). Neither of these areas will be affected by the project.

The only appropriation on record in the area of the proposed reservoirs (Susitna Reservoir township grid) is permit ADL-203386 currently held by the Alaska Power Authority for the 44 man Watana camp. The permit for the camp, from which field work for the project has been conducted, is for 3000 gpd (0.00465 cfs or 11,355 liters per day) from a nearby unnamed lake.

Downstream of the proposed facilities, in the Susitna township grid, surface water rights amount to 0.153 cfs while ground water appropriations total 0.56 acre-feet/year or 0.0498 cfs (Table E.2.29). No surface water rights on file with the ADNR withdraw directly from the Susitna River mainstem. In addition, an analysis of topographic maps and overlays denoting the specific location of each recorded appropriation indicate that all surface water diversions from tributaries, as well as all ground water withdrawals from wells, are located at elevations that will be unaffected by water level changes and/or flow regulation resulting from the construction, filling, and operation of the proposed Susitna Hydroelectric Project (Dwight 1981). As such, no further discussions regarding potential impacts to existing downstream water rights appropriations will be presented.

2.6.2 - Fishery Resources

The Susitna River supports populations of both anadromous and resident fish. Important commercial, recreational, and subsistence species include pink, chum, coho, sockeye and chinook salmon, eulachon, rainbow trout, Arctic grayling, burbot, and Dolly Varden. Natural flows presently provide for fish passage, spawning, incubation, rearing, overwintering, and outmigration. These activities are correlated to the natural hydrograph. Salmon migrate upstream and spawn on the receeding limb of the spring hydrograph and throughout most of the summer, the eggs incubate through the low-flow winter period, and fry out-migration occurs in association with spring breakup[1/]. Rainbow trout and grayling spawn during the high flows of the breakup period with embryo development occurring during the early summer. Further detail on the fishery resources is presented in Chapter 3.

2.6.3 - Navigation and Transportation

(a) Boat Navigation and Transportation

Navigation and transportation on the Susitna River from the headwaters to the Devil Canyon damsite is limited, being

[1/] See Appendix E.2.A for a description of mainstem flow relationships to hydraulic and hydrologic characteristics of sloughs.

primarily related to hunters' and fishers' access to the Tyone River (RM 247) after launching at the Denali Highway (RM 291). However, some use is made of recreational kayaking, canoeing and rafting. Downstream of the Tyone River, Vee Canyon rapids (RM 226-232) offer some of the finest rafting and white-water kayaking in Alaska, and are rated Class IV white-water.

Farther downstream are the Devil Creek and Devil Canyon rapids which offer 11 miles (18 km) of some of the most challenging kayaking in the world. The first successful running of these rapids, which are rated Class VI white-water occurred in 1978. Less than 40 kayakers from throughout the world have attempted the rapids since then, and at least five people have died trying.

Downstream of Devil Canyon, the Susitna River is considered navigable by the U.S. Department of the Interior, Bureau of Land Management (BLM) from its mouth to a distance 7.5 miles (12 km) upstream of Gold Creek (TES 1982). However, the river is used for navigation up to Portage Creek (RM 149). This entire reach is navigable under most flow conditions although abundant floating debris during extreme high water and occasional shallow areas during low water can make navigation difficult.

The Susitna River downstream of Devil Canyon is used for sport fishing, hunting, recreational boating, sightseeing, and transportation of some supplies. Access to the river is gained from four principal boat launching sites, Talkeetna (RM 97), Sunshine Bridge at the Parks Highway (RM 84), Kashwitna Landing (RM 61), and Willow Creek (RM 49); from several of the minor tributaries between Talkeetna and Cook Inlet; and from Cook Inlet. Other primary tributaries accessible by road are Willow Creek, Sheep Creek, and Montana Creek.

A very substantial increase in the use of the river and its tributaries has been noted within recent years. Dwight and Trihey (1981) reported a 50 percent increase in the use of certain salmon streams in past years. During 1976, 500 boats were launched at the Kashwitna Landing. Mid-summer 1981 estimates of launches at the Kashwitna Landing approximated 5000. One Friday, during the 1981 king salmon season, 147 craft were launched (TES 1982). An aerial survey of the river during moose season, Thursday, September 17, 1981, noted 22 craft on the mainstem below Talkeetna and 102 craft on its respective tributaries.

2.6 - Existing Instream Flow Uses

Under the existing flow regime, the ice on the river breaks up and the river becomes ice-free for navigation in mid to late May. Flows typically remain high from that time through the summer until September or early October, when freezeup begins. During freezeup frazil ice restricts boat operation, but often a frazil-free period of 1 to 2 weeks follows the initial stages of freezeup and navigation is again possible. The next sequence of frazil generation generally leads to continuous freezing of the river, prohibiting open-water navigation until after the following spring breakup.

In 1982, investigations were conducted on potential navigation problems downstream of the proposed hydroelectric dams on the Susitna River during the ice-free months (ADNR 1982). A review was made of river cross-sectional data, simulated water surface profiles determined by the HEC-2 program and aerial photographs for the reach between Portage Creek and Talkeetna. Figures E.2.63 and E.2.64 present the results of the simulation, converted to depths at each cross section for the various discharges considered. Figure E.2.63 shows that the major area of concern is a broad shallow reach 1 to 3 miles (1.6 to 4.8 km) below Sherman, where the main channel of the Susitna River crosses the floodplain. A representative cross section of the reach is depicted in Figure E.2.10. Water surface elevations for each of the discharges simulated and the estimated water surface elevation for a flow of 6000 cfs are presented. The water surface elevations are considered accurate to ±1 foot (0.3 m).

Using the stage-discharges relationship for cross section 32 presented in Figure E.2.10, the Alaska Department of Natural Resources (ADNR) determined that a discharge of 6500 cfs would be required to maintain a navigable depth of 2.5 feet (0.8 m). The 2.5 foot (0.8 m) depth was established as the navigation criterion even though 1.5 feet (0.5 m) was considered as an adequate depth for navigation, because of the 1 foot (0.3 m) potential error in the HEC-2 water surface prediction. Extrapolation of the stage-discharge rating curve to a 1.5 foot (0.5 m) depth indicates that the equivalent discharge would be approximately 3000 cfs.

A reconnaissance conducted on October 14, 1982 (R&M 1982j) when the Gold Creek discharge was 6000 cfs indicated that the reach downstream of Sherman was navigable if the center channel was used.

Downstream from Talkeetna, the ADNR study used personal interviews, aerial photographs and topographic maps to determine potential navigation problems. Four areas were designated as potentially adversely affected by reduced discharges.

1. A braided area on the east side of the Susitna River, about 6 river miles (10 km) downstream from Talkeetna near RM 91.

2. A braided area of the east side of the Susitna River, adjacent to and extending about 1 mile (1.6 km) downstream from Kashwitna. This is at approximately RM 60 to 61.

3. The Susitna River near its confluence with Willow Creek at about RM 48 to 49.

4. On Alexander Slough (also known as the west channel), just as it divides off the mainstem of the Susitna River (also known as the east channel downstream of this point). This is near RM 19.

The ADNR analysis indicates the following minimum discharges at Sunshine gage were necessary to maintain 1.5 foot and 2.5 foot (0.5 m and 0.8 m) depths, respectively.

Near Talkeetna <1000 cfs, <1000 cfs
Kashwitna Landing Upstream 2750 cfs, 7200 cfs
Kashwitna Landing Downstream 3550 cfs, 8100 cfs
Near Willow Creek 10,400 cfs, 16, 200 cfs
Near Willow Creek Middle Channel 6500 cfs, 11,000 cfs

Minimum discharges could not be determined for Alexander Slough.

Identified restrictions of open-water navigation over the full length of the river are tabulated in Table E.2.30.

(b) Other Navigation and Transportation Uses

The Susitna is used by several modes of non-boat transportation at various times of the year. Fixed-wing aircraft on floats make use of the river for landings and take-offs during the open water season. These are primarily at locations in the first 50 miles (80 km) above the mouth. The previously mentioned aerial survey conducted during moose season (September 17, 1981), located 12 planes on the mainstem and its tributaries below Talkeetna (TES 1982). Among the most common landing sites for floatplanes are Kashwitna River, Willow Creek, Little Willow Creek, Deshka River (Kroto

Creek), Susitna River near the mouth of Alexander Creek, and Alexander Slough near the mouth of the river. Floatplane access also occurs on occasion within the middle and upper Susitna reaches.

After the river ice cover has solidly formed in the fall, the river is used extensively for transportation access by ground methods in several areas. Snow machines and dogsleds are commonly used below Talkeetna; the Iditarod Trail crosses the river near the Yentna River confluence and is used for an annual dogsled race in February. Occasional crossings are also made by automobiles and ski, primarily near Talkeetna and near the mouth.

2.6.4 - Recreation

The summer recreation uses of the Susitna River include recreational boating, kayaking, canoeing, sport fishing, hunters' access, and sightseeing. In winter, recreation uses include snow machines and dogsleds. These uses were discussed in Section 2.6.3.

2.6.5 - Riparian Vegetation and Wildlife Habitat

Wetlands cover large portions of the Susitna River basin, including riparian zones along the mainstem Susitna, sloughs, and tributary streams. Wetlands are biologically important because they generally support a greater diversity of wildlife species per unit area than most other habitat types in Alaska. In addition, riparian wetlands provide winter browse for moose and, during severe winters, can be a critical survival factor for this species. They also help to maintain water quality throughout regional watersheds. Detailed information on riparian wetlands and wildlife habitat can be found in Chapter 3.

The processes affecting riparian vegetation include freezeup, spring ice jams and flooding. As noted in Section 2.3.2(c), spring ice jams can have a devestating impact on vegetation. However, ice jams are generally confined to specific areas. In the Devil Canyon to Talkeetna reach, both flooding and freezeup are believed to be important factors affecting vegetation. Because of the braided channel pattern downstream of Talkeetna, flooding is expected to be the dominant factor influencing riparian vegetation.

2.6.6 - Waste Assimilative Capacity

Review of the Alaska Department of Environmental Conservation "Inventory of Water Pollution Sources and Management Actions, Maps and Tables" (1978) indicates that the primary sources of pollution to the Susitna River watershed are placer mining operations. Approximately 350 sites were identified although many of these claims are inactive. As the result of these operations, large amounts of suspended sediment may be introduced into the watershed. However, no biochemical oxygen demand (BOD) is placed on the system, and therefore, the waste assimilative capacity remains unaffected by these mining activities.

As for BOD discharges in the watershed, the inventory did identify one municipal discharge in Talkeetna, two industrial wastewater discharges at Curry and Talkeetna, and three solid waste dumps at Talkeetna, Sunshine, and Peters Creek. No volumes are available for these pollution sources.

Personal communication (1982) with Joe LeBeau of the Alaska Department of Environmental Conservation (ADEC) revealed that no new wastewater discharges of any significance are believed to have developed since the 1978 report. Further, it was noted that the sources that do exist are believed to be insignificant.

Mr. Robert Flint of the ADEC indicated that, in the absence of regulated flows and significant wastewater discharges, the ADEC has not established minimum flow requirements necessary for the maintenance of the waste assimilative capacity of the river (personal communication 1982).

2.6.7 - Freshwater Recruitment to Cook Inlet Estuary

The Susitna River is the most significant contributor of freshwater to Cook Inlet and, as such, has a major influence on the salinity of Upper Cook Inlet. High summer freshwater flows associated with the occurrences of snow melt, rainfall, and glacial melt cause reduced salinities. During winter, low flows permit the more saline ocean water to increase Cook Inlet salinities.

A second major factor influencing the salinity levels in Cook Inlet are the large tidal variations that occur. These tides, which are amongst the largest in the world, cause increased mixing of freshwater and saltwater.

A numerical water quality model of Cook Inlet was developed for the U.S. Army Corp of Engineers (Tetra Tech, Inc. 1977). The results of this model were found to compare quite well with the available Cook Inlet surface salinity data from May 21-28, 1968; August 22-23, 1972; and September 25-29, 1972 (COE 1979).

Using this model, Resource Management Associates (1983) simulated pre-project monthly salinity concentrations throughout the Inlet using average freshwater flows from the Cook Inlet tributaries. Figure E.2.126 shows 5 select locations where salinities were computed. Near the mouth of the Susitna River (Node 27), the study results indicated a natural salinity of 5800 mg/l in August and 21,000 mg/l during April, or a range of 15,200 mg/l (Table E.2.31). The temporal salinity variation at this location is provided in Figure E.2.127.

In the center of Cook Inlet near East Foreland, approximately 45 miles southwest of the Susitna River mouth (Node 12), normal salinity values were estimated to vary between 21,100 mg/l during September and 26,800 mg/l in April, or a range of 5700 mg/l. Near the mouth of Cook Inlet (Node 1) the annual salinity range is 2100 mg/l with maximum and minimum average monthly values of 30,200 mg/l in April and 28,100 mg/l in August.

In addition to these three locations, estimated pre-project salinity values for the centers of Turnagain and Knik Arms (Nodes 55 and 46, respectively) are also provided in Table E.2.31.

Salinity measurements were recorded at the mouth of the Susitna River during spring tides on August 18 and 19, 1982 to determine if, and to what extent saltwater intruded upstream. No saltwater intrusion was detected. Flow was approximately 90,000 cfs at the mouth of the Susitna River at the time the measurements were made. Additional salinity measurements were made on February 14, 1983 to determine if saltwater penetration occurs upstream of the mouth of the river during low flow periods. Salinity was monitored over a tidal cycle at approximately RM 1. No salinity was detected.

2.7 - Access Plan

2.7.1 - Flows

The flow regime of the streams to be crossed by the access road is typical of subarctic, snow-dominated streams, in which a snow melt flood in spring is followed by generally moderate flows through the summer, punctuated by periodic rainstorm floods. Between October and April, precipitation falls as snow and remains on the ground. The annual low flow occurs during this period, and is predominately base flow.

Streamflow records for these small streams are sparse. Consequently, regression equations developed by the U.S. Geological Survey (Freethey and Scully 1980) have been utilized to estimate the 30-day low flows for recurrence intervals of 2, 10, and 20 years, and the peak flows for recurrence intervals of 2, 10, 25, and 50 years. These flows are tabulated in Table E.2.32 for the three access route segments: (1) Denali Highway to Watana Dam; (2) Watana Dam to Devil Canyon Dam; and (3) the Devil Canyon to Gold Creek railroad. Only named streams are presented.

2.7.2 - Water Quality

At present, little water quality data are available for the streams in the vicinity of the proposed access routes.

However, as noted in the fisheries discussions in Chapter 3, many of the major streams scheduled for crossing are known to support populations of Arctic grayling. Arctic grayling are generally residents of clear, cold streams (Scott and Crossman 1973) and as a result it is theorized that water quality is generally good.

In contrast, water quality conditions associated with tundra run-off are also expected. Among the conditions that might be anticipated are pH levels in the 6-7 range, total organic carbon concentrations exceeding the suggested criterion level of 3.0 mg/l (McNeely et al. 1979), and true color values as high as 100 units.

During periods of high flow conditions resulting from spring snow melt and summer rainstorms, elevated suspended sediment and turbidity levels are expected.

2.8 - Transmission Corridor

The transmission corridor consists of four segments: the Anchorage-Willow line and the Fairbanks-Healy line (called "Stubs"), the Willow-Healy Intertie, and the Gold Creek-Watana line.

The Intertie will extend from Willow to Healy, where it will ultimately connect with Susitna Hydroelectric Project features referred to as "Stubs." The Intertie is planned to be constructed in 1983. It will be a 170-mile (274 km) long facility constructed basically of guyed steel "X" poles. Angle structures will be three separate vertical pole structures with single-pole hillside structures. At initial construction, the intertie line will be energized at 138 kV.

When the Watana Project comes on line in 1993, a second parallel line will be added to the Intertie, the "Stubs" will be constructed at the two ends, the lines will be energized to 345 kV, and a switchyard built near Gold Creek to connect with Watana power. In 2002, when Devil Canyon comes on line, a third parallel line will be built on the Gold Creek to Willow portion of the line, and the Willow to Anchorage stub will also have a third line.

2.8 - Transmission Corridor

2.8.1 - Flows

Water bodies in each of the four sections will be crossed by the transmission line. Most of these are small creeks in remote areas of the region, but each segment has some major stream crossings. Data are limited on the small streams, both with respect to water quantity and water quality. Most of the major crossings, however, have been gaged at some point along their length by the USGS. Major stream crossings are identified below. Pertinent gage records are summarized in Table E.2.33.

The Anchorage-Willow segment will cross Knik Arm of Cook Inlet with a submarine cable. Farther north, major stream crossings include the Little Susitna River and Willow Creek, both of which have been gaged.

The Fairbanks-Healy line will make two crossings of the Nenana River and one of the Tanana River, both large rivers and gaged.

The intertie route between Willow and Healy will cross several dozen small creeks, many of which are unnamed. Major streams include the Talkeetna, Susitna, and Indian Rivers; the East Fork and Middle Fork of the Chulitna River; the Nenana River; Yanert Fork of the Nenana River; and Healy Creek.

The final leg of the transmission corridor, from Gold Creek to Watana Dam, will cross only one major river: the Susitna. Two smaller but sizeable tributaries that will be crossed are Devil Creek and Tsusena Creek, neither of which have been gaged.

2.8.2 - Water Quality

Water quality data are limited for those streams and rivers that exist in close proximity to the proposed transmission corridors. A literature search by Dwight (1982) directed towards USGS suspended sediment data collection identified one continuous sampling location on the Nenana River at Healy. In addition, sparse periodic data are available for monitoring stations at the following locations: Nenana River near Windy, Healy Creek near Suntrana, Healy Creek at Suntrana, Healy Creek 0.1 mile (0.2 km) above French Gulch near Usibelli, Lignite Creek 0.5 mile (0.8 km) above mouth near Healy, Lignite Creek near Healy and Francis Creek 100 feet above Lignite Creek near Suntrana.

2.8 - Transmission Corridor

At the USGS Station 15518000 on the Nenana River near Healy, 13 years of continuous records revealed mean daily summer sediment concentrations ranging up to 8330 mg/l. Although no winter data were available, late September and October measurements were approaching concentrations of near zero. These data are indicative of the glacial origins at the river's headwaters. Although no additional water quality parameters were investigated by Dwight 1982, it is assumed that previously noted characteristics associated with tundra runoff will also be present in the Nenana and its tributaries.

3 - PROJECT OPERATION AND FLOW SELECTION

3.1 - Project Reservoirs

3.1.1 - Watana Reservoir Characteristics

The Watana Reservoir will be operated at a normal maximum operating level of El 2185 ft (666 m) above mean sea level, but will be allowed to surcharge to El 2190 ft (668 m) in late August during wet years. Average annual drawdown will be to El 2093 ft (638 m) with Watana operation and El 2080 ft (665 m) with Watana/Devil Canyon operation. The maximum drawdown for either operation scenario will be to El 2065 ft (630 m). During extreme flood events, the reservoir will rise to El 2193.3 ft (668.7 m) for the 1:10,000 year flood and El 2200.5 ft (670.9 m) for the probable maximum flood.

At El 2185 ft (666 m), the reservoir will have a surface area of 38,000 acres (15,200 ha) and a total volume of 9.47 million acre-feet as indicated in the area-capacity curves in Figure E.2.128. Maximum depth will be 735 feet (223 m) and the mean depth will be 250 feet (76 m). The reservoir will have a retention time of 1.65 years. The shoreline length will be 183 miles (295 km). Within the Watana reservoir area the substrate classification varies greatly. It consists predominantly of glacial, colluvial, and fluvial unconsolidated sediments and several bedrock lithologies. Many of these deposits are frozen.

3.1.2 - Devil Canyon Reservoir Characteristics

Devil Canyon reservoir will be operated at a normal maximum operating level of El 1455 ft (441 m) above mean sea level. Average annual drawdown will be 28 feet (8.5 m) with the maximum drawdown equalling 50 feet (15 m). At El 1455 ft (441 m) the reservoir has a surface area of 7800 acres (3120 ha) and a volume of 1.09 million acre-feet. Figure E.2.129 illustrates the area capacity curve of the reservoir. The maximum depth will be 565 feet (171 m) and the mean depth will be 140 feet (42 m). The reservoir will have a retention time of 2 months. Shoreline length will total 76 miles (123 km). Materials forming the walls and floors of the reservoir area are composed predominantly of bedrock and glacial, colluvial, and fluvial materials.

3.2 - Simulation Model and Selection Process

A multi-reservoir energy simulation model was used to evaluate the optimum method of operating the Susitna Hydroelectric project for a range of post-project flows at the Gold Creek gaging station 15 miles (24 km) downstream from the Devil Canyon damsite.

The simulation model incorporates several features which are satisfied according to the following hierarchy:

- Minimum downstream flow requirements;
- Minimum energy demand;
- Reservoir operating rule curve; and
- Maximum usable energy level.

The physical characteristics of the two reservoirs, the operational characteristics of the powerhouses, and either the monthly or weekly average flow at each damsite and Gold Creek for the number of years to be simulated are required as input to the simulation program. The program operates the two reservoirs to produce the maximum possible average annual usable energy while satisfying the criteria listed above. First, the minimum flow requirement at Gold Creek is satisfied. Next, the minimum energy requirement is met. The reservoir operating rule curve is checked and if "extra water" is in storage, the "extra water" is used to produce additional energy up to the maximum usable energy level. There is a further consideration that the reservoir cannot be drawn below the maximum allowable drawdown limit. The energy produced, the flow at the damsites and at Gold Creek, and the reservoir levels are determined for the period of record input to the model.

The process that led to the selection of the flow scenario used in this license application includes the following steps:

- Determination of the pre-project flows at Gold Creek, Cantwell, Watana, and Devil Canyon for 32 years of record;

- Selection of the range of post-project flows at Gold Creek to be included in the analysis;

- Selection of timing of flow releases to match downstream fishery requirements;

- Determination of the energy produced and net benefits for the seven flow release scenarios[1/] being studied;

- Consideration of the influence of instream flow and fishery needs on the selection of project operational flows;

- Selection of a range of acceptable flows based on economic factors, fishery, and instream flow considerations; and

- Selection of the maximum drawdown at Watana.

A summary discussion of the detailed analysis is presented in the following paragraphs.

3.3 - Pre-project Flows

As discussed in Section 2.2.1 of Chapter 2, the 32-year discharge record at Gold Creek was combined with a regional analysis to develop a

[1/] Three additional flow regimes were investigated with respect to project economics. These regimes are discussed in Exhibit B, pp. B-2-123 through B-2-128 and are identified as Cases E, F, and G.

3.3 - Pre-Project Flows

32-year record for the Cantwell gage near Vee Canyon at the upper end of the proposed Watana reservoir. The flow at Watana and Devil Canyon was then calculated using the Cantwell flow as the base and adding an incremental flow proportional to the additional drainage area between the Cantwell gage and the damsites.

The available 32-year record was considered adequate for determining a statistical distribution of annual energies for each annual demand scenario considered, and hence, it was not considered necessary to synthesize additional years of record.

The 32-years of record contained a low flow event (water year 1969) with a recurrence interval of approximately 1000 years as illustrated in Figure E.2.23. This water year (WY) was adjusted to reflect a low flow frequency of 1:30-years since a 1:30-year event represents a more reasonable return period for firm energy used in system reliability tests.

Although the frequency of the adjusted or modified year is a 1:30-year occurrence, the two year low flow frequency of the modified WY 1969 and the succeeding low flow WY 1970 is approximately 1:100 years. The unmodified two year low flow frequency is approximately 1:250 years. This two-year low flow event is important in that, if the reservoir is drawn down to its minimum level after the first dry year, the volume of water in storage in the reservoir at the start of the winter season of the second year of the two-year sequence, will be insufficient to satisfy the minimum energy requirements. Hence, the modified record was adopted for use in the simulation studies (refer to Section 3.8 for the effect of this change on firm energy and average energy).

The 1:30 year annual volume was proportioned on a monthly basis according to the long term average monthly distribution. This increased the WY 1969 average annual discharge at Gold Creek 1600 cfs, from 5600 cfs to 7200 cfs, and the average annual discharge at Gold Creek for the 32 years of record by 0.5 percent. The resulting monthly flows at Watana, Devil Canyon, and Gold Creek are presented in Tables E.2.6, E.2.7, and E.2.8.

3.4 - Project Flows

3.4.1 - Range of Flows

A range of project operational target flows from 6000 to 19,000 cfs at Gold Creek were analyzed. The flow at Gold Creek was selected because it was judged to be representative of the Devil Canyon-to-Talkeetna reach where downstream impacts will be the greatest. Additionally, the flows can be directly compared with the 32 years of discharge records at Gold Creek.

3.4 - Project Flows

The range of project flows analyzed included the operational flow that would produce the maximum amount of usable energy from the project, neglecting all other considerations (referred to as Case A) and the operational flow which would have resulted in essentially no impact on the downstream fishery during the anadromous fish spawning period (referred to as Case D)[1/]. Between these two end points, five additional flow scenarios were analyzed.

In Case A, the minimum target flow at Gold Creek for the month of August and the first half of September was established at 6000 cfs. Flow was increased in increments of 2000 cfs for the August-September time period, thereby establishing the target flow for Cases A1, A2, C, C1, and C2. The August-September flow for Case D was established at 19,000 cfs. The resulting seven flow scenarios were adequate to define the change in project economics resulting from a change in project flow requirements. The monthly minimum target flows for all seven flow scenarios are presented in Table E.2.34 and Figure E.2.130.

3.4.2 - Timing of Flow Releases

In the reach of the Susitna River between Talkeetna and Devil Canyon, it is perceived that an important aspect of maintaining natural sockeye and chum salmon reproduction is providing access to the slough spawning areas hydraulically connected to the mainstem of the river. Access to these slough spawning areas is primarily a function of flow (water level) in the main channel of the river during the period when the salmon must gain access to the spawning areas. Field studies during 1981 and 1982 have shown that the most critical period for access is August and early September. Thus, the project operational flow has been scheduled to satisfy this requirement; i.e., the flow will be increased the last week of July, held constant during August and the first two weeks of September, and then decreased to a level specified by energy demands in mid September. Alternative modes that release the same volume of water but as short-term augmented flows are also being evaluated.

3.5 - Energy Production and Net Benefits

The reservoir simulation model was run for the seven flow cases. Monthly energies were determined for the 32 years of simulation assuming the year 2002 energy demand for Watana operation and 2010 for Watana/Devil Canyon operation. It was assumed that the distribution of energies obtained in the year 2002 simulation would apply for years 1993 to 2002 and the 2010 simulation would apply for the years 2002 to 2010. Beyond year 2010, the demand was assumed to remain constant.

[1/] Three additional flow regimes were investigated with respect to project economics. These regimes are discussed in Exhibit B, p. B-2-123 through B-2-128 and are identified as Cases E, F and G.

3.6 - Fishery and Instream Flow Impacts on Flow Selection

To determine the net economic value of the energy produced by the Susitna Hydroelectric Project, the mathematical model commonly known as OGP 5 (Optimized Generation Planning Model, Version 5, General Electric Co. 1979), was used to determine the present worth cost (1982 dollars) of the long-term (1993-2051) productions costs (LTPWC) of supplying the Railbelt energy needs by various alternative means of generation. A more detailed description of the OGP 5 model is contained in Exhibit B, Section 1.5. The analysis was performed for the "best thermal option" as well as for the seven flow scenarios for operating Susitna. The results are presented in Table E.2.35.

The net benefit presented in Table E.2.35 is the difference between the LTPWC for the "best thermal option" and the LTPWC for the various Susitna options. In Table E.2.35, Case A represents the maximum usable energy option and results in a net benefit of $1234 million. As flow is transferred from the winter to the August-September time period for fishery and instream flow mitigation purposes, the amount of usable energy decreases. This decrease is not significant until the flow provided at Gold Creek during August reaches the 12,000 to 14,000 cfs range. For a flow of 19,000 cfs at Gold Creek, a flow scenario that represents minimum downstream fishery impact, approximately 46 percent of the potential project net benefits have been foregone.

3.6 - Fishery and Instream Flow Impacts on Flow Selection

3.6.1 - Susitna River Fishery Impacts

As noted earlier, the primary function controlled by the late summer flow is the ability of the salmon to gain access to their traditional slough spawning grounds. Instream flow assessment conducted during 1981 (the wettest July-August on record) and 1982 (one of the driest July-August on record) has indicated that for flows of the Case A magnitude, severe impacts would occur which cannot be mitigated except by compensation through hatchery construction and operation1/.

For flows in the 12,000 cfs range (flows similar to those that occurred in August, 1982) the salmon can, with difficulty, obtain access to their spawning grounds. To insure that the salmon can always obtain access to spawning areas during a flow of 12,000 cfs, a series of habitat alteration techniques are incorporated into the mitigation plan presented in Section 2.4.4(a) of Chapter 3, Exhibit E. Because Case A, A1, and A2 flow scenarios are not expected to allow habitat alteration to mitigate the impacts caused by the changed flows, the lowest acceptable flow range was established at approximately 12,000 cfs (Case C) at Gold Creek during August.

1/The relationship between mainstem discharge and hydraulic characteristics of the sloughs is described for four sloughs in Appendix E.2.A.

3.6 - Fishery and Instream Flow Impacts on Flow Selection

3.6.2 - Tributary Fishery Impacts

Since three salmon species (chinook, coho, and pink) use the clear water tributaries for essentially all their spawning activities and chum use the tributaries for most of their spawning, a second primary concern relative to post-project flow modifications is maintaining access into the tributaries: i.e, the mouths of the tributaries cannot be permitted to become perched as a result of reduced mainstem stages. However, a tributary's response to perching is a function of its flow and the size of bed material at its mouth, neither of which will be affected by the post-project change in mainstem flow. Thus, perching of tributaries is more dependent on tributary characteristics than on the operational scenario selected.

Recent studies (R&M 1982f) have shown that for post-project flows, most of the tributaries will not become perched (Table E.2.27). However, eight tributaries showed potential for perching. Of these three named tributaries, Little Portage Creek (RM 117.8), Deadhorse Creek (RM 121.0), and Sherman Creek (RM 130.9), and two unnamed tributaries are not considered to be significant salmon streams (ADF&G comments on the November 15, 1982 Draft Exhibit E). If one of the three tributaries that provide some spawning potential does become perched, the entrance to the stream will be regraded so that salmon can gain access to traditional spawning areas.

3.6.3 - Other Instream Flow Considerations

(a) Downstream Water Rights

Water rights in the Susitna basin are minimal (see Section 2.6.1). Therefore, since all flow scenarios provided more than enough flow to meet downstream water rights, it was not a factor in minimum flow selection.

(b) Navigation and Transportation

As discussed in Section 2.6.3(a), an impact on navigation during the open water period could occur in the Sherman area with Gold Creek flows of 6000 cfs. However, if navigation problems develop, mitigation measures will insure that navigation is not affected (Section 6.3). Since minimum flows in May through September for Cases C, C1, C2, and D are 6000 cfs and since mitigation measures will be implemented if necessary, navigation was not considered to be a factor in selecting an appropriate operating flow scenario from among Cases C, C1, C2, and D[1/]. Cases A, A1, and A2 have minimum flows that are less than 6000 cfs and the minimum flows for these cases could lead to increased mitigation difficulty.

[1/] In Exhibit B, pp. 121 through 128, three additional regimes, Cases E, F, and G were considered.

From a navigation perspective Cases A, A1, and A2 are less acceptable than Cases C, C1, C2, and D.

(c) Recreation

Recreation on the Susitna River is closely associated with navigation and transportation, and the fishery resource. Since the Susitna River below Devil Canyon will be navigable during the summer months at all minimum flow scenarios because of the incorporated mitigation measures, the boating aspect of recreation was not a factor in the flow selection process. However, from a fishery perspective, if fishery habitat is lost, this could reduce the recreational potential of the fishery. At the Case A, A1, and A2 flows, there is some impact on the sockeye and chum fishery. For flows equal to or greater than Case C flows, the fishery impact can be mitigated. Hence, Case C or greater flows should be selected as the minimum operational flow based on recreational considerations.

The summer water quality improvement in turbidity, which will enhance the recreation potential of the area would be the same for all cases and thus was not a factor in flow selection.

(d) Riparian Vegetation and Wildlife Habitat

Riparian vegetation is affected by one or more of the following: floods, freezeup, and spring ice jams. Minimum flow selection for the cases considered is unrelated to any of these factors. Hence, riparian vegetation effects were not considered in minimum project flow selection.

Riparian vegetation is likely affected by the freezeup process, ice jams, and spring floods in the Devil Canyon-to-Talkeetna reach (Section 2.6.5). In the Talkeetna-to-Yentna and Yentna-to-Cook Inlet reaches, spring flooding likely has the major impact on riparian vegetation. Since spring floods in the Susitna River will be reduced from Watana to Cook Inlet (Section 4.1.3(a)(iii)), it may be desirable to maintain riparian vegetation by simulating spring floods for a short period of time. However, the spring runoff storage is a key element of the project. Large releases for even a few days would have a severe economic impact on the project. Hence, no minimum flood discharges were considered.

3.8 - Maximum Drawdown Selection

If late August or September floods have an effect on riparian vegetation, there would essentially be no difference between the flow cases. This is because minimum flows would not govern operation of the reservoir because the reservoir would be full and outflow would be set equal to inflow up to the capacity of the release facilities, thereby providing occasional high flows downstream during late August and September.

(e) Water Quality

The pre- and post-project downstream summer temperatures will be essentially the same for all cases, although the lower discharges would be slightly warmer during summer and would exhibit a faster temperature response to climatic changes.

The waste assimilative capacity for all cases will be adequate at a flow of 4000 cfs. All other water quality parameters will essentially be the same for all flow scenarios.

(f) Freshwater Recruitment to Cook Inlet Estuary

The change in salinity in Cook Inlet will essentially be the same for all seven flow scenarios although the higher minimum flows (Case D) will exhibit a salinity pattern closer to the natural condition. This was not considered significant in the flow selection process.

3.7 - Operational Flow Scenario Selection

Based on the economic analysis discussed above, it was judged that, while cases A, A1, and A2 flows produced essentially the same net benefit, the loss in net benefits for Case C is of acceptable magnitude. The loss associated with Case C1 is on the borderline between acceptable and unacceptable. However, as fishery and instream flow impacts (and hence mitigation costs associated with the various flow scenarios) are refined (see Table E.3.39 in Chapter 3), the potential decrease in mitigation costs associated with higher flows will not offset the loss in net benefits. Thus, selecting a higher flow case such as C1 cannot be justified by savings in mitigation costs. The loss in net benefits associated with Cases C2 and D are considered unacceptable and the mitigation cost reduction associated with these higher flows will not bring them into the acceptable range.

3.8 - Maximum Drawdown Selection

The Watana reservoir is used to redistribute the flow from the summer runoff period to the winter high energy demand period. The maximum reservoir drawdown is used to produce firm energy during a low flow sequence, which is usually one to two years in duration for the Susitna River above Gold Creek. The drawdown of the Devil Canyon reservoir is used either to provide the specified minimum downstream fishery flow during August and early September or to produce firm energy in April or early May during those years when the Watana reservoir has reached its maximum drawdown limit.

During the Susitna Hydroelectric Feasibility Study (Acres 1982b) the maximum drawdown of the Watana reservoir for power generation purposes was selected as 140 feet (43 m) and for the Devil Canyon reservoir as 50 feet (15 m). The 140-foot (43 m) drawdown was determined to be optimal for the Case A operational flow scenario. However, the maximum drawdown was re-evaluated for two reasons. As more flow is released for instream flow purposes during the summer season, less live storage volume is required on an annual basis to redistribute the remainder of the summer runoff into the winter high energy demand period. On the other hand, during a low flow year, less flow is available from reservoir storage because of the additional downstream flow requirements. The net effect may influence the maximum drawdown required and was therefore reassessed.

In addition, in the Case A scenario presented in the Susitna Hydroelectric Feasibility Study (Acres 1982b), the maximum drawdown was required for two years in the 32-year simulation period. For the other 30 years, the maximum drawdown was approximately 100 feet (30 m). Therefore, the frequency of the two-year low flow sequence that was controlling the maximum drawdown was reexamined to determine if the severity of the two-year dry spell was too conservative a basis for determination of the maximum drawdown. As discussed in Section 3.3, WY 1969 was modified to reflect a more representative planning period.

Taking into account the minimum downstream flow considerations, the average annual and firm energy production, and the intake structure cost, the reevaluation process resulted in the selection of 120 feet (37 m) as the maximum drawdown for the Watana reservoir with the Case C scenario. Because the Devil Canyon maximum drawdown is controlled by technical considerations, the 50-foot (15 m) drawdown was not reconsidered and has been retained as the limit for Devil Canyon.

The modified record had little effect other than on maximum drawdown which is controlled by the minimum annual (or firm) energy production, and vice versa. It has minimal effect on average flow, increasing the flow at Gold Creek by 0.5 percent over the unmodified record. Average annual energy increased by the same 0.5 percent. Project operation differed from the unmodified record only during the two-year low flow period and the succeeding one-year recovery period.

3.8 - Maximum Drawdown Selection

The downstream flow requirement at Gold Creek will be met at all times unless both the Watana and Devil Canyon reservoirs are drawn down to their minimum level and the natural flows at Gold Creek are less than the flow requirement. The possibility of this occurring in the summer months is remote. Even if a two-year low flow event with a recurrence interval greater than 100 years occured, downstream flows would be provided at all times. Only during a late spring breakup, occuring after a severe two-year low flow event when both reservoirs are drawdown to their minimum elevation would there be a possibility of not meeting the downstream flow requirement.

4 - PROJECT IMPACT ON WATER QUALITY AND QUANTITY

4.1 - Watana Development

For details of the physical features of the Watana development, refer to Section 1 of Exhibit A.

4.1.1 - Watana Construction

(a) Flows and Water Levels

During construction of the diversion tunnels, the flow of the mainstem Susitna will be unaffected. Upon completion of the diversion facilities in the autumn of 1986, closure of the upstream cofferdam will be completed and flow will be diverted through the lower diversion tunnel without any interruption in flow. Although flow will not be interrupted, a 1-mile (1.6 km) section of the Susitna River will be dewatered. (The fishery impacts resulting from this action are discussed in Chapter 3).

Flows, velocities, and associated water levels upstream from the proposed Watana damsite will be unaffected during construction except for approximately one-half mile (0.8 km) upstream from the upstream cofferdam during winter, and 1 mile (3 km) upstream during summer flood flows. During winter, ponding to El 1470 ft (449 m) will be required to form a stable ice cover. However, the volume of water contained in this pond will be insignificant relative to the total river flow.

During the summer, the diversion intake gates will be fully opened to pass the natural flows resulting in a run-of-river diversion. All flows up to approximately 30,000 cfs will be passed through the lower diversion tunnel. Average velocities through the tunnel will be 13 and 26 feet per second (fps) (4 to 8 m per sec) at discharges of 15,000 and 30,000 cfs, respectively. The mean annual flood of 40,800 cfs will cause higher than natural water levels for approximately 1 mile (1.6 km) upstream from the cofferdam. At the upstream cofferdam, the water level will rise from a pre-diversion natural river level of El 1468 ft (448 m) to El 1500 ft (457 m). One mile (1.6 km) upstream, the water level will be about 2 feet (0.6 m) higher than the natural level during the mean annual flood.

The two diversion tunnels are designed to pass the routed 1:50-year flood of 87,000 cfs with a maximum water surface elevation of 1536 ft (468 m). For flows up to the 1:50 year flood event, water levels and velocities downstream of the diversion tunnels will be the same as pre-project levels.

Floods greater than the 1:50-year event could overtop the Watana cofferdams and cause failure of the cofferdams. If a flood event of a magnitude large enough to overtop the cofferdam did occur, the only location within 80 miles downstream from the cofferdam where damage would occur is the main dam construction site. If the main dam height is less than the cofferdam when overtopping occurs, significant losses would occur. However, if the main dam is somewhat higher than the cofferdam when overtopping occurs, no damage is anticipated. Although damage could occur further downstream, the relatively small volume of the head pond and the attenuation of the flood wave as it moves downstream would significantly reduce the potential for downstream flooding.

(b) River Morphology

Since changes in flow will be negligible during Watana construction, impacts on river morphology will be confined to the dam and borrow sites. As previously stated, a one-mile segment of the Susitna River will be dewatered for construction of the main dam. The morphology at the primary borrow areas, Borrow Sites E, I, and L, will incur the greatest impacts. They are illustrated in Figure E.2.131. Borrow Sites J, if developed, and L will be inundated by the Watana reservoir. Borrow Site E will become a deep pool in the river. The river at Borrow Site I will become a deeper and wider channel. These areas will have no opportunity to fill with sediment once reservoir impoundment begins. Local morphological changes may occur near these sites in the period between Watana construction and Devil Canyon construction. However, both sites will be inundated once Devil Canyon Dam is constructed.

(c) Water Quality

(i) Water Temperature

Since the operation of the diversion structure will essentially be run-of-river, no impact on the temperature regime will occur downstream from the tunnel exit. A small amount of ponding will occur early in the freezeup stage to enhance the formation of a stable ice cover upstream from the tunnel intake. This will have no detectable effect on water temperatures.

(ii) Ice

During freezeup, the formation of a stable upstream ice cover facilitated by the use of an ice boom and some ponding to reduce approach velocities, will serve to protect the diversion works from ice damage or blockage and maintain its flow capacity. The early formation of the ice cover at this point will cause a more rapid ice front progression upstream from the damsite. The ice generated in the upper reach, which normally feeds the downstream ice growth, will no longer be available. However, because of the presence of a natural lodgement point immediately downstream from Watana (Photograph E.2.2), frazil ice upstream from Watana does not significantly contribute to the ice cover formation downstream from this lodgement point under the natural regime. Hence, no appreciable impact on ice formation downstream from Watana will occur as a result of the diversion scheme. The major contributor of frazil ice will continue to be the rapids through the Devil Creek to Devil Canyon reach as it is now (R&M 1982d).

The ice cover upstream from the damsite will thermally decay in place, since its movement downstream will be restricted by the diversion structure. Downstream from Devil Canyon, the ice cover volume will be the same as baseline conditions, and breakup will likely be similar to natural occurrences.

(iii) Suspended Sediments/Turbidity/Vertical Illumination

During construction, suspended sediment concentrations and turbidity levels are expected to increase within the impoundment area, and for some distance downstream. This will result from the necessary construction activities within and immediately adjacent to the river, including dragline excavation of gravel from borrow areas E and I, gravel processing, construction of the diversion tunnels, placement of cofferdams, clearing the construction site of vegetation and spoil material, and clearing the reservoir area of vegetation prior to impoundment.

The excavation of the material from the proposed borrow sites will create the greatest potential for problems due to increased suspended sediment and turbidity. The originally considered borrow sites are identified in Figure E.2.131. However, the primary borrow sites currently envisioned include D, L, E and I. The balance of the sites have been abandoned because of environmental reasons, economic or engineering constraints, or are now being considered only as backup sites.

Quarry Site L, located adjacent to the upstream cofferdam (Figure E.2.132), is considered a potential source for rock. Located wholly within the proposed reservoir, this 20-acre site is estimated to contain 2.5 million cy of rock. With careful removal of the vegetative and organic layers, the absence of work in the river channel and no tributaries in the immediate area, not siltation problems are envisioned.

Borrow Site D (Figure E.2.133) is the selected source of impervious and semi-pervious materials consisting of glacial tills for use in the cores of the main dam, cofferdam, freeboard dike, and the emergency spillway fuse plug. The site covers approximately 1150 acres and contains an estimated 180 million cy of alluvial material, from which 8.5 to 9 million cy of optimum materials would be mined. Borrow Site H is an alternative for this material; however, Site D is more desirable because of lower moisture content, less permafrost, material stratification, and its close proximity to the damsite and support facilities.

Selecting mining of the material will occur during the summer months (May-September) utilizing blocks of material that have been pre-drained with lateral perimeter ditches. All runoff will be collected and directed towards settling ponds prior to discharge into Deadman Creek or the Susitna River. No work is scheduled in or immediately adjacent to Deadman Creek, and therefore, no significant erosion control problems are anticipated. However, several small lakes within the area will be drained as a result of the mining activities.

The organic layer will be stripped and stockpiled prior to construction. Subsequent to disturbance, the mined-out pits will be continuously reclaimed with appropriate materials and techniques. Portions of the site will be within the annual reservoir drawdown zone and will be stabilized to control slumping.

Borrow Site E (Figure E.2.134), with an areal extent of approximately 800 acres, is proposed as the primary source of aggregate (52,000,000 cubic yards or 40 million cubic meters) for the gravel filters and shells of the dam and concrete. Borrow Site I, located immediately downstream as noted in Figure E.2.135, will also be used to obtain adequate supplies of aggregate.

4.1 - Watana Development

Mining is scheduled to begin just upstream from the natural (bedrock) flow restriction weir in Borrow Site I. A large dragline will be operated from the north shore, extending across the river and excavating up to 100 feet below river level. Subsequent mining will proceed upriver and to the north into the floodplain. River mining will only be conducted during the summer when high levels of suspended sediments and turbidity already exist. In addition, once this large pool is excavated, the impacts from subsequent upstream work should be significantly reduced by the sedimentation that will occur in this instream settling basin.

Assuming a one percent loss in material to the river during the summer construction period, there would be about a 4 percent increase in suspended sediment load over 1982 levels. Stockpiling of gravel will alleviate the need for wet excavation during winter when the impact from siltation to incubating eggs would be greatest. As a result of the proposed scheduling of activities, impacts will be minimized. However, it is inevitable that there will be some increases in suspended sediments and turbidity during winter, but these will be short term and localized. Downstream from Talkeetna, turbidity and suspended sediment levels should remain essentially the same as baseline conditions.

Decreases in winter vertical illumination are expected to be commensurate with any increased suspended sediment concentrations. However, because summer vertical illumination is naturally limited by high suspended sediment concentrations, elevated levels of suspended sediments and turbidity resulting from construction activities will have essentially no effect on summer vertical illumination.

The second major potential source of suspended sediments is the processing and deposition of borrow material. The primary processing operation of granular materials for dam construction will produce, over a 6 year period, 10 to 15 million cubic yards (7.6 to 11.4 million cubic meters) of waste materials ranging in size from oversize rock to silt and clay. Most of this material will be moved from the process plant by truck or belt conveyer and used to selectively backfill portions of the borrow area by placing the material at a depth to avoid entrainment in the river. About 2 to 3 million cubic yards (1.5 to 2.3 million cubic meters) will be suspended silt and clay in the wash water.

The wash water will be directed into a series of settling ponds. Considerable silt will settle out immediately after discharge, hence control of the discharge end will be necessary to spread the material. Silt and clay remaining in suspension will be settled by passing the water through additional settling ponds before discharging into the river. Control of flow between ponds will be regulated through gated culvert pipes. It is expected that much of the water will re-enter the Susitna by seeping through the granular soil in dikes between the disposal area and the river. This in itself will ensure that fines are removed from the water.

A secondary processing plant for concrete aggregates and filter gravels will be located at Borrow Site E. A limited amount of spoil will be produced by this aggregate processing plant which will be controlled by running the wash water into settling ponds as described above. It is estimated that 200,000 to 300,000 cubic yards (150,000 to 230,000 cubic meters) of fine sand, silt and clay will be produced by this operation. These wastes will be completely disposed of within the excavation area in a manner that will preclude their introduction into the river.

Summer flows will be passed through the diversion tunnel with no impoundment. Hence, no settling of suspended sediments being carried naturally by the river is expected to occur. The insignificant head pond that will be maintained during winter is not expected to affect the low suspended sediment and turbidity levels present during the winter season.

(iv) Nutrients and Organics

Increased concentrations of nutrients and organic compounds could occur as a result of the disturbance of vegetation and soil cover and the subsequent erosion of overburden and spoil materials. These potential impacts will be minimized by the careful removal and either burning or stockpiling by methods that will preclude their introduction into the watershed.

These spoil materials will latter be reused to rehabilitate construction impacted areas.

(v) Metals

Increases in the concentration of trace metals will result from construction disturbances to soils and rock on the river bank and in the riverbed. As noted in Section 2.3.8(k), many metals currently exceed established criteria. As such, increases are not expected to create adverse conditions in the aquatic ecosystem.

(vi) Contamination by Petroleum Products

Accidental spillage and leakage of petroleum products could contaminate surface water and ground water during construction. Lack of maintenance and service of vehicles could increase the leakage of fuel, lubricating oil, hydraulic fluid, and antifreeze. In addition, improper storage and handling techniques could lead to accidental spills. Large quantities of petroleum products, especially diesel fuel, will be stored on site. Given the dynamic nature of the Susitna River, the contaminated water from small oil spills would be quickly diluted. However, spills in the smaller clearwater streams could be deleterious to aquatic residents. In addition, spills that occur during winter are extremely difficult to contain.

All state and federal regulations governing the prevention and reclamation of accidental spills, including the development and implementation of a Spill Prevention, Containment and Countermeasure Plan (SPCC), will be adhered to as described in Sections 6.2 and Chapter 3, Section 2.4.3(e)(ii).

(vii) Concrete Contamination

Construction of the Watana project will create a potential for concrete contamination of the Susitna River. The wastewater and waste concrete associated with the operation of a concrete batch plant, if directly discharged to the river, could seriously degrade downstream water quality and result in substantial mortality of fish.

Approximately 500,000 cubic yards (cy) (380,000 cubic meters) of concrete will be placed at Watana. The use of an efficient central batch plant will reduce problems with waste concrete.

The production of concrete for the various permanent structures will produce 10,000 cy (7600 cubic meters) of waste material. Approximately one-half this quantity will be rejected concrete which will be disposed either by haulage directly to an upstream rock disposal area or dumped, allowed to harden and disposed in an excavated area.

The other one-half of the waste will be material washed from mixing and hauling equipment. This waste concrete will be processed through a washer/separator/classifier to provide aggregates for reuse. The wash water will be stored in a lined pond until its specific gravity drops to a point which allows its reuse as mixing water for batching new concrete. This system will minimize the waste water effluent to be returned to the river.

At concrete placement areas the wash water resulting from the cleanup of placing equipment, curing and green cutting will be collected in sumps and pumped to a series of settling ponds to remove most of the suspended materials before the effluent is discharged into the river. Ponds will generally be unlined, with sand filters to ensure removal of most waste products. Neutralization of wastewater will be conducted as required to obtain proper pH levels. It is expected that control of toxic chemicals in the effluent will be accomplished through careful selection of concrete additives, the provision of filters for effluent and the close monitoring of operations by the Construction Manager.

Airborne particulates are a second potential pollution problem related to concrete batching plants. No significant dust problems are anticipated since a modern control batch plant fully enclosed for winter operational requirements is envisioned. In addition, the transfer of materials will be facilitated through pipes, hence, dust should be further contained.

(viii) Other

No additional water quality impacts are anticipated.

(d) Ground Water Conditions

Since there will be no change in mainstem discharge and no change in water level other than in the localized area of the project, no ground water impacts are expected either upstream or downstream from the construction area. However, in the construction area, ground water impacts will likely result from the construction activity.

The relict channel at Watana has previously been identified as an area of potential ground water seepage problems after Watana Reservoir is filled (Acres 1982b). It lies within the drainage between Deadman Creek to the east, the Susitna River to the south, and Tsusena Creek to the west and northwest. Ground water gradients in the unconsolidated sediments of the channel are principally towards Tsusena and Deadman Creeks with the diorite pluton at the damsite acting as a ground water barrier to the south.

The ground water regime in the relict channel is complex and poorly understood due to the presence of intermittent permafrost, aquicludes, perched water tables, and confined aquifers. Possible artesian or confined water tables exist in several of the stratigraphic units while other units appear to be unsaturated.

Permeability testing indicate the range of average permeability in the more gravelly materials is about 10^{-3} cm/sec (3 ft/day), while the tills and lacustrine deposits can be estimated at about 10^{-4} to 10^{-5} cm/sec (0.3 to 0.03 ft/day).

Assuming worst case conditions, an estimated maximum seepage rate through the relict channel under full reservoir conditions would be approximately 9-10 cfs, which is not considered significant to the project operation.

Construction activities related to the relict channel will therefore, be limited to construction of the 10-foot (3 m) freeboard dike. However, during filling, the relict channel will be monitored with piezometers and at the outfall. If necessary, the outfall will be treated with a filter blanket to minimize the risk of piping.

(e) Lakes and Streams

As noted in (c)(iii) above, there will be impacts at the mouth of Tsusena Creek caused by excavation of material from

Borrow Site E. Figure E.2.134 provides a map of the area tentatively scheduled for disturbance.

The construction, operation, and maintenance of facilities to house and support construction personnel are expected to impact the Tsusena and Deadman Creek drainage basins and some of the small lakes located between the two creeks near the damsite. For more detailed discussions of these impacts refer to Support Facilities, Section (g) below.

(f) Instream Flow Uses

For all reaches of the Susitna River, except for the immediate vicinity of the Watana damsite, no impacts on navigation, transportation, recreation, fishery resources, riparián vegetation, wildlife habitat, waste load assimilation or the freshwater recruitment to Cook Inlet will occur for flows less than the 1:50-year flood event.

(i) Fishery Resources

During winter, the diversion gate will be partially closed to maintain a headpond at El 1470 ft (948 m). This will cause velocities greater than 20 fps (6 m/sec) at the gate intake. This velocity coupled with the 50-foot (15 m) depth at the intake will act as a barrier to resident fish passage.

During summer, the diversion gates will be fully opened. This will permit downstream fish movement during low flows of about 10,000 cfs (equivalent velocity of 9 fps (3 m/sec). Upstream migration is not anticipated. Higher flow rates and hence, velocities may lead to fish mortality.

The impacts associated with both winter and summer diversion tunnel operation are discussed in Chapter 3.

(ii) Navigation and Transportation

Since all flow will be diverted, there will be an impact on navigation and transportation only in the immediate vicinity of Watana dam and the diversion tunnel. The cofferdams will form an obstacle to navigation which will be difficult to circumvent. However, since this stretch of river has very limited use because of the rapids upstream and downstream from the site, impact will be minimal.

(iii) Riparian Vegetation

Existing shoreline vegetation immediately upstream from the cofferdam will be inundated approximately 30 feet (9 m) to El 1500 ft (457 m) during the mean annual flood. This flooding will be confined to a 1-mile (1.6 km) reach with the depth of flooding lessening with distance upstream. Since the flooding will be infrequent and temporary in nature and since the flooded lands are within the proposed reservoir, the impact is not considered significant. Further information on the impacts to riparian vegetation can be found in Chapter 3.

(g) Support Facilities

The construction of Watana will require the construction, operation, and maintenance of support facilities capable of providing the basic needs for a maximum population of 4720 people (3600 in the construction camp and 1120 in the village). The facilities, including roads, buildings, utilities, stores, recreation facilities, airport, etc., will be constructed in stages during the first three years (1985-1987) of the proposed ten-year construction period. The camp and village will be located approximately 2.5 miles (4 km) northeast of the Watana damsite, between Deadman and Tsusena Creeks. The location and layout of the camp and village facilities are presented in Plates F34, F36, and F37 of Exhibit F.

(i) Water Supply

Nearby Tsusena Creek will be utilized as the major source of water for the community (Plate F34). In addition, wells will be drilled in the Tsusena Creek alluvium as a backup water supply.

During construction, the required capacity of the water treatment plant has been estimated at 1,000,000 gallons per day, 700 gallons per minute or 2650 liters per minute (1.5 cfs) (Acres 1982a). With the use of the USGS regression equation described in Table E.2.32, a 30-day minimum flow with a recurrence interval of 20 years was estimated for Tsusena Creek near the water supply intake. This flow was estimated to be 17 cfs for the approximately 126 square miles (326 square km) of drainage basin. As a result, no significant adverse impacts are anticipated from the maximum water supply withdrawal of 1.5 cfs. Furthermore, a withdrawal of this magnitude will not occur during the low-flow winter months, since construction personnel will be reduced by approximately two-thirds from peak summer levels.

The water supply will be treated by chemical addition, flocculation, filtration, and disinfection prior to its use. Disinfection will probably be facilitated by the use of ozone to avoid the need for later dechlorination. In addition, the water will be demineralized and aerated, if necessary.

A water rights appropriation permit from the ADNR will be applied for. Presently, water rights appropriation permit ADL 203386-P (amended) is held by the Alaska Power Authority for use of 3000 gpd (11,350 liters per day) from a nearby unnamed lake for the 44-man Watana camp.

(ii) Wastewater Treatment

A secondary wastewater treatment facility will treat all wastewater prior to its discharge into Deadman Creek.

Treatment will reduce the BOD and TSS concentrations to levels acceptable to the Alaska Department of Environmental Conservation (ADEC) and the U.S. Environmental Protection Agency (EPA). The levels are likely to be 30 mg/l BOD and 30 mg/l TSS. In addition, wastewater will be treated with chlorine if necessary, to ensure that fecal coliform bacteria levels meet ADEC and EPA criteria. The maximum volume of effluent, 1 million gallons per day (3.8 million liters per day) or 1.5 cfs, will be discharged into Deadman Creek which has a winter low flow of 27 cfs (see below). Under the worst case flow conditions (maximum effluent and low flow in Deadman Creek), this will provide a dilution factor of about 17, thereby reducing BOD and TSS concentrations to about 2 mg/l after complete mixing. Thorough mixing will occur rapidly in the creek because of its turbulent nature.

The effluent is not expected to cause any degradation of water quality in the 1-1/2 mile (2.4 km) section of Deadman Creek between the wastewater discharge point and the creek's confluence with the Susitna River. Furthermore, no water quality problems are anticipated within the impoundment area or downstream on the Susitna River as a result of the input of this treated effluent.

With the use of the USGS regression analysis, the 1:20-year, 30-day low flow for Deadman Creek at the confluence with the Susitna was estimated at 27 cfs. Flow at the point of discharge, which is less than 2 miles (3.2 km) upstream, is not expected to differ significantly.

Construction of the wastewater treatment facility is expected to be completed in the first 12 months of the Watana construction schedule. Prior to its operation, all waste will be stored in a lagoon system for treatment at a later date. No raw sewage will be discharged to any water body.

Chemical toilets located throughout the construction areas will be regularly serviced to ensure proper treatment and disposal.

The applicant will obtain all the necessary ADEC, EPA, and ADNR permits for the water supply and wastewater discharge facilities. An ADEC wastewater disposal permit (WP 80-9) that allows the discharge of 4000 gpd (15,150 liters per day) of treated wastewater is presently held by the Alaska Power Authority for the existing Watana field camp.

Additional details pertaining to the proposed water supply and wastewater discharge facilities are available in the Susitna Hydroelectric Project Feasibility Report, Design Development Studies, Appendix B (Acres 1982a.

(iii) Construction, Maintenance, and Operation

Construction of the Watana camp, village, airstrips etc. will cause impacts to water quality similar to many of those occurring from dam construction. Increases in suspended sediment and turbidity levels are anticipated in the local drainage basins (i.e., Tsusena and Deadman Creeks). Even with extensive safety controls, accidental spillage and leakage of petroleum products could occur, creating localized contamination within the watershed. Additional discussions on the water quality impacts associated with facilities construction, operation, and maintenance are provided in Chapter 3, Section 2.3.1(a)(ii).

4.1.2 - Impoundment of Watana Reservoir

(a) Reservoir Filling Criteria

The filling of the Watana reservoir is scheduled to commence in May 1991 and will take three summer runoff periods before being completed. During filling, downstream flow requirements will be met and a flood storage safety factor maintained. Testing and commissioning of the powerhouse units will begin after the second summer of filling.

(i) Minimum Downstream Target Flows

Because of the naturally occurring low flows during winter, little water is available for filling the Watana reservoir during the winter season. Therefore, natural river flows will be maintained from November through April. During summer, runoff will be captured and stored in the reservoir in a manner similar to that which will occur during project operation. Therefore, the downstream flow requirements selected for project operation from May through September were adopted for the Watana reservoir filling period [see Sections 3.4.2 and 3.7]. The primary difference will be that the downstream flow requirements will be met by passage of water through the low level outlet rather than the powerhouse. Filling will continue during the month of October with the flow volume in excess of the downstream flow requirement being stored.

Table E.2.36 and Figure E.2.136 illustrate the targeted minimum Gold Creek flows. From May to the last week of July, the target flow will be increased to 6000 cfs to allow for navigation and mainstem fishery movement.

The 6000 cfs Gold Creek flow will provide a minimum river depth of 2 feet (0.6 m) for mainstem fishery movement at all 65 surveyed cross sections between Talkeetna and Devil Canyon as discussed in Section 2.6.3.

During the last 5 days of July, flow will be increased from 6000 cfs to 12,000 cfs in increments of approximately 1000 cfs per day. Flows will be maintained at 12,000 cfs from August 1 through mid-September to coincide approximately with the sockeye and chum spawning season in the sloughs upstream from

Talkeetna. Adverse impacts to the fishery resource resulting from this flow regime are discussed in Chapter 3.

Starting September 15, flows will be reduced to 6000 cfs in daily increments of 1000 cfs and then held constant until October when they will be further reduced to 2000 cfs. In November, natural flows will be released.

The minimum target flows at Gold Creek will be attained by releasing that flow necessary from the Watana impoundment which, when added to the flow contribution from the intervening drainage area between Watana and Gold Creek, will equal the minimum Gold Creek target flow. The minimum flow release at Watana from May through September will be 1000 cfs. During filling, flows at Gold Creek will be monitored and the flow at Watana adjusted as necessary to provide the required Gold Creek flow.

(ii) Flood Storage Protection

Taking into account the 30,000 cfs discharge capability of the low-level outlet, sufficient storage will be made available during the filling sequence so that flood volumes for all floods up to the 250-year recurrence interval flood can be temporarily stored in the reservoir without endangering the main dam. Whenever this storage criterion is violated, discharge from the Watana reservoir will be increased up to the maximum capacity of the outlet to lower the reservoir level behind the dam.

(b) Flows and Water Levels

(i) Simulation of Reservoir Filling

Taking into account the reservoir filling criteria, three reservoir filling sequences were simulated to determine the mean or likely filling sequence and probable deviations if wet or dry hydrologic sequences occurred during filling. Since approximately three years will be required to bring the reservoir to its normal operating level, three-year moving averages of the total annual flow volume at Gold Creek were computed from mean monthly flows. The probability of occurrence for each of the three year average values was then determined (Figure E.2.137). The annual flow volumes, with a 10 percent (wet), 50 percent (mean), and 90 percent (dry) change of exceedence, were then proportioned according to the long term average monthly Gold Creek flow distribution. This produced a synthesized Gold Creek monthly flow distribution. The same process was used to synthesize the 10, 50, and 90 percentile volumes and flow distributions at Watana. The intermediate flow contribution was taken as the difference between the Watana and Gold Creek monthly flows. The Watana and Gold Creek monthly flows for each of the three cases are identified as "pre-project" in Tables E.2.37 and E.2.38. The downstream flow criteria and the flow values at Watana and Gold Creek were then used to determine the filling sequence for each of the three cases by repeating the annual flow sequence for each percentile flow until the reservoir was filled.

The Watana reservoir water levels for each of the three filling cases considered are illustrated in Figure E.2.138. Under average conditions (50 percent case), the reservoir would fill sufficiently by autumn 1992 to allow testing and commissioning of the units to begin. However, the reservoir would not be filled to its normal operating level until the following summer. If the dry sequence were to occur, (90 percentile case) the reservoir would not be sufficently full to permit unit testing and commissioning until late spring 1993. If a wet sequence were to occur (10 percentile case) only about one month would be saved over the average filling time because the flood protection criterion would be violated and flow would be released rather than stored. The dry sequence and wet sequence each have a probability of occurrence of approximately 10 percent.

The Watana discharges for the high (10 percent), mean (50 percent), and low (90 percent) flow cases considered are compared to the Watana inflow in Table E.2.37. For the average hydrologic case, the May-October mean monthly flows are reduced up to 95 percent during the filling period. From November through April there is no change in flow during the filling period.

As previously stated, Gold Creek flows are considered representative for the Devil Canyon to Talkeetna reach. Percent changes in the flow at Gold Creek are similar to those at Watana but are somewhat reduced because of tributary inflow between Watana and Gold Creek. For the 50 percentile case, maximum mean monthly flow reduction is 78 percent (see Table E.2.38 and Figure E.2.138).

Flow will be altered in the Talkeetna to Cook Inlet reach, but because of significant tributary contributions, the impact on summer flows will be greatly reduced with distance downstream. Table E.2.39 is a comparison of mean pre-project monthly flows and monthly flows during reservoir filling at Sunshine and Susitna Station. Pre-project flows are based on the long-term average ratio between the respective stations and Gold Creek. Filling flows are pre-project flows reduced by the quantity of water stored in the reservoir. The maximum monthly flow reduction is 34 percent at Sunshine and 17 percent at Susitna Station.

(ii) Floods

The reservoir filling criteria dictates that available storage volume in the reservoir must provide protection for all floods up to the 250-year recurrence interval flood. Thus, the reservoir must be capable of storing the flood volume of a 1:250-year flood less the flow which can be discharged through the outlet facilities during the flood event. The maximum discharge of the outlet facilities at Watana is 30,000 cfs. The maximum flow of 30,000 cfs represents a substantial flood peak reduction. These flood peak reductions will be approximately maintained downstream to Cook Inlet. For example, the 1:50-year flood at Gold Creek would be reduced from 106,000 cfs to approximately 49,000 cfs.

After the flood event, the outlet facility will continue to discharge at its maximum capacity until the storage volume criterion is reestablished. This will cause the flood duration to be extended beyond its normal duration although at a greatly reduced discharge.

(iii) Flow Variability

Under natural conditions, substantial changes in flow can occur daily. This flow variability will be reduced during the filling process. Using August 1958 as an example, Figure E.2.139 shows the daily flow variation that occurs naturally. The August 1958 average flow of 22,540 cfs was close to the long term average monthly discharge of 22,000 cfs. Superimposed on Figure E.2.139 are the flow variations that would occur under filling conditions assuming the August 1958 flow occurred during the filling process. To obtain Curve (1) in Figure E.2.139, it was assumed that the reservoir storage criterion was violated (i.e., 30,000 cfs discharge at Watana). The second curve was obtained assuming the reservoir was capable of accommodating the entire inflow volume. Both Gold Creek filling hydrographs have reduced flood peaks.

In filling Sequence (1), outflow is greater than inflow at Watana on the receding limb of the hydrograph in order to reestablish the reservoir storage volume criterion. Hence, during this time period, the Gold Creek flow is greater than the natural flow. In this example, it was assumed that ongoing construction did not permit additional storage in the reservoir. In reality, the dam height will be increasing and additional storage would be permitted, thus reducing the required outflow from Watana. This would correspondingly reduce the Gold Creek discharge.

In filling Sequence (2), the Gold Creek flow is constant at 12,000 cfs. To maintain this constant flow, the flow release at Watana during the filling sequence would only be 4400 cfs at the natural Gold Creek flood peak of 47,800 cfs because flow from the drainage area between Watana and Gold Creek would contribute 7600 cfs to the flow at Gold Creek. The Watana contribution would be about 10,000 cfs when the natural Gold Creek flow drops to 12,000 cfs.

Farther downstream, the daily variation in flow for both sequences will increase and become similar to natural conditions, but would remain less than under natural conditions. The percent change from natural flow will become less because of the added tributary inflow.

(c) Testing and Commissioning

As reservoir filling nears completion and the reservoir level is above the minimum drawdown elevation, testing and commissioning of the powerhouse units will commence. This process may take several months and will require a number of tests for each unit. Every attempt will be made to commission the units so that the impact on downstream flow will be a minimum. The most severe fluctuations in flow could occur during the full load to off or off to full load tests when the flow through the turbine being tested will be quickly reduced from approximately 3500 cfs to 0 or increased from 0 to 3500 cfs, respectively. However, this will be compensated for by opening or closing the outlet facility gates or other units which have previously been tested in an effort to stabilize flow downstream. If testing is done during late summer, the additional downstream flow required from Watana and released through the outlet facilities will help to stabilize the flow. The natural attenuation of flow variation with distance downstream will also serve to stabilize the flow.

If testing occurs in winter and flow is less than 3500 cfs at Watana, flow will be gradually increased to 3500 cfs over a one day period and maintained at that level through the testing period. If testing is temporarily halted, flow will be gradually reduced to the natural flow.

(d) River Morphology

During filling of the Watana reservoir, the trapping of bedload and suspended sediment by the reservoir (Section (e) (iii) below) will greatly reduce the sediment being transported by the Susitna River in the Watana-Talkeetna reach. Except for isolated areas, bedload movement will remain limited over this reach because of the armor layer and the reduced flows. This is indicated by the bed material movement curves shown in Figure E.2.77 and in the River Morphology report (R&M 1982d). Bed material movement may occur in the regions of River Mile 124, 131-133, and near the confluence with the Chulitna River where bed material size is in the coarse gravel range, i.e., somewhat smaller than in most of the river between Devil Canyon and Talkeetna. The lack of suspended sediments will significantly reduce siltation in calmer areas. The Susitna River main channel will tend to become better defined with a narrower channel in this reach. The main channel river pattern will strive for a tighter, better defined meander pattern within the existing banks. A trend towards channel width reduction by encroachment of vegetation will begin. Tributary streams, including Portage Creek, Indian River, Gold Creek, and Fourth of July Creek, will extend their alluvial fans into the river.

4.1 - Watana Development

Figure E.2.140 illustrates the influence of the mainstem Susitna River on the sedimentation process that occurs at the mouth of the tributaries.

An analysis of 19 tributaries between Devil Canyon and Talkeetna was undertaken to determine which, if any, tributaries would become perched (R&M 1982f). The analysis indicated that eight tributaries showed a potential to perch (Table E.2.27). This is primarily the result of the large size bed material at the mouths of the tributaries. The remaining tributaries are expected to degrade.

Overflow into most of the side channels will not occur, as high flows will be reduced to a maximum of 30,000 cfs at Watana. The backwater effects at the mouths of side channels and sloughs will also be reduced. These factors will lead to vegetation encroachment in the side channels and sloughs. However, side channels and sloughs that are presently overtopped during the freezeup process will continue to be overtopped during freezeup and, hence, will have scouring flows of up to 3 feet per second (0.9 m/sec) [Section 2.3.2(a) and Section (e) (iii) below].

At the Chulitna-Susitna confluence, the Chulitna River is expected to expand and extend its alluvial deposits. Reduced summer flows in the Susitna River may allow the Chulitna River to extend its alluvial deposits to the east and south. However, high flows in the Chulitna River may cause rapid channel changes, inducing the main channel to migrate to the west. This would tend to relocate the deposition to the west (R&M 1982d).

Downstream from the Susitna-Chulitna confluence, the preproject mean annual bankfull flood will now have a recurrence interval of five to ten years. This will tend to decrease both the frequency and amount of bed material movement and, consequently, the frequency of changes in braided channel shape, form and network. A trend toward relatively stabilized floodplain features will begin, but this would occur over a long period of time perhaps several decades (R&M 1982d).

(e) Water Quality

Beginning with the filling of the reservoir, many of the physical, chemical, and biological processes common to a lentic environment should begin to appear. Some of the more important processes include sedimentation, leaching, nutrient enrichment, stratification, and ice cover formation.

These processes are expected to interact to alter the water quality conditions associated with the natural riverine conditions. A summary discussion of the processes and their interactions is provided in Peterson and Nichols (1982).

(i) Water Temperature

- Watana Reservoir

During the first summer of filling, the temperature in the Watana reservoir will be essentially a composite of the inflow temperature, increased somewhat near the surface by the effects of solar heating. The reservoir will fill very rapidly (to about a 400-foot depth (El 1875 ft, or 568 m) by the end of the first summer) and the effects of surface heat exchange will not penetrate to the depth at which the intake is located (El 1490-1528 ft, or 451-493 m). Therefore, outlet temperatures during the first summer of filling will be an average of the existing river water temperatures with some lagging behind the inflow water temperatures.

During fall, the reservoir will gradually cool to 4°C (39.2°F). Once at this temperature, the low-level outlet will discharge water at just above 4°C (39.2°F) until the reservoir water level has increased sufficiently to permit operation of the outlet facilities (fixed-cone valves).

The volume of water stored in the reservoir after October of the first summer of filling will be about 2.2 million acre-feet. From November through April, 0.5 million acre-feet of 4°C (39.2°F) water will be discharged from the reservoir and be replaced with 0°C (32°F) water which was contributed as inflow during this time. The 0°C (32°F) water, because it is less dense than the 4°C (39.2°F) water, will enter the reservoir as surface flow. Although there will be some mixing of 0°C (32°F) and 4°C (39.2°F) water, mixing will be confined to the upper layers. Even with cooling before the ice cover forms, little cooling will occur below a depth of 175 feet (53 m). It is the 0.5 million acre-feet stored below this depth which will be discharged during winter.

4.1 - Watana Development

In spring the ice on the reservoir surface will melt and the reservoir will warm to 4°C (39.2°F), probably by about the end of May. The surface will continue to warm above 4°C (39.2°F) and slowly this warmer layer will extend deeper into the reservoir. Also, warmer Susitna River inflow will be stored in the reservoir. Although there will be some mixing, the warmer surface water, because it is less dense that the 4°C (39.2°F) water, will enter the reservoir as surface flow. From May through mid-September, approximatley 1.8 million acre-feet of 4°C (39.2°F) bottom water would be released from the reservoir if the low level outlet continued to be used. This would still leave a reserve of 4°C (39.2°F) water in the bottom of the reservoir. However, it is anticipated that sometime in August, the reservoir will be sufficiently full to allow discharge through the outlet facilities.

Once the outlet facilities can be operated, downstream river temperatures should more closely approximate natural conditions. During the second winter of filling, outlet temperatures will be closer to 0°C (32°F). During the third summer of filling, reservoir temperatures will be similar to those during Watana operation, with the exceptions that water will be discharged through the outlet facilities rather than the powerhouse and flows will be slightly reduced from those during Watana operation. A discussion on reservoir temperatures during Watana operation can be found in Section 4.1.3(c)(i).

- Watana to Talkeetna

As discussed above, Watana outlet temperatures during the first summer of filling will be similar to natural temperatures. Hence, downstream temperatures between Watana and Talkeetna should also be similar to natural temperatures, except that there will be some additional warming of the water with distance downstream because of the reduced flows.

During winter, the outlet temperature will be constant at 4°C (39.2°F). To assess the effects of the warmer outlet water on water temperatures downstream, a downstream temperature analysis using the computer model HEATSIM was undertaken. Information on this model is contained in Appendix A, Hydrological Studies, Susitna Hydroelectric Project Feasibility Report (Acres 1982b).

With the use of the mean monthly natural flows and the long-term average meteorological data, downstream water temperature profiles were determined. These are shown for October to January in Figure E.2.141 and for January to April in Figure E.2.142. The results show that temperatures will stay above 0°C (32°F) from Watana to Talkeetna until late October, thus lagging natural temperatures by about one month. However, as colder air temperatures occur, the location of 0°C (32°F) water moves upstream. Even with the coldest winter temperatures, a reach of approximately 18 miles (29 km) below Watana remains above 0°C (32°F). In April, the downstream temperatures increase and if no ice cover were present, would remain above 0°C (32°F) downstream to Talkeetna. Since this is not the case (i.e., an ice cover will form, see (ii) below), the water temperatures will actually be near 0°C (32°F) at Talkeetna during April. The model does not consider tributary inflow which would be at 0°C (32°F).

A sensitivity analysis was also undertaken to determine the effect of lower winter flows and is presented in Figures E.2.143 and E.2.144. With reduced flows, 0°C (32°F) water will occur at a given location earlier in the freezeup process; however, a reach with water above 0°C (32°F) will continue to exist just downstream from the Watana dam.

Downstream summer temperatures were also modeled. This analysis used the median filling flows and the 1981 meteorological data recorded at Watana as input. The results are presented in Figure E.2.145. Temperatures increased with distance downstream with temperatures reaching 9°C (48.2°F) at Talkeetna during the lower flow period of June and July. The sensitivity to meteorological data is apparent given the variability of downstream temperatures at similar discharges.

It is anticipated that the outlet facilities will be operable sometime in August and thus able to draw water from the surface of the reservoir. However, if a low flow year occurs, the outlet facilities will not be useable and thus, downstream August temperatures would be considerably lower than natural temperatures. For example, temperatures at Gold Creek would be in the range of 5 to 6°C (41 to 42.8°F). Since this may have detrimental impacts on fisheries, a discharge sensitivity analysis was performed using an August flow of 6000 cfs at Gold Creek (Figure E.2.146). Gold Creek temperatures increased by approximately 0.3 to 1.3°C (0.5 to 2.3°F) compared to the 12,000 cfs flow case. Further downstream, the temperature changes were larger. Note that since tributary inflows are warmer than the predicted temperatures, they would tend to increase the Susitna temperatures above these predicted values.

- Talkeetna to Cook Inlet

The contributions of the Talkeetna and Chulitna Rivers will be much greater than the Susitna River during summer filling. Hence, the temperature in the mainstem, downstream of Talkeetna, will reflect those of the Talkeetna and Chulitna. Since their temperatures are cooler than the Susitna (Figure E.2.75), summer temperatures will be cooler than natural conditions. However, because of the reduced discharge in this reach, the water temperatures will warm faster than presently observed. Downstream from the confluence with the Yentna River, there will be no significant temperature differences from natural conditions.

During October, the temperature of the Susitna is likely to be above 0°C (32°F) (Figure E.2.141). However, since the Chulitna and Talkeetna River temperatures will be near 0°C (32°F), there should be little change from the natural temperature of near 0°C (32°F) downstream from Talkeetna.

(ii) Ice

- Reservoir

An ice cover will normally form on Watana reservoir in late November. Although the reservoir ice formation during filling has not been modeled, it should be similar to the ice formation during Watana operation, described in Section 4.1.3(c)(ii).

- Watana to Talkeetna

Because of the approximate 4°C (39.2°F) water which will be discharged from Watana, there will be a delay of 3-4 weeks in the ice formation process. From Figure E.2.141, the approximate location at which ice generation begins (i.e., first point of 0°C (32°F) water) can be determined. Until late November, there is little opportunity for ice generation. At this time, ice will be generated downstream from Devil Canyon.

By about mid-December air temperatures are low enough for the water to be cooled to 0°C (32°F) and ice generation to begin upstream of Devil Canyon. This will result in significant ice generation in Devil Canyon. Because of the colder temperatures at this time of year than during the natural freezeup period, once begun, the ice front will move upstream rapidly because of the generation of additional frazil ice. The freezeup staging will be similar to natural conditions, but slightly lower because of the natural reduction in flow as the winter progresses.

Sloughs and side channels that are currently overtopped will likely be overtopped during the winter freezeup. Hence, the natural scouring that takes place during freezeup will continue during the filling period.

The maximum upstream extent of the ice cover will be in the vicinity of Devil Canyon. Upstream from Devil Canyon, open water will exist year round.

In March and April, the 4°C (39.2°F) water being released will not be cooled to 0°C (32°F) by the time it reaches the ice front and will begin to melt the ice cover. This, coupled with reduced flows during breakup will result in less severe breakup conditions than currently occur.

- Talkeetna to Cook Inlet

Because of the delay in ice formation in the Watana to Talkeetna reach, the 70-80 percent contribution to the downstream ice cover formation process that is normally contributed by the Susitna upstream from Talkeetna (R&M 1982d), will be delayed until later in the year. Thus, the ice cover formation downstream from Talkeetna will also be delayed.

(iii) Suspended Sediments/Turbidity/Vertical Illumination

- Watana Reservoir

As the reservoir begins to fill, velocities will be reduced and deposition of the larger suspended sediment particles will occur. Initially, all but the larger particles will pass through the reservoir; but as more water is impounded, smaller diameter particles will settle before reaching the reservoir outlet. As the reservoir approaches normal operating levels, the percentage of particles settling will be similar to that occurring during reservoir operation. During the first year and through sometime in August of the second year of filling, water will be passed through the low-level outlet which is at invert El 1490 ft (454 m). During operation all water will be drawn from above El 2065 ft (630 m). As a consequence, larger particles are expected to pass through the reservoir during the early stages of filling, than during operation. (The deposition process during reservoir operation is discussed in detail in Section 4.1.3(c) [iii]).

During the filling process, reservoir turbidity will decrease in conjunction with the settling of suspended sediments. Turbidity will be highest at the upper end of the reservoir where the Susitna River enters. Turbid interflows and underflows may occur during summer months, depending on the relative densities of the reservoir and the incoming river water. Summer turbidity levels will be in the 20-50 NTU range (Peratrovich, Nottingham, and Drage 1982). Turbidity levels in the winter after freezeup are expected to decrease to 10-20 NTU (Peratrovich, Nottingham, and Drage 1982); however, turbidity will be greater than the pre-project winter levels.

4.1 - Watana Development

Vertical illumination in the reservoir will decrease during breakup as higher flows begin to bring increased suspended sediment concentrations into the reservoir. Vertical illumination during the summer will vary, depending on where the incoming river water finds its equilibrium depth (overflow, interflow, or underflow). Data from glacially fed Eklutna Lake indicate that vertical illumination will not exceed 4 meters (13.2 ft) during the mid-summer months (Figure E.2.147) (R&M 1982i). Vertical illumination will gradually increase during the autumn as glacial input decreases.

During reservoir filling, additional suspended sediment will be introduced to the reservoir due to slope instability along the shoreline. One of the principal factors influencing slope instability will be the thawing of the permafrost soils (Acres 1982c). A large portion of the reservoir shoreline is susceptible to shallow slides, primarily of skin and bimodal flow type with some shallow rotational slides. Reservoir slopes which are totally submerged or those with a break in slope below the reservoir surface will exhibit less stability problems than those with the reservoir surface at an intermediate or low level on the slope. Flow slides induced by permafrost thaw in fine-grained soils can, however, occur on very flat slopes.

The effects of the reservoir slides will primarily be confined to the area near the slides, and should quickly dissipate. Quantitative estimates of the total amount of sediment or the local changes in suspended sediment concentration and turbidity are not possible. However, the locations of potential reservoir slope stability problems are discussed in more detail in Appendix K of (Acres 1982c). The period in which restabilization of the slopes adjacent to the reservoir will occur is also unknown.

Construction activities, such as the removal of timber from within the impoundment, are also expected to contribute to increased suspended sediment concentrations and turbidity levels due to erosion. Once removed, the lack of soil stabilizing vegetative cover will likely accelerate wall slumping.

4.1 - Watana Development

- Watana to Talkeetna

  Maximum suspended particle sizes passing downstream through the project area will decrease from about 500 microns (20 mils) during pre-project conditions to about 5 microns (0.2 mils) as filling progresses. As can be observed from the particle size distribution curve in Figure E.2.80, this results in the retention of about 80 percent of the pre-project suspended sediment at Watana. Because of the clear water tributary inflow in the Watana to Talkeetna reach, further dilution of the suspended sediment concentration will occur as the flow moves downstream. In general, the suspended sediment concentration in the Watana to Talkeetna reach will be reduced by approximately 80 percent during the summer months and slightly increased during the winter months.

  However, during periods of high tributary flow, the same amount of suspended sediment will be added to the river by the tributaries as is presently added. Talus slides along the mainstem will also continue to contribute suspended sediment to the flow downstream from Watana as they have in the past.

  Downstream, summer turbidity levels will be reduced to an estimated 20-50 NTU. Winter turbidity levels will be increased to 10-20 NTU (Peratrovich, Nottingham, and Drage 1982). Because of the reduced turbidity in summer, the vertical illumination will be enhanced. Winter vertical illumination will be reduced slightly.

- Talkeetna to Cook Inlet

  In the Talkeetna to Cook Inlet reach, although the total suspended sediment load will be decreased, the suspended sediment concentration and turbidity levels during summer will remain high because of the suspended sediment concentration of the Chulitna River. The Chulitna River is the major sediment contributor to the Susitna with 28 percent of its drainage area covered by glacier. As discussed in Section 2.3.3(b), the preliminary 1982 summer data indicate that the suspended sediment load was twice that of the Susitna River above the confluence. The average Chulitna River flow was approximately 80 percent of the Susitna flow.

The relative change in suspended sediment concentration downstream of the confluence can be estimated by applying the following mass balance relationship.

$$\frac{\dfrac{S_C + S_S' + S_T}{Q_C + Q_S' + Q_T}}{\dfrac{S_C + S_S + S_T}{Q_C + Q_S + Q_T}}$$

Where:

S_C = Chulitna pre-project suspended sediment load in tons/day
S_S = Susitna pre-project suspended sediment load in tons/day
S_T = Talkeetna pre-project suspended sediment load in tons/day
Q_C = Chulitna pre-project discharge in cfs
Q_S = Susitna pre-project discharge in cfs
Q_T = Talkeetna pre-project discharge in cfs
S'_S = Susitna post-project suspended sediment load in tons/day
Q'_S = Susitna post-project discharge in cfs

The relationship can be approximated by

$$\frac{2}{3} \left[\frac{2.4 + Q_S'/Q_S\ (.2)}{1.3 + Q_S'/Q_S} \right]$$

if long term average flow relationships are used and if it is assumed that the suspended sediment concentration in the Susitna River is reduced to 20 percent of the pre-project concentration by the Watana reservoir, the Chulitna River has twice the suspended load of the Susitna; and the Talkeetna has the same suspended sediment concentration as the pre-project Susitna River.

With the use of this relationship, for a Susitna River pre-project discharge at Gold Creek of 30,000 cfs and a Gold Creek filling flow of 6000 cfs, the suspended sediment concentration downstream of the confluence is estimated to increase by 8 percent. This is because the Susitna River normally dilutes the Chulitna River suspended sediment concentration and although the Susitna River suspended sediment concentration is reduced by 80 percent, this is more than offset by the reduction in flow. However, at a filling flow of 12,000 cfs in the Susitna River, there would be a decrease in suspended sediment concentration of about 3 percent. Since it was assumed that there was a mass balance (i.e., no sediment deposition), it is possible that some accretion could occur at the confluence because of the reduced velocity at the confluence and because of the potential increase in concentration over natural conditions at Gold Creek filling flows of 6000 cfs.

Farther downstream, because of the varied tributary suspended sediment concentrations, additional changes in the suspended sediment concentration relative to the pre-project concentration will occur. However, these will be minor.

The summer vertical illumination will remain near zero. During winter, the low suspended sediment concentrations released from Watana dam will be diluted by inflow from the Chulitna and Talkeetna Rivers. Therefore, although suspended sediment concentrations will be higher than natural conditions downstream of the confluence, they should remain low.

(iv) Dissolved Oxygen

Initially, during the 3-year filling process, the reservoir D.O. levels should approximate riverine conditions. As filling progresses, some stratification will begin to develop, but no substantial decreases in dissolved oxygen levels are immediately anticipated. The volume of freshwater inflow, the effects of wind and waves especially during spring and fall turnovers, and the location of the outlet structure at the bottom of the reservoir are expected to keep the reservoir well mixed.

No significant biochemical oxygen demand is anticipated. The timber in the reservoir area will be cleared, thereby eliminating much of the associated oxygen demand that would be created by the inundation and decomposition of vegetation. Further, the chemical oxygen demand (COD) in the Susitna River is low. COD levels measured upstream at Vee Canyon during 1980 and 1981 averged 16 mg/l.

No significant BOD loading is expected from the construction camp and village, due to the wastewater treatment facility currently proposed.

As a result of the above factors, dissolved oxygen is expected to remain sufficiently high to support a diverse aquatic habitat.

As previously noted, the low-level outlet will be utilized for discharging water. During this time period, the reservoir D.O. level should be equal to the pre-project riverine conditions. Thus, the levels of oxygen immediately downstream from the outlet are expected to be unchanged from pre-project values.

(v) Total Dissolved Gas Concentration

As previously described, supersaturated dissolved gas conditions currently exist in the Susitna River below the Devil Canyon rapids due to the entrainment of air as the river flows through this violently turbulent reach.

Supersaturated conditions are also possible below high head dams as a result of the passing of water over a spillway into a deep plunge pool. The amount of water being spilled, the height of the spillway, and the depth of the plunge pool all influence the amount of air that is dissolved in the water. If the dissolved gases reach high levels (generally referred to as greater than 116 percent), a fish kill due to gas embolisms may result for many miles downstream (Turkheim 1975).

Since all water that is released during the filling of the reservoir will pass through the low-level outlet and thus, no spillage of water will occur at Watana, this problem will not exist. Furthermore, the reduced downstream flows during filling will result in lower summer dissolved gas concentrations below the Devil Canyon rapids. Based on observed pre-project conditions, August flows of 12,000 cfs at Gold Creek should result in total dissolved gas saturation levels of approximately 108 percent or less.

(vi) Nutrients

Two opposing factors will affect nutrient concentrations during the filling process. First, initial inundation will likely cause an increase in nutrient concentrations due to leaching. Second, sedimentation will strip some nutrients from the water column. The magnitude of net change in nutrient concentrations is unknown, but it is likely that nutrient concentrations will increase especially in close proximity to the reservoir floor for at least a short time during filling.

(vii) Total Dissolved Solids, Conductivity, Significant Ions, Alkalinity, and Metals

Peterson and Nichols (1982) note that short-term increases in dissolved solids, conductivity, and most of the major ions could occur immediately after filling begins. Bolke and Waddell (1975) found the highest concentrations of all major ions, except magnesium, occurred immediately after dam closure. Symons et al. (1965), also identified similar increases of alkalinity, iron, and manganese. These findings were all attributed to the initial inundation and leaching of rocks and soils in the reservoir.

The products of leaching are expected to remain in a narrow layer immediately adjacent to the impoundment floor (Peterson and Nichols 1982). In addition, inorganic glacial sediment will quickly blanket the reservoir bottom thereby inhibiting the leaching process. Hence, water quality within the balance of the impoundment should be unaffected. However, the discharge during filling will be via a low-level outlet and increased levels of the aforementioned parameters could occur downstream from the dam although no significant adverse impact are foreseen.

Further discussions of the effects of the anticipated leaching process are presented in Section 4.1.3(c) (viii) and in Peterson and Nichols (1982).

(viii) Other

No additional water quality impacts of any significance are anticipated.

(f) Ground Water Conditions

(i) Mainstem

Alluvial gravels in the river and tributary bottoms upstream from the dam will be inundated. Other than aquifers composed of the unconfined materials making up the relict channel and in the valley bottoms, no aquifers of significance are known to exist in the reservoir area.

As a result of the decreased summer flows (see Section 4.1.2(b) [i]), water levels in the mainstem of the river will be reduced between Watana and Talkeetna. This will in turn cause a reduction in adjacent ground water levels. However, the ground water level changes will be confined to the river floodplain area. The ground water level will be reduced by about 2 to 4 feet (0.6 to 1.2 m) during the summer near the streambank with less change occurring with distance away from the river.

A similar process will occur downstream from Talkeetna, but the changes in ground water levels will be less because of the decreased effect on river stages.

(ii) Sloughs

The reduced mainstem flows and associated lower Susitna River water levels will slightly modify the ground water relationship between the mainstem and the sloughs. The mainstem water levels upstream and downstream of a slough control the ground water gradient in the slough and since both levels change by approximately the same amount for different flows, the gradient will remain the same. Because the gradient is unchanged, the upwelling rate will likewise remain the same.

Because the sloughs are adjacent to the mainstem of the river, the ground water level in the sloughs will be lowered by the same amount as the stage change within the mainstem. This will have the effect of dewatering the areas in the sloughs between where the ground water table currently intersects the slough and where the lowered ground water table will intersect the slough.

Data to confirm the areal extent of upwelling at various flows are unavailable at this time. However, it is believed that slough upwelling extends from the slough mouths well upstream to the steeper reaches of the sloughs near the upstream berms. Therefore, the areas that will be dewatered will generally be the steep upstream ends of the sloughs. If both mainstem stage and ground water level change by approximately 2 feet (0.6 m), the potential loss in ground water upwelling length will be the stage change (2 feet, or 0.6 m)) multiplied by the slough gradient. Using the 18.6 foot per mile (3.5 m per km) gradient illustrated in Figure E.2.21, the dewatered length would be approximately 570 feet (171 m). This is 10 percent of the slough length and, if a uniform upwelling rate is assumed over the entire length of the slough, the decrease in slough discharge at the mouth will also be 10 percent.

(g) Lakes and Streams

Several tundra lakes will be inundated as the reservoir approachs full pool. The mouths of the tributary streams entering the reservoir will be inundated for several miles as discussed in Section 2.5.2 (see Table E.2.25). Bedload and suspended sediment carried by these streams will be deposited at or near the new mouths of the streams.

No significant impacts to Tsusena or Deadman Creeks are anticipated from their use as water supply and waste recipient, respectively.

(h) Instream Flow Uses

(i) Fishery Resources, Riparian Vegetation, and Wildlife Habitat

Impacts on fishery resources, riparian vegetation, and wildlife habitat during the filling process are discussed in Chapter 3. As summer flows are reduced, fish access to slough habitats will be decreased. Since the temperature of the upwelling ground water in sloughs will be essentially unchanged and upwelling will continue to occur, impacts on the incubation of salmonid eggs are not expected to be significant.

(ii) Navigation and Transportation

Once impoundment of the reservoir commences, the character of the river immediately upstream from the dam will change from a fast-flowing river with numerous rapids to a still-water reservoir. The reservoir will ultimately extend 54 river miles (87 km) upstream, terminating 8 miles (13 km) downstream from the confluence with the Tyone River, and will inundate the major rapids at Vee Canyon. The reservoir will make possible increased boat traffic to this reach of river by decreasing the navigational hazards through Vee Canyon.

The reduced summer flows released from the reservoir during filling could reduce the navigation difficulties between Watana and Devil Canyon during the summer months. However, the lower segment of this reach from Devil Creek to Devil Canyon will still consist of whitewater rapids suitable only for expert kayakers.

Navigational difficulties between Devil Canyon and the confluence with the Chulitna River will be increased as the result of shallower water and a somewhat constricted channel. From an examination of the navigation criterion established in Section 2.6.3 for the Portage Creek to Talkeetna reach (i.e, a required Gold Creek flow of 6500 cfs to maintain a 2.5-foot (0.8-m) depth near Sherman) and the Gold Creek flows for the three filling cases, it is apparent that slight navigational (Table E.2.38) problems could develop near Sherman during the second and third years of filling during May, June, July, and late September when the Gold Creek flows are 6000 cfs. If the first year of filling is a dry year, some navigational difficulty could also occur at Sherman during July of that year. However, to ensure that navigation is not impacted, the navigation depth near Sherman will be monitored. If this reach is not navigable, then, either the channel bottom in the problem reach near Sherman will be lowered to maintain a 1.5-foot (0.5-m) deep channel and the channel will be marked with buoys; or the Gold Creek discharge will be increased to 6500 cfs.

There will be no impact on navigation below the confluence of the Chulitna River except perhaps at Alexander slough. Examination of Table E.2.39 indicates that during filling, flows will be well in excess of those needed to maintain navigational depths at Kashwitna Landing or near Willow Creek (see Section 2.6.3). The reduced summer flows from the Susitna River will be somewhat compensated for by the high flows from other tributaries. Minor restrictions on navigation may occur at the upstream access to Alexander Slough, but this would occur only in low streamflow years when the other tributaries also have low flow.

Because of the delay in ice cover formation in the Watana to Talkeetna reach, use of the river by snowmobile and dogsled will also be delayed (Section 4.1.2(e) [iii]).

(iii) Recreation

Since summer navigation will not be negatively impacted and since fishery impacts will be mitigated downstream of Watana, recreation impacts should not be significant. However, the kayaking recreational potential of Vee Canyon will be lost due to reservoir filling.

(iv) Waste Assimilative Capacity

The previously noted reductions to downstream summer flows could result in a slight reduction in the waste assimilative capacity of the river. However, no adverse impacts will occur given the limited sources of waste loading to the river (see Sections 2.6.6 and 4.1.1(g) [ii]).

(v) Freshwater Recruitment to Cook Inlet Estuary

Given average hydrologic conditions, the annual Susitna River flow contribution to Cook Inlet will be reduced by its greatest proportion of approximately 11 percent, during the second year (WY 1992) of filling. Resource Management Associates (1983) used the previously identified computer model (Section 2.6.7) to estimate salinities during the entire filling period. As expected, higher salinities are present throughout the scenario, however, these increases are not substantial.

4.1 - Watana Development

At Node 27, near the mouth of the Susitna River (Figure E.2.126), the maximum increase in salinity levels of 1400 mg/l (increase from 9700 to 11,100 mg/l) was predicted to occur during June when the greatest percentage reduction in flow occurs (Figure E.2.127). Progressing southward down Cook Inlet away from the mouth of river, quantitive changes are less and a slight time lag is evident. At the center of Cook Inlet near East Foreland (Node 12) a maximum salinity increase of 600 mg/l was predicted during July and August. Salinity filling data (WY 1992) for five locations in Cook Inlet are presented in Table E.2.31.

These higher Cook Inlet salinities will last only until project operation, at which time a new equilibrium will be establishd as described in Section 4.1.3(f) (iii).

4.1.3 - Watana Operation

(a) Flows and Water Levels

(i) Project Operation

Watana will be operated in a storage-and-release mode, so that summer flows will be stored for release in winter. Generally, the Watana reservoir will be at or near its normal maximum operating level of 2185 feet (666 m) each year at the end of September. Gradually, the reservoir will be drawn down to meet winter energy demand. The flow during this period will be governed by the winter energy demand, the water level in the reservoir, and the powerhouse characteristics. The turbine characteristics will allow a maximum powerhouse flow of approximately 21,000 cfs at full gate although it is unlikely that this powerhouse flow would occur during the operation of Watana prior to the construction of Devil Canyon.

In eary May, the reservoir will reach its minimum annual level of approximately El 2093 ft (638 m) and then begin to refill with the spring runoff. Flow in excess of both the downstream flow requirements and power needs will be stored during the summer until the reservoir reaches the normal maximum operating level of 2185 ft (666 m). If the reservoir reaches El 2185 ft (666 m), flow greater than that required for power generation will be released. However, after the threat of significant flooding has passed in late August, the reservoir will be allowed to surcharge to El 2190 ft (668 m) to minimize the volume of water released in late August and September.

- Watana Turbine Operation

  The six turbine units at Watana can be operated to provide any flow above 1500 cfs up to the maximum capability of the powerhouse (21,000 cfs) and still maintain high efficiency. This is illustrated in Figure E.2.148.

- Minimum Downstream Target Flows

  During project operation, the minimum flows to be provided at Gold Creek will be those presented as Case C in Section 3.4.1. Target flows for May through September were discussed in Section 4.1.2(a) (i), Reservoir Impoundment. Flows from October through April will be maintained at or above 5000 cfs. It should be noted that these flows are minimum target flows. Project operation flows will normally be greater than the targeted minimum flows during the winter. During May, June, July and October, operational flows will also normally be greater than the minimums. The late July, August, and September flows will normally coincide closely with the minimum requirements. The minimum target flows during operation are shown in Table E.2.36 and Figure E.2.136.

  If, during the summer, the natural flow falls below the Gold Creek minimum values listed in Table E.2.36, the flow will be augmented to maintain the downstream flow requirement.

- Monthly Reservoir Simulations

  As discussed in Section 3.2, a monthly energy simulation program was run using the 32 years of synthesized Watana flow data given in Table E.2.6. The simulation was initiated with the reservoir at the normal maximum operating level and a full pool was required at the end of the simulation. Energy production was optimized by adjusting the monthly operating rule curve and by maximizing the minimum monthly energy production according to the monthly energy demand pattern, taking into account the reservoir characteristics and the downstream flow requirements. The optimized rule curve is presented in Table E.2.40. The minimum monthly energies and the associated powerhouse discharge are presented in Table E.2.41.

- Weekly Reservoir Simulations

The monthly reservoir simulations are adequate for determining energy benefits and mean monthly flow, but they do not provide a good indication of the flow variability during a month in which the Watana reservoir is close to its normal maximum operating level. Therefore, a weekly reservoir simulation program was developed. The weekly reservoir simulation program is similar to the monthly reservoir simulation except that the input data is weekly based rather than monthly based and the program uses a weekly time step instead of a monthly time step.

The mean daily flows for each of the 32 years of record at Gold Creek were divided into weekly periods starting at the beginning of the water year (October 1) and averaged to provide mean weekly flows. Flow on February 29 of leap years was not considered significant and was disregarded. However, flow on September 30 of each year is significant and was added to week 52 of each year.

Weekly flows at Watana and Devil Canyon were determined by taking the ratio of the discharge area of the damsite to the Gold Creek drainage area and multiplying by the Gold Creek weekly flow. Since the Cantwell weekly record was incomplete, it was not used in the determination of the weekly flows at Watana or Devil Canyon.

WY 1969 was modified as discussed in Section 3.3. The ratio of the long term weekly average flow to the mean annual flow was multiplied by the 1:30 year low flow.

Weekly simulations were conducted for the 32 years of record for the year 1995 and 2000 energy demand forecasts. Results from the two simulations are very similar. This is because most of the energy produced at Watana is usable, even in wet years, with both energy forecasts. There is, however, one important difference. With the 1995 demand, there is insufficient energy demand to provide a powerhouse flow equal to the August downstream flow requirement. To provide the required discharge, a flow release through the outlet facilities is necessary. By 2000, the demand is large enough so that a release of this kind is unnecessary.

- Daily Operation

In an effort to stabilize downstream flows, Watana will be operated as a base-loaded plant until Devil Canyon is completed. This will produce daily flows that are virtually constant throughout a 24-hour period for most of the year. There will be a gradual change in daily flow to adjust to the changing seasonal and weekend energy demands. During summer it may be economically desirable to vary flow on a daily basis to take advantage of the tributary flow contribution downstream from Watana to meet the flow requirements at Gold Creek. However, a daily variation of not more than 2000 cfs is anticipated. This would yield relatively stable flows from Portage Creek to Gold Creek, but somewhat variable river flows between Watana and Portage Creek.

(ii) Mean Monthly Flows, Annual Flows, and Water Levels

Monthly water levels and discharges at Watana for the 32-year period were computed using the monthly energy simulation program. The monthly maximum, minimum, and median Watana reservoir levels for the 32-year simulation are illustrated in Figure E.2.149.

The maximum reservoir levels represent a simulation of WY 1956, one of the wettest years on record. The maximum water levels coincide closely with the rule curve because the powerhouse has sufficient generation capacity to utilize all flow above that required to satisfy both the minimum energy production and the rule curve.

The minimum reservoir levels represent a simulation of WY 1970. This illustrates the effect of the modified WY 1969 drought and the lack of recovery during the WY 1970 drought. In October, November, and December of simulated WY 1971, the reservoir elevation is a few feet lower. However, from the end of December to the end of April, reservoir elevations during WY 1970 and WY 1971 are the same. In May of WY 1971, the reservoir level drops to El 2068 ft (627 m) but a strong recovery takes place in June, July, and August with water levels well above those for WY 1970.

WY 1966 was selected as being representative of the median year. The median year illustrates that during the winter months, the reservoir water surface elevation follows the reservoir rule curve most of the time.

The monthly Watana discharges for the simulation period are presented in Table E.2.42. The maximum, mean, and minimum flows for each month are summarized in Table E.2.43. Pre-project flows are also presented for comparison. In general, powerhouse flows from October through April will be much greater than natural flows. For example, in March the average operational flows will be nine times greater than the natural river flow. Average post-project flow for May will be about 27 percent less than the natural flow. Mean daily post-project flows during May will show a slight change through the month in response to the changing energy demand. In contrast, existing baseline flows vary considerably from the beginning to the end of the month because of the timing of the snow melt runoff. Flows during June, July, August and September will be substantially reduced from pre-project levels due to the annual reservoir filling process.

Pre- and post-project monthly flows at Gold Creek are listed in Tables E.2.8 and E.2.44. A summary is presented in Table E.2.45. The comparison is similar to that for Watana although the pre-project/post-project percentage change is less due to tributary flow contributions downstream from Watana. Figure E.2.150 illustrates the Watana inflow and outflow, the Watana reservoir level, and the Gold Creek pre-project and post-project flows for each month of the 32-year simulation.

Farther downstream at Sunshine and Susitna Station, pre- and post-project flow differences will be less.

During July, average monthly flows will be reduced by 11 percent at Susitna Station. However during the winter, flows will be 100 percent greater than existing conditions. Monthly pre- and post-project flows at the Sunshine and Susitna Stations are tabulated and summarized in Tables E.2.9, E.2.10, E.2.46, E.2.47, E.2.48, and E.2.49.

Mean annual flow will remain the same at all stations. However, flow will be redistributed from the summer months to the winter months to meet energy demands.

Water surface elevations based on maximum, mean, and minimum monthly flows at Gold Creek for May through September for selected mainstem locations between Portage Creek and Talkeetna are illustrated in Figures E.2.151 through E.2.153. The figures illustrate the water level change expected as a result of operation of Watana. In general, there is a 2 to 4 foot (0.6 to 1.2 m) decrease in water level from pre-project levels to post-project levels. However, during low flow years, there is approximately a 1 foot (0.6 m) decrease in water level during August and a half foot increase in September. Note that the water levels are based on observed stage-discharge measurements compiled by the Alaska Department of Fish and Game (1982c).

(iii) Floods

- Spring Floods

For the 32 years of monthly simulations, Watana reservoir had sufficient storage capacity to absorb all floods. The largest flood of record, June 7, 1964, had a peak discharge of 90,700 cfs at Gold Creek, corresponding to an annual flood recurrence interval of better than 20 years. This flood provided the largest mean monthly inflow on record at Gold Creek, 50,580 cfs, and contained the largest flood volume on record. However, even with this large a flood, the simulated reservoir level increased only 49 feet (15 m) from El 2089 ft (637 m) to El 2138 ft (652 m). A further 47 feet (14 m) of storage were available before a reservoir release would have been necessary.

The flood volume for the May-July 1:50-year flood was determined to be 2.3 million acre-feet (R&M

1981f). This is equivalent to the storage volume contained between El 2117 ft (645 m) and 2185 ft (666 m), neglecting discharge. Since the maximum elevation at the beginning of June was always less than 2117 ft (645 m) during the simulation, the 50-year flood volume can be stored without necessitating a release, if it occurs in June. If the flood event occurs in July, the 1:50-year flood volume can also be accommodated without exceeding El 2185 ft (666 m) if the powerhouse discharge averages 10,000 cfs. Thus, for flows up to the 1:50-year flood event, Watana reservoir is capable of totally absorbing the floods without requiring operation of the outlet facilities.

Only for flood events greater than the 1:50-year year event and/or after the reservoir reaches El 2185.5 ft (666.3 m), will the outlet facilities be operated. Discharge will be set equal to inflow up to the full operating capacity of the outlet facilities. During flood events of this magnitude the powerhouse will also operate at maximum energy demand capacity, thereby reducing the flood level in the reservoir. If inflow continues to be greater than outflow, the reservoir will gradually rise to El 2193 ft (669 m). At that time, the main spillway gates will be opened and operated so that the outflow matches the inflow. The main spillway will be able to handle floods up to the 1:10,000-year event. Peak inflow for the 1:10,000-year flood will exceed the combined powerhouse, outlet facilities and main spillway capacity resulting in a slight increase in water level above El 2193 feet (669 m). The discharges and water levels associated with the 1:10,000-year flood are shown in Figure E.2.154.

If a flood greater than the 1:10,000-year flood were to occur, the main spillway would be operated to match inflow until the inflow rate exceeds the capacity of the spillway. The reservoir elevation would rise until it reached El 2200 ft (671 m). At this elevation, the erodible dike in the emergency spillway would be breached and the emergency spillway would operate. The resulting total outflow through all the discharge structures would be 15,000 cfs less than the probable maximum flood (PMF) of 326,000 cfs. The inflow and outflow hydrographs for the PMF are illustrated in Figure E.2.154.

4.1 - Watana Development

Spring floods downstream will be reduced by the discharge stored in Watana reservoir for up to the 50-year flood event. This will be true for Gold Creek. However, further downstream, the timing of the flood peak at Watana will not necessarily be coincident with the flood peaks at Sunshine or Susitna and will lead to conservative estimates (i.e., reductions larger than would actually occur) of the flood peak at these downstream locations. Assuming the mean annual spring flood at Watana to be equal to the maximum usable powerhouse flow, the mean annual flood flow at Watana will be reduced approximately 30,000 cfs. Hence Gold Creek, Sunshine, and Susitna Station will have mean annual floods reduced from 49,500 to 20,000; 95,000 to 65,000; and 157,000 to 127,000 cfs, respectively. For the 1:10-year spring flood, the flow reduction at Watana will be 55,000 cfs. Hence the 1:10-year floods at Gold Creek, Sunshine, and Susitna Station will be reduced from 79,000 to 24,000; 144,000 to 89,000; and 239,000 to 184,000 cfs, respectively. It is important to note that these are spring floods and the flow above Watana is adsorbed almost in its entirety by the Watana reservoir. The annual floods which have larger peak flow values and the August summer floods which would occur when the reservoir is nearly full, could cause larger downstream floods than the spring floods.

For spring floods greater than the 1:50-year event, it is possible that the Watana reservoir would fill and inflow would be set equal to outflow. If this occurred, floods downstream would be unaffected.

- Summer Floods

During wet years, the Watana reservoir will reach El 2185 ft (666 m) sometime in August or September. Design considerations were therefore established to ensure that the powerhouse and outlet facilities would have sufficient capacity to pass the 1:50-year summer flood without operation of the main spillway, since this would result in nitrogen supersaturation which could be detrimental to downstream fisheries. A further decision criterion was established such that the reservoir would be allowed to surcharge to El 2193 ft (669 m) during the 1:50 year flood.

4.1 - Watana Development

The 1:50 year inflow and outflow hydrographs at Watana were derived as follows:

The mean annual flood peak at Watana was multiplied by the ratio of the mean annual summer flood peak at Gold Creek to the mean annual flood peak at Gold Creek to obtain the mean annual summer flood peak at Watana. This value was multiplied by the ratio of the 1:50-year summer flood to the mean annual summer flood at Gold Creek, to obtain the Watana 1:50-year summer flood peak of 64,500 cfs. The August to October dimensionless hydrograph (R&M 1981f) was next multiplied by the Watana flood peak flow to obtain the inflow hydrograph. To obtain the outflow hydrograph, the inflow was routed through the reservoir assuming that the reservoir was at El 2185 ft (666 m) at the commencement of the flood. The flows and associated reservoir water levels are illustrated in Figure E.2.154. The outflow is the sum of the release through the outlet facilities (24,000 cfs) and the powerhouse discharge. For the analysis, the powerhouse discharge was assumed to be 7000 cfs.

If summer floods of lesser magnitude than the 50-year event occur with the reservoir full, inflow will match outflow up to the discharge capability of the outlet facilities and powerhouse.

To determine the magnitude of flood events during project operation, weekly reservoir simulations were carried out (see Section 4.1.3(a) (i)). During the 32 years of reservoir simulations, the Watana reservoir did not exceed El 2190 ft (668 m). Hence, the spillway was not used.

- Annual Floods

The maximum weekly discharge at Gold Creek during the 32-year simulation period was 36,100 cfs occurring in WY 1981. The simulation also included the August 15, 1967 flood, which had an instantaneous peak of 80,200 cfs at Gold Creek and an equivalent summer return period of 1:65-years, thus demonstrating the conservative nature of the above analysis. Since the reservoir was not full until after the 1967 flood peaked, the maximum post-project weekly flow at Gold Creek was 29,100 cfs.

4.1 - Watana Development

The annual flood frequency curve for Gold Creek, based on the weekly simulations is depicted in Figure E.2.155. This curve represents both the 1995 and 2000 energy demand simulations, since there is virtually no difference in the frequency curves. The largest floods occur when the reservoir is full in late August or September when releases are necessary. However, high spring discharges during the snow melt runoff period from the drainage area downstream from Watana also occur. For example, Figure E.2.156 illustrates a post-project spring flood of about 28,000 cfs at Gold Creek during simulated year 1964.

The post-project mean annual flood at Gold Creek is approximately 15,000 cfs. This flood represents winter powerhouse discharges of up to 14,700 cfs and occurs during years when neither the reservoir outlet facilities operate or the contribution of snow melt runoff between Watana and Gold Creek is significant.

Post-project floods at Sunshine and Susitna Station will be reduced by approximately the reduction at Gold Creek, if it is assumed that flood peaks occur at Gold Creek and other downstream locations at approximately the same time.

(iv) Flow Variability

Under normal hydrologic conditions, flow from the Watana development will be totally regulated. The downstream flow will be controlled by one of the following criteria: downstream flow requirements, minimum power demand, or reservoir operating rule curve. There generally will not be significant changes in mean daily flow from one day to the next. However, there can be significant variations in discharge from one season to the next and for the same month from one year to the next.

The flow variability at Watana and Gold Creek is demonstrated by the weekly reservoir simulations for 1964, 1967, and 1970 shown in Figures E.2.156, E.2.157, and E.2.158. Average weekly flows for Watana and mean daily flows for Gold Creek are presented.

The Gold Creek flows were determined by adding the natural mean daily flow from the drainage area between Watana and Gold Creek to the weekly post-project Watana discharge. Note that because the weekly simulations were based on average weekly flows, superimposing daily values causes some of the daily Gold Creek flows to be slightly less than the downstream flow requirements. Natural Gold Creek flows are included in the figures for reference.

The Watana flows show little variability because of the high degree of reservoir regulation and the relatively constant powerhouse flow. Gold Creek exhibits considerably more daily variation because of the variability in local inflow. The year to year variability is evidenced in the comparison of flows between 1967 and 1970.

Monthly and annual flow duration curves based on the monthly average flows for pre-project and post-project operating conditions are illustrated in Figures E.2.159 through E.2.162 for Watana, Gold Creek, Sunshine, and Susitna Station. The flow duration curves show a diminished pre- and post-project difference with distance downstream from Watana. The annual flow duration curve, based on weekly average flows at Gold Creek, is presented in Figure E.2.163. This figure is similar to the monthly value except that higher flows can be detected in the weekly based flow duration curve.

(v) Operation of Watana Fixed-Cone Valves

The six 78-inch (2 m) diameter fixed-cone valves, each with a design capacity of 4000 cfs, will be operated to release excess water from the Watana reservoir to avoid downstream gas supersaturation. The valves will draw water from the reservoir between El 2025 ft (617 m) and El 2085 ft (636 m). The water will be discharged approximately 125 feet (38 m) above the normal tailwater elevation as a highly diffused jet to achieve significant energy dissipation without the provision of a stilling basin or plunge pool.

Table E.2.50 presents information on flow releases from the weekly reservoir simulations for both the 1995 and 2000 energy demand forecasts. Included for each year of the 32 years of simulation are the week of first release, the week of maximum release, the maximum Watana release, the powerhouse flow at the time of maximum release, and the volume released.

As shown in Table E.2.50, these valves would operate in the late summer of almost every year when the energy demand is equal to the 1995 demand. This occurs because the powerhouse flow must be augmented to provide the necessary 12,000 cfs downstream flow in August and September. By the year 2000, the energy demand will have increased so that flow augmentation is no longer necessary.

In all but 7 years of the 32 years of simulation, the maximum release is less than 2500 cfs. Therefore, there is an annual probability of approximately 20 percent that a release of more than 2500 cfs will occur.

The week of first release through the fixed-cone valves in any year begins the week of July 29 or later. Release made necessary because the reservoir has reached the maximum operating level, occur the week of August 19 or later.

Information on the downstream temperature impacts caused by the operation of the fixed-cone valves can be found in Section 4.1.3(c) (i).

(b) River Morphology

Impacts on river morphology occurring from May through September during Watana operation will be similar to those occurring during reservor impoundment (Section 4.1.2[d]), although flows will generally be increased during operations.

The reduction in streamflow peaks and the trapping of bedload and suspended sediments in the Watana reservoir will continue to significantly reduce morphological changes of the river above the Susitna-Chulitna confluence. The mainstem river channel will continue to become tighter and more clearly defined. Channel width reduction by vegetation encroachment will continue (R&M 1982d).

In winter, substantial differences may occur as the result of ice processes as discussed in Section 4.1.3(c) (ii). Above the Chulitna River, the effects of ice forces during breakup on the river morphology will be effectively eliminated (see Section 4.1.3(c) [ii]). Although an ice cover could form as far upstream as Devil Canyon, the rapid rise in streamflows which cause the initial ice movement at breakup will be eliminated because of the Watana reservoir flow regulation and because warmer water temperatures released from Watana will tend to melt the ice in place (Section 4.1.3(e) [i]).

In the sloughs, overtopping of the gravel berms at the upstream end during summer will seldom occur because of the reduced flows. Movement of sand and gravel bars in the sloughs will be minimized. Debris jams and beaver dams, which previously were washed out by high flows, will remain in place, with resultant ponding in those sloughs not maintained as part of the fisheries mitigation program (see Chapter 3). Vegetation encroachment in the sloughs and side channels may also occur as the high flows are reduced.

Impacts at the Chulitna River confluence and farther downstream will be similar to those occurring during reservoir impoundment.

(c) Water Quality

(i) Water Temperature

- Watana Reservoir

After impoundment, the Watana reservoir will exhibit the thermal characteristics of a deep glacial lake. Deep glacial lakes commonly show temperature stratification during both winter and summer (Mathews 1956; Gilbert 1973; Pharo and Carmack 1979; Gustavson 1975). However, stratification is often relatively weak. Bradley Lake, Alaska, (Figure E.2.164) demonstrated a distinct thermocline in late July 1980, but was virtually isothermal by late September. A reverse thermocline was observed during the winter months (U.S. Army Corps of Engineers 1982).

Similar thermal structures have been observed at Eklutna Lake, Alaska during 1982 and 1983 (Figures E.2.165 to E.2.167).

Reverse thermoclines during winter months are typical of deep reservoirs and lakes with ice covers as noted at Eklutna Lake and Williston Lake (Figure E.2.168). However, the depth of the thermocline under winter conditions is greatly influenced by time and mode of ice cover formation in addition to water withdrawals from under the ice cover.

The seasonal variation in temperature within the Watana reservoir and for a distance downstream will change after impoundment. Bolke and Waddell (1975) noted in an impoundment study that the reservoir not only reduced the range in temperature but also changed the timing of the high and low temperatures. This will also occur in the Susitna River where pre-project temperatures generally range from 0°C to 14°C (32°F to 57°F) with the lows occurring from October through April and the highs in July or August. However, to minimize the pre-project to post-project temperature differences downstream, Watana will be operated to take advantage of the temperature stratification within the reservoir.

During summer, warmer reservoir water will be withdrawn from the surface through a multilevel intake structure (Figure E.2.169). The intake nearest the surface generally will be used. In this way warmer waters will be passed downstream. In winter, the colder surface water will be withdrawn to provide the coldest possible water downstream.

To provide quantitative predictions of the reservoir temperature behavior and outlet temperatures, reservoir thermal studies were undertaken in 1981 and 1982.

Results of the 1981 studies are presented in Appendix A4 of the Susitna Hydroelectric Project Feasibility Report (Acres 1982b). Review of these studies resulted in the continuation of thermal studies into 1982 and 1983 to further define the likely reservoir temperature structure and the temperature and ice regime downstream of the Watana and Devil Canyon dams.

Detailed analyses were performed for Watana and Devil Canyon Reservoirs using a one-dimensional computer model, DYRESM. This model was verified, using data collected at Eklutna Lake during 1982. A brief description of the DYRESM model follows.

. DYRESM Model

Predictions of reservoir temperature stratification and outflow temperatures have been made using a one-dimensional numerical model developed by Imberger, et al. (1978). The dynamic reservoir simulation model, DYRESM, has been modified to include ice cover formation and outflow hydraulics associated with multiple intake structures.

DYRESM approaches the problem of reservoir temperature modeling by parameterization of the physical process rather than numerical solution of the appropriate differential equations. The reservoir is modeled by a system of horizontal layers with uniform properties which move up and down, in accordance with the volume-depth relationship, as inflow and withdrawal increase and decrease the reservoir volume. Each layer has dimensions suited to the function required of them. For example, the mixed layer may be modeled by a reasonably coarse layer structure in the epilimnion thinning down to a very narrow layer in the transition zone.

The construction of the DYRESM model is that of a main program with subroutines which separately model each of the physical processes of inflow, withdrawal, mixed layer dynamics, and vertical transport in the hypolimnion. Other subroutines provide support for frequently required data such as volumes and density.

The physical processes involved in the modeling require definition of the time step over which they act. Inflow and outflow dynamics generally change relatively slowly from day to day whereas the mixed layer dynamics requires a much finer sub-daily time step. In DYRESM, the base time step is set at one day for calls to subroutines which deal with inflow and outflow. Calls to other subroutines are based on the dynamics of the situation and range between one quarter hour and 12 hours.

Meteorological data are generally assumed to be inputed as daily averages except for wind speed which is given as six hour resultant wind speeds.

Allowance is built into the program for the difference in short wave radiation absorption between day and night. DYRESM requires comprehensive data on wind speed, short and long wave radiation, temperature, vapor pressure, and precipitation, in addition to physical characteristics of the reservoir and inflow and outflow quantities.

A detailed discussion of DYRESM is provided in Imberger and Patterson (1980).

- Eklutna Lake Modeling

The DYRESM program has been used extensively in Australia and Canada to predict thermal profiles within lakes and reservoirs. To assess the accuracy of DYRESM in predicting the thermal structure in glacially fed reservoirs, a data collection program was established in 1982 to obtain data on the thermal structure of Eklutna Lake located approximately 30 miles (50 km) north of Anchorage, Alaska (Figure E.2.1). A weather station was also established to provide the necessary meteorological input to DYRESM.

Detailed daily simulations were made of Eklutna Lake from June 1 to December 31, 1982 to establish the adequacy of the DYRESM model. Simulated and measured profiles at a station in the approximate center of the lake are given in Figures E.2.165 to E.2.167. In general most profiles are modeled to within 0.5°C (1°F). This is well within the observed variation of temperature at the data collection stations throughout the lake (R&M 1982i). Deviations in measured and simulated profiles can be explained through an assessment of the meteorological variables used and the reliability of the measurement of these variables. However, even with errors due to estimating weather data from sources other than that of the station at Eklutna Lake, the temperature profiles are reasonably modeled.

Outflow temperatures from Eklutna Lake for the period June through December 1982 are presented in Figures E.2.170 and E.2.171. In late June and early July, significant deviations occur between measured and simulated temperatures (Figure E.2.170). This deviation is believed to be the combined result of the inability of DYRESM to model a three-dimensional system, possible underestimation of air temperature and solar radiation, and possible overestimation of wind speed. In general, simulated outflow temperature is 1°C (1.8°F) below the measured temperature from July to mid-September. From mid-September to December, simulated and measured temperatures show good agreement.

The configuration of Eklutna is such that the portion of the lake near the intake structures is shallower than the rest of the lake, particularly in early spring when the lake is drawn down. This may result in a greater mixing influence from the intake structure than is modeled by DYRESM. However, the major portion of the temperature deviation is believed to be the result of uncertainties associated with data collected during this period. The model results for June 18 and July 14 indicate reasonable agreement with measured profiles (Figure E.2.165). This indicates that although average meteorological conditions over the entire period were suitably measured, conditions on a daily basis may be in error. Wind speed in particular would have the major influence since an overestimation of wind speed would result in too much epilimnion mixing which would result in cooler outflow temperatures.

The deviation in temperatures from July to mid-September is believed to be mainly due to the model approach of assuming an average lake temperature profile. Based on field measurements, the intake portion of Eklutna Lake is generally warmer than the mid-lake profile, and this would explain the higher measured outflow temperatures.

Ice cover formation on Eklutna Lake began during the latter part of November, 1982 with a full ice cover formed by mid-December. DYRESM, due to a slight overestimation of daily cooling rates during late October and November (Figure E.2.167), estimated ice cover formation to begin on November 17, with a full ice cover on November 19. Measurements made on January 14, 1983 indicates an ice cover thickness of approximately 18 inches (45 cm). This compares favorably with a predicted ice thickness of 21 inches (52 cm).

4.1 - Watana Development

Based on the 1982 study results, the ability of DYRESM to predict the winter and summer thermal stratification of a glacial lake under Alaskan meteorlogical conditions is excellent. Thus, the DYRESM program can be used to predict the Watana average reservoir temperature profile to within 0.5°C (1°F) and outflow temperature to within 1°C (1.8°F). Ice cover formation and ice thickness are believed to be predictable to within 5 days and 5 inches (13 cm), respectively.

- Watana Reservoir Modeling

Detailed daily simulations were made of the temperature structure of Watana reservoir operating under Case C summer flows and maximum winter energy productions based on reservoir level. Meteorological data collected at Watana camp from June through December 1981 was used as input to DYRESM. Watana reservoir inflow for the same period was also input to the model. Reservoir outflow requirements for the temperature simulation period were obtained from the weekly reservoir simulation program described in Section 3.2.

Temperature profiles for the first day of each month from June through December are illustrated in Figures E.2.172 and E.2.173. A profile for December 31, 1981 is also shown in Figure E.2.173. The temperature structure at Watana follows the typical pattern for reservoirs and lakes of similar size and climatic conditions. In general, stratification occurs during June, July, and August. Maximum surface temperatures occur in July and August. The maximum surface temperature simulated was 11°C (51.8°F) on July 3 and August 28.

Depths to the thermocline are variable with strong dependence upon weather conditions, particularly wind speed. In June, typical mixed layer depths are small and on the order of 5 to 15 feet (1.5 to 4.5 m). During July and August the heat balance is positive into the reservoir and strong stratification occurs. Mixed layer depths during this period can be on the order of 130 feet (39.4 m), with a sharp temperature gradient of approximately 5°C (41°F) in about 50 feet (15 m).

4.1 - Watana Development

Multiple mixed layers are established in Watana by the model due to periods of warm calm weather which provide surface warming with little mixing, interspersed with windy periods which cause deepening by mixing warm surface waters with cooler water below. The duration and magnitude of the wind dictates the effect on depth of mixing; hence, the step appearance of some summer profiles (Figure E.2.172).

Cooling in September results in the gradual destruction of the summer stratification and the deepening of the epilimnion to depths greater than 150 feet (45 m). This process continues until an isothermal condition exists, which in 1981, was simulated to occur in mid-October. Isothermal conditions continue until the reservoir water reaches maximum density after which reverse stratification occurs.

For the Watana reservoir simulation, a weak reverse stratification occurred in late November and remained relatively stable throughout December (Figure E.2.173). Under different meteorological conditions, the simulated depth of about 180 feet (55 m) to the hypolimnion could be much less due to less surface mixing or earlier ice cover formation.

Ice cover formation on Watana reservoir was estimated to occur on November 20, with a full ice cover by November 22. Ice thickness on December 31 was estimated at 31 inches (77.5 cm).

The multilevel intake at Watana provides the ability to select variable water temperatures within a range dictated by the thermal structure of the reservoir. The operating criterion for this structure is to discharge water temperatures as close to natural river temperatures as possible. This, in general, results in the intake closest to the surface being used, provided hydraulic submergence criteria are met. However, upon occasion, deeper intakes are used to provide water temperatures closer to normal.

The outflow temperature immediately downstream from the Watana dam is given in Figures E.2.174 and E.2.175. A release, which occurs in August, has been included in the estimate of outflow temperatures. This is further discussed below.

The comparison of natural temperatures and simulated outflow temperatures shows that during summer months the outflow temperature follows natural temperature trends but is cooler during July and slightly warmer in August. On most days, however, outflow temperatures in July and August are within 0.5°C (1°F) of natural temperatures. In June, outflow temperatures lag significantly behind natural temperatures due to reservoir filling and the heat required to warm the sizable Watana reservoir. The reverse is true in September when cooling is insufficient to provide near zero outflow temperatures (Figure E.2.174).

During September to mid-November the simulation shows a gradual cooling of outflow temperatures from 9.5°C (49.1°F) to 2°C (35.6°F) (Figures E.2.174 and E.2.175). Stable outflow temperatures of approximately 2°C (35.6°F) begin in mid-November and continue throughout December.

In the weekly reservoir operation simulations for WY 1981, a maximum release of 17,940 cfs occurs during the week of August 19-25. This release is the largest release in the 32-year simulation with the year 2000 demand (see Table E.2.50). Inspection of the Watana outflow temperatures in Figure E.2.174 for the week of August 19-25 indicates that maintaining water temperatures similar to natural conditions will not be a problem. This is because most of the water discharged through the fixed-cone valves will be drawn from the epilimnion. This can be observed by examination of the August/September temperature profiles in Figures E.2.172 and E.2.173. Since the intake elevation of the fixed-cone valves is between El 2025 ft (617 m) and 2085 ft (636 m) and the epilimnion extends from the surface down to approximately El 2025 ft (617 m) during the time period in which releases occur, it is apparent that warmer epilimnion water will be discharged.

- <u>Watana To Talkeetna</u>

. <u>Mainstem</u>

The Watana operation outflow temperatures, which were simulated using DYRESM with 1981 meteorological data were used to determine the water temperatures in the reach between Watana and Talkeetna. The discharge and outflow temperatures from Watana were input to the program HEATSIM. Watana discharges simulated for WY 1981, using the weekly reservoir model described in Section 3.2 were input for June through September. However, since the October to December 1981 period was not simulated with the weekly reservoir model, the long term average weekly simulated discharge was used for this period. Meteorological data for 1981 was used for June through December.

Results of the HEATSIM analysis are presented in Figures E.2.176, E.2.177, and E.2.178 for the period June to December. During June and July warming of the Watana discharge occurs between the damsite and Talkeetna. For the two August temperature profiles illustrated in Figures E.2.176, the heat balance between the water temperature and atmosphere results in essentially no heating or cooling. Temperatures at Talkeetna are equal to the Watana outflow temperatures.

In September the heat balance becomes negative causing cooling of the outlet temperatures. Talkeetna temperatures are less than the Watana outflow temperatures, but are much warmer than natural temperatures. This cooling continues throughout the winter months until spring when the heat balance again becomes positive. Due to the gradual reduction in Watana outflow temperatures and the climate conditions in October and November, the downstream temperatures exhibit a trend of progressively cooling through time which is clearly demonstrated by the upstream movement of the 0°C (32°F) front with time on Figure E.2.178.

Coincident with stable outflow temperatures is the establishment of a stable 0°C (32°F) water temperature at River Mile 150 (Portage Creek).

A comparison of 1981 observed water temperatures near Sherman and the DYRESM/HEATSIM temperature simulation for the same location for June through September with Watana operation is provided in Figure E.2.179. Although the absolute values do not match, the simulated temperatures are in the same range as the natural temperatures. In addition, both data sets show a similar response to meteorological conditions.

Sensitivity studies were undertaken to examine the variation in the upstream location of 0°C (32°F) water and the ice cover formation. The first assumed warm water discharge conditions from Watana, as could be obtained with the use of a low level intake, and the second assumed a linear reduction in Watana outlet temperature from 4°C to 2°C (39.2°F to 35.6°F) between November 1 and mid-January. Long-term average meteorological conditions and mean monthly Watana operation discharges were used as input to both downstream temperature simulations.

The simulation, assuming warm water withdrawal, results in water temperatures being greater than 0°C (32°F) upstream of RM 131 (near Sherman) at all times. The temperature profiles for the October to April simulation are presented in Figures E.2.180 and E.2.181. A comparison with Figures E.2.141 and E.2.142 (Watana Impoundment) shows the sensitivity of downstream temperatures with discharge. That is, the higher operational flows require a longer time to cool to 0°C (32°F) because of their larger heat content.

The second simulation illustrates a trend of upstream movement of the 0°C (32°F) front during the October to January period. The maximum upstream location of 0°C (32°F) water is to RM 150 at Portage Creek. Figures E.2.182 and E.2.183 illustrate this simulation.

The DYRESM and sensitivity runs place the upstream edge of 0°C (32°F) water somewhere between Sherman and Portage Creek by about the middle of January.

- Sloughs

During project operation, the sloughs will seldom be overtopped by the mainstem flow during the summer. Thus, the slough surface temperatures will be the same as existing slough temperatures for those times when, under pre-project conditions, the sloughs are not overtopped.

Preliminary investigations indicate that ground water upwelling temperatures in sloughs reflect the long-term average water temperature of the Susitna River which is approximately 3°C (37.4°F) (Section 2.4.4). In the Devil Canyon to Talkeetna reach, the long term average temperature will not change significantly from pre-project conditions as indicated by the temperature profiles discussed above. For example, using the DYRESM/HEATSIM temperature results for June through December, and assuming 0°C (32°F) water through April and an average May temperature of 3°C (37.4°F), the average annual temperature at Sherman is calculated to be 3.5°C (38.3°F).

- Talkeetna to Cook Inlet

During summer, temperatures downstream of the confluence will reflect the temperatures of the Talkeetna and Chulitna Rivers as discussed in Section 4.1.2(e)(i). However, during fall, winter, and early spring when natural flows are low, the Susitna River will experience increased flows and the Susitna River water temperatures will have a dominant effect on the downstream temperature. For example, using the October 15 simulation shown in Figure E.2.178, the water temperature upstream of Talkeetna is predicted to be 3.2°C (37.8°F). Assuming the natural temperature of 0°C (32°F) in October, average monthly discharges of 5000 and 2700 cfs for the Chulitna and Talkeetna Rivers (Table E.2.4) and a discharge of 6000 cfs for the Susitna, the composite temperature downstream of the confluence would be 1.4°C (34.5°F). Hence, this water temperature would be above the normal temperature of 0°C (32°F) for several miles downstream until it cooled to 0°C (32°F).

Later in the fall and during winter, the Susitna River water temperature near Talkeetna will be 0°C (32°F). Thus, in the reach downstream of the confluence there would be no change in temperature from the existing 0°C (32°F) temperatures.

(ii) Ice

- Watana Reservoir

As described in Section 4.1.3(c)(i), the DYRESM temperature model, using 1981 data input, predicts the ice cover to form on Watana reservoir on November 20 with a full ice cover on November 22. The ice thickness is estimated at 31 inches (77.5 cm) on December 31. Although not modeled, the ice cover thickness on the reservoir would continue to grow through the winter until the heat balance becomes positive. This is expected to occur in late April or May. Open water conditions are expected at the end of May.

- Watana to Talkeetna

To determine the extent, thickness and timing of the ice cover information and the associated river staging, the results of the HEATSIM downstream temperature modeling were input to an ice simulation model, ICESIM. A general description of the ICESIM model follows.

The ICESIM simulates the formation and mechanical progression of an ice cover and the water levels associated with the process.

The ICESIM model includes a simple subroutine which calculates backwater profiles in the river reach to assess water levels at different cross-sections. The routine is similar to but less complex than the HEC-2 model described in Section 2.2.4. This simplicity is required so that the computer computational time remains reasonable while accounting for the complexities of the ice processes. This results in less precise water level calculations compared to HEC-2 modeling accuracy, but it is considered adequate to provide representative results. The ICESIM model was calibrated against the HEC-2 model results for a river discharge of 9700 cfs. A comparison of the HEC-2 and ICESIM calculations indicates a reasonable agreement between the two model results.

The model simulates the formation and progression upstream from the ice cover given the starting location of the ice cover and the time of its occurrence. The model checks the stability of the ice cover and adjusts its thickness consistent with ice supply, river geometry, and hydraulics of the flow.

An attempt was made to calibrate the ice process simulation model with the field data collected during the 1980 river freezeup period. It became apparent that the model could not simulate numerous cross sections where critical or near-critical velocities occur in the river, due to the relatively large lengths of subreaches modeled. Nevertheless, the model was used to simulate ice formation and progression at average post-project winter flows, in which case, many of the minor riffles and rapids apparent at low natural flows are well submerged. Several qualitative checks were made to assess the accuracy of this simulation. These include general heat balance of the river waters, river hydraulic characteristics as observed in the field, and comparisons with similar studies elsewhere in northern climates.

During freezeup, because of the release of warmer water from Watana reservoir, frazil ice will not be generated for a considerable distance downstream from Watana. Based on the results of the HEATSIM temperature analyses, the reach between Watana and Devil Canyon will remain ice free.

Frazil ice should begin to form upstream from Talkeetna about the first week in November. However, farther upstream, the water temperature would still be above freezing. As with the natural ice cover progression, the frazil ice pans generated upstream will agglomerate at natural lodgement points and the cover will progress upstream from these. From the temperature analysis, the reach of the river that contributes ice to the system is limited due to warmer upstream water temperatures. Depending on the reservoir outflow temperatures, it could take from 30 to 90 days for the ice cover to progress to Devil Canyon. Using the combined simulation from the DYRESM and HEATSIM models for Watana operation as input to ICESIM, the time of progression would be about 30 days. The thickness of the ice cover as it progresses through the reach varies from a few feet to as much as 10 feet (3 m), which is not unlike existing conditions. The simulated ice cover thickness and progression are illustrated in Figure E.2.184.

With the formation of the ice cover, the river stage necessary to pass the required discharge will be greater than that for open water conditions. A comparison of the simulated staging during cover formation relative to the ice-free water surface profile at a flow of approximately 10,000 cfs is shown on Figure E.2.185.

A second ICESIM simulation was run assuming the Watana outlet temperatures linearly decrease from 4°C (39.2°F) on November 1 to 2°C (35.6°F) on January 15. The simulated ice thickness and ice front location at various times are illustrated in Figure E.2.184. River staging due to the ice cover is presented in Figure E.2.185. Figure E.2.184 shows a slower upstream progression with the 4°C (39.2°F) to 2°C (35.6°F) outlet temperatures than with the simulated reservoir outlet temperatures. This is because the simulated reservoir outlet temperatures are cooler in late November and December. Figure E.2.185 shows that although staging is similar in both examples, there are differences. This is attributable to the differences in discharge. The DYRESM/HEATSIM example uses 1981 climatic data and weekly average discharges whereas the 4°C (39.2°F) to 2°C (35.6°F) example considers the mean monthly discharges and the long term daily average based meteorological data.

After the solid cover forms, there will still be open leads due to high velocities and ground water upwelling. The size of these leads will be dependent on the weather conditions and extremely cold air temperatures will be required for these leads to become ice covered. The thickness of the stable cover will range from about 5 to 10 feet (1.5 to 3 m).

In spring, the onset of warmer air temperatures in the lower basin occurs several weeks before in the middle and upper reaches. This will progressively break up the cover starting from the downstream end. However, the warmer upstream temperature of water released from the reservoir will melt the cover between Devil Canyon and Talkeetna. The influx of warm water under the cover will tend to candle the ice and significantly weaken its structure. The timing of the warmer water outflow will be similar to the start of natural downstream breakup. However, regulation of the spring flood will encourage melting in place. With most of the cover melting in place coupled with the weakness of the remaining ice, the severity of ice jamming is expected to be significantly reduced.

- Sloughs

  With the staging that accompanies the pre-project ice formation process many of the sloughs are overtopped (Section 2.3.2[a]). With Watana operation, the higher discharge at freezeup will lead to a higher stage than under natural conditions. Consequently, discharge will be incresed through those sloughs currently overtopped if mitigation measures are not taken. Discharge may also occur in sloughs not currently overtopped. These higher discharges may cause scouring in the sloughs. However, because of the increased backwater at the slough mouths due to mainstem staging, velocities at the downstream end of the sloughs should be reduced, thereby reducing the chances of scouring in the lower reaches of the sloughs. Velocities upstream of the backwater effects may be as high as 3 fps (0.9 m/sec) under the ice cover and may cause erosion. However, the bed material in the sloughs becomes coarser (Figure E.2.21) with distance upstream and is more resistant to the flow.

  The important salmon spawning sloughs will be protected by the construction of elevated berms at the upstream end of those sloughs where ice effects are anticipated. Thus, overtopping of sloughs during the ice formation period will not occur. The slough bed material will be maintained on a 5 year rotating basis to provide suitable spawning habitat (See Chapter 3).

- Talkeetna to Cook Inlet

Since the Susitna is currently the main source of ice to the river system below Talkeetna, the timing of ice formation downstream from Talkeetna will be delayed about 4 weeks (currently October). The higher post-project winter flows combined with the ice formation will increase the water levels downstream. It is not possible to quantatively analyze the impact on the segment downstream of Talkeetna at this time. However, it is noted that the increased staging in this reach will be limited because of the numerous alternative channels and subchannels available to convey the discharge.

(iii) Suspended Sediments

As the sediment-laden Susitna River enters the Watana reservoir, the river velocity will decrease and the larger diameter suspended sediments will settle out to form a delta at the upstream end of the reservoir. The delta formation will be constantly adjusting to the changing reservoir water level. Sediment will pass through channels in the delta to be deposited over the lip of the delta formation. Depending on the relative densities of the reservoir water and the river water, the river water containing the finer unsettled suspended sediments will either enter the reservoir as overflow (surface current), interflow, or underflow (turbidity current).

Trap efficiency estimates using generalized trap efficiency envelope curves developed by Brune (1953) indicate 90-100 percent of the incoming sediment would be trapped in a reservoir the size of Watana reservoir. However, sedimentation studies at glacial lakes indicate that the Brune curve may not be appropriate for Watana. These studies have shown that the fine glacial sediment (flour) may pass through the reservoir. Glacial lakes immediately below glaciers have been reported to have trap efficiencies of 70-75 percent. Kamloops Lake, British Columbia, a deep glacial lake on the Thompson River, retains an estimated 66 percent of the incoming sediment (Pharo and Carmack 1979).

Particle diameters of 4 microns (0.16 mils) have been estimated to be the approximate maximum size of the sediment particles that will pass through the Watana reservoir (Peratrovich, Nottingham & Drage, 1982). By examining the particle size distribution curve (Figure E.2.80), it is estimated that about 80 percent of the incoming sediment will be trapped.

In the Watana reservoir, it is expected that wind mixing may be sufficient to retain particles less than 12 microns (0.5 mils) in suspension in the upper 50-foot (15 m) water layer (Peratrovich, Nottingham & Drage 1982). Re-entrainment of sediment from the shallow depths along the reservoir boundary during high winds will result in short-term elevated turbidity levels. This will be particularly important during the summer refilling process when water levels will rise, resubmerging sediment deposited along the shoreline during the previous winter drawdown period.

For an engineering estimate of the time it would take to fill the reservoir with sediment, a conservative assumption of a 100 percent trap efficiency was made. This resulted in the deposition of 472,500 acre-feet of sediment after 100 years (R&M 1982c), and is equivalent to 5 percent of the reservoir volume. Thus, sediment deposition will not affect the operation of Watana reservoir over the life of the project.

During reservoir operation, the efect of bank instability on suspended sediments in the reservoir will be the same as those that occur during reservoir filling discussed in Section 4.1.2(e). Suspended sediment concentrations downstream will be similar to that discussed in Section 4.1.2(e)(iii).

(iv) Turbidity

Turbidity patterns can have an impact on fisheries, both in the reservoir and downstream. The turbidity pattern is a function of thermal structure, wind-mixing, and reentrainment of fine sediments along the reservoir boundaries. Turbidity patterns observed in Eklutna Lake provide the best available physical model of anticipated turbidity within Watana reservoir. Although it is only one tenth the size of the Watana reservoir, its morphometric characteristics are similar to Watana. It is 7 miles (11 km) long, 200 feet (60 m) deep, has a surface area of 3420 acres (1368 ha), and has a total storage of about 414,000 acre-feet. Bulk annual residence time is 1.77 years as compared to Watana's 1.65 years. It also has 5.2 percent of its basin covered by glaciers, compared to 5.9 percent of Watana's drainage area. It is believed that turbidity patterns in the two bodies of water will be somewhat similar, although the distance from the glacier to the lake will affect the temperature of the river water as it enters the lake, thus, affecting its equilibrium density and depth.

Data collected at Eklutna from March through October 1982 demonstrate the expected pattern at Watana (R&M 1982i). In March, turbidity beneath the ice cover was uniformly less than 10 NTU in the downstream end of the lake near the intake to the Eklutna hydroelectric plant. Shortly after the ice melted in late May but before significant glacial melt had commenced, turbidity remained at 7-10 NTU throughout the water column. By mid-June, the turbidity had risen to 14-21 NTU, but no distinct turbidity plume was evident. In mid-June warming was evident only in the upper 10 feet (3 m). Thus, it is assumed the lake had completed its spring overturn only slightly before mid-June. By early July, a slight increase in turbidity was noted at the lake bottom near the river inlet. Distinct turbidity plumes were evident as interflows in the upstream end of the lake from late July through mid-September. Turbidity values had significantly decreased by the time the plume had traveled 5 miles (8 km) down the lake. In late September, a turbid layer was noted at the bottom of the lake as river water entered as underflow. By mid-October, the lake was in its fall overturn period, with near-uniform temperatures at approximately 7°C (44.6°F) and a turbidity of 30-35 NTU.

In Kamloops Lake, B.C., thermal stratification of the lake tended to "short-circuit" the river plumes especially during periods of high flow (St. John et al. 1976). The turbid plume was confined to the surface layers, resulting in a relatively short residence time of the incoming river water during summer. St. John et al. (1976) noted that high turbidity values extended almost the entire length of Kamloops Lake during the summer. He suggests that the effects of dilution and particle settling were minimal because the presence of the 10°-6°C (50°-42.8°F) thermocline, effectively separated the high turbidity water in the upper layers of the lake from the highly transparent hypolimnetic water. This phenomenon was not apparent in Eklutna Lake where plumes were evident up to 5 miles (8 km) down the lake, but were below the thermocline. In addition, Eklutna Lake particle settling and dilution were evident as turbidity continually decreased down the length of the lake.

The relatively cool, cloudy climate in south-central Alaska would tend to prevent a sharp thermocline from developing, so that the processes identical to those observed in Kamloops Lake would not be expected either in Eklutna Lake, or the Watana reservoir.

Turbidities based on the Eklutna Lake studies and other sources were estimated for Watana (Peratrovich Nottingham and Drage 1982). The analysis indicates that Watana reservoir turbidity levels will be in the range of 10-50 NTU. This range was determined from the regression equation developed between turbidity and suspended sediment concentration using existing USGS data for the Susitna River (Figure E.2.82). It was estimated that winter turbidity values at the outlet after formation of an ice cover on the reservoir will be in the 10-20 NTU range, summer values will be in the 20-50 NTU range, and maximum expected values at freezeup would be 40-50 NTU.

(v) Dissolved Oxygen

Susitna River inflow to the reservoir will continue to have both high dissolved oxygen concentrations and high percentage saturations. The oxygen demand of the water entering the reservoir will be low. No man-made sources of oxygen demanding effluent exist upstream from the impoundment. Chemical oxygen demand (COD) measurements at Vee Canyon during 1980 and 1981 were low, averaging 16 mg/l. No biochemical oxygen demand values were recorded.

Wastewater from the permanent town and anticipated recreationists will not contribute an oxygen demand of any significance to the reservoir. All wastewater will be treated to avoid effluent-related problems.

The trees within the inundated area will be cleared, removing the potential BOD they would have created. A layer of organic matter at the reservoir bottom will still remain and could create some localized oxygen depletion along the reservoir floor. However, the process of decomposition will be very slow because of the cold temperatures near the bottom.

The stratification that is anticipated in the reservoir may limit the oxygen replenishment in the hypolimnion. The spring turnover, with its large inflow of freshwater, will cause mixing; however, the depth to which this mixing will occur is unknown. However, based on the reservoir temperature modeling, it is anticipated that the upper 200 feet (60 m) of the impoundment should maintain high D.O.

Downstream from the dam, no dissolved oxygen changes are anticipated, since water will be drawn from the upper layer of the reservoir.

(vi) Total Dissolved Gas Concentration

As previously noted, supersaturated dissolved gas (nitrogen) conditions can result below high head dams as a result of flow releases. During project operation, specially designed fixed- cone valves will be used to discharge all releases with a recurrence interval of less than 1:50 years.

As previously described in Section 4.1.3(a)(v) operation of the fixed-cone valves will be linked to the energy demand. The forecasted energy demand for 1995 would necessitate releases for 30 of the 32 years of simulated reservoir operation although in 23 of the 30 years the maximum annual release would be less than 2500 cfs. Descriptions of the first week of release, week of maximum release, maximum release (cfs), simultaneous powerhouse flows (cfs) and total release (acre-feet) are provided in Table E.2.50. In contrast, the anticipated increase in energy demand for the year 2000 would result in operation of the fixed-cone valves in only 11 of the 32 years of simulated operation. Detailed information for the year 2000 simulation is also available in Table E.2.50. In all cases, the fixed-cone valves will be capable of discharging the released waters without increasing the dissolved gas concentrations.

Detailed information on the effectiveness of the valves for maintaining acceptable dissolved gas concentrations is available in Section 6.4.4.

Decreased downstream flows during summer operation will cause a reduction in the levels and variations of dissolved gas concentrations below Devil Canyon. Based upon pre-project data, mean post-project summer flows (June to September) of 7900 to 12,100 cfs are expected to produce concentrations, below the Devil Canyon rapids, of less than 106 and 108 percent, respectively.

Although no pre-project measurements of dissolved gas levels exist for the winter period, it is anticipated that average post-project flows at Devil Canyon (7570 to 10,550 cfs) will create elevated levels of dissolved gas below Devil Canyon. Concentrations are expected to vary from less than 106 percent to 108 percent based upon the available pre-project measurements taken at slightly higher discharge conditions and significantly higher ambient air temperatures. Given the frequent natural occurrence of levels greater than these concentrations, no adverse impacts are foreseen.

(vii) Trophic Status (Nutrients)

A detailed analysis of the anticipated trophic status of the Watana reservoir has been developed by Peterson and Nichols (1982). Information from their analysis follows.

Reservoir trophic status is determined in part by the relative amounts of carbon, silicon, nitrogen, and phosphorus present in a system, as well as the quality and quantity of light penetration. The average 1980-1981 C:Si:N:P June ratio of 1080:340:28:1 indicates that phosphorus will be the limiting nutrient in the Susitna impoundments. Vollenweider's (1976) model was considered to be the most reliable in determining phosphorus concentrations at the Watana impoundment. However, because the validity of this model is based on phosphorus data from temperate, clear-water lakes, predicting trophic status of silt-laden water bodies with reduced light conditions and high inorganic phosphorus levels may over estimate the actual trophic status.

The spring phosphorus concentration in phosphorus-limited lakes is considered the best estimate of a lake's trophic status. Bio-available phosphorus, or orthophosphate, is the fraction of total phosphorus which controls algae growth in a particular lake. The measured dissolved orthophosphate concentration at Vee Canyon was considered to be the bio-available fraction in the Susitna River. Accordingly, the average dissolved orthophosphate concentration in June was multiplied by the average annual flow to calculate the spring phosphorus supply. This value was in turn combined with phosphorus values from precipitation and divided by the surface area of the impoundment. The resultant spring phosphorus loading values for Watana reservoir were far below the minimum loading levels that would result in anything other than oligotrophic conditions. Likewise, upon incorporating spring loading values into Vollenweider's (1976) phosphorus model, the volumetric spring phosphorus concentration fell into the same range as oligotrophic lakes with similar mean depths, flushing rates, and phosphorus loading values (Peterson and Nichols 1982).

The aforementioned trophic status predictions depend upon several assumptions that cannot be quantified on the basis of existing information. These assumptions include:

- The C:Si:N:P ratio does not fluctuate to the extent that a nutrient other than phosphorus becomes limiting;

- No appreciable amount of bio-available phosphorus is released from the soil upon filling of the reservoirs;

- Phosphorus loading levels are constant throughout the peak algal growth period;

- June phosphorus concentrations measured at Vee Canyon correspond to the time of peak algal productivity;

- Phosphorus species other than dissolved orthophosphate are not converted to a bio-available form;

- Flushing rates and phosphorus sedimentation rates are constant;

- Phosphorus losses occur only through sedimentation and the outlet; and

- The net loss of phosphorus to sediments is proportional to the amount of phosphorus in each reservoir.

Artificial phosphorus loading of the reservoir from domestic sources was similarly investigated by

Peterson and Nichols (1982). They concluded that the maximum allowable artificial loading is equivalent to the waste from 115,800 permanent residents, if oligotrophic conditions are to be maintained. However, this estimate is conservative since the effects of low light penetration and the use of waste treatment have been neglected.

(viii) Total Dissolved Solids, Conductivity, Significant Ions, Alkalinity, and Metals

The leaching process, as previously identified in Section 4.1.2(e)(vii), is expected to result in increased levels of the above parameters within the reservoir immediately after impoundment. The magnitude of these changes cannot be quantified, but should not be significant (Peterson and Nichols 1982). Furthermore, Baxter and Glaude (1980) have found such effects are temporary and diminish with time.

The effects of leaching will diminish for two reasons. First, the most soluble elements will dissolve into the water rather quickly and the rate of leachate production will correspondingly decrease with time. Second, much of the inorganic sediment carried by the Susitna River will settle in the Watana reservoir. The formation of an inorganic sediment blanket on the reservoir bed will retard the leaching process (Peterson and Nichols 1982).

Leaching byproducts should not be reflected in the river below the dam since the leachate is expected to be confined to a small layer of water immediately adjacent to the reservoir floor and the intake structures will be near the surface (Peterson and Nichols 1982).

During periods of evaporation, slightly higher concentrations of dissolved substances have been found at the surface of impoundments (Love 1961; Symons 1969). Because of the large surface area of the proposed impoundment, evaporation will be substantially increased over existing conditions. The annual average evaporation rate for May through September at Watana is estimated at 10.0 inches or 0.3 percent of the reservoir volume (Peterson and Nichols 1982). Given the mixing effects of wind and waves and the fact that direct precipitation exceeds annual evaporation, no measurable increase in dissolved solids is expected.

Dissolved solid concentrations are expected to increase near the surface of the impoundment during winter. Mortimer (1941,1942) noted that the formation of ice at a reservoir surface forces dissolved solids out of the freezing water, thereby increasing concentrations of these solids at the top of the reservoir. No impacts should result either in the reservoir or downstream from the dam from this process.

In contrast to the above discussions, precipitation of metals such as iron, manganese and other trace elements have been noticed in reservoirs, resulting in reduced concentrations of these elements (Neal 1967). Oligotrophic reservoirs with high pH and high dissolved salt concentrations generally precipitate more metal than reservoirs with low pH and low dissolved salt concentrations. This is attributed to the dissolved salts reacting with the metal ions and subsequently settling out (Peterson and Nichols 1982). Average Susitna River TDS values for Vee Canyon and Gold Creek during winter are 141 and 150 mg/l, respectively. For summer they are somewhat lower, approximately 98 and 91 mg/l respectively. Average values for pH range between 6.9 and 7.6 for the two stations. Although neither of the parameters is excessively high, precipitation of metals may reduce the quantities of metals in the reservoir.

(d) Ground Water Conditions

(i) Mainstem

As a result of the annual water level fluctuation in the reservoir, there will be localized changes in ground water in the immediate vicinity of the reservoir. Ground water impacts downstream during summer will be similar to those described in Section 4.1.2(f)(i) and will be confined to the river area. Since powerhouse flows will generally be greater than filling flows during summer, the ground water level change from natural conditions will be slightly less than during filling. During winter, increased ice staging will occur during freezeup (Section 4.1.3(c) [iii]) and hence ground water level will be increased along ice covered sections of the mainstem.

(ii) Sloughs

During winter in the Devil Canyon to Talkeetna reach, some of the sloughs (i.e., those nearer Talkeetna) will be adjacent to an ice-covered section of the Susitna River. In ice-covered sections, the Susitna River will have staged to form an ice cover at project operation flows of about 10,000 cfs. The associated water level will be a few feet above normal winter water levels and will cause an increase in the ground water table. This will in turn cause an increase in ground water flow adjacent to an ice covered reach of the river.

Sloughs upstream of Gold Creek, in the vicinity of Portage Creek, may be adjacent to open water sections of the Susitna River. Because flows will average approximately 10,000 cfs in winter, the associated water level will be less than water levels occurring under the natural freezeup process. This is illustrated by the higher stage shown during the normal freezeup process than during an open water discharge of 10,000 cfs in Figure E.2.76. Hence, the ground water table will be lower. Sloughs in this area may experience a decrease in ground water flow in the winter.

During summer, the mainstem-slough ground water interaction will be similar to that discussed in Section 4.1.2(f)(ii), with the exception that operational flows will be greater than the downstream flows during filling, and thus, the ground water table will be closer to the natural elevation than during filling.

(e) Lakes and Streams

The numerous small lakes identified in Section 2.5.1 will be inundated by the Watana reservoir during the impoundment phase. Most of them will remain below the reservoir surface at all times but a few will become perched at low reservoir levels.

The mouths of streams flowing into the reservoir will shift upstream and downstream in response to the reservoir water level fluctuations. The position of the delta formation will likewise vary. Both bedload and suspended sediment load will be deposited wherever the stream current enters the still water of the impoundment.

The downstream tributaries described in Section 4.1.2(g) and listed in Table E.2.27, will begin to modify their geomorphologic regimes and either downcut their beds or remain perched above the Susitna in response to the reduced river levels during project operation. Anticipated stream impacts are listed in Table E.2.27.

(f) Instream Flow Uses

(i) Fishery Resources, Riparian Vegetation and Wildlife Habitat

Impacts of project operation on the fishery resources, riparian vegetation, and wildlife habitat are discussed in Chapter 3.

(ii) Navigation and Transportation

Because the Watana reservoir will decrease navigational difficulties between Watana and the Tyone River, increased boat traffic in the reservoir area will occur. Reservoir water craft navigation will extend to November because of the delay in ice-cover formation. Once an ice cover forms in late November and December, the reservoir will be available for surface travel by dogsled and snow machine through April.

Although summer flows downstream of the dam will be reduced from natural conditions during project operation, navigation and transportation in the Watana to Talkeetna reach will not be significantly impacted. However, because of the reduced water levels, caution will be required in navigating various reaches. From Figure E.2.160 there is a 10 percent chance that the monthly Gold Creek flow will be less than 6500 cfs in May and a 3 percent chance that the flow will be less than 6500 cfs in June. During July, August, and September Gold Creek flows during Watana operation are greater than 6500 cfs. Thus, there is a minor chance that navigation at Sherman will be impacted during May and June. If this occurs, the mitigation measures discussed in Section 4.1.2(h)(ii) will be implemented.

Downstream of Talkeetna, flows at Sunshine are greater than 17,000 cfs, 80 percent of the time in May and 100 percent of the time in June through September (Figure E.2.161). Since this flow will maintain adequate navigational water depths in this reach, no problems are anticipated from June through September. The fact that 20 percent of the May values are less than 17,000 cfs is attributable to a later breakup in some years. Since navigation cannot begin until after breakup, there will be no navigation problems in May either.

At Susitna Station, flows drop below 43,000 cfs about 10 percent of the time in May and 15 percent of the time in September. Figure E.2.162 indicates that at these percent exceedence levels, the flows are similar to pre-project flows. Therefore, although the flow necessary to maintain the navigability of the upper end of Alexander Slough is not known, any navigation problems at these flows would have occurred under pre-project conditions and thus, the post-project flows will not increase the navigational difficulties at Alexander slough.

During the fall and winter, a significant reach of the river between Watana and Talkeetna will be ice free for a few weeks longer than during existing conditions. The reach between Watana and Portage Creek will not develop an ice cover. This will allow for a longer boating season but will impede use of this river reach as a transportation corridor by snow machine or dogsled.

Downstream from Talkeetna, ice-cover formation will be delayed a few weeks and river stage during freeze-up will be increased. This will delay winter transportation across the ice.

(iii) Waste Assimilative Capacity

No impacts to the summer waste assimilative capacity of the river will occur during project operation. The wastes generated by the approximate 130 staff members and their families at the permanent town will receive secondary treatment similar to the previously described construction camp and village wastewater treatment. The winter waste assimilative capacity of the river will be at least doubled due to the increased winter flow.

4.1 - Watana Development

(iv) Freshwater Recruitment to Cook Inlet Estuary

Salinity changes in Cook Inlet due to Watana operation were simulated using a computer model (Resource Management Associates 1983). Results of the modeling indicate that the salinity in Cook Inlet will attain a dynamic equilibrium within approximately one year of reservoir operation. Winter salinities will be greater and summer salinities will be reduced.

Near the mouth of the Susitna River (Node 27) pre- and post-project salinity differences will be greatest during April. Watana operation salinity concentrations are estimated to be approximately 19,600 mg/l, or a decrease of 1400 mg/l from pre-project conditions. With the reduced flows during summer, a maximum salinity increase of 700 mg/l above pre-project salinity levels is predicted to occur in June (Figure E.2.127).

At the center of Cook Inlet near East Foreland (Node 12), salinity changes will be significantly less. Concentration decreases of approximately 400 mg/l are predicted in April. During August a salinity increase of about 100 mg/l is estimated to occur. Additional comparisons are presented in Table E.2.31.

In general, salinity variations will result in a reduced post-project salinity range. The maximum reduction will be near the mouth of the Susitna River where an annual maximum to annual minimum range decrease of about 2000 mg/l can be expected.

4.2 - Devil Canyon Development

4.2.1 - Watana Operation/Devil Canyon Construction

Access tunnel construction at the Devil Canyon site is scheduled to begin in 1995. The Devil Canyon development when completed in 2002 will consist of a 646-foot (196 m) high, concrete arch dam, outlet facilities capable of passing 38,500 cfs; a flipbucket spillway with a capacity of passing 125,000 cfs; an emergency spillway with a capacity of 160,000 cfs; and a 600-MW capacity underground powerhouse. Further information on the physical features of the Devil Canyon development can be found in Section 7 of Exhibit A.

4.2 - Devil Canyon Development

The Devil Canyon diversion tunnel is designed to pass the 1:25-year recurrence interval flood routed through Watana without endangering the diversion dam. This lower level of flood protection than used for the Watana diversion is possible because of the degree of regulation provided by the Watana reservoir.

During the Devil Canyon construction phase, most differences in the quantity and quality of the water from the existing baseline conditions will be the result of the presence and operation of the Watana facility. Therefore, the conditions described in Section 4.1.3 will, in many cases, be referred to when discussing the impacts of Devil Canyon construction.

(a) Flows and Water Levels

(i) Watana Operation

Operation of Watana will be unchanged during the construction of Devil Canyon. Hence, the discussion presented in Section 4.1.3(a) remains appropriate.

During construction of the diversion tunnel, the flow in the mainstem will be unaffected. Upon completion of the diversion tunnels in 1996, the upstream cofferdam will be closed and flow will be diverted through the diversion tunnel without any interruption in flow. This action will dewater approximately 1100 feet of the Susitna River between the upstream and downstream cofferdams.

Because ice will not be generated in the Watana to Devil Canyon reach, ponding during winter will be unnecessary at Devil Canyon (see Section 4.1.3(c) [ii]).

Velocites through the 30-foot (9 m) diameter tunnel at flows of 10,000 cfs will be 14 fps (4.2 mps).

(ii) Floods

The diversion tunnel is designed to pass flood flows up to the 1:25-year summer flood, routed through Watana (approximately 32,000 cfs). The flood frequency curve for Devil Canyon is illustrated in Figure E.2.186 and is based on the weekly reservoir simulations described in Section 4.1.3(a) (i). There is little change in discharge for floods up to the 1:50 year flood because the Watana reservoir can absorb the incoming flood, discharging a maximum of 31,000 cfs (24,000 cfs through the outlet facilities and 7000 cfs through the powerhouse [assuming minimum energy demand]).

(b) River Morphology

Since flows from Watana reservoir operation will be unchanged during construction of the Devil Canyon Dam, the morphological processes described in Sections 4.1.2(b) and 4.1.3(b) for Watana operation will continue to occur.

The most significant impacts from construction will be at the damsite, as the rapids at the upper end of Devil Canyon will be blocked off and approximately 1100 feet (330 m) of the Susitna River between the upstream and downstream cofferdams will be dewatered. No impacts to the morphology of the Susitna River are anticipated from borrow material excavation since there are no borrow sites located within the Susitna River. Although Borrow Site G (Figure E.2.187) is located south of and adjacent to the Susitna River, no mining activities will be undertaken in the riverbed.

Cheechako Creek will be rerouted to facilitate efficient borrow excavation. Consequently, it will be channelized to the eastern boundary of the borrow site.

(c) Water Quality

(i) Water Temperature

There will be no difference in water temperatures at Devil Canyon or at points downstream from the construction site from those discussed in Section 4.1.3(c)(i).

(ii) Ice

Ice processes will be unchanged from those discussed in Section 4.1.3(c) (ii), Watana operation.

(iii) Suspended Sediment/Turbidity/Vertical Illumination

Construction of the Devil Canyon facility is expected to have siltation and turbidity impacts similar to those anticipated at Watana, but of a much smaller magnitude.

Tunnel excavation, placement of the cofferdams, excavation of construction materials, dewatering, gravel washing, and the clearing and disposal of vegetation and overburden will all provide opportunities for the introduction of sediment to the river. However, the potential impacts from borrow site mining will be greatly reduced since no instream work is currently planned.

The material sources required for construction are Borrow Site G and Quarry Site K (shown in Figure E.2.188) and previously described in Borrow Site D located near Watana (Figure E.2.133). Borrow Site G is expected to provide approximately 2 million cubic yards (cy) of aggregate with less than 5 percent waste. Mining of this material will occur in the dry. The Susitna River will form the north boundary of the borrow area. The mouth of Cheechako Creek, however, will be diverted to the eastern boundary of the borrow site to facilitate access to all required material. The area of disturbance, located entirely within the confines of the Devil Canyon reservoir, is likely to exceed 40 acres, but is not expected to equal the approximate 80 acres shown in Figure E.2.187.

Although washing will be required, the quantities of fines should be limited since the borrow material is predominantly composed of river washed sands and gravels. All wash water will be directed to a series of settling ponds. Prior to mining, all overburden and vegetation will either be slashed and burned, carefully stockpiled for future reclamation work or buried.

Quarry Site K is located in an upland site that is estimated to contain total resources of 40 million cy of rock. However, only 1.5 million cy of this quantity will be needed for the saddle dam, riprap and other uses. Disposal of not more than 310,000 cy of oversized and undersized material will occur in either the existing talus pile at the base of the cliff (see Figure E.3.189), near the site of the saddle dam, or along the reservoir for beach material. No washing of materials will be required; and hence, no wastewater will be produced.

Overburden will be stripped and carefully stockpiled for subsequent rehabilitation of the area. No siltation problems will result from the development of this site. It is expected that 10 to 15 acres of the 30-acre primary quarry site will be disturbed.

Borrow Site D has been identified as the nearest source of 300,000 cy of fine grained core material required for the saddle dam and emergency spillway fuseplug. Hauling of this material will be via the main access road between Watana and Devil Canyon. Processing of the material will occur at Watana. No adverse sedimentation problems will occur due to the upland location of Borrow Site D and the use of settling ponds for runoff treatment.

In summary, the improved summer water clarity, resulting from the sediment trapping characteristics of the Watana reservoir, is not expected to be adversely affected during Devil Canyon construction activities. During winter, the suspended sediment concentratons and turbidity levels released from Watana, are expected to pass downstream of the Devil Canyon construction site without significant change.

Additional information on the proposed mitigation of erosion problems is discussed in Section 6.2 and Chapter 3.

(iv) Nutrients

Similar to Watana construction, increased concentrations of nutrients and organics could result from disturbances and subsequent erosion of organic soils. However, since the overburden layer near the Devil Canyon damsitè is quite shallow and overburden and vegetation will either be slashed and burned, safely stockpiled for future rehabilitation or buried, impacts should be insignificant.

(v) Metals

As discussed in Section 4.1.1(c)(v), Watana construction, disturbances to soils, and rock adjacent to the river will increase dissolved and suspended materials in the river. Although this may result in slightly elevated metal levels within the construction area and downstream, water quality should not be significantly changed (Section 2.3.8 (k)).

(vi) Contamination by Petroleum Products

All state and federal regulations governing the prevention and reclamation of accidental spills, including the development and implementation of a Spill Prevention Containment and Countermeasure Plan (SPCC), will be adhered to. Additional information on proposed mitigative measures are provided in Section 6.2 and Chapter 3.

(vii) Concrete Contamination

The potential for concrete contamination of the Susitna River during the construction of the Devil Canyon Dam will greatly exceed the potential for contamination during Watana construction because of the much larger volume of concrete required. It is estimated that 1.7 million cubic yards of concrete will be used in the construction of the dam. The wastewater and waste concrete associated with the batching of the concrete could, if directly discharged into the river, seriously degrade downstream water quality with subsequent fish mortality. To prevent these problems, a modern efficient central batch plant will be utilized. However, approximately 20,000 cubic yards of waste material will be generated. Methods similar to those discussed for Watana Construction, Section 4.1.1(c)(v), will be used to minimize potential contamination problems.

(viii) Other Parameters

No additional water quality impacts are expected.

(d) Ground Water Conditions

Since the construction at Devil Canyon will not modify the discharge, the ground water impacts discussed under Watana operation (Section 4.1.3(d)) will remain relevant during this period. Some local changes in ground water levels in the immediate vicinity of the damsite may occur due to dewatering of open and underground excavations.

(e) Lakes and Streams

The perched lake adjacent to the Devil Canyon damsite will be eliminated by construction of the saddle dam across the low area on the south bank between the emergency spillway and the main dam. The lake is just west of the downstream toe of the saddle dam and will be drained and partially filled during construction of the saddle dam. To facilitate efficient borrow excavation, Cheechako Creek will be rerouted to the eastern boundary of Borrow Site G.

(f) Instream Flow Uses

The diversion tunnel and cofferdams will block upstream fish movement at the Devil Canyon construction site. However, the Devil Canyon and Devil Creek rapids act as natural barriers to most upstream fish movement.

Navigational impacts will be the same as during Watana operation (Section 4.1.3(f)(ii)), except that the whitewater rapids at Devil Canyon will be eliminated because of construction activities.

(g) Support Facilities

The construction of the Devil Canyon hydropower project will require the construction, operation and maintenance of support facilities capable of providing the basic needs for a maximum population of 1,900 people (Acres 1982a). The facilities, including roads, buildings, utilities, stores and recreation facilities will be essentially completed during the first six years (1992-1997) of the proposed eleven-year construction period. The Devil Canyon construction camp and village will be built using components from the Watana camp. The camp and village will be located approximately 2.5 miles (4 km) southwest of the Devil Canyon damsite. The location and layout of the camp and village facilities are presented in Plates F.70, F.72, and F.73 of Exhibit F.

4.2 - Devil Canyon Development

(i) Water Supply and Wastewater Treatment

The Watana water supply and wastewater treatment plants will be reduced in size and reutilized at Devil Canyon. As a result, processes identical to those employed at Watana will be used to process the domestic water supply and treat the wastewater.

The water intake has been designed to withdraw a maximum of 775,000 gallons/day (less than 1 cfs) to provide for the needs of the support communities (Acres 1982a). Since the source of this supply is the Susitna River, no impacts on downstream flows will occur throughout the duration of the camps' existence. The water supply will be treated to conform to all state and federal regulations.

The wastewater treatment facility will be sized to handle 500,000 gallons daily. The effluent from this secondary treatment facility will not affect the waste assimilative capacity of the river and will be discharged approximately 1000 feet downstream from the intake.

Prior to the completion of the wastewater treatment facility, all wastewater will be chemically treated and stored in lagoons for future processing by the facility. No raw sewage will be discharged to the river.

Chemical toilets will be placed throughout the construction area and will be serviced and discharged into the treatment facility.

The applicant will obtain all the necessary state and federal permits for the water supply and waste discharge facilities.

Additional details pertaining to the proposed water supply and wastewater discharge facilities are available in Acres 1982a.

(ii) Construction, Operation, and Maintenance

Similar to Watana, the construction, operation and maintenance of the camp and village could cause increases in turbidity and suspended sediments in the local drainage basins (i.e., Cheechacko Creek and Jack Long Creek). In addition, there will be a potential for accidental spillage and leakage of petroleum products and concrete wastewater contaminating ground water and local streams and lakes. Through appropriate preventative techniques, these potential impacts will be minimized. All required permits for the construction and operation of the proposed facilities will be obtained.

4.2.2 - Watana Operation/Devil Canyon Impoundment

(a) Reservoir Filling Criteria

Reservoir filling will be completed in two distinct stages. Upon completion of the main dam to a height sufficient to allow ponding above the outlet facilities (fixed-cone valves) which are located at El 930 ft and 1050 ft, the intake gates will be partially closed to raise the upstream water level from its natural level of about El 850 ft. A minimum flow of 5,000 cfs will be maintained at Gold Creek if the first stage of filling occurs between October and April. From May through September, the minimum flows described in Section 4.1.3(a)(i) will be released (See Table E.2.36).

Once the level rises above the lower level discharge valves, the diversion gates will be permanently closed and flow will pass through the fixed cone valves. These valves will have a discharge capacity of 38,500 cfs. They are described in Section 4.2.3(a)(v).

Since the storage volume required before operation of the cone valves can commence is approximately 76,000 acre-feet, the first phase of the filling process will require from one to four weeks depending on time of year and Watana powerhouse flows when filling is begun. The reservoir will not be allowed to rise above 1135 ft (344 m) for approximately one year while the diversion tunnel is being plugged with concrete.

When the dam is completed, an additional one million acre-feet of water will be required to fill the reservoir to its normal operating elevation of 1455 ft (441 m). Filling will be accomplished as quickly as possible (currently estimated to be between 5 and 8 weeks) utilizing maximum powerhouse flows at Watana. During filling of Devil Canyon reservoir, Gold Creek flows will be maintained at or above the minimum flows listed in Table E.2.36.

(b) Flows and Water Levels

Because of the two distinct filling periods, the two-stage impoundment sequence will take several years to complete, even though the actual time for filling will only be two months. As noted above, flows during the first stage of filling will be impacted for only a few weeks.

Between the first stage and second stage of filling, the reservoir will not be allowed to exceed El 1135 ft (344 m). Thus, the Devil Canyon reservoir will be held at a relatively constant level. Flows in the Susitna River will be unchanged from those during Watana operation (see Section 4.1.3(a)).

During the second stage of filling, 1,014,000 acre-feet of water will be added to the Devil Canyon reservoir. The Watana powerhouse will be operated to supply either the total railbelt energy demand or maximum powerhouse capacity. whichever is less. Assuming the medium load forecast for 2002, the peak demand is 1158 MW. This would require a maximum Watana powerhouse flow of 22,000 cfs at normal maximum operating head. Since this is greater than the maximum possible powerhouse flow of 21,300, the maximum flow from Watana would be 21,300 cfs. However, it is anticipated that powerhouse flows during filling would be more in the range of 16,000 to 19,000 cfs.

The flow from the Watana reservoir that is in excess of the downstream requirements (Table E.2.36) flow will be used to fill the Devil Canyon reservoir. During this process, the Watana reservoir will be lowered about 25 feet. Although the flow from the Watana powerhouse will be up to twice the normal flow, the impact of increased flow will be minimal in the Devil Canyon reservoir.

Flow downstream from Devil Canyon will be slightly reduced during this filling process. However, the filling period will be short and downstream flows will be maintained at or above the minimum target flows at Gold Creek (Table E.2.36).

Since the filling time is short and will occur in the fall or winter, floods are likely to be important only during the time the reservoir is not allowed to increase above El 1135 ft. If a flood should occur during this time, the cone valves are designed to pass the routed 1:50-year design flood of 38,500 cfs.

(c) River Morphology

No additional impacts on river morphology will be caused by reservoir filling other than the obvious impact of transforming the Susitna River between the Watana dam and the Devil Canyon dam into a reservoir. Impacts described in Section 4.1.3(b) will remain relevant.

(d) Water Quality

(i) Water Temperature

The outlet water temperatures from Watana will be unchanged from those that occur when Watana is operated alone. Because of the rapid filling of the Devil Canyon reservoir, there will be minimal opportunity for changes in the outlet temperatures at Devil Canyon during both stages of filling. There will be some damping of the temperature fluctuations caused by varying meteorological conditions that occurred at the Devil Canyon site when Watana operated alone.

Between the filling stages, the larger surface area of the newly formed Devil Canyon reservoir will offer more opportunity for atmospheric heat exchange. However, since the retention time will only be about 4 days, it is expected that at the Devil Canyon outlet and further downstream, little change in water temperature will occur from that experienced with Watana operating alone.

(ii) Ice

An extensive ice cover is not expected to form on the Devil Canyon reservoir during the period when the pool is maintained at El 1135 ft (344 m) because of the warm water inflow from the Watana reservoir. Additionally, since downstream winter temperatures will not be significantly affected by the pool, ice processes downstream from Devil Canyon described in Section 4.1.3(c)(ii) will remain relevant.

(iii) Suspended Sediments/Turbidity/Vertical Illumination

As previously discussed, the Watana reservoir will act as a sediment trap, greatly reducing the quantity of suspended sediment entering the Devil Canyon reservoir.

Immediately prior to filling, the reservoir area will be cleared of all vegetation. By delaying this activity until filling is about to commence, erosion and siltation problems prior to filling the reservoir will be minimized. During filling, however, the lack of soil stabilizing vegetative cover may cause increased erosion. These impacts are only expected to create short-term increases in turbidity and suspended sediment concentrations. In addition, suspended sediment concentration and turbidity increases may also occur within the Devil Canyon impoundment as a result of the slumping of the valley walls. However, since the Devil Canyon impoundment area is characterized by a very shallow overburden layer with numerous outcroppings of bedrock, slope instability should not significantly affect turbidity and suspended sediment concentrations. A further discussion of the slope stability can be found in the Susitna Hydroelectric Project Geotechnical Report (Acres 1981c).

As reservoir filling progresses, the Devil Canyon reservoir will provide additional settling capability. Thus, the net result will be a slight decrease in suspended sediment and turbidity and a corresponding increase in vertical illumination downstream from Devil Canyon.

(iv) Dissolved Oxygen

As previously discussed in Section 4.1.3(c)(v), water discharged from Watana and entering Devil Canyon will have a high dissolved oxygen concentration and low BOD.

Because of the extremely short residence time, no hypolimentic oxygen depletion is expected to develop either during the one year that the reservoir is held at El 1135 ft (344 m), or during the final six weeks of reservoir filling.

Prior to filling, all standing vegetation in the reservoir area will be cleared and burned, thereby eliminating much of the oxygen demand that would be caused by inundation and subsequent long-term decomposition of this vegetation.

(v) Total Dissolved Gas Concentration

Dissolved gas supersaturation will not be a concern during the filling of the Devil Canyon reservoir. As the reservoir is filled, the rapids between the mouth of Devil Creek and the Devil Canyon dam site will be inundated and the turbulence that presently causes the supersaturation will thus be eliminated.

During the initial filling to El 1135 ft (344 m), the diversion tunnel will be utilized. As such, there will be no plunging discharge to entrain gas. After elevation 1135 ft (344 m) is attained and for the balance of the filling sequence, discharge will be via the fixed-cone valves. No nitrogen supersaturation is expected downstream from the dam. The operation of the fixed-cone valves is discussed in further detail in the Mitigation Section 6.6.3.

(vi) Nutrients

Similar to Watana, two opposing factors will affect nutrient concentrations during the filling process. First, initial inundation will likely cause an increase in nutrient concentrations due to leaching. Second, sedimentation will strip some nutrients from the water column. The magnitude of the net change in nutrient concentration is unknown, but it is likely that nutrient concentrations will increase in close proximity to the reservoir floor.

(vii) Total Dissolved Solids, Conductivity, Significant Ions, Alkalinity, and Metals

Similar to the process occurring during Watana filling, increases in dissolved solids, conductivity and most of the major ions will likely result from leaching of the reservoir soils and rocks during Devil Canyon filling. For initial filling from El 850 ft (283 m), no significant downstream impacts are foreseen, since it will take only about two weeks to accumulate the 76,000 acre-feet of water required to fill the Devil Canyon reservoir to EL 1135 ft (344 m). In such a short time, insignificant leaching would occur which could be detrimental to downstream water quality.

Subsequent to this initial phase of filling, and for the remainder of the filling process, fixed-cone valves will be utilized for reservoir discharge.

The valves will draw water from well above the bottom of the impoundment (El 930 ft (282 m) and El 1050 ft (318 m). Since the products of the leaching process will be confined to a layer of water near the bottom (Peterson and Nichols 1982), downstream water quality should not be adversely impacted.

(e) Ground Water Conditions

No major ground water impacts are anticipated during the filling of the Devil Canyon reservoir. The increased water level within the reservoir will be confined between bedrock walls. Downstream there may be a slight decrease in the ground water table caused by the reduced filling flows (see Section 2.4.4). A decrease in the ground water level in the same proportion as the decrease in mainstem stage would be expected. The change in ground water level will be confined to the alluvial deposits adjacent to the river.

(f) Lakes and Streams

As the Devil Canyon pool level rises, the mouths of the tributaries entering the reservoir will be inundated (See Table E.2.26). As the reservoir is filled, sediment transported by these streams will be deposited at the new mouth of the stream.

(g) Instream Flow Uses

(i) Fishery Resources, Wildlife Habitat, and Riparian Vegetation

As Devil Canyon reservoir is filled, new fishery habitat will become available within the reservoir. However, adverse impacts to fish habitat will occur as tributary mouths become inundated. In addition, terrestrial habitat will be permanently lost as a consequence of reservoir filling. Detailed information on reservoir and downstream fisheries, wildlife, and botanical impacts are presented in Chapter 3.

(ii) Navigation and Transportation

During filling, the rapids upstream from Devil Canyon will be inundated and whitewater kayaking opportunities will be lost. Since the water surface level of the reservoir will be rising as much as 8 ft (2.4 m) per day during filling, the reservoir will be unsafe for boating. Downstream water levels may be slightly less than normal Watana operation levels, but this will not affect navigation because the change will be confined to the fall and early winter season.

(iii) Waste Assimilative Capacity

Although flows in the river will be reduced during the two reservoir filling periods, the waste assimilative capacity of the river will not be affected.

(iv) Freshwater Recruitment to Cook Inlet Estuary

Small temporary changes in the Cook Inlet salinity regime established during the operation of Watana alone are expected only during the second phase of filling Devil Canyon. This is because of the brief period of filling and the small volume required relative to the average annual Susitna River discharge to Cook Inlet.

4.2.3 - Watana/Devil Canyon Operation

(a) Flows and Water Levels

(i) Project Operation

After Devil Canyon comes on line, Watana will be operated as a peaking plant and Devil Canyon will be operated as a baseloaded plant. Advantage will be taken of the two-reservoir system to optimize energy production with the constraint that the downstream flow requirements will be met.

Each September, the Watana reservoir will be filled up to its maximum water level reaching 2190 ft (664 m) during wet years. From October to May the reservoir will normally be drawn down to approximately El 2080 ft, although during dry years the reservoir will be drawn down to a minimum reservoir level of 2065 ft (626 m). In May, the spring runoff will begin to fill the reservoir. However, the reservoir will not be allowed to fill above El 2185 ft (626 m) until late August when the threat of a significant summer flood will have passed. If September is a wet month, the reservoir will be allowed to fill an additional 5 ft (1.5 m) to El 2190 ft (664 m).

4.2 - Devil Canyon Development

From November through the end of July, Devil Canyon will be operated at the normal maximum headpond elevation of 1455 ft (441 m) to optimize power production.

During August and early September, the Devil Canyon reservoir level will be drawn down to a minimum level of 1405 ft (426 m). Thus, most of the August downstream flow requirement at Gold Creek can be met by withdrawing water from storage at Devil Canyon. This will permit storage of additional water in the Watana reservoir which would otherwise have to be released because the energy that would be produced to meet the downstream flow requirements would be greater than the August 2010 energy demand. When the downstream flow requirements decrease in mid-September, the Devil Canyon reservoir will be filled to El 1455 ft (441 m).

- Devil Canyon Turbine Operation

  The four turbine units at Devil Canyon can be operated to provide any flow above 1700 cfs up to the maximum capacity of the powerhouse (15,000 cfs) while maintaining a high efficiency. This is illustrated in Figure E.2.190.

- Minimum Downstream Target Flows

  The minimum downstream flow requirements at Gold Creek will be unchanged when Devil Canyon comes on line. Table E.2.36 illustrates these flows. A further explanation is provided in Sections 4.1.2(a) and 4.1.3(a).

- Monthly Reservoir Simulations

  As described in Section 3.2, a multiple reservoir simulation program was run using the 32 years of synthesized Watana and Devil Canyon flow data. The development of the Watana and Devil Canyon flow sequences used in the simulation is discussed in Sections 2.2.1 and 3.3.

  Similar to the simulation for Watana operating alone, the simulation was initiated with both reservoirs at normal maximum operating levels and a full pool was required at the end of the simulation period. Energy production was optimized by adjusting the monthly reservoir operating rule curves for each reservoir according to the monthly energy demand pattern from mid-September to mid-May. The reservoir characteristics, salable energy, and downstream flow requirements were also considered in developing the operating rule curves. The optimized rule curve is illustrated in Table E.2.40. The minimum monthly energies and the associated powerhouse discharges are presented in Table E.2.51.

- Weekly Reservoir Simulations

Weekly reservoir simulations for the 32 years of record were conducted for both the 2002 and the 2010 energy demand forecasts. The weekly reservoir simulation program is described in Section 4.1.3(a)(i).

In the 2002 simulation, there is insufficient energy demand to utilize the energy potential of the system. However, by 2010, the demand has increased to where much of the previously excess energy can be used.

- Daily Operation

With both Watana and Devil Canyon operating, Watana can be operated as a peaking plant because it will discharge directly into the Devil Canyon reservoir, which will be used to regulate the flow. The peaking of Watana will cause a daily fluctuation of less than one foot in the Devil Canyon reservoir. Devil Canyon will operate as a baseloaded plant for the life of the project.

(ii) Mean Monthly Flows, Annual Flows, and Water Levels

The monthly maximum, minimum, and median Watana and Devil Canyon reservoir levels for the 32-year simulation are illustrated in Figures E.2.191 and E.2.192. For the 2010 reservoir operation simulations, water years 1956, 1970, and 1966 represent a wet year, a drought year and an average flow year respectively for both Watana and Devil Canyon. From October through April, the Watana maximum and median reservoir levels correspond closely to the reservoir operating rule curve (Table E.2.40). During the filling months of May through September, the water level is higher than the rule curve in wet years because the railbelt system can not use additional energy. Hence, the excess water goes into storage. In average years, from May to September, the reservoir level is at or lower than the rule curve. If the reservoir level matches the rule curve, then the railbelt system can absorb all available energy after the rule curves have been satisified. If the reservoir level is below the rule curve, then only the greater of the minimum energy demand or the energy production from the minimum downstream flow requirements is satisfied.

The Devil Canyon reservoir is maintained at El 1455 ft (441 m) most of the year. However, during August and September, the reservoir is often drawn down to meet the Gold Creek flow requirement. In wet years, there is an excess of flow and energy and hence no need to draw the reservoir down. In dry years, such as occured in WY 1970, the Devil Canyon reservoir is drawn down in April or early May to meet the minimum energy demand and downstream flow requirements if Watana has already been drawn down to its minimum level. However, at no time during the 32-year simulation are both reservoirs drawn down to their minimum level.

Monthly Watana, Devil Canyon, and Gold Creek flows for the 32-year monthly energy simulation are presented in Tables E.2.52, E.2.53, and E.2.54. The maximum, mean, and minimum flows for each month at Watana, Devil Canyon and Gold Creek are summarized and compared to pre-project flows and Watana operation flows in Tables E.2.43, E.2.55, and E.2.45. From October through April, the post-project flows are many times greater than the natural, unregulated flows. Post-project flows during the months of June, July, August, and September are 36, 34, 57, and 79 percent of the average mean monthly pre-project flow at Gold Creek, respectively. The flow reductions represent the volume of water used to fill the Watana reservoir. Variations in mean monthly post-project flows occur, but the range is substantially reduced from pre-project flows. Figures E.2.193 and E.2.194 illustrate the Watana inflow and outflow, the Watana reservoir level, the Devil Canyon reservoir inflow, the Devil Canyon outflow, and the pre-project and post-project flows at Gold Creek for each month of the 32-year simulation.

Farther downstream, percentage differences between pre- and post-project flows are reduced by tributary inflows. The pre- and post-project monthly flow summaries for Sunshine and Susitna Station are compared in Tables E.2.47 and E.2.49. Monthly post-project flows are presented in Tables E.2.56 and E.2.57. Although summer flows from May through October average about 8 percent less at Susitna Station, winter flows are about 100 percent greater than existing conditions.

A comparison of post-project mean monthly flows with Watana operating alone and with Watana/Devil Canyon operating shows that, although there are some differences, the differences are small.

Water surface elevations based on the maximum, mean, and minimum flows at Gold Creek for May through September for selected mainstem locations between Portage Creek and Talkeetna, are illustrated in Figures E.2.195 through E.2.197. Post-project water levels are generally 3 to 4 feet (0.9 to 1.2 m) less than natural water levels in June and July. In August, the differences are 1 to 3 feet (0.3 to 0.9 m), and in September, the water levels are within one foot (0.3 m). During low flow years, the post-project September water levels are higher.

(iii) Floods

- Spring Floods

Using the 2010 energy demand to drive the 32-year monthly simulation, no flow releases occurred between May and July at either Watana or Devil Canyon. All flow was either absorbed in the Watana reservoir or passed through the respective powerhouses. The June 7, 1964, flood of record with an annual flood recurrence interval of better than 20 years, resulted in a Watana reservoir elevation of 2151 ft (652 m) at the end of June, an elevation 34 ft (10.3 m) below the normal maximum operating level.

The maximum mean monthly discharge at Devil Canyon during the 1964 spring flood period was approximately 10,500 cfs. If peak inflow into Devil Canyon reservoir, from the drainage area downstream from Watana approached this discharge, flow at Watana would be virtually shut off to maintain a Devil Canyon reservoir level of 1455 feet (441 m). Local inflow would supply most of the power needs.

However, the peak contribution downstream from Watana is not likely to be as large as 10,500 cfs. For example, the Gold Creek maximum historical one day peak flow to mean monthly flow ratio for the month of June is 2.05 (R&M 1982d). If this ratio is used to compute the local inflow between Watana and Devil Canyon, the peak one-day June inflow during the simulation period would be approximately 9300 cfs, which is less than the maximum of 10,500 cfs.

For the 1:50-year flood, the Devil Canyon outflow with both Watana and Devil Canyon in operation will be similar to but less than the flow with Watana operating alone because the Devil Canyon reservoir is able to use the local runoff to help meet the energy demand. This requires less flow from Watana. Hence, less flow is passed into the Devil Canyon reservoir and hence on downstream.

The Watana reservoir will always be drawn down sufficiently during the winter and spring to produce energy such that the 1:50-year flood volume can be stored within the reservoir if the flood occurs in June. The flow contribution at Devil Canyon for the drainage area between Watana and Devil Canyon would approximate 11,000 cfs. Hence, the energy demands would be met by running Devil Canyon near capacity and reducing outflow from Watana as much as possible to prevent flow wastage.

For flood events greater than the 1:50 year event and after Watana reservoir elevation reaches 2185.5 ft (662 m), the powerhouse and outlet facilities at both Watana and Devil Canyon will be operated to match inflow up to the full operating capacity of the powerhouse and outlet facilities. If inflow to the Watana reservoir continues to be greater than outflow, the reservoir will gradually rise to El 2193 ft (664.5 m). When the reservoir level reaches 2193 ft (664.5 m), the main spillway gates will be opened such that outflow matches inflow. Concurrent with opening the Watana main spillway gates, the main spillway gates at Devil Canyon will be opened so that inflow matches outflow. The main spillways at both Watana and Devil Canyon will have sufficient capacity to pass the 1:10,000-year event. Peak inflow for the 1:10,000-year flood will exceed outflow capacity at

Watana resulting in a slight increase above 2193 ft (664.5 m). At Devil Canyon there will be no increase in water level. The discharges and water levels associated with a 1:10,000-year flood for both Watana and Devil Canyon are illustrated in Figures E.2.154 and E.2.198.

If the probable maximum flood (PMF) were to occur, the operation at Watana will be unchanged whether Watana is operating alone or in series with Devil Canyon. The main spillway will be operated to match inflow until the capacity of the spillway is exceeded. At this point, the reservoir elevation will rise until it reaches El 2200 ft (667 m). If the water level exceeds El 2200 ft (667 m), the erodible dike in the emergency spillway will be washed away and flow will be passed through the emergency spillway. The resulting total outflow through all discharge structures will be 311,000 cfs.

At Devil Canyon a similar scenario would occur. The main spillway will continue to operate, passing the main spillway discharge from Watana. Once the emergency spillway at Watana is overtopped, the Devil Canyon reservoir will surcharge to El 1465 ft (444 m) and its emergency spillway will begin to operate. Peak outflow will occur immediately after the fuse plug erodes away. However, the peak is slightly less than the peak inflow. The inflow and outflow hydrographs for both the Watana and Devil Canyon PMF are shown in Figures E.2.154 and E.2.198, respectively.

For floods larger than the 1:100 year flood, the Watana reservoir will fill to the normal maximum operating level and inflow will be set equal to outflow. Hence, for floods of magnitudes greater than 1:100 years, the flood discharges at downstream locations will be decreased by only a small amount from natural levels. The degree of reduction will depend on the volume of water the Watana reservoir can absorb into storage.

The mean annual and 1:10-year spring flood discharges at the Gold Creek, Sunshine, and Susitna Station will essentially be the same as those described in Section 4.1.3(a)(iii) less the local contribution between Watana and Devil Canyon. The loss of this local contribution will have the greatest effect on the Gold Creek flows.

4.2 - Devil Canyon Development

- Summer Floods

In wet years the combined, Watana and Devil Canyon operation will produce more energy than can be used, especially in the early years of the project. If this occurs, the excess flow will have to be released through the outlet facilities if the reservoir elevation exceeds El 2185.5 ft (662 m).

Since Watana can pass the 1:50-year summer flood without operating the main spillway, the summer flood flows at Watana for up to the 1:50-year flood will be the sum of the discharge through the outlet facilities and the powerhouse. Since the capacity of the outlet facilities is 24,000 cfs, the maximum flood flow will be 31,000 cfs, if a powerhouse flow of 7,000 cfs is assumed.

For the 1:50-year summer flood, if the Watana discharge is maintained at approximately 31,000 cfs, the reservoir will surcharge to 2193 ft (664.5).

At Devil Canyon, the Devil Canyon powerhouse and outlet facilities have sufficient capacity to pass the 1:50 year summer flood of 38,500 cfs without operation of the main spillway. This flood is passed through the Devil Canyon reservoir without any change in water level.

- Annual Floods

The reservoir operation studies using weekly flow values were used to determine the Gold Creek annual flood frequency curves for the years 2002 and 2010. The 2002 and 2010 flood frequency curves shown in Figure E.2.199 are noticeably different for floods with return periods between 1.4 years and 50 years. This difference is particularly significant during the weekly reservoir simulation of the August 1967 flood. Routing this flood through the Watana and Devil Canyon reservoirs necessitates a discharge of 5,300 cfs over the main spillway in the 2002 demand simulation. In the 2010 demand simulation, operation of the main spillway is unnecessary. It should be noted that the August 1967 flood has a recurrence interval of 1:65-years. For floods above the 1:50 year flood, the Watana reservoir will be surcharged to El 2193 ft (664.5 m) and inflow will be set equal to outflow up to the capacity of the main spillway.

Floods downstream of Gold Creek will be decreased by approximately the same amount flows at Gold Creek are reduced. However, because flood peaks in the lower basin do not occur at the same time as floods at Watana and Devil Canyon, the error in this approach will become increasingly larger with distance downstream.

In low flow years, the Watana reservoir provides total regulation of the flow at Gold Creek. Hence, annual maximum flows are determined by the Gold Creek flow requirement of 12,000 cfs in August.

Maximum winter flows at Gold Creek with both dams producing energy will decrease to approximately 12,000 cfs compared to maximum flows of 15,000 cfs with Watana operating alone. This is possible because the 12,000 cfs passes through both powerhouses where as the 15,000 cfs only passed through the Watana powerhouse. Additionally, the high spring discharges at Gold Creek are reduced because the local drainage area is reduced to the area between Devil Canyon and Gold Creek.

(iv) Flow Variability

Examples of the mean daily flow variability at Gold Creek for 1964, 1967, and 1970 for the 2002 and 2010 energy demand simulations are presented in Figures E.2.200 through E.2.205. Because the drainage area between Devil Canyon and Gold Creek is much less than the drainage area between Watana and Gold Creek, the local inflow and hence daily flow variation at Gold Creek is reduced with both dams operating compared to Watana alone.

The monthly and annual flow duration curves for pre-project and post-project conditions for the 32-year simulation period are illustrated in Figures E.2.206 through E.2.210 for Watana, Devil Canyon, Gold Creek, Sunshine, and Susitna Station. The flow duration curves show less variability during post-project operation and a diminished pre- and post-project difference with distance downstream from Watana.

The annual flow duration curve at Gold Creek based on weekly flows is presented in Figure E.2.211. Figure E.2.212 illustrates the flow at Gold Creek for various probabilities of exceedance for each week of the year assuming the 2010 demand.

(v) Operation of Devil Canyon Fixed Cone Valves

The fixed-cone valves at Devil Canyon will discharge excess water from the reservoir to maintain the normal maximum operating level at El 1455 ft (441 m). Four 102-inch (2.6 m) diameter valves, each with a capacity of 5800 cfs, will be located approximately 170 ft (51.5 m) above the normal tailwater elevation and three 90-inch (2.3 m) diameter valves, each with a capacity of 5100 cfs, will be located approximately 50 ft (15 m) above the normal tailwater elevation. Total discharge capacity will be 38,500 cfs.

The valves will draw water from El 930 ft (282 m) and El 1050 ft (318 m) and discharge it as highly diffused jets to achieve energy dissipation and avoid gas supersaturation.

Table E.2.58 provides data on flow releases based on the weekly reservoir simulations for the 2002 and 2010 forecasts. Included for each year are the first week of release, the week of maximum release, the maximum Devil Canyon release, the powerhouse flow at the time of maximum release, and the volume released for both the 2002 and 2010 simulations.

In the 2002 simulation, large releases occur at Devil Canyon in 22 of the 32 years even though most of the system energy is being generated by the Devil Canyon powerhouse. That is, there is an annual probability of 66 percent that significant releases will occur at Devil Canyon in the early years of the project. To minimize the Devil Canyon releases, when a release is necessary, the release is at Watana, thus, allowing the Devil Canyon powerhouse to be used up to its maximum capacity to provide the system energy needs. However, because the capacity of the outlet facilities at Watana is much less than at Devil Canyon (24,000 cfs versus 38,500 cfs), during high flow years when Watana outflow is greater than approximately 24,000 cfs, Watana will be used to generate the system energy needs to prevent the Watana reservoir from surcharging. This is evident in the simulations of WY 1959 and WY 1967. In WY 1967, Watana reservoir is full at the time of the late August flood. This not only results in operation of the Devil Canyon outlet facilities at their maximum capacity, but also requires operation of the Devil Canyon spillway.

In the 2002 simulation, reservoir releases occur as early as the week of July 8.

By the year 2010, the release pattern is vastly different. There is an annual probability of 30 percent that a sizeable release (over 2500 cfs) will occur. In WY 1967, for example, the release is reduced from 43,800 cfs in 2002 to 15,100 cfs in 2010. In addition, there are no occasions when either the Watana or Devil Canyon spillways operate.

Because the valves are located at the base of the Devil Canyon dam, there is a potential for downstream adverse temperature effects during periods of high release. This is discussed in Section 4.2.3 (c)(i).

(b) River Morphology

Average monthly flows during Watana/Devil Canyon operation will be similar to those of Watana operation, although minor redistribution of the flow does occur. The change in Watana reservoir operation during the first few years after Devil Canyon comes on line decreases the ability of the reservoir system to absorb high flows. Consequently, the occurrences of high flows capable of initiating gravel bed movement in the Susitna River above Talkeetna will be increased. Project impacts previously described in Sections 4.1.2(b) and 4.1.3(b) for Watana impoundment and operation will remain relevant except that river bed stability will tend to decrease since the larger return period flood flows have been increased.

(c) Water Quality

(i) Water Temperature

- Watana and Devil Canyon Reservoirs

The program DYRESM, described in Section 4.1.3(c) (i) was used to predict reservoir temperature profiles and outflow temperatures from both the Watana and Devil Canyon reservoirs. The Watana inflow, the inflow temperature, and the meteorology for the period June through December 1981 were used. These data are the same as for Watana operating alone (Section 4.1.3(c) (i)), however, Watana outflow is changed due to the different mode of operating the Watana reservoir when both projects are operational. The simulated flows for June through September of WY 1981 from the Case C weekly reservoir simulation for the 2010 demand were used as the source of inflow data for the two reservoirs. Since the available simulation data ended at the end of WY 1981 (September 30, 1981), mean weekly flows from the Case C, 2010 demand simulation were used for the October to December period.

Watana outflow, outflow temperature, and the flow contribution from the area between the damsites are inputs to the Devil Canyon reservoir. The temperature of the outflow from the Watana reservoir is more stable than the natural thermal regime. Thus, a stable temperature regime is input to Devil Canyon. However, the Devil Canyon inflow temperatures are cooler in June and warmer in September than occur naturally. Devil Canyon reservoir exhibits the general pattern of early summer warming, summer stratification, and fall to winter cooling through an isothermal condition to reverse stratification.

Stratification and outflow temperatures at Watana under the assumed operation scenario are essentially the same as for Watana operating alone.

Typical reservoir temperature profiles at Devil Canyon are given in Figures E.2.213 and E.2.214 for June to September and October to December, respectively. Devil Canyon reservoir, because of its smaller size than Watana, exhibits responses to meteorological conditions in a manner more similar to Eklutna Lake. This is particularly true for strong wind storms which result in stepped temperature profiles (see Figures E.2.166 and E.2.213). Generally, reservoir stratification is weak in June but builds during July and August. Typical mixed layer depths are in the order of 50 to 70 ft (15 to 21 m) during the summer months. For 1981 weather data, cooling at Devil Canyon is delayed to late September and early October. This is partly due to warmer Watana inflows to the Devil Canyon reservoir.

Isothermal conditions occur in late November. Cooling continues throughout the reservoir depth until maximum density is reached. Reverse stratification begins in mid-December. By the end of December, the reservoir is weakly stratified. The mixed layer depth in December is about 30 ft (9 m). However, it would be greatly influenced by severe, cold weather, mixing events, and Watana outflow and temperature.

4.2 - Devil Canyon Development

The maximum Devil Canyon reservoir surface temperature of 8.8°C (47°F) occurs on August 28. The minimum surface temperature occurs at the end of the simulation period (December 31, 1981) and equals 2.4°C (36°F).

The DYRESM model attempts to have the Devil Canyon outflow temperatures, like Watana, follow the inflow temperatures. The two-level intake structure at Devil Canyon provides some flexibility but not as much as at Watana. However, the stable water surface at Devil Canyon negates the need for additional intakes.

Figures E.2.215 and E.2.216 illustrate the Devil Canyon reservoir inflow and outflow temperature for June through December. Maximum outflow temperatures occur in late July to mid-August and are about 8°C (46°F). Temperatures in June fluctuate due to the tendency for mixing and deepening of the thermocline during this weak stratification period (Figure E.2.215).

For this simulation period, high summer runoff resulted in power operation at maximum reservoir operating levels with releases occurring at both reservoirs. This resulted in a depression of the temperatures to about 5°C (41°F) during the maximum release period of August 19-25 (Figure E.2.215). This coldest temperature only occurs for one day, with temperatures rising to about 6°C (43°F) in three days. As the release is reduced, outflow temperatures increase and eventually return to about 7°C (45°F) by early September.

Devil Canyon outflow temperatures from mid-September to December 31, exhibit a much more gradual reduction in temperatures than observed at Watana. Temperatures during this period fall from a high of 8°C (46°F) on September 14 to a low of 3.5°C (38°F) on December 31.

To test the effectiveness of the two-level intake structure at Devil Canyon in providing the desired temperatures, a temperature simulation was made using only the lower intake. All other input data were identical to the DYRESM simulation described above. The results of the simulation indicate that outlet temperatures of 1 to 2°C cooler would occur during June and July if only the lower intake was used. Because of the large flow release in August which dominated the outflow temperatures, there is little difference during August. Thus, based on this analysis, the two-level intake structure does provide increased flexibility in outlet temperature selection.

Because the Devil Canyon outlet facilities are located at El 930 ft (282 m) and El 1050 ft (318 m), any water released through them will be near 4°C (39.2°F). Since this could have an adverse impact on the downstream fishery, the Watana/Devil Canyon two reservoir system will be operated whenever possible so that the maximum power generation will occur at Devil Canyon and releases will be discharged at Watana. In this way, flows of 12,000 to 15,000 cfs from the Devil Canyon powerhouse at a temperature of approximately 8°C (46°F) (Figure E.2.215), will aid in maintaining acceptable downstream temperatures.

Examination of Table E.2.58 illustrates the frequency of releases and the discharge through the Devil Canyon powerhouse and outlet facilities. The data indicate that the worst case is WY 1981. The temperature simulation predicts a minimum temperature of 5°C at the dam during this release. Since the powerhouse flows are approximately equal to or greater than all other releases for the 2010 demand and will be about 8°C, the composite outlet temperature during all other releases should be greater than 6°C.

- <u>Devil Canyon to Talkeetna</u>

  . <u>Mainstem</u>

  The temperature regime downstream of Devil Canyon dam will differ from both the natural regime and the predicted Watana operation regime. Therefore, studies using the HEATSIM model described in Section 4.1.2(e)(i) were undertaken to estimate the temperatures in the reach between Devil Canyon and Talkeetna. Three outflow temperature scenarios were considered.

  The downstream temperatures were simulated using the DYRESM results from the reservoir operation simulation and 1981 meteorological data as input. The results of the HEATSIM program are shown in Figures E.2.217 and E.2.218 for June to September and October to December, respectively. Generally, outflow temperatures are warmed with distance downstream during June and July, and this warming is on the order of 2°C (3.5°F) between Devil Canyon and Talkeetna. In August there is no significant temperature change due to the 1981 climatic conditions and high flows used in the simulation.

Cooling begins slowly in September with a gradual 0.5°C (1°F) reduction between Devil Canyon damsite and Talkeetna on September 15. This accelerates as cooler air temperatures occur, reaching a maximum cooling in January. On December 21, outflow temperatures of 3.5°C (38°F) are cooled to approximately 0.5°C (33°F) by Talkeetna.

During the release period in August and early September in WY 1981, the minimum outflow temperature of 4.6°C (40°F) observed on August 21 has warmed to 4.7°C (40.5°F) by Sherman and to 4.9°C (41°F) by Talkeetna.

To assess the impact of winter outflow temperatures on downstream temperatures, scenarios assuming a constant outflow temperature of 4°C (39.2°F) and an outflow temperature decreasing linearily from 4°C (39.2°F) on November 1 to 2°C (35.6°F) on January 15 were simulated. The long-term average meteorological data for the Devil Canyon to Talkeetna reach were used for both simulations. The temperature profiles for the constant 4°C (39.2°F) outflow are illustrated in Figure E.2.219 and E.2.220. Temperatures are above 0°C (32°F) for the entire reach between Devil Canyon dam and Talkeetna until January 15. On January 15, 0°C (32°F) water is estimated to occur at river mile 99 just upstream from Talkeetna. In late January, less cooling occurs and water temperatures for the Devil Canyon to Talkeetna reach remains above 0°C (32°F) (Figure 3.2.220).

Figures E.2.221 and E.2.222 illustrate the temperature profiles with a reduction in outflow temperatures to 2°C (35.5°F) by January 15 and remaining constant thereafter. Water is predicted to cool to 0°C (32°F) at about river mile 119 on January 15 (Figure E.2.221). This is the maximum upstream location for 0°C (32°F) water during the winter. In February, the location of 0°C water moves downstream to about river mile 104 and moves to below Talkeetna in March (Figure E.2.222).

. Sloughs

Using the results of the downstream temperature program, the average annual temperature at Sherman is calculated to be approximately 4°C. This is an increase of about 1°C above the natural long-term average temperature. Therefore, based on the ground water studies described in Section 2.4.4 and the above preliminary analysis, the slough upwelling temperatures in the vicinity of Sherman may increase approximately 1°C.

- Talkeetna to Cook Inlet

As discussed in Section 4.1.2(e)(i), summer temperatures downstream of the Chulitna confluence will continue to reflect the temperatures of the Talkeetna and Chulitna Rivers. Temperature effects from October to April will be similar to those described in Section 4.1.3(c)(i), except that because the Susitna River water temperatures are warmer than during Watana operating alone, the influence will be felt farther downstream.

(ii) Ice

- Reservoir

Ice formation on the Watana reservoir will be similar to that described in Section 4.1.3(c)(ii). The DYRESM modeling of Devil Canyon reservoir for the case considered indicates that no ice cover will form on the Devil Canyon reservoir through December 31. Since the water surface temperature is 2.4°C at that time, an ice cover may not form on the Devil Canyon reservoir. If an ice cover does form, it will be limited.

- Devil Canyon to Talkeetna

The downstream temperature modeling indicates that the furthest upstream movement of 0°C (32°F) water in the three cases considered is RM 119. Thus, it is unlikely that there will be significant ice formation in this reach. Open water will likely exist from Devil Canyon to Talkeetna. Hence, no ice modeling was performed for this reach.

- Talkeetna to Cook Inlet

Because of the warmer water temperatures and the greater flows in the Susitna River, ice formation downstream of Talkeetna will be delayed. Increased staging further downstream will continue to occur because of the increased flow.

The warm water discharged from the Devil Canyon reservoir will begin to melt the downstream ice cover in the spring. This coupled with flow regulation by the Watana reservoir will tend to reduce the severity of ice jams.

(iii) Suspended Sediments/Turbidity/Vertical Illumination

Of the suspended sediments passing through the Watana reservoir, only a small percentage is expected to settle in the Devil Canyon reservoir. This is attributable to the small sizes of the particles (less than 4 microns in diameter) entering the reservoir from Watana and the relatively short retention time of the Devil Canyon reservoir (2 months) in comparison to the Watana reservoir (1.67 years). The suspended sediment and turbidity levels that occur within the Devil Canyon impoundment and downstream will be only slightly reduced from those that exist at the outflow from Watana. Vertical illumination will increase slightly.

Some slumping of the reservoir walls and resuspension of shoreline sediment will occur, especially during August and September when the reservoir may be drawn down as much as 50 feet (15 m). These processes will produce short-term, localized increases in suspended sediments. However, as noted in Acres (1982c), since the overburden layer is shallow, no significant slumping or sediment entrainment problems should arise.

(iv) Dissolved Oxygen

As discussed in Section 4.1.3(c)(v), reduction of dissolved oxygen concentrations can occur in the lower levels of deep reservoirs.

Stratification and the slow biochemical decomposition of organic matter will promote lower oxygen levels near the Devil Canyon reservoir bottom over time. However, all vegetation will have been cleared and burned prior to inundation thereby reducing the potential oxgen demanding decomposition process. No estimates of the extent of oxygen depletion are available.

Within the upper layers (epilimnion) of the reservoir, dissolved oxygen concentrations will remain high. Inflow water to the impoundment will continue to have a high dissolved oxygen content and low BOD. Ice cover formation, if it occurs, will be limited. Thus, there will be year round turbulence near the surface to maintain high dissolved oxygen levels. Since water for energy generation is drawn from the upper layers of the reservoir, no adverse effects to downstream dissolved oxygen levels will occur.

During periods of release through the Devil Canyon outlet facilities, water with somewhat reduced oxygen levels will be discharged. Given the dynamic nature of the river, these reduced concentrations should quickly return to saturation levels. No quantitative estimates of these reduced oxygen levels are available.

(v) Total Dissolved Gas Concentration

No supersaturated gas conditions will occur downstream from the Devil Canyon Dam. The fixed-cone valves described in Section 4.2.3(a)(v) will eliminate potential nitrogen supersaturation problems for all flow releases and floods with a recurrence interval less than 1:50-years. The frequency of fixed-cone valve operation is discussed in Section 4.2.3(a)(v) and presented in Table E.2.58. Further information is provided in Section 6.4.

(vi) Trophic Status (Nutrients)

Peterson and Nichols (1982) assessed the anticipated trophic status of Devil Canyon reservoir, similar to the discussion in Section 4.1.3(c)(vii). Vollenweider's (1976) model was utilized for their predictions.

The analysis indicates that under natural conditions, Devil Canyon reservoir will be oligotrophic. Estimates of permissible artificial phosphorus loading reveal that the reservoir is capable of maintaining oligotrophic status while receiving the untreated effluent of 48,300 permanent residents. This estimate is based upon Devil Canyon alone. With both reservoirs, permissible artificial phosphorus loading will be predicted on the artificial loading factor at Watana.

(vii) Total Dissolved Solids, Conductivity, Alkalinity, Significant Ions and Metals

Similar to the Watana reservoir, the leaching process in the Devil Canyon reservoir is expected to result in increased levels of the aforementioned water quality properties near the reservoir floor. Although leaching of the more soluble soils and minerals will diminish with time, other sources will continue to dissolve. These effects will not diminish as rapidly as is anticipated for Watana. The blanketing of the Devil Canyon reservoir floor with quantities of inorganic sediment will not occur. It is anticipated, however, that the leachate will be confined to a layer of water near the impoundment floor and although the magnitude of the increase cannot be quantified with available data, detrimental effects to aquatic organisms are not anticipated (Peterson and Nichols 1982).

During operation of the fixed-cone valves, no leaching products should be passed downstream. The lower set of valves at El 950 ft (288 m) will be located approximately 50 ft (15 m) above the reservoir floor. The zone of degredation is expected to be significantly closer to the floor (Peterson, personal communication 1983) and out of the range of the intake zone.

The presence and extent of the ice cover dictates the increase in dissolved solids near the reservoir surface during the winter. Reservoir temperature modeling (Section 4.2.3[i]) indicates that surface temperatures will only be reduced to 2.4°C (36°F) by the end of December. Consequently, little if any ice cover is anticipated, and no increases in dissolved solids are expected near the reservoir surface during the winter.

Similar to Watana, concentrations of metals will be reduced by reactions with dissolved salts and subsequent precipitation. No quantitative estimates of these changes are available.

(d) Ground Water Conditions

Effects on ground water conditions will be confined to the Devil Canyon reservoir itself. Downstream flows and hence impacts will be similar to those occurring with Watana operating alone.

(e) Lakes and Streams

A maximum drawdown of 50 feet will occur during the August and September with subsequent refilling in late September or October. As a result, the streams flowing into the Devil Canyon reservoir listed in Table E.2.26 will be affected similar to those streams entering Watana reservoir, described in Section 4.1.3(e). However, with the decreased drawdown, the impacts will be less.

No lakes in the Devil Canyon impoundment will be impacted other than the previously described small lake at the Devil Canyon damsite.

The impacts to tributaries downstream from Devil Canyon will not change from the conditions established during Watana operation as discussed in Section 4.1.3(e).

(f) Instream Flow Uses

The effects on the fishery resource, wildlife habitat, and riparian vegetation are described in Chapter 3.

(i) Navigation and Transporation

The Devil Canyon reservoir will transform the Devil Creek rapids and most of the Devil Canyon rapids into calm water. This will afford recreational opportunities for leisure boaters but totally eliminate the world-class whitewater kayaking opportunities.

Since the Devil Canyon facility will be operated as a baseloaded plant, downstream impacts will be similar to those resulting from Watana operation (Section 4.1.3(f)(ii)).

Examination of Figure E.2.208 reveals that flows drop below 6500 cfs at Gold Creek about 10 percent of the time in May and June. During July, August, and September, flow is always greater than 6500 cfs. Therefore, since a preliminary analysis showed the Sherman area to be navigable at that flow, impacts to navigation will be minimal (see Section 2.6.3). However, if navigation problems develop, the mitigation measures described in Section 6.3 will be implemented.

Downstream from Talkeetna, flows are greater than the minimum navigation discharges established in Section 2.6.3, 100 percent of the time from June through September. Therefore, no navigation impacts will occur below Talkeetna.

(ii) Freshwater Recruitment to Cook Inlet Estuary

Numerical modeling of the Cook Inlet salinity variations indicate that concentrations will be essentially the same for either Watana operating alone or both Watana and Devil Canyon operating (RMA 1983).

Table E.2.31 compares the expected salinities at five select locations identified in Figure E.2.126, assuming average hydrologic and operational conditions.

4.3 - Access Plan

The Watana access road will begin with the construction of a 2.0-mile (3.2 km) road from the Alaska Railroad at Cantwell, to the junction of the George Parks and Denali Highways. Access will then follow the existing Denali Highway for 21.3 miles (34.4 km). Portions of this road segment will be upgraded to meet standards necessary for the anticipated construction traffic. From the Denali Highway, a 41.6-mile (67.1 km) gravel road will be constructed in a southerly direction to the Watana campsite. An additional 2.6 miles (4.2 km) of road will allow access to the south side of the damsite after completion of construction of the main dam.

Access to the Devil Canyon site will be via a 37.0-mile (59.7 km) road from Watana, north of the Susitna River, and a 12.2-mile (19.7 km) railroad extension from Gold Creek to Devil Canyon, on the south side of the Susitna River.

Access roads will consist of unpaved 24-feet (7.3 m) wide running surfaces with shoulder widths of 5 feet (1.5 m). Design speed will be 55 mph (89 kmph) where acceptable, and 40 mph (65 kmph) in areas of steep grades and sharp turns to avoid the need for excessively deep cuts and extensive fills.

Side borrow techniques will be the primary construction method used to develop the access roads. This will minimize disturbance to areas away from the access road by confining construction-related activities to a narrow strip on each side of the road. Careful stripping of the vegetation and organic soils, excavation, construction, backfilling and vegetative rehabilitation should be confined to an area with a maximum width of between 100 and 140 feet (30 and 42 m).

4.3 - Access Plan

A few borrow sites of 10-20 acres (5-10 ha) will be needed along the road alignment for construction materials. These borrow sites will be located in well-drained upland areas.

Additional detail on the proposed access corridors and their construction can be found in Chapter 10 and in Exhibit A, Sections 1.12 and 7.12. The methodology behind the selection of these corridors is explained in Chapter 10, Section 2.4.

4.3.1 - Flows

Flow rates on streams crossed by the access road will not be changed. However, localized impacts on water levels and flow velocities could occur if crossings are improperly designed. Because they do not restrict streamflow, bridge crossings will be preferred to culverts or low-water crossings. Bridge supports will be located outside active channels, if possible.

Improperly designed culverts can restrict upstream fish movement because of high velocities or perching of the culvert above the streambed. However, maintenance of adequate fish passage will be ensured as per AS-16.05-840. Culverts are more susceptible to ice blockage problems which can cause restricted drainage and road flooding, especially during winter snowmelt periods. All culverts will be designed to handle flood flows and icing problems.

Low-water crossings will only be used in areas of infrequent, light traffic (for example, for construction of the transmission line). They will conform to the local streambed slope and will be constructed of materials that will allow water to flow over them instead of percolating through them.

4.3.2 - Water Quality

Most water quality impacts associated with the proposed access routes will occur during construction. The principal impacts associated with construction will be increased suspended sediment and turbidity levels and accidental leakage and spillage of petroleum products. Given proper design, construction, and monitoring, few water quality impacts are anticipated from the subsequent use and maintenance of these facilities.

(a) Turbidity and Sedimentation

Some of the more apparent potential sources of turbidity and sedimentation problems during access road construction include:

- Instream operation of heavy equipment;
- Location and type of permanent stream crossings (culverts vs. bridges);
- Location of borrow sites;
- Lateral stream transits;
- Vegetation clearing;
- Side hill cuts;
- Disturbances to permafrost; and
- Construction timing and schedules.

These potential sources of turbidity and sedimentation are addressed in Chapter 3, Sections 2.3 and 2.4.3.

(b) Contamination by Petroleum Products

Contamination of water courses from accidental spills of hazardous materials, namely fuels and oils, is a major concern. During construction of the trans-Alaska oil pipeline, oil spills were a greater problem than anticipated. Most spills occurred as a result of improperly maintained machines, equipment repair, refueling, and vehicle accidents.

Water pumping for dust control, gravel processing, dewatering, and other purposes can also lead to petroleum contamination since water pumps are usually placed on the river or lake bank.

A Spill Prevention Containment and Countermeasure Plan (SPCC) will be developed and implemented prior to the start of construction to minimize petroleum contamination problems, as required by law.

A more detailed discussion of petroleum contamination problems as they relate to fishery impacts are provided in Chapter 3, Sections 2.3 and 2.4.3.

4.4 - Transmission Corridor

The transmission line consists of four segments: the Anchorage-Willow line, the Fairbanks-Healy line, the Willow-Healy Intertie, and the Gold Creek-Watana line. All Susitna transmission lines will be 345 kV. A description of the segments is contained in Section 2.8. Route selection is discussed in detail in Chapter 10.

The Gold Creek-Watana segment is composed of two sections: Watana to Devil Canyon and Devil Canyon to Gold Creek. Construction of the portion from the Watana damsite to Devil Canyon will follow the same central corridor as the access road between Watana and Devil Canyon. Hence, impacts to stream flows and water quality will be confined to those streams discussed in Section 4.3. From Devil Canyon to the intertie at Gold Creek, the transmission corridor will parallel the railroad extension from Gold Creek to Devil Canyon. This will help to minimize impacts associated with vehicular construction access.

The Willow-Healy intertie is being built as a separate project and will be completed in 1984 (Commonwealth Associates 1982). When Watana is completed a second parallel line will be added to the Intertie. Also, the existing line will be increased in voltage from 138 kV to 345 kV. In 2002, when Devil Canyon comes online, a third parallel line will be constructed from Gold Creek to Willow. The existing access points and construction trails will be utilized to construct the additional lines. Thus, the impacts of new construction will be minimized as a result of the previous construction. The Environmental Assessment Report for the intertie (Commonwealth Associates 1982) discusses the expected environmental impacts of transmission line construction in this segment.

For construction of the north (Fairbanks-Healy) and south (Anchorage-Willow) stubs, stream crossings will be required. The potential effects will be of the same type as those previously discussed in Section 4.3 and in Chapter 2, Section 2.3. However, impacts should be less than those caused by access road construction because of the limited access necessary to construct a transmission line. Short-term erosion related problems can be caused by stream crossings, vegetative clearing, siting of transmission towers, locations and methods of access and disturbances to the permafrost. With proper design and construction practices, few erosion-related problems are anticipated.

Contamination of local waters from accidental spills of fuels and oils is a second potential water quality impact. The Spill Containment and Countermeasure Plan (SPCC) to be developed and implemented will minimize the potential contamination of the watershed.

Once the transmission line has been built, there should be few impacts associated with routine inspection and maintenance of towers and lines. Some localized temporary sedimentation and turbidity problems could occur when maintenance vehicles are required to cross streams to repair damaged lines or towers. A thorough description of all transmission corridors, their development and maintenance is presented in Exhibit A, Sections 4 and 10.

5 - AGENCY CONCERNS AND RECOMMENDATIONS

Throughout the past three years, all the appropriate State and Federal resource agencies have been consulted. Numerous water quantity and quality concerns were raised. The issues identified have been emphasized in this report. Some of the major topics include:

- Flow regimes during filling and operation;
- Morphological stream changes expected;
- Reservoir and downstream thermal regime;
- Winter ice regime;
- Sediment and turbidity increases during construction;
- Sedimentation process and turbidity in the reservoirs and downstream;
- Dissolved oxygen levels in the reservoirs and downstream;
- Nitrogen supersaturation downstream from the dams;
- Trophic status of the reservoirs;
- Potential contamination from accidental petroleum spills and leakage;
- Potential contamination from concrete wastewater;
- Wastewater discharge from the construction camps and villages;
- Downstream ground water impacts; and
- The effects on instream flow uses including navigation, transportation, and recreation.

A complete complement of the correspondence with the various agencies is presented in Chapter 11. Included are the comments received from the agencies on the Draft Exhibit E submitted to them on November 15, 1982 for review and comment.

6 - MITIGATION, ENHANCEMENT, AND PROTECTIVE MEASURES

6.1 - Introduction

Mitigation measures were developed to protect, maintain, and/or enhance the water quality and quantity of the Susitna River. These measures were developed primarily to avoid or minimize impacts to aquatic habitats, although all instream flow needs were given consideration.

The first phase of the mitigation process identified water quality and quantity impacts from construction, filling, and operation, and incorporated mitigative measures in the preconstruction planning, design, and scheduling where feasible. Three key mitigation measures were incorporated into the engineering design: (1) minimum flow requirements were selected to provide the fishery resources with adequate flows and water levels for upstream migration, spawning, rearing, overwintering and out-migration while maintaining the economic viability of the project; (2) multilevel intakes were added to improve downstream temperature control; and (3) fixed-cone valves were incorporated to prevent excessive total dissolved gas supersaturation from occurring more frequently than once in fifty years.

The second phase of the mitigation process will involve the implementation of environmentally sound construction practices during construction. This will involve the education of project personnel in the proper techniques needed to minimize impacts to aquatic habitats. Monitoring of construction practices will be required to identify and correct problems.

Upon completion of construction, the third phase of mitigation will consist of operational monitoring and surveillance to identify problems and employ corrective measures as quickly and effectively as possible.

Mitigation planning, development, and refinement will continue throughout the detail design, permitting and licensing, construction, and operation and maintenance phases of the project. A design criteria manual and a construction procedures manual are currently being prepared. In addition, a detailed erosion control plan and a Spill Prevention Containment and Countermeasure Plan (SPCC) will be developed. The mitigative, enhancement and protective measures presently proposed, are highlighted in the following sections. In some cases, the reader has been referred to other chapters, especially Chapter 3, for a thorough discussion of proposed mitigation.

6.2 - Mitigation - Construction

Mitigation measures during construction will be necessary to minimize the potential of significant impacts occuring to the quality of the adjacent water resources.

6.2 - Mitigation - Construction

Prior to construction, all permits and certificates required for dam construction and instream work will be obtained including:

- COE Section 404 Permit;
- FAA 14 CFR 77.13;
- ADNR 18AAC93.150.200; and
- ADF&G AS 16.05.870.

A 401 Water Quality Certification, pursuant to Section 401 of the Federal Water Pollution Control Act, was filed with ADEC on December 9, 1982. A copy of the letter requesting this certification is attached at the end of this section.

Compliance with the terms and conditions of the various permits, certifications and licenses will mitigate many of the project-related impacts on water resources.

The more likely water quality impacts of Watana construction are: siltation related problems associated with development of Borrow Areas E and I, contamination caused by concrete production waste products, contamination by petroleum products, and construction, operation, and maintenance of Support Facilities. Detailed discussion of additional fishery oriented mitigative measures is contained in Chapter 3.

6.2.1 - Borrow Areas

Prior to development of the borrow areas, all necessary permits for material removal will be obtained from the Bureau of Land Management (BLM), Corps of Engineers, ADEC, ADNR, and the Cook Inlet Region Incorporated (CIRI). The development of Borrow Sites E and I has been identified as a major concern because of their potential contributions to increased siltation and turbidity in the immediate area and downstream. Mitigation of these impacts primarily involves the methodology and scheduling of mining activities and the construction and operation of settling ponds.

Instream mining of Borrow Sites E and I will be scheduled for the summer (May - September) when high sediment and turbidity levels in the Susitna River already exist. Mining will begin in Site I, just upstream of the natural rock weir as shown in Figure E.2.135. By developing this section first and the continuing upstream into E, it is believed that the pool created behind the weir will serve as a settling pond for future upriver instream work, Additional geotechnical investigations will be completed to confirm the stability of the rock formation for this purpose.

No instream activities will occur between October and May. Stockpiling of borrow material and dry excavation in bermed areas will eliminate the need for winter instream gravel mining activities.

6.2 - Mitigation - Construction

The waste products from the gravel processing operation will be redeposited into the excavated site in areas of low velocities to avoid their entrainment in the river flow. Washwater resulting from these operations will be discharged into bermed settling ponds where suspended particles will be allowed to settle.

The processing plant for concrete aggregates and filters will produce a limited amount of spoil. Potential impacts will be controlled by running the wash water into a series of settling ponds. Fines will be removed from the wash water by gravity or as it filters through the existing granular soil berms before reentering the river. It is estimated that 200-300,000 cy of fine sand, and silt will be produced by this operation. These fines will be disposed of within the excavation area to preclude their entrainment in the river flow.

All waste water will be discharged into receiving waters in accordance with ADEC permit requirements (AS46.03.100).

Upon completion of mining activities, most of the borrow sites will be below the natural river level. Additional areas will be inundated by the future Devil Canyon reservoir. Selective spoil disposal will provide a diversified shoreline. All upland areas will be rehabitated using the stockpiled organic layer and required erosion prevention activities will be employed.

Tsusena Creek and Bear Creek, if required, will be reconstructed to allow natural fish movements to and from the river. Further information on material removal and erosion control is discussed in Chapter 3, Section 2.4.3.

6.2.2 - Contamination by Petroleum Products

A SPCC will be developed in accordance with 40 CFR 112.7 as required by EPA.

All oil spills will be reported to the ADEC regardless of their size as mandated in 18 AAC 70-080.

Section 2.4.3 (e) of Chapter 3 describes specific measures that will be employed to minimize the potential contamination of surface water and ground water from petroleum products.

6.2.3 - Concrete Contamination

The use of an efficient central batch plant will reduce the potential problems that could be caused by waste concrete and concrete wash water. Rejected concrete will be disposed of by haulage directly to an upland disposal area or dumped, allowed to harden and disposed in an excavated area.

6.2 - Mitigation - Construction

Waste water from the washing of mixing and hauling equipment will be processed and stored in a lined pond until its specific gravity drops to a point which allows its reuse as mixing water for concrete batching. This system will minimize the wastewater effluent to be returned to the river systems.

At concrete placement areas, the wash water resulting from clean-up of placing equipment, curing and green cutting will be collected in sumps and pumped to settling ponds to remove the suspended materials before the effluent is discharged into the river. Ponds will generally be unlined with sand filters to ensure removal of most waste products. Wastewater will be neutralized to avoid elevated pH discharges. Control of toxic chemicals in the effluent will be accomplished through careful selection of concrete additives, the provision of filters for the effluent, and the close monitoring of operations by the Construction Manager.

All effluents will comply with ADEC and EPA effluent standards (AS 46.03.100; 18 AAC 70.020 and 18 AAC 72.010).

Airborne particulates will also be controlled with the use of a modern central batching plant. The plant will be fully enclosed to facilitate winter operation requirements and the transfer of materials will be via enclosed pipes.

6.2.4 - Support Facilities

(a) Water Supply

All required permits will be obtained and complied with. Withdrawal of water for the construction camp and village will meet ADF&G criteria for the protection of fisheries resources. A water appropriation permit (AS 46.15; 11AAC93) will be obtaind from ADNR.

An application will be filed with ADEC for approval of the proposed water supply system plan as mandated by 18 AAC 80.100.

(b) Wastewater Treatment

As noted in Section 4.1.1 all the necessary wastewater and waste disposal permits will be obtained, and complied with. These include ADEC permits 18 AAC 72.060 and 18 AAC 72 and a

401 Water Quality Certification pursuant to Section 401 of the Federal Water Pollution Control Act.

It is anticipated that compliance with all the necessary permits and certificate(s) will include the mitigation of any water quality impacts associated with the support facilities.

6.2.5 - Others

Additional mitigation measures are contained in Chapter 3. These measures include: stream crossings and encroachments guidelines, erosion control plans, blasting guidelines, and guidelines for clearing of vegetation.

6.3 - Mitigation - Watana Impoundment

The primary concerns during filling and operation of the reservoir, as discussed in Section 4, include:

- Maintenance of minimum downstream flows for fishery resources and other instream flow needs.

- Morphological changes to the river and adjoining tributary mouths;

- Changes in downstream sediment concentrations;

- Maintenance of an acceptable downstream thermal regime throughout the year;

- Ice processes;

- Downstream gas supersaturation;

- Eutrophication processes and trophic status; and

- Effects on ground water levels and ground water upwelling rates.

Downstream flows will be provided to minimize the impact filling the reservoir could have on downstream fishery resources and other instream flow uses. Flow selection is discussed in Sections 3.4, 3.6, and 4.1.2. Reduction in salmon access to the sloughs has been identified as a key impact to be mitigated. A flow of 12,000 cfs from August through mid-September in combination with the fishery mitigation measures discussed in Chapter 3, will provide access to the important salmon spawning sloughs.

Minimum flows of 6000 cfs at Gold Creek are proposed for May, June, July, and late September. Navigation problems are not anticipated with these flows (see Section 2.6.3), however, there is a potential for a slight increase in navigational difficulty in the vicinity of Sherman. If this occurs, either the channel near Sherman will be dredged to provide the minimum 1.5 foot depth required and the channel will be marked, or the minimum flow will be increased to 6500 cfs.

Changes in mainstem river morphology between Devil Canyon and Talkeetna will occur (see Section 4.1.2), but are not expected to be significant enough to warrant mitigation except for the mouths of some tributaries where selective reshaping and grading may be required to insure salmon access.

During the first winter of filling the reservoir will cool to 4°C (39.2°F). From then until the following August when the outlet facility will begin operating, the water temperature at the Watana low-level outlet will be approximately 4°C to 5°C (39.2 to 41.0°F). Although these temperatures will be moderated somewhat downstream, downstream thermal impacts may occur. Although, no mitigation measures have been incorporated to offset these below normal downstream temperatures, the filling sequence is designed to fill the reservoir to an elevation which will allow operation of the outlet facilities sometime during the salmon spawning season. Thus, the impact of the reduced temperatures can be minimized.

Eutrophication was determined not to be a problem and therefore no mitigation is required.

6.4 - Mitigation - Watana Operation

The primary concerns during Watana operation are identical to those identified for Watana filling.

6.4.1 - Flows

The operational flow selection process is discussed in Section 3.

From May through September, the minimum downstream flows at Gold Creek will be the same as those provided during reservoir filling. However, from October through April the flow at Gold Creek will be increased from pre-project natural flows to a minimum of 5000 cfs. The minimum flows were selected to provide a balance between power generation and instream flow requirements, particularly in the Devil Canyon to Talkeetna reach of the river.

To provide stable downstream flows Watana will be operated primarily as a base-loaded plant until Devil Canyon is constructed. Further discussion is presented in Section 4.1.3.

6.4 - Mitigation - Watana Operation

6.4.2 - River Morphology

The mainstem Susitna River will remain stable between Watana and Talkeetna. However, three streams crossed by the Alaska Railroad, Skull Creek and two unnamed creeks at RM 127.3 and 110.1 could degrade from 3.6 to 7.0 feet (R&M 1982f). If this occurs and bridge abutments are threatened, mitigation measures will be taken to limit the scouring.

Because of the increased discharge during freezeup, the river stage will be higher. Without mitigation, this will result in increased flow through some of the sloughs which are currently overtopped during the freezeup process. The higher stage may also cause flow through some sloughs which are presently not overtopped in winter. To minimize the impact on important salmon spawning sloughs, berms will be constructed at the heads of these sloughs to prevent the sloughs from being overtopped during post-project river freezeup. The spawning gravels in these sloughs will be maintained on a 5-year rotating schedule. Further information on this mitigation measure is contained in Chapter 3.

6.4.3 - Temperature

As noted in Section 4, the impoundment of the Watana reservoir will change the downstream temperature regime of the Susitna River. To minimize the potential change, multilevel intakes have been incorporated in the power plant intake structures so that water can be drawn from various depths. By selectively withdrawing water, an acceptable temperature for the downstream fishery can be maintained at the powerhouse outlet and downstream throughout the year. Using a reservoir temperature model, it was possible to closely match existing Susitna River water temperatures for most of the year.

6.4.4 - Total Dissolved Gas Concentration

The avoidance of gas supersaturation will be achieved by the inclusion of fixed-cone valves as the "normal" outlet facilities.

By using the reservoir storage capacity coupled with the minimum summer powerhouse flow and the fixed-cone valve discharge, all flow releases with a recurrence interval of up to 1:50 years will be discharged with minimum potential for nitrogen supersaturation. As previously described in Section 4.1.3, six 78-inch (2 m) diameter valves with a design capacity of 4000 cfs each, will be located approximately 125 feet (38 m) above normal tailwater levels. These valves will discharge the flow as highly diffused jets to achieve significant energy dissipation without a stilling basin or plunge pool.

6.6 - Mitigation - Devil Canyon Impoundment

Little literature and no precedent data were available regarding the performance of fixed-cone valves in reducing or preventing supersaturated discharges. As such, a theoretical assessment of their anticipated performance was conducted based upon available studies of the aeration efficiency of similar Howell-Bunger valves (fixed-cone) and the physical and geometric characteristics of diffused jets discharging freely into the atmosphere.

The results of the assessment indicated that no serious supersaturation of nitrogen is likely to occur with flow releases through the valves. Estimated gas concentrations that would occur as a result of a flow release are 101 percent at Watana and 102 percent at Devil Canyon. For releases of greater frequency at less discharge, the concentrations are expected to be slightly lower.

To support these conclusions, a field test of similar valves was undertaken at the Lake Comanche Dam on the Mokelumne River in California (Ecological Analysts 1982). The results of the tests indicate that the valves prevented supersaturation and, to a limited extent, may have reduced existing nitrogen concentrations. Flows of 4000 cfs with a dissolved nitrogen concentration of 101 percent at the intake structure were passed through four Howell-Bunger valves. Gas concentrations in the discharge were 97 percent. At 330 feet and 660 feet (100 and 200 m) downstream, concentrations were 95 and 97 percent, respectively.

6.5 - Mitigation - Devil Canyon Construction

Mitigation of the impacts of Devil Canyon construction activities will be achieved using the same measures described for Watana. All the appropriate permits and certifications will be obtained and adhered to.

Borrow site development at Devil Canyon is not expected to cause significant increases in suspended sediment loads and turbidities. Excavation of Site G will be outside the river. Subsequently, it will be completely inundated during Devil Canyon reservoir filling. Petroleum product contamination will be minimized through the development and implementation of a SPCC. Concrete wastes and wash water will be handled in similar manners to those described for Watana. All the applicable water supply and wastewater treatment criteria will be maintained as specified in the appropriate permits. Fish and wildlife mitigation measures are described in Chapter 3.

6.6 - Mitigation - Devil Canyon Impoundment

Other than the continuance of the downstream flows at Gold Creek established during the operation of Watana, no additional mitigation measures are planned during the Devil Canyon impoundment period.

6.8 - Mitigation - Access Road and Transmission Line

6.7 - Mitigation - Devil Canyon/Watana Operation

6.7.1 - Flows

The downstream flow requirements at Gold Creek will be the same as those used to govern Watana operating by itself. After Devil Canyon is on line, Watana will be operated as a peaking plant. The Watana tailrace will discharge directly into the Devil Canyon reservoir thus, peaking at Watana will have no downstream impacts. The Devil Canyon reservoir will provide the flow regulation required to stabilize the downstream flows.

The Devil Canyon power facilities will always be operated as a base loaded plant.

6.7.2 - Temperature

Multilevel intakes similar to those at Watana have been incorporated into the Devil Canyon design. Only two intake levels will be needed because of the limited drawdown at Devil Canyon.

6.7.3 - Total Dissolved Gas Concentration

Similar to Watana (Section 6.5.3), fixed-cone valves will be utilized to minimize dissolved gas (nitrogen) supersaturation downstream of the dam.

As discussed in Section 4.2.3(c), the Devil Canyon dam will include seven valves at two levels with a total design capacity of 38,500 cfs. Four 102-inch (2.6 m) diameter valves, each with a capacity of 5800 cfs, will be located approximately 170 feet (52 m) above normal tailwater. Three more valves, with diameters of 90 inches (2.3 m) and respective capacities of 5100 cfs, will be located approximately 50 feet (15 m) above normal tailwater elevations. Operation of these valves is expected to result in a maximum dissolved gas concentration of 102 percent for the 1:50 year flood event.

6.8 - Mitigation - Access Road and Transmission Lines

The mitigation plan to be used to minimize the impacts of construction, operation, and maintenance of the access roads and transmission lines is described in Chapter 3.

DEC 10 1982

ALASKA POWER AUTHORITY
SUSITNA
FILE P5700
SEQUENCE NO. 12067

ACTION	INFORM.	DISTRIB.	INITIAL
		JDG	
		VTS	
	√	JWH	
		RC	
		DF	
		DC	
		APA	
		BUFF.	
		FILE	

ALASKA POWER AUTHORITY

334 WEST 5th AVENUE - ANCHORAGE, ALASKA 99501

Phone: (907) 277-7641
(907) 276-0001

December 9, 1982

Mr. Robert Martin
Regional Environmental Supervisor
Alaska Department of Environmental
Conservation
437 "E" Street
Anchorage, Alaska 99501

Re: Section 401 Water Quality Certification
Susitna Hydroelectric Project

Dear Mr. Martin:

Federal Energy Regulatory Commission (FERC) regulations (December, 1982) pertaining to preparation of License Exhibit E for major unconstructed projects require that as an appendix, either:

"(A) A copy of the water quality certificate (or agency statement that such certification is waived) as described in Section 401 of the Federal Water Pollution Control Act (Clean Water Act) [see U.S.C. 134]; or

(B) A copy of a dated letter from the applicant to the appropriate agency requesting such certification."

Please consider this letter as a request by the Alaska Power Authority to the Alaska Department of Environmental Conservation for a Section 401 water quality certification.

Please keep us informed regarding any other requirements pursuant to Section 401 certification.

Sincerely,

Eric P. Yould

Eric P. Yould
Executive Director

cc: T. Arminski
J. Hayden - Acres
J. Marx - Harza-Ebasco

STATE OF ALASKA

DEPT. OF ENVIRONMENTAL CONSERVATION

SOUTHCENTRAL REGIONAL OFFICE

BILL SHEFFIELD, GOVERNOR

☐ 437 E. Street
SECOND FLOOR
ANCHORAGE, ALASKA 99501
(907) 274-2533

☐ P.O. BOX 515
KODIAK, ALASKA 99615
(907) 486-3350

☐ P.O. BOX 1207
SOLDOTNA, ALASKA 99669
(907) 262-5210

☐ P.O. BOX 1709
VALDEZ, ALASKA 99686
(907) 835-4698

☐ P.O. BOX 1064
WASILLA, ALASKA 99687
(907) 376-5038

December 21, 1982

Mr. Eric Yould
Executive Director
Alaska Power Authority
334 West 5th Avenue
Anchorage, Alaska 99501

Subject: Susitna Hydroelectric Project
401 Water Quality Certificate

Dear Mr. Yould:

This letter is to confirm that our office has received your December 9, 1982 request for Section 401 certification of the Federal Energy Regulatory Commission (FERC) license for the subject project.

As you are aware, studies are still under way to evaluate the project's potential impacts upon the environment. These studies and conclusions from others must be completed when your agency applies for the necessary Corps of Engineers construction permit(s). As this Department must also issue a 401 certificate for the Corps permit(s) and the above data, necessary for project evaluation, will then be available, we will honor your December 9, 1982 request for 401 certification at that time. Thus, a 401 certificate will be issued of the Corps of Engineer permit(s) and the FERC license at the same time.

If you have any questions concerning the above, please advise.

Sincerely,

Tim Rumfelt

Tim Rumfelt
Environmental Field Officer

TR/mr

RECEIVED

DEC 27 1982

ALASKA POWER AUTHORITY

E-2-193

18-09LH

REFERENCES

Acres American Incorporated. 1982a. Susitna Hydroelectric Project, Feasibility Report. Design Development Studies. Final Draft. Volume 5. Appendix B. Prepared for the Alaska Power Authority.

______. 1982b. Susitna Hydroelectric Project, Feasibility Report. Hydrological Studies. Final Draft. Volume 4. Appendix A. Prepared for the Alaska Power Authority.

______. 1982c. Susitna Hydroelectric Project, 1980-81 Geotechnical Report. Final Draft. Volume 1. Prepared for the Alaska Power Authority.

______. 1982d. Susitna Hydroelectric Project. Scour Hole Development Downstream from High Head Dams.

______. 1983. Susitna Hydroelectric Project, Slough Geohydrology Report. Unpublished.

Acres Consulting Services Limited. 1980. Dunvegan Power Project Peace River Ice Study. Prepared for the Energy Resources Conservation Board.

Alaska Department of Environmental Conservation (ADEC). 1978. Inventory of Water Pollution Sources and Management Actions. Maps and Tables. Alaska Department of Environmental Conservation, Division of Water Programs. Juneau, Alaska.

______. 1979. Water Quality Standards. Alaska Department of Environmental Conservation. Juneau, Alaska.

Alaska Department of Fish and Game (ADF&G). 1981. Susitna Hydroelectric Project, Final Draft Report. Aquatic Habitat and Instream Flow Project. Prepared for Acres American Incorporated.

______. 1982a. Susitna Hydroelectric Project, Final Draft Report. Aquatic Studies Program. Prepared for Acres American Incorporated.

______. 1982c. Unpublished data.

______. 1983. Dissolved Gas Studies. Unpublished data.

______. Koenings, J. P. and G. B. Kyle. 1982b. Limnology and Fisheries Investigations at Crescent Lake 1979-1982, Part I: Crescent Lake Limnology Data Summary. Soldotna, Alaska.

Alaska Department of Natural Resources (ADNR). 1981. State of Alaska Water Users Handbook. Alaska Department of Natural Resources, Division of Land and Water Management, Water Management Section. Anchorage, Alaska.

______. 1982. Susitna Hydroelectric Project Water Resources Analysis: A Preliminary Analysis of Potential Navigational Problems Downstream from Proposed Hydroelectric Dams on the Susitna River. Paul Janke, ADNR, Division of Land and Water Management, Water Management Section. Prepared for Acres American Incorporated.

Alyeska Pipeline Service Company. 1974. Environmental and Technical Stipulation Compliance Assessment Document for the Trans-Alaska Pipeline System. Volume 1. Alyeska Pipeline Service Co., Anchorage, Alaska.

Baxter, R. M. and P. Glaude, 1980. Environmental Effects of Dams and Impoundments in Canada: Experience and Prospects. Canadian Bulletin of Fisheries and Aquatic Sciences. No. 205. Department of Fisheries and Oceans. Ottawa, Canada.

Bohme, V. E. and E. R. Brushett. 1979. Oil Spill Control in Alberta. 1977 Oil Spill Conference (Prevention, Behavior, Control, Cleanup). American Petroleum Institute. Environmental Protection Agency, U.S. Coast Guard. New Orleans, Louisiana.

Brune, G. M. Trap Efficiency of Reservoirs. Trans. Am. Geophys. Union. Miscellaneous Publications 970. U.S. Department of Agriculture.

Bryan, M. L. 1974. Sublacustrine Morphology and Deposition, Kluane Lake, Yukon Territory. In: V. C. Bushnell and M. B. Marcus (editors). Ice Field Ranges Research Project Scientific Results. Volume 4.

Bolke E. L. and K. M. Waddell. 1975. Chemical Quality and Temperature in Flaming Gorge Reservoir, Wyoming and Utah, and the Effect of the Reservoir on the Green River. U.S. Geological Survey, Water Supply Paper 2039-A.

Burger, C. and L. Swenson. 1977. Environmental Surveillance of Gravel Removal on the Trans-Alaska Pipeline System and Recommendations for Future Gravel Mining. Special Report Series No. 13. Joint State/Federal Fish and Wildlife Advisory Team, Alaska.

Cole, G. A. 1975. Textbook of Limnology. Department of Zoology, Arizona State University. C. V. Mosby Co. St. Louis.

Commonwealth Associates, Incorporated. 1982. Anchorage - Fairbanks Transmission Intertie. Prepared for the Alaska Power Authority.

Dwight, L. P. 1981. Susitna Hydroelectric Project, Review of Existing Water Rights in the Susitna River Basin. Prepared for Acres American Incorporated.

Dwight, L. P. 1982. Transmission Corridor Water Quality Literature Search. Unpublished letter/report.

Dwight, L. P. and E. W. Trihey. 1981. Susitna Hydroelectric Project, A Survey of Questions and Concerns Pertaining to Instream Flow Aspects of the Proposed Susitna Hydroelectric Project. Prepared for Acres American Incorporated.

Ecological Analysts, Inc. 1982. Lake Comanche Dissolved Nitrogen Study. Concord, California. Prepared for Milo Bell.

Environmental Protection Agency (EPA). 1976. Quality Criteria for Water. U.S. Environmental Protection Agency. Washington, D. C.

______. November 28, 1980. Water Quality Criteria Documents: Availability, Environmental Protection Agency. Federal Register. 45.

Flint, R. ADEC. October 1982. Personal communication.

Fortier, S. and F. C. Scobey. 1926. Permissible Canal Velocities. Trans. ASCE. Volume 89. 0-956.

Freethey, G.W. and D.R. Scully, 1980. Water Resources of the Cook Inlet Basin, Alaska. USGS Hydrological Investigations Atlas. HA-620.

General Electric Co. 1979. Optimized Generation Planning Program (OGP). General Electric Company, Electric Utility Systems Engineering Department. Schenectady, New York.

Gilbert, R. 1973. Processes of Underflow and Sediment Transport in a British Columbia Lake. Proceedings of the 9th Hydrology Symposium. University of Alberta. Edmonton, Canada. 493-507.

Gustavson, J. 1977. An Evaluation of Low Water Crossings at Fish Streams Along with Trans-Alaska Pipeline System. JFWAT Special Report, No. 16. Joint State/Federal Fish and Wildlife Advisory Team. Anchorage, Alaska.

Gustavson, T. C. 1975. Bathymetry and Sediment Distribution in Proglacial Malaspina Lake, Alaska. Journal of Sedimentary Petrology. 450:461.

Harrison, W. D. University of Alaska, Geophysical Institute. February 1983. Personal Communication.

Hydro-North. 1972. Contingency Plan Study Paxson - Summit Lakes Area Trans-Alaska Pipeline. Prepared for Alyeska Pipeline Service Company.

Imberger, J. and J. C. Patterson. 1980. A Dynamic Reservoir Simulation Model - DYRESM:5. Proc. Symposium on Predictive Ability of Surface Water Flow and Transport Models. Berkeley, California.

Imberger, J. et al. 1978. Dynamics of Reservoir of Medium Size. Jour Hydraulic Div., Proc. American Society of Civil Engineers, 104, No. HY5. 725-743.

Joyce, M. R., L. A. Rundquist and L. L. Moulton. 1980. Gravel Removal Guidelines Manual for Arctic and Subarctic Floodplains. U. S. Fish and Wildlife Service, Biological Services Program FS/OBS-80/09.

Kavanagh, N. and A. Townsend. 1977. Construction-Related Oil Spills Along Trans-Alaska Pipeline. JFWAT Special Report, 15. Joint State/Federal Fish and Wildlife Advisory Team, Alaska.

Lamke, R. D. 1970. Flood Characteristics of Alaskan Streams. USGS, Water Resources Investigation. 78-129.

Lantz, R. L. 1977. Guidelines for Stream Protection in Logging Operations. Research Division, Oregon State Game Commission. Oregon.

Lauman, T. E. 1976. Salmonid Passage at Stream-Road Crossings. Oregon Department of Fish and Wildlife. Oregon.

LeBeau, J. ADEC. October 1982. Personal communication.

Lindstedt, S. J. 1979. Oil Spill Response Planning for Biologically Sensitive Areas. 1977 Oil Spill Conference (Prevention, Behavior, Control, Cleanup). American Petroleum Institute, Environmental Protection Agency, U. S. Coast Guard. New Orleans, Louisiana.

Love, K. S. 1961. Relationship of Impoundment to Water Quality. JAWWA. Volume 53.

Mathews, W. H. 1956. Physical Limnology and Sedimentation in a Glacial Lake. Bulletin of the Geological Society of America. Volume 67.

McNeely, R. N. V. P. Neimanism and K. Dwyer. 1979. Water Quality Sourcebook -- A Guide to Water Quality Parameters. Environment Canada, Inland Water Directorate, Water Quality Branch. Ottawa, Canada.

Meier, M. F. 1966. Some Glaciological Interpretations of Remapping Programs on South Cascade, Nisqually and Klawatti Glaciers, Washington. Canadian Journal of Earth Sciences. Volume 3. 811-818.

Michel, B. 1971. Winter Regime of Rivers and Lakes. Cold Regions Science and Engineering Monograph 111-B1A. U. S. Army Corps of Engineers.

Mortimer, C. H. 1941. The Exchange of Dissolved Substances Between Mud and Water in Lakes, Parts 1 and 2. Journal of Ecology. Volume 29.

Mortimer, C. H. 1942. The Exchange of Dissolved Substances Between Mud and Water in Lakes, Parts 3 and 4. Journal of Ecology. Volume 30.

Neal, J. K. 1967. Reservoir Eutrophication and Dystrophication Following Impoundment. Reservoir Fish Resources Symposium. Georgia University. Athens, Georgia.

Neill, C. R. 1967. Mean Velocity Criteria for Scour of Coarse Uniform Bed Material. IAHR, 12th Congress. Fort Collins, Colorado.

______. 1968. A Re-examination of Beginning of Movement for Coarse Granular Bed Materials. Internal Report. Hydrologic Research Station. Wallingford, England.

Parker, G. 1980. Downstream Response of Gravel-Bed Streams to Dams; An Overview. Surface Water Impoundments. ASCE. New York. 792-801.

Peratrovich, Nottingham and Drage, Inc. 1982. Susitna Reservoir Sedimentation and Water Clarity Study. Prepared for Acres American Incorporated.

______. 1983. Susitna Hydroelectric Project Nitrogen Supersaturation Study. Prepared for Acres American Incorporated.

Peterson, L. A. February 1983. Personal communication.

Peterson, L. A. and G. Nichols. 1982. Water Quality Effects Resulting from Impoundment of the Susitna River. Prepared for Acres American Incorporated.

Pharo, C. H. and E. D. Carmack. 1979. Sedimentation Processes in a Short Residence - Time Intermontane Lake, Kamloops Lake, British Columbia. Sedimentology. 26.

R & M Consultants, Inc. 1981a. Preliminary Channel Geometry, Velocity and Water Level Data for the Susitna River at Devil Canyon. Prepared for Acres American Incorporated.

______. Harrison, W. D. 1981b. Susitna Hydroelectric Project, Glacier Studies. Prepared for Acres American Incorporated.

______. 1981c. Susitna Hydroelectric Project, Hydrographic Surveys Closeout Report: Surveys and Site Facilities. Final Draft. Prepared for Acres American Incorporated.

______. 1981d. Susitna Hydroelectric Project, Hydrology: Lower Susitna Studies: Open Water Calculations. Preliminary Draft. Prepared for Acres American Incorporated.

______. 1981e. Susitna Hydroelectric Project, Ice Observations 1980-81. Prepared for Acres American Incorporated.

______. 1981f. Susitna Hydroelectric Project, Regional Flood Studies. Prepared for Acres American Incorporated.

______. 1981g. Susitna Hydroelectric Project, River Mile Index. Prepared for Acres American Incorporated.

______. 1981h. Susitna Hydroelectric Project, Water Quality. Annual Report 1980. Prepared for Acres American Incorporated.

______. 1981i. Susitna Hydroelectric Project, Water Quality Annual Report, 1981. Prepared for Acres American Incorporated.

______. Harrison, W. D. 1982a. Susitna Hydroelectric Project, 1982 Susitna Basin Glacier Studies. Prepared for Acres American Incorporated.

______. 1982b. Susitna Hydroelectric Project, Hydraulic and Ice Studies. Prepared for Acres American Incorporated.

______. 1982c. Susitna Hydroelectric Project, Reservoir Sedimentation. Prepared for Acres American Incorporated.

______. 1982d. Susitna Hydroelectric Project, River Morphology. Prepared for Acres American Incorporated.

______. 1982e. Susitna Hydroelectric Project, Slough Hydrology Interim Report. Prepared for Acres American Incorporated.

______. 1982f. Susitna Hydroelectric Project, Tributary Stability Analysis. Prepared for Acres American Incorporated.

______. 1982g. Susitna Hydroelectric Project, Water Quality Interpretation 1981. Prepared for Acres American Incorporated.

______. 1982h. Susitna Hydroelectric Project, Winter 1981-1982 Ice Observations Report. Prepared for Acres American Incorporated.

______. 1982i. Eklutna Lake Data. Unpublished.

______. 1982j. Susitna River Hydroelectric Project Data. Unpublished.

Raphael, J. M. 1962. Prediction of Temperature in Rivers and Reservoirs. Journal Power Division, Proc. American Society of Civil Engineers, 88 (PO2). 157-181.

Resource Management Associates. 1983. Susitna Hydroelectric Project, Salinity Model. Prepared for Acres American Incorporated.

St. John et al. 1976. The Limnology of Kamloops Lake. B.C. Department of Environment. Vancouver, B. C.

Schmidt, D. 1981. Summary of Key Findings of 1981 Dissolved Gas Investigation of the Susitna River in the Devil Canyon Vicinity. Unpublished report.

Schmidt, D., ADF&G. October 1982. Personal communication.

Sittig , M. 1981. Handbook of Toxic and Hazardous Chemicals. Noyes Publications. Park Ridge, New Jersey.

Simons, D. B. and F. Senturk. 1977. Sediment Transport Technology. Water Resources Publications. Fort Collins, Colorado. 465.

Stevens, M. A. and D. B. Simons. 1971. Stability Analyses for Coarse Granular Material on Slopes. Chapter A. In: H. W. Shen (editor). River Hydraulics. Volume 1. Fort Collins, Colorado.

Symons, J. M., S. R. Weibel and G. G. Robeck. 1965. Impoundment Influences on Water Quality. JAWWA. Volume 57. No. 1.

______. 1969. Water Quality Behavior in Reservoirs. U. S. Public Health Service, Bureau of Water Hygiene. Cincinnati, Ohio.

Terrestrial Environmental Specialists, Inc. 1982. Susitna Hydroelectric Project, Environmental Studies Land Use Analysis: Navigational Use. Prepared for Acres American Incorporated.

Tetra Tech, Inc. 1977. User's Guide for the Estuary Hydrodynamic and Water Quality Models. Donald T. Smith, Tetra Tech, Inc. Prepared for U.S. Department of the Army Corps of Engineers, Alaska District.

Texas Water Development Board. 1970. A Completion Report on Stochastic Optimization and Simulation Techniques for Management of Regional Water Resource Systems - Volume IIB - FILLIN - 1 Program Description.

Trihey, E. W. 1981. Susitna Hydroelectric Project, Instream Flow Assessment for the Proposed Susitna Hydroelectric Project: Issue Identification and Baseline Data Analysis 1981 Study Plan. Prepared for Acres American Incorporated.

______. 1982a. Preliminary Assessment of Access by Spawning Salmon to Side Slough Habitat Above Talkeetna. Draft. Prepared for Acres American Incorporated.

______. 1982b. Susitna Hydroelectric Project, Instream Flow Assessment for the Proposed Susitna Hydroelectric Project: Issue Identification and Baseline Data Analysis 1981 Summary Report. Prepared for Acres American Incorporated.

______. 1982c. Susitna Intergravel Temperature Report. Draft. AEIDC.

______. ADF&G. September 15, 1982. Personal communication.

______. ADF&G. October 1982. Personal communication.

Turkheim, R. A. 1975. Biophysical Impacts of Arctic Hydroelectric Development. In: J. C. Day (editor). Impacts of Hydroelectric Projects and Associated Developments on Arctic Renewable Resources and the Inuit. University of Western Ontario, Ontario, Canada.

U.S. Army Corps of Engineers. 1975. Program Description and User Manual for Streamflow Synthesis and Reservoir Regulation (SSARR). U.S. Army Corps of Engineers, North Pacific Division. Portland, Oregon.

______. 1979. Volume 3: Water Quality Knik Arm - Upper Cook Inlet. U.S. Army Corps of Engineers, Alaska District.

______. 1982. Bradley Lake Hydroelectric Project - Design Memorandum No. 2, Appendix E.

USFWS. 1982. A Guide to Stream Habitat Analysis Using the Instream Flow Incremental Methodology: Instream Flow Information Paper No. 12. Ken Bovee, Instream Flow and Aquatic Systems Group, Western Energy and Land Use Team, USFWS. Fort Collins, Colorado.

U. S. Forest Service. 1979. Roadway Drainage Guide for Installing Culverts to Accommodate Fish. Alaska Region Report No. 42. U.S. Department of Agriculture, Alaska.

U.S. Geological Survey (USGS). 1949-1964. Surface Water Records for Alaska.

______. 1965-1982. Water Resources Data for Alaska.

Vollenweider, R. A. 1976. Advances in Defining Critical Loading Levels for Phosphorous in Lake Eutrophication. Mem. 1st. Ital, Idrobio. No. 33.

TABLE E.2.1: SUSITNA RIVER REACH DEFINITIONS

River Mile	Average Slope	Predominant Channel Pattern
RM 149 to 144	0.00195	Single channel confined by valley walls. Frequent bedrock control points.
RM 144 to 139	0.00260	Split channel confined by valley wall and terraces.
RM 139 to 129.5	0.00210	Split channel confined occasionally by terraces and valley walls. Main channels, side channels and sloughs occupy valley bottom.
RM 129.5 to 119	0.00173	Split channel with occasional tendency to braid. Main channel frequently flows against west valley wall. Subchannels and sloughs occupy east floodplain.
RM 119 to 104	0.00153	Single channel frequently incised and occasional islands.
RM 104 to 95	0.00147	Transition from split channel to braided. Occasionally bounded by terraces. Braided through the confluence with Chulitna and Talkeetna Rivers.
RM 95 to 61	0.00105	Braided with occasional confinement by terraces.
RM 61 to 42	0.00073	Combined patterns; western floodplain braided, eastern floodplain split channel.
RM 42 to 0	0.00030	Split channel with occasional tendency to braid. Deltaic distributary channels begin forming at about RM 20.

Source: R&M 1982d

TABLE E.2.2: PERIODS OF RECORD FOR GAGING STATIONS

Station Name	USGS Gage Number	Susitna River Mile	Drainage Area (mi^2)	Periods of Record: Streamflow (Continuous)[1]	Periods of Record: Water Quality[2]	Agency
Susitna River nr. Denali	15291000	290.8	950	5/57-9/66, 11/68-Present	1957-66, 1968-69, 1974-Present (6/30/82)	USGS
Susitna River nr. Cantwell (Vee Canyon)	15291500	223.1	4,140	5/61-9/72, 5/80-Present	1962-72, 1980-Present(7/27/82)	USGS
Susitna River nr. Cantwell (Vee Canyon)	-	223.1	4,140	-	1980-81	R&M Consult.
Susitna River nr. Watana Damsite	-	182.2[3]	5,180	6/80-Present	10/80-12/81	R&M Consult.
Susitna River at Gold Creek	15292000	136.6	6,160	8/49-Present	1949-58, 1962, 1967-68, 1974-Present (9/16/82)	USGS
Susitna River at Gold Creek	-	136.6	6,160	-	1980-Present(10/14/82)	R&M
Susitna River at Sunshine	15292780	83.9	11,100	5/81-Present	1971, 1975, 1977, 1981-Present (10/13/82)	
Susitna River at Susitna Station	15294350	25.8	19,400	10/74-Present	1955, 1970, 1975-Present(10/5/82)	USGS
Maclaren River nr. Paxson	15291200	259.8[4]	280	6/58-Present	1958-61, 1967-68, 1975	USGS
Chulitna River nr. Talkeetna	15292400	98.0[4]	2,570	2/58-9/72, 5/80-Present	1958-59, 1967-72, 1980-Present (6/3/82)	USGS
Talkeetna River nr. Talkeetna	15291500	97.0[4]	2,006	6/64-Present	1954, 1966-Present(10/14/82)	USGS
Skwentna River nr. Skwentna	15294300	28.0[5]	2,250	10/59-Present	1959, 1961, 1967-68, 1974-75, 1980-81	USGS
Yentna River nr. Susitna Station	15294345	28.0[4]	6,180	10/80-Present	1981-Present (8/11/82)	USGS

Notes:

1. All streamflow gage stations are currently active, however, flow data included in this document is through September 1981.
2. "Present" in periods of record indicates station is active as of January 1983. A date after "Present" indicates the most recent data available.
3. Watana continuous water quality monitor was installed at river mile 183.0.
4. River mile at tributary's confluence with Susitna River.
5. River mile at Yentna-Susitna confluence.

Source: USGS and R&M

TABLE E.2.3: USGS STREAMFLOW SUMMARY (cfs)

Station		Denali	Cantwell	Gold Creek	Susitna	Maclaren	Chulitna	Talkeetna	Skwentna
Yrs. of Record		22+	12+	32	7	23+	16+	17+	22
Oct	Max	2,165	5,472	8,212	58,640	734	8,062	4,438	7,254
	Mean	1,187	3,236	5,757	35,694	421	4,916	2,562	4,492
	Min	528	1,638	3,124	19,520	249	2,898	1,450	1,929
Nov	Max	878	2,487	4,192	31,590	370	3,213	1,718	4,195
	Mean	528	1,514	2,568	16,289	189	2,075	1,180	1,930
	Min	290	780	1,215	9,933	95	1,480	765	678
Dec	Max	575	1,658	3,264	14,690	246	2,100	1,103	2,871
	Mean	344	1,053	1,793	9,794	127	1,494	836	1,320
	Min	169	543	866	6,000	49	1,000	556	624
Jan	Max	444	1,694	2,452	10,120	162	1,623	851	2,829
	Mean	257	896	1,463	8,417	100	1,299	680	1,117
	Min	119	437	724	6,529	44	974	459	600
Feb	Max	330	1,200	2,028	9,017	140	1,414	777	1,821
	Mean	215	761	1,243	7,665	87	1,115	573	952
	Min	81	426	723	5,614	42	820	401	600
Mar	Max	290	1,200	1,900	8,906	121	1,300	743	1,352
	Mean	195	711	1,123	6,842	78	988	512	839
	Min	42	429	713	5,368	41	738	380	600
Apr	Max	415	1,223	2,650	12,030	145	1,600	1,038	2,138
	Mean	232	883	1,377	8,350	87	1,176	603	1,110
	Min	43	465	745	6,233	50	700	422	607
May	Max	3,468	12,150	21,890	83,580	2,131	13,890	8,840	22,370
	Mean	2,092	8,044	13,277	64,896	823	8,634	4,336	8,755
	Min	629	1,915	3,745	48,670	208	2,355	2,145	1,635
June	Max	12,210	34,630	50,580	165,900	4,297	40,330	19,040	36,670
	Mean	7,261	18,808	27,658	123,447	2,886	22,527	11,619	19,137
	Min	4,647	9,909	15,500	90,930	1,751	17,390	5,207	10,650
July	Max	12,110	22,790	34,400	181,400	4,649	35,570	15,410	28,620
	Mean	9,600	17,431	24,383	141,300	3,216	27,047	10,974	17,811
	Min	6,756	12,220	16,100	115,200	2,441	20,820	7,080	11,670
Aug	Max	12,010	22,760	38,538	159,600	4,122	33,670	16,770	20,160
	Mean	8,246	15,252	21,996	118,973	2,633	22,749	9,459	13,535
	Min	3,919	6,597	8,879	91,360	974	11,300	3,787	7,471
Sept	Max	5,452	12,910	21,240	91,200	2,439	22,260	10,610	13,090
	Mean	3,300	7,971	13,175	71,239	1,138	11,544	5,369	8,156
	Min	1,822	3,376	5,093	48,910	470	6,704	2,070	3,783

Note: Sunshine streamflow data were not included due to the brief period of record (approximately 1 yr).

Source: USGS

TABLE E.2.4: FILLED STREAMFLOW SUMMARY (cfs)

Station		Denali	Cantwell	Watana	Devil Canyon	Gold Creek	Sunshine	Susitna	Maclaren	Chulitna	Talkeetna	Skwentna
Oct	Max	2,165	5,472	6,458	7,518	8,212	18,555	58,640	734	9,314	4,438	7,254
	Mean	1,165	3,149	4,513	5,312	5,757	13,906	31,102	418	5,040	2,720	4,329
	Min	528	1,638	2,403	2,867	3,124	18,593	15,940	249	2,898	1,450	1,929
Nov	Max	878	2,487	3,525	3,955	4,192	9,400	31,590	370	3,277	1,786	4,195
	Mean	500	1,460	2,052	2,383	2,568	6,104	13,361	182	2,083	1,209	1,867
	Min	192	780	1,021	1,146	1,215	3,978	6,606	95	1,236	765	678
Dec	Max	575	1,658	2,259	2,905	3,264	6,137	15,081	246	2,143	1,239	2,871
	Mean	315	951	1,405	1,652	1,793	4,249	8,426	117	1,487	846	1,295
	Min	146	543	709	810	866	2,650	4,279	49	891	515	624
Jan	Max	651	1,694	1,780	2,212	2,452	4,739	12,669	162	1,673	1,001	2,829
	Mean	248	850	1,157	1,352	1,463	3,550	7,971	99	1,288	682	1,068
	Min	85	437	619	687	724	2,218	5,032	44	974	459	600
Feb	Max	422	1,200	1,560	1,836	2,028	4,057	11,532	140	1,414	805	1,821
	Mean	206	706	979	1,147	1,243	3,009	7,117	81	1,092	568	911
	Min	64	426	602	682	723	2,082	4,993	42	820	401	490
Mar	Max	290	1,273	1,560	1,779	1,900	3,898	9,193	121	1,300	743	1,352
	Mean	192	659	898	1,042	1,123	2,683	6,397	74	979	491	826
	Min	42	408	569	664	713	2,013	4,910	36	738	379	522
Apr	Max	415	1,702	1,965	2,405	2,650	5,109	12,030	145	1,600	1,038	2,138
	Mean	231	835	1,113	1,282	1,377	3,257	7,242	86	1,194	573	1,088
	Min	43	465	609	697	745	2,205	5,531	50	700	371	607
May	Max	4,259	13,751	15,973	19,777	21,890	50,302	94,143	2,131	20,025	8,840	22,370
	Mean	2,306	7,473	10,398	12,230	13,277	27,955	61,376	832	9,519	4,150	8,555
	Min	629	1,915	2,857	3,428	3,745	8,645	29,809	208	2,355	1,694	1,635
June	Max	12,210	34,630	42,842	47,816	50,580	110,073	176,219	4,297	40,330	19,045	40,356
	Mean	7,532	17,567	22,913	25,938	27,658	63,810	123,830	2,888	22,892	11,416	18,462
	Min	4,647	9,909	13,233	14,710	15,500	39,311	67,838	1,751	15,587	5,207	10,650
July	Max	12,110	22,790	28,767	32,388	34,450	85,600	181,400	4,649	35,570	15,410	28,620
	Mean	9,688	16,873	20,778	23,101	24,383	64,538	134,130	3,241	27,044	11,118	16,997
	Min	6,756	12,220	14,844	15,651	16,100	45,267	102,121	2,441	20,820	7,080	11,670

TABLE E.2.4 (Page 2)

Station		Denali	Cantwell	Watana	Devil Canyon	Gold Creek	Sunshine	Susitna	Maclaren	Chulitna	Talkeetna	Skwentna
Yrs. of Record												
Aug	Max	12,010	22,760	31,435	35,270	38,538	84,940	159,600	4,122	33,670	18,033	20,590
	Mean	8,431	14,614	18,431	20,709	21,996	56,642	112,851	2,644	22,732	10,459	13,335
	Min	3,919	6,597	7,772	8,484	8,879	24,656	62,368	974	11,300	3,787	7,471
Sep	Max	6,955	12,910	17,206	19,799	21,240	53,703	104,218	2,439	23,260	10,610	13,371
	Mean	3,334	7,969	10,670	12,276	13,175	32,169	66,790	1,167	11,956	6,084	8,371
	Min	1,194	3,376	4,260	4,796	5,093	14,268	34,085	470	6,424	2,070	3,783
Ann	Max	3,651	7,962	9,833	10,947	11,565	28,226	63,159	1,276	12,114	5,276	10,024
	Mean	2,885	6,184	7,986	9,084	9,703	23,611	48,873	998	9,045	4,226	6,622
	Min	2,127	4,159	4,712	5,352	5,596	14,355	31,428	693	6,078	2,233	4,939

Notes: 1. Based on 32 years of record.

2. Gold Creek data are not filled since 32 years of record are available.

3. Sunshine discharge for WY1980 and Oct-Apr WY1981 were computed from Gold Creek, Talkeetna, and Chulitna discharges for the same period.

TABLE E.2.5: MODIFIED STREAMFLOW SUMMARY

Station		Watana	Devil Canyon	Gold Creek	Sunshine	Susinta Station
Oct	Max	6,458	7,518	8,212	18,555	58,640
	Mean	4,523	5,324	5,770	13,966	31,426
	Min	2,403	2,867	3,124	9,416	18,026
Nov	Max	3,525	3,955	4,192	9,400	31,590
	Mean	2,059	2,391	2,577	6,028	13,501
	Min	1,021	1,146	1,215	3,978	6,799
Dec	Max	2,259	2,905	3,264	6,139	15,081
	Mean	1,415	1,665	1,807	4,267	8,518
	Min	709	810	866	2,734	4,763
Jan	Max	1,780	2,212	2,452	4,739	12,669
	Mean	1,166	1,362	1,474	3,565	8,030
	Min	636	757	824	2,507	6,071
Feb	Max	1,560	1,836	2,028	4,057	11,532
	Mean	983	1,153	1,249	2,999	7,149
	Min	602	709	768	1,731	4,993
Mar	Max	1,560	1,779	1,900	3,898	9,193
	Mean	898	1,042	1,124	2,681	6,408
	Min	569	664	713	2,013	4,910
Apr	Max	1,965	2,405	2,650	5,109	12,030
	Mean	1,100	1,267	1,362	3,226	7,231
	Min	609	697	745	2,205	5,531
May	Max	15,973	19,777	21,890	50,302	94,143
	Mean	10,355	12,190	13,240	27,949	61,646
	Min	2,857	3,428	3,745	8,645	29,809
June	Max	42,842	47,816	50,580	111,073	176,219
	Mean	23,024	26,078	27,815	64,089	124,614
	Min	13,233	14,710	15,530	39,311	67,838
July	Max	28,767	32,388	34,400	85,600	181,400
	Mean	20,810	23,152	24,445	64,641	134,550
	Min	15,871	17,291	18,093	48,565	102,184
Aug	Max	31,435	35,270	38,538	84,940	159,600
	Mean	18,629	20,928	22,228	57,215	113,935
	Min	13,412	15,257	16,220	42,118	80,252
Sep	Max	17,206	19,799	21,240	53,703	104,218
	Mean	10,792	12,414	13,321	32,499	67,530
	Min	5,712	6,463	6,881	18,502	39,331
Annual	Max	9,833	10,947	11,565	28,226	63,159
	Mean	8,023	9,130	9,753	23,732	49,004
	Min	6,100	6,800	7,200	17,951	36,285

Note: Based on 32 years of record.

TABLE E.2.6: WATANA PRE-PROJECT MONTHLY FLOW (CFS) MODIFIED HYDROLOGY

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1	4720.	2084.	1169.	815.	642.	569.	680.	8656.	16432.	19193.	16914.	7320.	6648.1
2	3299.	1107.	906.	808.	673.	620.	1302.	11650.	18518.	19787.	16478.	17206.	7733.7
3	4593.	2170.	1501.	1275.	841.	735.	804.	4217.	25773.	22111.	17356.	11571.	7776.7
4	6286.	2757.	1281.	819.	612.	671.	1382.	15037.	21470.	17355.	16682.	11514.	8035.2
5	4219.	1600.	1184.	1088.	803.	638.	943.	11697.	19477.	16984.	20421.	9166.	7400.4
6	3859.	2051.	1550.	1388.	1051.	886.	941.	6718.	24881.	23788.	23537.	13448.	8719.3
7	4102.	1588.	1039.	817.	755.	694.	718.	12953.	27172.	25831.	19153.	13194.	9051.0
8	4208.	2277.	1707.	1373.	1189.	935.	945.	10176.	25275.	19949.	17318.	14841.	8381.0
9	6035.	2936.	2259.	1481.	1042.	974.	1265.	9958.	22098.	19753.	18843.	5979.	7769.4
10	3668.	1730.	1115.	1081.	949.	694.	886.	10141.	18330.	20493.	23940.	12467.	8011.0
11	5166.	2214.	1672.	1400.	1139.	961.	1070.	13044.	13233.	19506.	19323.	16086.	7954.0
12	6049.	2328.	1973.	1780.	1305.	1331.	1965.	13638.	22784.	19840.	19480.	10146.	8602.9
13	4638.	2263.	1760.	1609.	1257.	1177.	1457.	11334.	36017.	23444.	19887.	12746.	9832.9
14	5560.	2509.	1709.	1309.	1185.	884.	777.	15299.	20663.	28767.	21011.	10800.	9277.7
15	5187.	1789.	1195.	852.	782.	575.	609.	3579.	42842.	20083.	14048.	7524.	8262.7
16	4759.	2368.	1070.	863.	773.	807.	1232.	10966.	21213.	23236.	17394.	16226.	8451.5
17	5221.	1565.	1204.	1060.	985.	985.	1338.	7094.	25940.	16154.	17391.	9214.	7374.4
18	3270.	1202.	1122.	1102.	1031.	890.	850.	12556.	24712.	21987.	26105.	13673.	9095.7
19	4019.	1934.	1704.	1618.	1560.	1560.	1577.	12827.	25704.	22083.	14148.	7164.	8032.2
20	3447.	1567.	1073.	884.	748.	686.	850.	7942.	17509.	15871.	14078.	8150.	6100.4
21	2403.	1021.	709.	636.	602.	624.	986.	9536.	14399.	18410.	16264.	7224.	6114.6
22	3768.	2496.	1687.	1097.	777.	717.	814.	2857.	27613.	21126.	27447.	12189.	8588.5
23	4979.	2587.	1957.	1671.	1491.	1366.	1305.	15973.	27429.	19820.	17510.	10956.	8963.4
24	4301.	1978.	1247.	1032.	1000.	874.	914.	7287.	23859.	16351.	18017.	8100.	7112.0
25	3057.	1355.	932.	786.	690.	627.	872.	12889.	14781.	15972.	13524.	9786.	6313.7
26	3089.	1474.	1277.	1216.	1110.	1041.	1211.	11672.	26689.	23430.	15127.	13075.	8402.7
27	5679.	1601.	876.	758.	743.	691.	1060.	8939.	19994.	17015.	18394.	5712.	6834.8
28	2974.	1927.	1688.	1349.	1203.	1111.	1203.	8569.	31353.	19707.	16807.	10613.	8232.6
29	5794.	2645.	1980.	1578.	1268.	1257.	1408.	11232.	17277.	18385.	13412.	7133.	6992.2
30	3774.	1945.	1313.	1137.	1055.	1101.	1318.	12369.	22905.	24912.	16671.	9097.	8183.7
31	6150.	3525.	2032.	1470.	1233.	1177.	1404.	10140.	23400.	26740.	18000.	11000.	8907.9
32	6458.	3297.	1385.	1147.	971.	889.	1103.	10406.	17017.	27840.	31435.	12026.	9580.4
MAX	6458.	3525.	2259.	1780.	1560.	1560.	1965.	15973.	42842.	28767.	31435.	17206.	9832.9
MIN	2403.	1021.	709.	636.	602.	569.	609.	2857.	13233.	15871.	13412.	5712.	6100.4
MEAN	4523.	2059.	1415.	1166.	983.	898.	1100.	10355.	23024.	20810.	18629.	10792.	8023.0

TABLE E.2.7: DEVIL CANYON PRE-PROJECT MONTHLY FLOW (CFS) MODIFIED HYDROLOGY

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1	5758.	2405.	1343.	951.	736.	670.	802.	10491.	18469.	21383.	18821.	7951.	7537.8
2	3652.	1231.	1031.	906.	768.	697.	1505.	13219.	19979.	21576.	18530.	19799.	8615.9
3	5222.	2539.	1758.	1484.	943.	828.	879.	4990.	30014.	24862.	19647.	13441.	8918.0
4	7518.	3233.	1550.	1000.	746.	767.	1532.	17758.	25231.	19184.	19207.	13928.	9356.4
5	5109.	1921.	1387.	1224.	930.	729.	1131.	15286.	23188.	19154.	24072.	11579.	8866.9
6	4830.	2507.	1868.	1649.	1275.	1024.	1107.	8390.	28082.	26213.	24960.	13989.	9707.4
7	4648.	1789.	1207.	922.	893.	852.	867.	15979.	31137.	29212.	22610.	16496.	10608.2
8	5235.	2774.	1987.	1583.	1389.	1105.	1109.	12474.	28415.	22110.	19389.	18029.	9668.7
9	7435.	3590.	2905.	1792.	1212.	1086.	1437.	11849.	24414.	21763.	21220.	6989.	8866.8
10	4403.	2000.	1371.	1317.	1179.	878.	1120.	13901.	21538.	23390.	28594.	15330.	9649.6
11	6061.	2623.	2012.	1686.	1340.	1113.	1218.	14803.	14710.	21739.	22066.	18930.	9084.4
12	7171.	2760.	2437.	2212.	1594.	1639.	2405.	16031.	27069.	22881.	21164.	12219.	10021.3
13	5459.	2544.	1979.	1796.	1413.	1320.	1613.	12141.	40680.	24991.	22242.	14767.	10946.5
14	6308.	2696.	1896.	1496.	1387.	958.	811.	17698.	24094.	32388.	22721.	11777.	10431.8
15	5998.	2085.	1387.	978.	900.	664.	697.	4047.	47816.	21926.	15586.	8840.	9250.7
16	5744.	2645.	1161.	925.	829.	867.	1314.	12267.	24110.	26196.	19789.	18234.	9555.5
17	6497.	1908.	1478.	1279.	1187.	1187.	1619.	8734.	30446.	18536.	20245.	10844.	8697.0
18	3844.	1458.	1365.	1358.	1268.	1089.	1054.	14436.	27796.	25081.	30293.	15728.	10460.4
19	4585.	2204.	1930.	1851.	1779.	1779.	1791.	14982.	29462.	24871.	16091.	8226.	9175.4
20	3976.	1783.	1237.	1012.	859.	780.	959.	9154.	19421.	17291.	15500.	9188.	6800.1
21	2867.	1146.	810.	757.	709.	722.	1047.	10722.	17119.	21142.	18653.	8444.	7063.9
22	4745.	3082.	2075.	1319.	944.	867.	986.	3428.	31031.	22942.	30316.	13636.	9657.2
23	5537.	2912.	2313.	2036.	1836.	1660.	1566.	19777.	31930.	21717.	18654.	11884.	10199.0
24	4639.	2155.	1387.	1140.	1129.	955.	987.	7896.	26393.	17572.	19478.	8726.	7738.3
25	3491.	1463.	997.	843.	746.	690.	949.	15005.	16767.	17790.	15257.	11370.	7160.5
26	3507.	1619.	1487.	1409.	1342.	1272.	1457.	14037.	30303.	26188.	17032.	15155.	9606.6
27	7003.	1853.	1008.	897.	876.	825.	1261.	11305.	22814.	18253.	19298.	6463.	7705.5
28	3552.	2392.	2148.	1657.	1470.	1361.	1510.	11212.	35607.	21741.	18371.	11916.	9438.8
29	6936.	3211.	2371.	1868.	1525.	1481.	1597.	11693.	18417.	20079.	15327.	8080.	7765.1
30	4502.	2324.	1549.	1304.	1204.	1165.	1403.	13334.	24052.	27463.	19107.	10172.	9023.0
31	6900.	3955.	2279.	1649.	1383.	1321.	1575.	11377.	26255.	30002.	20196.	12342.	9994.5
32	7246.	3699.	1554.	1287.	1089.	997.	1238.	11676.	17741.	31236.	35270.	12762.	10577.9
MAX	7518.	3955.	2905.	2212.	1836.	1779.	2405.	19777.	47816.	32388.	35270.	19799.	10946.5
MIN	2867.	1146.	810.	757.	709.	664.	697.	3428.	14710.	17291.	15257.	6463.	6800.1
MEAN	5324.	2391.	1664.	1362.	1152.	1042.	1267.	12190.	26078.	23152.	20928.	12414.	9129.7

TABLE E.2.8: GOLD CREEK PRE-PROJECT MONTHLY FLOW (CFS) MODIFIED HYDROLOGY

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1	6335.	2583.	1439.	1027.	788.	726.	870.	11510.	19600.	22600.	19880.	8301.	8032.1
2	3848.	1300.	1100.	960.	820.	740.	1617.	14090.	20790.	22570.	19670.	21240.	9106.0
3	5571.	2744.	1900.	1600.	1000.	880.	920.	5419.	32370.	26390.	20920.	14480.	9552.1
4	8202.	3497.	1700.	1100.	820.	820.	1615.	19270.	27320.	20200.	20610.	15270.	10090.4
5	5604.	2100.	1500.	1300.	1000.	780.	1235.	17280.	25250.	20360.	26100.	12920.	9681.6
6	5370.	2760.	2045.	1794.	1400.	1100.	1200.	9319.	29860.	27560.	25750.	14290.	10256.4
7	4951.	1900.	1300.	980.	970.	940.	950.	17660.	33340.	31090.	24530.	18330.	11473.3
8	5806.	3050.	2142.	1700.	1500.	1200.	1200.	13750.	30160.	23310.	20540.	19800.	10384.1
9	8212.	3954.	3264.	1965.	1307.	1148.	1533.	12900.	25700.	22880.	22540.	7550.	9476.4
10	4811.	2150.	1513.	1448.	1307.	980.	1250.	15990.	23320.	25000.	31180.	16920.	10559.9
11	6558.	2850.	2200.	1845.	1452.	1197.	1300.	15780.	15530.	22980.	23590.	20510.	9712.3
12	7794.	3000.	2694.	2452.	1754.	1810.	2650.	17360.	29450.	24570.	22100.	13370.	10809.3
13	5916.	2700.	2100.	1900.	1500.	1400.	1700.	12590.	43270.	25850.	23550.	15890.	11565.2
14	6723.	2800.	2000.	1600.	1500.	1000.	830.	19030.	26000.	34400.	23670.	12320.	11072.9
15	6449.	2250.	1494.	1048.	966.	713.	745.	4307.	50580.	22950.	16440.	9571.	9799.6
16	6291.	2799.	1211.	960.	860.	900.	1360.	12990.	25720.	27840.	21120.	19350.	10168.8
17	7205.	2098.	1631.	1400.	1300.	1300.	1775.	9645.	32950.	19860.	21830.	11750.	9431.8
18	4163.	1600.	1500.	1500.	1400.	1200.	1167.	15480.	29510.	26800.	32620.	16870.	11218.5
19	4900.	2353.	2055.	1981.	1900.	1900.	1910.	16180.	31550.	26420.	17170.	8816.	9810.6
20	4272.	1906.	1330.	1086.	922.	833.	1022.	9852.	20523.	18093.	16322.	9776.	7200.1
21	3124.	1215.	866.	824.	768.	776.	1080.	11380.	18630.	22660.	19980.	9121.	7591.2
22	5288.	3407.	2290.	1442.	1036.	950.	1082.	3745.	32930.	23950.	31910.	14440.	10251.0
23	5847.	3093.	2510.	2239.	2028.	1823.	1710.	21890.	34430.	22770.	19290.	12400.	10885.5
24	4826.	2253.	1465.	1200.	1200.	1000.	1027.	8235.	27800.	18250.	20290.	9074.	8086.2
25	3733.	1523.	1034.	874.	777.	724.	992.	16180.	17870.	18800.	16220.	12250.	7631.0
26	3739.	1700.	1603.	1516.	1471.	1400.	1593.	15350.	32310.	27720.	18090.	16310.	10275.4
27	7739.	1993.	1081.	974.	950.	900.	1373.	12620.	24380.	18940.	19800.	6881.	8189.3
28	3874.	2650.	2403.	1829.	1618.	1500.	1680.	12680.	37970.	22870.	19240.	12640.	10109.0
29	7571.	3525.	2589.	2029.	1668.	1605.	1702.	11950.	19050.	21020.	16390.	8607.	8194.5
30	4907.	2535.	1681.	1397.	1286.	1200.	1450.	13870.	24690.	28880.	20460.	10770.	9489.3
31	7311.	4192.	2416.	1748.	1466.	1400.	1670.	12060.	29080.	32660.	20960.	13280.	10747.7
32	7725.	3986.	1773.	1454.	1236.	1114.	1368.	13317.	18143.	32000.	38538.	13171.	11255.3
MAX	8212.	4192.	3264.	2452.	2028.	1900.	2650.	21890.	50580.	34400.	38538.	21240.	11565.2
MIN	3124.	1215.	866.	824.	768.	713.	745.	3745.	15530.	18093.	16220.	6881.	7200.1
MEAN	5771.	2577.	1807.	1474.	1249.	1124.	1362.	13240.	27815.	24445.	22228.	13321.	9753.3

TABLE E.2.9: SUNSHINE PRE-PROJECT MONTHLY FLOW (CFS) MODIFIED HYDROLOGY

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1	14003.	5639.	3611.	2748.	2276.	2033.	2311.	22418.	45613.	59179.	54849.	27734.	20347.1
2	12226.	4712.	3804.	2930.	2435.	2144.	3563.	42196.	58872.	69474.	58356.	51069.	26136.1
3	13713.	5702.	3782.	3470.	2511.	2282.	2357.	11258.	68738.	64937.	53363.	32057.	22117.5
4	17394.	7199.	4080.	2818.	2343.	2317.	4292.	50302.	64075.	54231.	49954.	33737.	24544.3
5	13227.	5092.	3977.	3667.	2889.	2423.	3204.	32595.	54805.	53386.	57701.	28376.	21921.8
6	12188.	6340.	4313.	3927.	3189.	2577.	2658.	21758.	69686.	70894.	77692.	35385.	26041.6
7	11011.	4367.	3161.	2612.	2286.	2209.	2244.	33157.	73941.	80569.	69034.	44495.	27588.4
8	15252.	7029.	4907.	4006.	3471.	2844.	2907.	34140.	79153.	62302.	53243.	48121.	26550.7
9	18399.	9032.	6139.	4067.	2996.	2643.	3399.	27759.	60752.	59850.	56902.	20098.	22824.2
10	11578.	5331.	3592.	3387.	3059.	2280.	2895.	29460.	64286.	67521.	71948.	36915.	25345.8
11	15131.	6415.	4823.	4059.	3201.	2675.	2928.	34802.	39311.	58224.	55315.	43086.	22651.3
12	16996.	6109.	5504.	4739.	3478.	3480.	5109.	32438.	60886.	63640.	60616.	36071.	25075.2
13	14579.	6657.	4820.	4222.	3342.	2975.	3581.	24520.	87537.	67756.	61181.	38711.	26766.6
14	13956.	6052.	4690.	4074.	3621.	2399.	2025.	35245.	56629.	78219.	52938.	29182.	24260.8
15	18555.	5907.	3533.	2797.	2447.	2013.	2381.	8645.	111073.	58836.	46374.	23267.	23864.9
16	15473.	7472.	4536.	3373.	2962.	2818.	3435.	24597.	58488.	65042.	56375.	53703.	24971.3
17	18208.	5321.	3965.	3404.	3009.	2875.	3598.	16479.	69569.	55243.	62007.	30156.	22934.7
18	11551.	4295.	3856.	3698.	3294.	2793.	2639.	32912.	66162.	77125.	82747.	37379.	27566.1
19	10706.	5413.	4563.	4181.	3986.	3898.	4359.	36961.	76770.	69735.	46730.	20885.	24149.1
20	10524.	4481.	3228.	2689.	1731.	2022.	2442.	21306.	49349.	48565.	42970.	24832.	17950.7
21	9416.	3978.	2848.	2600.	2448.	2382.	3150.	25687.	47602.	60771.	54926.	27191.	20393.7
22	12264.	7467.	4930.	3325.	2514.	2351.	2640.	10652.	76208.	64787.	74519.	32402.	24629.0
23	14313.	6745.	4922.	4257.	3801.	3335.	3210.	36180.	66856.	62292.	51254.	34156.	24407.1
24	13588.	6018.	4030.	3312.	2984.	2646.	2821.	18215.	59933.	51711.	51085.	25238.	20235.8
25	11284.	4699.	3524.	2882.	2519.	2220.	2916.	31486.	43713.	51267.	43222.	29114.	19195.1
26	12302.	4938.	3777.	3546.	2990.	2810.	3160.	29380.	72836.	75692.	51678.	35567.	25023.2
27	15565.	4238.	2734.	2507.	2355.	2281.	3294.	22875.	56366.	55506.	52155.	18502.	20000.7
28	10620.	5888.	5285.	4231.	3640.	3171.	3537.	27292.	87773.	62194.	55157.	32719.	25221.6
29	17399.	7130.	5313.	4213.	3227.	3002.	3542.	22707.	48044.	57930.	42118.	22742.	19910.2
30	11223.	5648.	4308.	3674.	3206.	2963.	3704.	33876.	59849.	71774.	48897.	26790.	23144.3
31	17688.	9400.	5189.	4218.	3699.	3519.	4627.	26907.	65084.	84273.	50624.	27835.	25416.2
32	16580.	8195.	4805.	4433.	4057.	3412.	4292.	36160.	50890.	85600.	84940.	32460.	28226.1
MAX	18555.	9400.	6139.	4739.	4057.	3898.	5109.	50302.	111073.	85600.	84940.	53703.	28226.1
MIN	9416.	3978.	2734.	2507.	1731.	2013.	2025.	8645.	39311.	48565.	42118.	18502.	17950.7
MEAN	13966.	6028.	4267.	3565.	2999.	2681.	3226.	27949.	64089.	64641.	57215.	32499.	23731.6

TABLE E.2.10: SUSITNA PRE-PROJECT MONTHLY FLOW (CFS) MODIFIED HYDROLOGY

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1	26869.	11367.	6197.	6072.	5256.	5377.	5657.	66294.	101616.	124890.	106432.	39331.	42444.7
2	18026.	6933.	5981.	7074.	7295.	6382.	7354.	59273.	82255.	123164.	100947.	73471.	41783.1
3	31053.	16364.	6989.	8274.	7036.	5853.	5985.	45294.	132547.	137322.	116186.	82076.	49825.4
4	44952.	16289.	9746.	8069.	6775.	6350.	7993.	88840.	130561.	125949.	97610.	44168.	49279.5
5	20169.	11829.	5272.	7202.	4993.	4980.	6306.	58516.	108881.	116732.	128587.	66275.	45270.4
6	23896.	9168.	6183.	7255.	5845.	5316.	6412.	58164.	169045.	148877.	120120.	53504.	51429.1
7	19923.	10522.	7295.	6179.	6831.	6324.	7182.	82486.	161346.	168815.	131620.	104218.	59701.9
8	41822.	21548.	14146.	10600.	8356.	7353.	7705.	63204.	176219.	140318.	124813.	87825.	58911.9
9	52636.	19887.	10635.	7553.	6387.	6679.	8099.	70321.	112897.	122280.	99609.	53053.	47830.1
10	30543.	9528.	4763.	7795.	6564.	5666.	6468.	56601.	110602.	146217.	138334.	67904.	49606.5
11	25754.	10165.	7005.	6716.	6310.	5651.	5830.	50062.	84134.	129403.	113972.	81565.	44172.5
12	33782.	12914.	13768.	12669.	10034.	9193.	9803.	85457.	151715.	138969.	116697.	62504.	55111.2
13	29029.	13043.	8977.	9050.	6183.	5951.	6635.	54554.	163049.	143441.	121221.	74806.	53254.8
14	27716.	10755.	8865.	8671.	7854.	6058.	5565.	53903.	85648.	146420.	106707.	70782.	45235.4
15	37846.	11702.	5626.	6351.	5762.	4910.	5531.	35536.	153126.	124806.	92280.	46110.	44338.1
16	28747.	10458.	6127.	6952.	6196.	6170.	7120.	49485.	110075.	138407.	111846.	89944.	47893.5
17	36553.	12313.	9159.	8031.	7489.	7091.	8048.	52311.	125183.	117607.	118729.	63887.	47470.1
18	26396.	12963.	8322.	8029.	7726.	6683.	7281.	58107.	134881.	136306.	137318.	89527.	53073.6
19	37725.	15873.	15081.	11604.	11532.	8772.	8763.	94143.	137867.	130514.	86875.	42385.	50399.0
20	26323.	11086.	7195.	6924.	6164.	5535.	6112.	52954.	108336.	115548.	97076.	57772.	41999.8
21	22683.	6799.	5016.	6074.	5581.	5732.	5769.	53036.	94612.	132985.	117728.	80585.	45014.0
22	32817.	16607.	8633.	6509.	6254.	5883.	5788.	29809.	122258.	139183.	133310.	69021.	48289.9
23	32763.	14922.	8791.	9380.	8458.	6646.	6895.	74062.	176024.	142787.	107597.	60220.	54305.3
24	26782.	14853.	8147.	7609.	7477.	6313.	7688.	64534.	122797.	123362.	107261.	45227.	45453.5
25	20976.	10113.	6081.	7402.	6747.	6294.	6963.	61458.	67838.	102184.	80252.	56124.	36285.1
26	19520.	10400.	9419.	8597.	7804.	7048.	6867.	47540.	128800.	135700.	91360.	77740.	46102.6
27	31550.	9933.	6000.	6529.	5614.	5368.	7253.	70460.	107000.	115200.	99650.	48910.	43089.2
28	30140.	18270.	13100.	10100.	8911.	6774.	6233.	56180.	165900.	143900.	125500.	83810.	55979.3
29	38230.	12630.	7529.	6974.	6771.	6590.	7033.	48670.	90930.	117600.	102100.	55500.	42002.4
30	36810.	15000.	9306.	8823.	7946.	7032.	8683.	81260.	119900.	142500.	128200.	74340.	53676.8
31	58640.	31590.	14690.	10120.	9017.	8906.	12030.	66580.	142900.	181400.	126400.	91200.	63158.6
32	34970.	16200.	8516.	7774.	7589.	6177.	10350.	83580.	108700.	152800.	159600.	67170.	55728.8
MAX	58640.	31590.	15081.	12669.	11532.	9193.	12030.	94143.	176219.	181400.	159600.	104218.	63158.6
MIN	18026.	6799.	4763.	6072.	4993.	4910.	5531.	29809.	67838.	102184.	80252.	39331.	36285.1
MEAN	31426.	13501.	8517.	8030.	7149.	6408.	7231.	61646.	124614.	134550.	113935.	67530.	49003.6

TABLE E.2.11: INSTANTANEOUS PEAK FLOWS OF RECORD

Denali		Cantwell		Gold Creek		Maclaren	
Date	Flows (cfs)	Date	Flow (cfs)	Date	Flow (cfs)	Date	Flow (cfs)
8/10/71	38,200	8/10/71	55,000[2]	6/7/64	90,700	8/11/71	9,260
8/14-15/67	28,200	6/8/64	51,200	8/10/71	87,400	9/13/60	8,920
7/28/80	24,300	6/15/62[3]	46,800	6/17/72	82,600	8/14/67	7,460
8/4/76	22,100	6/17/72	44,700	6/15/62	80,600	7/18/63	7,300
8/9-10/81	22,000[1]	8/14/67	38,800	8/15/67	80,200	6/16/72	7,070
7/12/75	21,700	7/18/63	32,000[4]	6/6/66	63,600	6/14/62	6,540
7/27/68	19,000	8/14/81	30,500[1]	8/25/59	62,300	8/5/61	6,540

Notes: [1] Maximum daily flow from preliminary USGS data.
[2] Estimated maximum daily flow based on discharge records at Denali and Gold Creek.
[3] Approximate date.
[4] Maximum daily flow.

Source: USGS

TABLE E.2.12: DISTRIBUTION STATIST

Gage Station	River	N	Gumbel 1 CS	CK	Sum of Deviations	Mean Deviation	Log Normal CSL	CKL	Sum of Deviations	Mean Deviation
Denali	Susitna	20	2.4985	10.3480	-49.50	12.95	1.8453	7.0725	-33.19*	11.21
Cantwell	Susitna	11	0.3325	3.1348	-0.90*	6.46	-0.1474	3.2888	1.15	5.85*
Gold Creek	Susitna	25	0.6830	2.9269	-22.90	5.16	0.0664*	2.8362	-10.28	4.23
Maclaren	Maclaren	22	0.9062	3.4430	-15.76	7.16	0.5539	2.6682*	-8.75	6.14
Chulitna	Chulitna	18	2.9054	13.7449	-33.82	10.15	2.0599	10.0328	-23.88*	10.58
Talkeetna	Talkeetna	15	1.8140	6.6111	-1.99	8.16	1.0398	4.7599	5.88	8.80

Notes: N = record length in years
CS = coefficient of skewness of natural data
CK = coefficient of kurtosis of natural data
CSL = coefficient of skewness of the natural logs of the data
CKL = coefficient of kurtosis of the natural logs of the data
CSLA = coefficient of skewness of the natural logs of the transformed data
CKLA = coefficient of kurtosis of the natural logs of the transformed data

Avg. CV = average coeffi
Sum of Deviations = < Q
Mean Deviation = <| $\overline{Q}$ -
Q = measured flow
Q_D = mean flow
* = Distribution best fi

Theoretical Values -

Gumbel 1

CS = 1.14
CK = 5.4

Log Norma

CSL = 0.0
CKL = 3.0

Source: R&M 1981f

ICS FOR ANNUAL INSTANTEOUS PEAK FLOWS

		3 Parameter Log Normal			Log Person Type III (Moments)			Log Pearson Type III (Maximum Likelihood)		
CSLA	CKLA	Avg. CV	Sum of Deviations	Mean Deviation	Avg. CV	Sum of Deviations	Mean Deviation	Avg. CV	Sum of Deviations	Mean Deviation
0.0633*	4.2263*	23.59*	38.16	8.39*	35.46	-38.81	8.39*	No Solution		
-0.1172*	3.2667*	18.79*	1.32	6.01	19.01	1.92	6.21	Upper Boundary is Too Low		
-0.0805	2.9658*	15.01*	-18.09*	4.11*	15.39	-19.01	3.97	15.51	-20.67	5.38
-0.3915*	2.6563	25.66	8.93	3.99*	15.93*	-8.18*	4.90	No Solution		
0.3512*	6.8509*	14.05	-27.36	9.21*	Lower Boundary is Too High			12.85*	-29.93	9.45
-0.0921*	4.0752*	30.54*	-0.74*	5.27	40.08	-3.38	5.65	32.65	-5.43	1.92*

cient of variation for all return periods estimated
- Q_D/Q_D for 1.25, 2, 5, 10, and 20 year return periods
$Q_D|$ /5 for 1.25, 2, 5, 10 and 20 year return periods

tting a given parameter

I 3 Parameter Log Normal

CSLA = 0.0
CKLA = 3.0

TABLE E.2.13: COMPARISON OF SUSITNA REGIONAL FLOOD PEAK ESTIMATES WITH USGS METHODS FOR GOLD CREEK

Station Location	Return Period (Yrs.)	Single[1] Station Estimate (cfs)	Susitna Regional Estimate (cfs)	USGS[2] Area II Regional Estimate (cfs)	USGS[3] Cook Inlet Regional Estimate (cfs)
Susitna River at Gold Creek	1.25	37,100	37,700	48,700	-
	2	49,500	49,000	59,200	43,800
	5	67,000	64,200	73,000	53,400
	10	79,000	74,500	83,400	55,300
	50	106,000	100,000	104,000	71,600
	100	118,000	110,000	115,000	

Notes:

1 Based on three parameter log normal distribution and shown to three significant figures.

2 Lamke, R.D., 1970. Flood Characteristics of Alaskan Streams, USGS, Water Resources Investigation, 78-129.

3 Freethey, G.W., and D.R. Scully, 1980. Water Resources of the Cook Inlet Basin, Alaska, USGS, Hydrological Investigations Atlas HA-620.

Source: R&M 1981f

TABLE E.2.14: HEC 2 WATER SURFACE ELEVATIONS (feet)

Deadman Creek to Devil Creek for Select Watana Flows

River Mile	8100 cfs	17200 cfs	26700 cfs	30700 cfs	42200 cfs	46400 cfs
162.1	1211.2	1213.5	1215.7	1216.5	1218.4	1219.3
167.0	1276.3	1278.7	1279.9	1280.6	1281.4	1281.3
173.1	1330.8	1333.0	1334.9	1335.7	1337.3	1337.9
174.0	1340.0	1342.8	1344.2	1345.0	1346.0	1346.2
176.0	1363.9	1366.5	1367.9	1368.5	1369.5	1369.8
176.7	1370.8	1373.5	1375.1	1375.9	1377.3	1377.6
178.8	1391.6	1394.3	1396.3	1397.2	1398.8	1399.2
180.1	1410.6	1412.1	1412.9	1413.4	1414.2	1414.6
181.0	1414.4	1416.5	1417.8	1418.3	1419.2	1419.4
181.8	1428.8	1432.0	1434.2	1435.1	1436.6	1436.8
182.1	1435.3	1437.9	1439.8	1440.7	1442.4	1442.8
182.5	1440.7	1442.4	1443.8	1444.5	1445.7	1446.0
182.8	1443.7	1445.6	1446.8	1447.4	1448.3	1448.5
183.5	1449.8	1452.2	1453.8	1454.5	1455.7	1456.0
183.8	1451.6	1454.1	1455.8	1456.5	1457.8	1458.0
184.0	1453.5	1456.3	1458.1	1458.9	1460.3	1460.6
184.2	1454.6	1457.5	1459.4	1460.2	1461.6	1461.8
184.4	1456.2	1459.3	1461.3	1462.3	1464.0	1464.4
184.8	1462.9	1465.9	1467.4	1468.1	1469.1	1469.2
185.4	1473.0	1475.8	1477.4	1478.1	1479.4	1479.7
185.9	1497.3	1497.9	1498.3	1498.5	1498.3	1499.0
186.5	1505.3	1509.0	1510.9	1511.6	1513.5	1513.1
186.8	1510.1	1513.0	1515.0	1515.9	1517.8	1518.2

Source: R&M 1982b

TABLE E.2.15: HEC 2 WATER SURFACE ELEVATIONS (feet)

Devil Canyon to Talkeetna for Select Gold Creek Flows

River Mile	9700 cfs	13400 cfs	17000 cfs	23400 cfs	34500 cfs	52000 cfs
98.6	344.0	344.5	345.5	346.5	348.0	348.5
99.6	348.6	350.1	350.8	352.3	353.1	355.1
100.4	359.2	359.4	359.7	359.9	360.7	362.0
101.0	362.7	363.4	363.8	364.5	365.3	366.8
101.5	366.6	367.2	367.6	368.4	369.2	370.8
102.4	373.0	373.9	374.5	375.6	376.7	378.4
103.2	378.1	379.4	380.3	381.8	383.4	386.2
104.8	391.5	392.5	393.2	394.2	395.5	397.8
106.7	409.9	410.6	411.2	412.0	413.1	415.1
108.4	421.6	422.8	423.6	424.8	426.4	429.2
110.4	437.6	438.8	439.6	440.8	442.6	445.9
110.9	443.8	444.7	445.4	446.3	447.8	450.6
111.8	452.5	453.2	453.8	454.8	455.7	458.0
112.3	455.7	456.6	457.2	458.3	459.4	461.6
112.7	459.4	460.1	460.5	461.4	462.3	464.0
113.0	461.3	462.1	462.7	463.8	464.9	466.6
116.4	485.6	486.6	487.4	489.0	490.7	493.5
117.2	495.5	496.2	496.7	497.8	499.0	501.1
119.2	510.0	511.2	512.0	513.4	514.9	516.5
119.3	511.6	512.5	513.3	514.5	515.9	517.5
120.3	520.0	520.4	520.8	521.8	522.6	524.5
120.7	521.7	522.6	523.3	524.3	525.4	527.2
121.6	530.6	530.9	531.1	532.7	533.4	534.8
122.6	538.5	539.4	539.9	541.5	542.8	544.6
123.3	542.9	543.7	544.4	545.7	547.1	549.4
124.4	555.2	555.8	556.3	557.1	558.2	560.1
126.1	571.0	571.7	572.3	573.3	574.2	575.8
127.5	585.3	585.9	586.4	587.3	588.1	589.4
128.7	595.0	595.9	596.5	597.6	598.4	599.7
129.7	605.2	606.0	606.7	607.8	608.9	610.8
130.1	612.9	613.7	614.1	614.2	615.0	616.1
130.5	616.0	616.9	617.4	618.0	619.0	620.4
130.9	617.7	618.7	619.4	620.3	621.6	623.3
131.2	619.5	620.5	621.3	622.7	624.2	626.6
131.8	627.1	627.6	628.0	628.9	629.4	630.4
132.9	639.0	639.9	640.6	641.8	643.4	645.6
133.3	645.8	646.3	646.6	647.5	648.2	649.7
134.3	655.1	655.9	656.5	657.5	658.6	660.4
134.7	659.9	660.6	661.2	662.3	663.6	665.7
135.4	668.9	669.4	669.8	670.4	671.1	672.4
135.7	671.2	672.1	672.7	674.1	675.4	677.1
136.4	681.2	682.2	683.0	684.1	685.3	687.3
136.7	684.0	685.1	685.8	687.0	688.1	689.9
137.0	687.1	688.2	688.9	690.5	692.0	694.9
137.2	690.6	691.6	692.3	693.2	694.6	697.0
137.4	693.1	694.1	694.9	695.7	697.2	699.5
138.2	702.0	702.9	703.6	704.5	705.4	706.9
138.5	703.7	704.7	705.5	706.7	707.8	709.7
138.9	707.2	708.1	708.9	710.3	711.7	714.3
139.4	716.8	717.4	717.8	718.3	719.1	720.7
140.2	723.6	724.5	725.2	726.3	727.3	728.9
140.8	733.2	734.1	734.8	736.0	737.4	739.9
141.5	744.0	744.8	745.4	746.2	747.2	749.0
142.1	752.2	753.2	753.9	755.4	756.7	758.7
142.3	754.4	755.3	756.1	757.6	759.0	761.3
143.2	763.9	764.7	765.2	766.2	767.5	769.9
144.8	786.0	787.1	788.0	789.4	790.9	793.3
147.6	818.8	819.9	820.7	822.1	823.8	827.0
148.7	832.9	834.3	835.3	836.6	838.6	841.7
148.9	835.1	836.4	837.5	838.8	840.9	844.2
149.2	837.5	838.8	839.8	841.1	843.1	846.5
149.3	839.6	840.9	841.9	843.3	845.3	848.9
149.4	841.5	842.6	843.5	844.7	846.9	850.5
149.5	844.3	845.1	845.8	846.8	848.4	851.3
149.8	848.4	849.4	850.1	851.1	852.4	854.6
150.2	850.6	851.9	852.8	854.0	855.8	858.7

Source: R&M 1982b

TABLE E.2.16: DETECTION LIMITS AND CRITERIA FOR WATER QUALITY PARAMETERS

Parameters[1]	R&M Detection Limit	USGS Detection Limit[4]	Criteria Levels
Temperature, °C	0.1	--	20,15(M),13(Sp)
Total Suspended Sediments[2]	1	1	no measurable increase
Turbidity (NTU)	0.05	1	25 NTU increase
Dissolved Oxygen	0.1	--	7 and 17
D.O. Percent Saturation	1	--	110
Nitrate Nitrogen	0.1	0.01	10
Total Phosphorus	0.01	0.01	0.01
Ortho-Phosphate	0.01	0.01	--
Total Dissolved Solids[3]	1	1	1,500
Conductivity, umhos/cm @ 25°C	1	--	--
Significant Ions			
Sulfate	1	0.05	200
Chloride	0.2	0.01	200
Ca, Calcium	0.05	0.01	--
Mg, Magnesium	0.05	0.1	--
Na, Sodium	0.05	0.1	--
K, Potassium	0.05	0.1	--
Total Hardness	1	--	--
pH, pH Units	$\pm$ 0.01	--	6.5 - 9.0
Total Alkalinity, as $CaCO_3$	2	--	20
Free Carbon Dioxide	1	--	--
Chemical Oxygen Demand	1	--	--
Total Organic Carbon	1.0	--	3.0 (S)
True Color, Platinum Cobalt Units	1	1	50
Metals			
Ag, Silver	0.05	0.001	0.05
Al, Aluminum	0.05	0.01	0.073 (S)
As, Arsenic	0.10	0.001	0.440
Au, Gold	0.05	--	--
B, Boron	0.05	0.01	0.043
Ba, Barium	0.05	0.1	1.0
Bi, Bismuth	0.05	--	0.0035 (S)
Cd, Cadmium	0.01	0.001	0.0012, 0.0004
Co, Cobalt	0.05	0.001	--
Cr, Chromium	0.05	0.001	0.1
Cu, Copper	0.05	0.001	0.01
Fe, Iron	0.05	0.01	1.0
Hg, Mercury	0.1	0.0001	0.00005
Mn, Manganese	0.05	0.001	0.05
Mo, Molybdenum	0.05	0.001	0.07
Ni, Nickel	0.05	0.001	0.025
Pb, Lead	0.05	0.001	0.03
Pt, Platinum	0.05	--	--
Sb, Antimony	0.10	0.001	9
Se, Selenium	0.10	0.001	0.01
Si, Silicon	0.05	--	--
Sn, Tin	0.10	0.1	--
Sr, Strontium	0.05	0.01	--
Ti, Titanium	0.05	--	--
W, Tungsten	1.0	--	--
V, Vanadium	0.05	--	0.007 (S)
Zn, Zinc	0.05	0.01	0.03
Zr, Zirconium	0.05	--	--
Organic Chemicals (ug/1)			
- Endrin	0.0002	0.00001	0.004
- Lindane	0.004	0.00001	0.01
- Methoxychlor	0.1	0.00001	0.03
- Toxaphene	0.005	0.001	0.013
- 2, 4-D	0.1	0.00001	100
- 2, 4, 5-TP Silvex	0.01	0.00001	10
Gross Alpha (Picocurie/liter)	3	--	15

TABLE E.2.16 (Cont'd)

Parameters[1]	R&M Detection Limit	USGS Detection Limit[4]	Criteria Levels
Others			
Settleable Solids, ml/l	0.1	---	--
Ammonia Nitrogen	0.05	0.01	0.02
Organic Nitrogen	0.1	--	--
Kheldahl Nitrogen	0.1	0.1	--
Nitrite Nitrogen	0.01	0.01	--
Total Nitrogen	0.1	0.01	--
Total Inorganic Carbon	1.0	--	--

(1) All parameters and values are expressed in mg/l unless otherwise noted.

(2) TSS - (nonfilterable) material on a standard fiber filter after filtration of a well-mixed sample.

(3) TDS - (filterable) material that passes through a standard glass fiber filter and remains after evaporation.

(4) USGS detection limits are taken from "1982 Water Quality Laboratory Services Catalog" USGS Open-File Report 81-1016. The limits used are the limits for the most precise test available.

(M) - Migration Routes

(Sp) - Spawning Areas

(S) - Suggested Criteria

Source: USGS and RM

TABLE E.2.17: PARAMETERS EXCEEDING CRITERIA BY STATION AND SEASON

Parameter	Station	Season	Criteria
D.O. % Saturation	G	S	L
Phosphorus, Total (d)	V, G, T, S, SS	S, W, B	E
pH	T	S	L
	V, S	W	
	G, T	B	
Total Organic Carbon	G, SS	S	S
	V, G, SS	W	
	SS	B	
True Color	V, G, T, S	S	L
Aluminum (d)	V, G	S, W	S
Aluminum (t)	G, T, S	S	S
Bismuth (d)	V, G	S	S
	G	W	
Cadmium (d)	G, T, SS	S	E
Cadmium (t)	G, T, S, SS	S	E
	T, SS	W	
Copper (d)	SS	S	A
	T	W	
	T, SS	B	
Copper (t)	G, T, S, SS	S	A
	T, SS	W, B	
Iron (t)	G, T, S, SS	S	E
	T, SS	B	
Lead (t)	G, T, S, SS	S	A
	SS	B	
Manganese (d)	G,	S	E
Manganese (t)	G, T, S, SS	S	E
	T, SS	B	
Mercury (d)	G, T, S, SS	S	E
	T, S	W	
Mercury (t)	G, T, S, SS	S	E
	T, S, SS	W	
	T, SS	B	
Nickel (t)	G, S, SS	S	A
Zinc (d)	S	W	A
	T	B	
Zinc (t)	G, T, S, SS	S	A
	T, SS	W, B	

Notes:

Parameter

(d) dissolved
(t) total recoverable

Stations

D - Denali
V - Vee Canyon
G - Gold Creek
C - Chulitna
T - Talkeetna
S - Sunshine
SS - Susitna Station

Seasons

S - Summer
W - Winter
B - Breakup

Criteria

L - Established by law as per Alaska Water Quality Standards, 1979.

E - Established by law as per EPA Quality Criteria for Water, 1976.

S - Criteria that have been suggested but are not law, or levels which natural waters usually do not exceed.

A - Alternate level to 0.01 of the 96-hour LC_{50} determined through bioassay (EPA 1976).

Source: USGS AND R&M

TABLE E.2.18: LOCATION OF OPEN LEADS OBSERVED BETWEEN PORTAGE CREEK AND TALKEETNA DURING MID-WINTER 1982

	Location	River Mile
1.	Slough 21	142.0
2.	Slough 19	139.8
3.	East Bank	139.5
4.	West Bank	138.8
5.	Mouth of Indian River	138.6
6.	Side Channel on East Side	137.2
7.	Side Channel	136.3
8.	Slough 11	135.7
9.	Side Channel on East Side	135.0
10.	Mouth of Slough 10	133.8
11.	Braided Segment on West Side	131.3
12.	Side Channel on East Side	130.2
13.	Slough 9A	129.4
14.	Slough 9	128.7
15.	Slough 8A	125.5
16.	Side Channel through Islands	125.0
17.	Slough 8B	122.5
18.	Curry Slough	119.7
19.	Side Channel on West Bank	119.4
20.	Island Complex	117.2
21.	Side Channel between Islands	115.0
22.	Lane Creek Slough	113.8
23.	Side Channel (near Gash Creek outflow)	111.3

Source: Trihey personal communication 1983

TABLE E.2.19: 1981 BEDLOAD TRANSPORT DATA SUSITNA RIVER BASIN

Station	Date	Water Discharge (cfs)	Total Bedload Transport Rate (tons/day)
Susitna River at Gold Creek	7/22/81	37,200	2,180
Chulitna River[1]	7/22/81	31,900	3,450
Talkeetna River	7/21/81	16,800	1,940
Susitna River at Sunshine	7/22/81	89,000	3,520
Susitna River at Gold Creek	8/26/81	25,900	380
Chulitna River	8/25/81	22,500	5,000
Talkeetna River	8/25/81	9,900	800
Susitna River at Sunshine	8/26/81	61,900	4,520
Susitna River at Gold Creek	9/28/81	8,540	1
Chulitna River	9/29/81	6,000	3,820
Talkeetna River	9/29/81	2,910	30
Susitna River at Sunshine	9/30/81	19,100	400

Note: 1. Bedload data gathered approximately 4 miles below Chulitna River gaging site on 7/22/81. Data gathered at Chulitna gaging site on other dates.

Source: R&M 1982d

TABLE E.2.20: SUSPENDED S
MAY TO SEPT

	May			June			July	
		Suspended Sediment			Suspended Sediment			Sus
Day	Mean Discharge (cfs)	Mean Concentration (mg/l)	Tons Per Day	Mean Discharge (cfs)	Mean Concentration (mg/l)	Tons Per Day	Mean Discharge (cfs)	Mean Conce (mg/l
1	1,100	9	27	25,000	1,730	117,000	33,000	1,3
2	1,200	13	a42	23,500	2,030	129,000	31,100	1,2
3	1,300	17	60	27,500	2,200	a163,000	29,500	5
4	1,400	18	a68	29,000	1,800	a141,000	27,800	5
5	1,500	19	a77	26,500	1,300	a93,000	25,900	6
6	1,600	19	82	22,500	940	a57,100	23,600	6
7	1,600	20	a86	24,400	1,000	a65,900	22,500	5
8	1,600	21	a91	22,300	950	a57,200	21,100	6
9	1,500	22	a89	21,500	730	a42,400	19,700	5
10	1,400	23	87	26,800	495	35,800	18,900	4
11	1,400	20	a76	37,300	249	25,100	17,700	6
12	1,500	18	a73	36,700	189	18,700	17,200	1,0
13	1,600	18	78	34,000	290	26,600	19,500	1,1
14	1,700	15	69	31,400	464	39,300	23,300	1,1
15	1,900	12	62	37,400	493	49,800	25,000	1,1
16	2,100	12	a68	42,400	562	64,300	25,400	9
17	2,200	15	a89	43,300	936	109,000	25,700	7
18	2,400	17	a110	41,300	885	98,700	25,400	8
19	2,600	19	133	40,200	256	27,800	25,200	9
20	2,800	30	a227	36,300	241	23,600	24,700	1,1
21	3,000	50	a405	35,400	232	22,200	24,200	1,0
22	3,400	80	734	35,600	212	20,400	23,700	8
23	3,700	270	a2,700	34,700	203	19,000	24,700	9
24	4,500	549	6,670	34,300	213	19,700	25,900	8
25	6,000	828	13,400	34,100	184	16,900	27,400	9
26	8,000	1,120	24,200	33,600	278	25,200	28,900	9
27	10,000	1,270	34,300	34,300	1,040	96,300	28,400	8
28	15,000	747	30,300	33,000	1,220	109,000	31,300	9
29	25,000	450	30,400	33,400	1,220	110,000	38,300	1,1
30	28,000	540	40,800	33,400	1,270	115,000	41,300	1,3
31	27,000	1,670	122,000	--	--	--	41,700	1,3
TOTAL..	168,000	--	307,603	971,100	--	1,938,000	818,000	

Total discharge for period (cfs-days) ....

Total load for period (tons) ....

Note:

[a] Computed from estimated concentration graph.

Source: USGS

EDIMENT AT GOLD CREEK
EMBER 1952

		August			September		
pended Sediment			Suspended Sediment			Suspended Sediment	
ntration)	Tons Per Day	Mean Discharge (cfs)	Mean Concentration (mg/l)	Tons Per Day	Mean Discharge (cfs)	Mean Concentration (mg/l)	Tons Per Day
00	116,000	41,900	1,390	157,000	30,000	870	a70,500
20	102,000	38,300	981	101,000	28,700	772	59,800
62	44,800	32,100	826	71,600	24,500	682	45,100
44	40,880	27,100	900	65,900	21,400	602	34,800
95	48,600	24,500	900	59,500	18,000	560	a27,200
70	42,700	23,500	909	57,700	14,800	520	20,800
60	34,000	23,600	860	54,800	12,900	420	a14,600
87	39,100	24,700	828	55,200	11,900	270	a8,680
95	31,600	25,600	824	57,000	12,400	130	4,350
29	21,900	26,200	873	61,800	12,700	70	a2,400
62	31,600	27,400	836	61,800	13,500	54	1,970
30	47,800	24,400	1,150	75,800	14,200	50	a1,920
90	62,700	22,400	2,190	132,000	13,500	50	a1,820
40	71,700	20,400	2,100	a116,000	12,300	50	a1,660
50	77,600	19,800	1,580	a84,500	10,800	50	a1,460
09	62,300	18,700	1,200	a60,600	10,200	58	1,600
56	52,500	16,500	960	a42,800	10,500	65	1,840
60	a59,000	15,600	650	27,400	10,000	70	a1,890
90	a67,400	14,800	531	21,200	9,500	70	a1,800
30	75,400	14,400	639	24,800	10,000	70	a1,890
80	70,600	14,800	554	22,100	11,300	70	a2,140
37	53,600	15,100	414	16,900	15,700	73	3,090
18	61,200	15,300	435	18,000	15,400	76	3,160
73	61,000	15,200	531	21,800	14,800	90	3,600
72	71,900	15,000	377	15,300	13,800	90	3,350
72	75,800	15,000	275	11,100	12,900	99	3,450
88	68,100	14,200	293	11,200	12,300	110	3,650
27	78,300	13,500	410	a14,900	12,000	89	2,880
20	116,000	13,600	568	20,900	12,000	81	2,620
10	146,000	15,000	720	a29,200	12,400	68	2,280
60	153,000	20,000	860	a46,400	--	--	--
--	2,085,000	648,600	--	1,616,200	434,400	--	336,300
....							3,067,700
....							6,284,363

TABLE E.2.21: 1982 TURBIDITY AND SUSPENDED SEDIMENT ANALYSIS

Location	Date Sampled	Date Analyzed	Turbidity[2] (NTU)	Suspended[3] Sediment Concentration (mg/l)	Discharge (cfs)
Susitna River at Vee Canyon (RM 223)	6/4/82	6/11/82	82	--	--
	6/30/82	8/3/82	384	--	--
	7/27/82	8/18/82	720	--	--
	8/26/82	9/14/82	320	--	--
Susitna River near Chase[4] (RM 103)	6/3/82	6/11/82	140	769	35,800
	6/8/82	6/24/82	130	547	44,400
	6/15/82	6/24/82	94	170	24,200
	6/22/82	8/3/82	74	426	37,000
	6/30/82	8/18/82	376	392	30,200
	7/8/82	8/18/82	132	156	20,700
	7/14/82	8/3/82	728	729	30,800
	7/21/82	8/18/82	316	232	24,900
	7/28/82	8/18/82	300	464	30,800
	8/4/82	8/18/82	352	377	22,700
	8/10/82	8/26/82	364	282	20,000
	8/18/82	8/26/82	304	275	17,700
	8/25/82	9/14/82	244	221	16,800
	8/31/82	9/14/82	188	252	19,300
	9/19/82	10/12/82	328	439	28,700
Susitna River at Cross Section LRX-4[1,4] (RM 99)	5/26/82	5/29/82	81	--	--
Susitna River below Talkeetna[1,5] (approximately RM 91)	5/26/82	5/29/82	98	--	--
	5/28/82	6/2/82	256	--	43,600
	5/29/82	6/2/82	140	--	42,900
	5/30/82	6/2/82	65	--	38,400
	5/31/82	6/2/82	130	--	39,200
	6/1/82	6/2/82	130	--	47,000
Susitna River at Sunshine-Parks Highway Bridge[5] (RM83)	6/3/82	6/11/82	164	847	71,000
	6/10/82	6/24/82	200	414	64,500
	6/17/82	6/24/82	136	322	50,800
	6/21/82	8/3/82	360	755	78,300
	6/28/82	8/18/82	1,056	668	75,700
	7/6/82	8/3/82	352	507	46,600
	7/12/82	8/3/82	912	867	59,800
	7/19/82	8/18/82	552	576	60,800
	7/26/82	8/18/82	696	1180	96,800
	8/2/82	8/18/82	544	704	62,400
	8/9/82	8/26/82	720	746	54,000
	8/16/82	8/26/82	784	728	47,800
	8/23/82	9/14/82	552	496	38,600
	8/30/82	9/14/82	292	439	39,800
	9/17/82	10/12/82	784	1290	86,500
Chulitna River[1] (approximately 1 mile above Chulitna-Susitna Confluence)	5/26/82	5/29/82	194	--	--
	5/28/82	6/2/82	272	--	--
	5/29/82	6/2/82	308	--	--
	5/30/82	6/2/82	120	--	--
	5/31/82	6/2/82	360	--	--
	6/1/82	6/2/82	324	--	--

TABLE E.2.21 (Page 2)

Location	Date Sampled	Date Analyzed	Turbidity[2] (NTU)	Suspended[3] Sediment Concentration (mg/l)	Discharge[4] (cfs)
Chulitna River (Canyon)[6] (18 miles above the Chulitna-Susitna Confluence)	6/4/82	6/11/82	272	424	11,500
	6/22/82	8/3/82	680	813	19,500
	6/29/82	8/18/82	1,424	1600	29,000
	7/7/82	8/3/82	976	1030	20,700
	7/13/82	8/18/82	1,136	1200	22,700
	7/20/82	8/18/82	1,392	1250	23,100
	7/27/82	8/18/82	664	1010	31,900
	8/3/82	8/18/82	704	960	23,300
	8/11/82	8/26/82	592	753	21,300
	8/17/82	8/26/82	1,296	1250	21,900
	8/24/82	9/14/82	632	843	18,200
	9/1/82	9/14/82	316	523	17,300
	9/18/82	10/12/82	1,920	1550	29,200
Talkeetna River at Railroad Bridge[1,7] (0.5 miles above Susitna-Talkeetna Confluence)	5/26/82	5/29/82	17	--	5,680
	5/28/82	6/2/82	39	--	6,250
	5/29/82	6/2/82	21	--	5,860
	5/30/82	6/2/82	20	--	5,660
	5/31/82	6/2/82	44	--	7,400
	6/1/82	6/2/82	55	--	9,560
Talkeetna River at USGS Cable[7] (6 miles above Susitna-Talkeetna Confluence)	6/2/82	6/11/82	146	340	17,900
	6/9/82	6/24/82	49	311	14,700
	6/17/82	6/24/82	28	216	11,400
	6/23/82	8/3/82	26	164	12,400
	6/29/82	8/18/82	41	321	10,700
	7/7/82	8/3/82	20	100	6,750
	7/13/82	8/3/82	132	226	8,880
	7/20/82	8/18/82	148	226	8,400
	7/28/82	8/18/82	272	--	14,200
	8/3/82	8/18/82	49	180	8,980
	8/10/82	8/26/82	53	212	6,980
	8/17/82	8/26/82	82	198	6,230
	8/24/82	9/14/82	68	263	5,920
	8/31/82	9/14/82	37	276	9,120
	9/20/82	10/12/82	34	301	14,800

Notes: [1] Samples collected by R&M Consultants. All other samples were collected by USGS.

[2] R&M Consultants conducted all turbidity analysis.

[3] Suspended sediment concentrations are preliminary unpublished data provided by the U.S. Geological Survey (USGS).

[4] Discharges for "Susitna near Chase" and "Susitna at LRX-4" are from provisional USGS stream gage data at the Alaska Railroad Bridge at Gold Creek.

[5] Discharges for "Susitna Below Talkeetna" and "Susitna at Sunshine" are from provisional USGS stream gage data at the Parks Highway Bridge at Sunshine.

[6] Discharges for "Chulitna River (Canyon)" are from provisional USGS stream gage data at the Parks Highway Bridge at Chulitna.

[7] Discharges for "Talkeetna at R.R. Bridge" and "Talkeetna at USGS Cable" are from provisional USGS stream gage data near Talkeetna.

TABLE E.2.22: SUSITNA RIVER AT GOLD CREEK - MONTHLY SUMMARY OF SUSPENDED SEDIMENT, WY 1953

Month	Discharge (cfs-days)	Suspended sediment (tons)
1952		
October	254,260	30,120
November	104,900	2,700
December	52,700	--
1953		
January	34,100	--
March	22,900	--
April	48,450	--
May	597,400	1,053,000
June	819,700	2,248,000
July	626,100	1,965,000
August	638,900	1,819,000
September	458,180	--

Source: USGS

TABLE E.2.23: SIGNIFICANT ION CONCENTRATIONS

	Ranges of Concentrations (mg/l)			
	Upstream of Project[1]		Downstream of Project[2]	
	Summer	Winter	Summer	Winter
Bicarbonate (alkalinity)	39 - 81	57 - 161	23 - 87	46 - 88
Chloride	1.5 - 11	16 - 30	1.2 - 15	5.7 - 35
Sulfate	2 - 31	11 - 39	1 - 31	10 - 38
Calcium (dissolved)	13 - 29	25 - 51	10 - 37	18 - 39
Magnesium (dissolved)	1.1 - 6.4	3.8 - 16.0	1.2 - 7.8	3.2 - 10.0
Sodium (dissolved)	2.1 - 10.0	6.3 - 23.0	1.8 - 10	4.9 - 21.1
Potassium (dissolved)	1.3 - 7.3	2.0 - 9.0	0.9 - 4.4	1.2 - 5

Notes: [1] = Denali and Vee Canyon

[2] = Gold Creek, Sunshine and Susitna Station

Source: USGS & R&M

TABLE E.2.24: LAKES POTENTIALLY IMPACTED BY ACCESS ROADS AND/OR TRANSMISSION LINES

Lake	Location	Impacts
Deadman Lake	Sec. 13 & 14, T22S, R4W, Fairbanks, Meridian	Increased access from Watana access road near MP 27
Big Lake	Sec. 19 &20, T22S, R4W; Sec. 25, T22S, R4W; Fairbanks Meridian	Increased access from Watana access road near MP 28; Location of proposed campground (see Chapter 7 of Exhibit E)
Unnamed Lake, NW of Deadman Creek	Sec. 25, T22S, R5W Fairbanks, Meridian	Increased access from Watana access road near MP 27
Unnamed Lake east of Tsusena Butte	Sec. 21, T33N, R5E, Seward Meridian	Increased access from Watana access road near MP 32
Lake complex near Watana camp at MP 41	Sec. 15, 16, & 21, T32N, R5E, Seward Meridian	Impact from location of camp; water quality
Fog Lakes	T31N, R5E & R6E, Seward Meridian	Increased access by road across to Watana Dam; potential development by Native Corporation
Swimming Bear Lake	Sec. 4, T32N, R3E, Seward Meridian	Increased access from Devil Canyon access road near MP 18
High Lake	Sec. 20, T32N, R2E, Seward Meridian	Increased access from Devil Canyon access road near MP 28
Mermaid Lake	Sec. 25, T32N, R1E, Seward Meridian	Increased access from Devil Canyon access road near MP 29; Location of proposed campground (see Chapter 7 of Exhibit E)
Unnamed Lake complex	Sec. 15, 16, 21, 22 & 28, T32N, R1E, Seward Meridian	Increased access from Devil Canyon access road near MP 31

TABLE E.2.25: STREAMS AND SLOUGHS TO BE PARTIALLY OR COMPLETELY INUNDATED BY WATANA RESERVOIR (El 2,190)

Stream	Susitna River Mile at Mouth	Approximate[1] Elevation at Mouth (ft. msl)	Approximate Stream Gradient of Reach to be Inundated (ft/mile)	Length of Stream to be Inundated (miles)
1. unnamed	236.0	2,140	500	0.1
2. unnamed	233.8	2,055	450	0.3
3. Oshetna River	233.5	2,050	70	2.0
4. unnamed	232.7	2,040	750	0.2
5. Goose Creek	231.2	2,030	133	1.2
6. unnamed	230.8	2,025	825	0.2
7. unnamed	229.8	2,015	575	0.3
8. unnamed	229.7	2,015	875	0.2
9. unnamed	229.1	2,010	1,800	0.1
10. unnamed	228.5	2,000	1,900	0.1
11. unnamed	228.4	2,000	950	0.2
12. unnamed	227.4	1,980	2,100	0.1
13. unnamed	226.8	1,970	350	0.6
14. unnamed	225.0	1,930	650	0.4
15. unnamed	224.4	1,920	1,350	0.2
16. unnamed	221.5	1,875	300	1.0
17. unnamed	220.9	1,865	1,625	0.2
18. unnamed	219.2	1,845	350	1.0
19. unnamed	217.6	1,830	725	0.5
20. unnamed	215.1	1,785	1,350	0.3
21. unnamed	213.2	1,760	1,075	0.4
22. unnamed	213.0	1,755	725	0.6
23. unnamed slough	212.2	1,750	13	0.3 (entire length
24. unnamed	212.1	1,750	1,475	0.3
25. unnamed slough	212.0	1,750	13	0.5 (entire length)
26. unnamed	211.7	1,745	1,475	0.3
27. unnamed	210.2	1,720	670	0.7
28. unnamed slough	208.7	1,705	13	0.3 (entire length)
29. Jay Creek	208.6	1,700	150	3.2
30. unnamed slough	208.0	1,695	9	0.4 (entire length)
31. unnamed	207.3	1,690	300	0.9 (entire length)
32. unnamed	207.0	1,685	500	1.0
33. Kosina Creek	206.9	1,685	120	4.2
34. unnamed slough	205.7	1,670	18	0.5 (entire length
35. unnamed	205.0	1,665	1,050	0.5 (entire length)
36. unnamed	204.9	1,665	750	0.4 (entire length)
37. unnamed	203.9	1,655	775	0.7
38. unnamed	203.4	1,650	350	0.5 (entire length)
39. unnamed	201.8	1,635	700	0.8
40. unnamed slough	200.9	1,630	9	0.2 (entire length)
41. unnamed	200.7	1,625	575	1.0
42. unnamed	198.7	1,610	825	0.7
43. unnamed	198.6	1,605	975	0.6
44. unnamed	197.9	1,600	975	0.6
45. unnamed	197.1	1,595	850	0.7
46. unnamed	196.7	1,590	850	0.7
47. unnamed	196.2	1,585	600	1.0
48. unnamed	195.8	1,580	550	1.1

TABLE E.2.25 (Page 2)

Stream Name	Susitna River Mile at Mouth	Approximate[1] Elevation at Mouth (ft. msl)	Approximate Stream Gradient at Mouth (ft/mile)	Length of Stream to be Inundated (miles)
49. unnamed	195.2	1,575	200	1.3 (entire length)
50. unnamed	194.9	1,560	375	1.7
51. Watana Creek	194.1	1,560	50	10.0 (longest fork)
51A. Delusion Creek (tributary to Watana Creek)	--	1,700	250	1.9
52. unnamed slough	193.6	1,565	9	0.4 (entire length)
53. unnamed	192.7	1,550	400	1.5 (entire length)
54. unnamed	192.0	1,545	175	3.9 (longest fork)
55. unnamed	190.0	1,530	1,300	0.5
56. unnamed	187.0	1,505	975	0.7
57. unnamed	186.9	1,505	400	1.7
58. Deadman Creek	186.7	1,500	300	2.3

1 The elevations at the mouths were approximated from USGS 1:63,360 topographic quadrangle maps. A control survey, conducted by R&M Consultants, identified several inaccuracies in the USGS contours along the length of the reservoir. Most notable of those is an elevation "reduction" of approximately 30 feet at the upstream end of the reservoir. Thus, there are four unnamed streams on the USGS maps which would appear to be inundated at their mouths but are actually above the upper end of the reservoir as surveyed.

TABLE E.2.26: STREAMS AND SLOUGHS TO BE PARTIALLY OR COMPLETELY INUNDATED BY DEVIL CANYON RESERVOIR (EL 1,455)

Stream Name	Susitna River Mile at Mouth	Approximate Elevation at Mouth (ft. msl)	Approximate Stream Gradient of Reach to be Inundated (ft/mile)	Length of Stream to be Inundated (miles)
1. Tsusena Creek	181.9	1,450	25	0.2
2. unnamed (Bear Creek)	181.2	1,440	75	0.2
3. unnamed slough	180.1	1,430	10	0.6 (entire length)
4. unnamed	179.3	1,420	350	0.1
5. unnamed slough	179.1	1,420	175	0.2
6. unnamed slough	177.0	1,385	700	0.1
7. Fog Creek	176.7	1,380	75	1.0
8. unnamed	175.3	1,370	150	0.6
9. unnamed	175.1	1,365	900	0.1
10. unnamed	174.9	1,360	950	0.1
11. unnamed	174.3	1,350	350	0.3
12. unnamed slough	173.9	1,345	13	0.1 (entire length)
13. unnamed	173.9	1,345	275	0.4
14. unnamed	173.0	1,335	1,200	0.1
15. unnamed	173.0	1,335	600	0.2
16. unnamed	172.9	1,330	625	0.2
17. unnamed slough	172.2	1,350	15	2.0 (entire length)
17A. unnamed (tributary to slough)	--	1,350	550	0.2
17B. unnamed (tributary to slough)	--	1,350	1,050	0.1
18. unnamed slough	172.0	1,320	13	0.5 (entire length)
19. unnamed slough	171.5	1,315	13	0.8 (entire length)
19A. unnamed (tributary to slough)	--	1,320	1,350	0.1
19B. unnamed (tributary to slough)	--	1,320	1,350	0.1
20. unnamed slough	171.5	1,315	13	0.2 (entire length)
21. unnamed	171.4	1,315	1,400	0.1
22. unnamed	171.0	1,310	250	0.6
23. unnamed slough	169.5	1,290	15	0.7 (entire length)
24. unnamed	168.8	1,280	875	0.2
25. unnamed slough	168.0	1,265	16	0.2 (entire length)
26. unnamed	166.5	1,235	350	0.6
27. unnamed	166.0	1,230	1,125	0.2
28. unnamed	164.0	1,200	1,275	0.2
29. unnamed	163.7	1,180	1,350	0.2
30. Devil Creek	161.4	1,120	250	1.4
31. unnamed	157.0	1,030	350	1.3
32. unnamed	154.5	985	1,175	0.4
33. unnamed (Cheechako Creek)	152.4	950	325	1.6

TABLE E.2.27: DOWNSTREAM TRIBUTARIES POTENTIALLY IMPACTED BY PROJECT OPERATION

No.	Name	River Mile	Bank of Susitna[1]	Reason for Concern	Anticipated Post-Project Response	Potential Impacts Foreseen
1	Portage Creek	148.9	RB	fish access	degrade	
2	Jack Long Creek	144.8	LB	fish access	perch	possible restriction of fish access
3	Indian River	138.5	RB	fish access	degrade	
4	Gold Creek	136.7	LB	fish access	degrade	
5	unnamed	132.0	LB	Railroad (RR)	perch	
6	Fourth of July Creek	131.1	RB	fish access	degrade	
7	Sherman Creek	130.9	LB	RR/fish access	perch	possible restriction of fish access
8	unnamed	128.5	LB	Railroad	perch	
9	unnamed	127.3	LB	Railroad	degrade	possible limited scour at RR bridge
10	Skull Creek	124.7	LB	Railroad	degrade	possible limited scour at RR bridge
11	unnamed	123.9	RB	fish access	perch	
12	Deadhorse Creek	121.0	LB	RR/fish access	perch	possible restriction of fish access
13	unnamed	121.0	RB	fish access	degrade	
14	Little Portage Creek	117.8	LB	Railroad	perch	
15	McKenzie Creek	116.7	LB	fish access	degrade	
16	Lane Creek	113.6	LB	fish access	degrade	
17	Gash Creek	111.7	LB	fish access	degrade	possible limited scour at RR bridge
18	unnamed	110.1	LB	Railroad	degrade	
19	Whiskers Creek	101.2	RB	fish access	perch (but backwater)	

[1]Referenced by facing downstream (LB = left bank, RB = right bank).

Source: R&M 1982f

TABLE E.2.28: SUMMARY OF SURFACE WATER AND GROUND WATER APPROPRIATIONS

Township Grid	Surface Water Appropriation		Ground Water Appropriation	
	Equivalent Flow Rates		Equivalent Flow Rates	
	cfs	ac-ft/yr	cfs	ac-ft/yr
Susitna	0.153	50.0	0.0498	16.3
Fish Creek	0.000116	0.02100	0.00300	2.24
Willow Creek	18.3	5,660	0.153	128
Little Willow Creek	0.00613	1.42	0.00190	1.37
Montana Creek	0.0196	7.85	0.366	264
Chunilna	0.00322	0.797	0.000831	0.601
Susitna Reservoir	0.00465	3.36	--	--
Chulina (Chunilna)	--	--	0.00329	2.38
Kroto-Trapper Creek	0.0564	10.7	--	--
Kahiltna	125	37,000	--	--
Yentna	0.00155	0.565	--	--
Skwentna	0.00551	1.90	0.000775	0.560

Source: Dwight 1981

TABLE E.2.29: WATER RIGHT APPROPRIATIONS ADJACENT TO THE SUSITNA RIVER

ADL Number	Type	Source (Depth)	Amount	Days Of Use
	Certificate			
45156	single family dwelling	well (unknown)	650 gpd	365
	general crops	" "	0.5 ac-ft/yr	91
	Certificate			
43981	single family dwelling	well (90 ft)	500 gpd	365
	Certificate			
78895	single family dwelling	well (20 ft)	500 gpd	365
200540	grade school	well (27 ft)	990 gpd	334
209233	fire station	well (34 ft)	500 gpd	365
	Certificate			
200180	single family dwelling	unnamed stream	200 gpd	365
	lawn & garden irrigation	" "	100 gpd	153
200515	single family dwelling	unnamed stream	500 gpd	365
206633	single family dwelling	unnamed lake	75 gpd	365
206930	single family dwelling	unnamed lake	250 gpd	365
206931	single family dwelling	unnamed lake	250 gpd	365
	Permit			
206929	general crops	unnamed creek	1 ac-ft/yr	153
	Permit			
206735	single family dwelling	unnamed stream	250 gpd	365
	Pending			
209866	single family dwelling	Sherman Creek	75 gpd	365
	lawn and garden irrigation	" "	50 gpd	183

Source: Dwight 1981

TABLE E.2.30: SUSITNA RIVER - LIMITATIONS TO NAVIGATION

River Mile Location[1]	Description	Severity
19	Alexander Slough Head	Access to slough limited at low water due to shallow channel
49	Mouth of Willow Creek	Access from creek limited at low water
61	Sutitna Landing-Mouth of Kashwitna River	Access from launching site limited at low water
127-128	River Cross-Over near Sherman and Cross-Section 32	Shallow in riffle at low water
151	Devil Canyon	Severe rapids at all flow levels
160-161	Devil Creek Rapids	Severe rapids at all flow levels
225	Vee Canyon	Hazardous but navigable rapids at most flows
291-295	Denali Highway Bridge	Shallow water and frequent sand bars at low water

Note: [1]Locations obtained from River Mile Index (R&M Consultants 1982)

TABLE E.2.31: TEMPORAL SALINITY ESTIMATES FOR SELECT COOK INLET LOCATIONS

Location	Conditions	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Cook Inlet near the Susitna River Mouth (Node #27)	Pre-Project	9,949	12,856	15,153	16,937	18,543	19,942	20,976	15,699	9,729	6,592	5,792	7,231
	Watana Filling (WY 1992)	10,330	13,151	15,411	17,159	18,734	20,107	21,133	16,439	11,071	7,588	6,508	7,836
	Watana Operation (WY 1995)	10,080	12,539	14,374	15,930	17,355	18,617	19,612	15,475	10,393	7,206	6,252	7,616
	Watana/Devil Canyon Operation	10,093	12,498	14,313	15,825	17,188	18,451	19,500	15,570	10,484	7,248	6,290	7,609
Center of Cook Inlet near East Foreland (Node #12)	Pre-Project	21,868	22,911	23,921	24,813	25,591	26,263	26,824	26,788	25,388	22,912	21,174	21,072
	Watana Filling (WY 1992)	22,100	23,102	24,077	24,942	25,698	26,352	26,900	26,910	25,742	23,476	21,738	21,545
	Watana Operation (WY 1995)	22,048	22,995	23,900	24,704	25,411	26,028	26,548	26,537	25,345	23,107	21,442	21,315
	Watana/Devil Canyon Operation	22,050	22,992	23,891	24,688	25,385	25,995	26,514	26,519	25,354	23,128	21,465	21,326
Mouth of Cook Inlet (Node #1)	Pre-Project	29,109	29,496	29,727	29,893	30,037	30,158	30,239	29,816	29,000	28,270	28,112	28,567
	Watana Filling (WY 1992)	29,160	29,529	29,754	29,916	30,056	30,173	30,253	29,878	29,164	28,435	28,254	28,676
	Watana Operation (WY 1995)	29,127	29,472	29,673	29,828	29,965	30,080	30,161	29,798	29,076	28,359	28,190	28,625
	Watana/Devil Canyon Operation	29,128	29,468	29,667	29,821	29,954	30,070	30,155	29,806	29,085	28,364	28,196	28,624
Center of Turnagain Arm (Node # 55)	Pre-Project	8,916	10,616	12,659	14,681	16,522	18,158	19,551	19,442	16,083	12,100	9,263	8,301
	Watana Filling (WY 1992)	9,262	10,951	12,963	14,951	16,760	18,365	19,732	19,677	16,541	12,752	9,931	8,928
	Watana Operation (WY 1995)	9,212	10,810	12,665	14,466	16,108	17,573	18,834	18,772	15,782	12,171	9,508	8,601
	Watana/Devil Canyon Operation	9,216	10,809	12,652	14,436	16,054	17,495	16,745	18,712	15,776	12,192	9,534	8,623
Center of Knik Arm (Node # 46)	Pre-Project	3,675	6,538	9,252	11,610	13,657	15,446	16,550	11,970	1,923	325	400	1,248
	Watana Filling (WY 1992)	3,834	6,754	9,482	11,832	13,862	15,630	16,710	12,119	2,008	350	437	1,355
	Watana Operation (WY 1995)	3,807	6,658	9,260	11,445	13,318	14,950	15,939	11,540	1,913	335	421	1,312
	Watana/Devil Canyon Operation	3,809	6,658	9,249	11,422	13,276	14,885	15,862	11,502	1,916	337	422	1,315

Notes: 1. All concentrations are reported in mg/l and represent end of the month salinity estimates.
2. Nodes correspond to computer simulation locations.

Source: RMA 1983

TABLE E.2.32: ESTIMATED LOW AND HIGH FLOWS AT ACCESS ROUTE STREAM CROSSINGS

Drainage Basin	Road Mile Location	A Area (mi^2)	30-Day Minimum Flow (cfs)[1] Recurrence Interval (yrs)			Peak Flows (cfs)[2] Recurrence Interval (yrs)			
			2	10	20	2	10	25	50
Denali Highway to Watana Camp Segment									
Lily Creek	3	3.7	0.8	0.6	0.5	25	54	78	96
Seattle Creek	6	11.1	2.4	1.8	1.5	74	147	205	248
Seattle Creek Tributary	8	1.5	0.3	0.2	0.2	10	24	35	44
Seattle Creek Tributary	9	2.7	0.8	0.5	0.4	13	29	42	51
Brushkana Creek	12	22.0	5.5	3.8	3.4	115	217	299	354
Brushkana Creek Site	14	21.0	4.9	3.5	3.1	121	228	315	374
Upper Deadman Creek	20	12.1	3.0	2.1	1.9	64	127	177	211
Deadman Creek Tributary	28	54.5	13.2	9.3	8.2	276	488	661	767
Watana to Devil Canyon Segment									
Tsusena Creek	2.5	126.6	26	19	17	780	1309	1744	2000
Devil Creek	22	31.0	6.7	4.8	4.2	199	369	506	597
Devil Canyon to Gold Creek Railroad Segment									
Gold Creek	0.2[3]	25.0	5.4	3.9	3.4	162	304	418	497

NOTES:

1 Minimum flows estimated from the following USGS regression equation (Freethey and Scully 1980).

$$M_{d,rt} = aA^b (LP + 1)^c (J + 10)^d$$

where:
- M = minimum flow (cfs)
- d = number of days
- rt = recurrence interval (yrs)
- A = drainage area (mi^2)
- LP = area of lakes and ponds (percent)
- J = mean minimum January air temperature (°F)
- a,b,c = coefficients

2 Peak flows estimated from the following USGS regression equation (Freethey and Scully 1980).

$$Q_t = aA^b (LP + 1)^c P^d$$

where:
- Q = annual peak discharge (cfs)
- t = recurrence interval (yrs)
- A = drainage area (mi^2)
- LP = areas of lakes and ponds (percent)
- P = mean annual precipitation (in)
- a,b,c,d = coefficients

3 Railroad mile location.

TABLE E.2.33: AVAILABLE STREAMFLOW RECORDS FOR MAJOR STREAMS CROSSED BY TRANSMISSION CORRIDOR

Stream Name	USGS Gage Description	USGS Number	Period of Continuous Record	Drainage Area[1] (mi^2)	Transmission Line Crossing from Gage[2] (approx.)	Mean Annual Streamflow[3] (cfs)
Anchorage-Willow Segment						
Little Susitna River	Near Palmer	15290000	1948-present	61.9	35 mi. d/s	206
Willow Creek	Near Willow	15294005	1978-present	166	7 mi. d/s	472
Fairbanks-Healy Segment						
Nenana River #1	Near Healy	15518000	1950-1979	1,910	2 mi. d/s	3,506
Nenana River #2	Near Healy	15518000	1950-1979	1,910	20 mi. d/s	3,506
Tanana River	At Nenana	15515500	1962-present	15,600	5 mi. u/s	23,460
Willow-Healy Intertie						
Talkeetna River	Near Talkeetna	15292700	1964-present	2,006	5 mi. d/s	4,050
Susitna River	At Gold Creek	15292000	1949-present	6,160	5 mi. u/s	9,647
Indian River	--	--	--	82	15 mi. u/s	--
E.F. Chulitna River	Chulitna River near Talkeetna	15292400	1958-72,1980-present	2,570	40 mi. u/s	8,748
M.F. Chulitna River	Chulitna River near Talkeetna	15292400	1958-72,1980-present	2,570	50 mi. u/s	8,748
Nenana River	Near Windy	15516000	1950-56,1958-73	710	5 mi. u/s	--
Yanert Fork	--	--	--	N/A	1 mi. u/s	--
Healy Creek	--	--	--	N/A	1 mi. u/s	--
Watana-Gold Creek Segment						
Tsusena Creek	--	--	--	149	3 mi. u/s	--
Devil Creek	--	--	--	71	9 mi. u/s	--
Susitna River	At Gold Creek	15292000	1949-present	6,160	13 mi. u/s	9,647

[1]Areas for ungaged streams are at the mouth.
[2]d/s = downstream, u/s = upstream. Distances for ungaged streams are from the mouth.
[3]Averages determined through the 1980 water year at gage sites.

TABLE E.2.34: MONTHLY FLOW REQUIREMENTS AT GOLD CREEK

MONTH	A	A1	A2	C	C1	C2	D[1/]
OCT	5000	5000	5000	5000	5000	5000	5000
NOV	5000	5000	5000	5000	5000	5000	5000
DEC	5000	5000	5000	5000	5000	5000	5000
JAN	5000	5000	5000	5000	5000	5000	5000
FEB	5000	5000	5000	5000	5000	5000	5000
MAR	5000	5000	5000	5000	5000	5000	5000
APR	5000	5000	5000	5000	5000	5000	5000
MAY	4000	5000	5000	6000	6000	6000	6000
JUN	4000	5000	5000	6000	6000	6000	6000
JUL[1]	4000	5100	5320	6480	6530	6920	7260
AUG	6000	8000	10000	12000	14000	16000	19000
SEP[1]	5000	6500	7670	9300	10450	11620	13170

Notes:

Derivation of transitional flows.

[1] DATE		CASE						
JUL	SEP	A	A1	A2	C	C1	C2	D
25	21	4000	5000	5000	6000	6000	6000	6000
26	20	4000	5000	5000	6000	7000	7000	7500
19	19	4000	5000	5000	7000	8000	8500	9000
18	18	4000	5000	6000	8000	9000	10000	10500
17	17	4000	5000	7000	9000	10000	11500	12000
16	16	4000	6000	8000	10000	11000	13000	14000
15	15	5000	7000	9000	11000	12500	14500	16000

[1/] Three additional flow regimes were investigated with respect to project economics. These regimes are discussed in Exhibit B, pp. B-2-123 through B-2-128 and are identified as Cases E, F, and G.

TABLE E.2.35: NET BENEFITS FOR SUSITNA HYDROELECTRIC PROJECT OPERATING SCENARIOS

	LTPWC[1] (1982 dollars x 10^6)	NET BENEFITS (1982 dollars x 10^6)	PERCENT CHANGE RELATIVE TO CASE A
Thermal Option [2]	8238		
Case A	7004	1234	
Case A_1	6998	1240	+0.5
Case A_2	7012	1226	-0.6
Case C	7097	1141	-7.5
Case C_1	7189	1049	-15.0
Case C_2	7357	881	-29.0
Case D	7569	669	-46.0

Note:

[1] Long-Term Present Worth Costs

[2] Three additional flow regimes were investigated with respect to project economics. These regimes are discussed in Exhibit B, pp. B-2-123 through B-2-128 and are identified as Cases E, F, and G.

TABLE E.2.36: MINIMUM DOWNSTREAM FLOW REQUIREMENTS AT GOLD CREEK

Month	Flow (cfs) During Filling	Flow (cfs) Operation
Oct	2,000	5,000
Nov	Natural	5,000
Dec	Natural	5,000
Jan	Natural	5,000
Feb	Natural	5,000
Mar	Natural	5,000
Apr	Natural	5,000
May	5,680 (1)	6,000
Jun	6,000	6,000
Jul	6,480 (2)	6,480 (2)
Aug	12,000	12,000
Sep	9,100 (3)	9,300 (4)

Notes:

(1)

May	1	2,000*
	2	3,000*
	3	4,000*
	4	5,000*
	5-31	6,000

(2)

Jul	1-26	6,000
	27	7,000
	28	8,000
	29	9,000
	30	10,000
	31	11,000

(3)

Sep	1-14	12,000
	15	11,000
	16	10,000
	17	9,000
	18	8,000
	19	7,000
	20-27	6,000
	28	5,000
	29	4,000
	30	3,000

(4)

Sep	1-14	12,000
	15	11,000
	16	10,000
	17	9,000
	18	8,000
	19	7,000
	20-30	6,000

* Natural flows up to 6000 cfs will be discharged when they are greater than stated flows.

TABLE E.2.37: WATANA FLO

Month	Pre-Project Flow	Filling Case With 10% Probability of Exceedance WY 1991 Outflow	% Change	WY 1992 Outflow	% Change	WY 1993 Outflow	% Change	Pre-Project Flow	Filling Case With 50% Probability of WY 1991 Outflow	% Change	WY 1992 Outflow	% Chang
Oct	5,272	5,272	-	5,272	0.0	819	84.5	4,713	4,713	-	3,454	26.7
Nov	2,352	2,352	-	2,352	0.0	2,352	0.0	2,102	2,102	-	2,102	0.0
Dec	1,642	1,642	-	1,642	0.0	1,642	0.0	1,468	1,468	-	1,468	0.0
Jan	1,340	1,340	-	1,340	0.0	1,340	0.0	1,198	1,198	-	1,198	0.0
Feb	1,138	1,138	-	1,138	0.0	1,138	0.0	1,018	1,018	-	1,018	0.0
Mar	1,028	1,028	-	1,028	0.0	1,028	0.0	919	919	-	919	0.0
Apr	1,261	1,261	-	1,261	0.0	1,261	0.0	1,127	1,127	-	1,127	0.0
May	12,158	8,690[1]	28.5	2,956	75.7	2,956[3]	75.7	10,870	7,402[1]	31.9	3,329	69.4
Jun	25,326	20,005	21.0	1,000	96.1	8,989	64.5	22,644	17,323	23.5	1,103	95.1
Jul	22,327	5,309	76.2	9,076	59.3	1,477	93.4	19,963	2,945	85.2	2,378	88.1
Aug	20,142	14,993	25.6	8,649[2]	57.1	15,382[4]	23.6	18,008	12,859	29.6	8,105[2]	55.0
Sep	12,064	6,743	44.1	6,397	47.1			10,787	6,767	37.3	6,767	37.3

Notes: 1. Filling begins.

2. Commissioning of units possible.

3. Operation possible.

4. Filling complete.

S FOR THREE FILLING CASES (CFS)

Exceedance			Filling Case With 90% Probability of Exceedance								
	WY 1993		Pre-Project Flow	WY 1991		WY 1992		WY 1993		WY 1994	
e	Outflow	% Change		Outflow	% Change	Outflow	% Change	Outflow	% Change	Outflow	% Change
	981	79.2	4,213	4,213	-	1,493	64.6	1,140	72.9	1,140[4]	73.0
	2,102	0.0	1,879	1,879	-	1,879	0.0	1,879	0.0		
	1,468	0.0	1,312	1,312	-	1,312	0.0	1,312	0.0		
	1,198	0.0	1,071	1,071	-	1,071	0.0	1,071	0.0		
	1,018	0.0	910	910	-	910	0.0	910	0.0		
	919	0.0	822	822	-	822	0.0	822	0.0		
	1,127	0.0	1,008	1,008	-	1,008	0.0	1,008	0.0		
	3,329[3]	69.4	9,715	6,247[1]	36.0	3,696	62.0	3,696[2]	62.0		
	1,103	95.1	20,238	14,917	26.3	1,867	90.8	1,867	90.8		
	2,163	89.2	17,842	2,836	84.1	2,836	84.1	2,836	84.0		
	9,668[4]	46.3	16,095	8,934	44.5	8,713	45.9	8,713	45.9		
			9,641	7,131	26.0	7,131	26.0	7,131[3]	26.0		

TABLE E.2.38: GOLD CREEK FL

Month	Filling Case With 10% Probability of Exceedance							Filling Case With 50% Probability of				
	Pre-Project Flows	WY 1991		WY 1992		WY 1993		Pre-Project Flows	WY 1991		WY 1992	
		Flows	% Change	Flows	% Change	Flows	% Change		Flows	% Change	Flows	% Change
Oct	6,453	6,453	-	6,453	0.0	2,000	69.0	5,732	5,732	-	4,473	22.0
Nov	2,879	2,879	-	2,879	0.0	2,879	0.0	2,557	2,557	-	2,557	0.0
Dec	2,010	2,010	-	2,010	0.0	2,010	0.0	1,785	1,785	-	1,785	0.0
Jan	1,640	1,640	-	1,640	0.0	1,640	0.0	1,457	1,457	-	1,457	0.0
Feb	1,393	1,393	-	1,393	0.0	1,393	0.0	1,238	1,238	-	1,238	0.0
Mar	1,258	1,258	-	1,258	0.0	1,258	0.0	1,118	1,118	-	1,118	0.0
Apr	1,544	1,544	-	1,544	0.0	1,544	0.0	1,371	1,371	-	1,371	0.0
May	14,882	11,414[1]	23.3	5,680	61.8	5,680[3]	61.8	13,221	9,753[1]	26.2	5,680	57.0
Jun	31,001	25,680	17.2	6,675	78.5	14,664	52.7	27,541	22,220	19.3	6,000	78.2
Jul	27,330	10,312	62.3	14,079	48.5	6,480	76.3	24,280	7,262	70.1	6,694	72.4
Aug	24,655	19,506	20.8	13,162[2]	46.0	19,895[4]	19.3	21,903	16,754	23.5	12,000[2]	45.2
Sep	14,767	9,446	36.0	9,100	38.4			13,120	9,100	30.6	9,100	30.6

Notes: 1. Filling begins.

2. Commissioning of units possible.

3. Operation possible.

4. Filling complete.

]WS FOR THREE FILLING CASES (CFS)

	...xceedance			Filling Case With 90% Probability of Exceedance								
	WY 1993		Pre-Project Flows	WY 1991		WY 1992		WY 1993		WY 1994	
...e	Flows	% Change		Flows	% Change	Flows	% Change	Flows	% Change	Flows	% Change
	2,000	65.1	5,073	5,073	-	2,353	53.6	2,000	60.6	2,000[4]	60.6
	2,557	0.0	2,263	2,263	-	2,263	0.0	2,263	0.0		
	1,785	0.0	1,580	1,580	-	1,580	0.0	1,580	0.0		
	1,457	0.0	1,290	1,290	-	1,290	0.0	1,290	0.0		
	1,238	0.0	1,096	1,096	-	1,096	0.0	1,096	0.0		
	1,118	0.0	990	990	-	990	0.0	990	0.0		
	1,371	0.0	1,214	1,214	-	1,214	0.0	1,214	0.0		
	5,680[3]	57.0	11,699	8,231[1]	29.6	5,680	57.4	5,680[2]	51.4		
	6,000	78.2	24,371	19,050	21.8	6,000	75.4	6,000	75.4		
	6,480	73.3	21,486	6,480	69.8	6,480	69.8	6,480	69.8		
	13,563[4]		19,382	12,221	36.9	12,000	38.1	12,000	38.1		
			11,610	9,100	21.6	9,100	21.6	9,100[3]	21.6		

TABLE E.2.39: MONTHLY PRE-PROJECT AND WATANA FILLING FLOWS AT GOLD CREEK, SUNSHINE AND SUSITNA STATION

Month	Gold Creek			Sunshine			Susitna Station		
	Pre-Project[1] Flows	Filling[3] Flows	Percent Change	Pre-Project[2] Flows	Filling[3] Flows	Percent Change	Pre Project[2] Flows	Filling[3] Flows	Percent Change
Oct	5,732	4,473	22.0	13,874	12,615	9.1	31,219	29,960	4.0
Nov	2,557	2,557	0.0	5,981	5,981	0.0	13,396	13,396	0.0
Dec	1,785	1,785	0.0	4,215	4,215	0.0	8,414	8,414	0.0
Jan	1,457	1,457	0.0	3,524	3,524	0.0	7,937	7,937	0.0
Feb	1,238	1,238	0.0	2,973	2,973	0.0	7,086	7,086	0.0
Mar	1,118	1,118	0.0	2,667	2,667	0.0	6,374	6,374	0.0
Apr	1,371	1,371	0.0	3,247	3,247	0.0	7,279	7,279	0.0
May	13,221	5,680	57.0	27,909	20,368	27.0	61,558	54,017	12.3
Jun	27,541	6,000	78.2	63,458	41,917	33.9	123,387	101,846	17.4
Jul	24,280	6,694	72.4	64,205	46,619	27.4	133,642	116,056	13.2
Aug	21,903	12,000	45.2	56,378	46,475	17.6	112,269	102,366	8.8
Sep	13,120	9,100	30.6	32,009	27,989	12.6	66,511	62,491	6.0
Annual	9,599	4,479	53.3	23,418	18,216	22.2	48,194	43,079	10.6

Notes: 1. Based on the median three-year moving average annual flow.

2. Sunshine and Susitna Station pre-project flows are based on the long-term ratio of the mean at Gold Creek.

3. Filling flows based on the second year (WY 1992) of filling scenario.

TABLE E.2.40: MONTHLY OPERATING RULE CURVES AT WATANA AND DEVIL CANYON

	Elevation (ft)[1]		
	Watana Operation	Watana/Devil Canyon Operation	
Month	Watana	Watana	Devil Canyon
Oct	2184	2185	1455
Nov	2171	2170	1455
Dec	2154	2150	1455
Jan	2137	2130	1455
Feb	2122	2112	1455
Mar	2107	2095	1455
Apr	2093	2080	1455
May	2100	2092	1455
Jun	2135	2125	1455
Jul	2165	2160	1455
Aug	2180	2180	1455
Sept	2190	2190	1455

Notes: 1 Target elevation at end of month.

TABLE E.2.41: WATANA OPERATION - MONTHLY MINIMUM ENERGY DEMANDS

Month	Demand Pattern Percent of Annual Demand	Minimum Energy GWh[1]	Associated Powerhouse Discharge (cfs)
Oct	8.70	220.7	5910
Nov	9.06	243.1	6810
Dec	11.17	284.5	7860
Jan	10.21	260.0	7330
Feb	8.78	202.0	6420
Mar	8.88	226.2	6620
Apr	7.66	188.9	5830
May	7.14	181.7	5430
Jun	6.70	165.3	4980
Jul	6.62	168.8	4750
Aug	6.96	304.2	8280
Sept	7.32	266.0	7400

(1) Taken from year 21 of energy simulation.

TABLE E.2.42: WATANA POST-PROJECT MONTHLY FLOW (CFS) WATANA OPERATION

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1	5665.	9716.	11285.	9706.	8958.	8081.	7384.	5633.	4854.	4617.	9034.	8301.	7761.9
2	5841.	6641.	7716.	7190.	6290.	6468.	5674.	7874.	4836.	4778.	8808.	5266.	6459.0
3	7083.	10164.	11617.	10165.	9158.	8247.	7508.	5327.	5002.	4797.	8436.	6391.	7819.7
4	8269.	10751.	11398.	9709.	8928.	8182.	8086.	11376.	4960.	4561.	8072.	5544.	8325.3
5	5691.	6592.	11300.	9978.	9120.	8150.	7646.	8369.	4962.	4591.	6321.	5546.	7353.8
6	5684.	7246.	11666.	10279.	9367.	8398.	7644.	5259.	5175.	6850.	14063.	8458.	8345.5
7	7620.	9582.	11155.	9707.	9071.	8206.	7422.	9500.	9089.	8819.	10055.	8275.	9046.5
8	7779.	10271.	11823.	10264.	9506.	8447.	7649.	7001.	7123.	4748.	8778.	7254.	8381.0
9	9605.	10930.	12375.	10371.	9358.	8485.	7969.	6804.	4964.	4756.	8303.	7550.	8455.1
10	5732.	6513.	7773.	9972.	9266.	8206.	7589.	6969.	4838.	4781.	8969.	7390.	7325.4
11	8736.	10207.	11789.	10291.	9455.	8473.	7774.	9582.	4870.	4813.	7733.	4876.	8220.4
12	6483.	10322.	12090.	10670.	9621.	8843.	8669.	10116.	5203.	4747.	9380.	6076.	8519.7
13	6050.	10257.	11877.	10499.	9574.	8689.	8161.	8042.	16899.	7579.	11004.	7286.	9649.7
14	9131.	10503.	11825.	10199.	9501.	8395.	7480.	11611.	4959.	9516.	12488.	7780.	9468.1
15	6516.	9783.	11311.	9743.	9098.	8087.	7313.	5333.	18354.	5020.	9608.	7253.	8931.5
16	5759.	6536.	7538.	9561.	9089.	8319.	7936.	7712.	4963.	5167.	8274.	10382.	7592.4
17	8792.	9559.	11320.	9951.	9301.	8496.	8042.	5259.	6476.	4555.	7561.	6764.	7999.0
18	5722.	6505.	7606.	9993.	9348.	8401.	7553.	9142.	6838.	5550.	16189.	8754.	8471.0
19	7590.	9928.	11821.	10508.	9877.	9072.	8280.	9386.	7756.	5706.	8978.	7648.	8876.0
20	5757.	6543.	7573.	7637.	9065.	8198.	7554.	5259.	4852.	4630.	9756.	7674.	7028.9
21	5908.	6809.	7856.	7330.	6420.	6619.	5826.	5428.	4983.	4747.	8284.	7403.	6470.6
22	5971.	6790.	7879.	7336.	6419.	6615.	5823.	5502.	5167.	4939.	8686.	7049.	6518.8
23	7860.	10581.	12074.	10561.	9808.	8878.	8009.	12218.	9601.	4742.	10220.	7856.	9367.6
24	5697.	6590.	11363.	9922.	9317.	8386.	7618.	5259.	4974.	4585.	9727.	8326.	7641.5
25	5781.	6573.	7622.	7092.	6638.	8139.	7576.	9442.	4860.	4655.	9304.	6836.	7052.8
26	5901.	6783.	7811.	7274.	6359.	6537.	5739.	5347.	7870.	6791.	9037.	6065.	6798.3
27	7756.	9595.	10993.	9648.	9060.	8202.	7763.	5887.	4964.	4588.	10594.	6881.	7993.1
28	5828.	6628.	7677.	7136.	6231.	7593.	7907.	5555.	12444.	4745.	9567.	7273.	7378.6
29	5692.	9188.	12096.	10468.	9584.	8768.	8112.	7951.	4844.	4608.	9022.	7826.	8176.0
30	5882.	6684.	7751.	7216.	6307.	6478.	5679.	8310.	5123.	7742.	8211.	7627.	6929.3
31	5681.	11305.	12148.	10361.	9550.	8689.	8108.	6968.	5433.	9232.	9070.	7020.	8630.1
32	9053.	11291.	11501.	10038.	9288.	8401.	7807.	7208.	4874.	5632.	19391.	9316.	9497.5
MAX	9605.	11305.	12375.	10670.	9877.	9072.	8669.	12218.	18354.	9516.	19391.	10382.	9649.7
MIN	5665.	6505.	7538.	7092.	6231.	6468.	5674.	5259.	4836.	4555.	6321.	4876.	6459.0
MEAN	6766.	8668.	10301.	9399.	8685.	8098.	7478.	7520.	6628.	5550.	9779.	7311.	8015.1

TABLE E.2.43: MONTHLY MAXIMUM, MINIMUM, AND MEAN FLOWS AT WATANA (CFS)

MONTH	PRE-PROJECT			POST-PROJECT					
				WATANA OPERATION			W/DC OPERATION		
	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN
OCT	6458.0	2403.1	4522.8	9605.4	5664.6	6766.1	11900.7	5564.1	9764.4
NOV	3525.0	1020.9	2059.1	11305.1	6504.8	8667.7	11048.4	6683.3	9112.6
DEC	2258.5	709.3	1414.8	12374.9	7538.2	10300.9	12386.3	7775.9	10881.2
JAN	1779.9	636.2	1165.5	10670.4	7091.7	9399.2	11497.6	7227.3	10287.5
FEB	1560.4	602.1	983.3	9876.9	6231.4	8685.3	11021.6	6272.0	9924.6
MAR	1560.4	569.1	898.3	9072.1	6468.3	8098.3	10315.6	6459.8	9059.2
APR	1965.0	609.2	1099.7	8668.6	5674.3	7478.1	9199.9	5100.4	7793.9
MAY	15973.1	2857.2	10354.7	12218.0	5258.9	7519.6	7501.6	4072.9	5826.6
JUN	42841.9	13233.4	23023.7	18353.5	4835.5	6628.3	6626.9	3198.6	5123.6
JUL	28767.4	15871.0	20810.1	9515.9	4555.1	5549.6	6625.6	3442.5	4736.1
AUG	31435.0	13412.1	18628.5	19391.0	6320.6	9778.8	14043.2	3263.4	5947.5
SEP	17205.5	5711.5	10792.0	10381.7	4875.6	7310.7	13672.9	4009.2	7838.4
ANNUAL	9832.9	6100.4	8023.0	9649.7	6459.0	8015.1	9832.9	6343.8	8015.1

TABLE E.2.44: GOLD CREEK POST-PROJECT MONTHLY FLOW (CFS) WATANA OPERATION

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1	7280.	10216.	11555.	9918.	9105.	8238.	7574.	8487.	8022.	8024.	12000.	9282.	9145.8
2	6390.	6833.	7910.	7342.	6437.	6589.	5989.	10314.	7108.	7562.	12000.	9300.	7831.3
3	8061.	10738.	12016.	10491.	9317.	8392.	7624.	6529.	11599.	9076.	12000.	9300.	9595.1
4	10186.	11491.	11816.	9991.	9137.	8332.	8319.	15608.	10810.	7406.	12000.	9300.	10380.5
5	7076.	7092.	11616.	10191.	9317.	8292.	7939.	13953.	10736.	7967.	12000.	9300.	9635.0
6	7195.	7955.	12161.	10685.	9717.	8612.	7904.	7860.	10153.	10622.	16276.	9300.	9882.5
7	8469.	9894.	11416.	9871.	9287.	8452.	7654.	14207.	15257.	14078.	15432.	13411.	11468.8
8	9377.	11044.	12258.	10591.	9817.	8712.	7904.	10575.	12008.	8110.	12000.	12213.	10384.1
9	11783.	11948.	13380.	10856.	9624.	8660.	8237.	9746.	8566.	7883.	12000.	9121.	10162.0
10	6875.	6933.	8170.	10339.	9624.	8492.	7954.	12818.	9829.	9288.	16209.	11843.	9874.3
11	10129.	10844.	12316.	10736.	9769.	8709.	8004.	12318.	7167.	8287.	12000.	9300.	9978.8
12	8227.	10994.	12810.	11343.	10071.	9322.	9354.	13838.	11869.	9478.	12000.	9300.	10726.1
13	7329.	10694.	12216.	10791.	9817.	8912.	8404.	9299.	24152.	9986.	14667.	10430.	11381.9
14	10294.	10794.	12116.	10491.	9817.	8512.	7534.	15342.	10296.	15149.	15147.	9300.	11263.3
15	7778.	10244.	11610.	9939.	9283.	8225.	7449.	6061.	26092.	7887.	12000.	9300.	10468.3
16	7291.	6967.	7679.	9658.	9177.	8412.	8064.	9736.	9470.	9772.	12000.	13506.	9309.7
17	10776.	10092.	11747.	10291.	9617.	8812.	8479.	7810.	13487.	8262.	12000.	9300.	10056.4
18	6616.	6903.	7985.	10391.	9717.	8712.	7871.	12067.	11636.	10363.	22704.	11951.	10593.9
19	8471.	10347.	12171.	10872.	10217.	9412.	8614.	12740.	13602.	10043.	12000.	9300.	10654.4
20	6582.	6882.	7830.	7839.	9239.	8345.	7726.	7169.	7866.	6852.	12000.	9300.	8128.7
21	6629.	7004.	8013.	7518.	6586.	6771.	5920.	7272.	9214.	8997.	12000.	9300.	7947.1
22	7491.	7701.	8482.	7681.	6678.	6848.	6091.	6390.	10484.	7762.	13149.	9300.	8181.2
23	8728.	11087.	12626.	11130.	10345.	9335.	8414.	18135.	16602.	7692.	12000.	9300.	11289.7
24	6222.	6865.	11581.	10091.	9517.	8512.	7731.	6207.	8914.	6484.	12000.	9300.	8615.7
25	6457.	6742.	7725.	7179.	6725.	8236.	7696.	12733.	7949.	7483.	12000.	9300.	8370.1
26	6551.	7008.	8138.	7574.	6719.	6896.	6121.	9025.	13491.	11081.	12000.	9300.	8671.0
27	9816.	9987.	11197.	9865.	9267.	8412.	8077.	9568.	9350.	6513.	12000.	8051.	9347.6
28	6728.	7351.	8393.	7616.	6647.	7982.	8384.	9665.	19061.	7908.	12000.	9300.	9255.0
29	7469.	10068.	12705.	10920.	9985.	9117.	8406.	8669.	6617.	7243.	12000.	9300.	9378.3
30	7015.	7274.	8119.	7476.	6537.	6577.	5811.	9811.	6908.	11710.	12000.	9300.	8235.0
31	6842.	11972.	12532.	10639.	9783.	8912.	8374.	8888.	11113.	15152.	12030.	9300.	10469.9
32	10320.	11980.	11890.	10344.	9552.	8626.	8071.	10118.	6000.	9792.	26494.	10461.	11172.4
MAX	11783.	11980.	13380.	11343.	10345.	9412.	9354.	18135.	26092.	15152.	26494.	13506.	11468.8
MIN	6222.	6742.	7679.	7179.	6437.	6577.	5811.	6061.	6000.	6484.	12000.	8051.	7831.3
MEAN	8014.	9186.	10693.	9708.	8951.	8324.	7740.	10405.	11420.	9185.	13378.	9840.	9745.4

TABLE E.2.45: MONTHLY MAXIMUM, MINIMUM, AND MEAN FLOWS AT GOLD CREEK (CFS)

MONTH	PRE-PROJECT			POST-PROJECT					
				WATANA OPERATION			W/DC OPERATION		
	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN
OCT	8212.0	3124.0	5770.8	11782.5	6221.8	8014.0	10983.0	6453.2	7764.9
NOV	4192.0	1215.0	2577.1	11979.9	6741.5	9185.7	11848.8	7103.9	9630.8
DEC	3264.0	866.0	1807.2	13380.4	7678.9	10693.3	13134.1	8040.5	11270.9
JAN	2452.0	824.0	1474.1	11342.5	7179.3	9707.8	12045.8	7423.9	10596.7
FEB	2028.0	768.0	1249.1	10344.5	6437.0	8951.1	11452.8	6457.3	10190.9
MAR	1900.0	713.0	1123.7	9411.7	6576.7	8323.7	10604.2	6618.1	9285.6
APR	2650.0	745.0	1361.7	9353.6	5811.1	7740.1	9759.4	5950.4	8100.4
MAY	21890.0	3745.0	13240.0	18134.9	6061.3	10404.9	12380.0	6000.0	8706.3
JUN	50580.0	15530.0	27814.9	26091.6	6000.0	11419.5	13305.2	6000.0	9882.9
JUL	34400.0	18093.0	24445.1	15151.9	6484.0	9184.6	11846.2	6484.0	8387.3
AUG	38538.0	16220.0	22228.1	26494.0	12000.0	13378.4	21146.2	12000.0	12633.5
SEP	21240.0	6881.0	13320.9	13506.1	8050.5	9839.6	18330.0	9300.0	10510.3
ANNUAL	11565.2	7200.1	9753.3	11468.8	7831.3	9745.4	11473.3	7776.4	9745.4

TABLE E.2.46: SUNSHINE POST-PROJECT MONTHLY FLOW (CFS) WATANA OPERATION

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1	14948.	13272.	13727.	11639.	10593.	9545.	9015.	19395.	34035.	44603.	46969.	28715.	21460.9
2	14768.	10245.	10614.	9312.	8052.	7993.	7935.	38420.	45190.	54466.	50686.	39129.	24861.4
3	16203.	13696.	13898.	12361.	10828.	9794.	9061.	12368.	47967.	47623.	44443.	26877.	22160.5
4	19378.	15193.	14196.	11709.	10660.	9829.	10996.	46640.	47565.	41437.	41344.	27767.	24834.4
5	14699.	10084.	14093.	12558.	11206.	9935.	9908.	29268.	40291.	40993.	43601.	24756.	21875.2
6	14013.	11535.	14429.	12818.	11506.	10089.	9362.	20299.	49979.	53956.	68218.	30395.	25667.8
7	14529.	12361.	13277.	11503.	10603.	9721.	8948.	29704.	55858.	63556.	59936.	39576.	27583.9
8	18823.	15023.	15023.	12897.	11788.	10356.	9611.	30965.	61001.	47102.	44703.	40534.	26550.7
9	21970.	17026.	16255.	12958.	11313.	10155.	10103.	24605.	43618.	44853.	46362.	21669.	23509.9
10	13642.	10114.	10249.	12278.	11376.	9792.	9599.	26288.	50795.	51809.	56977.	31838.	24660.1
11	18702.	14409.	14939.	12950.	11518.	10187.	9632.	31340.	30948.	43531.	43725.	31876.	22917.7
12	17429.	14103.	15620.	13630.	11795.	10992.	11813.	28916.	43305.	48548.	50516.	32001.	24992.0
13	15992.	14651.	14936.	13113.	11659.	10487.	10285.	21229.	68419.	51892.	52298.	33251.	26583.3
14	17527.	14046.	14806.	12965.	11938.	9911.	8729.	31557.	40925.	58968.	44415.	26162.	24451.1
15	19884.	13901.	13649.	11688.	10764.	9525.	9085.	10399.	86585.	43773.	41934.	22996.	24533.6
16	16473.	11640.	11004.	12071.	11279.	10330.	10139.	21343.	42238.	46974.	47255.	47859.	24112.2
17	21779.	13315.	14081.	12295.	11326.	10387.	10302.	14644.	50106.	43645.	52177.	27706.	23559.4
18	14004.	9598.	10341.	12589.	11611.	10305.	9343.	29499.	48288.	60688.	72831.	32460.	26941.5
19	14277.	13407.	14679.	13072.	12303.	11410.	11063.	33521.	58822.	53358.	41560.	21369.	24992.9
20	12834.	9457.	9728.	9442.	10048.	9534.	9146.	18623.	36692.	37324.	38648.	24356.	18879.2
21	12921.	9767.	9995.	9294.	8266.	8377.	7990.	21579.	38186.	47108.	46946.	27370.	20749.6
22	14467.	11761.	11122.	9564.	8156.	8249.	7649.	13297.	53762.	48599.	55758.	27262.	22559.2
23	17194.	14739.	15038.	13148.	12118.	10847.	9914.	32425.	49028.	47214.	43964.	31056.	24811.2
24	14984.	10630.	14146.	12203.	11301.	10158.	9525.	16187.	41047.	39945.	42795.	25464.	20765.2
25	14008.	9918.	10215.	9187.	8467.	9732.	9620.	28039.	33792.	39950.	39002.	26164.	19934.2
26	15114.	10246.	10312.	9604.	8238.	8306.	7688.	23055.	54017.	59053.	45588.	28557.	23418.8
27	17642.	12232.	12850.	11398.	10672.	9793.	9998.	19823.	41336.	43079.	44355.	19672.	21159.0
28	13474.	10589.	11275.	10018.	8669.	9653.	10241.	24277.	68864.	47232.	47917.	29379.	24367.6
29	17297.	13673.	15429.	13104.	11544.	10514.	10246.	19426.	35611.	44153.	37728.	23435.	21094.0
30	13331.	10387.	10746.	9753.	8457.	8340.	8065.	29817.	42067.	54604.	40437.	25320.	21889.9
31	17219.	17180.	15305.	13109.	12016.	11031.	11331.	23735.	47117.	66765.	41694.	23855.	25138.4
32	19175.	16189.	14921.	13324.	12374.	10924.	10996.	32962.	38747.	63392.	72896.	29750.	28143.3
MAX	21970.	17180.	16255.	13630.	12374.	11410.	11813.	46640.	86585.	66765.	72896.	47859.	28143.3
MIN	12834.	9457.	9728.	9187.	8052.	7993.	7649.	10399.	30948.	37324.	37728.	19672.	18879.2
MEAN	16209.	12637.	13153.	11798.	10701.	9881.	9604.	25114.	47694.	49381.	48365.	29018.	23723.7

TABLE E.2.47: MONTHLY MAXIMUM, MINIMUM, AND MEAN FLOWS AT SUNSHINE (CFS)

MONTH	PRE-PROJECT			POST-PROJECT WATANA OPERATION			POST-PROJECT W/DC OPERATION		
	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN
OCT	18555.0	9416.0	13966.0	21969.5	12833.8	16209.3	21536.9	13141.6	15960.1
NOV	9400.0	3978.0	6028.4	17180.1	9457.1	12637.0	16926.8	9753.6	13082.2
DEC	6139.0	2734.0	4267.2	16255.4	9728.0	13153.3	16009.1	9989.0	13730.9
JAN	4739.0	2507.0	3564.6	13629.5	9187.3	11798.2	14738.9	9383.1	12687.1
FEB	4057.0	1731.0	2998.9	12373.5	8052.0	10701.0	14089.6	8133.9	11940.7
MAR	3898.0	2013.0	2681.0	11409.7	7992.5	9881.0	12746.1	8035.9	10842.9
APR	5109.0	2025.0	3225.6	11812.6	7649.4	9604.0	12314.5	7508.4	9964.3
MAY	50302.0	8645.0	27948.9	46640.4	10399.3	25113.8	42287.3	10338.0	23415.2
JUN	111073.0	39311.0	64089.0	86584.6	30948.0	47693.7	73798.2	30357.5	46157.0
JUL	85600.0	48565.0	64641.4	66764.9	37323.7	49380.9	63459.2	36956.0	48583.6
AUG	84940.0	42118.0	57214.7	72896.0	37728.0	48364.9	67548.2	37728.0	47620.1
SEP	53703.0	18502.0	32499.2	47859.1	19671.5	29018.0	44997.5	20921.0	29688.6
ANNUAL	28226.1	17950.7	23731.6	28143.3	18879.2	23723.7	28024.6	19068.6	23723.7

TABLE E.2.48: SUSITNA POST-PROJECT MONTHLY FLOW (CFS) WATANA OPERATION

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1	27814.	19000.	16313.	14962.	13572.	12888.	12361.	63270.	90038.	110314.	98552.	40312.	43558.5
2	20568.	12466.	12791.	13456.	12912.	12230.	11726.	55497.	68572.	108156.	93277.	61531.	40508.4
3	33543.	24358.	17105.	17165.	15353.	13365.	12689.	46405.	111776.	120008.	107266.	76896.	49868.4
4	46936.	24283.	19862.	16959.	15091.	13862.	14696.	85178.	114051.	113155.	89000.	38198.	49569.6
5	21641.	16821.	15388.	16093.	13310.	12491.	13009.	55189.	94367.	104339.	114487.	62655.	45223.8
6	25721.	14363.	16299.	16145.	14162.	12827.	13116.	56705.	149338.	131938.	110646.	48514.	51055.3
7	23441.	18516.	17411.	15070.	15147.	13836.	13886.	79033.	143263.	151802.	122522.	99299.	59697.5
8	45392.	29542.	24263.	19491.	16673.	14865.	14409.	60029.	158067.	125118.	116273.	80238.	58911.8
9	56207.	27881.	20752.	16443.	14703.	14191.	14802.	67167.	95763.	107283.	89069.	54625.	48515.7
10	32607.	14312.	11421.	16686.	14881.	13177.	13171.	53430.	97111.	130505.	123363.	62827.	48920.8
11	29325.	18158.	17121.	15607.	14627.	13163.	12533.	46599.	75771.	114710.	102382.	70355.	44438.9
12	34216.	20908.	23885.	21560.	18351.	16704.	16506.	81935.	134134.	123876.	106597.	58434.	55028.0
13	30441.	21037.	19093.	17941.	14499.	13462.	13339.	51263.	143931.	127577.	112337.	69346.	53071.5
14	31287.	18749.	18981.	17561.	16170.	13570.	12268.	50215.	69944.	127169.	98183.	67762.	45425.8
15	39175.	19696.	15742.	15242.	14078.	12422.	12234.	37291.	128638.	109743.	87840.	45839.	45006.8
16	29747.	14626.	12595.	15649.	14512.	13682.	13824.	46231.	93824.	120338.	102726.	84100.	47034.4
17	40124.	20307.	19276.	16921.	15806.	14602.	14752.	50476.	105720.	106009.	108899.	61437.	48094.7
18	28849.	18265.	14807.	16919.	16043.	14195.	13984.	54693.	117007.	119869.	127402.	84608.	52448.9
19	41295.	23867.	25197.	20495.	19849.	16284.	15466.	90703.	119919.	114136.	81705.	42869.	51242.8
20	28632.	16063.	13695.	13677.	14480.	13047.	12816.	50271.	95679.	104307.	92754.	57296.	42928.4
21	26188.	12588.	12163.	12768.	11399.	11727.	10609.	48928.	85196.	119322.	109748.	80764.	45370.0
22	35021.	20901.	14825.	12748.	11896.	11780.	10797.	32454.	99812.	122996.	114549.	63881.	46220.2
23	35644.	22916.	18907.	18270.	16775.	14158.	13599.	70307.	158196.	127709.	100307.	57120.	54709.5
24	28178.	19465.	18264.	16500.	15793.	13824.	14392.	62506.	103911.	111596.	98971.	45453.	45983.0
25	23700.	15332.	12772.	13707.	12696.	13805.	13666.	58011.	57917.	90867.	76032.	53174.	37024.2
26	22332.	15708.	15954.	14655.	13052.	12544.	11395.	41215.	109981.	119061.	85270.	70730.	44498.1
27	33627.	17927.	16116.	15420.	13931.	12880.	13957.	67408.	91970.	102773.	91850.	50080.	44247.5
28	32994.	22971.	19090.	15887.	13940.	13256.	12937.	53165.	146992.	128938.	118260.	80470.	55125.2
29	38128.	19173.	17645.	15865.	15088.	14102.	13737.	45389.	78497.	103823.	97710.	56193.	43186.2
30	38918.	19739.	15744.	14902.	13197.	12409.	13044.	77201.	102118.	125330.	119740.	72870.	52422.5
31	58171.	39370.	24806.	19011.	17334.	16418.	18734.	63408.	124933.	163892.	117470.	87220.	62880.8
32	37565.	24194.	18632.	16665.	15906.	13689.	17054.	80382.	96557.	130592.	147556.	64460.	55646.0
MAX	58171.	39370.	25197.	21560.	19849.	16704.	18734.	90703.	158196.	163892.	147556.	99299.	62880.8
MIN	20568.	12466.	11421.	12748.	11399.	11727.	10609.	32454.	57917.	90867.	76032.	38198.	37024.2
MEAN	33670.	20109.	17404.	16264.	14851.	13608.	13610.	58811.	108218.	119289.	105086.	64049.	48995.7

TABLE E.2.49: MONTHLY MAXIMUM, MINIMUM, AND MEAN FLOWS AT SUSITNA (CFS)

MONTH	PRE-PROJECT			POST-PROJECT					
				WATANA OPERATION			W/DC OPERATION		
	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN
OCT	58640.0	18026.1	31426.3	58171.2	20567.9	33669.5	58425.2	20926.6	33420.4
NOV	31590.0	6799.3	13500.7	39370.1	12466.2	20109.3	36526.8	12773.9	20554.5
DEC	15081.0	4763.4	8517.5	25197.4	11420.8	17403.6	25763.1	11432.2	17981.2
JAN	12669.1	6071.9	8030.0	21559.6	12747.9	16263.6	22262.9	12763.8	17152.6
FEB	11532.2	4993.1	7148.6	19848.7	11399.4	14850.7	20933.1	11427.2	16090.4
MAR	9192.6	4910.4	6407.9	16704.3	11726.5	13607.9	17986.8	11699.0	14569.8
APR	12030.0	5530.8	7231.2	18733.6	10608.9	13609.6	19717.5	10655.9	13969.9
MAY	94143.2	29809.3	61646.1	90702.7	32453.9	58811.0	88615.3	32626.2	57112.4
JUN	176218.8	67838.0	124613.8	158195.6	57916.9	108218.5	157474.1	57089.1	106681.9
JUL	181400.0	102184.3	134549.5	163891.9	90867.2	119289.1	160586.2	90191.2	118491.8
AUG	159600.0	80251.5	113935.4	147556.0	76031.5	105085.6	142208.2	76031.5	104340.8
SEP	104218.4	39331.2	67529.9	99299.0	38197.7	64048.6	104218.4	38197.7	64719.3
ANNUAL	63158.6	36285.1	49003.6	62880.8	37024.2	48995.7	62736.3	36786.6	48995.7

TABLE E.2.50: WATANA FIXED

Simulated Water Year	1995 Simulation Week of First Release	Week of Maximum Release	Maximum Release cfs	Powerhouse Flow cfs	Total Relea Acre-
1950	Aug 26-Sept 1	Sep 2-8	1,011	9,514	30,6
1951	Aug 5-11	Aug 5-11	167	9,030	2,3
1952	Aug 19-25	Aug 19-25	724	8,898	20,8
1953	Aug 12-18	Aug 12-18	266	8,946	5,1
1954	Sept 2-8	Sept 9-15	347	9,424	6,9
1955	Sept 9-15	Sept 9-15	343	9,265	4,8
1956	Aug 19-25	Sept 9-15	9,615	9,245	545,5
1957	---	---	---	---	-
1958	Aug 19-25	Sept 2-8	1,309	9,337	53,1
1959	Aug 5-11	Sept 2-8	4,925	9,089	119,5
1960	---	---	---	---	-
1961	Aug 26-Sept 1	Sept 2-8	828	9,194	23,6
1962	Aug 26-Sept 1	Sept 2-8	10,755	9,066	298,9
1963	Aug 19-25	Aug 26-Sept 1	7,546	8,887	189,6
1964	July 29-Aug 4	Sept 9-15	1,113	9,414	66,1
1965	Aug 26-Sept 1	Aug 26- Sept 1	1,112	9,082	15,4
1966	Oct 1-6	Oct 1-6	2,379	10,140	48,1
1967	Aug 19-25	Sept 2-8	15,380	9,066	47,1
1968	Aug 12-18	Sept 2-8	921	9,285	49,4
1969	Sept 2-8	Sept 2-8	302	9,776	8,3
1970	Aug 26-Sept 1	Sept 9-15	692	9,801	22,0
1971	Sept 2-8	Sept 2-8	5,597	9,076	119,6
1972	July 29-Aug 4	Aug 26-Sept 1	795	9,011	22,2
1973	July 29-Aug 4	Sept 9-15	917	9,659	25,5
1974	Aug 12-18	Sept 9-15	677	9,840	21,9
1975	Aug 5-11	Sept 2-8	898	9,233	34,5
1976	Aug 19-25	Sept 9-15	1,286	9,706	53,6
1977	Aug 26-Sept 1	Sept 2-8	1,083	9,267	30,9
1978	Aug 19-25	Aug 26-Sept 1	859	9,440	33,0
1979	Aug 19-25	Sept 2-8	1,208	9,288	42,8
1980	Aug 26-Sept 1	Sept 2-8	1,187	9,130	39,1
1981	Aug 19-25	Aug 19-25	21,526	8,710	602,5

CONE VALVE OPERATION

l ase -feet	2000 Simulation				
	Week of First Release	Week of Maximum Release	Maximum Release cfs	Powerhouse Flow cfs	Total Release Acre-feet
500	---	---	---	---	---
500	---	---	---	---	---
300	---	---	---	---	---
100	---	---	---	---	---
900	---	---	---	---	---
300	---	---	---	---	---
500	Aug 26-Sept 1	Sept 9-15	8,587	10,272	356,400
---	---	---	---	---	---
100	Sept 2-8	Sept 2-8	272	10,375	3,800
500	Sept 2-8	Sept 9-15	2,196	10,272	42,300
---	---	---	---	---	---
500	---	---	---	---	---
900	Aug 26-Sept 1	Sept 2-8	9,747	10,073	182,700
500	Aug 26-Sept 1	Sept 2-8	2,660	10,073	57,600
100	---	---	---	---	---
400	---	---	---	---	---
100	---	---	---	---	---
100	Aug 19-25	Sept 2-8	14,372	10,073	371,900
400	---	---	---	---	---
500	---	---	---	---	---
000	---	---	---	---	---
500	Sept 2-8	Sept 2-8	2,614	10,090	64,000
200	---	---	---	---	---
500	---	---	---	---	---
900	---	---	---	---	---
500	---	---	---	---	---
500	Sept 2-8	Sept 2-8	204	10,566	5,500
900	---	---	---	---	---
000	---	---	---	---	---
300	Sept 2-8	Sept 2-8	176	10,320	2,400
100	Sept 2-8	Sept 2-8	167	10,150	2,300
500	Aug 19-25	Aug 19-25	17,943	9,684	500,300

TABLE E.2.51: WATANA/DEVIL CANYON OPERATION MONTHLY MINIMUM ENERGY DEMANDS

		WATANA		DEVIL CANYON	
Month	Demand Pattern Percent of Annual Demand	Minimum Energy GWh	Associated Powerhouse Discharge (cfs)	Minimum Energy GWh	Associated Powerhouse Discharge (cfs)
Oct	8.70	442.9	11,900	207.2	6,660
Nov	9.86	247.5	7,020	224.2	7,140
Dec	11.17	287.3	8,040	264.0	8,140
Jan	10.21	259.5	7,420	244.6	7,540
Feb	8.78	199.7	6,450	192.0	6,550
Mar	8.88	221.3	6,590	217.0	6,690
Apr	7.66	162.7	5,100	203.6	6,540
May	7.14	205.4	6,240	195.7	6,090
Jun	6.70	121.9	3,730	202.4	6,450
Jul	6.62	126.5	3,590	205.1	6,320
Aug	6.96	143.6	3,910	335.3	10,670
Sept	7.32	218.1	6,030	251.0	8,620

Note: Monthly minimum energy demands taken from year 21 of energy simulation.

TABLE E.2.52: WATANA POST-PROJECT MONTHLY FLOW (CFS) WATANA/DEVIL CANYON OPERATION

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1	5564.	10435.	12315.	11438.	10786.	8708.	7283.	4470.	4011.	3800.	4081.	7547.	7512.1
2	11900.	6948.	7941.	7346.	6377.	6512.	6824.	6344.	4283.	3925.	3994.	6939.	6617.0
3	9062.	9851.	12276.	11401.	11022.	9708.	7407.	4993.	3199.	3629.	5170.	5760.	7776.7
4	9261.	10917.	12249.	11409.	11003.	9827.	7985.	7029.	6219.	3931.	3768.	4193.	8134.8
5	11478.	6741.	11580.	11103.	10783.	8778.	7545.	6287.	3312.	3780.	3263.	4124.	7391.6
6	10209.	6683.	12250.	11377.	10962.	10316.	7544.	4550.	5182.	5129.	7016.	12466.	8628.5
7	7078.	10812.	12317.	11456.	10735.	8834.	7321.	6881.	6114.	5830.	8243.	13194.	9051.0
8	7183.	10907.	12248.	11395.	10967.	10194.	8572.	4982.	6537.	3771.	5122.	8992.	8381.0
9	8806.	10831.	12129.	11313.	10943.	10208.	9198.	6060.	5625.	3855.	4418.	5853.	8252.1
10	11674.	6810.	7784.	9626.	10929.	8833.	7489.	4878.	3432.	3443.	5550.	10150.	7528.3
11	8141.	10947.	12222.	11360.	10967.	10203.	8619.	7502.	4273.	3791.	3700.	4009.	7964.5
12	10337.	10068.	12172.	11374.	11004.	10125.	9074.	7178.	5969.	4107.	6899.	4895.	8592.4
13	9420.	9620.	12348.	11410.	10992.	10210.	8946.	6097.	5752.	6626.	13869.	12746.	9832.9
14	8536.	11048.	12290.	11405.	10966.	10240.	8273.	7187.	6378.	5757.	8597.	10800.	9277.7
15	8163.	11013.	12306.	11443.	11000.	8715.	7212.	5143.	5707.	6499.	6927.	5164.	8262.7
16	10477.	8758.	12353.	11498.	10753.	8947.	7835.	5742.	4737.	4587.	5402.	10488.	8451.5
17	8197.	10789.	12268.	11399.	10978.	9626.	7941.	4566.	5896.	3674.	3624.	4935.	7803.3
18	11738.	6815.	7793.	9300.	11011.	9029.	7453.	7144.	6563.	5029.	8676.	13673.	8666.8
19	6994.	11011.	12386.	11388.	10961.	10170.	9185.	7299.	6230.	6135.	4013.	6880.	8537.2
20	11765.	6840.	7834.	8576.	10728.	8825.	7453.	4777.	4080.	4168.	4335.	7482.	7218.3
21	11901.	7018.	8039.	7419.	6448.	6592.	5100.	6242.	3729.	3593.	3914.	6029.	6343.8
22	11696.	6814.	7898.	7352.	6397.	6537.	5682.	4624.	4463.	3927.	6384.	9000.	6736.5
23	7955.	10985.	12210.	11300.	10870.	10124.	9154.	6463.	5819.	6512.	7118.	9214.	8963.4
24	7715.	10748.	12330.	11451.	11014.	9397.	7517.	5073.	4338.	4230.	4381.	8326.	8022.4
25	11844.	6936.	7938.	7336.	6370.	8005.	7475.	7327.	4025.	3979.	4185.	6235.	6815.1
26	11900.	6975.	7942.	7335.	6337.	6460.	5608.	5810.	6308.	6148.	5613.	7337.	6990.9
27	8655.	10825.	12334.	11217.	10723.	8830.	7663.	4209.	3625.	4226.	5226.	8131.	7953.8
28	11801.	6792.	7776.	7227.	6272.	8825.	7806.	4073.	5982.	6466.	6986.	5189.	7113.6
29	10179.	10413.	12205.	11360.	10940.	10167.	9200.	6261.	4440.	4028.	4075.	7047.	8344.7
30	11758.	6849.	7904.	7322.	6356.	6519.	7233.	7022.	6458.	6041.	5073.	4972.	6970.3
31	11642.	8455.	12272.	11412.	10993.	10208.	9085.	5002.	6627.	5933.	6653.	7035.	8768.7
32	9433.	10951.	12289.	11453.	11004.	10223.	8723.	5240.	4643.	5011.	14043.	12026.	9580.4
MAX	11901.	11048.	12386.	11498.	11022.	10316.	9200.	7502.	6627.	6626.	14043.	13673.	9832.9
MIN	5564.	6683.	7776.	7227.	6272.	6460.	5100.	4073.	3199.	3443.	3263.	4009.	6343.8
MEAN	9764.	9113.	10881.	10288.	9925.	9059.	7794.	5827.	5124.	4736.	5947.	7838.	8015.1

TABLE E.2.53: DEVIL CANYON POST-PROJECT MONTHLY FLOW (CFS) WATANA/DEVIL CANYON OPERATION

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1	6602.	10756.	12482.	11575.	10887.	8809.	7405.	6305.	6048.	5990.	10941.	8950.	8886.0
2	6553.	7072.	8066.	7443.	6472.	6589.	7026.	7913.	5744.	5714.	10860.	7859.	7286.3
3	6490.	10226.	12526.	11611.	11124.	9808.	7481.	5766.	7439.	6373.	10727.	8261.	8975.4
4	6623.	11386.	12518.	11589.	11137.	9930.	8135.	9744.	9980.	5760.	10597.	7958.	9603.3
5	6757.	7069.	11783.	11240.	10910.	8869.	7733.	9876.	7024.	5951.	9972.	7959.	8758.6
6	6747.	7139.	12562.	11638.	11186.	10460.	7710.	6222.	8383.	7547.	11210.	10144.	9239.5
7	7630.	11012.	12479.	11567.	10873.	8992.	7470.	9901.	10079.	9211.	11700.	16496.	10608.2
8	8217.	11398.	12528.	11605.	11167.	10364.	8743.	7280.	9671.	5932.	10849.	8402.	9668.7
9	10206.	11485.	12775.	11624.	11113.	10320.	9370.	7957.	7941.	5865.	10680.	8739.	9834.1
10	6708.	7080.	8040.	9862.	11159.	9017.	7723.	8639.	6640.	6340.	10198.	13013.	8682.2
11	9043.	11350.	12561.	11646.	11168.	10355.	8774.	9254.	5756.	6024.	10476.	7720.	9509.1
12	6581.	10507.	12629.	11806.	11292.	10433.	9515.	9571.	10255.	7147.	11064.	8149.	9904.4
13	6617.	9907.	12560.	11597.	11148.	10353.	9108.	6905.	10408.	8173.	16223.	14767.	10638.6
14	9290.	11229.	12477.	11593.	11169.	10315.	8314.	9579.	9808.	9378.	11051.	11008.	10431.8
15	8980.	11309.	12492.	11569.	11126.	8803.	7299.	5740.	10542.	8342.	11146.	8569.	9650.2
16	6759.	9042.	12437.	11566.	10809.	9006.	7917.	7043.	7634.	7540.	10669.	9529.	9156.0
17	9478.	11132.	12536.	11618.	11181.	9835.	8222.	6206.	10396.	6057.	10415.	8394.	9610.5
18	6612.	7071.	8036.	9556.	11248.	9228.	7657.	9024.	9641.	8123.	12865.	15728.	9546.8
19	7567.	11274.	12612.	11622.	11180.	10389.	9400.	9455.	9988.	8923.	10921.	8710.	10165.1
20	6594.	7056.	7998.	8704.	10839.	8919.	7562.	5989.	5992.	5682.	11178.	8712.	7918.0
21	6664.	7143.	8140.	7540.	6555.	6689.	6544.	6088.	6449.	6325.	10673.	8623.	7293.0
22	6972.	7400.	8285.	7574.	6564.	6687.	5855.	6245.	6796.	5742.	10406.	9249.	7320.5
23	8519.	11304.	12565.	11665.	11215.	10418.	9414.	10267.	10320.	8409.	11364.	8784.	10350.8
24	6266.	10932.	12464.	11559.	11143.	9484.	7590.	5682.	6871.	5806.	11188.	8952.	8981.6
25	6579.	7044.	8004.	7393.	6426.	8067.	7552.	9436.	6018.	5797.	11037.	8420.	7662.0
26	6618.	7120.	8152.	7528.	6569.	6690.	5853.	8174.	9915.	8906.	10942.	8145.	7896.4
27	7792.	11077.	12459.	11363.	10856.	8965.	7864.	6575.	6445.	5797.	11498.	8882.	9123.0
28	6680.	7257.	8236.	7536.	6539.	9076.	8113.	6715.	10229.	8499.	11131.	8576.	8225.7
29	6722.	10985.	12591.	11650.	11197.	10391.	9389.	6730.	5580.	5721.	10937.	8773.	9211.8
30	6786.	7228.	8141.	7489.	6504.	6583.	7318.	7986.	7606.	8586.	10647.	8702.	7809.6
31	6685.	8892.	12513.	11591.	11143.	10352.	9263.	6239.	9482.	9188.	11236.	8362.	9572.1
32	7855.	11346.	12458.	11593.	11122.	10331.	8865.	6510.	5598.	8177.	17878.	12762.	10376.4
MAX	10206.	11485.	12775.	11806.	11292.	10460.	9515.	10267.	10542.	9378.	17878.	16496.	10638.6
MIN	6266.	7044.	7998.	7393.	6426.	6583.	5853.	5682.	5580.	5682.	9972.	7720.	7286.3
MEAN	7318.	9445.	11128.	10485.	10094.	9204.	8006.	7657.	8146.	7094.	11334.	9603.	9121.7

TABLE E.2.54: GOLD CREEK POST-PROJECT MONTHLY FLOW (CFS) WATANA/DEVIL CANYON OPERATION

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1	7179.	10934.	12578.	11650.	10939.	8865.	7473.	7324.	7179.	7206.	12000.	9300.	9380.2
2	6749.	7141.	8135.	7498.	6524.	6632.	7139.	8785.	6555.	6708.	12000.	9300.	7776.4
3	6839.	10431.	12669.	11727.	11181.	9860.	7523.	6195.	9795.	7902.	12000.	9300.	9609.5
4	7307.	11650.	12668.	11690.	11212.	9983.	8218.	11255.	12070.	6776.	12000.	9300.	10337.3
5	7252.	7248.	11896.	11316.	10980.	8919.	7838.	11870.	9085.	7156.	12000.	9300.	9573.3
6	7287.	7392.	12739.	11782.	11311.	10536.	7803.	7151.	10161.	8894.	12000.	10444.	9788.5
7	7933.	11124.	12572.	11625.	10950.	9079.	7553.	11582.	12282.	11089.	13620.	18330.	11473.3
8	8788.	11674.	12683.	11722.	11278.	10459.	8834.	8556.	11415.	7132.	12000.	10173.	10384.1
9	10983.	11849.	13134.	11797.	11208.	10383.	9465.	9008.	9227.	6982.	12000.	9300.	10443.8
10	7116.	7230.	8182.	9993.	11287.	9119.	7853.	10728.	8423.	7949.	12783.	14603.	9592.6
11	9540.	11577.	12750.	11805.	11280.	10439.	8856.	10231.	6577.	7265.	12000.	9300.	10137.1
12	7204.	10747.	12887.	12046.	11453.	10604.	9759.	10900.	12635.	8837.	12000.	9300.	10692.4
13	7074.	10063.	12681.	11701.	11234.	10433.	9195.	7354.	12998.	9032.	17532.	15890.	11257.3
14	9705.	11333.	12581.	11697.	11282.	10356.	8333.	10911.	11714.	11390.	12000.	11551.	11072.9
15	9431.	11474.	12599.	11639.	11191.	8852.	7348.	6000.	13305.	9366.	12000.	9300.	10199.1
16	7306.	9196.	12487.	11601.	10840.	9039.	7963.	7766.	9244.	9185.	12000.	10645.	9769.4
17	10187.	11322.	12689.	11739.	11293.	9948.	8378.	7117.	12900.	7381.	12000.	9300.	10345.3
18	6931.	7213.	8172.	9698.	11380.	9339.	7770.	10069.	11354.	9841.	15192.	16870.	10305.0
19	7882.	11423.	12737.	11752.	11301.	10510.	9519.	10652.	12076.	10472.	12000.	9300.	10800.3
20	6890.	7179.	8091.	8778.	10902.	8972.	7625.	6687.	7094.	6484.	12000.	9300.	8318.1
21	6921.	7212.	8196.	7607.	6614.	6743.	6578.	6746.	7960.	7842.	12000.	9300.	7820.4
22	7515.	7725.	8500.	7697.	6656.	6770.	5950.	6562.	8695.	6750.	12000.	10053.	7914.2
23	8829.	11485.	12762.	11868.	11406.	10581.	9559.	12380.	12820.	9462.	12000.	9300.	11037.3
24	6453.	11030.	12542.	11620.	11214.	9529.	7630.	6021.	8279.	6484.	12000.	9300.	9329.5
25	6820.	7104.	8041.	7424.	6457.	8102.	7595.	10612.	7121.	6807.	12000.	9300.	8132.5
26	6850.	7200.	8269.	7635.	6698.	6818.	5990.	9487.	11922.	10438.	12000.	9300.	8565.2
27	8528.	11217.	12532.	11440.	10930.	9039.	7976.	7890.	8011.	6484.	12000.	9300.	9606.7
28	7001.	7516.	8491.	7708.	6687.	9215.	8283.	8184.	12592.	9629.	12000.	9300.	8895.9
29	7357.	11299.	12808.	11811.	11340.	10516.	9494.	6986.	6213.	6662.	12000.	9300.	9641.2
30	7191.	7439.	8272.	7582.	6587.	6618.	7366.	8522.	8244.	10003.	12000.	9300.	8275.9
31	7096.	9129.	12650.	11690.	11226.	10431.	9358.	6922.	12307.	11846.	12000.	9300.	10325.4
32	8334.	11633.	12677.	11760.	11268.	10448.	8994.	8150.	6000.	8941.	21146.	13171.	11053.7
MAX	10983.	11849.	13134.	12046.	11453.	10604.	9759.	12380.	13305.	11846.	21146.	18330.	11473.3
MIN	6453.	7104.	8041.	7424.	6457.	6618.	5950.	6000.	6000.	6484.	12000.	9300.	7776.4
MEAN	7765.	9631.	11271.	10597.	10191.	9286.	8100.	8706.	9883.	8387.	12634.	10510.	9745.4

TABLE E.2.55: MONTHLY MAXIMUM, MINIMUM, AND MEAN FLOWS AT DEVIL CANYON

MONTH	PRE-PROJECT			POST-PROJECT					
				WATANA OPERATION			W/DC OPERATION		
	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN
OCT	7517.6	2866.5	5324.3	11005.0	6034.4	7567.6	10205.5	6265.8	7318.4
NOV	3955.0	1145.7	2390.8	11735.1	6681.4	8999.4	11485.2	7043.8	9444.5
DEC	2904.9	810.0	1664.5	13021.3	7628.7	10550.6	12775.0	7998.0	11128.2
JAN	2212.0	756.9	1362.1	11102.5	7148.0	9595.7	11805.8	7392.6	10484.6
FEB	1836.4	708.7	1152.5	10152.9	6384.5	8854.5	11292.4	6426.2	10094.3
MAR	1778.7	663.8	1042.1	9290.4	6541.4	8242.1	10459.6	6582.8	9203.9
APR	2405.4	696.5	1267.0	9109.0	5763.9	7645.4	9514.8	5853.2	8005.7
MAY	19776.8	3427.9	12190.3	16021.7	5801.2	9355.2	10266.8	5682.3	7656.6
JUN	47816.4	14709.8	26078.1	23328.0	5598.0	9682.7	10541.6	5579.5	8146.1
JUL	32388.4	17291.0	23152.2	13136.9	5805.8	7891.7	9378.0	5682.0	7094.4
AUG	35270.0	15257.0	20928.2	23226.0	9971.6	12078.5	17878.2	9971.6	11333.6
SEP	19799.1	6463.3	12413.6	12390.3	7632.8	8932.3	16495.8	7719.9	9603.0
ANNUAL	10946.5	6800.1	9129.7	10763.2	7341.2	9121.8	10638.6	7286.3	9121.7

TABLE E.2.56: SUNSHINE POST-PROJECT MONTHLY FLOW (CFS) WATANA/DEVIL CANYON OPERATION

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1	14847.	13990.	14750.	13371.	12427.	10172.	8914.	18232.	33192.	43785.	46969.	28733.	21695.3
2	15127.	10553.	10839.	9468.	8139.	8036.	9085.	36891.	44637.	53612.	50686.	39129.	24806.6
3	14981.	13389.	14551.	13597.	12692.	11262.	8960.	12034.	46163.	46449.	44443.	26877.	22174.9
4	16499.	15352.	15048.	13408.	12735.	11480.	10895.	42287.	48825.	40807.	41344.	27767.	24791.3
5	14875.	10240.	14373.	13683.	12869.	10562.	9807.	27185.	38640.	40182.	43601.	24756.	21813.5
6	14105.	10972.	15007.	13915.	13100.	12013.	9261.	19590.	49987.	52228.	63942.	31539.	25573.7
7	13993.	13591.	14433.	13257.	12266.	10348.	8847.	27079.	52883.	60568.	58124.	44495.	27588.4
8	18234.	15653.	15448.	14028.	13249.	12103.	10541.	28946.	60408.	46124.	44703.	38494.	26550.7
9	21170.	16927.	16009.	13899.	12897.	11878.	11331.	23867.	44279.	43952.	46362.	21848.	23791.6
10	13883.	10411.	10261.	11932.	13039.	10419.	9498.	24198.	49389.	50470.	53551.	34598.	24378.4
11	18113.	15142.	15373.	14019.	13029.	11917.	10484.	29253.	30358.	42509.	43725.	31876.	23076.1
12	16406.	13856.	15697.	14333.	13177.	12274.	12218.	25978.	44071.	47907.	50516.	32001.	24958.3
13	15737.	14020.	15401.	14023.	13076.	12008.	11076.	19284.	57265.	50938.	55163.	38711.	26458.7
14	16938.	14585.	15271.	14171.	13403.	11755.	9528.	27126.	42343.	55209.	41268.	28413.	24260.8
15	21537.	15131.	14638.	13388.	12672.	10152.	8984.	10338.	73798.	45252.	41934.	22996.	24264.4
16	16488.	13869.	15812.	14014.	12942.	10957.	10038.	19373.	42012.	46387.	47255.	44998.	24571.8
17	21190.	14545.	15023.	13743.	13002.	11523.	10201.	13951.	49519.	42764.	52177.	27706.	23848.3
18	14319.	9908.	10528.	11896.	13274.	10932.	9242.	27501.	48006.	60166.	65319.	37379.	26652.5
19	13688.	14483.	15245.	13952.	13387.	12508.	11968.	31433.	57296.	53787.	41560.	21369.	25138.8
20	13142.	9754.	9989.	10381.	11711.	10161.	9045.	18141.	35920.	36956.	38648.	24356.	19068.6
21	13213.	9975.	10178.	9383.	8294.	8349.	8648.	21053.	36932.	45953.	46946.	27370.	20622.9
22	14491.	11785.	11140.	9580.	8134.	8171.	7508.	13469.	51973.	47587.	54609.	28015.	22292.2
23	17295.	15137.	15174.	13886.	13179.	12093.	11059.	26670.	45246.	48984.	43964.	31056.	24558.8
24	15215.	14795.	15107.	13732.	12998.	11175.	9424.	16001.	40412.	39945.	42795.	25464.	21479.0
25	14371.	10280.	10531.	9432.	8199.	9598.	9519.	25918.	32964.	39274.	39002.	26164.	19696.6
26	15413.	10438.	10443.	9665.	8217.	8228.	7557.	23517.	52448.	58410.	45588.	28557.	23313.0
27	16354.	13462.	14185.	12973.	12335.	10420.	9897.	18145.	39997.	43050.	44355.	20921.	21418.1
28	13747.	10754.	11373.	10110.	8709.	10886.	10140.	22796.	62395.	48953.	47917.	29379.	24008.5
29	17185.	14904.	15532.	13995.	12899.	11913.	11334.	17743.	35207.	43572.	37728.	23435.	21356.9
30	13507.	10552.	10899.	9859.	8507.	8381.	9620.	28528.	43403.	52897.	40437.	25320.	21930.9
31	17473.	14337.	15423.	14160.	13459.	12550.	12315.	21769.	48311.	63459.	41664.	23855.	24993.9
32	17189.	15842.	15709.	14739.	14090.	12746.	11919.	30994.	38747.	62541.	67548.	32460.	28024.6
MAX	21537.	16927.	16009.	14739.	14090.	12746.	12315.	42287.	73798.	63459.	67548.	44998.	28024.6
MIN	13142.	9754.	9989.	9383.	8134.	8036.	7508.	10338.	30358.	36956.	37728.	20921.	19068.6
MEAN	15960.	13082.	13731.	12687.	11941.	10843.	9964.	23415.	46157.	48584.	47620.	29689.	23723.7

TABLE E.2.57: SUSITNA POST-PROJECT MONTHLY FLOW (CFS) WATANA/DEVIL CANYON OPERATION

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1	27714.	19719.	17336.	16695.	15407.	13516.	12260.	62108.	89195.	109496.	98552.	40330.	43792.9
2	20927.	12774.	13016.	13611.	12999.	12273.	12876.	53967.	68020.	107303.	93277.	61531.	40453.6
3	32321.	24051.	17757.	18401.	17217.	14833.	12588.	46070.	109972.	118833.	107266.	76896.	49882.8
4	44058.	24442.	20714.	18658.	17166.	15513.	14595.	80825.	115311.	112525.	89000.	38198.	49526.4
5	21816.	16977.	15668.	17218.	14973.	13119.	12908.	53107.	92716.	103528.	114487.	62655.	45162.1
6	25812.	13800.	16877.	17243.	15756.	14752.	13015.	55996.	149346.	130211.	106370.	49659.	50961.3
7	22905.	19746.	18567.	16824.	16811.	14464.	13785.	76407.	140288.	148813.	120709.	104218.	59701.9
8	44804.	30171.	24687.	20622.	18134.	16612.	15339.	58010.	157474.	124140.	116273.	78198.	58911.9
9	55407.	27781.	20505.	17385.	16288.	15913.	16031.	66429.	96424.	106382.	89069.	54803.	48797.4
10	32848.	14609.	11432.	16340.	16544.	13805.	13071.	51339.	95705.	129166.	119938.	65587.	48639.1
11	28736.	18892.	17554.	16676.	16138.	14894.	13386.	44513.	75181.	113688.	102382.	70355.	44597.2
12	33192.	20662.	23961.	22263.	19733.	17987.	16912.	78997.	134900.	123235.	106597.	58434.	54994.3
13	30187.	20406.	19558.	18852.	15917.	14983.	14130.	49317.	132777.	126623.	115202.	74806.	52946.9
14	30698.	19287.	19445.	18767.	17635.	15414.	13067.	45784.	71362.	123410.	95037.	70013.	45235.4
15	40828.	20925.	16731.	16942.	15987.	13050.	12134.	37229.	115852.	111222.	87840.	45839.	44737.5
16	29762.	16855.	17403.	17593.	16176.	14309.	13723.	44261.	93599.	119751.	102726.	81239.	47494.0
17	39535.	21536.	20217.	18370.	17483.	15738.	14651.	49783.	105132.	105128.	108899.	61437.	48383.6
18	29164.	18575.	14993.	16226.	17706.	14823.	13883.	52695.	116725.	119348.	119890.	89527.	52160.0
19	40706.	24943.	25763.	21375.	20933.	17382.	16371.	88615.	118393.	114565.	81705.	42869.	51388.7
20	28940.	16359.	13956.	14616.	16143.	13675.	12715.	49789.	94907.	103939.	92754.	57296.	43117.8
21	26481.	12797.	12347.	12857.	11427.	11699.	11267.	48402.	83942.	118167.	109748.	80764.	45243.2
22	35044.	20925.	14843.	12764.	11874.	11703.	10656.	32626.	98023.	121984.	113400.	64634.	45953.2
23	35745.	23314.	19043.	19009.	17836.	15404.	14744.	64552.	154414.	129479.	100307.	57120.	54457.1
24	28409.	23630.	19224.	18029.	17491.	14842.	14291.	62320.	103276.	111596.	98971.	45453.	46696.8
25	24063.	15694.	13088.	13952.	12428.	13672.	13566.	55889.	57089.	90191.	76032.	53174.	36786.6
26	22631.	15900.	16085.	14716.	13031.	12466.	11264.	41677.	108413.	118418.	85270.	70730.	44392.3
27	32339.	19157.	17451.	16995.	15594.	13507.	13856.	65730.	90631.	102744.	91850.	51329.	44506.6
28	33267.	23136.	19188.	15979.	13980.	14489.	12836.	51684.	140522.	130659.	118260.	80470.	54766.1
29	38016.	20404.	17748.	16756.	16443.	15501.	14825.	43706.	78093.	103242.	97710.	56193.	43449.0
30	39094.	19904.	15897.	15008.	13247.	12450.	14599.	75912.	103454.	123623.	119740.	72870.	52463.4
31	58425.	36527.	24924.	20062.	18777.	17937.	19718.	61442.	126127.	160586.	117440.	87220.	62736.3
32	35579.	23847.	19420.	18080.	17622.	15511.	17977.	78414.	96557.	129741.	142208.	67170.	55527.3
MAX	58425.	36527.	25763.	22263.	20933.	17987.	19718.	88615.	157474.	160586.	142208.	104218.	62736.3
MIN	20927.	12774.	11432.	12764.	11427.	11699.	10656.	32626.	57089.	90191.	76032.	38198.	36786.6
MEAN	33420.	20554.	17981.	17153.	16090.	14570.	13970.	57112.	106682.	118492.	104341.	64719.	48995.7

TABLE E.2.58: DEVIL CANYON F

	2002 Simulation				
Simulated Water Year	Week of First Release	Week of Maximum Release	Maximum Release cfs	Powerhouse Flow cfs	Total Release Acre-fe
1950	--	--	--	--	--
1951	--	--	--	--	--
1952	Aug 5-11	Aug 5-11	7,533	12,315	331,5
1953	July 29-Aug 4	July 29-Aug 4	9,399	12,127	570,7
1954	Aug 5-11	Aug 12-18	10,207	12,428	456,0
1955	July 29-Aug 4	Aug 26-Sept 1	22,289	12,838	801,8
1956	July 15-21	July 29-Aug 4	17,516	12,127	1,385,7
1957	July 29-Aug 4	July 29-Aug 4	7,639	12,127	806,1
1958	July 29-Aug 4	July 29-Aug 4	14,748	12,127	532,3
1959	Aug 12-18	Aug 26-Sept 1	38,979	0	1,427,9
1960	Aug 26-Sept 1	Sept 9-15	13,943	13,355	463,7
1961	July 15-21	July 22-28	12,452	11,976	897,6
1962	July 9-14	July 22-28	13,665	11,976	1,326,3
1963	July 15-21	July 22-28	18,744	11,976	1,200,2
1964	July 15-21	July 15-21	11,173	12,097	437,0
1965	Aug 5-11	Aug 12-18	16,231	12,428	691,8
1966	Oct 1-6	Aug 19-25	8,952	12,579	244,4
1967	July 29-Aug 4	Aug 12-18	43,844 (1)	0	1,707,0
1968	July 15-21	July 22-28	11,590	11,976	535,8
1969	--	--	--	--	--
1970	--	--	--	--	--
1971	--	--	--	--	--
1972	July 9-14	July 9-14	8,237	12,217	764,6
1973	--	--	--	--	--
1974	--	--	--	--	--
1975	Sept 9-15	Sept 16-22	3,957	13,613	113,8
1976	--	--	--	--	--
1977	July 29-Aug 4	July 29-Aug 4	8,892	12,127	399,0
1978	--	--	--	--	--
1979	Aug 5-11	Aug 12-18	6,462	12,428	167,3
1980	July 15-21	July 29-Aug 4	19,011	12,127	935,3
1981	July 22-26	Aug 12-18	31,645	12,428	1,849,4

(1) Includes discharge of 5344 cfs over spillway.

IXED CONE VALVE OPERATION

	2010 Simulation				
ət	Week of First Release	Week of Maximum Release	Maximum Release cfs	Powerhouse Flow cfs	Total Release Acre-feet
	--	--	--	--	--
	--	--	--	--	--
)0	--	--	--	--	--
)0	--	--	--	--	--
)0	--	--	--	--	--
)0	Sept 2-8	Sept 2-8	4,790	13,763	72,200
)0	Aug 5-11	Aug 12-18	10,760	13,763	567,500
)0	Sept 23-30	Sept 23-30	1,353	13,763	18,800
)0	--	--	--	--	--
)0	Aug 26-Sept 1	Sept 2-8	13,306	13,763	256,400
)0	--	--	--	--	--
)0	Sept 23-30	Sept 23-30	815	13,763	11,300
)0	Aug 12-18	Sept 2-8	8,469	13,763	387,800
)0	Aug 12-18	Aug 19-25	7,997	13,763	258,100
)0	--	--	--	--	--
)0	Sept 23-30	Sept 23-30	7,486	13,763	103,900
)0	Oct 1-6	Octo 1-6	465	13,763	6,500
)0	Aug 12-18	Aug 19-25	15,098	13,763	582,800
)0	--	--	--	--	--
	--	--	--	--	--
	--	--	--	--	--
	--	--	--	--	--
)0	Sept 9-15	Sept 9-15	3,241	13,763	45,000
	--	--	--	--	--
	--	--	--	--	--
)0	Sept 23-30	Sept 23-30	3,160	13,763	43,900
	--	--	--	--	--
)0	--	--	--	--	--
	--	--	--	--	--
)0	--	--	--	--	--
)0	Sept 16-22	Sept. 16-22	445	13,763	6,200
)0	Aug 12-18	Aug 19-25	26,856	8,069	822,600

GLOSSARY

Accretion - the gradual addition of material by the deposition of sediment carried by the water of a stream.

Alluvium - a general term for all detrital deposits resulting from the operations of modern rivers, thus including the sediments laid down in riverbeds, floodplains, lakes, fans at the foot of mountain slopes and estuaries.

Aquiclude - a formation that will not transmit water fast enough to furnish an appreciable supply for a well or spring.

Aquifer - stratum or zone below the surface of the earth capable of producing water as from a well.

Aufeis - a sheet of ice on a river floodplain

Bankfull stage - the water surface elevation attained by the stream when flowing at capacity; i.e., stage above which banks are overflowed.

Bifurcate - forked as in a Y-shape.

Candle - elongate prismatic crystals of ice arranged perpendicular to the surface and in a weakened state.

Colluvial - consisting of alluvium in part and also containing angular fragments of the original rocks.

Diel - a chronological day (24 hours) or distinct from the daylight portion of varying duration.

Epilimnion - the upper layer of a body of water, usually with a small but variable temperature gradient.

Eutrophication - the process by which a body of water becomes overly rich in nutrients and deficient in dissolved oxygen.

Floodplain - that portion of a river valley, adjacent to the river channel, which is built of sediments during the present regimen of the stream and which is covered with water when the river overflows its banks at flood stages.

Fluvial - of or pertaining to rivers; produced by river action.

Frazil ice - ice of small plate-like crystals suspended in the flow.

Glacial flour - rock finely ground by a glacier.

Hypolimnion - that part of a lake below the thermocline.

Ice pan - a large, flat piece of ice.

Lacustrine - pertaining to, produced by, or formed in a lake or lakes.

Lithology - the physical character of a rock.

Meltstream - water resulting from the melting of snow or of glacier ice.

Outwash - drift deposited by meltwater streams beyond active glacier ice.

Periglacial - refers to areas, conditions, processes, and deposits adjacent to the margin of a glacier.

Stratigraphic unit - unit consisting of stratified mainly sedimentary rocks grouped for description.

Thalweg - the line joining the deepest points of a stream channel.

Thermocline - the horizontal plane in a thermal stratified lake located at the depth where temperature decreases most rapidly with depth.

Till - nonsorted, nonstratified sediment carried or deposited by a glacier.

Water year - a one year period extending from October 1 to September 30.