SUSITNA HYDROELECTRIC PROJECT

FERC LICENSE APPLICATION

EXHIBIT E

CHAPTERS 1 AND 2

DRAFT

NOVEMBER 15, 1982

Prepared by:

ACRES

ALASKA POWER AUTHORITY

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1 - GENERAL DESCRIPTION OF THE LOCALE

SUSITNA HYDROELECTRIC PROJECT

EXHIBIT E

VOLUME 1 SECTION 1

GENERAL DESCRIPTION OF THE LOCALE

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1 - GENERAL DESCRIPTION OF THE LOCALE

1.1 - Location

The location of the proposed Susitna Hydroelectric Project is within the east to west flowing section of the upper Susitna River, Alaska, approximately 140 miles north-northeast of Anchorage and 110 miles south-southwest of Fairbanks (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 and 184 river miles upstream of the river's mouth at Cook Inlet. The nearest settlements (Gold Creek, Canyon, Chulitna) are along the Alaska Railroad, approximately 12 miles from Devil Canyon.

1.2 - Physiography and Topography

The Susitna River basin lies 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. In the vicinity of the proposed impoundments (Figure E.1.2), the river cuts a narrow, steep-walled gorge up to 1000 feet deep through the Clarence lake Upland and Fog Lakes Upland, areas of broad, rounded summits 3,000 to 4,200 feet in elevation. Between these uplands, the gorge cuts through an extension of the Talkeetna Mountains, where rugged peaks are 6,900 feet high. Downstream of 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 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 in elevation (the Tanana Flats), and then parallel a ridge on the edge of the Yukon-Tanana Upland.

1.3 - Geology and Soils

In its complex geologic history, the upper Susitna River region has undergone uplifting and subsidence, marine deposition, volcanic intrusion, glacial planing and erosion. The Susitna basin lies within the Talkeetna terrain, a zone of moderate seismicity (see Chapter 6). Continuing erosion has removed much of the glacial debris at higher elevations, but very little alluvial deposition has occurred here. 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 ares, the acidic, relatively infertile soils of the forests; and raw gravels and sands along the river. The upper basin is generally underlaid by discontinuous permafrost.

1.4 - Hydrology

The entire drainage area of the Susitna River is about 19,400 square miles of which the upper basin above Gold Creek comprises approximately 6,160 square miles (Figures E.1.3 and E.1.4). Three glaciers in the Alaska Range feed forks of the Susitna River, flow southbound for about 18 miles before joining to form the main stem of the Susitna River. The river flows an additional 55 miles southward through a broad valley where much of the coarse sediment from the glaciers settle out. The river then flows westward about 96 miles through a narrow valley, with the constrictions at 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 downstream of Devil Canyon its gradient gradually decreases. The river is joined about 40 miles 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 until it empties into Cook Inlet near Anchorage, approximately 318 miles from its source.

Approximately 80 percent of the annual flow occurs between May and September, when the Susitna is heavily laden with glacial silt. Average summer flows at Gold Creek are 20,250 cubic feet per second (cfs); winter flows average only 2100 cfs. In the winter, the river runs clear. The Susitna River above the confluence with the Chulitna River contributes about 20 percent of the mean annual flow measured near the river's mouth.

The upper reaches of the Susitna start to freeze in early October, and by the end of November, the lower river is icebound. Breakup begins in late April or early May, and occasional ice jams may cause the water level to rise as much as 10 feet.

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

1.6 - 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. The major vegetation types within the proposed transmission corridor from Healy to Fairbanks are closed and open deciduous forests, closed and open mixed forests, and mixed low shrub.

1.7 - 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 of the impoundment zone. Moose are farily 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 3,000 feet 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 characteristics 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 peregrime falcon nests exist in or near the reservoir area. One nest exists near the northern leg of the transmission corridor. This nest has not been known to be active since the early 1960's.

1.8 - Fish

Anadromous fish in the Susitna basin include all five species of Pacific salmon: pink (humpback); shum (dog); coho (silver); sockeye (red); and chinook (king) salmon. Salmon migrate up the Susitna to spawn in tributary streams, sloughs, and side channels below Devil Canyon. Limited spawning occurs in the mainstem. Surveys to date indicate that, except for extremely dry years, salmon are unable to ascend the Devil Canyon rapids and are thus prevented from migrating farther into the upper basin. Anadromous smelt (eulachon) are known to migrate into the lower Susitna River, and Bering cisco have recently been discovered.

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.

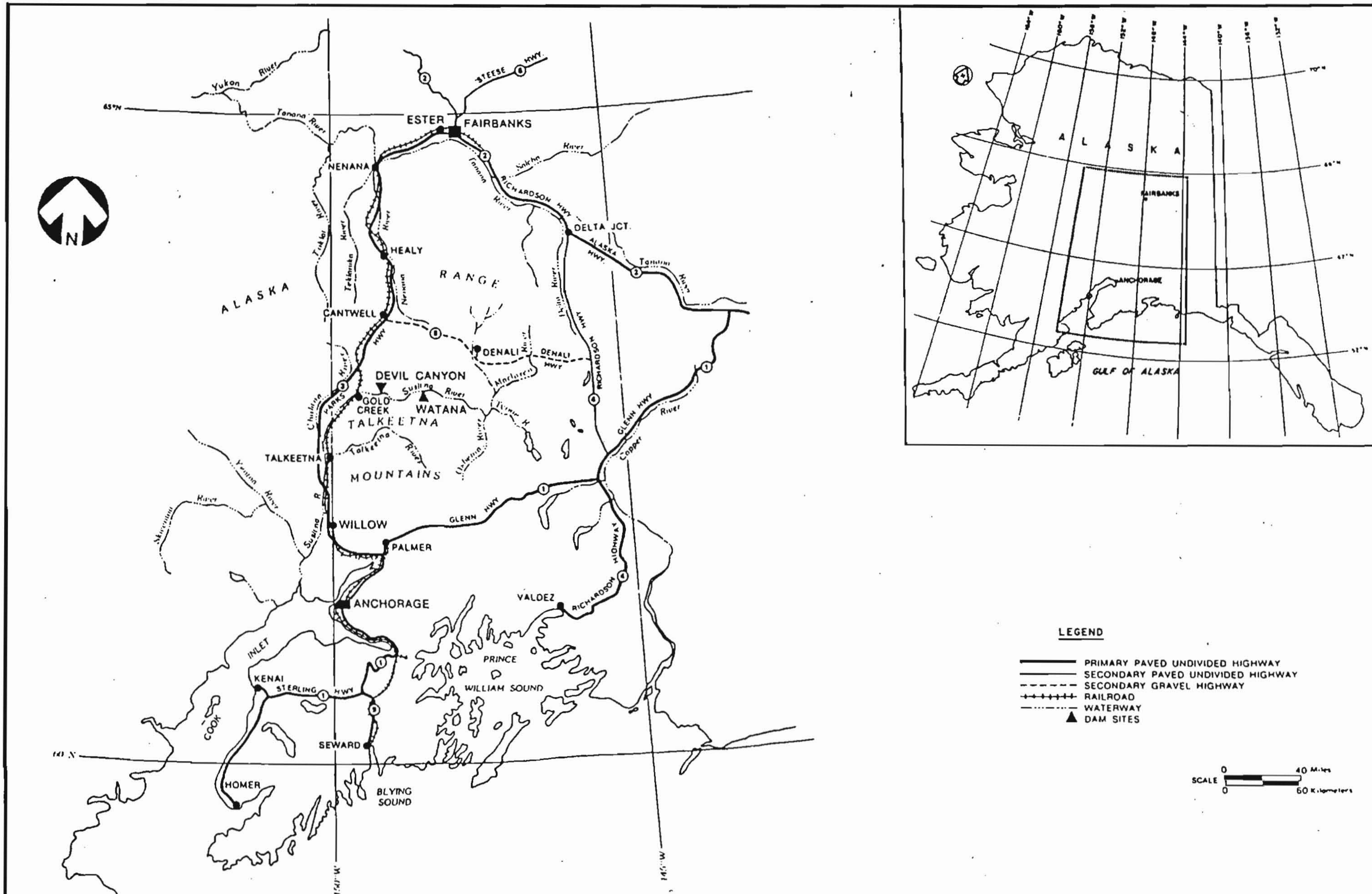
1.9 - Land Use

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. 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).

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.



LOCATION OF THE PROPOSED SUSITNA HYDROELECTRIC PROJECT

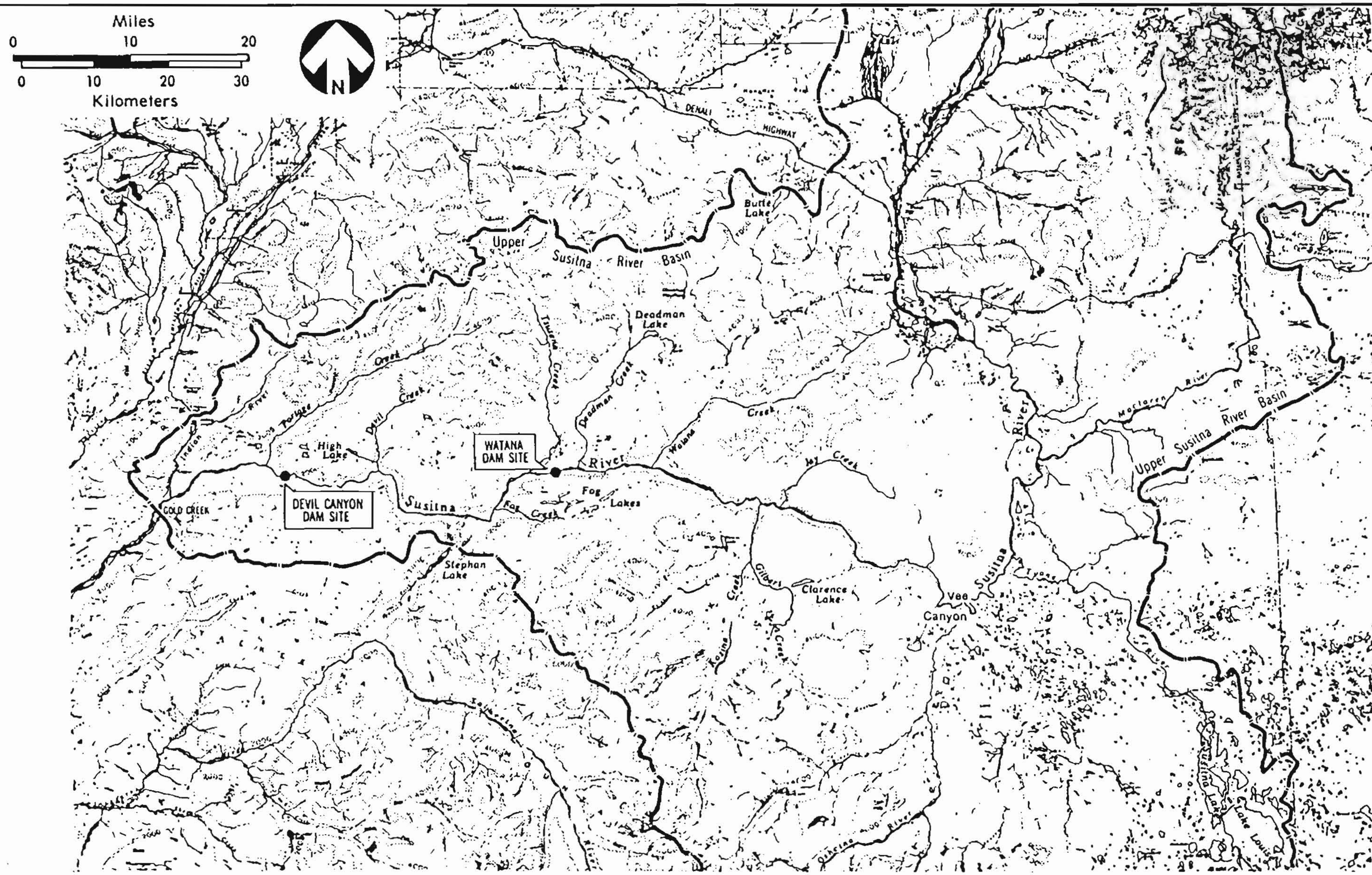
FIGURE E.1.1

WATANA, VIEW UPSTREAM

DEVIL CANYON, VIEW UPSTREAM

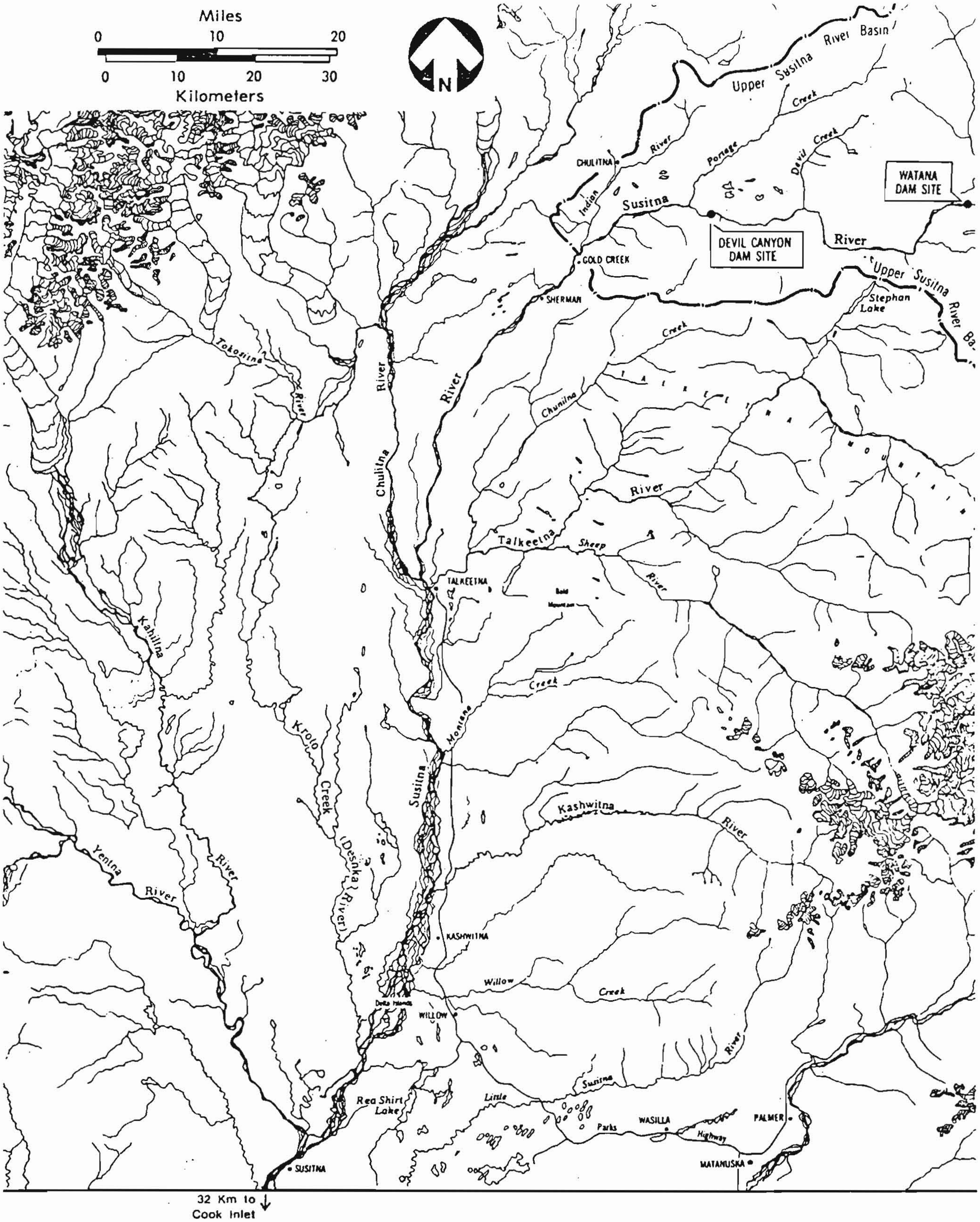
VICINITIES OF THE PROPOSED
DAM SITES, SUSITNA HYDROELECTRIC PROJECT

FIGURE E.1.2



UPPER SUSITNA RIVER BASIN

FIGURE E.1.3



LOWER SUSITNA RIVER DRAINAGE

FIGURE E.1.4

2 - WATER USE AND QUALITY

SUSITNA HYDROELECTRIC PROJECT

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VOLUME 1 CHAPTER 2

WATER USE AND QUALITY

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2 - REPORT ON WATER USE AND QUALITY

1 - INTRODUCTION

The Report on Water Use and Quality is divided into four basic sections: baseline conditions, project impacts, agency concerns and recommendations, and mitigatives, enhancement, and protective measures. Within the sections on baseline conditions and project impacts, emphasis is placed on flows, water quality parameters, ground water conditions and instream flow uses. The importance of flows cannot be overstressed. Flows are important to all instream uses. Mean flows, flood flows, low flows and flow variability are discussed.

The primary focus of the water quality discussion is on those parameters determined most critical for the maintenance of fish populations and other aquatic organisms. Detailed discussions are presented on water temperature both in the mainstem Susitna River and in the sloughs downstream of Devil Canyon, ice, suspended sediment in the reservoirs and downstream, turbidity, dissolved oxygen, nitrogen supersaturation and nutrients. These parameters have previously been identified as areas of greatest concern.

Mainstem-slough groundwater interaction downstream of Devil Canyon is important to salmonid spawning in sloughs and is discussed.

The primary instream flow uses of the Susitna are for fish, wildlife and riparian vegetation. As these are fully discussed in Chapter 3, they are only briefly discussed in this Chapter. However, other instream flow uses including navigation and transportation, waste assimilative capacity and freshwater recruitment to estuaries are discussed. Since minimal out of river use is made of the water, Talkeetna being the only town located near the river and not relying on the river for its water supply, only limited discussions have been presented on out of river uses.

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

The agency concerns and recommendations received to date are summarized.

The mitigation plan incorporates 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 upper basin above Gold Creek comprises approximately 6160 square miles (Figure E.2.1). Three glaciers in the Alaska Range feed forks of the Susitna River, flow southward for about 18 miles and then join to form the Susitna River. The river flows an additional 55 miles 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 constrictions at 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 downstream of the mouth of Devil Canyon, its gradient gradually decreases. The river is joined about 40 miles 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 about 97 miles until it empties into Cook Inlet near Anchorage, approximately 318 miles from its source.

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.

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 snow melt 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.

2.1 - Susitna River Water Quality

(a) Mean Monthly and Annual Flows

Continuous historical streamflow records of various record length (8 to 32 years) exist for gaging stations on the Susitna River and its tributaries: Gages are located at Denali, Cantwell (Vee Canyon), Gold Creek and Susitna Station on the Susitna River; on the Maclaren River near Paxson; Chulitna Station on the Chulitna River; Talkeetna on the Talkeetna River; and Skwentna on the Skwentna River. In 1981 a USGS gaging station was constructed at Sunshine on the Susitna River; however, the streamflow record is of such a short duration it has not been used in most of the hydrologic analysis. Statistics on river mile, drainage area and years of record are shown in Table E.2.1. The station locations are illustrated in Figure E.2.1.

A complete 32 year streamflow data set for each gaging station was generated through a correlation analysis, whereby missing mean monthly flows were estimated (Acres 1982a). The resultant monthly and annual maximum, mean and minimum flows for the 32 year record are presented in Table E.2.2.

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 gage sites. The resultant mean, maximum and minimum monthly flows are also provided in Table E.2.2.

Comparison of flows indicates that 40 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 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 and winter flows is greater than a 10 to 1 ratio at all stations. This large seasonal difference is due to the characteristics of the basin. Glacial melt, snowmelt, and rainfall provide the majority of the annual river flow during the summer. At Gold Creek, for example, 88 percent of the annual streamflow occurs during the summer months of May through September.

The maximum and minimum monthly flows for the months of May through September indicate a high flow variability at all stations on a year to year basis.

(b) Floods

The most commong causes of floods in the Susitna River Basin are snowmelt or a combination of snowmelt 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 also occurred in August, September or October. These floods are augmented by snowmelt from higher elevations and glacial run-off. Table E.2.3 presents selected flood peaks at four gaging stations. Figures E.2.2 to E.2.8 illustrate annual instantaneous flood frequency curves for individual stations.

A regional flood frequency analysis was conducted using the recorded floods in the Susitna River and its principal tributaries (R&M, 1981a). The resulting dimensionless regional frequency curve is depicted in Figure E.2.9. 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 cubic feet per second (cfs) and 45,900 cfs respectively. The regional flood frequency curve was compared to the station frequency curve at Gold Creek (Table E.2.4). As the Gold Creek 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 flood frequency curves for Watana and Devil Canyon are presented in Figures E.2.10 and E.2.11.

Dimensionless flood hydrographs for the Susitna River at Gold Creek were developed for the May - July snowmelt floods and the August - October rainfall floods using the five largest Gold Creek floods occurring in each period (R&M, 1981a). 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.2.12 and E.2.13 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. These studies which are based on Susitna Basin climatic data and hydrology, indicate that the PMF peak at the Watana damsite is 326,000 cfs.

(c) 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, 1982a). These curves which are based on mean daily flows are illustrated on Figures E.2.14 through E.2.17.

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. Streamflow is low in the winter months, with little variation in flow and no unusual peaks. Groundwater contributions are the preliminary 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 snowmelt/breakup flows occur. June has the highest peaks and the highest median flow. 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 snowmelt and glacial melt during the summer. More variability of flow is evident in September and October as cooler weather becomes more prevalent.

The 1-day, 3-day, 7-day and 15-day high and low flow values were determined for each month from May through October for the periods of record at Gold Creek, Chulitna River near Talkeetna, Talkeetna River near Talkeetna and Susitna River at Susitna Station (R&M, 1982a). The high and low flow values are presented for Gold Creek in the form of frequency curves in Figures E.2.18 through E.2.21. May showed the most variability. It is the month when either low winter flows or high breakup flows may occur and thus significant changes occur from year to year. June and July generally exhibited less variability than the late summer months. Flow variability increased in the August through October period. Heavy rainstorms often occur in August, with 28 percent of the annual floods occurring in this month.

2.2 - Susitna River Morphology

(a) Mainstem

The Susitna River originates in the glaciers of the southern slopes of the central Alaskan Range, flowing 318 miles to its mouth at Cook Inlet.

The headwaters of the Susitna River and its major upper tributaries are characterized by broad braided gravel floodplains below the glaciers, with several meltstreams exiting from beneath the glaciers before they combine further downstream. The West Fork Susitna River joins the main river about 18 miles below Susitna Glacier. Below the West Fork confluence, the Susitna River becomes a split-channel configuration with numerous islands. The river is generally constrained by low bluffs for about 55 miles. The Maclaren River, a significant glacial tributary, and the 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 through steep-walled canyons before reaching the mouth of Devil Canyon. The river has a high gradient through this reach and includes the Watana and Devil Canyon Damsites. It is primarily a single channel with intermittent islands. Bed material primarily consists of large grravel cobbles. The mouth of Devil Canyon, at River Mile (RM) 149 forms the lower limit of this reach.

Between Devil Canyon and the mouth at Cook Inlet, the river has been subdivided into nine separate reaches. These reaches are identified in Table E.2.5, together with the average slope and predominent channel pattern. These reaches are discussed in more detail below.

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, depostion 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.

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.

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 receive Susitna water only at flows above 15,000 to 20,000 cfs. Often, valley bottom springs flow into sloughs. 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 armoured.

Primary tributaries include Indian River, Gold Creek and Fourth of July Creek. Each has formed an alluvial fan extending into the valley bottom and 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.

RM 129.5 to RM 119

River patterns through this reach are similar to those in the previous reach. The most prominent characteristic between Sherman and Curry is that the main channel prefers to flow against the west valley wall and the east floodplain has several side channels and sloughs. The alluvial fan at Curry constricts the Susitna to a single channel and terminates the above described patterns. A fair correlation exists between bankfull stage and mean annual flood through this reach. Comparison of 1950 and 1980 airphotos reveals 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.

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.

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 Chulitna River has a mean annual flow similar to the Susitna at Gold Creek, yet its drainage basin is about 40 percent smaller. Its glacial tributaries are much closer to the confluence than the Susitna. As it emerges from the incised canyon 20 miles 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 confluence, the Chulitna exhibits a highly braided pattern with no vegetation on intermediate gravel bars, evidence of recent lateral instability. This pattern continues beyond the confluence and giving the impression that the Susitna is tributary to the dominant Chulitna River. The split channel Talkeetna River is 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.

RM 95 to 61

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

The channel network consits 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 (split) 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 five feet higher. Their flow regime is dependent on the main channel stage and hydraulic flow controls 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 is intermittently controlled laterally where it flows 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 is where the terraces constrict the river to a single channel at the Parks Highway bridge. Subchannels are directly dependent on main channel flow and sediment regime, and generally react the same. Minor channels react to both of the larger channels' behaviors.

RM 61 to RM 42

Downstream of the Kashwitna River confluence, the Susitna River branches into multiple channels separated by islands with established vegetation. This reach of the river has been named 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.

RM 42 to RM 0

Downstream of the Delta Islands, the Susitna River gradient decreases as it approaches Cook Inlet. 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 the Cook Inlet rise above 30 feet and therefore control the water surface profile and to some degree the sediment regime of the lower river. River elevation of 30 feet exists at about RM 20 and corresponds to where the Susitna begins to branch out into its delta channels.

(b) Sloughs

Sloughs are spring-fed, perched overflow channels that only convey glacial meltwater from the mainstem during median and high flow periods. At intermediate and low flows, the sloughs convey clear water from small tributaries and/or upwelling groundwater. Differences between mainstem water surface elevations and the streambed elevation of the side sloughs are notably greater at the upstream entrance to the slough than at the mouth of the slough. The graidents within the slough are typically greater than the adjacent mainstem. An alluvial berm separates the head of the slough from the river, whereas the water surface elevation of the mainstem generally causes a backwater effect at the mouth of the slough. The sloughs function like small stream systems. Several hundred feed of channel exist in each slough conveying water independent of mainstem backwater effects.

The sloughs vary in length from 2,000 - 6,000 feet. Cross-sections of sloughs are typically rectangular with flat bottoms. At the head of the sloughs, substrates are dominated by boulders and cobbles (8-14 inch diameter). Progressing towards the slough mouth, substrate particles reduce in size with gravels and sands predominating. Beavers frequently inhabit the sloughs. Active and abandoned dams are visible. Vegetation commonly covers the banks to the waters edge with bank cutting and slumping occurring during spring break-up flows. The importance of the sloughs as salmon spawning habitat is discussed in detail in Chapter 3.

2.3 - Susitna River Water Quality

As previously described in Section 2.2, the Susitna River is characterized by large seasonal fluctuations in discharge. These flow variations along with the glacial origins of the river essentially control the water quality of the river.

Existing water quality data have been compiled for the mainstem Susitna River from stations located at Denali, Vee Canyon, Gold Creek, Sunshine, and Susitna Station. In addition, data from two Susitna River tributaries, the Chulitna and Talkeetna Rivers, have also been compiled (R&M, 1982b). The station locations are presented in Figure E2.1.

Data were compiled corresponding to three seasons: breakup, summer, and winter. Breakup is usually short and extends from the time ice begins to move down river until recession of spring runoff. Summer extends from the end of breakup until the water temperature drops to essentially 0°C in the fall, and winter is the period from the end of summer to breakup. The water quality parameters measured and their respectively detection limits appear in Table E.2.6.

The water quality was evaluated (R&M 1982b) using guidelines and criteria established from the following references:

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

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

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

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

- EPA, Water Quality Criteria Documents; Availability. Environmental Protection Agency, Federal Register, 45, 79318-79379 (November 28, 1980).

The guidelines or criteria used for the parameters were chosen based on a priority system. Alaska Water Quality Standards were the first choice, followed by criteria presented in EPA's Quality Criteria for Water. If a criterion expressed as a specific concentration was not presented in the above two references, the other cited references were used as the source.

A second priority system was used for selecting the guidelines or criteria presented for each parameter. This was required because the various references presented above cite levels of parameters that provide for the protection of identified water uses, such as (1) the propagation of fish and other aquatic organisms, (2) water supply for drinking, food preparation, industrial processes, and agriculture, and (3) water recreation. The first priority, therefore, was to present the guidelines or 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 or criteria if available. It should be noted that water quality standards set criteria which limit man-induced pollution to protect identified water uses. Although the Susitna River basin is a pristine area, some parameters naturally exceeded their respective criterion. These parameters are presented in Table E.2.7. As noted in Table E.2.7, criteria for three parameters have been set at a level which natural waters usually do not exceed. The suggested criteria for aluminum and bismuth are based on human health effects. The criterion for total organic carbon (TOC) was established at 3 mg/l. Water containing less than this concentration has been observed to be relatively clean. However, streams in Alaska receiving tundra runoff commonly exceed this level. The maximum TOC concentration reported herein, 20 mg/l, is likely the result of natural conditions. The criterion for manganese was established to protect water supplies for human consumption. The criteria presented for the remaining parameters appearing in Table E.2.7 are established by law for protection of freshwater aquatic organisms. The water quality standards apply to man-induced alterations and constitute the degree of degradation which may not be exceeded. Because there are no industries, 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. Since criteria exceedance is attributed to natural conditions, little additional discussion will be given to these phenomenon. Also, these rivers support diverse populations of fish and other aquatic life. Consequently, it is concluded that the parameters exceeding their criteria probably do not have significant adverse effects on aquatic organisms.

In the following discussion, parameters measured during breakup will generally not be discussed since data normally indicate a transition period between the winter and summer extremes and the data itself is usually limited. Levels of water quality parameters discussed in the following section are reported by R&M (1982b), unless otherwise noted.

(a) Physical Parameters

(i) Water Temperature

- Mainstem

In general, during winter, the entire mainstem Susitna River is at or near 0°C. However, there are a number of small discontinuous areas with groundwater inflow of near 2°C. As spring breakup occurs the water temperature begins to rise, generally warming with distance downstream.

In summer, glacial melt is near 0°C as it leaves the glacier, but as it flows across the wide gravel floodplain below the glaciers the water begins to warm. As the water winds its way downstream to the proposed Watana damsite it can reach temperatures as high as 14°C. Further downstream there is generally some additional warming but, temperatures may be cooler at some locations due to the effect of tributary inflow. In August, temperatures begin to drop, reaching 0°C in late September or October.

The seasonal temperature variation for the Susitna River at Denali and Vee Canyon during 1980 and for Denali and Watana during 1981 are displayed in Figures E.2.26 and E.2.27. Weekly averages for Watana in 1981 are shown in Figure E.2.28. The shaded area indicates 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 presented in Figure E.2.29. The recorded variation in water temperatures at the seven USGS gaging stations is displayed in Figure E.2.30.

Additional data on water temperature are available in the annual reports of U.S.G.S. 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 - 1982), and in Water Quality Data - 1981b, ~~1981c~~, R&M Consultants.

- Sloughs

The sloughs downstream of Devil Canyon have a temperature regime that differs form 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.2.31. These measurements indicated that intergravel temperatures were relatively constant through February and March at each location but exhibited some variability from one location to another. At most stations intergravel temperatures were within the 2-3°C range. Slough surface temperatures showed more variability at each location and were generally lower than intergravel temperatures during February and March (Trihey, 1982a).

During spring and summer, when flow at the head of the slough is cut off, slough temperatures tend to differ from mainstem temperatures. During periods of high flows, when the head end is overtopped, slough water temperatures correspond more closely to mainstem temperatures. Figure E.2.32 compares weekly diel surface water temperature variations during September, 1981 in Slough 21 with the mainstem Susitna River at Portage Creek (ADF&G, 1982). The slough temperatures show a marked diurnal variation caused by increased solar warming of the shallow water during the day and subsequent long wave back radiation at night. Mainstem water temperatures are more constant because of the buffering and mixing capability of the river.

- Tributaries

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

The 1982 mean daily temperature records for Indian River and Portage Creek are compared in Figure E.2.33. Portage Creek was consistently cooler than Indian River by 0.1 to 1.9°C. The flatter terrain in the lower reaches of the Indian River valley is apparently more conducive to solar and connective heating than the steep-walled canyon of Portage Creek. Figure E.2.33 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 flucutations in the open-water tributary temperatures, though not as extreme as in the sloughs. Daily variation of up to 6.5°C (from 3.0 to 9.5°C) was observed at Portage Creek in 1982 (June 14).

The major tributaries joining the Susitna at Talkeetna show uniform variation in temperatures from the mainstem. Compared to the Talkeetna fishwheel site on the Susitna, the Talkeetna River temperature is 1-3°C cooler on a daily average basis. The Chulitna River, being closer to its glacial headwaters, is from 0 to 2°C cooler than the Talkeetna river, and has less during fluctuations.

Winter stream temperatures are expected to be very close to 0°C, as all the tributaries do freeze up. Groundwater inflow at some locations may create local conditions above freezing, but the overall temperature regime would be affected by the extreme cold in the environment.

(ii) Ice

- Freeze-up

Air temperatures in the Susitna basin increase from the headwaters to the lower reaches. While the temperature gradient is partially due to the two - degree latitudinal span of the river, it is, for the most part due to the 3,300-foot difference in elevation 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) in which the air temperatures in the lower basin are above freezing while subfreezing in the upper basin. The location of freezing air temperatures moves in a downstream direction as winter progresses (R&M, 1982c).

Frazil ice forms in the upper segment of the river first, due to the initial cold temperatures of glacial melt and the earlier cold 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 lower river, often a result of frazil-ice pans and floes jamming in suitable reaches.

Once frazil ice jams form, the ice cover progresses upstream, often raising water levels by 2 to 4 feet. Border ice formation along the river banks also serves to restrict the channel.

The upper Susitna River is the primary contributor of ice to the river system below Talkeetna, contributing 75-85 percent of the ice load in the Susitna-Chulitna-Talkeetna Rivers. Ice formation on the Chulitna and Talkeetna Rivers normally commences several weeks after freeze-up on the middle and upper Susitna River.

- Winter Ice Conditions

Once the solid ice cover forms, open leads still occur in areas of high-velocity water or groundwater 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 thick by breakup, but thicknesses of over 10 feet have been recorded near Vee Canyon.

Some of the side-channels and sloughs above Talkeetna do not form an ice cover during winter due to groundwater exfiltration. Winter groundwater temperatures generally varying between 2°C to 4°C contribute enough heat to prevent the ice cover from forming (Trihey 1982a). These areas are often salmonid egg incubation areas.

- Breakup

The onset of warmer air temperatures occurs in the lower basin several weeks earlier than in the upper basin, due to the temperature gradient previously noted. The low-elevation snowpack melts first, causing 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 snowmelt rate, on 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. Strong forces on the ice cover do not occur to initiate ice movement resulting in a mild breakup, as occurred in 1981 (R&M, 1981d). 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 this movement coupled with ice left in a strong condition from the cooler temperatures leads to numerous and possibly severe ice jams which may result in flooding and erosion, as occurred in 1982 (R&M, 1982f).

The flooding results in high flows through numerous side-channels 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, 1982a).

(iii) 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 snowmelt. Beginning with spring breakup, suspended sediment concentrations begin to rise from their near zero winter levels. During summer, values as high as 5700 mg/l have been recorded at Denali, the gaging station nearest the glacially-fed headwaters. Before entering the areas of the proposed reservoirs, concentrations decrease due to the inflow from several clear water tributaries. Maximum summer concentrations of 2600 mg/l have been observed at Gold Creek. Below Talkeetna, concentrations increase due to the contribution of the sediment-laden Chulitna River which has 28 percent of its drainage area covered by year round ice. Maximum values of 3000 mg/l have been recorded at the Susitna Station gage. A more extensive summary of suspended sediment concentrations is presented in Figure E.2.34.

Suspended sediment discharge has been shown to increase with discharge (R&M, 1982d). This relationship for various upper Susitna River stations is illustrated in Figure E.2.35.

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

Gaging Station	Average Annual Suspended Sediment Load (tons/year)
Susitna River at Denali	2,965,000
Susitna River near Cantwell	6,898,000
Susitna River at Gold Creek	7,731,000

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 (R&M, 1982d).

A suspended sediment size analysis for upper Susitna River stations is presented in Figure E.2.36. The analysis indicates that between 20 and 25 percent of the suspended sediment is less than 4 microns (.004 millimeters) in diameter.

(iv) Turbidity

- Mainstem

The Susitna River is typically clear during the winter months with values at or very near zero. Turbidity increases as snowmelt and breakup commence. The peak turbidity values occur during summer when glacial input is greatest.

Limited turbidity data are available for the headwaters of the Susitna River. However, measurements up to 350 Nepholometer Turbidity units (NTU) have been recorded at Denali. Turbidity tends to decrease in the vicinity of the project areas due to clearwater inflow, although high values still exist. At the mouth of the Chulitna River near Talkeetna, values of over 1900 NTU have been observed. In contrast, maximum observed values on the Talkeetna River, with its minimal glacial input, were 270 NTU. Results of data collection are summarized in Figure E.2.37 (R&M, 1982e). Data collected at various sites in 1982 are tabulated in Table E.2.8.

Figure E.2.38 shows the direct relationship between suspended sediment concentation and turbidity as measured on the Susitna River at Cantwell, Gold Creek, and Chase (Peratrovich, Nottingham and Drage, 1982a). However, suspended sediment concentrations can vary significantly at similar flow ranges, as the glaciers contribute highly variable amounts of sediment (R&M, 1982d).

- Sloughs

Turbidity values for selected sloughs were collected by ADF&G during the summer of 1981. The turbidity in the sloughs was less than the turbidity in the mainstem except when upstream ends were overtopped at which time the turbidities usually mirrored mainstem levels (ADF&G, 1982). Even with overtopping, some sloughs maintained lower turbidity due to groundwater or tributary inflow.

(v) Vertical Illumination

Vertical illumination through the water column varies directly with turbidity and suspended sediment concentration and hence follows the same temporal and spatial patterns. 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, as the river is exceptionally clear. Vertical illumination under an ice cover is inhibited, especially if the ice is not clear and if a snow cover exists over the ice.

(vi) Total Dissolved Solids (TDS)

Dissolved solids concentratons are higher, and exhibit a wider range during the winter low-flow periods than during the summer period. Data at Denali range from 110-270 mg/l in the winter and from 40-170 mg/l in the summer. Progressing downstream on the Susitna River basin, TDS concentrations are generally lower.

Gold Creek TDS winter values are 100-190 mg/l, while summer concentrations are 50-140 mg/l. Measurements at Susitna Station, range from 100-140 mg/l during winter and between 55 and 80 mg/l in the summer. Figure E.2.39 provides a graphic representation of the data collected.

(vii) Specific Conductance (Conductivity)

Susitna River conductivity values are high during winter low-flow periods and low during the summer. In the upstream reaches where glacial input is most significant, conductivity is generally higher. At Denali, values range from 190-510 umhos/cm in the winter and from 120-205 umhos/cm in the summer.

Below Devil Canyon, conductivity values range from 160-300 umhos in the winter and from 60-230 umhos/cm in the summer. The Chulitna and Talkeetna Rivers have slighly lower conductivity values, but are in the same range as in the Susitna River.

Figure E.2.40 graphically provides the maximum, minimum and the mean values as well as the number of conductivity observations for the seven gaging stations.

(viii) Significant ions

Concentrations of the significant ions are generally low to moderate, with summer concentrations lower than winter concentrations. 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 listed in Table E.2.9. The ranges of ion concentrations at each monitoring station are presented in Figures E.2.41 to E.2.46.

(ix) pH

Average pH values tend to be slightly alkaline with values typically ranging between 7 and 8. A wider range is generally exhibited during the spring breakup and summer months with values occasionally dropping below 7. This phenomenon is common in Alaskan streams and is attributable to the acidic tundra runoff.

Winter pH ranges at the Gold Creek station are between 7.0 and 8.1 while the range of summer values is 6.6 to 8.1. Figure E.2.47 displays the pH information for the seven stations of record.

(x) Total Hardness

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

Total hardness, measured as calcium magnesium hardness and reported in terms of $CaCO_3$, ranges between 60-120 mg/l at Gold Creek during winter, and betwen 30-105 mg/l in the summer. At Susitna Station, winter values are 70-95 mg/l while summer values range from 45 to 60 mg/l.

Figure E.2.48 presents more detailed total hardness information.

(xi) Total Alkalinity

Total Alkalinity concentrations with bicarbonate typically being the only form of alkalinity present, exhibit moderate to high levels and display a much larger range during winter than the low to moderate summer values. In addition, upstream concentrations are generally larger than downstream values.

Winter values at Gold Creek range between 45 and 145 mg/l, while summer values are in the range of 25 to 85 mg/l. In the lower river at Susitna Station, winter concentrations are between 60-75 mg/l and summer levels are in the range of 40-60 mg/l.

Figure E.2.49 displays a more detailed description of total alkalinity concentrations.

(xii) True Color

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

Color levels at Gold Creek vary between 0 and 10 color units during winter and 0 to 40 units in the summer. It is not uncommon for color levels in Alaska to be as high as 100 units for streams receiving tundra runoff, i.e., the maximum recorded value at the Sunshine gauge.

Figure E.2.50 displays the data collected.

(xiii) Metals

The concentrations of many metals monitored in the river were low or within the range characteristic of natural waters. Eight parameters antimony (sb), boron (B), gold (Au), dissolved molybdenum (M), platinum (Pt), tin (Sn), vanadium (V) and zirconium (Zr) were below detectable limits. However, the concentrations of some trace elements exceeded water quality guidelines for the protection of freshwater organisms. (Table E.2.4). 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 have exceeded these limites include aluminum (Al), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), mercury (Hg), nickel (Ni) and zinc (Zn).

Figures E.2.51 through E.2.68 summarize the heavy metal data that were collected.

(b) Dissolved Gases

(i) Dissolved Oxygen

Dissolved oxygen (D.O.) concentrations generally remain quite high throughout the drainage basin. Winter values average near 13 mg/l while summer concentrations average between 11 and 12 mg/l. These concentrations equate to dissolved oxygen saturation levels generally exceeding 80 percent, although summer values average near 100 percent. Winter saturation levels decline slightly from summer levels, averaging near 97 percent at Gold Creek and 80 percent at Susitna Station.

Figures E.2.69 and E.2.70 contain additional dissolved oxygen data.

(ii) Nitrogen Supersaturation

Limited sampling for dissolved gas concentrations, namely nitrogen and oxygen, was performed during the 1981 field season. However, continuous monitoring equipment was installed in the vicinity of Devil Canyon for approximately two months (8 August - 10 October) during 1982. This data is not available at this time but will be included when it is available. The 1981 data indicated that supersaturation existed above Devil Canyon as well as below ranging from 105.3 percent to 116.7 percent, respectively.

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

(c) Nutrients

Nutrient concentrations, specifically nitrate nitrogen and orthophosphate, exist in low to moderate concentration throughout the Susitna River. Nitrate concentrations are less than 1.0 mg/l along the Susitna, although Talkeetna River values have reached 2.5 mg/l. Gold Creek nitrate concentrations vary from below detectable limits to 0.4 mg/l.

Biologically available orthophosphates are generally less than 0.2 mg/l throughout the drainage basin. Gold Creek orthophosphate values vary from below detectable limits to 0.1 mg/l. most values at Vee Canyon are also in this range. This data is depicted in Figures E.2.71 and E.2.72.

Studies of glacially influenced lakes in Alaska (Koenings and Kyle, 1982) and Canada (St. John et al., 1976) indicate that over 50 percent of the total phosphorus concentration in the lakes studied was biologically inactive. This was attributed to the fact that the greatest percentage of the lakes' total phosphorus occurred in the particulate form. Consequently, phosphorus available in the dissolved form is much less than recorded values. This is discussed in more detail by Peterson and Nichols, (1982).

Of the major nutrients--carbon, silica, nitrogen and phosphorus, the limiting nuturient in the Susitna River is phosphorus (Peterson and Nichols 1982).

(d) Other Parameters

(i) Chlorophyll-a

Chlorophyll-a as a measure of algal biomass is quite low due to the poor light transmissivity of the glacial 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 for chlorophyll-a (periphyton uncorrected) have been recorded. However, using the chromospectropic technique, 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.

No data on chlorophyll-a are available for the upper basin. However, with the very high suspended sediment concentrations and turbidity values, it is expected that chlorophyll-a values are very low.

(ii) Bacteria

No data are available for bacteria in the upper river basin. 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 quite low.

Only 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 quite low, with all 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.

(iii) Others

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. Since no significant sources of these parameters are known to exist in the drainage basin, no further discussions will be pursued.

(e) Water Quality Summary

The Susitna River is a fast flowing, cold-water glacial stream of the calcium bicarbonate type containing soft to moderately hard water during breakup and 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 acquatic organisms.

2.4 - Baseline Ground Water Conditions

(a) Description of Water Table and Artesian Conditions

The landscape of the upper 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, although there is 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 unconfined aquifers. The bedrock within the basin comprises 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 (Freethey and Scully, 1980).

(b) 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.

(c) Locations of Springs, Wells, and Artesian Flows

Due to the wilderness character of the basin, there is no data on the location of springs, wells, and artesian flows. However, 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 unconfined aquifers (Freethey and Scully, 1980).

(d) Hydraulic Connection of Mainstem and Sloughs

Ground water studies in respresentative sloughs downstream of Devil Canyon indicate that there is a hydraulic connection between the mainstem Susitna River and the sloughs. These sloughs are used by salmonid species for spawning and hence are important to the fisheries. Ground water observation wells indicate that the upwelling in the sloughs, which is necessary for egg incubation, 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 indicates that the mainstem Susitna River is the major source of ground water inflow in 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.

2.5 - Existing Lakes, Reservoirs, and Streams

(a) Lakes and Reservoirs

There are no existing reservoirs on the Susitna River or on any of the tributaries flowing into either Watana or Devil Canyon Reservoirs. No lakes downstream of the reservoirs are expected to realize any impact from project construction, impoundment, or operation. A few lakes at and upstream of the damsites, however, will be affected by the project.

The annual maximum pool elevation of 2190 feet in the Watana Reservoir will inundate several lakes, none of which are named on USGS topographic quadrangle maps. Most of these are small tundra lakes and are located along the Susitna between RM 191 and RM 197 near the mouth of Watana Creek. There are 27 lakes less than 5 acres in surface area, one between 5 and 10 acres, and one relatively large one of 63 acres, all on the north side of the river. In addition, a small lake (less than 5 acres) lies on the south shore of the Susitna at RM 195.5 and another of about 10 acres in area lies on the north side of the river at RM 204. Most of these lakes appear to be simply perched, but five of them are connected by small streams to Watana Creek or to the Susitna River itself.

A small lake (2.5 acres) lies on the south abutment near the Devil Canyon damsite, at RM 151.3, and at about elevation 1400 feet. No other lakes exist within the proposed Devil Canyon Reservoir.

(b) Streams

Several streams in each reservoir will be completely or partially inundated by the raised water levels during project filling and operation. The streams appearing on the 1:63,360 sclae USGS quadrangle maps are listed by reservoir in Tables E.2.10 and E.2.11. Listed in the tables are map name of each stream, river mile locations of the mouth, existing elevation of the stream mouths, the average stream gradient, the number of miles of stream to be inundated. Annual maximum reservoir elevations of 2190 feet and 1455 feet were used for these determinations for the Watana and Devil Canyon pools, respectively.

There is a small slough with two small ponds on it at RM 212, four miles upstream from the mouth of Jay Creek. This slough, which is at approximately elevation 1750, will be completely inundated by the Watana Reservoir. Similarly, there are five sloughs (at RM 180.1, 174.0, 173.4, 172.1, and 169.5) which will be totally inundated by the Devil Canyon Reservoir.

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. Analysis was done on 19 streams between Devil Canyon and Talkeenta which were determined to be important for fishery reasons or for maintenance of existing crossings by the Alaska Railroad (R&M 1982). These streams are listed in Table E.2.12, with their river mile locations and reason for concern.

2.6 - Existing Instream Flow Uses

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

(a) Downstream Water Rights

The 18 different areas in the Susitna River Basin investigated for water rights are shown in Figure E.2.73 (Dwight, 1981). Table E.2.13 indicates the total amount of surface water and ground water appropriated within each area. The only significant uses of surface water in the Susitna River Basin occur in the headwaters of the Kahiltna and Willow Creek township grids where placer mining operations take place on a seasonal basis. No surface water withdrawals from the Susitna River are on file with the Alaska Department of Natural Resources (DNR). Ground water appropriations on file with DNR for the mainstem Susitna River corridor are minimal, both in terms of number of users and the amount of water being withdrawn.

An analysis of topographic maps and overlays showing the specific location of each recorded appropriation within the mainstem Susitna River corridor indicated that neither the surface water diversions from small tributaries nor the groundwater withdrawals from shallow wells will be adversely affected by the proposed Susitna Hydroelectric project (Dwight 1981). Hence, no further discussion on water rights is presented.

(b) 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, and Arctic grayling. Instream flows presently provide for fish passage, spawning, incubation, rearing, overwintering, and outmigration. These activities are correlated to the natural hydrograph. Salmon spawn on the receeding limb of the hydrograph, the eggs incubate through the low-flow period and fry emergence occurs on the ascending limb of the hydrograph. Rainbow trout and grayling spawn during the high flows of the breakup period with embryo development occurring during the early summer. Alteration of the natural flow regime during reservoir filling and project operation will likely result in both detrimental and beneficial effects on the fishery resources of the Susitna River (see Chapter 3).

(c) Navigation and Transportation

Navigation and transportation use of the Susitna River presently consists of boating for recreation sport fishing, hunting, and some transportation of goods. The reach from the headwaters of the Susitna River to the Devil Canyon damsite has experienced limited use, primarily related to hunters and fishers' access to the Tyone River area after launching at the Denali Highway. Some recreational kayaking, canoeing, and rafting has also taken place downstream from the Denali Highway Bridge, generally stopping near Stephan Lake or some other points above the rapids at Devil Creek. Steep rapids near Devil Creek and at the Devil Canyon damsite are barriers to most navigation, though a very small number of kayakers have successfully traveled through the Devil Canyon rapids in recent years. There have been several unsuccessful attempts to penetrate the canyon, both going upstream and downstream, in a powerboat and in kayaks.

Below Devil Canyon, the river is used for access to salmon fishing at several sites as far upstream as Portage Creek. This is undertaken by private boat-owners and by anglers using commercial boat operators. In either case, most of the boat-launching is done at Talkeetna. Commercial operators from Talkeetna also cater to sightseeing tourists, who travel upriver to view the diversified terrain and wildlife. There is recreational boating in this reach, frequently by kayakers or canoeists floating downriver to Talkeetna from the railroad access point at Gold Creek.

Access to the Susitna downstream of Talkeetna is obtained at Talkeetna, from a boat-launching site at Susitna Landing near Kashwitna, at 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. Virtually this entire reach of the Susitna is navigable under most flow conditions although abundant floating debris during extreme high water and occasional shallow areas during low water make navigation treacherous at times.

Identified restrictions of open-water navigation over the full length of the river are tabulated in Table E.2.14.

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 later September or early October, when freezing begins. The onset of river freezing causes discharge of significant frazil ice for several days in an initial surge, which hinders boat operation, but this is often followed by a frazil-free period of 1 to 2 weeks when navigation is again feasible. The next sequence of frazil generation generally leads into continuous freezing of the river, prohibiting open-water navigation until after the next spring breakup.

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 lower 50 miles above the mouth. 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.

(d) Recreation

Information on the recreation uses on the Susitna River are presented in Chapter 7.

(e) 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. Further information on riparian wetlands and wildlife habitat can be found in Chapter 3.

(f) Waste Assimilative Capacity

Review of the Alaska Department of Environmental Conservation document entitled "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 sediments are 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.

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

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

(g) Freshwater Recruitment to Estuaries

The Susitna River is the chief contributor of freshwater to Cook Inlet and as such has a major influence on the salinity of Cook Inlet. The high summer freshwater flows cause a reduction in Cook Inlet salinities. During winter flows the reduced flows permit the more saline water to move up Cook Inlet from the ocean. Using a computer model for the Cook Inlet, Resource Management

Associates (RMA, 1982) predicted a seasonal salinity variation near the mouth of the Susitna River of 15 parts per thousand (ppt). In the central part of the inlet, salinity varies seasonally by about 5 ppt.

Salinity measurements were taken at the mouth of the Susitna River in August 1982 to determine if and to what extent saltwater intruded upstream. No saltwater intrusion was detected. Flow was approximately 100,000 cfs at Susitna Station at the time the measurements were made. Additional salinity measurements will be made during the 1982-83 winter season to determine if salt water penetration occurs upstream of the mouth of the river during low flow periods.

2.7 - Access Plan

(a) Flows

The streams crossed by the access road are typical of the subarctic, snow-dominated flow regime, in which a snowmelt flood in spring is followed by generally low flow through the summer, punctuated by periodic rainstorm floods. During October- April, precipitation falls as snow and remains on the ground. The annual low flow occurs during this period, and is almost completely 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.2.15 for three segments of the access route: (1) Denali Highway to Watana Camp; (2) Watana Camp to Devil Canyon Camp; and (3) Devil Canyon to Gold Creek. Only named streams are presented.

(b) Water Quality

At present very little water quality data is available for the water resources in the vicinity of the proposed access routes.

2.8 - Transmission Corridor

The transmission corridor consists of four segments: the Anchorage-Willow line, the Fairbanks-Healy line, the Willow-Healy Intertie, and the Gold Creek-Watana line. The first two (from Anchorage and Fairbanks) have existing facilities, but they will be upgraded before Watana comes on line. The intertie is currently being constructed under another contract. The line between the dam and the intertie has yet to be designed, sited, or constructed.

(a) Flows

Numerous waterbodies 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 crossings. Data are very 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.2.16.

The Anchorage-Willow segment will cross Knik Arm of Cook Inlet with a submarine cable. Further 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; 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 are Devil Creek and Tsusena Creek, neither of which have been gaged.

(b) Water Quality

At present, essentially no data is available for those sections of streams, rivers, and lakes that exist in close proximity to the proposed transmission corridors.

3 - PROJECT IMPACT ON WATER QUALITY AND QUANTITY

3.1 - Proposed Project Reservoirs

(a) Watana Reservoir Characteristics

The Watana Reservoir will be operated at a normal maximum water level of 2185 feet above mean sea level, but will be allowed to surcharge to 2190 feet in late August during wet years. Average annual drawdown will be 105 feet with the maximum drawdown equalling 120 feet. During extreme flood events the reservoir will rise to 2193.3 for the 1 in 10,000 year flood and 2200.5 feet for the probable maximum flood respectively.

At elevation 2185, the reservoir will have a surface area of 38,000 acres and a total volume of 9.47 million acre-feet. Maximum depth will be 735 feet and the corresponding mean depth will be 250 feet. The reservoir will have a retention time of 1.65 years. The shoreline length will be 183 miles. 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.

(b) Devil Canyon Reservoir Characteristics

Devil Canyon reservoir will be operated at a normal maximum operating level of 1455 feet above mean sea level. Average annual drawdown will be 28 feet with the maximum drawdown equalling 50 feet. At elevation 1455 the reservoir has a surface area of 7800 acres and a volume of 1.09 million acre-feet. The maximum depth will be 565 feet and the mean depth 140 feet. The reservoir will have a retention time of 2.0 months. Shoreline length will total 76 miles. Materials forming the walls and floors of the reservoir area are composed predominantly of bedrock and glacial, colluvial, and fluvial materials.

3.2 - Watana Development

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

(a) Watana Construction

(i) Flows

During construction of the diversions tunnel, the flow of the mainstem Susitna will be unaffected except during spring flood runoff. 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 one mile

What Section

section of the Susitna River will be dewatered. No significant impacts should result from this action.

Flows, velocities, and associated water levels upstream of the proposed Watana damsite will be unaffected during construction except for approximately one half mile upstream of the upstream cofferdam during winter and two miles upstream during summer flood flows. During winter, ponding to elevation 1470 feet will be required to form a stable ice cover. However, the volume of water contained in this pond is 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 operation. All flows up to approximately the mean annual flood will be passed through the lower diversion tunnel. Average velocities through the diversion tunnel will be 18, and 35 feet per second (f/s) at discharges of 20,000, and 40,000 cfs respectively. The mean annual flood of 40,800 cfs will cause higher than natural water levels for about several miles upstream of the cofferdam. The water level will rise at the upstream cofferdam from a natural water level of 1,468 feet to 1,520 feet. Two miles upstream, the water level will be about 4 feet higher than the natural water level during the mean annual flood.

The two diversion tunnels are designed to pass the 1 in 50 year return period flood of 87,000 cfs with a maximum headpond elevation of 1,536 feet. For flows up to the 1 in 50 year flood event, water levels and velocities downstream of the diversion tunnels will be the same as preproject levels.

(ii) Effects on Water Quality

- Water Temperature

Since the operation of the diversion structure will essentially be run-of-river, no impact on the temperature regime will occur downstream of the tunnel exit. A small amount of ponding will occur early in the freeze-up stage to enhance the formation of a stable ice cover upstream of the tunnel intake. This will not have a noticeable effect downstream.

- Ice

During freeze-up, the formation of an upstream stable ice cover by use of an ice-boom and some ponding to reduce approach velocities, will serve to protect the diversion works and maintain its flow capacity. The early formation of the cover at this point will cause a more rapid ice front progression upstream of the damsite. The ice formed in the upper reach, which normally feeds the downstream ice growth, will no longer be available. However the major contributer of frazil ice will be the rapids through Devil Canyon as it now is. Hence, no appreciable impact on ice formation downstream of Watana will occur due to the diversion scheme.

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

- 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: dredging and excavation of gravel from borrow areas, excavation of diversion tunnels, placement of cofferdams, vegetative clearing, blasting, gravel processing and dewatering.

The location and subsequent excavation of the material from proposed borrow sites will create the greatest potential for suspended sediment and turbidity problems. The proposed borrow sites, identified in Figure E2.74, are tentatively located in the river floodplain both upstream and downstream of the dam site. However, except for the material for the upstream cofferdam, the lower borrow material will be obtained from sites D and E. Material for the core of the main dam will be obtained from site D (10,000,000 yards). Material for the filters and shell of the main dam will be obtained from site E (52,000,000 yards). Borrow excavation will take place during the summer months when suspended sediment and turbidity values in the mainstem of the river are already quite high. As a result, incremental impacts during the summer should not be significant. Stockpiling of gravel is expected to alleviate the need for excavation during the winter, when the impact on overwintering fish due to changes in suspended load 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 should be short-term and localized. Downstream, turbidity and suspended sediment levels should remain essentially the same as baseline conditions.

Decreases in summer and winter vertical illumination are expected to be commensurate with any increased suspended sediment concentrations.

Since summer flows will be passed through the diversion tunnel with no impoundment, no settling of suspended sediments is expected to occur. The insignificant headpond that will be maintained during winter is not expected to affect the very low suspended sediment and turbidity levels present during the winter season.

- <u>Metals</u>

Slight increases in the concentration of trace metals could occur during construction when disturbances to soils and rock occur on the shoreline and in the river-bed. Such increases are expected to be below detection limits and thus would not indicate a change from baseline conditions described in Section 2.3 (a) (xiii).

- <u>Contamination by Petroleum Products</u>

Accidental spillage and leakage of petroleum products can contaminate water during construction. Lack of maintenance and service to vehicles could increase the leakage of fuel, lubricating oils, hydraulic fluid, anti-freeze, etc. In addition, poor storage and handling techniques could lead to accidental spills. Given the dynamic nature of the river, the contaminated water would be quickly diluted; however the potential for such situations will be minimized. All state and federal regulations governing the prevention and reclamation of accidental spills will be adhered to.

- <u>Concrete Contamination</u>

Construction of the Watana project will create a potential for concrete contamination of the Susitna River. The wastewater associated with the batching of concrete, if directly discharged to the river, could seriously degrade downstream water quality and result in substantial mortality of fish. However, this potential problem should not occur since the wastewater will be neutralized and settling ponds will be employed to allow the concrete contaminants to settle prior to the discharge of the wastewater to the river.

- <u>Other</u>

No additional water quality impacts are anticipated.

(iii) Effects on Groundwater Conditions

No impacts on groundwater will occur because of construction, either in the impoundment area or downstream other than in the localized area of the project.

(iv) Impact on Lakes and Streams in Impoundment Area

There will be minor impacts on lakes and streams in the impoundment area due to excavation of borrow material. Also, facilities will be constructed to house and support construction personnel and their families. The construction, operation and maintenance of these facilities is expected to impact the Tsusena and Deadman Creek drainage basins and some of the small lakes located between the two creeks near the dam site. For a complete discussion of these impacts refer to the discussion on Facilities in paragraph (vi) below.

(v) Instream Flow Uses

For all reaches of the Susitna River except for the immediate vicinity of the Watana damsite, there will be virtually no impact on navigation, transportation, recreation, fisheries, riparian vegetation, wildlife habitat, waste load assimilation or the freshwater recruitment to Cook Inlet for flows less than the 1 in 50 year flood event.

- Navigation and Transportation

Since all flow will be diverted, there will only be an impact on navigation and transportation 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 due to the heavy rapids upstream and downstream of the site, impact will be minimal.

- Fisheries

During winter, the diversion gate will be partially closed to maintain a headpond with a water surface elevation of 1,470 feet. This will cause velocities greater than 20 feet per second at the gate intake. This coupled with the 50 foot depth at the intake will impact fisheries. The impacts associated with the winter diversion are discussed in Chapter 3.2.3.

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 9 feet per second (fps)). Higher tunnel velocities will lead to fish mortality. The impacts associated with summer tunnel velocities are discussed in Chapter 3.2.3.

- Riparian Vegetation

Existing shoreline vegetation upstream of the cofferdam will be inundated approximately 50 feet to elevation 1,520 during flood events. However, the flooding will be confined to a two mile river section upstream of the cofferdam, with the depth of flooding lessening with distance upstream. Since the flooding will be infrequent and temporary in nature, and 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.

(vi) Facilities

The construction of the Watana power project will require the construction, operation and maintenance of support facilties capable of providing the basic needs for a maximum population of 4,720 people (3,600 in the construction camp and 1,120 in the village) (Acres, 1982). The facilities, including roads, buildings, utilities, stores, recreation facilities, airports, 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 northeast of the Watana damsite, between Deadman and Tsusena Creeks. The location and layout of the camp and village facilities are presented in Plates 34, 35, and 36 of Exhibit F.

- Water Supply

Nearby Tsusena Creek will be utilized as the major source of water for the community (Plate 34). 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, or 700 gallons per minute (1.5 cfs) (Acres, 1982). Using the USGS regression equation described in Table E2.15, 30-day minimum flows (cfs), with recurrence intervals of 20 years were estimated for Tsusena Creek near the water supply intake. The low flow was estimated to be 17 cfs for the approximate 126 square miles of drainage basin. As a result, no significant adverse impacts are anticipated from the maximum water supply withdrawal of 1.5 cfs. Further, a withdrawal of this magnitude should not occur during the low flow winter months since construction personnel will be significantly less than during summer.

The water supply will be treated by chemical addition, flocculation, filtration and disinfection prior to its use. Disenfection should probably be with ozone to avoid having to dechlorinate. In addition, the water will be demineralized and aerated, if necessary.

- Wastewater Treatment

A secondary waste water treatment facility will treat all waste water prior to its discharge into Deadman Creek (Plate 34).

Treatment will reduce the BOD and total suspended solids (TSS) concentrations to levels acceptable to the Alaska Department of Environmental Conservation. The levels are likely to be 30 mg/l BOD and 30 mg/l TSS. The maximum volume of effluent, 1 million gallons per day or 1.5 cfs, will be discharged to Deadman Creek which has a low flow of 27 cfs (see below). This will provide a dilution factor of about 17, thereby reducing BOD and TSS concentrations to about 2 mg/l after complete mixing under the worst case flow conditions (maximum effluent and low flow in Deadman Creek). Mixing will occur rapidly in the creek because of turbulent conditions.

The effluent is not expected to cause any degredations of water quality in the 1 1/2 mile section of Deadman Creek between the waste water 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. Using the USGS regression analysis, the one in 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 two miles upstream, are not expected to differ significantly.

Construction of the waste water 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.

The applicant will obtain all the necessary DEC, EPA, DNR, and PHS permits for the water supply and wastewater discharge facilities.

- Construction, Maintenance and Operation

Construction of the Watana camp, village, airstrips, etc. will cause impacts to water quality similar to many of those occuring from dam construction. Increases in sedimentation and turbidity levels are anticipated in the local drainage basns. (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.

(b) Impoundment of Watana Reservoir

(i) Reservoir Filling Criteria

The filling of the Watana reservoir is scheduled to commence in May 1991.

- Minimum downstream target flows

In the selection of minimum target flows, fishery concerns and economics were the two controlling factors. Although not unimportant in the overall impact assessment, other instream flow uses, were determined not to have a significant influence on the selection of minimum downstream target flows. However, instream uses such as navigation and transportation, recreation, and waste load assimilation are closely related to the instream flow requirements of the fishery resources.

Minimum downstream target flows will be provided at Gold Creek since Gold Creek flows are judged to be representative of the Talkeetna to Devil Canyon reach where downstream impacts will be greatest. 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 absolute minimum flow release at Watana will be 1,000 cfs or natural flows, whichever is less. During filling, flows at Gold Creek will be monitored and the flow at Watana adjusted as necessary to provide the required Gold Creek flow.

Table E.2.17 illustrates the targeted minimum Gold Creek flows. The minimum downstream flow of 1000 cfs from November through April is somewhat lower than the average winter flow at Gold Creek.

From May to the last week of July, the target flow will be increased to 6,000 cfs to allow for mainstem fishery movement. During June, it may be desirable to spike the flows to trigger the outmigration of salmon fry from the sloughs. (Schmidt, 1982 personal communication). It is believed that the outmigration is triggered by a combination of stage, discharge and temperature. Trihey (1982) has observed that the fry outmigrate during the falling limb of the spring flood hydrograph.

The 6,000 cfs Gold Creek flow will provide a minimum of 2 feet of river stage for mainstem fishery movement at all 65 surveyed cross sections between Talkeetna and Devil Canyon. Figure E2.75 illustrates computed water surface elevations for various discharges at cross section 32 located near Sherman (RM 130). (Accuracy is ± 1 foot). This cross section is believed to be the shallowest in the Talkeetna to Devil Canyon reach. The estimated water surface elevation for a discharge of 6000 cfs indicates that the depth is greater than 2 feet.

During the last 5 days of July, flows will be increased from 6,000 cfs to 12,000 cfs in increments of approximately 1,500 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 of Talkeetna. Adverse impacts to fish resulting from this flow regime are discussed in Chapter 3.2.3.

After 15 September, flows will be reduced to 6,000 cfs in daily increments of 1,500 cfs and then held constant until October when they will be further reduced to 2,000 cfs. In November, the flow will be lowered to 1,000 cfs.

- Flood Flows

Taking into account the 30,000 cfs discharge capability of the low level outlet, sufficient storage will be made available during the filling sequence such 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 criteria 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.

(ii) Reservoir Filling Schedule and Impact on Flows

Using the reservoir filling criteria, three simulated reservoir filling sequences were examined to determine the likely filling sequence and probable deviations. As approximately three years will be required to bring the reservoir to its normal operating level, three year running averages of the total annual flow volume at Gold Creek were computed. The probability of occurrence for each of the three year average values was then determined. Using the 10, 50, and 90 percent exceedence probability volumes and the long term average monthly Gold Creek flow distribution, Gold Creek flow hydrographs were synthesized for each probability. An identical process was used to synthesize the 10, 50, and 90 percent probability volumes and flow distributions at Watana. The intermediate flow contribution was taken as the difference between the Watana and Gold Creek monthly flows. Then using the downstream flow criteria and the flow values at Watana and Gold Creek, the filling sequence for the three probabilities was determined by repeating the annual flow sequence until the reservoir was filled.

The reservoir water levels and the Gold Creek flows for the three filling cases considered are illustrated in Figure E2.76. Under average conditions the reservoir would fill sufficiently by autumn 1992 to allow testing and commissioning of the units to commence. However, the reservoir would not be filled to its normal operating level until the following summer. There is a 10 percent chance that the reservoir would not be sufficently full to permit the start of testing and commissioning until late spring 1993. Only about one month is saved over the average filling time if a wet sequence occurs. This is because the flood protection criteria is violated and flow must be bypassed rather than stored.

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 E2.18. For the average hydrologic case, pre-project discharge for the May-October period is reduced by approximately 60 percent during the filling period. However, from November through April there is little difference.

For the Devil Canyon to Talkeetna reach, Gold Creek flows are considered representative. Monthly pre-project and filling flows at Gold Creek for the wet, (10 percent), mean (50 percent), and dry (90 percent) sequences are illustrated in Table E2.19. Percentage summer and winter flow changes are similar to those at Watana but are somewhat reduced because of additional tributary inflow. For the mean case, August monthly flow at Gold Creek is reduced by 45 percent (21,900 cfs to 12,000 cfs) when the reservoir is capable of storing all flow less the downstream flow requirement.

Flows 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 E2.20 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 flow stored in the reservoir.

- 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 all flood inflow except for the flow which can be discharged through the outlet facilities during the flood event. The maximum Watana discharge of the outlet facilities is 30,000 cfs. A maximum flow at Watana at 30,000 cfs represents a substantial flood peak reduction which will reduce downstream flood peaks substantially as far downstream as Talkeetna. For example, the once in fifty year flood at Gold Creek would be reduced from 106,000 cfs to 49,000 cfs.

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

The flood frequency curve for Watana during reservoir filling is illustrated in Figure E.2.77.

- Flow Variability

The variability of flow in the Watana to Talkeetna reach will be altered. Under natural conditions substantial change in flows can occur daily. This flow variability will be reduced during filling. Using August, 1958 as a example, Figure E.2. 78 shows the daily flow variation that would occur. The average monthly flow of 22,540 cfs during August, 1958 yields a value close to the long term average monthly discharge of 22,000 cfs. Superimposed on Figure E.2.78 are the flow variations that could occur under filling conditions with the August 1958 inflow, first, assuming that the reservoir was capable of accommodating the inflow and second, assuming that the reservoir storage criteria was violated (i.e., 30,000 cfs discharge at Watana). Both Gold Creek hydrographs have reduced flood peaks. In filling sequence 1, outflow is greater than inflow at Watana on the receeding limb of the hydrograph in order to meet the reservoir storage volume criteria. Hence during this time period, Gold Creek flows are greater than natural. In this example it was assumed that ongoing construction did not permit additional storage. 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, Gold Creek flow is constant at 12,000 cfs. However, at Watana, flow would be 4,350 cfs at the peak and about 10,000 cfs when the natural Gold Creek flow drops to 12,000 cfs.

Further downsteam, the variability of flow for both sequences will increase as a result of tributary inflow, but will be less than under natural conditions.

(iii) River Morphology

During the filling of Watana reservoir, the trapping of bedload and suspended sediment by the reservoir will greatly reduce the sediment transport 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 low flows. The lack of suspended sediments will significantly reduce siltation in calmer areas. The Susitna River main channel will tend to become more 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 of channel width reduction by encroachment of vegetation will begin, and will continue during reservoir operation. Tributary streams, including Portage Creek, Indian River, Gold Creek, and Fourth of July Creek, will extend their alluvial fans into the river. Figure E.2.79 illustrates the influence of the mainstem Susitna River on the sedimentation process occurring at the mouth of the tributaries. Overflow into most of the side-channels will not occur, as high flows will be greatly reduced. The backwater effects at the mouths of side-channels and sloughs will be significantly reduced.

At the Chulitna 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.

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

(iv) Effects on 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, evaporation and ice cover. These processes are expected to interact to alter the water quality conditions associated with the natural riverine conditions that presently exist. A summary discussion of the processes and their interactions is provided in Peterson and Nichols (1982).

- Water Temperature

During the first summer of filling, the temperature in the Watana reservoir will be essentially a composite of the inflow temperature, increased somewhat by the effects of solar heating. The reservoir will fill very rapidly (to about a 400 foot depth by the end of summer) and the effects of solar heating will not penetrate to the depth at which the outlet is located. Therefore, outlet temperatures during the first summer of filling should be an average of the existing river water temperatures with some lagging with the inflow water temperatures.

During fall, the reservoir will gradually cool to 4°C. Once at this temperature the low level outlet will continue to discharge water at just above 4°C until the reservoir water level has increased to where the fixed cone valves can be used.

Downstream of the Watana development the water temperature will be modified by heat exchange with the atmosphere. The filling sequence will cover two winter periods and the temperature at the downstream end of Devil Canyon will reach 0°C at or about the beginning of November in the first year and toward the end of October in the second. This will have the effect of lagging the downstream temperatures by about 5 weeks from the baseliner. Further downstream, the lagging in temperatures will be reduced as climatic conditions continue to influence the water temperature.

During the second summer of filling, outlet temperatures will be 4°C. Downstream of Watana, the water temperature will increase but, will be well below normal water temperatures.

- Ice

With the delay of freezing water temperatures, the entire ice formation process will occur 3-4 weeks later than for natural conditions. However, due to the lower flows the severity of jams will be diminshed and the staging due to ice will be less than presently experienced. At breakup, the reduced flows in combination with the diminished jamming in the river, will tend to produce a less severe breakup than currently occurs.

- Suspended Sediments/Turbidity/Vertical Illumination

  . Watana Reservoir

  As the reservoir beings 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 with more and more water impounded, smaller diameter particles will settle. As the reservoir approaches normal operating levels, the percentage of particles settling will be similar to that occurring during reservoir operation. However, since during filling, water will be passed through the low level outlet which is at invert elevation 1490 feet, whereas during operation it will be drawn from above elevation 2065 feet, larger particles would be expected to pass through the reservoir during filling than during operation (The deposition process during reservoir operation is discussed in detail in Section 3.2 (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 river waters. Turbidity levels in the winter are expected to decrease significantly from summer levels, however, turbidity is likely to be greater than pre-project winter levels.

  Vertical illumination in the reservoir will decrease during breakup as flow begins to bring glacial silts into the reservoir. Vertical illumination during the summer will vary, depending on where the river water finds its equilibrium depth (overflow, interflow, or underflow). Data from glacially fed Eklutna Lake indicates that vertical illumination will not exceed 4 meters during the mid-summer months (Figure E.2.80). Vertical illumination will gradually increase during the autumn as glacial input decreases.

  During the filling process additional suspended sediments will be introduced to the reservoir by the slumping of the valley walls and continued construction activities. The slumping of valley walls will provide intermittent quantities of suspended sediments. Although no quantitative estimates of this impact are available, it is anticipated that these impacts will be localized, of short duration, and thus not very significant. However, slumping is expected to continue after operation of the project begins until equilibrium is attained. Construction activities, such as the removal of timber from within the proposed impoundment area are also expected to contribute to increased suspended sediment concentrations and turbidity levels and decreased vertical illumination. Once removed, the lack of soil-stabilizing vegetative cover will likely accelerate wall slumping. However, the increase in suspended sediments due to valley wall slumping will be significantly less the reduction due to the sedimentation process and thus the river will be clearer than under natural conditions.

- <u>Watana to Talkeetna</u>

Maximum particle sizes passing through the project area downstream, will decrease from about 500 microns during pre-project conditions to about 5 microns as filling progresses. As can be observed from the particle size distribution (Figure E.2.36) this results in a 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 reduction of the suspended sediment concentration will occur as the flow moves downstream. During high tributary flow periods, additional suspended sediment will be added to the river by the tributaries. Talus slides may also contribute to the downstream suspended sediment concentrations. 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.

Downstream summer turbidity levels will be reduced to an estimated 30-50 NTU. Winter turbidity levels, although not presently quantifiable, will be increased above natural levels of near zero. Because of the reduced turbidity in summer, the vertical illumination will be enhanced. Winter vertical illumination will be reduced.

- <u>Talkeetna to Cook Inlet</u>

In the Talkeetna to Cook Inlet reach, the suspended sediment and turbidity levels during summer will decrease slightly from pre-project levels. The Chulitna River is a major sediment contributor to the Susitna with 28 percent of its drainage area covered by glacier. As such, it will tend to keep the suspended sediment concentrations high during summer. Therefore, the summer character of this reach will not change significantly.

- Dissolved Oxygen

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

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

No significant BOD loading is expected from the construction camp and village.

As previously noted, a low level outlet will be utilized for discharging water. Therefore, the levels of oxygen immediately downstream of the outlet could be slightly reduced. However, pre-project values will be established within a short distance downstream of the outlet due to reaeration enhanced by the turbulent nature of the river.

- Nitrogen Supersaturation

Nitrogen supersaturation of water below a dam is possible in certain seasons, extending a considerable distance downstream. The detrimental impact of nitrogen supersaturation is its lethal effect on fish. If dissolved gases reach lethal levels of supersaturation, a fish kill due to gas embolisms may result for miles downstream of an impoundment (Turkheim, 1975).

Nitrogen supersaturation can be caused by passing water over a high spillway into a deep plunge pool. The factors influencing this phenomenon include the depth of the plunge pool, the height of the spillway and the amount of water being spilled. Since all flow will be passed through the low level diversion tunnel and no spilling of water will occur at the Watana damsite, this problem will not exist during filling.

- Nutrients

Two opposing factors will affect nutrient concentrations during the filling process. First, initial inundation will likely cause an increase in nutrient concentrations.

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 for at least a short-term during filling.

- <u>Other</u>

No significant changes in any other water quality parameters are anticipated.

(v) <u>Effects on Groundwater Conditions</u>

- <u>Mainstem</u>

Alluvial gravels in the river and tributary bottoms will be inundated. No significant aquifers are known to be in the reservoir area, other than the unconfined aquifers at the relic channel and in valley bottoms.

Summer releases from the reservoir during filling are discussed in Section 3.2(b)(i). As a result of the decreased summer flows, water levels will be reduced, especially above Talkeetna. This will in turn cause a reduction in groundwater levels downstream but the groundwater level changes will be confined to the river floodplain area. The groundwater table will be reduced by about 2 feet in summer near the shoreline with less change occurring with distance away from the river.

A similar process will occur downstream of Talkeetna, but the changes in groundwater levels will be of less magnitude due to the decreased effect on river stages.

- <u>Impacts on Sloughs</u>

The reduced mainstem flows and subsequently lower Susitna River water levels will reduce the water level gradient between the mainstem and the sloughs. At locations where slough upwelling is unaffected by mainstem backwater effects, the reduced gradient will result in reduced slough upwelling rates. However, an analysis of mainstem water elevations at the decreased flow rate and the slough upwelling elevations, indicates a continued positive flow toward these upwelling areas with the exception that the intersection of the slough and the groundwater table will move downstream. Data to confirm the areal extent of upwelling at low flows is unavailable at this time.

The thalweg profile in slough 9 and computed mainstem water surface profiles in the vicinity of Slough 9 are illustrated in Figure E.2.81. The thalweg profile taken at right angles to the mainstem flow together with the mainstem water levels show that upwelling will continue at lower mainstem flows. (The water surface profiles which were computed using HEC-2 are sufficiently accurate to illustrate the relationship). It should also be noted that the groundwater driving head is more in an upstream-downstream direction than in a direction perpendicular to the mainstem. This can in general be attributed to the location of most sloughs at natural bends in the river. The distance from the mainstem at the head end of the sloughs to the mainstem at the mouth of the sloughs is usually shorter through the sloughs than along the mainstem.

At the slough upwelling locations which are affected by the mainstem backwater, the groundwater gradient between mainstem and slough is relatively unaffected by discharge until backwater effects are no longer present at the upwelling location. (As the mainstem water level decreases at the head end of the slough, there is a corresponding decrease in mainstem water level at the mouth of the slough where the backwater is controlled. Therefore, the gradient between the mainstem water level upstream and the backwater elevation in the slough is essentially unchanged.) Hence upwelling rates in backwater areas would remain virtually unchanged until the area is no longer affected by backwater. At that time the upwelling would behave as discussed above.

Under ice conditions the mainstem water levels increase, resulting in an increased head differential between mainstem and slough, and increased upwelling in the sloughs. Under reservoir filling conditions during winter, discharge will be reduced to about 1000 cfs at Gold Creek during the freeze-up period. This will result in reduced staging from pre-project ice staging levels. Hence, during winter, the mainstem- slough water level differential will be reduced with a corresponding reduction in upwelling area.

In summary, based on available information to date, upwelling in sloughs will continue but at an equal or slightly reduced rate from the natural rate. Additionally, the upper ends of some sloughs may be dewatered because of the lower groundwater table associated with the decrease in mainstem water levels.

(vi) Impacts on Lakes and Streams

Several tundra lakes will be inundated as the reservoir approaches full pool. The mouths of tributary streams entering the reservoir will be inundated for several miles (Sec. 2.4 (b)). Bedload and suspended sediment carried by these streams will be deposited at or near the new mouths of the streams as the river mouths move upstream during the filling process. No significant impacts to Tsusena or Deadman Creeks are anticipated from their use as water supply and waste recipient, respectively.

(vii) Effects on Instream Flow Uses

- Fishery Resources, Riparian Vegetation, and Wildlife Habitat

Impacts on fishery resources, riparian vegetation and wildlife habitat during the filling process are discussed more fully in Chapter 3. As summer flows are reduced, fish access to slough habitats will be decreased. Since temperatures of upwelling groundwater in sloughs are expected to be unchanged and upwelling should continue at most locations, though possibly at a reduced rate, impacts on the incubation of salmonid eggs are not expected to be severe.

- Navigation and Transportation

Once impoundment of the reservoir commences, the character of the river immediately upstream of the dam will change from a fast-flowing river with numerous rapids to a still-water reservoir. The reservoir will ultimately extend 54 miles upstream, just downstream of the confluence with the Tyone River, and will inundate the major rapids at Vee Canyon when the reservoir reaches full pool. The reservoir will allow increased boat traffic to this reach of river by decreasing the navigational difficulties.

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 heavy white-water rapids suitable only for expert kayakers.

Navigational difficulties between Devil Canyon and the confluence with the Chulitna River will be increased due to shallower water and a somewhat constricted channel. Although there will be sufficient depth in the river to navigate it, greater care will be required to avoid grounding. There will be less floating debris in this reach of the river, which will reduce the navigational danger somewhat.

There will be little impact on navigation below the confluence of the Chulitna River. The Susitna River is highly braided from Talkeetna to Cook Inlet with numerous channels which can change rapidly due to the high bedload movement and readily erodible bed material. Navigation can be difficult at present and knowledge of the river is beneficial at low flows. The reduced summer flows from the Susitna River will be somewhat compensated for by the high flows from other tributaries. No impacts near the existing boat access points of Susitna Landing, Kaskwitna River or Willow Creek have been identified. 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.

- Recreation

Information on recreation can be found in Chapter 7.

- 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 significant impact is anticipated given the limited sources of waste loading on the river (see Section 3.2(a)(ii)).

- Freshwater Recruitment to Estuaries

During filling, under average flow conditions, the mean annual freshwater inflow to Cook Inlet will be reduced by about 12 percent. This will cause a few parts per thousand increase in the natural salinity conditions. However, the salinity change would still be within the range of normal variation. If filling were to take place during an average hydrologic sequence, then the annual freshwater input to Cook Inlet would still be greater than the existing annual flows into Cook Inlet 15 percent of the time.

During a dry flow sequence, the downstream flow requirements at Gold Creek would be maintained. Thus, a smaller percentage of the Gold Creek flow is available for storage. Consequently the percent reduction in fresh water inflow into Cook Inlet is less for a sequence of dry years than for average conditions.

The higher Cook Inlet salinities will last only until project operation, at which time a new equilibrium wil be established as described in Section 3.2(c)(v).

(c) Watana Operation

(i) Flows

- Project Operation

Watana will be operated in a storage-and-release mode, such that summer flows will be captured for release in winter. Generally, the Watana reservoir will be at or near its normal maximum operating level of 2185 feet each year at the end of September. Gradually the reservoir will be drawn down to meet winter energy demand. In early May, the reservoir will reach its minimum annual level and then begin to refill from the spring melt. 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 feet. Once the reservoir is at this elevation, flow above that required for power will be wasted. After the threat of significant flooding has passed in late August, the reservoir will be allowed to surcharge to 2190 feet to minimize wasting of water in late august and September. Then, at the end of September, the annual cycle will be repeated.

. Minimum Downstream Target Flows

During project operation, minimum Gold Creek target flows from May through September will be unchanged from those during reservoir impoundment except that flows from October to April will be maintained at or above 5,000 cfs. It should be noted that these flows are minimum target flows. In reality, project operation flows will normally be greater than the targeted minimum flows during 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 probably coincide very closely with the minimum requirements. The minimum target flows during operation are shown in Table E.2.17.

If during summer, the natural flows fall below the Gold Creek minimum target, then these flows will be augmented to maintain the downstream flow requirement.

. Monthly Energy Simulations

A monthly energy simulation program was run using the 32 years of Watana synthesized flow data given in Table E2.2 except that the extreme drought (recurrence interval greater than one in 500 years) which occurred in water year 1969, dominated the analysis and was therefore modified to reflect a drought with recurrence interval of one in 32 years for energy planning and drawdown optimization. Energy production was optimized, taking into account the reservoir operating criteria and the downstream flow requirements. The energy simulation program is discussed in Volume 4, Appendix A of the Feasibility Study (Acres, 1982).

Monthly maximum ,minimum,and median Watana reservoir levels for the 32 year simulation are illustrated in Figure E.2.82.

- 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 most of the year. During summer it may be economically desirable to vary flow on a daily basis to take advantage of the flow contribution downstream of Watana to meet the flow requirements at Gold Creek. This would yield stable flows at Gold Creek, but somewhat variable river flows between Watana and Portage Creek.

- Mean Monthly and Annual Flows

Monthly discharges at Watana for the 32 year period were computed using the monthly energy simulation program and are presented in Table E.2.21. The maximum, mean, and minimum flows for each month are summarized in Table E.2.22. 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 operational flows will be eight times greater than natural river flow. Average post project flow for May will be about 30 percent less than the natural flow. Mean daily post project flows during May will be similar for each day of the month. In contrast, existing baseline flows vary considerably from the start of the month to the end of the month due to the timing of the snowmelt. Flows during June, July, August and September will be substantially reduced, to effect reservoir filling.

Pre and post project montly flows at Gold Creek are listed in Tables E2.23 and E2.24. A summary is presented in Table E2.25. The comparison is similar to that for Watana although the pre-project/post-project percentage change is less.

Further downstream at the Sunshine and Susitna Station, gaging station pre-and-post project flow differences will become less significant. During July, average monthly flows will be reduced by eleven 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 in Tables E.2.26 through E.2.29 and summarized in E2.30 and E2.31.

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

- Floods

  - Spring Floods

    For the 32 years simulated, 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 from elevation 2089 to elevation 2138. A further 47 feet of storage were available before reservoir spillage would have occurred.

    The flood volume for a May-July once in fifty year flood was determined to be 2.3 million acre feet (R&M, 1981a). This is equivalent to the storage volume contained between elevation 2117 and 2185, neglecting discharge. Since the maximum elevation at the beginning of June was always less than 2117 during the simulation, the 50 year flood volume can be stored without spillage if it occurs in June. Assuming the maximum June 30th water level in the simulation, if the flood event occurs in July, the once in fifty year flood volume can also be accommodated without exceeding Elevation 2185 if the powerhouse discharge averages 10,000 cfs. Thus, for flows up to the once in fifty year spring flood event, Watana reservoir capacity is capable of totally absorbing the flood without spillage.

    Only for flood events greater than the once in fifty year event and after the reservoir elevation reaches 2185.5 feet, will the powerhouse and outlet facilities will be operated to match inflow up to the full operating capacity of the outlet facilities and powerhouse. If inflow continues to be greater than outflow, the reservoir will gradually rise to Elevation 2193. 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 once in 10,000-year event. Peak inflow for a once in 10,000-year flood will exceed outflow capacity resulting in a slight increase in water level above 2193 feet. The discharges and water levels associated with a once in 10,000-year flood are shown in Figure E.2.83.

If the probable maximum flood were to occur, the main spillway will be operated to match inflow until the capacity of the spillway is exceeded. The reservoir elevation would rise until it reached Elevation 2200. At this elevation, the erodable dike in the emergency spillway would be eroded 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.2.83.

- Summer Floods

For floods occurring in August and September, it is probable that the Watana reservoir could reach Elevation 2185. Design considerations were therefore established to ensure that the powerhouse and outlet facilities will have sufficient capacity to pass the once in fifty year summer flood without operating the main spillway as the resultant nitrogen supersaturation could be detrimental to downstream fisheries. During the flood, the reservoir will be allowed to surcharge to Elevation 2193.

An analysis of the once in fifty year summer flood was carried out assuming that the reservoir was at 2185 feet when the flood commenced. The inflow flood hydrograph at Watana was derived by multiplying the mean annual flood peak at Watana by the ratio of the once in two year summer flood peak at Gold Creek to mean annual flood peak at Gold Creek to obtain the once in two year summer flood peak at Watana. This value was then multiplied by the ratio of the once in fifty year summer flood to the once in two year summer flood at Gold Creek, to obtain the Watana once in fifty year summer flood peak of 64,500 cfs. The August to October dimensionless hydrograph (R&M, 1981a) was next multiplied by the Watana peak flood flow to obtain the inflow hydrograph. The inflow was then routed through the reservoir to obtain the outflow hydrograph. Maximum outflow is the sum of the outlet facility discharge and the powerhouse flows. Flows and associated water levels are illustrated in Figure E.2.83.

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

August floods occurring in the 32 year energy simulation period did not cause the reservoir to exceed elevation 2190 feet. Hence, no spills occurred. The simulation included the August 15, 1967 flood. This flood had an instantaneous peak of 80,200 cfs at Gold Creek and an equivalent return of once in 65 years; thus demonstrating the conservative nature of the above analysis.

Downstream of Watana, flood flows at Gold Creek, will be reduced corresponding to the reduction in flood flow at Watana. Flood peaks at Sunshine and Susitna Station will also be attenuated, but to a lesser extent.

The annual and summer flood frequency curves for Watana are illustrated in Figure E.2.84.

- 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 level operating rule curve. There will generally 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.

Monthly and annual flow duration curves based on the monthly average flows for pre-project and post-project operating conditions for the simulation period are illustrated in Figures E.2.85 through E.2.88 for Watana, Gold Creek, Sunshine, and Susitna Station. The flow duration curves show a diminished pre-and-post-project difference with distance downstream of Watana.

(ii) River Morphology

Impacts on river morphology during Watana operation will be similar to those occurring during reservor impoundment (Section 3.2(b)(ii), although flow levels will generally be increased for power operations. The reduction in streamflow peaks, and the trapping of bedload and suspended sediments will continue to significantly reduce morphological changes in the river above the Susitna-Chulitna confluence.

The mainstem river will tend to become tighter and better defined. Channel width reduction by vegetation encroachment will continue.

The effects of ice forces during breakup on the river morphology above the Chulitna River will be effectively eliminated. Although an ice cover could form up to Devil Canyon, the rapid rise in streamflows which causes the initial ice movement at breakup will be eliminated due to the reservoir regulation. Instead of moving downriver and forming ice jams, the ice will thermally degrade. When it does move, it will be in a weakened state and will not cause a significant amount of damage.

Occurrences of the overtopping of the gravel berms at the upstream end of sloughs will be virtually eliminated. Movement of sand and gravel bars will be minimized. Debris jams and beaver dams, which previously were washed out by high flows, will remain in place, with resultant ponding. Vegetation encroachment in the sloughs and side-channels will also be evident as the high flows are reduced.

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

(iii) Water Quality

- Water Temperature

. Reservoir and Outlet Water Temperature

After impoundment, Watana reservoir will exhibit the thermal characteristics of a deep glacial lake. Deep glacial lakes commonly show temperature stratification both during winter and summer (Mathews, 1956; Gilbert, 1973; Pharo and Carmack, 1979, Gustavson, 1975), although stratification is often relatively weak. Bradley Lake, Alaska, (Figure E.2.89) demonstrated a weak thermocline in late July, 1980, but was virtually isothermal by late September, and demonstrated a reverse thermocline during winter months (Corps of Engineers, unpublished data).

The range and 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 temperature. This will also be the case for the Susitna River where pre-project temperatures generally range from 0°C to 14°C with the lows occurring from October through April and the highs in July or August. However, to minimize the preproject 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 multiport intake structure (Figure E.2.90). The intake nearest the surface generally will be used. In this way warmer waters will be passed downstream.

When water is released from the epilimnion of a deep reservoir, there is likely to be a warming effect on the stream below the dam (Turkheim, 1975; Baxter and Glaude, 1980). However, given the hydrological and meteorological conditions at Watana, this may not occur.

To provide quantitative predictions of the reservoir temperature behavior and outlet temperatures, reservoir thermal studies were undertaken in 1981 and 1982. To date, detailed studies have been completed for only the open water period. A one dimensional computer model, DYRESM, was used to determine the thermal regime of the Watana reservoir and the outlet temperatures.

Temperature profiles were simulated for the June through October time period using 1981 field data. Monthly reservoir temperature profiles and the mean daily inflow and outlet water temperatures are illustrated in Figures E.2.91 and E.2.92. The maximum reservoir temperature simulated was 10.4°C and occurred in early August. This is less than the maximum recorded inflow temperature of 13°C. Although there is an initial lag in outflow temperatures in early June, it is possible to reasonably match inflow temperatures from late June to mid-September. Thus, the summer outlet temperatures from Watana will have no impact on the downstream fishery resource.

In late September the natural water temperature falls to near zero degrees. Because of the large quantity of heat stored in the reservoir, it is not possible to match these natural temperatures. The lowest outlet temperature that could be obtained is 4°C with the use of a lower level outlet.

From September through November, reservoir water temperatures will gradually decrease until an ice cover is developed in late November or December. During the ice cover formation process and throughout the winter, outflow temperatures will be between 0°C and 4°C but, most likely the low temperature will be 1°C or greater. This range of outflow temperature (1°C to 4°C) can be obtained by selectively withdrawing water of the desired temperature from the appropriate port within the intake structure. Thus, when the optimum temperature, between approximately 1°C and 4°C, has been determined, the reservoir will be operated to match that temperature as closely as possible.

- Downstream Mainstem Water Temperatures

In winter, the outflow temperature will initially decrease as reservoir heat is exchanged with the cold atmosphere. The downstream temperatures were investigated with a constant 4°C outflow and also with a temperature of 4°C up to October 15 and decreasing linearly to 1°C by January 1. This sort of analysis brackets the expected temperature regime during Watana operation.

At the downstream end of Devil Canyon, the temperatures would be in the range of 1.5° to 0°C by about the first week in January. This would place the upstream edge of 0°C water somewhere between Sherman and Portage Creek by about the middle of January. This regime would continue through the remainder of the winter until about April when the net heat exchange again becomes positive.

During summer, outlet water temperatures will approximate existing baseline water temperatures. Downstream water temperatures will essentially be unchanged from existing water temperature. For example, at Gold Creek maximum June water temperatures will approximate 13°C. Through July, temperatures will vary from 10°C to 12°C and through mid-August temperatures will remain at about 10°C. About mid-August, temperatures will begin to decrease.

- Slough Water Temperatures

Preliminary investigations show that ground water upwelling temperatures in sloughs reflect the long term water temperature of the Susitna River. Downstream of Devil Canyon, the long term average is not expected to change significantly.

Post-project summer Susitna River water temperatures downstream of Portage Creek will be similar to existing temperatures. Fall temperatures will be slightly warmer but should fall to 0°C by January and will remain at 0°C until temperatures begin to warm. In spring, however, water temperatures should remain cooler longer. This will counteract the warmer fall temperatures and result in the average annual water temperature remaining close to existing conditions in the Talkeetna to Devil Canyon reach.

- Ice

The delayed occurrence of 0°C water in the reach below Devil Canyon will tend to delay the formation of an ice cover significantly. Since 75-80% of the ice supply below Talkeetna is currently from the Susitna River, the formation of the cover will be delayed until about December and ice front progression above the confluence starting in late December or early January. Depending on the water temperatures upstream, the ice cover will progress to a point between Sherman and Portage Creek. Staging will range from about 4 ft at Talkeetna to about 3 ft at Sherman. The more likely occurrence is an ice cover to Portage Creek.

During breakup, the cover will tend to thermally erode from both downstream and upstream. The downstream erosion will be similar to existing conditions while the upstream will be due to the warm water supplied by the reservoir as well as the positive net atmospheric heat exchange. Due to the lower flows, the breakup of the ice cover will be less severe than the baseline case.

- 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. 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 lake 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 may pass through the reservoir. Indeed, 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 3-4 microns 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 E2.36), it is estimated that about 80 percent of the incoming sediment will be trapped.

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 can be made. This results in 472,500 ac-ft. of sediment being deposited after 100 years (R&M, 1982d) and is equivalent to 5 percent of total reservoir volume and 12.6 percent of the live storage. Thus, sediment deposition will not affect the operation of Watana reservoir.

In the Watana reservoir, it is expected that wind mixing will be significant in retaining particles less than 12 microns in suspension in the upper 50-foot 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 high 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.

Slumping will occur for a number of years until the valley walls attain stability. This process will cause locally increased suspended sediment and turbidity levels. Sediment suspended during this process are expected to be silts and clays. Because of their small size these particles may stay in suspension for a long period of time. Nonetheless, during summer, the levels of suspended sediments and turbidity should remain on the order of five times less than during pre-project riverine conditions. If slumping occurs during winter, increases in suspended sediment concentrations over natural conditions will occur. Since cold ambient air temperatures during the winter will freeze the valley walls, the number of slides will be reduced and impacts should be minor.

Suspended sediment concentrations downstream will be similar to that discussed in Section 3.2(b), (iv) except that maximum particle sizes leaving the reservoir will be 3-4 microns.

- Turbidity

Turbidity patterns may have an impact on fisheries, both in the reservoir and downstream. Turbidity in the top 100 feet of the reservoir is of primary interest. The turbidity pattern is a function of the thermal structure, wind mixing and reentrainment along the reservoir boundaries. Turbidity patterns observed within Eklutna Lake, a lake 30 miles north of Anchorage, may provide the best available physical model of 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 long, 200 feet deep, has a surface area of 3,420 acres, and has a total storage of about 414,000 ac-ft. Bulk annual residence time is 1.77 years, 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. Consequently, it is believed that turbidity patterns in the two bodies of water will be somewhat similar.

Data collected at Eklutna from March through October 1982 demonstrates the expected pattern at Watana. In March, turbidity beneath the ice cover was uniformly less than 10 NTU in the lower 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. It is believed the lake had recently completed its spring overturn, as a warming trend was evident only in the upper 3 meters. 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 levels had significantly decreased by the time the plume had traveled 5 miles down the lake, as sediment was deposited in the lake. In late September, a turbid layer was noted on 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 and turbidity at about 7°C and 30-35 NTU, respectively.

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 at., 1976). The turbid plume was confined to the surface layers, resulting in a relatively short residence time of the 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, suggesting that the effects of dilution and particle settling were minimal due to the thermocline at 10°-6°C effectively separating the high turbidity waters in the upper layers of the lake from highly transparent hypolimmion waters. This was not apparent in the Eklutna Lake data. Plumes were evident up to 5 miles down the lake, but they were below the thermocline. In addition, particle settling and dilution were evident, as turbidity continually decreased down the length of the lake.

The relatively cool, cloudy climate in southcentral Alaska would tend to prevent a sharp thermocline from developing, so that the processes evident in Kamloops Lake would not be expected in Eklutna Lake, nor will they be expected in the Watana reservoir.

- Total Dissolved Solids, Conductivity, Alkalinity, Significant Ions and Metals

The leaching process, as previously identified in Section 3.2.(a)(ii), 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, 1982). Furthermore, Baxter and Glaude (1980) have found such effects are temporary and diminish with time.

The effects will diminish for two reasons: First, the most soluable elements will dissolve into the water rather quickly and the rate of leachate production will 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 leaching (Peterson and Nichols, 1982).

The effects of the leaching process 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.

Due to 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). During evaporation, slightly higher concentrations of dissolved substances have been found at the surface of impoundments (Love, 1961; Symons, 1969). Neglecting precipitation which would negate the effects of evaporation, the potential increase of less than one percent is not considered significant (Peterson and Nichols, 1982).

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 the reservoir surface forces dissolved solids out of the freezing water, thereby increasing concentrations of these solids at the top of the reservoir. No significant impacts should result either in the reservoir or downstream of the dam.

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 conductivity values for Vee Canyon and Gold Creek during winter are 70 and 125 umhos/cm at 25°C, respectively. For summer they are somewhat lower, 45 umhos/cm at 25°C for both stations. Values for pH range between 7.3 and 7.6 for the two stations. Although neither of the parameters were high, some precipitation of metals is expected to reduce the quantities suspended in the reservoir.

- Dissolved Oxygen

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

Wastewater from the permanent town 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 have been cleared, removing the potential BOD they would have created. The layer of organic matter at the reservoir bottom will still remain and could create some short term localized oxygen depletion. However, the process of decomposition should be very slow due to the cold temperatures.

The weak stratification of the reservoir may cause the oxygen levels in the hypolimnion to diminish due to lack of oxygen replenishment. The spring turnover, with its large inflow of water, will cause mixing; however, the depth to which this mixing will occur is unknown. As a result, the hypolimnion could experience reduced oxygen levels. The upper 200 feet of the impoundment should maintain high D.O. due to river inflow and continual mixing.

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

- Nitrogen Supersaturation

As previously noted, nitrogen supersaturation can occur below high-head dams due to spillage. During project operation, specially designed fixed cone valves will be used to discharge spills up to the once in fifty year flood.

- Trophic Effects (Nutrients)

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 C:Si:N:P ratio indicates which nutrient levels will limit algae productivity. The nutrient which is least abundant will be limiting. On this basis, it was concluded 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 overestimate 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 is the fraction of the total phosphorus pool 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 spring phosphorus supplies. These values were in turn combined with phosphorus values from precipitation and divided by the surface area of the impoundment. The resultant spring phosphorus loading values at Watana 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.

(iv) Effects on Groundwater Conditions

- Mainstem

As a result of the annual water level fluctuation in the reservoir, there will be localized changes in groundwater in the immediate vicinity of the reservoir. Groundwater impacts downstream will be confined to the river area.

- Impacts on Sloughs

During winter, in the Talkeetna to Devil Canyon reach, some sloughs (i.e. those nearer Talkeetna) will be adjacent to an ice covered section of the Susitna River and others will be adjacent to an ice free section. In ice covered sections, the Susitna River will have staged to form the 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 increased upwelling in the sloughs because of the increased gradient. The berms at the head end of the sloughs may be overtopped.

A number of sloughs may be adjacent to open water sections of the Susitna River. Since flows will average approximately 10,000 cfs in winter, the associated water level will be less than the existing baseline Susitna River water levels in winter because ice staging under present conditions yields a water level equivalent to an open water discharge that is greater than 20,000 cfs. Hence, it is expected that the winter gradient will be reduced and will result in a decreased upwelling rate in the sloughs.

Duirng summer, the mainstem - slough ground water interaction will be similar to that discussed in Section 3.2 (b)(v), with the exception that operational flows will be greater than the downstream flows during filling and thus upwelling rates will be closer to the natural condition than were the upwelling rates during filling.

(v) Instream Flow Uses

- Fishing Resources, Riparian Vegetation and Wildlife Habitat

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

- Navigation and Transportation

Within the reservoir area, water craft navigation will extend to November because of the delay in ice cover formation. During winter, the reservoir will be available for use by dogsled and snow machine.

Although summer flows will be reduced from natural conditions during project operation, navigation and transportation in the Watana to Talkeetna reach will not be significantly impacted. Flows will be stabilized due to a base-loaded operation. However, because of the reduced water levels, caution will be required in navigating various reaches. There will be less floating debris in this reach of the river, which will reduce the navigational hazards.

During the fall and winter a significant reach of the river downstream of Watana will contain open water. This will allow for a longer boating season but will impede use of the river as a transportation corridor by snow machine or dog sled.

Downstream of Talkeetna, ice formation may be delayed and river stage during freezeup will be increased. This may impede winter transportation across the ice.

- Estuarine Salinity

Salinity changes in Cook Inlet due to project operations were projected through the use of a computer model (Resource Management Associates, 1982). A comparison of the salinity impacts of average project flows with average natural inflow showed that under project operation, the salinity range decreased a maximum of two parts per thousand (ppt) near the mouth of the Susitna River. The change was most notable at the end of winter when post project salinities were 1.5 ppt lower than existing conditions. At the end of September post project salinities were about 0.5 ppt higher than natural salinities because of the reduced summer freshwater inflow. Although there will be seasonal differences in salinity, the post project salinity changes should not have a significant impact.

3.3 - Devil Canyon Development

(a) Watana Operation/Devil Canyon Construction

Construction of the Devil Canyon site is scheduled to begin in 1995. When completed, the Devil Canyon development will consist of a 646 foot high, concrete arch dam, outlet facilities capable of passing 38,500 cfs, a flipbucket spillway with a capacity of 125,000 cfs, an emergency spillway with a capacity of 160,000 cfs, and a 600 MW capacity powerhouse. Further information on the physical features of the Devil Canyon development can be found in Section 7 of Exhibit A.

The Devil Canyon diversion is designed for the 25 year recurrence interval flood. This is because of the degree of regulation provided by Watana.

Any differences in the quantity and quality of the water from existing baseline conditons during the Devil Canyon construction will be primarily due to the presence and operation of the Watana facility. Therefore, the impacts described in Section 3.2(c) will, in most cases, be referred to when discussing the impacts of Devil Canyon construction.

(i) Flows

Operation of Watana will be unchanged during the construction of Devil Canyon. Hence, flows will be as discussed in Section 3.2(c). Mean monthly flows for Watana, Gold Creek, Sunshine, and Susitna Station are illustrated in Tables E.2.21, E.2.24, E.2.27, and E.2.29. Monthly flow duration curves are shown in Figures E.2.85 through E.2.88.

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 diverted through the diversion tunnel without any interruption in flow. This action will dewater approximately 1,100 feet of the Susitna River between the upstream and downstream cofferdams.

Because little ice will be generated through the Watana Devil Canyon reach, ponding during winter will be unnecessary at Devil Canyon.

Velocites through the 30 foot diameter tunnel at flows of 10,000 cfs will be 14 feet per second.

The diversion tunnel is designed to pass flood flows up to the once in 25 year summer flood, routed through Watana. The flood frequency curve for Devil Canyon is illustrated in Figure E.2.93. Initially, there is little change in discharge with frequency. This is due to the fact that the

Watana Reservoir can absorb the one in fifty year flood, discharging a maximum of 31,000 cfs (24,000 cfs through the outlet facilities and 7,000 cfs through the powerhouse [assuming minimum energy demand]).

(ii) Water Quality

- Water Temperatures

There will be no detectable difference in water temperatures at Devil Canyon or points downstream from those discussed in Section 3.2(c)(iii) Watana Operation.

- Ice

Ice processes will be unchanged from those discussed in Section 3.2(c)(iii) Watana Operation except that in the event water temperatures are lowered to 0°C upstream of Devil Canyon, any frazil ice produced will be passed through the diversion tunnel.

- Suspended Sediment/Turbidity/Vertical Illumination

Construction of the Devil Canyon facility will have impacts similar to those expected during the Watana construction. Increases in suspended sediments and turbidity are expected during tunnel excavation, placement of the cofferdams, blasting, excavation of gravel from borrow areas, gravel washing, and clearing of vegetation from the reservoir. Any impacts that occur during summer will be minimal compared to pre-Watana baseline conditions. However, stringent construction practices will have to be imposed during the construction of Devil Canyon to prohibit suspended sediments from entering the river and negating the improved water quality, relative to suspended sediments, that will result when Watana becomes operational. During winter, slightly increased suspended sediment concentrations can be expected since particles less than 3-4 microns in diameter will probably pass through the reservoir.

No impoundment of water will occur during the placement and existence of the cofferdam. As a result, no settling of sediments will occur.

Slightly decreased vertical illumination will occur with any increase in turbidity.

- Metals

Similar to Watana construction, disturbances to soils and rock or shorelines and riverbeds will increase dissolved and suspended materials to the river. Although this may result in elevated metal levels within the construction area and downstream, the water quality should not be significantly impaired since substantial concentrations of many metals already exist in the river (Section 2.3(a)).

- Petroleum Contamination

Construction activities at Devil Canyon will increase the potential for contamination of the Susitna River by petroleum products. However, as per the Watana construction, precautions will be taken to ensure this does not happen (Section 3.2(a)ii).

- Concrete Contamination

The potential for concrete contamination of the Susitna River during the construction of the Devil Canyon Dam will be greater than during Watana construction because of the large volume of concrete required. It is estimated that 1.3 million cubic yards of concrete will be used in the construction of the dam. The wastewater 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 this, the wastewater will be neutralized and settling ponds will be employed to allow settlement of concrete contaminants prior to the discharge of wastewater to the river.

- Other Parameters

No additional ground water quality impacts are expected from those discussed for the proposed operation of the Watana facility.

(iii) Ground Water

There will be no ground water impacts from Devil Canyon construction other than in the immediate vicinity of the construction site.

(iv) Impact on Lakes and Streams in Impoundment

The perched lake adjacent to the Devil Canyon damsite will be impacted 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 construcion of the saddle dam.

(v) 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, themselves act as natural barriers to most upstream fish movement.

Navigational impacts will be the same as during Watana operation, except that the whitewater rapids at Devil Canyon will be inaccessible because of construction activities.

(vi) Facilities

The construction of the Devil Canyon power 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 1982). The facilities, including roads, buildings, utilities, stores, recreation facilities, etc., will be essentially completed during the first three years (1993-1995) of the proposed nine-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 southwest of the Devil Canyon damsite. The location and layout of the camp and village facilities are presented in Plates 70, 71, and 72 of Exhibit F.

- Water Supply and Wastewater Treaatment

The Watana water treatment 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 to provide for the needs of the support communities, or less than 1 cfs (Acres 1982). Since the source of this supply is the Suistna River no impacts on flows will occur throughout the duration of the camps existence.

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. The effluent will be discharged approximately 1,000 feet downstream of the intake.

Prior to the completion of the wastewater treatment facility, all wastewater will be chemically treated and stored for future processing by the facility.

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

- Construction, Operation and Maintenance

Similar to Watana, the construction, operation and maintenance of the camp and village could cause slight 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 contaminating groundwater and local streams and lakes. Through appropriate preventative techniques, these potential impacts will be minimized.

(b) Watana Operation/Devil Canyon Impoundment

(i) Reservoir Filling

Upon completion of the main dam to a height sufficient to allow ponding above the primary outlet facilities (elevations 930 feet and 1,050 feet), the intake gates will be partially closed to raise the upstream water level from its natural level of about 850 feet. Flow will be maintained at a minimum of 5,000 cfs at Gold Creek if this process occurs between October and April. From May through September, the minimum environmental flows described in Section 3.2(b) will be released (See Table E.2.17).

Once the level rises above the lower level discharge valves, the diversion gates will be permanently closed and flow passed through the fixed cone valves.

Since the storage volume required before operation of the cone valves can commence is less than 76,000 acre feet, the filling process will require about one to four weeks. The reservoir will not be allowed to rise above 1135 feet for approximately one year, while the diversion tunnel is being plugged with concrete.

When the dam is completed, an additional storage volume of one million acre feet will be required to fill the reservoir to its normal operating elevation of 1455 feet. 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 target flows depicted in Table E.2.17.

(ii) Flows

Because of the two distinct filling periods, the two-stage impoundment sequence will be several years long, even though the actual time for filling will only be about two months long. Flows during the first stage of filling will be impacted for a short duration.

Between the first stage and second stage of filling, the reservoir will not be allowed to exceed 1135 feet. Thus, the Devil Canyon reservoir will be more or less held at a constant level. Flows along the Susitna will be unchanged from those during Devil Canyon construction (See Section 3.3(a)).

During the second stage of filling, wherein 1,014,000 acre-feet are added to the Devil Canyon reservoir, the Watana reservoir will be lowered about 25 feet if filling occurs during either fall or winter. Although the flow into Devil Canyon will be approximately twice normal power flow from Watana, the impact of increased flow will be minimal in the Devil Canyon-Watana reach because the two sites are close to one another.

Flow downstream of Devil Canyon will be slightly reduced during this filling process. However, the time period will be short and flows will be maintained at or above the minimum target flow at Gold Creek.

Since actual filling times are short and since filling will likely occur in fall or winter, floods are likely to be important only during the time the reservoir is not allowed to increase above 1135 feet. If a flood should occur during this time, the cone valves are designed to pass the once in fifty year design flood of 38,500 cfs.

(iii) Effects on Water Quality

- Water Temperature

The outlet water temperatures from Watana will be unchanged from those of the Watana alone scenario. Because of the rapid filling of the Devil Canyon reservoir, there will be minimal impact on the outlet temperatures at Devil Canyon during both stages of filling.

Between the filling stages, the larger surface area of the reservoir will offer more opportunity for atmospheric heat exchange. However, since the retention time will only be in the order of 4 days, it is expected that little change in water temperature will occur from that experienced under Watana along at the Devil Canyon outlet or downstream.

- Ice

An extensive ice cover is not expected to form on the Devil Canyon reservoir during the period wherein a pool at approximate elevation 1135 is maintained. Additionally, since winter temperatures downstream will not be significantly affected by the pool, ice processes downstream of Devil Canyon will remain the same as during Devil Canyon construction.

- 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. During the filling of Devil Canyon from approximately elevation 1135 feet to full pool, the flow will be increased to the maximum power flow from Watana.

Because of the reduced residence time, this could cause a slight increase in suspended sediment concentrations leaving Watana reservoir. However, Devil Canyon will provide additional settling capability and thus, the net result in suspended sediment concentration downstream of Devil Canyon will not be different from that during operation of Watana alone. Turbidity levels and vertical illumination will remain unchanged from Watana only operation.

Some short-term increases in suspended sediment concentration and turbidity may occur within the Devil Canyon impoundment from slumping of 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 concentration. A further discussion of slope stability can be found in Appendix K of the Susitna Hydroelectric Project Geotechnical Report (Acres 1981).

- Total Dissolved Solids, Conductivity, Alkalinity, Significant Ions and Metals

Similar to the process occurring during Watana filling, increases in dissolved soilds, conductivity and most of the major ions will likely result from leaching of the impoundment soils and rocks during Devil Canyon filling. However, for initial filling, from elevation 850 to 1135, no significant downstream impacts are foreseen, since it will take only about two weeks to accumulate the 76,000 acre-feet of storage. In such a short time, insignificant leaching would occur which could be detrimental to downstream water quality.

Subsequent to initial filling and for the remainder of the filling process, fixed-cone valves will be utilized for reservoir discharge. Since they will be drawing water from well above the bottom of the impoundment and since 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.

Evaporation at the Devil Canyon reservoir surface will be increased above existing riverine evaporation, but this will be negated by precipitation falling directly on the reservoir. Hence, there will be no impact on total dissolved solid concentration from evaporation.

- Dissolved Oxygen

As previously discussed in Section 3.2(c), (iii) Watana Operation, water entering Devil Canyon will have a high dissolved oxygen concentration and low BOD.

Because of the extremely short residence times, no hypolimentic oxygen depletion is expected to develop during either the one year that the reservoir is held near elevation 1135 feet or the final six weeks of reservoir filling.

Treated wastewater will continue to be discharged downstream of the dam, but the river flow will be more than ample to assimilate any wastes.

- Nitrogen Supersaturation

Nitrogen supersaturation will not be a concern during the filling of Devil Canyon reservoir. During the initial filling to an elevation of no greater than 1135, low level outlets will be employed. No superstauration within the lower level of the reservoir will occur during this two week time frame. Further, there will be no plunging discharge to entrain nitrogen.

During the remainder of the filling sequence, discharge will be via the fixed cone valves. Therefore, no nitrogen superstauration conditions are expected downstream of the dam.

- Support Facilities

No impacts are anticipated during the filling process as the result of the withdrawal of water and the subsequent discharge of the treated wastewater from either the camp or village.

Some localized increases in suspended sediments and turbidity are expected to occur during the dismantling of the camp which may begin at this time. Using the appropriate preventive procedures, any impacts should be minimized.

(iv) Groundwater

No major groundwater impacts are anticipated during the impoundment of Devil Canyon. The increased water level within the reservoir will be confined between bedrock walls. Downstream there may be a slight decrease in water level from reduced flows if filling occurs other than in August or the first 3 weeks of September. The associated change in groundwater level will be confined to the immediate area of the riverbank.

(v) Impacts on Lakes and Streams in Impoundment

As the Devil Canyon pool level rises, the mouths of the tributaries entering the reservoir will be inundated for up to 1.6 miles (See Table E.2.11). Sediment transporated by these streams will be deposited at the new stream mouth established when the reservoir is filled.

(vi) Instream Flow Uses

- Fisheries

As Devil Canyon reservoir is filled, additional fishery habitat will become available within the reservoir. However, impacts to fish habitat will occur as tributary mouths become inundated. Further information on reservoir and downstream impacts in Chapter 3.

- Navigation and Transportation

During filling, the rapids upstream of Devil Canyon will be inundated and white water kayaking opportunities will be lost. Since the reservoir will be rising about as much as 8 feet per day during filling, the reservoir will be unsafe for boating. Downstream water levels may be slightly lowered, but this is not expected to affect navigation because of the slight change most likely confined to the winter season.

- Waste Assimilative Capacity

Although flows in the river will be reduced during the two segments of reservoir filling, the waste assimilative capacity of the river will not be affected.

(c) Watana/Devil Canyon Operation

(i) Flows

- Project Operation

When Devil Canyon comes on line, Watana will be operated as a peaking plant and Devil Canyon will be baseloaded. Advantage will be taken of the reservoir storage at Devil Canyon to optimize energy production while at the same time providing the downstream flow requirements.

Each September, the Watana reservoir will be filled to as near the maximum water level of 2190 feet as possible, while still meeting the downstream flow requirements. From October to May the reservoir will be drawn down to approximately elevation 2080 feet, although the reservoir will be allowed to fall to a minimum reservoir level of 2065 feet during dry years. In May, the spring runoff will begin to fill the reservoir.

However, the reservoir will not be allowed to fill above elevation 2185 until late August when the threat of a summer flood will have passed. If September is a wet month, the reservoir will be allowed to fill an additional 5 feet to elevation 2190 because the probability of significant flooding will have passed until the next spring.

From November through the end of July, Devil Canyon will be operated at the normal maximum headpond elevation of 1455 feet to optimize power production. In August, the Devil Canyon reservoir will be allowed to fall to a minimum level of 1405 feet. In this way, much of the August downstream flow requirement at Gold Creek can be met from water coming out of storage at Devil Canyon. This will allow most of the water entering the Watana reservoir to be stored rather than pass through the turbines and produce unsalable energy. In September, the Devil Canyon reservoir will be further lowered if it is not already at its minimum elevation of 1405 feet and if the Watana reservoir is not full. When the downstream flow requirements diminish in October, the Devil Canyon reservoir will be filled to 1455 feet.

- Minimum Downstream Target Flows

The minimum downstream target flows at Gold Creek which controlled the summer operation of Watana alone will be unchanged when Devil Canyon comes on line. Table E.2.17 illustrates these flows (A further explanation is provided in Section 3.2(c)(i)).

. Monthly Energy Simulations

The monthly energy simulation program was run using the 32 years of Watana and Devil Canyon synthesized flow data. Pre-project flow data is presented in Tables E.2.32 and E.2.33. (The development of the Watana and Devil Canyon flow sequences used in the simulation was discussed in Sections 2.1(a) and 3.2(c), (i).)

Monthly maximum, minimum, and median Watana and Devil Canyon reservoir levels for the 32 year simulation are illustrated in Figures E.2.94 and E.2.95.

. Daily Operation

With both Devil Canyon and Watana operating, Watana will operate as a peaking plant since it will discharge directly into the Devil Canyon reservoir where the flow can be regulated. Water levels in Devil Canyon will fluctuate less than one foot on a daily basis due to the peaking operation of Watana. Devil Canyon will operate as a baseloaded plant for the life of the project.

- Mean Monthly and Annual Flows

Monthly Watana, Devil Canyon and Gold Creek flows for the 32 year monthly energy simulation are presented in Tables E.2.34, E.2.35, and E.2.36. The maximum, mean, and minimum flows for each month are summarized and compared to pre-project flows and Watana only post-project flows (where appropriate) in Tables E.2.22, E.2.37, and E.2.25. 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, 56, and 79 percent of the average mean monthly pre-project flow at Gold Creek respectively. The reductions represent the flow volume used to fill the Watana reservoir. Variations in mean monthly post-project flows occur but the range is substantially reduced from pre-project flows.

Further 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.2.30 and E.2.31. Monthly post-project flows are presented in Tables E.2.38 and E.2.39. 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 and Devil Canyon both operating shows that although there are some differences, the differences are minor.

- Floods

  . Spring Floods

  For the 32 years simulated, 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 feet at the end of June, an elevation well below the elevation at which flow is released.

  The maximum mean monthly discharge at Devil Canyon during the spring flood period was approximately 10,500 cfs. If peak inflow into Devil Canyon reservoir contributed from the drainage area downstream of Watana approached this discharge, flow at Watana would be virtually shut off to maintain a Devil Canyon reservoir level of 1455 feet . Lateral inflow would supply most of the power needs. However, it is unlikely the peak contribution downstream of Watana would 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. If it is assumed this is valid for the drainage area between Watana and Devil Canyon, the peak 1 day June inflow during the simulation period would approximate 9300 cfs.

  For the once in fifty year flood, the downstream flow with both Watana and Devil Canyon in operation will be similar to the flow with Watana operating alone. The Watana reservoir will be drawn down sufficiently such that the once-in-fifty-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, power needs would be met by running Devil Canyon to near capacity and reducing outflow from Watana as much as possible to prevent flow wastage.

  For flood events greater than the once in fifty year event and after Watana reservoir elevation reaches 2185.5, 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 elevation 2193. When the reservoir level reaches 2193, the main spillway gates will be opened and operated so that outflow matches inflow. Concurrent with opening the Watana main spillway gates, the main spillway gates at Devil Canyon will be opened such that inflow matches outflow. The main spillways at both Watana and Devil Canyon will have sufficient capacity to pass the one in 10,000 year event. Peak inflow for the one in 10,000 year flood will exceed outflow capacity at Watana resulting in a slight increase above 2193 feet. At Devil Canyon there will be no increase in water level. The discharges and water levels associated with a once in 10,000 year flood for both Watana and Devil Canyon are illustrated in Figures E.2.83 and E.2.96.

If the probable maximum flood (PMF) were to occur, the operation at Watana would 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 would rise until it reached elevation 2200. If the water level exceeds elevation 2200, the erodible dike in the emergency spillway would be washed out and flow would be passed through the emergency spillway. The resulting total outflow through all discharge structures would be 311,000 cfs, 15,000 cfs less than the PMF.

At Devil Canyon a similar scenario would occur. The main spillway would continue to operate, passing the main spillway discharge from Watana. Once the emergency spillway at Watana started operating, the Devil Canyon reservoir would surcharge to 1465 and its emergency spillway would begin to operate. Peak outflow would occur immediately after the fuse plug eroded 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.2.83 and E.2.96, respectively.

. Summer Floods

Although there were no flow releases at the Watana site during August or September in the 32 year simulation, in wet years Watana and Devil Canyon may produce more energy than can be used. If this occurs, flow will have to be released through the outlet facilities. However, on a mean monthly basis, the total discharge at Watana will be less than the Watana powerhouse flow capacity of 19,400 cfs. Flow will only be released when the reservoir exceeds elevation 2185.5 feet.

Since Watana was designed to pass the once in fifty year summer flood without requiring operation of the main spillway and since the capacity of the powerhouse and outlet facilities is 31,000 cfs, Watana summer flood flows will vary from a low value equal to the powerhouse flows up to 31,000 cfs for floods with a recurrence interval less than fifty years.

For the once-in-fifty-year summer flood, the Watana discharge will be maintained at 31,000 cfs but the reservoir will surcharge to 2193 feet (refer to Section 3.2(c)(i) for the derivation of the once-in-fifty-year summer flood hydrograph).

At Devil Canyon, design consideration were also established to ensure that the Devil Canyon powerhouse and outlet facilities will have sufficient capacity to pass the once in fifty year summer flood of 39,000 cfs without operating the main spillway as the resultant nitrogen supersaturation could be detrimented to downstream fisheries. This flood is passed through the Devil Canyon reservoir without any change in water level. It includes the 31,000 cfs inflow from the once in fifty year summer flood routed through Watana plus a lateral inflow of 8000 cfs. The lateral inflow of 8000 cfs was obtained by subtracting the once-in-fifty-year Watana natural flood peak from the once-in-fifty-year Devil Canyon natural flood peak.

In the 32 year simulation period there were four years in which flow releases occurred during high summer flow periods. Although the maximum monthly release was only 4100 cfs, the peak flow may vary well have been higher depending on the variability of the tributary inflow downstream of Watana and on the Watana reservoir level. However, the peak Devil Canyon outflow would not have exceeded the capacity of the powerhouse and outlet facilities.

- Flow Variability

As discussed above, at both Watana and Devil Canyon, peak monthly flows may differ from mean monthly flows if the reservoir exceeds elevation 2185.5 at Watana and flow is released. For Devil Canyon, as reservoir inflow from sources other than the Watana Reservoir varies, the peak outflow may also differ from the mean monthly flow.

For the 32 years of simulation, the maximum Devil Canyon discharge in August was 17,900 cfs which included 14,100 cfs from Watana and 3800 cfs from tributary inflow into the Devil Canyon reservoir. In examining flow ratios of one day peaks to mean monthly flow at Gold Creek for the month of August it can be seen that these ratios vary from 1.10 to 2.40. If these ratios can be applied to the tributary inflow, then the peak inflow could have been as high as 9100 cfs. Also, if the Watana powerhouse flow was not constant for the month, then some flow variability could also be attributed to Watana. The net result is a Devil Canyon outflow that could be a constant value for the entire month or a variable outflow that has the same mean value but a peak on the order of 30,000 cfs. The actual variability would depend on the daily inflow hydrograph for Devil Canyon.

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.2.97 through E.2.100 for Watana, Gold Creek, Sunshine, and Susitna Station. The flow duration curves show less variability during post-project operations and a diminished pre- and post-project difference with distance downstream of Devil Canyon.

(ii) Effects on Water Quality

- Water Temperatures

The winter time temperatures discharged from Devil Canyon will range from about 4°C to 1°C. The temperature will slowly decrease in the downstream direction because of heat exchange with the colder atmosphere. In January by the time the flow reaches Sherman, a drop in temperature of about 1.3°C will be expected while a drop of about 4°C will occur to Talkeetna. Depending on the outflow temperature, the threshhold of 0°C water will vary from Talkeetna to Sherman. Throughout the winter water temperatures upstream of Sherman will always be above freezing, approaching the outflow temperature as it moves upstream. The minimum temperature expected at Gold Creek will be between 0.5°C and 3°C.

The summer time temperatures will be slightly higher than those for the Watana because of the larger surface area for heat exchange. A peak temperature of about 13°C will be reached at Gold Creek about the middle of June. Through July and the first half of August, the temperatures will ab about 10 to 12°C, slowly decreasing through the latter part of August to the end of September.

- Ice

The initiation of ice formation at Talkeetna will be delayed by several months. The large volume of warm water from upstream will delay and reduce the quantity of ice supplied from the Upper Susitna River. Depending on the reservoir outflow temperatures, the ice cover will start to form by the end of January and progress a short distance upstream through February. The location of the ice front is expected to be between Talkeetna and Sherman. Staging due to the ice cover will be about 3-4 feet.

The breakup in the spring will occur downstream due to warmer climatic conditions and also from the upstream front because of the warmer water from the project. The cover will tend to thermally decay in place. Therefore, the intensity of the breakup should be less severe with fewer ice jams than the preproject occurances.

- 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 3-4 microns in diameter) entering the reservoir and the relatively short retention time. The suspended sediment, turbidity, and vertical illumination levels that occur within the impoundment and downstream wil be only slightly reduced from that which exists at the outflow from Watana.

Some minor slumping of the reservoir walls and resuspension of shoreline sediment will probably continue to occur, especially during August and September when the reservoir may be drawn down as much as 50 feet. These processes will produce short term, localized increases in suspended sediments. However, as previously noted, the overburden layer is shallow so no significant problems will arise. Additionally, since most of this sediment will settle out, downstream increases will be minor.

- <u>Total Dissolved Solids, Conductivity, Alkalinity, Significant Ions and Metals</u>

As previously identified in Section 3.3(b)(iii) the leaching process is expected to result in increased levels of the aforementioned water quality properties. These effects are not expected to diminish as rapidly as was indicated for Watana. Although leaching of the more soluable chemicals will diminish, others will continue to be leached because large quantities of inorganic sediment will not be covering the reservoir bottom. It is, however, anticipated that the leachate will be confined to a layer of water near the impoundment floor and should not degrade the remainder of the reservoir or downstream water quality.

As was the case at Watana, the increased surface area will lead to an increase in the amount of evaporation. However, because of the 2.0 month retention time and the mixing actions of the winds and waves, the concentrations of dissolved substances should virtually be unchanged and no adverse affect on water quality within the reservoir or downstream should occur.

Since no ice cover is anticipated, no increased concentrations of dissolved solids will result at the ice-water interface.

- <u>Dissolved Oxygen</u>

As was previously discussed in Section 3.2 (c)(iii), reduction of dissolved oxygen concentrations can occur in the hypolimnion of deep reservoirs.

Stratification and the slow biochemical decomposition of organic matter will promote low oxygen levels near the reservoir bottom over time. 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. Since water for energy generation is drawn from the upper layers of the reservoir, no adverse effects to downstream oxygen levels will occur.

- <u>Nitrogen Supersaturation</u>

No supersaturated conditions will occur downstream of the Devil Canyon Dam. Fixed-cone valves will be employed to minimize potential nitrogen supersaturation problems for all floods with a recurrence interval less than one in fifty years.

For flood flows greater than once in fifty year flood when spillage will unavoidably occur, nitrogen supersaturation will be minimized through the installation of spillage deflectors which will prevent the creation of a plunging action that could entrain air.

- Facilities

The construction camp and village will be decommissioned upon completion of construction and filling. Localized increases in turbidity and suspended sediments will occur in the local drainage basins due to these activities, but these effects will not be significant as erosion control measures will be employed.

(iii) Effects on Groundwater 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.

(iv) Impact on Lakes and Streams

All the effects identified in Section 3.2(c)(ii) for the streams in the Watana reservoir will be experienced by the streams flowing into the Devil Canyon reservoir listed in Table E.2.11. No lakes in the Devil Canyon impoundment will be impacted other than the previously described small lake at the Devil Canyon damsite. The tributaries downstream of Devil Canyon will not change from the conditions established when Watana was operating alone as discussed earlier.

(v) Instream Flow Uses

The effects on the fishery, wildlife habitat, and riparian vegetation are described in Chapter 3.

- Navigation and Transporation

The Devil Canyon reservoir will transform the heavy whitewater upstream of the dam into flat water. This will afford recreational opportunities for less experienced boaters but totally eliminate the whitewater kayaking opportunities.

Since the Devil Canyon facility will be operated as a base loaded plant, downstream impacts should remain similar to the Watana only operation. The reach of river that remains free of ice may be extended somewhat further downstream.

- Estuarine Salinity

Salinity variations in Cook Inlet were computed using a numerical model of Cook Inlet (Resource Management Associates, 1982). As expected, the salinity changes from baseline conditions were almost identical with those determined for Watana operation alone. The post- project salinity range is reduced, there being lower salinities in winter and higher salinity in summer. Figure E.3.101 illustrates the comparison of annual salinity variation off the mouth of the Susitna River using mean monthly pre- and post-project Susitna Station flows.

3.4 Access Plan Impacts

The Watana access route will begin with the construction of a 2-mile 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 twenty-one miles. Portions of this road segment will be upgraded to meet standards necessary for the anticipated construction traffic. From the Denali Highway, a 42 mile road will be constructed in a southerly direction to the Watana site.

Access to the Devil Canyon site will be via a 37 mile road from Watana, north of the Susitna River, and a 12 mile railroad extension from Gold Creek, on the south side of the Susitna River. For a more detailed description of the access routes refer to Exhibit A, Section 1.12 and 7.12.

(a) Flows

Flow rates on streams crossed by the access road will not be impacted. However, localized impacts on water levels and flow velocities could occur if crossings are poorly designed. Because they do not restrict streamflow, bridge crossings are preferred to culverts or low-water crossings. Bridge supports should be located outside active channels, if possible.

Where not properly designed, culverts can restrict fish movement due to high velocities or perching of the culvert above the streambed. Culverts are also more susceptible to icing problems, causing restricted drainage, especially during winter snowmelt periods.

Low-water crossings may be used in areas of infrequent, light traffic. They should conform to the local streambed slope and are to be constructed of materials so that water will flow over them instead of percolating through them, which would also restrict fish passage.

(b) Water Quality

Most water quality impacts associated with the proposed access routes will occur during construction. The principal anticipated water quality impacts associated with construction will be increased suspended sediment and turbidity levels and accidental leakage and spillage of petroleum products. Given proper design and construction techniques, few water quality impacts are anticipated from the subsequent use and maintenance of these facilities.

(i) Turbidity and Sedimentation

Some of the more apparent potential sources of turbidity and sedimentation problems include:

- Instream operation of heavy equipment;
- Placement and types of permanent stream crossings (culverts vs. bridges);
- Location of borrow areas;
- Lateral stream transits;
- Vegetative clearing;
- Side hill cuts;
- Disturbances to permafrost; and
- Timing and schedules for construction.

These potential sources of turbidity and sedimentation are discussed more fully in Chapter 3.

(ii) 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, it became apparent that oil spills of various sorts were a greater problem than anticipated. Most spills occurred as a result of equipment repair, refueling and vehicle accidents. When equipment with leaky hydraulic hoses are operated in streams petroleum products are very likely to reach the water. To avoid this, vehicles and equipment will be properly maintained.

Water pumping for dust control, gravel processing, dewatering, and other purposes can also lead to petroleum spills if proper care is not taken. Since water pumps are usually placed on river or lake banks very near the water, poor refueling practices could result in frequent oil spills into the water.

3.5 Transmission Corridor Impacts

The transmission line can be divided into 4 segments: central (Watana to Gold Creek), intertie (Wilow to Healy), northern (Healy to Ester), and southern (Willow to Anchorage).

The central segment is composed of two sections: Watana to Cheechako Creek and Cheechako Creek to Gold Creek. Construction of the portion from the Watana damsite to Cheechako Creek will be undertaken during winter with minimal disturbance to vegetation. Hence, impact on stream flow and water quality should be minimal. From Cheechako Creek to the intertie, the transmission corridor will follow the existing trail. This should also result in minimal impacts.

The Willow-Healy intertie is being built as a separate project and will be completed in 1984 (Commonwealth Associates, 1982). The Susitna project will add another line of towers within the same right-of-way. The impacts, then, will be similar to those experienced during intertie construction. The existing access points and construction trails will be utilized. 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 and south stubs, stream crossings will be required. The potential effects will be of the same type as those discussed in Section 3.4, although generally much less severe because of the limited access needed to construct a transmission line. 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. However, given proper design and construction practices, few erosion related problems are anticipated.

Contamination of local waters from accidental spills of fuels and oils is another potential water quality impact. To minimize this potential, vehicles will be properly maintained and appropriate refueling practices will be required.

Once the transmission line has been built, there should be very 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 wetlands and streams to repair damaged lines or towers. Permanent roads will not be built in conjunction with transmission lines. Rather, grasses and shrubs will be allowed to grow along the transmission corridor but will be kept trimmed so that vehicles are able to follow the right-of-way associated with the lines. Streams may need to be forded, sometimes repeatedly, in order to effect repairs. Depending on the season, crossing location, type and frequency of vehicle traffic, this could cause erosion downstream reaches.

4 - AGENCY CONCERNS AND RECOMMENDATIONS

Throughout the past three years, 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;
- Reservoir and downstream thermal regime;
- Sedimentation process in the reservoir and downstream suspended sediment levels and turbidity;
- Nitrogen supersaturation downstream of the dams;
- Winter ice regime;
- Trophic status of the reservoirs;
- Dissolved oxygen levels in the reservoir and downstream;
- Downstream ground water and water table impacts;
- Effects on instream flow uses;
- Sediment and turbidity increases during construction;
- Potential contamination from accidental petroleum spills and leakage; and
- Wastewater discharge from the temporary community.

A thorough and complete compliment of agency concerns and recommendations will be presented pursuant to the review of this draft license application.

5 - MITIGATION, ENHANCEMENT, AND PROTECTIVE MEASURES

5.1 - Introduction

Mitigation measures were developed to protect, maintain, or enhance the the water quality and quantity of the Susitna River. These measures were developed primarily to avoid or minimize impacts to aquatic habitats, but they will also have a beneficial effect on other instream flow uses.

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. Three key mitigation measures were incorporated into the engineering design: (1) Minimum flow requirements were selected during the salmon spawning season that were greater than what would be discharged if flow was selected solely from an optimum economic point of view. (2) A multilevel intake was added to improve temperature control and minimize project effects. (3) Fixed-cone valves were incorporated to prevent nitrogen supersaturation from occurring more frequently than once in fifty years. Other mitigation measures incorporated in the project design and construction procedures are discussed below.

The second phase of the mitigation process will be the implementation of environmentally sound construction practices during the construction planning process. This will involve the education of project personnel to the proper techniques needed to minimize impacts to aquatic habitats. Monitoring of construction practices will be required to identify and correct construction related problems. Upon completion of construction, the third phase of mitigation consists of operational monitoring and surveillance to identify problems and employ corrective measures.

5.2 - Construction

The mitigation, enhancement, and protective measures included in Chapter 3.2.4(a) are appropriate for construction of the Watana and Devil Canyon facilities; the access road construction; and the transmission line construction.

5.3 - Mitigation of Watana Impoundment Impacts

The primary concerns during filling of the reservoir discussed in Section 3 of this chapter include:

- Maintenance of minimum downstream flows;
- Maintenance of an acceptable downstream thermal regime throughout the year;
- Changes in downstream sediment loads, deposition and flushing;

- Downstream gas supersaturation;
- Eutrophication processes and trophic status; and
- Effects on ground water levels and ground water upwelling rates.

Minimum downstream flows, will be provided to mitigate the impact the filling of the reservoir could have on downstream fish and other instream flow uses. Although access may be difficult, the 12,000 cfs flow at Gold Creek in August will provide spawning salmon access to most of the sloughs between Devil Canyon and Talkeetna. Additionally, the selected downstream flow of 12,000 cfs will assist in maintaining adequate ground water levels and upwelling rates in the sloughs.

Eutrophication was determined not be a problem and therefore no mitigation is required.

Downstream gas supersaturation will be prevented by the design of the energy disipating valves and chambers incorporated in the emergency release outlet.

Changes in the downstream river morphology will occur but are not expected to be significant enough to warrant mitigation except for the mouth of some tributaries between Devil Canyon and Talkeetna where selective reshaping of the mouth may be required to insure salmon access.

From the first winter of filling to the commencement of project operation, the water temperature at the Watana low level outlet will approximate 4°C to 5°C. Although these temperatures will be moderated somewhat downstream, downstream impacts are likely to occur. No mitigation measures have been incorporated in the design to offset these low downstream temperatures during the second and third year of the filling process. If during the final design phase of the project a technically acceptable cost-effective method can be developed to mitigate this potential temperature impact, it will be incorporated into the final designs.

5.4 - Mitigation of Watana Operation Impacts

The primary concerns during Watana operation are identified in Section 5.3.

(a) Flows

The minimum downstream flows at Gold Creek will be unchanged from those provided during impoundment from May through September. However, for October through April, the minimum flow at Gold Creek will be increased to 5000 cfs.

These mininum flows are not the most attractive from a project economic point of view. However, they do provide a base flow of sufficient magnitude that permits the development of mitigation measures to substantially reduce the project's impact on the downstream fishery. Hence, the minimum downstream flows will provide a balance between power generation and downstream flow requirements.

To provide stable flows downstream and minimize the potential for downstream ice jams, Watana when it is operating alone will be operated primarily as a base loaded plant, even though it would be desirable to operate Watana as a peaking plant.

(b) Temperature and D.O.

As noted in Section 3, the impoundment of the Watana reservoir will change the downstream temperature regime of the Susitna River. Multilevel intakes have been incorporated in the power plant intake structures so that water can be drawn from various depths (usually the surface). By selectively withdrawing water, the desired temperature can be maintained at the powerhouse tailrace and downstream. Using a reservoir temperature model, it was possible to closely match existing Susitna River water temperatures except for periods in spring and fall.

(c) Nitrogen Supersaturation

Nitrogen supersaturation is avoided by the inclusion of fixed-cone valves in the outlet facilities. Fixed-cone valves have been proven effective in preventing nitrogen supersaturation (Ecological Analysts Inc. 1982). Instead of passing water over the spillway into a plunge pool, excess water is released through the valves. These facilities are designed to pass a once in fifty year flood event without creating supersaturated water conditions downstream.

The Watana facilities incorporate six fixed-cone valves that are capable of passing a total design flow of 24,000 cfs.

5.5 - Mitigation of Devil Canyon Impoundment Impacts

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.

5.6 - Mitigation of Devil Canyon/Watana Operation

(a) Flows

The downstream flow requirement at Gold Creek will be the same as for Watana operation alone. After Devil Canyon is on line, Watana will be operated as a peaking plant since the discharge feeds directly into the Devil Canyon reservoir. The Devil Canyon reservoir will provide the flow regulation required to stabilize the downstream flows.

(b) Temperature

As with Watana, multilevel intakes will be incorporated into the Devil Canyon design. Two intake ports will be needed because of the limited drawdown at Devil Canyon.

(c) Nitrogen Supersaturation

The Devil Canyon Dam is designed with seven fixed-cone valves, three with a diameter of 90 inches and four more with a diameter of 102 inches. Total design capacity of the seven valves will be 38,500 cfs.

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TABLE E.2.1: GAGING STATION DATA

Station	USGS Gage Number	Drainage Area (mi^2)	Years of Record	River Mile
Denali	15291000	950	25	291
Maclaren	15291200	280	24	260(1)
Cantwell	15291500	4140	20	225
Gold Creek	15292000	6160	32	137
Chulitna	15292400	2570	23	98
Talkeetna	15291500	2006	18	97(1)
Skwenta	15294300	2250	20	28(1)
Susitna	15294350	19400	9	26

(1) Confluence of tributary with Susitna River.

TABLE E.2.2: BASELINE MONTHLY FLOWS (cfs)

		Denali[1] (20)	Vee Canyon[2] (30)	Devil Watana[2] (32)	Gold Canyon[2] (32)	Susitna Creek (32)	Maclaren Station (5)	Chulitna (Paxson) (21)	Station (14)	Talkeetna (15)	Skwenta (20)
OCT	Max	2135	4626	6458	7518	8212	52636	687	9314	4438	6196
	Mean	1132	3033	4523	5324	5654	31250	409	4859	2505	4297
	Min	528	1638	2403	2867	3124	15940	249	2898	1450	1929
NOV	Max	680	2200	3525	3955	3954	21548	265	3014	1786	3094
	Mean	500	1449	2050	2391	2476	13247	177	1994	1146	1780
	Min	192	780	1021	1146	1215	6606	95	1236	770	678
DEC	Max	575	1535	2259	2905	3264	15081	190	2143	1239	2871
	Mean	317	998	1415	1665	1788	9070	118	1457	842	1267
	Min	146	543	709	810	866	4279	49	891	515	628
JAN	Max	651	1300	1780	2212	2452	12269	162	1673	1001	2829
	Mean	246	824	1166	1362	1466	8205	96	1276	675	1078
	Min	85	437	636	757	824	6072	44	974	504	600
FEB	Max	321	1200	1560	1836	2028	11532	140	1400	805	1821
	Mean	206	722	983	1153	1242	7409	84	1099	565	903
	Min	64	426	602	709	768	4993	42	820	401	490
MARCH	Max	287	1273	1560	1779	1900	9193	121	1300	743	1200
	Mean	188	692	898	1042	1115	6562	76	978	496	809
	Min	42	408	569	664	713	4910	36	738	379	522
APRIL	Max	415	1702	1965	2405	2650	9803	145	1600	710	1700
	Mean	230	853	1099	1267	1351	7214	87	1154	569	1016
	Min	43	465	609	697	745	5531	50	700	371	607
MAY	Max	4259	13751	15973	19777	21890	94143	2084	20025	7790	13460
	Mean	2056	7520	10355	12190	13277	60822	802	8371	4195	7920
	Min	629	2643	2857	3428	3745	29809	208	3971	1694	1635
JUNE	Max	12210	34630	42842	47816	50580	176219	4297	40330	19040	40356
	Mean	7306	19655	23024	26078	28095	122510	2891	22495	11610	18583
	Min	4647	9909	13233	14710	15530	67838	1751	15587	7429	10650
JULY	Max	12110	22890	28767	32388	34400	168815	4649	35570	14440	25270
	Mean	9399	17079	20810	23152	23919	130980	3165	26424	10560	17089
	Min	6756	12220	15871	17291	18093	102121	2441	22761	7080	11670
AUGUST	Max	10400	22710	31435	35270	32620	138334	3741	33670	18033	20590
	Mean	8124	14474	18629	20928	21727	109360	2566	22292	9331	13374
	Min	3919	6597	13412	15257	16220	62368	974	11300	3787	7471
SEPT	Max	5452	12910	17206	19799	21240	104218	2439	23260	10610	13371
	Mean	3356	7897	792	12414	13327	68060	1166	12003	5546	8156
	Min	1822	3376	5712	6463	6881	34085	470	6424	2070	3783
ANNUAL	Max	3651	7962	9833	10947	11565	59395	1276	12114	5276	10024
	Mean	2723	6295	8023	9130	9670	48148	975	8748	4029	6386
	Min	2127	4159	6100	7200	7200	31228	693	6078	2233	4939

NOTES:

1 Years of Record
2 Computed

TABLE E.2.3: INSTANTANEOUS PEAK FLOWS OF RECORD

GOLD CREEK		CANTWELL		DENALI		MACLAREN	
Date	cfs	Date	cfs	Date	cfs	Date	cfs
8/25/59	62,300	6/23/61	30,500	8/18/63	17,000	9/13/60	8,900
6/15/62	80,600	6/15/62	47,000	6/07/64	16,000	6/14/62	6,650
6/07/64	90,700	6/07/64	50,500	9/09/65	15,800	7/18/65	7,350
6/06/66	62,600	8/11/70	20,500	8/14/67	28,200	8/14/67	7,600
8/15/67	80,200	8/10/71	60,000	7/27/68	19,000	8/10/71	9,300
8/10/71	87,400	6/22/72	45,000	8/08/71	38,200	6/17/72	7,100
6/17/72	82,600						

TABLE E.2.4: COMPARISON OF SUSITNA REGIONAL FLOOD PEAK ESTIMATES WITH USGS METHODS FOR GOLD CREEK

Station Location	Return Period (Yrs.)	Single 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	37,100	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	

1 Based on three parameter log normal distribution and shown to three significant figures.

2 Lamke, R.D. (1970) Flood Characteristics of Alaskan Stream, 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.

TABLE E.2.5: SUSITNA RIVER REACH DEFINITIONS

River Mile	Average Slope	Predominent 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 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.

TABLE E.2.6: DETECTION LIMITS FOR WATER QUALITY PARAMETERS

	R&M Detection Limit (1)	USGS Detection Limit (5)	Criteria Levels
Field Parameters			
Dissolved Oxygen	0.1	--	7-17
D. O. Percent Saturation	1	--	110
pH, pH Units	$\pm$0.01	--	6.5 - 9.0
Conductivity, umhos/cm @ 25°C	$\pm$1	--	--
Temperature, °C	0.1	--	20,15 (M), 13 (Sp)
Free Carbon Dioxide	1	--	--
Alkalinity, as $CaCO_3$	2	--	20
Settleable Solids, ml/l	0.1	--	--
Laboratory Parameters			
Ammonia Nitrogen	0.05	.01	0.02
Organic Nitrogen	0.1	--	--
Kjeldahl Nitrogen	0.1	.1	--
Nitrate Nitrogen	0.1	.01	10
Nitrate Nitrogen	0.01	.01	--
Total Nitrogen	0.1	.01	--
Ortho-Phosphate	0.01	.01	--
Total Phosphorus	0.01	.01	0.01
Chemical Oxygen Demand	1	--	--
Chloride	0.2	.01	200
Color, Platinum Cobalt Units	1	1	50
Hardness	1	--	--
Sulfate	1	.05	200
Total Dissolved Solids(2)	1	1	1,500
Total Suspended Solids(3)	1	1	no measurable measurable increase
Turbidity (NTU)	0.05	1	25 NTU increase
Gross Alpha, picocurie/liter	3	--	15
Total Organic Carbon	1.0	--	3.0 (S)
Total Inorganic Carbon	1.0	00	00
Organic Chemicals			
- Endrin, ug/l	0.0002	.00001	0.004
- Lindane, ug/l	0.004	.00001	0.01
- Methoxychlor, ug/l	0.1	.00001	0.03
- Toxaphene, ug/l	0.005	.001	0.013
- 2, 4-D, ug/l	0.1	.00001	100
- 2, 4, 5-TP Silvex, ug/l	0.01	.00001	10
ICAP Scan(4)			
- Ag, Silver	0.05	.001	0.05
- Al, Aluminum	0.05	.01	0.073 (S)
- As, Arsenic	0.10	.001	0.440
- Au, Gold	0.05	--	--
- B, Boron	0.05	.01	0.043
- Ba, Barium	0.05	.1	1.0
- Bi, Bismuth	0.05	--	0.0035 (S)
- Ca, Calcium	0.05	.01	--
- Cd, Cadmium	0.01	.001	0.0012, 0.0004
- Co, Cobalt	0.05	.001	--
- Cr, Chromium	0.05	.001	0.1

TABLE E.2.6: DETECTION LIMITS FOR WATER QUALITY PARAMETERS (Cont'd)

	R&M Detection Limit(1)	USGS Detection Limit(5)	Criteria Levels
Laboratory Parameters (Cont'd)			
- Cu, Copper	0.05	.001	0.01
- Fe, Iron	0.05	.01	1.0
- Hg, Mercury	0.1	.0001	0.00005
- K, Potassium	0.05	.1	--
- Mg, Magnesium	0.05	.1	--
- Mn, Manganese	0.05	.001	0.05
- Mo, Molybdenum	0.05	.001	0.07
- Na, Sodium	0.05	.1	--
- Ni, Nickel	0.05	.001	0.025
- Pb, Lead	0.05	.001	0.03
- Pt, Platinum	0.05	--	--
- Sb, Antimony	0.10	.001	9
- Se, Selenium	0.10	.001	0.01
- Si, Silicon	0.05	--	--
- Sn, Tin	0.10	.1	--
- Sr, Strontium	0.05	.01	--
- Ti, Titanium	0.05	--	--
- W, Tungsten	1.0	--	--
- V, Vanadium	0.05	--	0.007 (S)
- Zn, Zinc	0.05	.01	0.03
- Zr, Zirconium	0.05	--	--

(1) All values are expressed in mg/l unless otherwise noted.

(2) TDS - (filterable) material that passes through a standard glass fiber filter and remains after evaporation (SM p 93).

(3) TSS - (nonfilterable) material required on a standard fiber filter after filtration of a well-mixed sample.

(4) ICAP SCAN - thirty-two (32) element computerized scan in parts/million (Ag, Al, As, Au, B, Ba, Bi, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Mo, Na, Ni, Pb, Pt, Sb, Se, Si, Sn, Sr, Ti, V, W, Zn, Zr).

(5) 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.

(S) - Suggested Criteria

(M) - Migration Routes

(Sp) - Spawning Areas

TABLE E.2.7: PARAMETERS EXCEEDING CRITERIA BY STATION AND SEASON

Parameter	Station	Season	Criteria
D.O. % Saturation	G	S	L
pH	T	S, W, B	L
	G	B	
Color	T, S	S	L
Phosphorus, Total (d)	V, G, T, S, SS	S, W, B	L
Total Organic Carbon	G, SS	S	S
	V, G, SS	W	
	SS	B	
Aluminum (d)	V, G	S, W	S
Aluminum (t)	G, S, SS	S	
Bismuth (d)	V, G	S	S
	G	W	
Cadmium (d)	T, SS	S, W	L
	SS	B	
Cadmium (t)	G, T, S, SS	S	
	T, SS	W, B	
Copper (d)	T, SS	S	A
	T	W	
	SS	B	
Copper (t)	G, T, S, SS	S	
	T, S, SS	W	
	T, SS		
Iron (d)	D, V, C	S	L
Iron (t)	G, T, S, SS	S	
	T	B	
Lead (t)	G, T, S, SS	S	A
	T, SS	W, B	
Manganese (d)	D, V, G, C	S	L
Manganese (t)	G, T, S	S	
	T, SS	B	
Mercury (d)	G, S	S	L
	S	W	
Mercury (t)	G, T, S, SS	S	
	T, S, SS	W	
	T, SS	B	
Nickel (t)	G, S, SS	S	A
Zinc (d)	V	S	A
Zinc (t)	G, S, SS	S	
	T, S, SS	W	
	SS	B	

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

S - Criteria that have been suggested but are now law, or levels which natural waters usually do not exceed

A - Alternate level to 0.02 of the 96-hour LC50 determined through bioassay

TABLE E.2.8: 1982 TURBIDITY ANALYSIS OF THE SUSITNA, CHULITNA AND TALKEETNA RIVERS CONFLUENCE AREA

Location	Date Sampled[1]	Date Analyzed	Turbidity[2] (NTU)	Suspended[3] Sediment Concentration (mg/l)	Discharge[4] (cfs)
Susitna at Sunshine (Parks Highway Bridge)	6/3/82	6/11/82	164	--	71,800
	6/10/82	6/24/82	200	403	62,100
	6/17/82	6/24/82	136	322	48,700
	6/21/82	8/3/82	360	755	76,600
	6/28/82	8/18/82	1,056	--	71,600
	7/6/82	8/3/82	352	--	44,800
	7/12/82	8/3/82	912	--	58,000
	7/19/82	8/18/82	552	--	59,400
	7/26/82	8/18/82	696	--	97,100
	8/2/82	8/18/82	544	--	61,000
	8/9/82	8/26/82	720	--	50,200
	8/16/82	8/26/82	784	--	45,600
	8/23/82	9/14/82	552	--	--
	8/30/82	9/14/82	292	--	--
	9/17/82	10/12/82	784	--	--
Susitna Below Talkeetna	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 at LRX-4[5]	5/26/82*	5/29/82	81	--	--
Susitna near Chase[5] (R.R. Mile 232)	6/3/82	6/11/82	140		
	6/8/82	6/24/82	130	547	--
	6/15/82	6/24/82	94	170	20,700
	6/22/82	8/3/82	74	426	--
	6/30/82	8/18/82	376	--	--
	7/8/82	8/18/82	132	--	18,100
	7/14/82	8/3/82	728	--	27,300
	7/21/82	8/18/82	316	--	21,900
	7/28/82	8/18/82	300	--	25,600
	8/4/82	8/18/82	352	--	18,500
	8/10/82	8/26/82	364	--	16,700
	8/18/82	8/26/82	304	--	--
	8/25/82	9/14/82	244	--	--
	8/31/82	9/14/82	188	--	--
	9/19/82	10/12/82	328	--	--
Susitna at Vee Canyon	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	--	--
Chulitna (Canyon)[6]	6/4/82	6/11/82	272	--	--
	6/22/82	8/3/82	680	--	--
	6/29/82	8/18/82	1,424	--	--
	7/7/82	8/3/82	976	--	--
	7/13/82	8/18/82	1,136	--	--
	7/20/82	8/18/82	1,392	--	--
	7/27/82	8/18/82	664	--	--
	8/3/82	8/18/82	704	--	--
	8/11/82	8/26/82	592	--	--
	8/17/82	8/26/82	1,296	--	--
	8/24/82	9/14/82	632	--	--
	9/1/82	9/14/82	316	--	--
	9/18/82	10/12/82	1,920	--	--

TABLE E.2.8 - (Cont'd)

Location	Date Sampled[1]	Date Analyzed	Turbidity[2] (NTU)	Suspended Sediment Concentration[3] (mg/l)	Discharge[4] (cfs)
Chulitna near Confluence[6]	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	--	--
Talkeetna at USGS Cable[7]	6/2/82	6/11/82	146	311	16,000
	6/9/82	6/24/82	49	311	13,400
	6/17/82	6/24/82	28	--	10,300
	6/23/82	8/3/82	26	164	11,700
	6/29/82	8/18/82	41	--	11,800
	7/7/82	8/3/82	20	--	6,830
	7/13/82	8/3/82	132	--	9,390
	7/20/82	8/18/82	148	--	8,880
	7/28/82	8/18/82	272	--	16,000
	8/3/82	8/18/82	49	--	9,730
	8/10/82	8/26/82	53	--	7,400
	8/17/82	8/26/82	82	--	6,490
	8/24/82	9/14/82	68	--	--
	8/31/82	9/14/82	37	--	--
	9/20/82	10/12/82	34	--	--
Talkeetna at R.R. Bridge[7]	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

Notes: [1] *Refers to samples collected by R&M Consultants, all other samples were collected by USGS.

[2] R&M Consultants conducted all turbidity measurements.

[3] Suspended sediment concentrations are preliminary, unpublished data provided by the U.S. Geological Survey.

[4] Discharges for "Susitna at Sunshine" and "Susitna Below Talkeetna" are from the U.S. Geological Survey stream gage at the Parks Highway Bridge at Sunshine.

[5] Discharges for "Susitna at LRX-4" and "Susitna near Chase" are from the USGS stream gage at the Alaska Railroad Bridge at Gold Creek.

[6] Discharges for "Chulitna" and "Chulitna near Confluence" are from the USGS stream gage at the Parks Highway Bridge at Chulitna.

[7] Discharges for "Talkeetna at USGS Cable" and "Talkeetna at R.R. Bridge" are from the USGS stream gage near Talkeetna.

TABLE E.2.9: SIGNIFICANT ION CONCENTRATIONS

	Ranges of Concentrations (mg/l)			
	Upstream of Project		Downstream of Project	
	Summer	Winter	Summer	Winter
Bicarbonate (alkalinity)	39 - 81	57 - 187	25 - 86	45 - 145
Chloride	0 - 11	4 - 30	1 - 15	6 - 35
Sulfate	2 - 23	11 - 39	1 - 28	10 - 38
Calcium (dissolved)	13 - 29	23 - 51	10 - 37	22 - 32
Magnesium (dissolved)	1 - 4	0 - 16	1 - 6	1 - 10
Sodium (dissolved)	2 - 10	4 - 23	2 - 8	5 - 17
Potassium (dissolved)	1 - 7	0 - 9	1 - 4	1 - 5

TABLE E.2.10: STREAMS TO BE PARTIALLY OR COMPLETELY INUNDATED BY WATANA RESERVOIR (El. 2,185)

Stream Name	Susitna River Mile at Mouth	Approximate Existing Elevation at Mouth (ft. msl)	Approximate Stream Gradient at Mouth (ft/mile)	Length of Stream to be Inundated (miles)
1. unnamed	240.8	2,185	380	mouth only
2. unnamed	240.0	2,175	1,000	mouth only
3. unnamed	239.4	2,170	500	mouth only
4. unnamed	238.5	2,165	600	mouth only
5. unnamed	236.0	2,140	500	0.1
6. unnamed	233.8	2,055	400	0.3
7. Oshetna River	233.5	2,050	65	2.0
8. unnamed	232.7	2,040	1,500	0.2
9. Goose Creek	231.2	2,030	125	1.2
10. unnamed	230.8	2,025	1,400	0.2
11. unnamed	229.8	2,015	550	0.3
12. unnamed	229.7	2,015	1,500	0.2
13. unnamed	229.1	2,010	2,000	0.1
14. unnamed	228.5	2,000	1,300	0.1
15. unnamed	228.4	2,000	2,000	0.2
16. unnamed	227.4	1,980	1,700	0.1
17. unnamed	226.8	1,970	250	0.6
18. unnamed	225.0	1,930	400	0.4
19. unnamed	224.4	1,920	1,250	0.2
20. unnamed	221.5	1,875	230	1.0
21. unnamed	220.9	1,865	1,000	0.2
22. unnamed	219.2	1,845	350	1.0
23. unnamed	217.6	1,830	700	0.5
24. unnamed	215.1	1,785	900	0.3
25. unnamed	213.2	1,760	1,000	0.4
26. unnamed	213.0	1,755	600	0.6
27. unnamed	212.1	1,750	1,200	0.3
28. unnamed slough	212.0	1,750	13	0.5 (full length)
29. unnamed slough	211.7	1,745	1,000	0.3
30. unnamed	210.2	1,720	400	0.7
31. Jay Creek	208.6	1,700	120	3.2
32. unnamed	207.3	1,690	300	0.9 (full length)
33. unnamed	207.0	1,685	160	1.0
34. Kosina Creek	206.9	1,685	120	4.2
35. unnamed	205.0	1,665	1,100	0.5 (full length)
36. unnamed	204.9	1,665	750	0.4 (full length)
37. unnamed	203.9	1,655	800	0.7
38. unnamed	203.4	1,650	350	0.5 (full length)
39. unnamed	201.8	1,635	400	0.8
40. unnamed	200.7	1,625	1,000	1.0
41. unnamed	198.7	1,610	400	0.7
42. unnamed	198.6	1,605	700	0.6
43. unnamed	197.9	1,600	500	0.6
44. unnamed	197.1	1,595	650	0.7
45. unnamed	196.7	1,590	1,000	0.7
46. unnamed	196.2	1,585	550	1.0
47. unnamed	195.8	1,580	350	1.1
48. unnamed	195.2	1,575	200	1.3 (full length)
49. unnamed	194.9	1,570	200	1.7
50. Watana Creek	194.1	1,560	50	10.0 (longest fork)

TABLE E.2.10 - (Cont'd)

Stream Name	Susitna River Mile at Mouth	Approximate Existing Elevation at Mouth (ft. msl)	Approximate Stream Gradient at Mouth (ft/mile)	Length of Stream to be Inundated (miles)
50A. Delusion Creek (tributary to Watana Creek)	--	1,700	200	1.9
51. unnamed	192.7	1,550	400	1.5 (full length)
52. unnamed	192.0	1,545	200	3.9 (longest fork)
53. unnamed	190.0	1,530	1,300	0.5
54. unnamed	187.0	1,505	1,250	0.7
55. unnamed	186.9	1,505	2,000	1.7
56. Deadman Creek	186.7	1,500	450	2.3

TABLE E.2.11: STREAMS TO BE PARTIALLY OR COMPLETELY INUNDATED BY DEVIL CANYON RESERVOIR (EL. 1,455)

Stream Name	Susitna River Mile at Mouth	Approximate Existing Elevation at Mouth (ft. msl)	Approximate Stream Gradient at Mouth (ft/mile)	Length of Stream to be Inundated (miles)
1. Tsusena Creek	181.9	1,450	250	0.2
2. unnamed	181.2	1,440	250	0.2
3. unnamed slough	180.1	1,430	10	0.6 (full length)
4. unnamed slough	179.3	1,420	250	0.1
5. unnamed slough	179.1	1,420	500	0.2
6. unnamed slough	177.0	1,385	600	0.1
7. Fog Creek	176.7	1,380	125	1.0
8. unnamed	175.3	1,370	75	0.6
9. unnamed	175.1	1,365	1,100	0.1
10. unnamed	174.9	1,360	650	0.1
11. unnamed	174.3	1,350	350	0.3
12. unnamed slough	174.0	1,350	15	2.0 (full length)
12A. unnamed (tributary to slough)	--	1,350	550	0.2
12B. unnamed (tributary to slough)	--	1,350	550	0.2
12C. unnamed (tributary to slough)	--	1,350	1,600	0.1
13. unnamed slough	173.4	1,340	20	0.5 (full length)
14. unnamed	173.0	1,335	600	0.1
15. unnamed	173.0	1,335	1,000	0.2
16. unnamed	172.9	1,330	1,300	0.2
17. unnamed slough	172.1	1,320	15	0.8 (full length)
17A. unnamed (tributary to slough)	--	1,320	2,000	0.1
17B. unnamed (tributary to slough)	--	1,320	2,000	0.1
18. unnamed	171.4	1,315	2,000	0.1
19. unnamed	171.0	1,310	250	0.6
20. unnamed slough	169.5	1,290	15	0.7 (full length)
21. unnamed	168.8	1,280	1,400	0.2
22. unnamed	166.5	1,235	350	0.6
23. unnamed	166.0	1,230	1,250	0.2
24. unnamed	164.0	1,200	2,000	0.2
25. unnamed	163.7	1,180	1,350	0.2
26. Devil Creek	161.4	1,120	180	1.4
27. unnamed	157.0	1,030	400	1.3
28. unnamed	154.5	985	3,000	0.4
29. unnamed (Cheechako Creek)	152.4	950	500	1.6

TABLE E.2.12: DOWNSTREAM TRIBUTARIES POTENTIALLY IMPACTED BY PROJECT OPERATION

No.	Name	River Mile	Bank of Susitna[1]	Reason for Concern
1	Portage Creek	148.9	RB	fish
2	Jack Long Creek	144.8	LB	fish
3	Indian River	138.5	RB	fish
4	Gold Creek	136.7	LB	fish
5	Trib. @ 132.0	132.0	LB	RR
6	Fourth of July Creek	131.1	RB	fish
7	Sherman Creek	130.9	LB	RR, fish
8	Trib. @ 128.5	128.5	LB	RR
9	Trib. @ 127.3	127.3	LB	RR
10	Skull Creek	124.7	LB	RR
11	Trib. @ 123.9	123.9	RB	fish
12	Deadhorse Creek	121.0	LB	fish, RR
13	Trib. @ 121.0	121.0	RB	fish
14	Little Portage Creek	117.8	LB	RR
15	McKenzie Creek	116.7	LB	fish
16	Lane Creek	113.6	LB	fish
17	Gash Creek	111.7	LB	fish
18	Trib. @ 110.1	110.1	LB	RR
19	Whiskers Creek	101.2	RB	fish

[1] Referenced by facing downstream (LB = left bank, RB = right bank).

TABLE E.2.13: SUMMARY OF SURFACE WATER AND GROUND WATER APPROPRIATIONS IN EQUIVALENT FLOW RATES

Township Grid	Surface Water Equivalent		Ground Water Equivalent	
	cfs	ac-ft/yr	cfs	ac-ft/yr
Susitna	.153	50.0	.0498	16.3
Fish Creek	.000116	.02100	.00300	2.24
Willow Creek	18.3	5,660	.153	128
Little Willow Creek	.00613	1.42	.001907	1.37
Montana Creek	.0196	7.85	.366	264
Chulina	.00322	.797	.000831	.601
Susitna Reservoir	.00465	3.36		
Chulitna			.00329	2.38
Kroto-Trapper Creek	.0564	10.7		
Kahiltna	125	37,000		
Yentna	.00155	.565		
Skwentna	.00551	1.90	.000775	.560

TABLE E.2.14: SUSITNA RIVER - LIMITATIONS TO NAVIGATION

River Mile Location*	Description	Severity
19	Alexander Slough Head	Access to slough limited at low water due to shallow channel
52	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 accessible rapids at most flows
291	Denali Highway Bridge	Shallow water and frequent sand bars at low water

*Reference: River Mile Index (R&M Consultants, 1981)

TABLE E.2.15: ESTIMATED LOW AND HIGH FLOWS AT ACCESS ROAD STREAM CROSSINGS

Drainage[1] Basin	A Area (mi^2)	30-Day Minimum Flow (cfs) Recurrence Interval (yrs)			Peak Flows (cfs) Recurrence Interval (yrs)			
		2	10	20	2	10	25	50
Denali Highway to Watana Camp								
Lily Creek	3.70	0.8	0.6	0.5	25	54	78	96
Seattle Creek	11.13	2.4	1.8	1.5	74	147	205	248
Seattle Creek Tributary	1.49	0.3	0.2	0.2	10	24	35	44
Seattle Creek Tributary	2.70	0.8	0.5	0.4	13	29	42	51
Brushkana Creek	22.00	5.5	3.8	3.4	115	217	299	354
Brushkana Creek Site	21.01	4.9	3.5	3.1	121	228	315	374
Upper Deadman Creek	12.08	3.0	2.1	1.9	64	127	177	211
Deadman Creek Tributary	21.28	4.6	3.3	2.9	138	263	363	432
Deadman Creek Tributary	14.71	3.2	2.3	2.0	97	189	262	315
Watana to Devil Canyon								
Tsusena Creek	126.61	26	19	17	780	1309	1744	2000
Devil Creek	31.0	6.7	4.8	4.2	199	369	506	597
Devil Canyon to Gold Creek								
Gold Creek	25.00	5.4	3.9	3.4	162	304	418	497

[1]Minimum flows estimated from the following equation (Freethey and Scully, 1980, Water Resources of the Cook Inlet Basin, U.S. Geological Survey, Atlas HA-620)

$$M_{d,rt} = aA^b (LP + 1)^c (J + 10)^d$$

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)

TABLE E2.16: 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-	61.9	35 mi. d/s	206
Willow Creek	Near Willow	15294005	1978-	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-	15,600	5 mi. u/s	23,460
Willow-Healy Intertie						
Talkeetna River	Near Talkeetna	15292700	1964-	2,006	5 mi. d/s	4,050
Susitna River	At Gold Creek	15292000	1949-	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-	2,570	40 mi. u/s	8,748
M.F. Chulitna River	Chulitna River near Talkeetna	15292400	1958-72,1980-	2,570	50 mi. u/s	8,748
Nenana River	Near Windy	15516000	1950-56,1958-73	710	5 mi. u/s	--
Yanent 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	--	--	--	N/A	3 mi. u/s	--
Susitna River	At Gold Creek	15292000	1949-	6,160	15 mi. u/s	9,647

[1] Areas for ungaged streams are at the mouth.
[2] d/s = downstream, u/s = upstream. Distances for ungaged stream are from the mouth.
[3] Averages determined through the 1980 water year at gage sites.

TABLE E2.17: DOWNSTREAM FLOW REQUIREMENTS AT GOLD CREEK

Month	Flow (cfs) During Filling	Flow (cfs) Operation
Jan	1,000	5,000
Feb	1,000	5,000
Mar	1,000	5,000
Apr	1,000	5,000
May	6,000	6,000
Jun	6,000	6,000
Jul	6,480(1)	6,480
Aug	12,000	12,000
Sep	9,300(2)	9,300
Oct	2,000	5,000
Nov	1,000	5,000
Dec	1,000	5,000

(1)	July 1-26	6,000
	27	6,000
	28	7,500
	29	9,000
	30	10,500
	31	12,000
(2)	September 1-14	12,000
	15	12,000
	16	10,500
	17	9,000
	18	7,500
	19	6,000
	20	6,000

TABLE E2.18: WATANA INFLOW AND OUTFLOW FOR FILLING CASES

	10%				50%				90%			
	Inflow	Outflow (cfs)			Inflow	Outflow (cfs)			Inflow	Outflow (cfs)		
	(cfs)	1991	1992	1993	(cfs)	1991[1]	1992	1993	(cfs)	1991[1]	1992	1993
Jan	1,340	1,340	1,340	1,340	1,190	1,198	1,198	1,000	1,071	1,071	1,071	1,000
Feb	1,138	1,138	1,138	1,138	1,018	1,018	1,018	1,000	910	910	910	910
Mar	1,028	1,028	1,028	1,028	919	919	919	919	822	822	822	822
Apr	1,261	1,261	1,000	1,000	1,127	1,127	1,000	1,000	1,008	1,008	1,000	1,000
May	12,158	8,690	3,276	3,276	10,870	7,402	3,649	3,649	9,715	6,247	4,016	4,016
Jun	25,326	20,005	1,000	10,527	22,644	17,323	1,103	1,939	20,238	14,917	1,867	1,867
Jul	22,327	5,309	9,031	1,000	19,963	2,945	2,181	2,163	17,842	2,836	2,836	2,836
Aug	20,142	14,993	8,649	15,859	18,008	12,859	8,105	10,198	16,095	8,934	8,713	8,713
Sep	12,064	6,743	6,597	12,064	10,787	6,967	6,967	10,787	9,641	7,331	7,331	7,331
Oct	5,272	5,272	1,000	5,272	4,713	3,261	1,000	4,713	4,213	1,230	1,000	1,000
Nov	2,352	2,352	1,000	2,352	2,102	2,102	1,000	2,102	1,879	1,879	1,000	1,000
Dec	1,642	1,642	1,020	1,642	1,468	1,468	1,000	1,468	1,312	1,312	1,000	1,000

Note: [1] Prior to 1991, no water is stored in Watana reservoir.

TABLE E2.19: FLOWS AT GOLD CREEK DURING WATANA FILLING

	10%				50%				90%			
	Pre-Project	During Filling 1991	1992	1993	Pre-Project	During Filling 1991	1992	1993	Pre-Project	During Filling 1991	1992	1993
Jan	1,640	1,640	1,640	1,640	1,457	1,457	1,457	1,259	1,290	1,290	1,290	1,219
Feb	1,393	1,393	1,393	1,393	1,238	1,238	1,238	1,220	1,096	1,096	1,096	1,096
Mar	1,258	1,258	1,258	1,258	1,118	1,118	1,118	1,118	990	990	990	990
Apr	1,544	1,544	1,283	1,283	1,371	1,371	1,244	1,244	1,214	1,214	1,206	1,206
May	14,882	11,414	6,000	6,000	13,221	9,753	6,000	6,000	11,699	8,231	6,000	6,000
Jun	31,002	25,680	6,675	16,202	27,541	22,220	6,000	6,836	24,371	19,050	6,000	6,000
Jul	27,331	10,312	4,034	6,003	24,280	7,262	6,498	6,480	21,486	6,480	6,480	6,480
Aug	24,655	19,506	3,162	20,371	21,903	16,754	2,000	14,093	19,382	12,221	12,000	12,000
Sep	14,767	9,446	9,300	14,767	13,119	9,300	9,300	3,120	11,609	9,300	9,300	9,300
Oct	6,453	6,453	2,181	6,453	5,732	4,280	2,019	5,732	5,073	2,159	1,860	1,860
Nov	2,879	2,879	1,527	2,879	2,557	2,557	1,455	2,557	2,263	2,263	1,384	1,384
Dec	2,010	2,010	1,388	2,010	1,785	1,785	1,317	1,785	1,580	1,580	1,268	1,268

TABLE E2.20: MONTHLY AVERAGE PRE-PROJECT AND WATANA FILLING FLOWS AT GOLD CREEK, SUNSHINE AND SUSITNA STATIONS

Month	Pre-Project Gold Creek	Pre-Project Sunshine	Pre-Project Susitna	During Filling[1] Gold Creek	During Filling[1] Sunshine	During Filling[1] Susitna
Oct	5,654	13,755	30,401	2,019	10,120	26,766
Nov	2,476	5,844	12,808	1,455	4,823	11,787
Dec	1,788	4,219	8,312	1,317	3,748	7,841
Jan	1,466	3,514	7,969	1,457	3,505	7,960
Feb	1,242	2,940	7,072	1,238	2,936	7,068
Mar	1,115	2,629	6,332	1,118	2,632	6,335
Apr	1,351	3,143	6,967	1,244	3,036	6,860
May	13,277	27,710	60,750	6,000	20,433	53,473
Jun	28,095	64,496	124,535	6,000	42,401	102,440
Jul	23,919	63,288	132,379	6,498	45,867	114,958
Aug	21,727	56,510	111,998	12,000	46,783	102,271
Sep	13,327	32,656	66,753	9,300	28,629	62,726

Notes:

1. Assume 50% filling case, year 1992 (lowest).

TABLE 2.21 POST-PROJECT FLOW AT WATANA (cfs)
WATANA ALONE : CASE C

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1	5664.6	9716.3	11285.3	9705.6	8958.2	8080.8	7383.7	5632.5	4853.9	4617.4	9033.6	8301.0	7761.9
2	5840.9	6640.7	7716.0	7189.9	6290.0	6468.3	5674.3	7874.1	4835.5	4778.1	8808.0	5265.5	6459.0
3	7092.9	10164.1	11617.4	10165.0	9157.5	8246.7	7507.5	5326.8	5002.3	4797.2	8436.3	6391.0	7819.7
4	8269.3	10750.7	11397.6	9709.4	8928.2	8182.4	8085.6	11375.6	4959.6	4560.9	8071.6	5543.5	8325.3
5	5691.2	6591.6	11300.2	9978.3	9119.6	8149.9	7646.2	8369.3	4962.2	4590.8	6320.6	5545.5	7353.8
6	5684.0	7246.1	11665.9	10278.8	9367.0	8397.8	7644.4	5258.9	5174.6	6849.6	14063.1	8457.8	8345.5
7	7620.0	9582.1	11155.0	9707.4	9071.3	8206.1	7421.9	9500.1	9088.6	8818.7	10055.4	8275.0	9046.5
8	7778.5	10270.5	11823.4	10263.5	9505.5	8446.7	7648.7	7006.7	7123.4	4748.4	8777.7	7254.1	8381.0
9	9605.4	10929.9	12374.9	10371.1	9358.2	8485.2	7969.0	6804.2	4963.6	4755.7	8303.4	7550.0	8455.1
10	5731.9	6512.7	7772.5	9971.5	9265.5	8205.7	7589.3	6968.7	4838.2	4780.9	8969.2	7390.3	7325.4
11	8736.0	10207.4	11788.7	10290.9	9455.4	8472.8	7773.5	9581.9	4870.4	4812.9	7733.1	4875.6	8270.4
12	6482.7	10321.7	12089.6	10670.4	9621.3	8842.7	8668.6	10116.3	5203.3	4747.4	9380.2	6076.2	8519.7
13	6050.3	10257.3	11876.8	10499.4	9573.9	8688.5	8161.0	8042.3	16898.9	7579.4	11004.0	7786.0	9649.7
14	9130.6	10502.9	11825.3	10199.4	9501.2	8395.3	7480.2	11611.4	4959.4	9515.9	12488.0	7780.0	9468.1
15	6516.0	9783.1	11311.1	9742.5	9098.1	8086.9	7312.8	5333.1	18353.5	5020.1	9608.2	7253.2	8831.5
16	5759.3	6535.8	7538.2	9560.5	9089.2	8319.0	7936.0	7711.6	4962.8	5167.4	8274.1	10381.7	7592.4
17	8791.7	9559.3	11320.0	9950.9	9301.2	8496.4	8042.0	5258.9	6476.3	4555.1	7560.9	6764.1	7999.0
18	5722.3	6504.8	7606.3	9992.7	9347.8	8401.2	7553.3	9142.1	6837.7	5550.2	16188.9	8753.5	8471.0
19	7589.5	9928.2	11820.6	10508.1	9876.9	9072.1	8280.3	9386.2	7755.8	5705.5	8977.5	7647.6	8976.0
20	5756.8	6543.1	7573.0	7636.5	9064.5	8197.7	7553.6	5258.9	4851.7	4629.7	9756.0	7674.0	7028.9
21	5907.9	6809.4	7856.2	7330.4	6420.2	6619.0	5826.2	5428.1	4982.6	4747.2	8283.8	7403.1	6470.6
22	5971.4	6790.2	7879.0	7336.3	6419.1	6614.8	5823.1	5501.8	5166.8	4930.7	8685.6	7048.9	6519.8
23	7860.2	10580.9	12073.8	10561.4	9807.9	8877.7	8009.0	12218.0	9601.0	4742.3	10219.5	7855.7	9367.6
24	5697.0	6589.5	11362.9	9922.0	9316.7	8385.6	7617.7	5258.9	4973.6	4585.1	9726.7	8325.7	7641.5
25	5780.5	6573.2	7622.2	7091.7	6638.2	8139.0	7575.5	9442.3	4859.5	4654.8	9303.7	6836.2	7052.8
26	5901.1	6782.7	7811.4	7274.2	6358.6	6537.0	5739.0	5346.7	7869.7	6791.1	9036.6	6065.3	6798.3
27	7756.1	9595.1	10992.6	9648.3	9059.7	8202.4	7763.4	5887.1	4964.3	4587.9	10593.5	6881.0	7993.1
28	5827.7	6628.1	7677.0	7135.9	6231.4	7593.1	7907.0	5554.6	12444.1	4745.4	9567.3	7273.1	7378.6
29	5692.1	9188.0	12096.1	10468.4	9584.2	8768.4	8112.0	7950.5	4844.1	4608.4	9022.1	7825.6	8176.0
30	5881.8	6683.9	7750.7	7215.6	6306.8	6477.9	5679.0	8309.9	5122.8	7742.0	8210.7	7626.7	6929.3
31	5681.2	11305.1	12148.4	10360.5	9549.5	8688.7	8107.6	6968.2	5432.6	9231.9	9070.3	7020.0	8630.1
32	9053.3	11290.9	11501.4	10037.5	9287.5	8400.7	7806.6	7207.6	4874.0	5632.0	19391.0	9316.0	9497.5
MAX	9605.4	11305.1	12374.9	10670.4	9876.9	9072.1	8668.6	12219.0	18353.5	9515.9	19391.0	10381.7	9649.7
MIN	5664.6	6504.8	7538.2	7091.7	6231.4	6468.3	5674.3	5258.9	4835.5	4555.1	6320.6	4875.6	6459.0
ME[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE 2.22 MONTHLY MAXIMUM, MINIMUM, AND MEAN FLOWS AT WATANA

MONTH	PRE-PROJECT			POST-PROJECT WATANA ALONE			POST-PROJECT WATANA/DEVIL CANYON		
	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

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TABLE 2.23 PRE-PROJECT FLOW AT GOLD CREEK (cfs)
MODIFIED HYDROLOGY

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1	6335.0	2583.0	1439.0	1027.0	788.0	726.0	870.0	11510.0	19600.0	22600.0	19880.0	8301.0	8032.1
2	3848.0	1300.0	1100.0	960.0	820.0	740.0	1617.0	14090.0	20790.0	22570.0	19670.0	21240.0	9106.0
3	5571.0	2744.0	1900.0	1600.0	1000.0	880.0	920.0	5419.0	32370.1	26390.0	20920.0	14480.0	9552.1
4	8202.0	3497.0	1700.0	1100.0	820.0	820.0	1615.0	19270.0	27320.1	20200.0	20610.0	15270.0	10090.4
5	5604.0	2100.0	1500.0	1300.0	1000.0	780.0	1235.0	17280.0	25250.0	20360.0	26100.0	12920.0	9681.6
6	5370.0	2760.0	2045.0	1794.0	1400.0	1100.0	1200.0	9319.0	29860.0	27560.0	25750.0	14290.0	10256.4
7	4951.0	1900.0	1300.0	980.0	970.0	940.0	950.0	17660.0	33340.0	31090.1	24530.0	18330.0	11473.3
8	5806.0	3050.0	2142.0	1700.0	1500.0	1200.0	1700.0	13750.0	30160.0	23310.0	20540.0	19800.0	10384.1
9	8212.0	3954.0	3264.0	1965.0	1307.0	1148.0	1533.0	12900.0	25700.0	22880.0	22540.0	7550.0	9476.4
10	4811.0	2150.0	1513.0	1448.0	1307.0	980.0	1250.0	15990.0	23320.0	25000.0	31180.0	16920.0	10559.9
11	6558.0	2850.0	2200.0	1845.0	1452.0	1197.0	1300.0	15780.0	15530.0	22980.0	23590.0	20510.0	9712.3
12	7794.0	3000.0	2694.0	2452.0	1754.0	1810.0	2650.0	17360.0	29450.0	24570.0	22100.0	13370.0	10809.3
13	5916.0	2700.0	2100.0	1900.0	1500.0	1400.0	1700.0	12590.0	43270.0	25850.0	23550.0	15890.0	11565.2
14	6723.0	2800.0	2000.0	1600.0	1500.0	1000.0	830.0	19030.0	26000.0	34400.0	23670.0	12320.0	11072.9
15	6449.0	2250.0	1494.0	1048.0	966.0	713.0	745.0	4307.0	50580.0	22950.0	16440.0	9571.0	9799.6
16	6291.0	2799.0	1211.0	960.0	860.0	900.0	1360.0	12990.0	25720.0	27840.0	21120.0	19350.0	10168.8
17	7205.0	2098.0	1631.0	1400.0	1300.0	1300.0	1775.0	9645.0	32950.0	19860.0	21830.0	11750.0	9431.8
18	4163.0	1600.0	1500.0	1500.0	1400.0	1200.0	1167.0	15480.0	29510.0	26800.0	32620.0	16870.0	11218.5
19	4900.0	2353.0	2055.0	1931.0	1900.0	1900.0	1910.0	16180.0	31550.0	26420.0	17170.0	8816.0	9810.6
20	4272.0	1906.0	1330.0	1086.0	922.0	833.0	1022.0	9852.0	20523.0	18093.0	16322.0	9776.0	7200.1
21	3124.0	1215.0	866.0	824.0	768.0	776.0	1080.0	11380.0	18630.0	22660.0	19980.0	9121.0	7591.2
22	5288.0	3407.0	2290.0	1442.0	1036.0	950.0	1082.0	3745.0	32930.0	23950.0	31910.0	14440.0	10251.0
23	5847.0	3093.0	2510.0	2239.0	2028.0	1823.0	1710.0	21890.0	34430.0	22770.0	19290.0	12400.0	10885.5
24	4826.0	2253.0	1465.0	1200.0	1200.0	1000.0	1027.0	8235.0	27800.0	18250.0	20290.0	9074.0	8086.2
25	3733.0	1523.0	1034.0	874.0	777.0	724.0	992.0	16180.0	17870.0	18800.0	16220.0	12250.0	7631.0
26	3739.0	1700.0	1603.0	1516.0	1471.0	1400.0	1593.0	15350.0	32310.0	27720.0	18090.0	16310.0	10275.4
27	7739.0	1993.0	1081.0	974.0	950.0	900.0	1373.0	12620.0	24380.0	18940.0	19800.0	6881.0	8189.3
28	3874.0	2650.0	2403.0	1829.0	1618.0	1500.0	1680.0	12680.0	37970.0	22870.0	19240.0	12640.0	10109.0
29	7571.0	3525.0	2589.0	2029.0	1668.0	1605.0	1702.0	11950.0	19050.0	21020.0	16390.0	8607.0	8194.5
30	4907.0	2535.0	1681.0	1397.0	1286.0	1200.0	1450.0	13870.0	24690.0	28880.1	20460.0	10770.0	9489.3
MAX	8212.0	3954.0	3264.0	2452.0	2028.0	1900.0	2650.0	21890.0	50580.0	34400.0	32620.0	21240.0	11565.2
MIN	3124.0	1215.0	866.0	824.0	768.0	713.0	745.0	3745.0	15530.0	18093.0	16220.0	6881.0	7200.1
MEAN	5654.3	2476.3	1788.0	1465.7	1242.3	1114.8	1351.3	13276.7	28095.1	23919.4	21726.7	13327.2	9670.1

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TABLE 2.24 POST-PROJECT FLOWS AT GOLD CREEK (cfs)
WATANA : CASE C

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1	7279.7	10215.7	11555.4	9917.5	9104.5	8237.7	7573.6	8486.6	8021.8	8024.0	12000.0	9281.6	9145.8
2	6389.8	6833.4	7909.8	7341.9	6437.0	6588.5	5989.1	10314.3	7107.6	7561.5	12000.0	9300.0	7831.3
3	8061.0	10738.0	12016.4	10490.5	9316.5	8391.7	7623.6	6529.3	11599.0	9076.3	12000.0	9300.0	9595.1
4	10185.6	11490.9	11816.4	9990.5	9136.5	8331.7	8318.6	15608.4	10809.9	7405.6	12000.0	9300.0	10380.5
5	7076.3	7092.0	11616.4	10190.5	9316.5	8291.7	7938.6	13952.5	10735.5	7967.2	12000.0	9300.0	9635.0
6	7194.8	7955.0	12161.4	10684.5	9716.5	8611.7	7903.6	7859.8	10153.2	10621.7	16276.1	9300.0	9882.5
7	8468.7	9894.0	11416.4	9870.5	9286.5	8451.7	7653.6	14206.8	15256.8	14077.5	15432.0	13410.6	11468.8
8	9376.5	11044.0	12258.4	10590.5	9816.5	8711.7	7903.6	10574.5	12008.4	8109.5	12000.0	12213.0	10384.1
9	11782.5	11948.0	13380.4	10855.5	9623.5	8659.7	8236.6	9746.4	8565.8	7883.0	12000.0	9121.3	10162.0
10	6874.9	6933.2	8170.4	10338.5	9623.5	8491.7	7953.6	12818.1	9828.6	9287.8	16208.8	11843.4	9874.3
11	10128.5	10843.9	12316.4	10735.5	9768.5	8708.7	8003.6	12317.7	7167.0	8286.8	12000.0	9300.0	9978.8
12	8227.4	10993.9	12810.4	11342.5	10070.5	9321.7	9353.6	13838.4	11869.2	9477.6	12000.0	9300.0	10726.1
13	7328.7	10694.0	12216.4	10790.5	9816.5	8911.7	8403.6	9298.8	24151.8	9985.7	14666.9	10429.8	11381.9
14	10293.5	10794.0	12116.4	10490.5	9816.5	8511.7	7533.6	15342.2	10296.0	15148.5	15146.6	9300.0	11263.3
15	7777.9	10244.0	11610.4	9938.5	9282.5	8224.7	7448.6	6061.3	26091.6	7887.3	12000.0	9300.0	10468.3
16	7290.9	6966.6	7678.9	9657.5	9176.5	8411.7	8063.6	9735.6	9469.8	9771.5	12000.0	13506.1	9309.7
17	10775.5	10092.0	11747.4	10290.5	9616.5	8811.7	8478.6	7809.8	13486.7	8261.6	12000.0	9300.0	10056.4
18	6615.5	6902.6	7984.7	10390.5	9716.5	8711.7	7870.6	12066.6	11635.8	10362.9	22704.4	11950.6	10593.9
19	8470.5	10346.9	12171.4	10871.5	10216.5	9411.7	8613.6	12739.5	13601.8	10042.6	12000.0	9300.0	10654.4
20	6581.8	6882.1	7830.0	7838.5	9238.5	8344.7	7725.6	7168.9	7865.7	6851.7	12000.0	9300.0	8128.7
21	6628.8	7003.5	8012.9	7518.2	6586.1	6770.9	5919.8	7271.7	9213.6	8997.1	12000.0	9300.0	7947.1
22	7491.4	7700.8	8481.6	7681.2	6677.7	6847.7	6091.4	6389.6	10484.0	7762.3	13149.0	9300.0	8181.2
23	8728.1	11086.9	12626.4	11129.5	10344.5	9334.7	8413.6	18134.9	16601.7	7692.0	12000.0	9300.0	11289.7
24	6221.8	6864.6	11581.4	10090.5	9516.5	8511.7	7730.6	6206.9	8914.3	6484.0	12000.0	9300.0	8615.7
25	6457.0	6741.5	7724.6	7179.3	6725.3	8235.7	7695.6	12733.3	7948.9	7482.9	12000.0	9300.0	8370.1
26	6551.3	7008.3	8137.7	7574.4	6719.3	6895.6	6120.8	9024.5	13490.5	11080.7	12000.0	9300.0	8671.0
27	9816.0	9987.0	11197.4	9864.5	9266.5	8411.7	8076.6	9568.3	9350.3	6512.6	12000.0	8050.5	9347.6
28	6728.2	7351.4	8392.5	7616.2	6646.5	7982.3	8383.6	9665.2	19061.3	7908.1	12000.0	9300.0	9255.0
29	7469.2	10067.7	12705.4	10919.5	9984.5	9116.7	8405.6	8669.0	6616.9	7243.2	12000.0	9300.0	9378.3
30	7014.9	7274.0	8119.1	7475.8	6537.4	6576.7	5811.1	9810.6	6908.0	11710.4	12000.0	9300.0	8235.0
31	6842.2	11972.1	12532.4	10638.5	9782.5	8911.7	8373.6	8888.2	11112.6	15151.9	12030.3	9300.0	10469.9
32	10320.3	11979.9	11889.5	10344.1	9552.1	8626.0	8071.1	10118.3	6000.0	9792.0	26494.0	10461.1	11172.4
MAX	11782.5	11979.9	13380.4	11342.5	10344.5	9411.7	9353.6	18134.9	26091.6	15151.9	26494.0	13506.1	11468.8
MIN	6221.8	6741.5	7678.9	7179.3	6437.0	6576.7	5811.1	6061.3	6000.0	6484.0	12000.0	8050.5	7831.3
MEAN	8014.0	9185.7	10693.3	9707.8	8951.1	8323.7	7740.1	10404.9	11419.5	9184.6	13378.4	9839.6	9745.4

TABLE 2.25 MONTHLY MAXIMUM, MINIMUM, AND MEAN FLOWS AT GOLD CREEK

MONTH				POST-PROJECT					
	PRE-PROJECT			WATANA ALONE			WATANA/DEVIL CANYON		
	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN
OCT	8212.0	3124.0	5654.3	11782.5	6221.8	8014.0	10983.0	6453.2	7764.9
NOV	3954.0	1215.0	2476.3	11979.9	6741.5	9185.7	11848.8	7103.9	9630.8
DEC	3264.0	866.0	1788.0	13380.4	7678.9	10693.3	13134.1	8040.5	11270.9
JAN	2452.0	824.0	1465.7	11342.5	7179.3	9707.8	12045.8	7423.9	10596.7
FEB	2028.0	768.0	1242.3	10344.5	6437.0	8951.1	11452.8	6457.3	10190.9
MAR	1900.0	713.0	1114.8	9411.7	6576.7	8323.7	10604.2	6618.1	9285.6
APR	2650.0	745.0	1351.3	9353.6	5811.1	7740.1	9759.4	5950.4	8100.4
MAY	21890.0	3745.0	13276.7	18134.9	6061.3	10404.9	12380.0	6000.0	8706.3
JUN	50580.0	15530.0	28095.1	26091.6	6000.0	11419.5	13305.2	6000.0	9882.9
JUL	34400.0	18093.0	23919.4	15151.9	6484.0	9184.6	11846.2	6484.0	8387.3
AUG	32620.0	16220.0	21726.7	26494.0	12000.0	13378.4	21146.2	12000.0	12633.5
SEP	21240.0	6881.0	13327.2	13506.1	8050.5	9839.6	18330.0	9300.0	10510.3
ANNUAL	11565.2	7200.1	9670.1	11468.8	7831.3	9745.4	11473.3	7776.4	9745.4

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TABLE 2.26 PRE-PROJECT FLOW AT SUNSHINE (cfs)
MODIFIED HYDROLOGY

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1	14003.0	5639.0	3611.0	2748.0	2276.0	2033.0	2311.0	22418.0	45613.0	39179.0	54849.0	27734.0	20347.1
2	12226.0	4712.0	3804.0	2930.0	2435.0	2144.0	3563.0	42196.0	58872.0	69474.0	58356.0	51069.0	26136.1
3	13713.0	5702.0	3782.0	3470.0	2511.0	2282.0	2357.0	11258.0	68738.0	64937.0	53363.0	32057.0	22117.5
4	17394.0	7199.0	4080.0	2818.0	2343.0	2317.0	4292.0	50302.0	64075.0	54231.0	49954.0	33737.0	24544.3
5	13227.0	5092.0	3977.0	3667.0	2889.0	2423.0	3204.0	32595.0	54805.0	53386.0	57701.0	28376.0	21921.8
6	12188.0	6340.0	4313.0	3927.0	3189.0	2577.0	2658.0	21758.0	69686.0	70894.0	77692.0	35385.0	26041.6
7	11011.0	4367.0	3161.0	2612.0	2286.0	2209.0	2244.0	33157.0	73941.0	80569.0	69034.0	44495.0	27588.4
8	15252.0	7029.0	4907.0	4006.0	3471.0	2844.0	2907.0	34140.0	79153.0	62302.0	53243.0	48121.0	26550.7
9	18399.0	9032.0	6139.0	4067.0	2996.0	2643.0	3399.0	27759.0	60752.0	59850.0	56902.0	20098.0	22824.2
10	11578.0	5331.0	3592.0	3387.0	3059.0	2280.0	2895.0	29460.0	64286.0	67521.0	71948.0	36915.0	25345.8
11	15131.0	6415.0	4823.0	4059.0	3201.0	2675.0	2928.0	34802.0	39311.0	58224.0	55315.0	43086.0	22651.3
12	16996.0	6109.0	5504.0	4739.0	3478.0	3480.0	5109.0	32438.0	60886.0	63640.0	60616.0	36071.0	25075.2
13	14579.0	6657.0	4820.0	4222.0	3342.0	2975.0	3581.0	24520.0	87537.0	67756.0	61181.0	38711.0	26766.6
14	13956.0	6052.0	4690.0	4074.0	3621.0	2399.0	2025.0	35245.0	56629.0	78219.0	52938.0	29182.0	24260.8
15	18555.0	5907.0	3533.0	2797.0	2447.0	2013.0	2381.0	8645.0	111073.0	38836.0	46374.0	23267.0	23864.9
16	15473.0	7472.0	4536.0	3373.0	2962.0	2818.0	3435.0	24597.0	58488.0	65042.0	56375.0	53703.0	24971.3
17	18208.0	5321.0	3965.0	3404.0	3009.0	2875.0	3598.0	16479.0	69569.0	55243.0	62007.0	30156.0	22934.7
18	11551.0	4295.0	3856.0	3698.0	3294.0	2793.0	2639.0	32912.0	66162.0	77125.0	82747.0	37379.0	27566.1
19	10706.0	5413.0	4563.0	4181.0	3986.0	3898.0	4359.0	36961.0	76770.0	69735.0	46730.0	20885.0	24149.1
20	10524.0	4481.0	3228.0	2689.0	1731.0	2022.0	2442.0	21306.0	49349.0	48565.0	42970.0	24832.0	17950.7
21	9416.0	3978.0	2848.0	2600.0	2448.0	2382.0	3150.0	25687.0	47602.0	60771.0	54926.0	27191.0	20393.7
22	12264.0	7467.0	4930.0	3325.0	2514.0	2351.0	2640.0	10652.0	76208.0	64787.0	74519.0	32402.0	24629.0
23	14313.0	6745.0	4922.0	4257.0	3801.0	3335.0	3210.0	36180.0	66856.0	62292.0	51254.0	34156.0	24407.1
24	13588.0	6018.0	4030.0	3312.0	2984.0	2646.0	2821.0	18215.0	59933.0	51711.0	51085.0	25238.0	20235.8
25	11284.0	4699.0	3524.0	2882.0	2519.0	2220.0	2916.0	31486.0	43713.0	51267.0	43222.0	29114.0	19195.1
26	12302.0	4938.0	3777.0	3546.0	2990.0	2810.0	3160.0	29380.0	72836.0	75692.0	51678.0	35567.0	25023.2
27	15565.0	4238.0	2734.0	2507.0	2355.0	2281.0	3294.0	22875.0	56366.0	55506.0	52155.0	18502.0	20000.7
28	10620.0	5888.0	5285.0	4231.0	3640.0	3171.0	3537.0	27292.0	87773.0	62194.0	55157.0	32719.0	25221.6
29	17399.0	7130.0	5313.0	4213.0	3227.0	3002.0	3542.0	22707.0	48044.0	57930.0	42118.0	22742.0	19910.2
30	11223.0	5648.0	4308.0	3674.0	3206.0	2963.0	3704.0	33876.0	59849.0	71774.0	48897.0	26790.0	23144.3
MAX	18555.0	9032.0	6139.0	4739.0	3986.0	3898.0	5109.0	50302.0	111073.0	80569.0	82747.0	53703.0	27588.4
MIN	9416.0	3978.0	2734.0	2507.0	1731.0	2013.0	2025.0	8645.0	39311.0	48565.0	42118.0	18502.0	17950.7
MEAN	13754.8	5843.8	4218.5	3513.8	2940.3	2628.7	3143.4	27709.9	64495.8	63288.4	56510.2	32656.0	23525.6

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TABLE 2.27 POST-PROJECT FLOW AT SUNSHINE (cfs)
WATANA ALONE ; CASE C

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1	14947.7	13271.7	13727.4	11638.5	10592.5	9544.7	9014.6	19394.6	34034.8	44603.0	46969.0	28714.6	21460.9
2	14767.8	10245.4	10613.8	9311.9	8052.0	7992.5	7935.1	38420.3	45189.6	54465.5	50686.0	39129.0	24861.4
3	16203.0	13696.0	13898.4	12360.5	10827.5	9793.7	9060.6	12368.3	47966.9	47623.3	44443.0	26877.0	22160.5
4	19377.6	15192.9	14196.4	11708.5	10659.5	9828.7	10995.6	46640.4	47564.8	41436.6	41344.0	27767.0	24834.4
5	14699.3	10084.0	14093.4	12557.5	11205.5	9934.7	9907.6	29267.5	40290.5	40993.2	43601.0	24756.0	21875.2
6	14012.8	11535.0	14429.4	12817.5	11505.5	10088.7	9361.6	20298.8	49979.2	53955.7	68218.1	30395.0	25667.8
7	14528.7	12361.0	13277.4	11502.5	10602.5	9720.7	8947.6	29703.8	55857.8	63556.4	59936.0	39575.6	27583.9
8	18822.5	15023.0	15023.4	12896.5	11787.5	10355.7	9610.6	30964.5	61001.4	47101.5	44703.0	40534.0	26550.7
9	21969.5	17026.0	16255.4	12957.5	11312.5	10154.7	10102.6	24605.4	43617.8	44853.0	46362.0	21669.3	23509.9
10	13641.9	10114.2	10249.4	12277.5	11375.5	9791.7	9598.6	26288.1	50794.6	51808.8	56976.8	31838.4	24660.1
11	18701.5	14408.9	14939.4	12949.5	11517.5	10186.7	9631.6	31339.7	30948.0	43530.8	43725.0	31876.0	22917.7
12	17429.4	14102.9	15620.4	13629.5	11794.5	10991.7	11812.6	28916.4	43305.2	48547.6	50516.0	32001.0	24992.0
13	15991.7	14651.0	14936.4	13112.5	11658.5	10486.7	10284.6	21228.8	68418.8	51891.7	52297.9	33250.8	26583.3
14	17526.5	14046.0	14806.4	12964.5	11937.5	9910.7	8728.6	31557.2	40925.0	58967.5	44414.6	26162.0	24451.1
15	19883.9	13901.0	13649.4	11687.5	10763.5	9524.7	9084.6	10399.3	86584.6	43773.3	41934.0	22996.0	24533.6
16	16472.9	11639.6	11003.9	12070.5	11278.5	10329.7	10138.6	21342.6	42237.8	46973.5	47255.0	47859.1	24112.2
17	21778.5	13315.0	14081.4	12294.5	11325.5	10386.7	10301.6	14643.8	50105.7	43644.6	52177.0	27706.0	23559.4
18	14003.5	9597.6	10340.7	12588.5	11610.5	10304.7	9342.6	29498.6	48287.8	60687.9	72831.4	32459.6	26941.5
19	14276.5	13406.9	14679.4	13071.5	12302.5	11409.7	11062.6	33520.5	58821.8	53357.6	41560.0	21369.0	24992.9
20	12833.8	9457.1	9728.0	9441.5	10047.5	9533.7	9145.6	18622.9	36691.7	37323.7	38648.0	24356.0	18879.2
21	12920.8	9266.5	9994.9	9294.2	8266.1	8376.9	7989.8	21578.7	38185.6	47108.1	46946.0	27370.0	20749.6
22	14467.4	11760.8	11121.6	9564.2	8155.7	8248.7	7649.4	13296.6	53767.0	48599.3	55758.0	27262.0	22559.2
23	17194.1	14738.9	15038.4	13147.5	12117.5	10846.7	9913.6	32424.9	49027.7	47214.0	43964.0	31056.0	24811.2
24	14983.8	10629.6	14146.4	12202.5	11300.5	10157.7	9524.6	16186.9	41047.3	39945.0	42795.0	25464.0	20765.2
25	14008.0	9917.5	10214.6	9187.3	8467.3	9731.7	9619.6	28039.3	33791.9	39949.9	39002.0	26164.0	19934.2
26	15114.3	10246.3	10311.7	9604.4	8238.3	8305.6	7687.8	23054.5	54016.5	59052.7	45588.0	28557.0	23418.8
27	17642.0	12232.0	12850.4	11397.5	10671.5	9792.7	9997.6	19823.3	41336.3	43078.6	44355.0	19671.5	21159.0
28	13474.2	10589.4	11274.5	10018.2	8668.5	9653.3	10240.6	24277.2	68864.3	47232.1	47917.0	29379.0	24367.6
29	17297.2	13672.7	15429.4	13103.5	11543.5	10513.7	10245.6	19426.0	35610.9	44153.2	37728.0	23435.0	21094.0
30	13330.9	10387.0	10746.1	9752.8	8457.4	8339.7	8065.1	29816.6	42067.0	54604.3	40437.0	25320.0	21889.9
MAX	21969.5	17026.0	16255.4	13629.5	12302.5	11409.7	11812.6	46640.4	86584.6	63556.4	72831.4	47859.1	27583.9
MIN	12833.8	9457.1	9728.0	9187.3	8052.0	7992.5	7649.4	10399.3	30948.0	37323.7	37728.0	19671.5	18879.2
MEAN	16076.7	12367.2	13022.6	11703.7	10601.4	9807.9	9500.0	24898.2	48011.1	48334.4	47769.6	29165.7	23529.2

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TABLE 2.28 PRE-PROJECT FLOW AT SUSITNA (cfs)
MODIFIED HYDROLOGY

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1	26869.4	11367.1	6197.0	6071.9	5255.5	5376.7	5656.9	66293.5	101615.7	124889.8	106431.8	39331.2	42444.7
2	18026.1	6932.8	5980.9	7073.6	7294.9	6381.5	7354.2	59272.5	82254.6	123164.1	100946.9	73471.0	41783.1
3	31052.6	16363.8	6988.5	8274.3	7036.4	5853.0	5985.1	45294.3	132547.3	137321.8	116186.1	82076.3	49825.4
4	44952.4	16289.1	9746.0	8068.7	6774.5	6349.8	7992.6	88840.0	130561.3	125949.2	97610.0	44167.7	49279.5
5	20168.5	11829.1	5271.6	7202.0	4993.1	4979.7	6305.5	58516.4	108881.0	116731.6	128586.7	66275.3	45270.4
6	23895.7	9167.8	6183.0	7254.6	5845.1	5315.6	6412.4	58164.0	169044.8	148876.5	120120.0	53504.2	51429.1
7	19923.4	10521.9	7294.7	6179.2	6830.8	6324.4	7182.2	82485.8	161346.1	168814.6	131619.5	104218.4	59701.9
8	41821.6	21547.5	14146.3	10600.1	8356.1	7353.1	7705.3	63204.4	176218.8	140318.3	124812.9	87825.0	58911.9
9	52636.0	19886.6	10635.3	7552.9	6386.9	6678.8	8098.6	70320.5	112896.8	122280.2	99608.5	53053.3	47830.1
10	30543.1	9528.4	4763.4	7795.1	6564.3	5665.5	6467.8	56601.4	110602.3	146216.8	138334.3	67903.5	49606.5
11	25754.1	10164.5	7004.6	6716.3	6310.0	5651.4	5829.6	50061.6	84134.4	129403.4	113971.6	81565.4	44172.5
12	33782.3	12914.2	13768.2	12669.1	10034.0	9192.6	9802.6	85456.7	151715.1	138968.5	116696.5	62504.3	55111.2
13	29028.7	13043.3	8976.6	9050.1	6182.5	5950.6	6635.2	54553.8	163049.0	143441.3	121220.5	74806.4	53254.8
14	27716.2	10754.5	8864.6	8670.7	7853.6	6058.1	5564.7	53903.2	85647.9	146420.1	106706.8	70782.4	45235.4
15	37846.3	11701.6	5626.0	6351.1	5761.6	4910.4	5530.8	35536.2	153126.4	124805.8	92279.5	46109.8	44338.1
16	28746.9	10458.0	6126.6	6951.9	6195.8	6169.9	7120.1	49485.4	110074.6	138406.5	111845.9	89944.3	47893.5
17	36553.2	12312.5	9159.3	8030.8	7489.4	7090.5	8048.3	52311.4	125182.8	117607.4	118729.3	63887.3	47470.1
18	26396.2	12962.6	8321.9	8028.5	7726.1	6683.2	7280.6	58106.6	134880.9	136306.3	137318.0	89527.0	53073.6
19	37724.5	15872.8	15081.0	11604.2	11532.2	8772.0	8762.6	94143.2	137867.2	130513.6	86874.5	42384.8	50399.0
20	26322.5	11086.4	7194.5	6924.0	6163.5	5535.3	6112.0	52954.0	108336.2	115547.9	97076.0	57771.6	41999.8
21	22683.4	6799.3	5016.4	6074.2	5581.3	5731.6	5769.1	53036.2	94612.1	132984.7	117728.0	80584.8	45014.0
22	32817.3	16607.2	8633.2	6508.7	6253.8	5882.6	5787.5	29809.3	122258.2	139183.4	133310.1	69021.2	48289.9
23	32763.2	14921.9	8790.8	9379.7	8458.3	6645.8	6894.9	74062.0	176023.9	142786.8	107596.6	60220.4	54305.3
24	26781.9	14852.9	8147.1	7609.2	7476.7	6312.6	7688.2	64534.0	122797.1	123362.2	107260.8	45226.8	45453.5
25	20975.7	10113.3	6081.0	7401.6	6747.3	6293.7	6962.8	61457.8	67838.0	102184.3	80251.5	56123.5	36285.1
26	19520.0	10400.0	9419.0	8597.0	7804.0	7048.0	6867.0	47540.0	128800.2	135700.0	91360.1	77740.1	46102.6
27	31550.0	9933.0	6000.0	6529.0	5614.0	5368.0	7253.0	70460.1	107000.0	115200.1	99650.1	48910.0	43089.2
28	30140.0	18270.0	13100.0	10100.0	8911.0	6774.0	6233.0	56180.0	165900.3	143900.0	125500.1	83810.1	55979.3
29	38230.0	12630.0	7529.0	6974.0	6771.0	6590.0	7033.0	48670.0	90930.0	117600.1	102100.2	55500.0	42002.4
30	36810.0	15000.0	9306.0	8823.0	7946.0	7032.0	8683.0	81260.1	119900.0	142500.0	128200.0	74340.0	53676.8
MAX	52636.0	21547.5	15081.0	12669.1	11532.2	9192.6	9802.6	94143.2	176218.8	168814.6	138334.3	104218.4	59701.9
MIN	18026.1	6799.3	4763.4	6071.9	4993.1	4910.4	5530.8	29809.3	67838.0	102184.3	80251.5	39331.2	36285.1
MEAN	30401.0	12807.7	8311.8	7968.9	7071.7	6332.3	6967.3	60750.5	124534.8	132379.5	111997.7	66752.9	48307.6

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TABLE 2.29 POST-PROJECT FLOW AT SUSITNA (cfs)
WATANA ALONE : CASE C

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1	27814.1	18999.8	16313.4	14962.4	13572.0	12888.4	12360.5	63270.1	90037.5	110313.8	98551.8	40311.8	43558.5
2	20567.9	12466.2	12790.7	13455.5	12911.9	12230.0	11726.3	55496.8	68572.2	108155.6	93276.9	61531.0	40508.4
3	33542.6	24357.8	17104.9	17164.8	15352.9	13364.7	12688.7	46404.6	111776.2	120008.1	107266.1	76896.3	49868.4
4	46936.0	24283.0	19862.4	16959.2	15091.0	13861.5	14696.2	85178.4	114051.1	113154.8	89000.0	38197.7	49569.6
5	21640.8	16821.1	15388.0	16092.5	13309.6	12491.4	13009.1	55188.9	94366.5	104338.8	114486.7	62655.3	45223.8
6	25720.5	14362.8	16299.4	16145.1	14161.6	12827.3	13116.0	56704.8	149338.0	131938.2	110646.1	48514.2	51055.3
7	23441.1	18515.9	17411.1	15069.7	15147.3	13836.1	13885.8	79032.6	143262.9	151802.0	122521.5	99299.0	59697.5
8	45392.1	29541.5	24262.7	19490.6	16672.6	14864.8	14408.9	60028.9	158067.2	125117.8	116272.9	80238.0	58911.8
9	56206.5	27880.6	20751.7	16443.4	14703.4	14190.5	14802.2	67166.9	95762.6	107283.2	89068.5	54624.6	48515.7
10	32607.0	14311.6	11420.8	16685.6	14880.8	13177.2	13171.4	53429.5	97110.9	130504.6	123363.1	62826.9	48920.8
11	29324.6	18158.4	17121.0	15606.8	14626.5	13163.1	12533.2	46599.3	75771.4	114710.2	102381.6	70355.4	44438.9
12	34215.7	20908.1	23884.6	21559.6	18350.5	16704.3	16506.2	81935.1	134134.3	123876.1	106596.5	58434.3	55028.0
13	30441.4	21037.3	19093.0	17940.6	14499.0	13462.3	13338.8	51262.6	143930.8	127577.0	112337.4	69346.2	53071.5
14	31286.7	18748.5	18981.0	17561.2	16170.1	13569.8	12268.3	50215.4	69943.9	127168.6	98183.4	67762.4	45425.8
15	39175.2	19695.6	15742.4	15241.6	14078.1	12422.1	12234.4	37290.5	128638.0	109743.1	87839.5	45838.8	45006.8
16	29746.8	14625.6	12594.5	15649.4	14512.3	13681.6	13823.7	46231.0	93824.4	120338.0	102725.9	84100.4	47034.4
17	40123.7	20306.5	19275.7	16921.3	15805.9	14602.2	14751.9	50476.2	105719.5	106009.0	108899.3	61437.3	48094.7
18	28848.7	18265.2	14806.6	16919.0	16042.6	14194.9	13984.2	54693.2	117006.7	119869.2	127402.4	84607.6	52448.9
19	41295.0	23866.7	25197.4	20494.7	19848.7	16283.7	15466.2	90702.7	119919.0	114136.2	81704.5	42868.8	51242.8
20	28632.3	16062.5	13694.5	13676.5	14480.0	13047.0	12815.6	50270.9	95678.9	104306.6	92754.0	57295.6	42928.4
21	26188.2	12587.8	12163.3	12768.4	11399.4	11726.5	10608.9	48927.9	85195.7	119321.8	109748.0	80763.8	45370.0
22	35020.7	20901.0	14824.8	12747.9	11895.5	11780.3	10796.9	32453.9	99812.2	122995.7	114549.1	63881.2	46220.2
23	35644.3	22915.8	18907.2	18270.2	16774.8	14157.5	13598.5	70306.9	158195.6	127708.8	100306.6	57120.4	54709.5
24	28177.7	19464.5	18263.5	16499.7	15793.2	13824.3	14391.8	62505.9	103911.4	111596.2	98970.8	45452.8	45983.0
25	23699.7	15331.8	12771.6	13706.9	12695.6	13805.4	13666.4	58011.1	57916.9	90867.2	76031.5	53173.5	37024.2
26	22332.3	15708.3	15953.7	14655.4	13052.3	12543.6	11394.8	41214.5	109980.7	119060.7	85270.1	70730.1	44498.1
27	33627.0	17927.0	16116.4	15419.5	13930.5	12879.7	13956.6	67408.4	91970.3	102772.7	91850.1	50079.5	44247.5
28	32994.2	22971.4	19089.5	15887.2	13939.5	13256.3	12936.6	53165.2	146991.6	128938.1	118260.1	80470.1	55125.2
29	38128.2	19172.7	17645.4	15864.5	15087.5	14101.7	13736.6	45389.0	78496.9	103823.3	97710.2	56193.0	43186.2
30	38917.9	19739.0	15744.1	14901.8	13197.4	12408.7	13044.1	77200.7	102118.0	125330.3	119740.0	72870.0	52422.5
MAX	56206.5	29541.5	25197.4	21559.6	19848.7	16704.3	16506.2	90702.7	158195.6	151802.0	127402.4	99299.0	59697.5
MIN	20567.9	12466.2	11420.8	12747.9	11399.4	11726.5	10608.9	32453.9	57916.9	90867.2	76031.5	38197.7	37024.2
MEAN	32723.0	19331.1	17115.8	16158.7	14732.8	13511.6	13324.0	57938.7	108050.0	117425.5	103257.1	63262.5	48311.2

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TABLE 2.30 MONTHLY MAXIMUM, MINIMUM, AND MEAN FLOWS AT SUNSHINE

MONTH				POST-PROJECT					
	PRE-PROJECT			WATANA ALONE			WATANA/DEVIL CANYON		
	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN
OCT	18555.0	9416.0	13754.8	21969.5	12833.8	16076.7	21536.9	13141.6	15868.7
NOV	9032.0	3978.0	5843.8	17026.0	9457.1	12367.2	16926.8	9753.6	12948.4
DEC	6139.0	2734.0	4218.5	16255.4	9728.0	13022.6	16009.1	9989.0	13608.6
JAN	4739.0	2507.0	3513.8	13629.5	9187.3	11703.7	14332.8	9383.1	12569.7
FEB	3986.0	1731.0	2940.3	12302.5	8052.0	10601.4	13402.5	8133.9	11818.5
MAR	3898.0	2013.0	2628.7	11409.7	7992.5	9807.9	12508.0	8035.9	10722.5
APR	5109.0	2025.0	3143.4	11812.6	7649.4	9500.0	12218.4	7508.4	9820.8
MAY	50302.0	8645.0	27709.9	46640.4	10399.3	24898.2	42287.3	10338.0	23217.5
JUN	111073.0	39311.0	64495.8	86584.6	30948.0	48011.1	73798.2	30357.5	46332.3
JUL	80569.0	48565.0	63288.4	63554.4	37323.7	48334.4	60567.5	36956.0	47622.6
AUG	82747.0	42118.0	56510.2	72831.4	37728.0	47769.6	65318.8	37728.0	47154.4
SEP	53703.0	18502.0	32656.0	47859.1	19671.5	29165.7	44997.5	20921.0	29790.7
ANNUAL	27588.4	17950.7	23525.6	27583.9	18879.2	23529.2	27588.4	19068.6	23538.0

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TABLE 2.31 MONTHLY MAXIMUM, MINIMUM, AND MEAN FLOWS AT SUSITNA

MONTH	PRE-PROJECT			POST-PROJECT WATANA ALONE			POST-PROJECT WATANA/DEVIL CANYON		
	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN
OCT	52636.0	18026.1	30401.0	56206.5	20567.9	32723.0	55407.0	20926.6	32514.9
NOV	21547.5	6799.3	12807.7	29541.5	12466.2	19331.1	30171.3	12773.9	19912.3
DEC	15081.0	4763.4	8311.8	25197.4	11420.8	17115.8	25763.1	11432.2	17701.8
JAN	12669.1	6071.9	7968.9	21559.6	12747.9	16158.7	22262.9	12763.8	17024.7
FEB	11532.2	4993.1	7071.7	19848.7	11399.4	14732.8	20933.1	11427.2	15949.8
MAR	9192.6	4910.4	6332.3	16704.3	11726.5	13511.6	17986.8	11699.0	14426.2
APR	9802.6	5530.8	6967.3	16506.2	10608.9	13324.0	16912.0	10655.9	13644.7
MAY	94143.2	29809.3	60750.5	90702.7	32453.9	57938.7	88615.3	32626.2	56258.1
JUN	176218.8	67838.0	124534.8	158195.6	57916.9	108050.0	157474.1	57089.1	106371.2
JUL	168814.6	102184.3	132379.5	151802.0	90867.2	117425.5	148813.1	90191.2	116713.7
AUG	138334.3	80251.5	111997.7	127402.4	76031.5	103257.1	120709.4	76031.5	102641.9
SEP	104218.4	39331.2	66752.9	99299.0	38197.7	63262.5	104218.4	38197.7	63887.6
ANNUAL	59701.9	36285.1	48307.6	59697.5	37024.2	48311.2	59701.9	36786.6	48320.0

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TABLE 2.32 PRE-PROJECT FLOW AT WATANA (cfs)
MODIFIED HYDROLOGY

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1	4719.9	2083.6	1168.9	815.1	641.7	569.1	680.1	8655.9	16432.1	19193.4	16913.6	7320.4	6648.1
2	3299.1	1107.3	906.2	808.0	673.0	619.8	1302.2	11649.8	18517.9	19786.6	16478.0	17205.5	7733.7
3	4592.9	2170.1	1501.0	1274.5	841.0	735.0	803.9	4216.5	25773.4	22110.9	17356.3	11571.0	7776.7
4	6285.7	2756.8	1281.2	818.9	611.7	670.7	1382.0	15037.2	21469.8	17355.3	16681.6	11513.5	8035.2
5	4218.9	1599.6	1183.8	1087.8	803.1	638.2	942.6	11696.8	19476.7	16983.6	20420.6	9165.5	7400.4
6	3859.2	2051.1	1549.5	1388.3	1050.5	886.1	940.8	6718.1	24881.4	23787.9	23537.0	13447.8	8719.3
7	4102.3	1588.1	1038.6	816.9	754.8	694.4	718.3	12953.3	27171.8	25831.3	19153.4	13194.4	9051.0
8	4208.0	2276.6	1707.0	1373.0	1189.0	935.0	945.1	10176.2	25275.0	19948.9	17317.7	14841.1	8381.0
9	6034.9	2935.9	2258.5	1480.6	1041.7	973.5	1265.4	9957.8	22097.8	19752.7	18843.4	5978.7	7769.4
10	3668.0	1729.5	1115.1	1081.0	949.0	694.0	885.7	10140.6	18329.6	20493.1	23940.4	12466.9	8011.0
11	5165.5	2213.5	1672.3	1400.4	1138.9	961.1	1069.9	13044.2	13233.4	19506.1	19323.1	16085.6	7954.0
12	6049.3	2327.8	1973.2	1779.9	1304.8	1331.0	1965.0	13637.9	22784.1	19839.8	19480.2	10146.2	8602.9
13	4637.6	2263.4	1760.4	1608.9	1257.4	1176.8	1457.4	11333.5	36017.1	23443.7	19887.1	12746.2	9832.9
14	5560.1	2508.9	1708.9	1308.9	1184.7	883.6	776.6	15299.2	20663.4	28767.4	21011.4	10800.0	9277.7
15	5187.1	1789.1	1194.7	852.0	781.6	575.2	609.2	3578.8	42841.9	20082.8	14048.2	7524.2	8262.7
16	4759.4	2368.2	1070.3	863.0	772.7	807.3	1232.4	10966.0	21213.0	23235.9	17394.1	16225.6	8451.5
17	5221.2	1565.3	1203.6	1060.4	984.7	984.7	1338.4	7094.1	25939.6	16153.5	17390.9	9214.1	7374.4
18	3269.8	1202.2	1121.6	1102.2	1031.3	889.5	849.7	12555.5	24711.9	21987.3	26104.5	13672.9	9095.7
19	4019.0	1934.3	1704.2	1617.6	1560.4	1560.4	1576.7	12826.7	25704.0	22082.8	14147.5	7163.6	8032.2
20	3447.0	1567.0	1073.0	884.0	748.0	686.0	850.0	7942.0	17509.0	15871.0	14078.0	8150.0	6100.4
21	2403.1	1020.9	709.3	636.2	602.1	624.1	986.4	9536.4	14399.0	18410.1	16263.8	7224.1	6114.6
22	3768.0	2496.4	1687.4	1097.1	777.4	717.1	813.7	2857.2	27612.8	21126.4	27446.6	12188.9	8588.5
23	4979.1	2587.0	1957.4	1670.9	1491.4	1366.0	1305.4	15973.1	27429.3	19820.3	17509.5	10955.7	8963.4
24	4301.2	1977.9	1246.5	1031.5	1000.2	873.9	914.1	7287.0	23859.3	16351.1	18016.7	8099.7	7112.0
25	3056.5	1354.7	931.6	786.4	689.9	627.3	871.9	12889.0	14780.6	15971.9	13523.7	9786.2	6313.7
26	3088.8	1474.4	1276.7	1215.8	1110.3	1041.4	1211.2	11672.2	26689.2	23430.4	15126.6	13075.3	8402.7
27	5679.1	1601.1	876.2	757.8	743.2	690.7	1059.8	8938.8	19994.0	17015.3	18393.5	5711.5	6834.8
28	2973.5	1926.7	1687.5	1348.7	1202.9	1110.8	1203.4	8569.4	31352.8	19707.3	16807.3	10613.1	8232.6
29	5793.9	2645.3	1979.7	1577.9	1267.7	1256.7	1408.4	11231.5	17277.2	18385.2	13412.1	7132.6	6992.2
30	3773.9	1944.9	1312.6	1136.8	1055.4	1101.2	1317.9	12369.3	22904.8	24911.7	16670.7	9096.7	8183.7
31	6150.0	3525.0	2032.0	1470.0	1233.0	1177.0	1404.0	10140.0	23400.0	26740.0	18000.0	11000.0	8907.9
32	6458.0	3297.0	1385.0	1147.0	971.0	889.0	1103.0	10406.0	17017.0	27840.0	31435.0	12026.0	9580.4
MAX	6458.0	3525.0	2258.5	1779.9	1560.4	1560.4	1965.0	15973.1	42841.9	28767.4	31435.0	17205.5	9832.9
MIN	2403.1	1020.9	709.3	636.2	602.1	569.1	609.2	2857.2	13233.4	15871.0	13412.1	5711.5	6100.4
MEAN	[illegible]	2059.1	1414.9	1149.5	993.3	898.3	1099.7	10354.7	23023.7	20810.1	18628.5	10792.0	8023.0

TABLE 2.33 PRE-PROJECT FLOW AT DEVIL CANYON (cfs)
MODIFIED HYDROLOGY

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1	5758.2	2404.7	1342.5	951.3	735.7	670.0	802.2	10490.7	18468.6	21383.4	18820.6	7950.8	7537.8
2	3652.0	1231.2	1030.8	905.7	767.5	697.1	1504.6	13218.5	19978.5	21575.9	18530.0	19799.1	8615.9
3	5221.7	2539.0	1757.5	1483.7	943.2	828.2	878.5	4989.5	30014.2	24861.7	19647.2	13441.1	8918.0
4	7517.6	3232.6	1550.4	999.6	745.6	766.7	1531.8	17758.3	25230.7	19184.0	19207.0	13928.4	9356.4
5	5109.3	1921.3	1387.1	1224.2	929.7	729.4	1130.6	15286.0	23188.1	19154.1	24071.6	11579.1	8866.9
6	4830.4	2506.8	1868.0	1649.1	1275.2	1023.6	1107.4	8390.1	28081.9	26212.8	24959.6	13989.2	9707.4
7	4647.9	1788.6	1206.6	921.7	893.1	852.3	867.3	15979.0	31137.1	29212.0	22609.8	16495.8	10608.2
8	5235.3	2773.8	1986.6	1583.2	1388.9	1105.4	1109.0	12473.6	28415.4	22109.6	19389.2	18029.0	9668.7
9	7434.5	3590.4	2904.9	1792.0	1212.2	1085.7	1437.4	11849.2	24413.5	21763.1	21219.8	6988.8	8866.8
10	4402.8	1999.8	1370.9	1316.9	1179.1	877.9	1119.9	13900.9	21537.7	23390.4	28594.4	15329.6	9649.6
11	6060.7	2622.7	2011.5	1686.2	1340.2	1112.8	1217.8	14802.9	14709.8	21739.3	22066.1	18929.9	9084.4
12	7170.9	2759.9	2436.6	2212.0	1593.6	1638.9	2405.4	16030.7	27069.3	22880.6	21164.4	12218.6	10021.3
13	5459.4	2544.1	1978.7	1796.0	1413.4	1320.3	1613.4	12141.2	40679.7	24990.6	22241.8	14767.2	10946.5
14	6307.7	2696.0	1896.0	1496.0	1387.4	958.4	810.9	17697.6	24094.1	32388.4	22720.5	11777.2	10431.8
15	5998.3	2085.4	1387.1	978.0	900.2	663.8	696.5	4046.9	47816.4	21926.0	15585.8	8840.0	9250.7
16	5744.0	2645.1	1160.8	925.3	828.8	866.9	1314.4	12267.1	24110.3	26195.7	19789.3	18234.2	9555.5
17	6496.5	1907.8	1478.4	1278.7	1187.4	1187.4	1619.1	8734.0	30446.3	18536.2	20244.6	10844.3	8697.0
18	3844.0	1457.9	1364.9	1357.9	1268.3	1089.1	1053.7	14435.5	27796.4	25081.2	30293.0	15728.2	10460.4
19	4585.3	2203.5	1929.7	1851.2	1778.7	1778.7	1791.0	14982.4	29462.1	24871.0	16090.5	8225.9	9175.4
20	3976.0	1783.0	1237.0	1012.0	859.0	780.0	959.0	9154.0	19421.0	17291.0	15500.0	9188.0	6800.1
21	2866.5	1145.7	810.0	756.9	708.7	721.8	1046.6	10721.6	17118.9	21142.2	18652.8	8443.5	7063.9
22	4745.2	3081.8	2074.8	1318.8	943.6	866.8	986.2	3427.9	31031.0	22941.6	30315.9	13636.0	9657.2
23	5537.0	2912.3	2312.6	2036.1	1836.4	1659.8	1565.5	19776.8	31929.8	21716.5	18654.1	11884.2	10199.0
24	4638.6	2154.8	1387.0	1139.8	1128.6	955.0	986.7	7896.4	26392.6	17571.8	19478.1	8726.0	7738.3
25	3491.4	1462.9	997.4	842.7	745.9	689.5	949.1	15004.6	16766.7	17790.0	15257.0	11370.1	7160.5
26	3506.8	1619.4	1486.5	1408.8	1342.2	1271.9	1456.7	14036.5	30302.6	26188.0	17031.6	15154.7	9606.6
27	7003.3	1853.0	1007.9	896.8	876.2	825.2	1261.2	11305.3	22813.6	18252.6	19297.7	6463.3	7705.5
28	3552.4	2391.7	2147.5	1657.4	1469.7	1361.0	1509.8	11211.9	35606.7	21740.5	18371.2	11916.1	9438.8
29	6936.3	3210.8	2371.4	1867.9	1525.0	1480.6	1597.1	11693.4	18416.8	20079.0	15326.5	8080.4	7765.1
30	4502.3	2324.3	1549.4	1304.1	1203.6	1164.7	1402.8	13334.0	24052.4	27462.8	19106.7	10172.4	9023.0
31	6900.0	3955.0	2279.0	1649.0	1383.0	1321.0	1575.0	11377.0	26255.0	30002.0	20196.0	12342.0	9994.5
32	7246.0	3699.0	1554.0	1287.0	1089.0	997.0	1238.0	11676.0	17741.0	31236.0	35270.0	12762.0	10577.9
MAX	7517.6	3955.0	2904.9	2212.0	1836.4	1778.7	2405.4	19776.8	47816.4	32388.4	35270.0	19799.1	10946.5
[illegible]	[illegible]866.[illegible]	114[illegible]	[illegible]0	[illegible].9	[illegible]08.[illegible]	663.[illegible]	6[illegible]	3[illegible]9	1[illegible].6	[illegible]91.[illegible]	[illegible]257.[illegible]	64[illegible]	[illegible]00.[illegible]

TABLE 2.34 POST-PROJECT FLOW AT WATANA (cfs)
WATANA/DEVIL CANYON ; CASE C

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1	5564.1	10435.0	12314.6	11438.4	10785.8	8708.4	7282.9	4470.2	4011.0	3799.5	4080.9	7546.7	7512.1
2	11900.0	6948.4	7941.1	7345.6	6377.0	6511.7	6823.8	6344.3	4283.0	3925.0	3994.0	6939.1	6617.0
3	9061.9	9850.5	12276.3	11401.4	11021.6	9708.1	7406.7	4992.5	3198.6	3628.9	5170.1	5760.3	7776.7
4	9261.1	10916.8	12249.2	11408.5	11003.3	9827.2	7984.8	7029.0	6219.4	3931.4	3767.8	4192.5	8134.8
5	11477.9	6740.6	11580.1	11103.4	10782.9	8777.5	7545.4	6287.2	3312.1	3779.9	3263.4	4123.9	7391.6
6	10208.6	6683.3	12250.4	11376.7	10961.5	10315.6	7543.6	4550.3	5182.4	5128.7	7015.6	12466.0	8628.5
7	7077.7	10811.9	12317.2	11455.6	10734.6	8833.7	7321.1	6881.3	6114.0	5829.8	8243.3	13194.4	9051.0
8	7183.4	10907.1	12248.1	11394.9	10967.3	10193.6	8572.1	4982.2	6537.0	3771.0	5121.8	8991.7	8381.0
9	8805.9	10830.7	12128.6	11312.9	10942.6	10208.1	9197.8	6059.5	5625.0	3854.8	4418.0	5853.2	8252.1
10	11673.8	6809.6	7783.9	9626.1	10928.8	8833.3	7488.5	4878.2	3432.3	3442.5	5550.2	10149.9	7528.3
11	8140.9	10947.2	12222.0	11360.3	10967.0	10203.4	8619.3	7501.6	4273.2	3790.8	3700.2	4009.2	7354.5
12	10336.7	10068.4	12172.4	11373.7	11003.6	10125.2	9074.4	7178.1	5969.3	4106.5	6898.7	4894.6	8592.4
13	9420.4	9619.6	12347.8	11410.3	10991.6	10209.5	8945.7	6097.0	5751.8	6625.6	13868.6	12746.2	9832.9
14	8535.5	11048.4	12289.7	11405.4	10966.2	10239.9	8272.6	7186.8	6377.5	5757.0	8597.1	10800.0	9277.7
15	8162.5	11012.9	12305.9	11442.9	10999.7	8714.5	7212.0	5142.5	5707.4	6499.0	6927.4	5163.5	8262.7
16	10477.4	8758.0	12353.0	11497.6	10752.5	8946.6	7835.2	5742.0	4736.9	4587.1	5402.3	10487.7	8451.5
17	8196.6	10789.1	12267.8	11399.3	10978.1	9625.9	7941.2	4566.1	5895.8	3674.0	3623.9	4935.2	7803.3
18	11738.4	6814.9	7793.1	9300.0	11011.1	9028.8	7452.5	7144.1	6562.7	5028.6	8676.3	13672.9	8666.8
19	6994.4	11011.0	12386.3	11388.2	10961.3	10170.4	9185.3	7298.8	6230.0	6134.6	4013.0	6880.4	8537.2
20	11765.1	6839.6	7834.0	8575.6	10727.8	8825.3	7452.8	4776.5	4079.7	4168.0	4335.2	7482.2	7218.3
21	11900.7	7018.2	8039.4	7419.3	6448.0	6591.5	5100.4	6241.5	3729.0	3592.5	3913.5	6028.6	6343.8
22	11695.6	6814.1	7897.6	7352.2	6397.3	6537.0	5682.1	4624.2	4462.9	3926.8	6383.9	8999.6	6736.5
23	7954.5	10985.4	12209.5	11299.8	10869.5	10123.9	9154.2	6463.1	5819.1	6512.3	7118.4	9213.6	8963.4
24	7715.4	10748.3	12329.9	11451.0	11014.3	9396.7	7516.9	5072.9	4338.0	4230.3	4381.1	8325.7	8022.4
25	11844.4	6935.6	7938.1	7336.3	6370.2	8005.1	7474.7	7327.0	4024.9	3978.8	4185.4	6234.6	6815.1
26	11900.1	6974.5	7942.4	7334.7	6337.0	6459.8	5607.7	5809.6	6308.3	6148.0	5613.0	7336.6	6990.9
27	8654.5	10824.9	12333.9	11217.3	10723.0	8830.0	7662.6	4208.7	3625.2	4225.9	5226.4	8130.5	7953.8
28	11801.3	6792.3	7775.9	7227.3	6272.0	8825.4	7806.2	4072.9	5981.5	6465.8	6985.7	5188.5	7113.6
29	10178.6	10412.9	12205.4	11359.5	10940.1	10167.2	9199.9	6261.4	4439.9	4027.5	4074.8	7047.3	8344.7
30	11758.0	6849.0	7903.9	7321.9	6356.0	6519.3	7233.4	7021.5	6458.3	6041.3	5072.9	4971.9	6970.3
31	11642.2	8455.1	12272.0	11411.6	10992.6	10207.8	9084.8	5001.7	6626.9	5932.7	6652.7	7034.9	8768.7
32	9433.4	10950.5	12289.0	11452.9	11003.6	10223.1	8723.2	5239.5	4642.9	5011.1	14043.2	12026.0	9580.4
MAX	11900.7	11048.4	12386.3	11497.6	11021.6	10315.6	9199.9	7501.6	6626.9	6625.6	14043.2	13672.9	9832.9
MIN	5564.1	6683.3	7775.9	7227.3	6272.0	6459.8	5100.4	4072.9	3198.6	3442.5	3263.4	4009.2	6343.8
MEAN	9764.4	9112.6	10881.2	10287.5	9924.6	9059.2	7793.9	5826.6	5123.6	4736.1	5947.5	7838.4	8015.1

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TABLE 2.35 POST-PROJECT FLOW AT DEVIL CANYON (cfs)
WATANA /DEVIL CANYON : CASE C

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1	6602.4	10756.1	12488.2	11574.6	10879.8	8809.3	7405.0	6305.0	6047.5	5989.5	5987.9	8177.1	8401.8
2	12252.9	7072.3	8065.7	7443.3	6471.5	6589.0	7026.2	7913.0	5743.6	5714.3	6046.0	9532.7	7499.2
3	9690.7	10219.4	12532.8	11610.6	11123.8	9801.3	7481.3	5765.5	7439.4	6379.7	7461.0	7630.4	8918.0
4	10493.0	11392.6	12518.4	11589.2	11137.2	9923.2	8134.6	9750.1	9980.3	5760.1	6293.2	6607.4	9456.0
5	12368.3	7062.3	11783.4	11239.8	10909.5	8868.7	7733.4	9876.4	7023.5	5950.4	6914.4	6537.5	8858.1
6	11179.8	7139.0	12568.9	11637.5	11186.2	10453.1	7710.2	6222.3	8382.9	7553.6	8438.2	13007.4	9616.6
7	7623.3	11012.4	12485.2	11560.4	10872.9	8991.6	7470.1	9907.0	10079.3	9210.5	11699.7	16495.8	10608.2
8	8210.7	11404.3	12527.7	11605.1	11167.2	10364.0	8736.0	7279.6	9677.4	5931.7	7193.3	12179.6	9668.7
9	10205.5	11485.2	12775.0	11624.3	11113.1	10320.3	9369.8	7950.9	7940.7	5865.2	6794.4	6863.3	9349.4
10	12408.6	7079.9	8039.7	9862.0	11158.9	9017.2	7722.7	8638.5	6640.4	6339.8	10204.2	13012.6	9166.9
11	9036.1	11356.4	12561.2	11646.1	11168.3	10355.1	8767.2	9260.3	5749.6	6024.0	6443.2	6853.5	9094.8
12	11458.3	10500.5	12635.8	11805.8	11292.4	10433.1	9514.8	9570.9	10254.5	7147.3	8582.9	6967.0	10010.8
13	10242.2	9900.3	12566.1	11597.4	11147.6	10353.0	9101.7	6904.7	10414.4	8172.5	16223.3	14767.2	10946.5
14	9283.1	11235.5	12476.8	11592.5	11168.9	10314.7	8306.9	9585.2	9808.2	9378.0	10306.2	11777.2	10431.8
15	8973.7	11309.2	12498.3	11568.9	11118.3	8803.1	7299.3	5610.6	10681.9	8342.2	8465.0	6479.3	9250.7
16	11462.0	9034.9	12443.5	11559.9	10808.6	9006.2	7917.2	7043.1	7634.2	7546.9	7797.5	12496.3	9555.5
17	9471.9	11131.6	12542.6	11617.6	11180.8	9828.6	8221.9	6206.0	10402.5	6056.7	6477.6	6565.4	9125.9
18	12312.6	7070.6	8036.4	9555.7	11248.1	9228.4	7656.5	9024.1	9647.2	8122.5	12864.8	15728.2	10031.5
19	7560.7	11280.2	12611.8	11621.8	11179.6	10388.7	9399.6	9454.5	9988.1	8922.8	5956.0	7942.7	9680.4
20	12294.1	7055.6	7998.0	8703.6	10838.8	8919.3	7561.8	5988.5	5991.7	5588.0	5757.2	8520.2	7918.0
21	12364.1	7143.0	8140.1	7540.0	6554.6	6689.2	5160.6	7426.7	6448.9	6324.6	6302.5	7248.0	7293.0
22	12672.8	7399.5	8285.0	7573.9	6563.5	6686.7	5854.6	5194.9	7881.1	5742.0	9253.2	10446.7	7805.2
23	8512.4	11310.7	12564.7	11665.0	11214.5	10417.7	9414.3	10266.8	10319.6	8408.5	8263.0	10142.1	10199.0
24	8052.8	10925.2	12470.4	11559.3	11142.7	9477.8	7589.5	5682.3	6871.3	5451.0	5842.5	8952.0	8648.6
25	12279.3	7043.8	8003.9	7392.6	6426.2	8067.3	7551.9	9442.6	6011.0	5796.9	5918.7	7818.5	7662.0
26	12318.1	7119.5	8152.2	7527.7	6568.9	6690.3	5853.2	8173.9	9921.7	8905.6	7518.0	9416.0	8194.8
27	9978.7	11076.8	12465.6	11356.3	10856.0	8964.5	7864.0	6575.2	6444.8	5463.2	6130.6	8882.3	8824.6
28	12380.2	7257.3	8235.9	7536.0	6538.8	9075.6	8112.6	6715.4	10235.4	8499.0	8549.6	6491.5	8319.8
29	11321.0	10978.4	12597.1	11649.5	11197.4	10391.1	9388.6	6723.3	5579.5	5721.3	5989.2	7995.1	9117.7
30	12486.4	7228.4	8140.7	7489.2	6504.2	6582.8	7318.3	7986.2	7605.9	8592.4	7508.9	6047.6	7809.6
31	12392.2	8885.1	12519.0	11590.6	11142.6	10351.8	9255.8	6238.7	9491.9	9194.7	8848.7	8376.9	9855.3
32	10221.4	11352.5	12458.0	11592.9	11121.6	10331.1	8858.2	6509.5	5366.9	8407.1	17878.2	12762.0	10577.9
MAX	12672.8	11485.2	12775.0	11805.8	11292.4	10453.1	9514.8	10266.8	10681.9	9378.0	17878.2	16495.8	10946.5
MIN	6602.4	7043.8	7998.0	7392.6	6426.2	6582.8	5160.6	5194.9	5366.9	5451.0	5757.2	6047.6	7293.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE 2.36 POST-PROJECT FLOWS AT GOLD CREEK (cfs)
WATANA/DEVIL CANYON : CASE C

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1	7179.2	10934.4	12578.2	11650.3	10939.3	8865.3	7472.8	7324.3	7178.9	7206.1	12000.0	9300.0	9380.2
2	6748.5	7141.1	8134.9	7497.6	6524.0	6631.9	7138.6	8784.5	6555.1	6708.4	12000.0	9300.0	7776.4
3	6839.1	10431.1	12668.8	11726.9	11180.6	9859.6	7522.8	6195.0	9795.3	7901.5	12000.0	9300.0	9609.5
4	7307.4	11650.3	12668.0	11689.6	11211.6	9983.0	8217.8	11255.3	12069.7	6776.1	12000.0	9300.0	10332.3
5	7251.7	7247.7	11896.3	11315.6	10979.8	8919.3	7837.8	11870.4	9085.4	7156.4	12000.0	9300.0	9573.3
6	7286.5	7392.2	12739.4	11782.4	11311.0	10536.0	7802.8	7151.2	10161.0	8894.3	12000.0	10444.4	9788.5
7	7932.9	11123.8	12572.1	11625.2	10949.8	9079.3	7552.8	11581.5	12282.2	11088.6	13619.9	18330.0	11473.3
8	8787.9	11673.8	12683.1	11721.9	11278.3	10458.6	8833.8	8556.0	11415.3	7132.1	12000.0	10172.8	10384.1
9	10983.0	11848.8	13134.1	11797.3	11207.9	10382.6	9465.4	9008.2	9227.2	6982.1	12000.0	9300.0	10443.8
10	7116.3	7230.1	8181.8	9993.1	11286.8	9119.3	7852.8	10727.6	8422.7	7949.4	12783.3	14603.0	9572.6
11	9539.9	11577.0	12749.7	11804.9	11280.1	10439.3	8856.2	10230.9	6576.5	7264.7	12000.0	9300.0	10137.1
12	7203.6	10747.3	12886.7	12045.8	11452.8	10604.2	9759.4	10900.2	12635.2	8836.7	12000.0	9300.0	10692.4
13	7073.8	10062.9	12680.9	11701.4	11234.2	10432.7	9195.0	7353.5	12998.0	9031.9	17531.5	15890.0	11257.3
14	9704.9	11332.8	12580.8	11696.5	11281.5	10356.3	8332.7	10911.1	11714.1	11389.6	12000.0	11550.9	11072.9
15	9430.9	11473.8	12598.7	11638.9	11191.3	8852.3	7347.8	6000.0	13305.2	9366.2	12000.0	9300.0	10199.1
16	7305.8	9195.6	12487.2	11601.1	10839.8	9039.3	7962.8	7766.0	9243.9	9184.7	12000.0	10644.5	9769.4
17	10136.9	11321.8	12688.7	11738.9	11293.4	9947.7	8377.8	7117.0	12899.5	7380.5	12000.0	9300.0	10345.3
18	6931.1	7212.7	8171.5	9697.8	11379.8	9339.3	7769.8	10068.6	11354.1	9841.3	15191.8	16870.0	10305.0
19	7881.9	11423.0	12737.1	11751.6	11300.9	10510.0	9518.6	10632.1	12076.0	10471.8	12000.0	9300.0	10800.3
20	6899.6	7178.6	8091.0	8777.6	10901.8	8772.3	7474.8	6686.5	7093.7	6484.0	12000.0	9300.0	8318.1
21	6921.1	7212.3	8196.1	7607.1	6613.9	6745.4	6577.8	6746.0	7960.0	7042.4	12000.0	9300.0	[illegible]
22	7515.1	7724.7	8500.2	7697.1	6655.9	6769.9	5950.4	6561.9	8695.2	6750.4	12000.0	10052.8	7914.2
23	8828.9	11484.7	12762.1	11867.9	11406.1	10580.9	9558.8	12380.0	12819.8	9462.0	12000.0	9300.0	11037.3
24	6453.2	11030.1	12541.9	11619.5	11214.1	9529.3	7629.8	6020.9	8278.7	6484.0	12000.0	9300.0	9329.5
25	6820.4	7103.9	8040.5	7423.9	6457.3	8101.8	7594.8	10611.5	7121.1	6806.9	12000.0	9300.0	8132.5
26	6849.9	7200.1	8268.7	7634.9	6697.7	6818.4	5989.5	9487.4	11922.4	10437.6	12000.0	9300.0	8565.2
27	8527.6	11216.8	12532.2	11440.0	10929.8	9039.3	7975.8	7889.9	8011.2	6484.0	12000.0	9300.0	9606.7
28	7001.4	7515.6	8491.4	7707.6	6687.1	9214.6	8282.8	8183.5	12592.0	9628.5	12000.0	9300.0	8895.9
29	7356.7	11299.3	12808.2	11810.6	11340.4	10515.5	9493.5	6986.4	6212.7	6662.3	12000.0	9300.0	9641.2
30	7190.6	7439.1	8272.3	7582.1	6586.6	6618.1	7365.5	8522.2	8243.5	10003.2	12000.0	9300.0	8275.9
31	7096.2	9128.8	12649.5	11689.6	11225.6	10430.8	9357.5	6921.7	12306.9	11846.2	12000.0	9300.0	10325.4
32	8334.0	11632.7	12677.1	11759.5	11268.2	10448.4	8994.4	8150.2	6000.0	8940.9	21146.2	13171.1	11053.7
MAX	10983.0	11848.8	13134.1	12045.8	11452.8	10604.2	9759.4	12380.0	13305.2	11846.2	21146.2	18330.0	11473.3
MIN	6453.2	7103.9	8040.5	7423.9	6457.3	6618.1	5950.4	6000.0	6000.0	6484.0	12000.0	9300.0	7776.4
MEAN	7764.9	9630.8	11270.9	10596.7	10190.9	9285.6	8100.4	8706.3	9882.9	8387.3	12633.5	10510.3	9745.4

TABLE 2.37 MONTHLY MAXIMUM, MINIMUM, AND MEAN FLOWS AT DEVIL CANYON

MONTH				POST-PROJECT					
	PRE-PROJECT			WATANA ALONE			WATANA/DEVIL CANYON		
	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN
OCT	7517.6	2866.5	5324.3	11005.0	6034.4	7567.6	12672.8	6602.4	10565.9
NOV	3955.0	1145.7	2390.8	11735.1	6681.4	8999.4	11485.2	7043.8	9444.3
DEC	2904.9	810.0	1664.5	13021.3	7628.7	10550.6	12775.0	7998.0	11130.9
JAN	2212.0	756.9	1362.1	11102.5	7148.0	9595.7	11805.8	7392.6	10484.0
FEB	1836.4	708.7	1152.5	10152.9	6384.5	8854.5	11292.4	6426.2	10093.8
MAR	1778.7	663.8	1042.1	9290.4	6541.4	8242.1	10453.1	6582.8	9202.9
APR	2405.4	696.5	1267.0	9109.0	5763.9	7645.4	9514.8	5160.6	7961.2
MAY	19776.8	3427.9	12190.3	16021.7	5801.2	9355.2	10266.8	5194.9	7662.2
JUN	47816.4	14709.8	26078.1	23328.0	5598.0	9682.7	10681.9	5366.9	8178.0
JUL	32388.4	17291.0	23152.2	13136.9	5805.8	7891.7	9378.0	5451.0	7078.2
AUG	35270.0	15257.0	20928.2	23226.0	9971.6	12078.5	17878.2	5757.2	8247.2
SEP	19799.1	6463.3	12413.6	12390.3	7632.8	8932.3	16495.8	6047.6	9460.0
ANNUAL	10946.5	6800.1	9129.7	10763.2	7341.2	9121.8	10946.5	7293.0	9121.8

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TABLE 2.38 POST-PROJECT FLOW AT SUNSHINE (cfs)
WATANA/DEVIL CANYON ; CASE C

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1	14847.2	13990.4	14750.2	13371.3	12427.3	10172.3	8913.8	18232.3	33191.9	43785.1	46969.0	28733.0	21625.3
2	15126.5	10553.1	10838.9	9467.6	8139.0	8035.9	9084.6	36890.5	44637.1	53612.4	50686.0	39129.0	24806.6
3	14981.1	13389.1	14550.8	13596.9	12691.6	11261.6	8959.8	12034.0	46163.2	46448.5	44443.0	26877.0	22174.9
4	16499.4	15352.3	15048.0	13407.6	12734.6	11480.0	10894.8	42287.3	48824.6	40867.1	41344.0	27767.0	24291.3
5	14874.7	10239.7	14373.3	13682.6	12868.8	10562.3	9806.8	27185.4	38640.4	40182.4	43601.0	24756.0	21813.5
6	14104.5	10972.2	15007.4	13915.4	13100.0	12013.0	9260.8	19590.2	49907.0	52228.3	63942.0	31539.4	25573.[illegible]
7	13992.9	13590.8	14433.1	13257.2	12265.8	10348.3	8846.8	27078.5	52883.2	60567.5	58123.9	44495.0	27588.4
8	18233.9	15652.8	15448.1	14027.9	13249.3	12102.6	10540.8	28946.0	60408.3	46124.1	44703.0	38493.8	26550.7
9	21170.0	16926.8	16009.1	13899.3	12896.9	11877.6	11331.4	23867.2	44279.2	43952.1	46362.0	21848.0	23771.6
10	13883.3	10411.1	10260.8	11932.1	13038.8	10419.3	9497.8	24197.6	49388.7	50470.4	53551.3	34598.0	24378.4
11	18112.9	15142.0	15372.7	14018.9	13029.1	11917.3	10484.2	29252.9	30357.5	42508.7	43725.0	31876.0	23076.1
12	16405.6	13856.3	15696.7	14332.8	13176.8	12274.2	12218.4	25978.2	44071.2	47906.7	50516.0	32001.0	24958.3
13	15736.8	14019.9	15400.9	14023.4	13076.2	12007.7	11076.0	19283.5	57265.0	50937.9	55162.5	38711.0	26458.7
14	16937.9	14584.8	15270.8	14170.5	13402.5	11755.3	9527.7	27126.1	42343.1	55208.6	41268.0	28412.9	24260.8
15	21536.9	15130.8	14637.7	13387.9	12672.3	10152.3	8983.8	10338.0	73798.2	45252.2	41934.0	22926.0	24264.4
16	16487.8	13868.6	15812.2	14014.1	12941.8	10957.3	10037.8	19373.0	42011.9	46386.7	47255.0	44997.5	24571.9
17	21189.9	14544.8	15022.7	13742.9	13002.4	11532.7	10200.8	13951.0	49518.5	42763.5	52177.0	27706.0	23848.3
18	14319.1	9907.7	10527.5	11895.8	13273.8	10932.3	9241.8	27500.6	48006.1	60166.3	65318.8	37379.0	26652.5
19	13687.9	14483.0	15245.1	13951.6	13386.9	12508.0	11967.6	31433.1	57296.0	53786.8	41560.0	21369.0	25139.3
20	13141.6	9753.6	9989.0	10380.6	11710.8	10161.3	9644.8	18140.5	35919.7	36956.0	38648.0	24356.0	19068.6
21	13213.1	9973.3	10178.1	9383.1	8293.9	8349.4	8647.8	21053.0	36932.0	45953.4	46946.0	27370.0	20622.9
22	14491.1	11784.7	11140.2	9580.1	8133.9	8170.9	7508.4	13468.9	51973.2	47587.4	54609.0	28014.8	22292.2
23	17294.9	15136.7	15174.1	13885.9	13179.1	12092.9	11058.8	26670.0	45245.8	40984.0	43964.0	31056.0	24558.8
24	15215.2	14795.1	15106.9	13731.5	12998.1	11175.3	9423.8	16000.9	40411.7	39945.0	42795.0	25464.0	21479.0
25	14371.4	10279.9	10530.5	9431.9	8199.3	9597.8	9518.8	25917.5	32964.1	39273.9	39002.0	26161.0	19696.6
26	15412.9	10438.1	10442.7	9664.9	8216.7	8228.4	7556.5	23517.4	52448.4	58409.6	45588.0	28557.0	23313.0
27	16353.6	13461.8	14185.2	12973.0	12334.8	10420.3	9896.8	18144.9	39997.2	43050.0	44355.0	20921.0	21418.1
28	13747.4	10753.6	11373.4	10109.6	8709.1	10885.6	10139.8	22795.5	62395.0	48952.5	47917.0	29379.0	24608.5
29	17184.7	14904.3	15532.2	13994.6	12899.4	11912.5	11333.5	17743.4	35206.7	43572.3	37728.0	23435.0	21356.9
30	13506.6	10552.1	10899.3	9859.1	8506.6	8381.1	9619.5	28528.2	43402.5	52897.1	40437.0	25320.0	21930.9
MAX	21536.9	16926.8	16009.1	14332.8	13402.5	12508.0	12218.4	42287.3	73798.2	60567.5	65318.8	44997.5	27588.4
MIN	13141.6	9753.6	9989.0	9383.1	8133.9	8035.9	7508.4	10338.0	30357.5	36956.0	37728.0	20921.0	19068.6
MEAN	15868.7	12948.4	13608.6	12569.7	11818.5	10722.5	9820.8	23217.5	46332.3	47622.6	47154.4	29790.7	23538.0

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TABLE 2.39 POST-PROJECT FLOW AT SUSITNA (cfs)
WATANA/DEVIL CANYON : CASE C

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1	27713.6	19718.5	17336.2	16695.2	15406.8	13516.0	12259.7	62107.8	89194.6	109495.9	98551.8	40330.2	44792.9
2	20926.6	12773.9	13015.8	13611.2	12998.9	12273.4	12875.8	53967.0	68019.7	107302.5	93276.9	61531.0	40453.6
3	32320.7	24050.9	17757.3	18401.2	17217.0	14832.6	12587.9	46070.3	109972.5	118833.3	107266.1	76896.3	49082.8
4	44057.8	24442.4	20714.0	18658.3	17166.1	15512.8	14595.4	86825.3	115310.9	112525.3	89000.0	38197.7	49526.4
5	21816.2	16976.8	15667.9	17217.6	14972.9	13119.0	12908.3	53106.8	92716.4	103528.0	114486.7	62655.3	45162.1
6	25812.2	13800.0	16877.4	17243.0	15756.1	14751.6	13015.2	55996.2	149345.8	130210.8	106370.0	49658.6	50961.3
7	22905.3	19745.7	18566.8	16824.4	16810.6	14463.7	13785.0	76407.3	140288.3	148813.1	120709.4	104218.4	59701.9
8	44803.5	30171.3	24687.4	20622.0	18134.4	16611.7	15339.1	58010.4	157474.1	124140.4	116272.9	78197.8	58911.9
9	55407.0	27781.4	20505.4	17385.2	16287.8	15913.4	16031.0	66428.7	96424.0	106382.3	89068.5	54803.3	48797.4
10	32848.4	14608.5	11432.2	16340.2	16544.1	13804.8	13070.6	51339.0	95705.0	129166.2	119937.6	65586.5	48639.1
11	28736.0	18891.5	17554.3	16676.2	16138.1	14893.7	13385.8	44512.5	75180.9	113688.1	102391.6	70355.4	49597.2
12	33191.9	20661.5	23960.9	22262.9	19732.8	17986.8	16912.0	78996.9	134900.3	123235.2	106596.5	58434.3	54994.3
13	30186.5	20406.2	19557.5	18851.5	15916.7	14983.3	14130.2	49317.3	132777.0	126623.2	115202.0	74806.4	52946.9
14	30698.1	19287.3	19445.4	18767.2	17635.1	15414.4	13067.4	45784.3	71362.0	123409.7	95036.8	70013.3	45235.4
15	40928.2	20925.4	16730.7	16942.0	15986.9	13049.7	12133.6	37229.2	115851.6	111222.0	87839.5	45838.8	44737.5
16	29761.7	16854.6	17402.8	17593.0	16175.6	14309.2	13722.9	44261.4	93598.5	119751.2	102725.9	81238.8	47494.0
17	39535.1	21536.3	20217.0	18369.7	17482.8	15738.2	14651.1	49783.4	105132.3	105127.9	108899.3	61437.3	48383.6
18	29164.3	18575.3	14993.4	16226.3	17705.9	14822.5	13883.4	52695.2	116725.0	119347.6	119889.8	89527.0	52160.0
19	40706.4	24942.8	25763.1	21374.8	20933.1	17382.0	16371.2	88615.3	118393.2	114565.4	81704.5	42868.8	51388.7
20	28940.1	16359.0	13955.5	14615.6	16143.3	13674.6	12714.8	49788.5	94906.9	103938.9	92754.0	57295.6	43117.0
21	26480.5	12796.6	12346.5	12857.3	11427.2	11699.0	11266.9	48402.2	83942.1	118167.1	109748.0	80763.8	45213.2
22	35044.4	20924.9	14843.4	12763.8	11873.7	11702.5	10655.9	32626.2	98023.4	121983.8	113400.1	64634.0	45553.2
23	35745.1	23313.6	19042.9	19008.6	17836.4	15403.7	14743.7	64552.0	154413.7	129478.8	100306.6	57120.4	54457.1
24	28409.1	23630.0	19224.0	18028.7	17490.8	14841.9	14291.0	62319.9	103275.8	111596.2	98970.8	45452.8	46696.8
25	24063.1	15694.2	13087.5	13931.5	12427.6	13671.5	13565.6	55889.3	57089.1	90191.2	76031.5	53173.5	36786.6
26	22630.9	15900.1	16084.7	14715.9	13030.7	12466.4	11263.5	41677.4	108412.6	118417.6	85270.1	70730.1	44392.3
27	32338.6	19156.8	17451.2	16995.0	15593.8	13507.3	13855.8	65730.0	90631.2	102744.1	91850.1	51329.0	44506.6
28	33267.4	23135.6	19188.4	15978.6	13980.1	14488.6	12835.8	51683.5	140522.3	130658.5	118260.1	80470.1	54766.1
29	38015.7	20404.3	17748.2	16755.6	16443.4	15500.5	14824.5	43706.4	78092.7	103242.4	97710.2	56193.0	43449.0
30	39093.6	19904.1	15897.3	15008.1	13246.6	12450.1	14598.5	75912.3	103453.5	123623.1	119740.0	72870.0	52463.4
MAX	55407.0	30171.3	25763.1	22262.9	20933.1	17986.8	16912.0	88615.3	157474.1	148813.1	120709.4	104218.4	59701.9
MIN	20926.6	12773.9	11432.2	12763.8	11427.2	11699.0	10655.9	32626.2	57089.1	90191.2	76031.5	38197.7	36786.6
MEAN	32514.9	19912.3	17701.8	17024.7	15949.8	14426.2	13644.7	56258.1	106371.2	114713.7	102641.9	63887.6	48320.0

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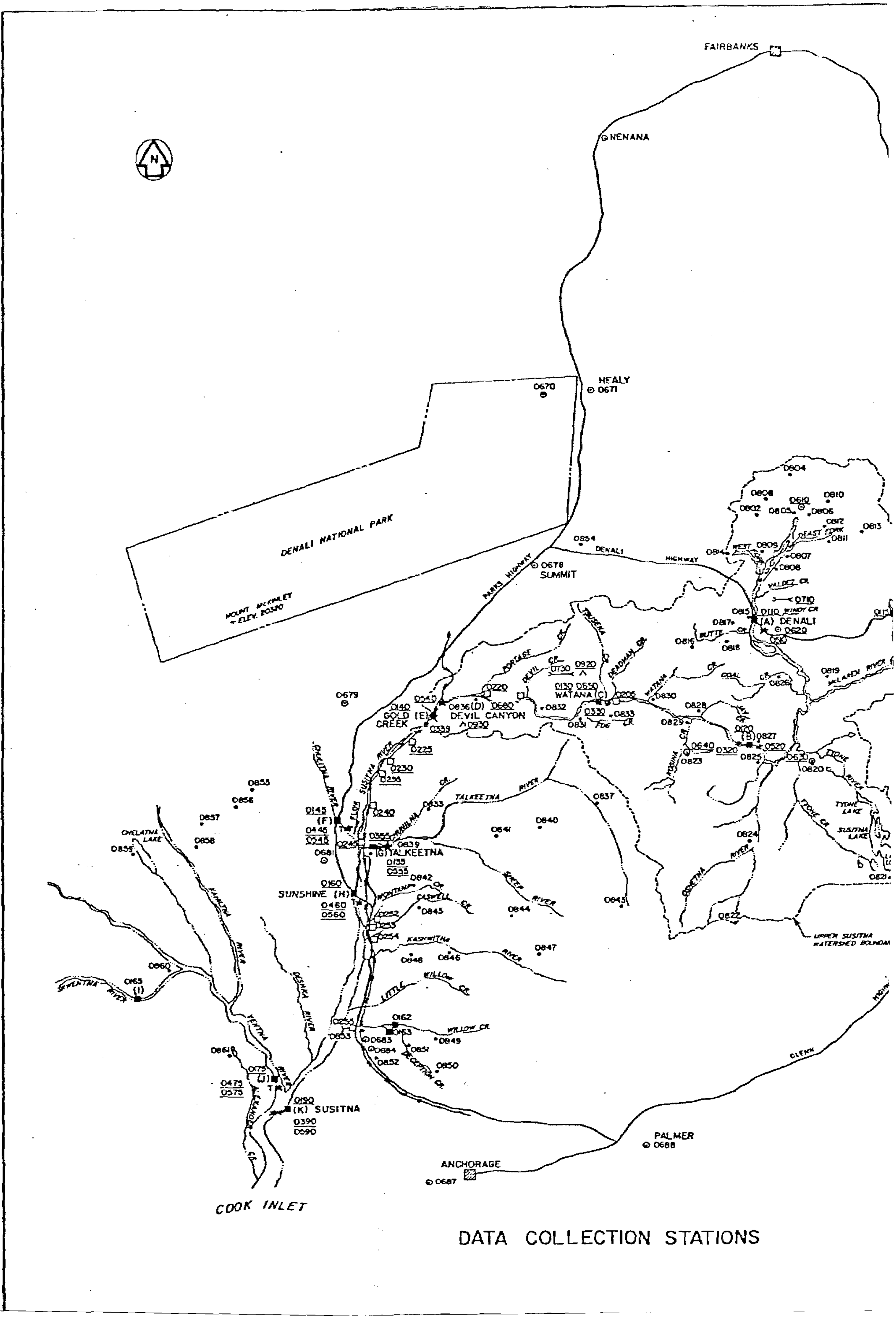
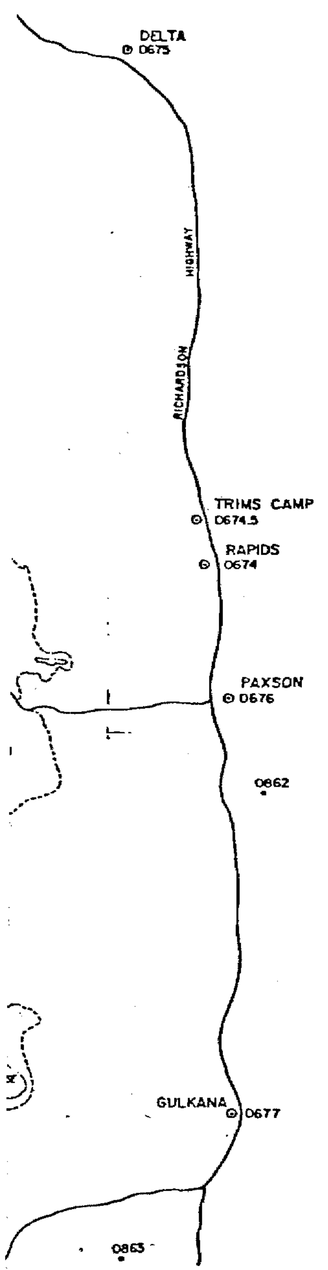


DATA COLLECTION STATIONS



DATA COLLECTED

		INDEX NUMBERING
■	STREAMFLOW - CONTINUOUS RECORD	0100
□	STREAMFLOW - PARTIAL RECORD	0200
●	WATER QUALITY	0300
T	WATER TEMPERATURE	0400
★	SEDIMENT DISCHARGE	0500
⊙	CLIMATE	0600
⊢	FREEZING RAIN AND INCLOUD ICING	0700
•	SNOW COURSE	0800
▲	SNOW CREEP	0900

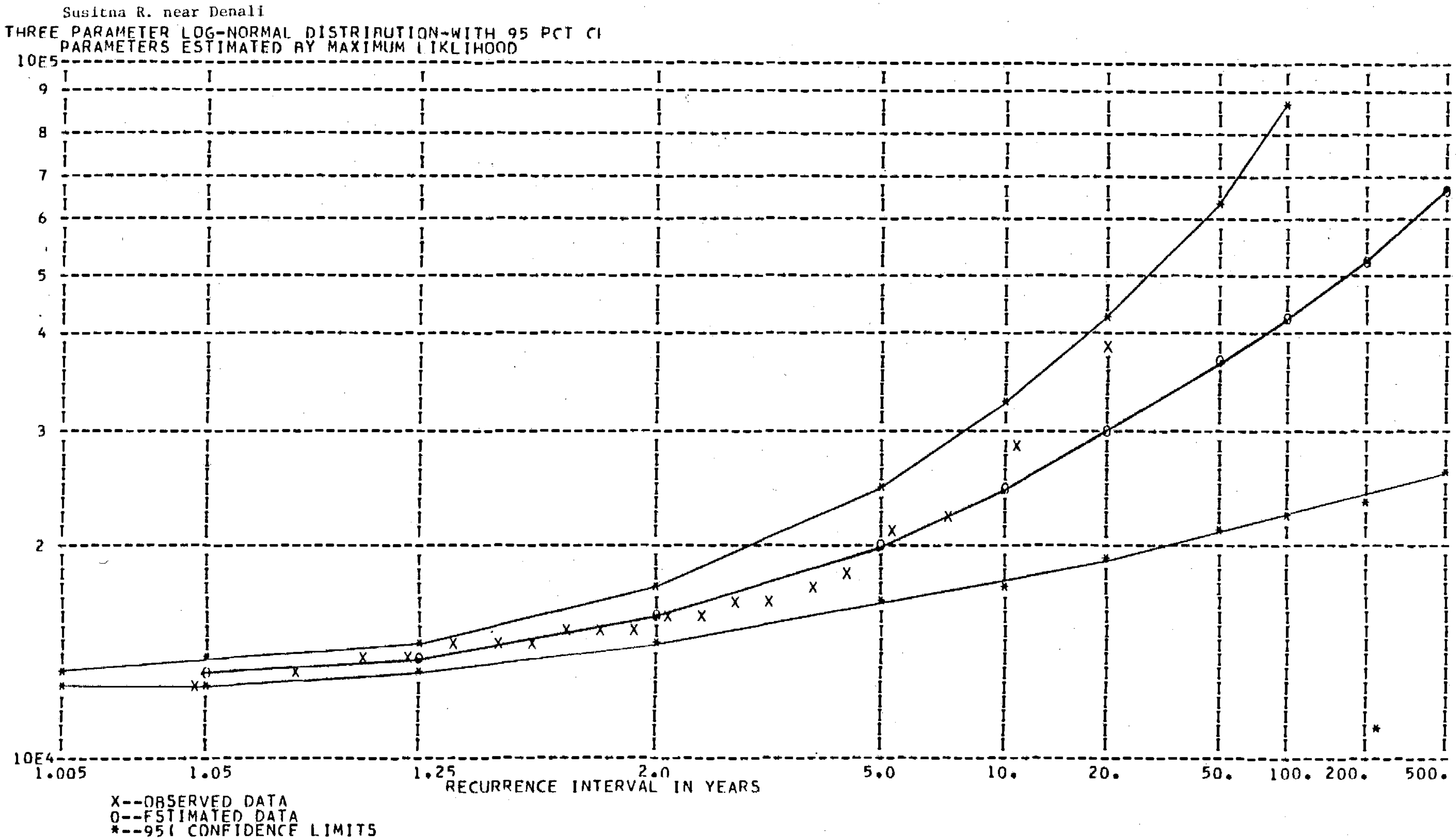
NOTES

2. CONTINUOUS WATER QUALITY MONITOR INSTALLED
3. DATA COLLECTION 1981 SEASON
4. THE LETTER BEFORE EACH STATION NAME IN THE TABLE IS USED ON THE MAP TO MARK THE APPROXIMATE LOCATION OF THE STATIONS.
5. STATION NUMBERS UNDERLINED INDICATES DATA COLLECTED BY STUDY TEAM IN 1980-82. SNOW COURSES MEASURED ARE NOT UNDERLINED FOR CLARITY.

SCALE 0 10 20 MILES (APPROX.)

STATION	STREAMFLOW GAGING	CREST STAGE GAGE	STAFF GAGE	WATER QUALITY (1)	WATER TEMPERATURE	SEDIMENT DISCHARGE	BEDLOAD SAMPLING (3)	CLIMATE	IN-CLOUD ICING	FREEZING RAIN	SNOW CREEP	PERIOD OF RECORD OF STREAMFLOW
(A) SUSITNA RIVER NEAR DENALI	X		X		X	X		X	X	X		1957 - PRESENT
(B) SUSITNA RIVER AT VEE CANYON	X		X	X	X	X						1961 - 1972 B 1980 - PRESENT
(C) SUSITNA RIVER NEAR WATANA DAMSITE	X	X		X^2	X			X	X	X	X	1980 - PRESENT
(D) SUSITNA RIVER NEAR DEVIL CANYON		X	X					X			X	
(E) SUSITNA RIVER AT GOLD CREEK	X			X	X	X	X					1949 - PRESENT
(F) CHULITNA RIVER NEAR TALKEETNA	X				X	X	X					1958 - 1972 B 1980 - PRESENT
(G) TALKEETNA RIVER NEAR TALKEETNA	X			X	X	X	X					1964 - PRESENT
(H) SUSITNA RIVER NEAR SUNSHINE	X				X	X	X					198. -- PRESENT
(I) SKWENTNA RIVER NEAR SKWENTNA	X			X	X	X		X				1959 - 1980
(J) YENTNA RIVER NEAR SUSITNA STATION	X				X	X						1980 - PRESENT
(K) SUSITNA RIVER AT SUSITNA STATION	X			X	X	X						1974 - PRESENT
(L) MCLAREN RIVER AT PAXSON	X											

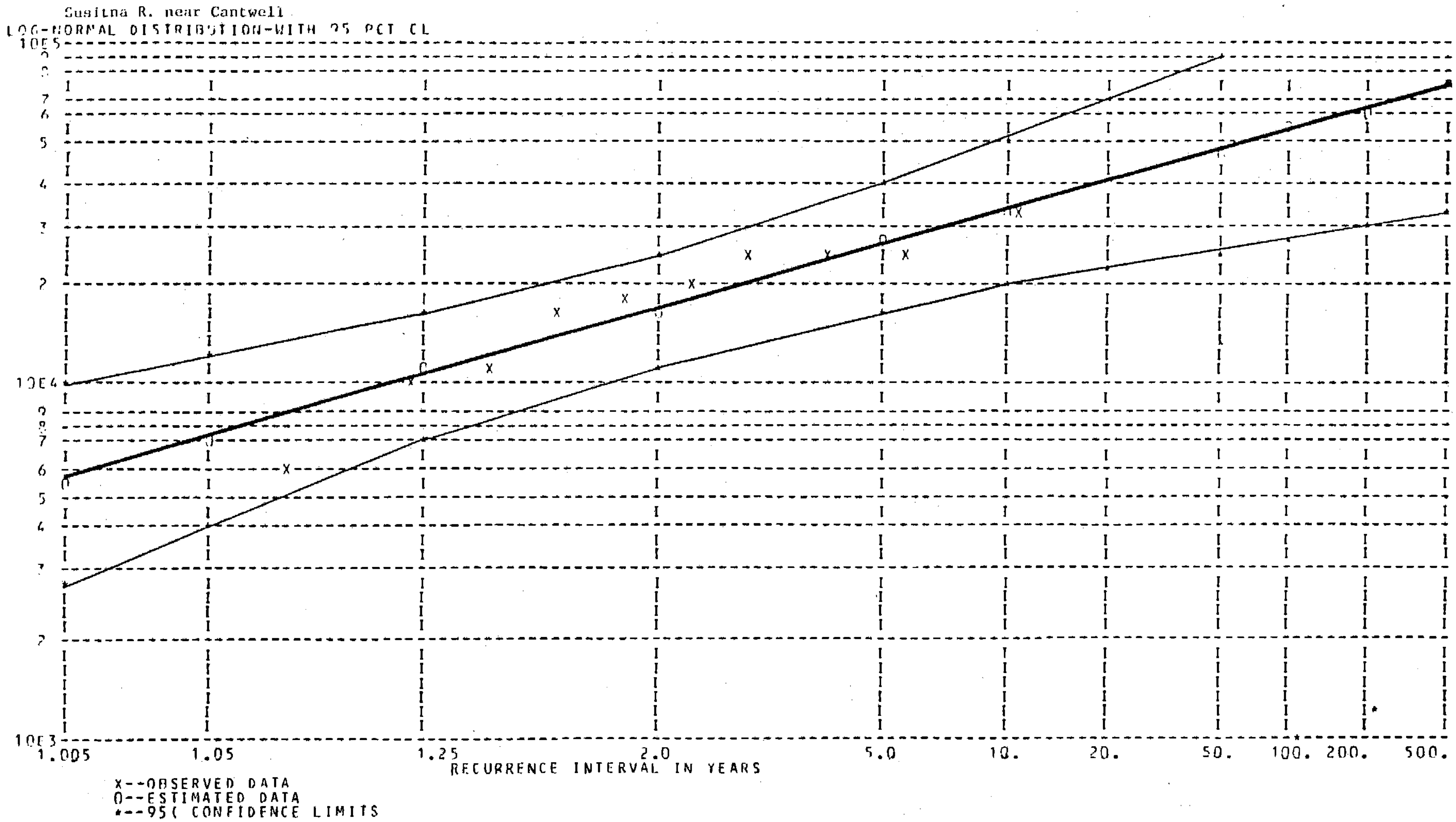
FIGURE E.2.1



ANNUAL FLOOD FREQUENCY CURVE

SUSITNA RIVER NEAR DENALI

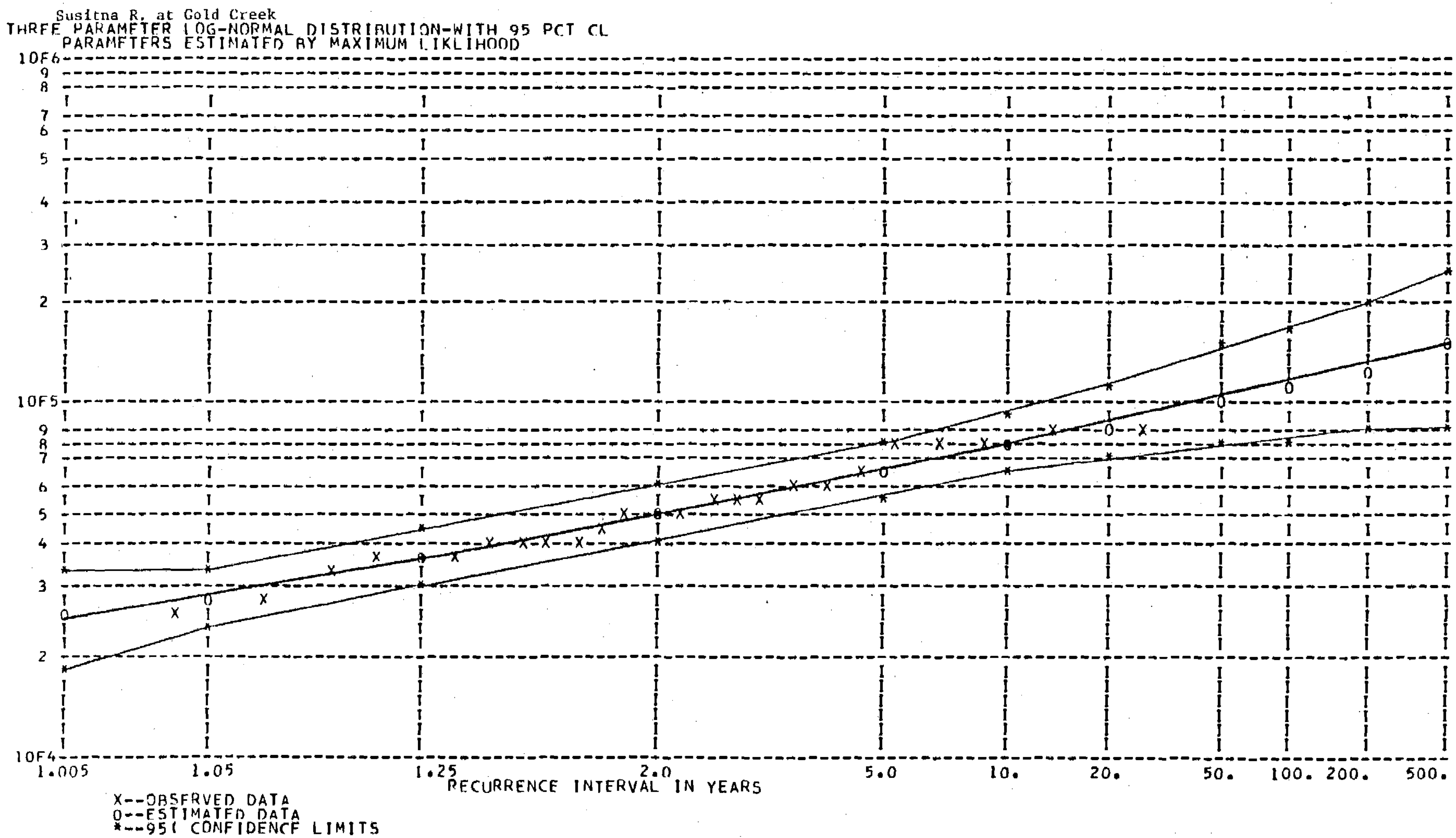
FIGURE E.2.2



ANNUAL FLOOD FREQUENCY CURVE

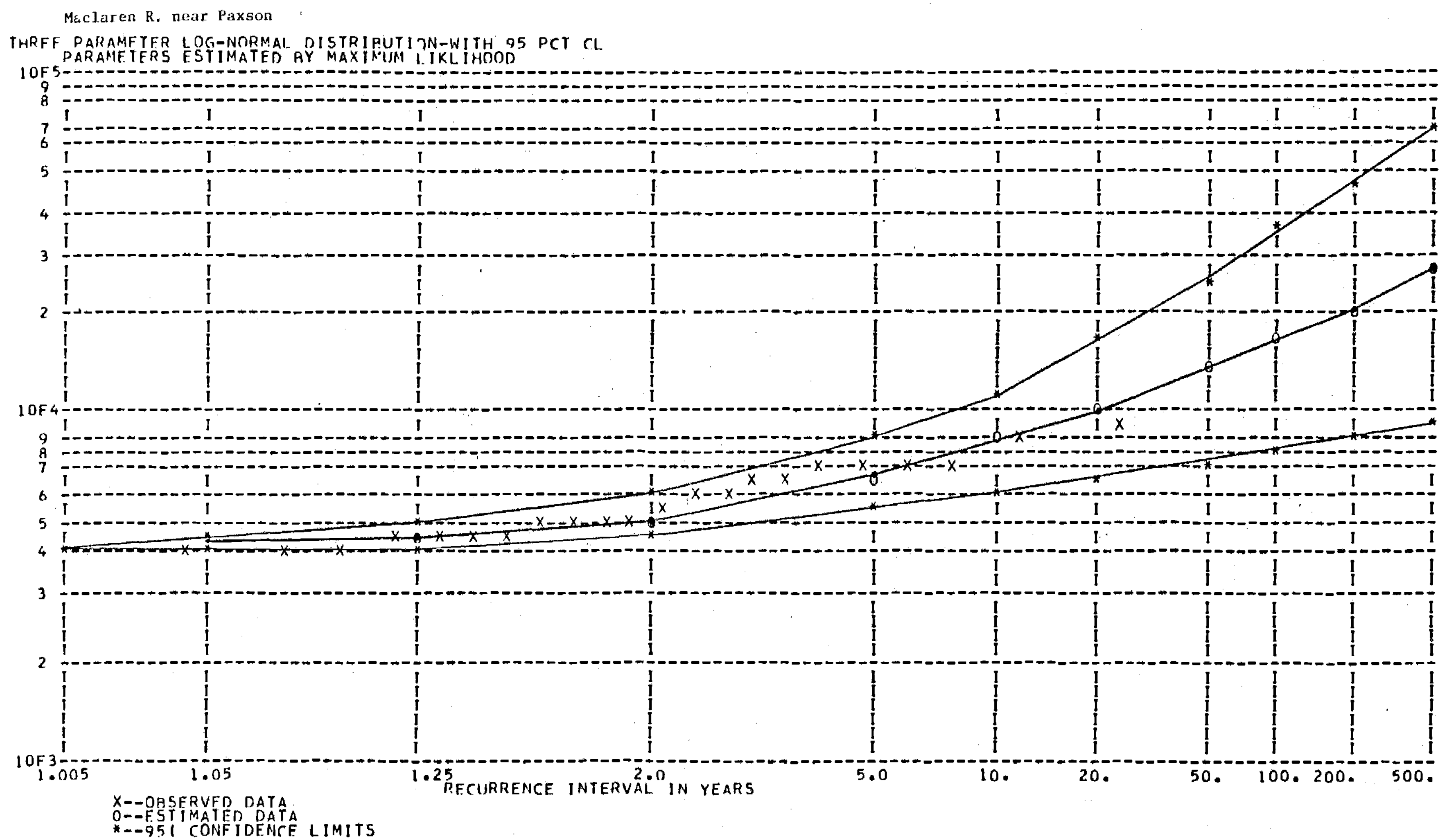
SUSITNA RIVER NEAR CANTWELL

FIGURE E.2.3



ANNUAL FLOOD FREQUENCY CURVE
SUSITNA RIVER AT GOLD CREEK

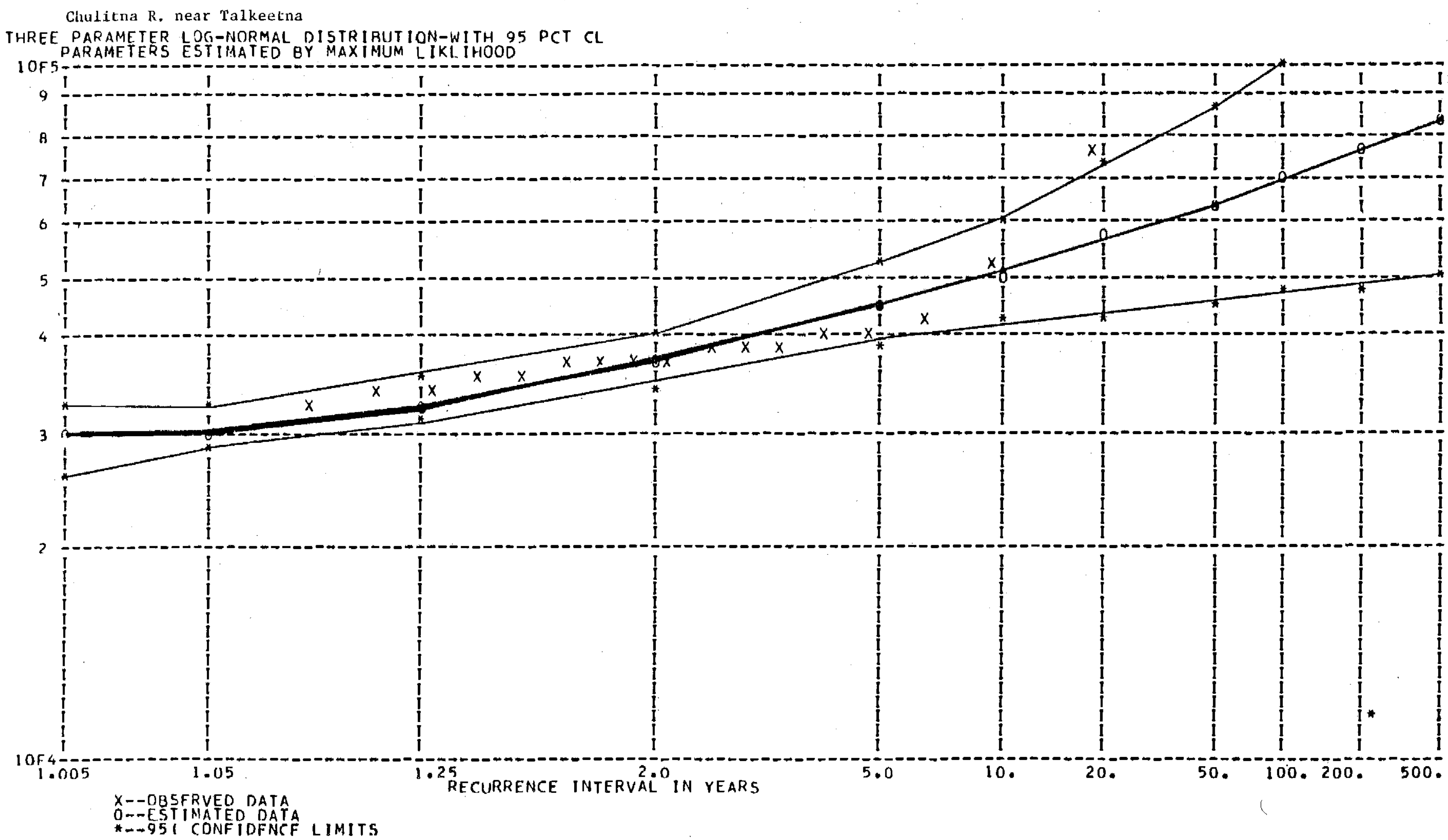
FIGURE E.2.4



ANNUAL FLOOD FREQUENCY CURVE

MACLAREN RIVER NEAR PAXSON

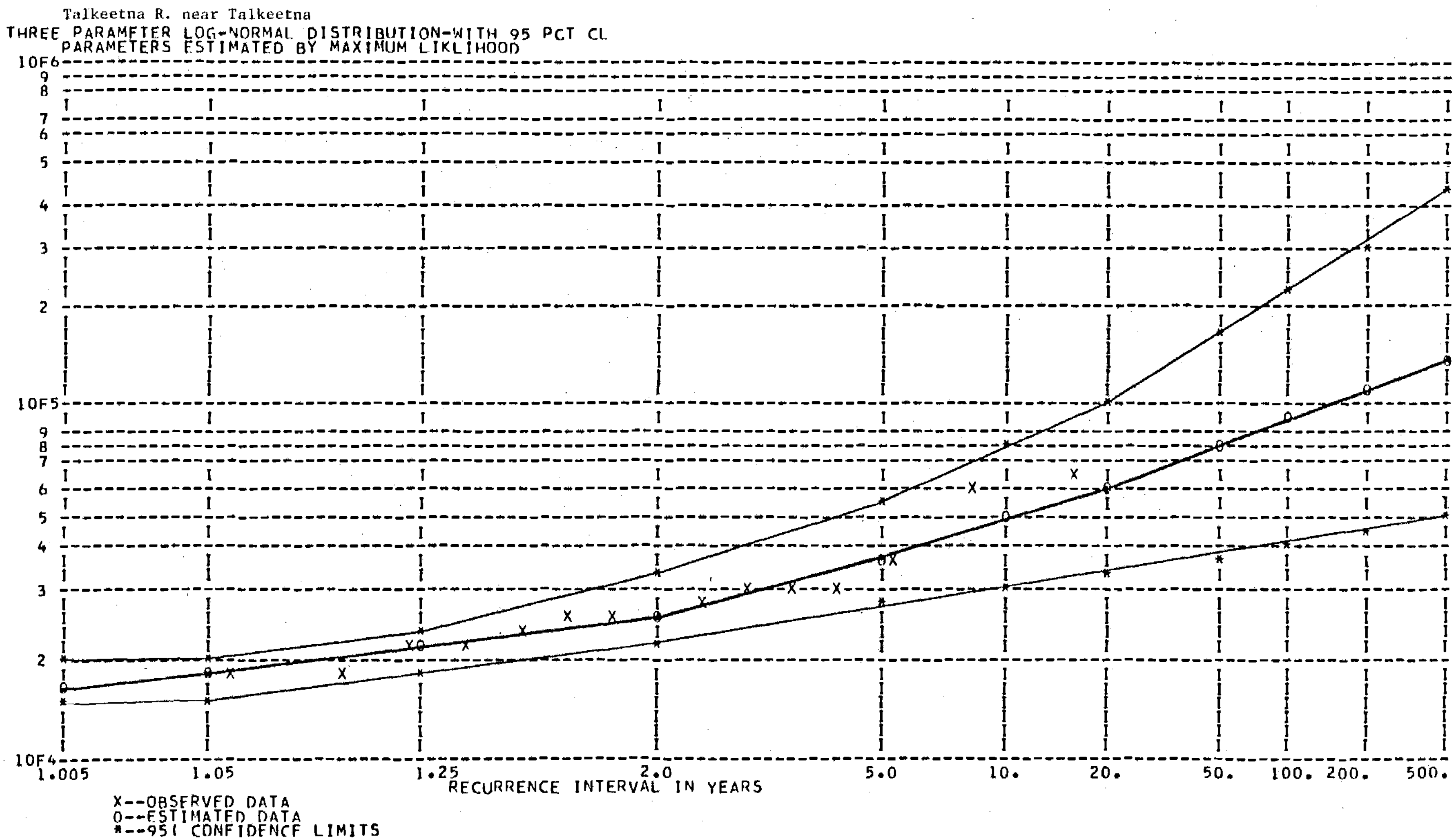
FIGURE E.2.5



ANNUAL FLOOD FREQUENCY CURVE

CHULITNA RIVER NEAR TALKEETNA

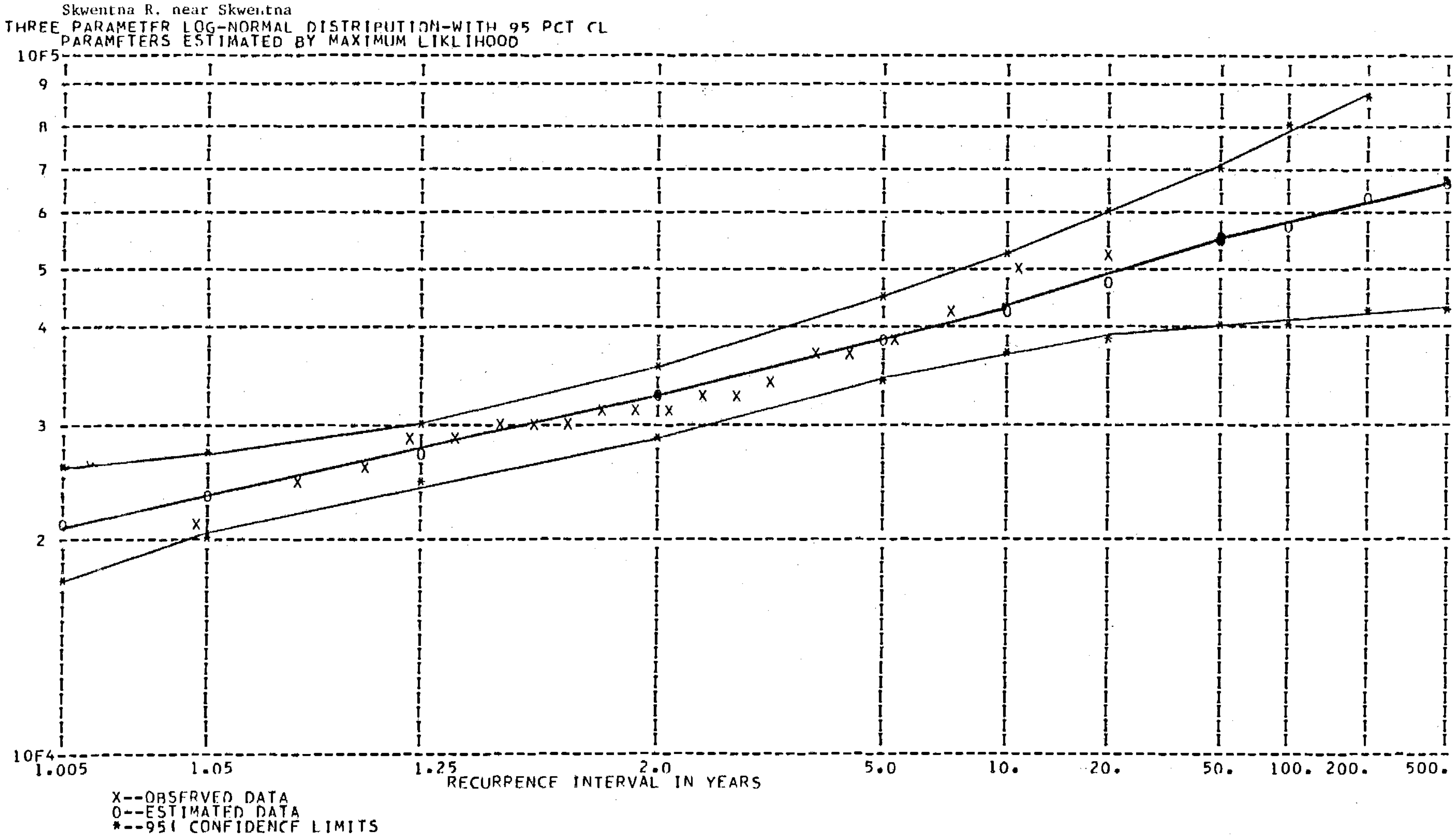
FIGURE E.2.6



ANNUAL FLOOD FREQUENCY CURVE

TALKEETNA RIVER NEAR TALKEETNA

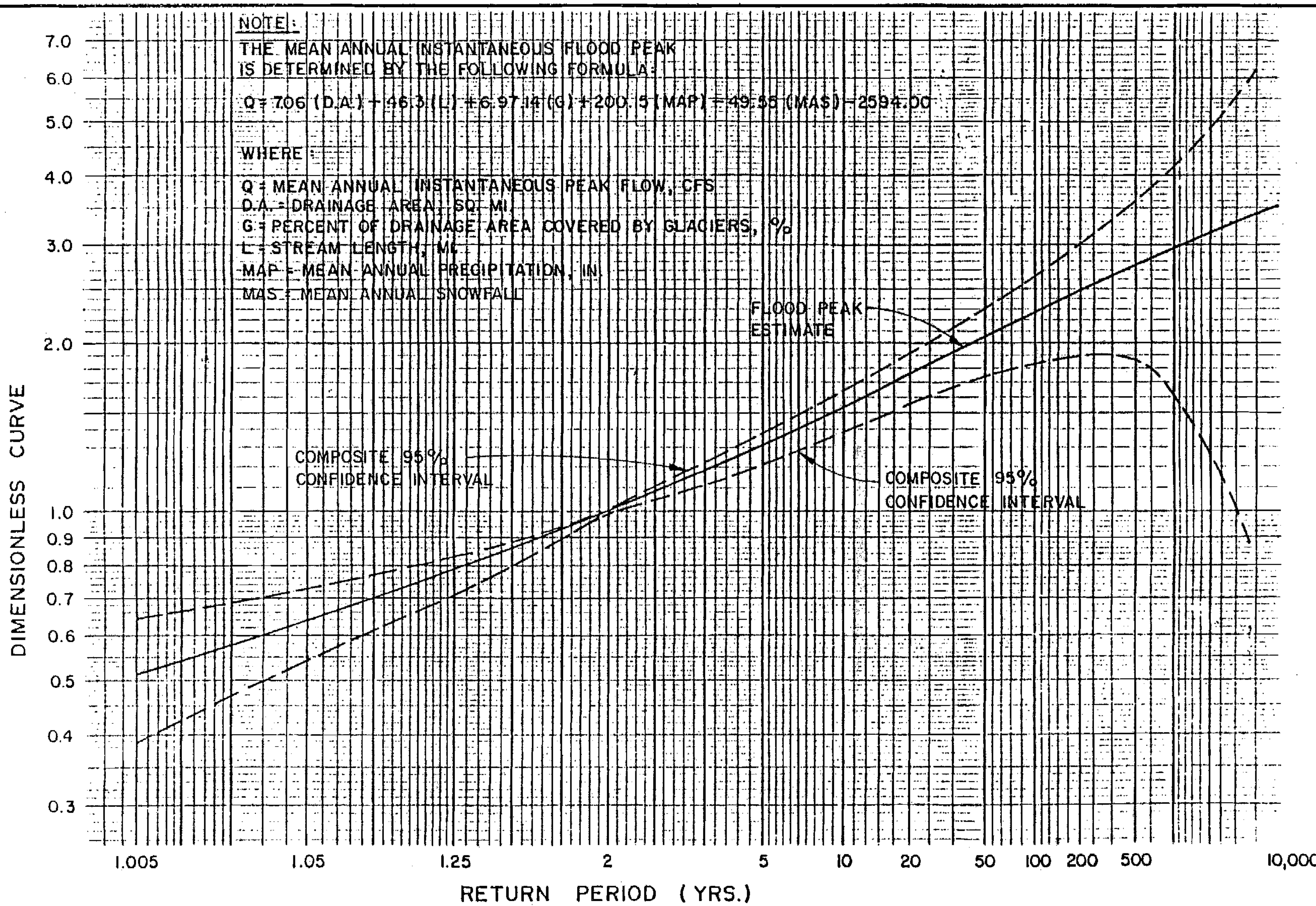
FIGURE E.2.7



ANNUAL FLOOD FREQUENCY CURVE

SKWENTNA RIVER NEAR SKWENTNA

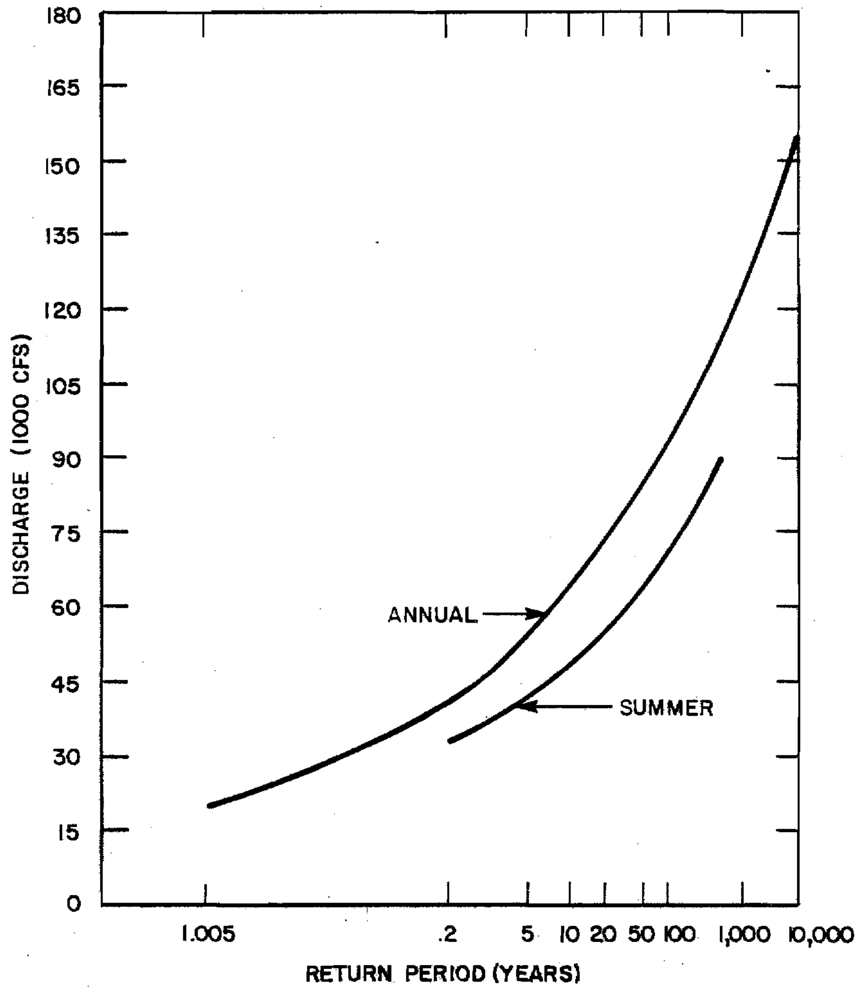
FIGURE E.2.8



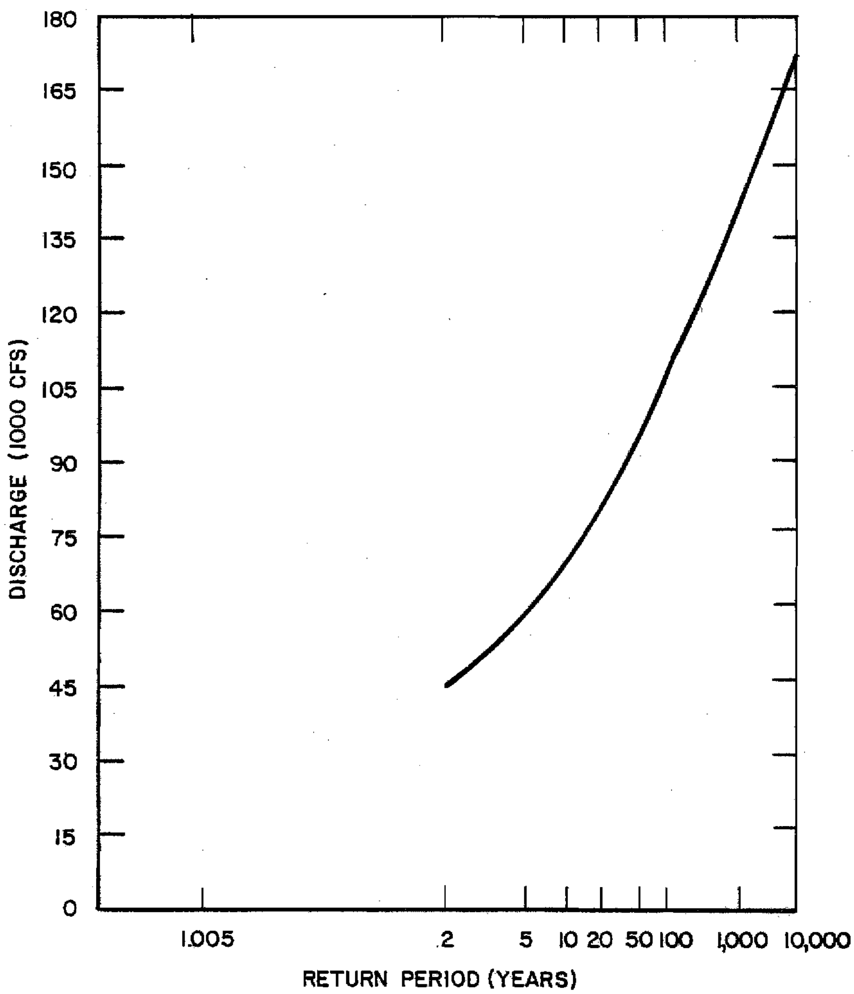
DESIGN DIMENSIONLESS REGIONAL FREQUENCY CURVE

ANNUAL INSTANTANEOUS FLOOD PEAKS

FIGURE E.2.9

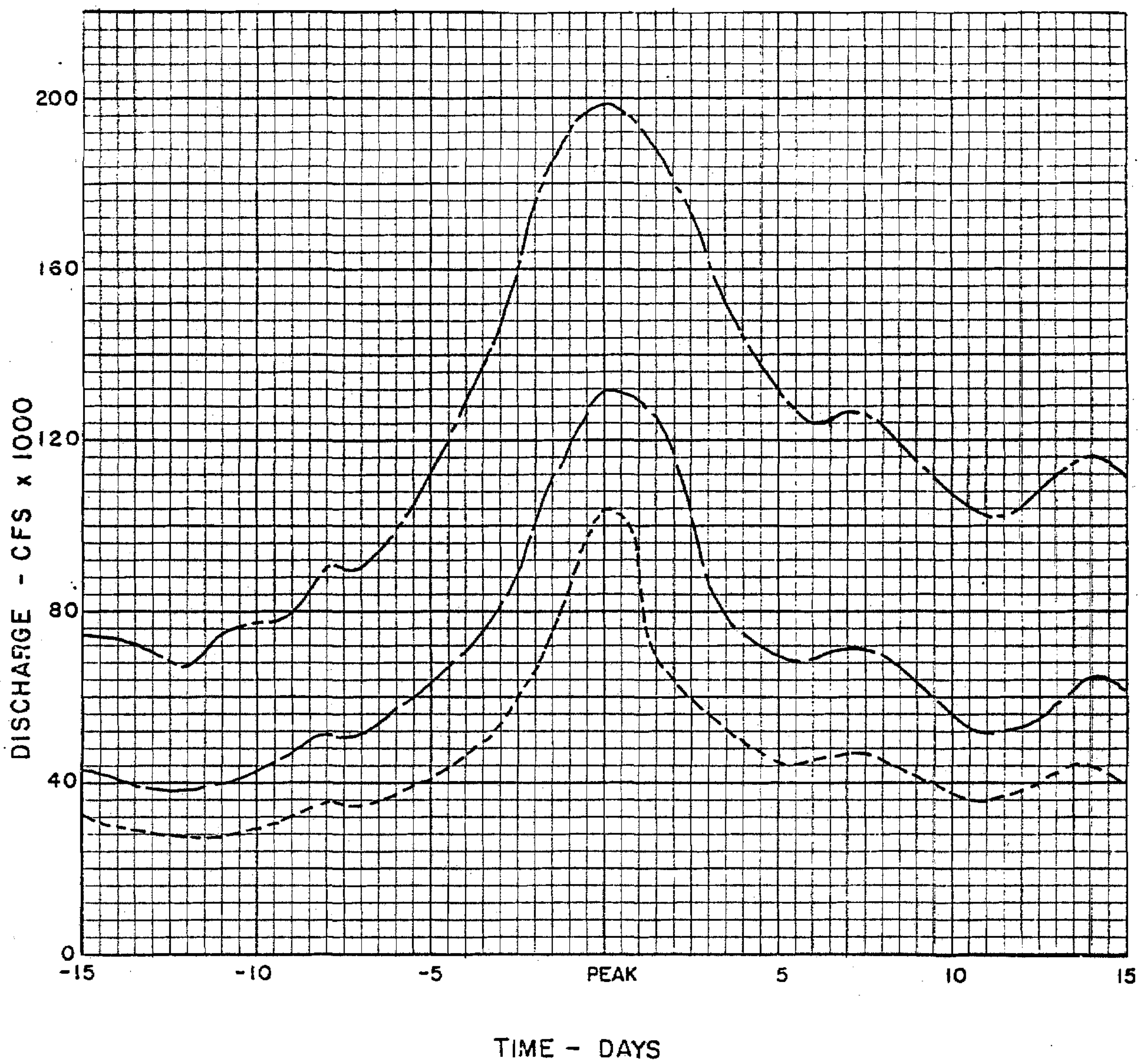


WATANA
NATURAL FLOOD FREQUENCY CURVE



DEVIL CANYON
NATURAL FLOOD FREQUENCY CURVE

FIGURE E.2.11



SUSITNA RIVER AT GOLD CREEK

100, 500, 10000 yr. FLOOD VOLUMES

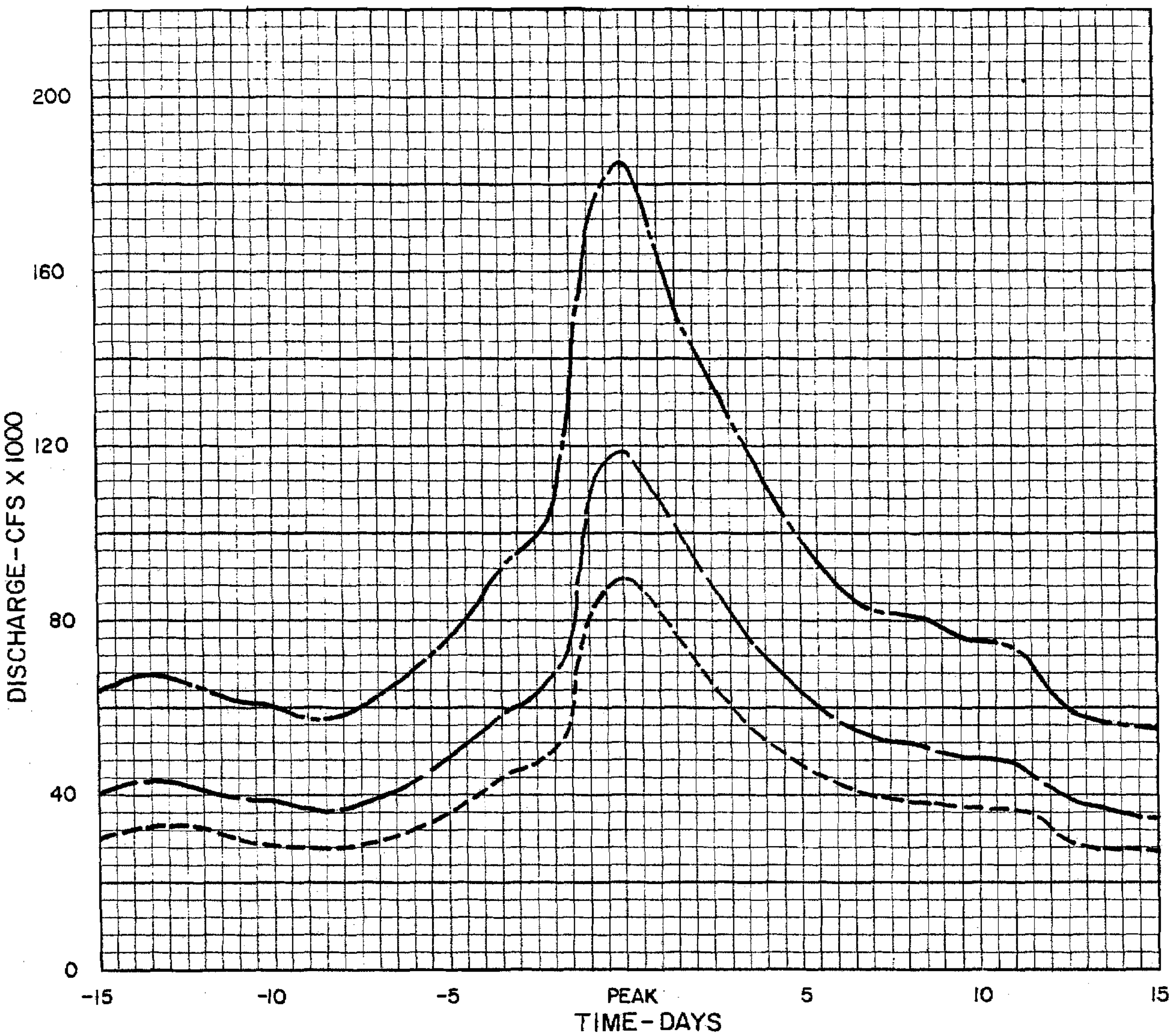
LEGEND

	Flood Volume ft^3	Peak Discharge (cfs)
-----100 yr	122.3×10^9	104,550
— —500 yr	178.2×10^9	131,870
—·—10,000 y	310.0×10^9	198,000

FLOOD HYDROGRAPHS

MAY - JULY

FIGURE E.2.12



SUSITNA RIVER AT GOLD CREEK

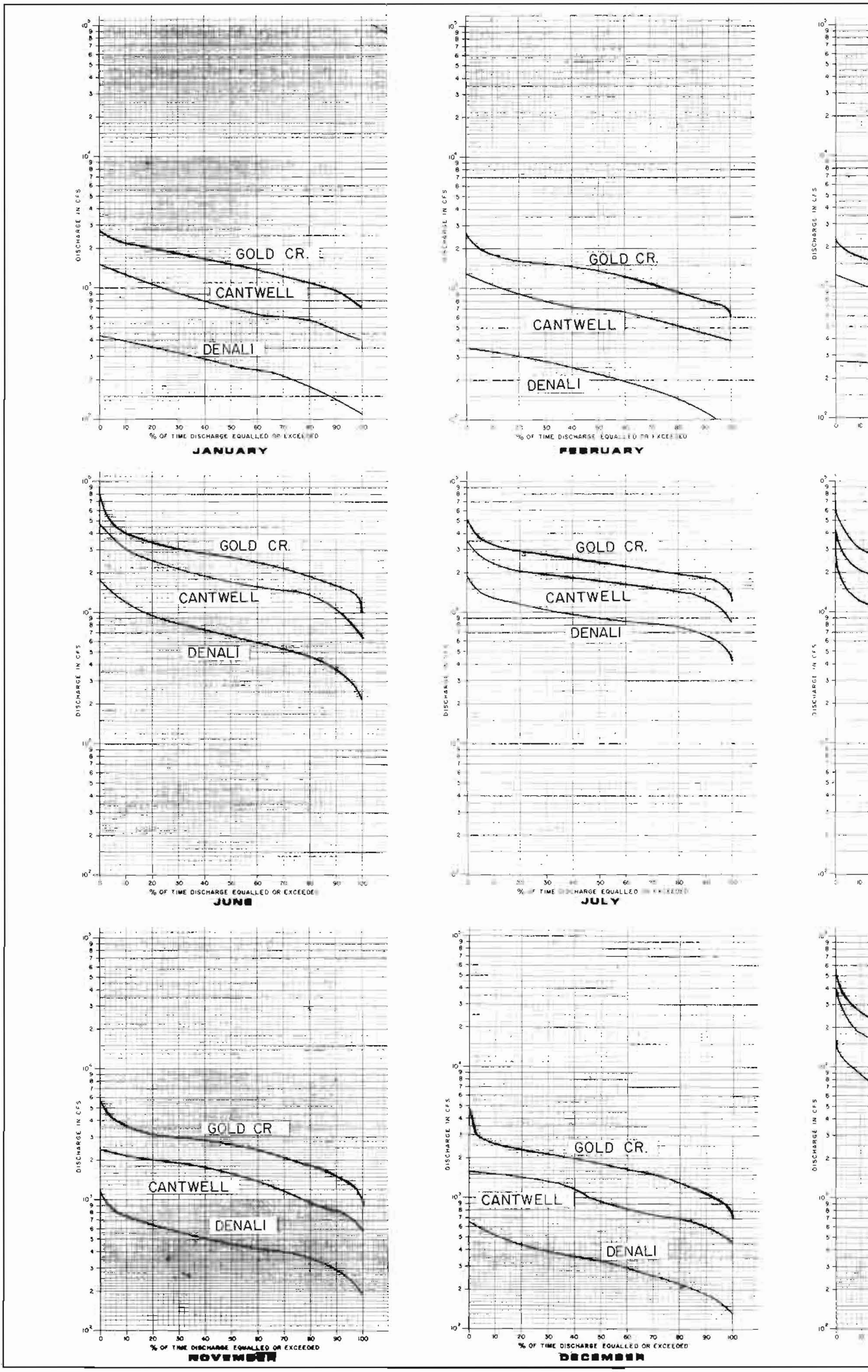
LEGEND

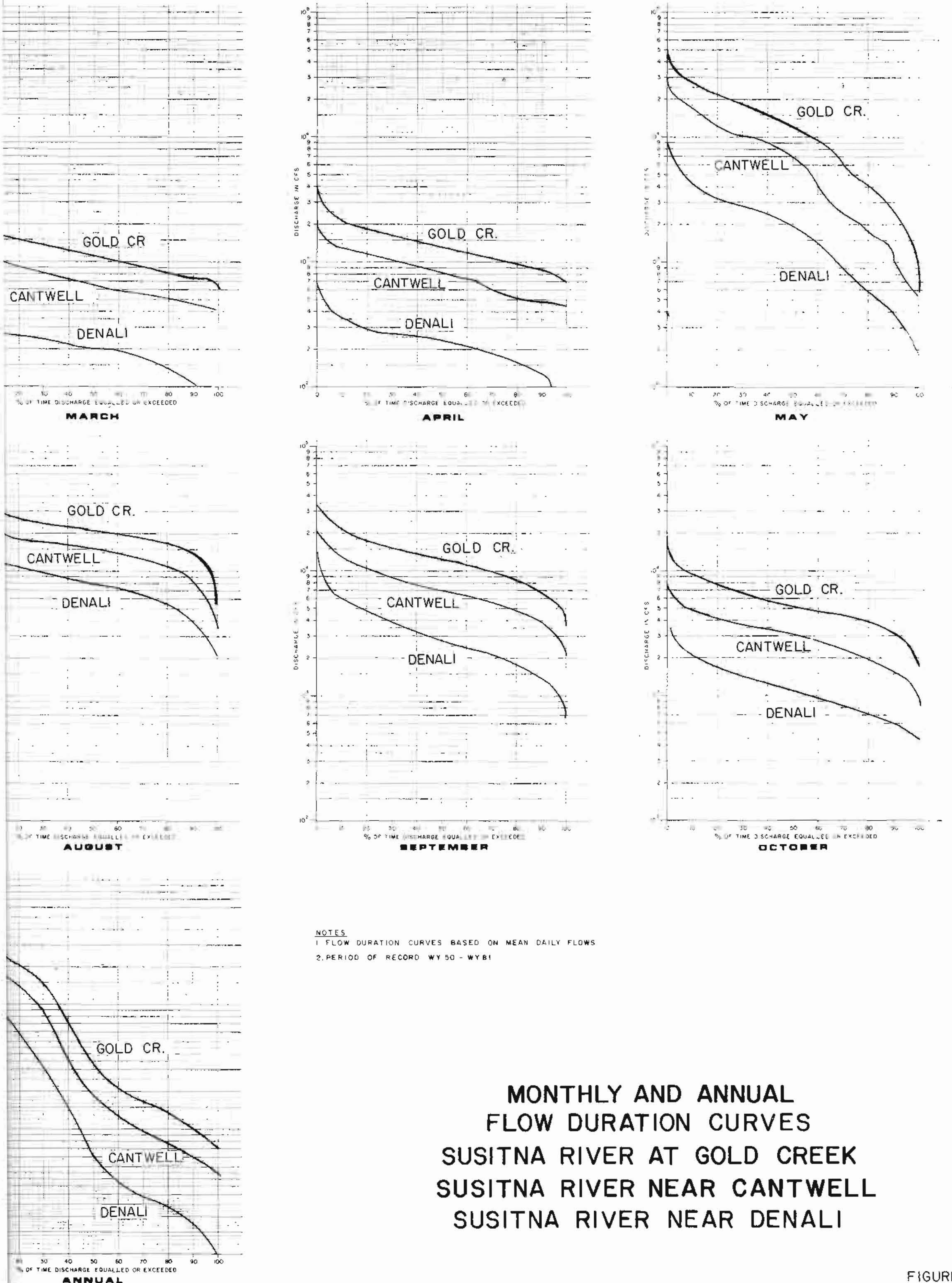
	Flood Volume ft^3	Peak Discharge (cfs)
---- 100 yr	53.8×10^9	90,140
—— 500 yr	78.8×10^9	119,430
–·–·– 10,000 yr	140.0×10^9	185,000

FLOOD HYDROGRAPHS

AUG - OCT

FIGURE E.2.13

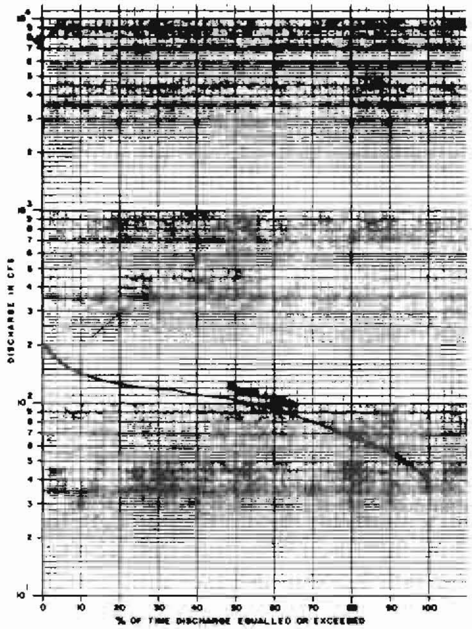

DISCHARGE IN CFS
GOLD CR.
CANTWELL
DENALI
% OF TIME DISCHARGE EQUALLED OR EXCEEDED
JANUARY
FEBRUARY
JUNE
JULY
NOVEMBER
DECEMBER



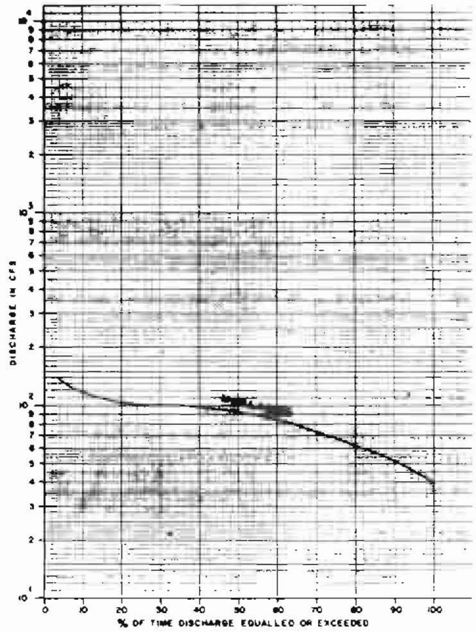
NOTES
1. FLOW DURATION CURVES BASED ON MEAN DAILY FLOWS
2. PERIOD OF RECORD WY 50 - WY 81

MONTHLY AND ANNUAL
FLOW DURATION CURVES
SUSITNA RIVER AT GOLD CREEK
SUSITNA RIVER NEAR CANTWELL
SUSITNA RIVER NEAR DENALI

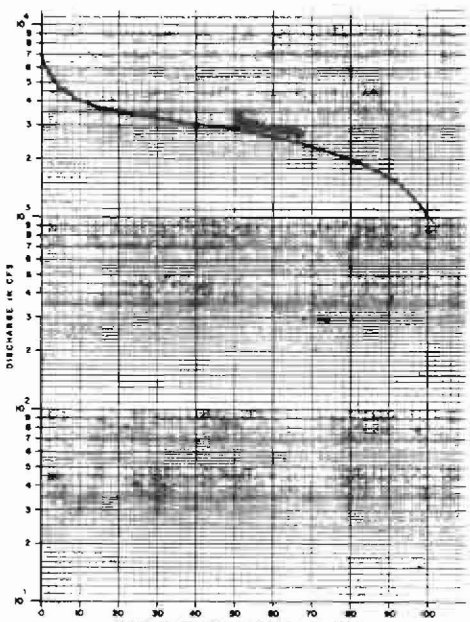
FIGURE E.2.14



JANUARY



FEBRUARY



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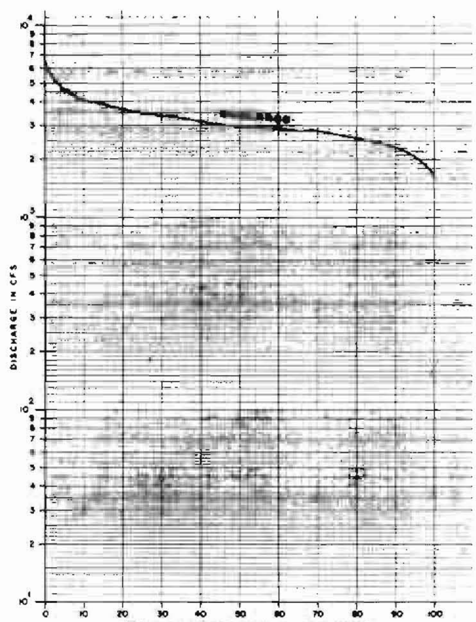
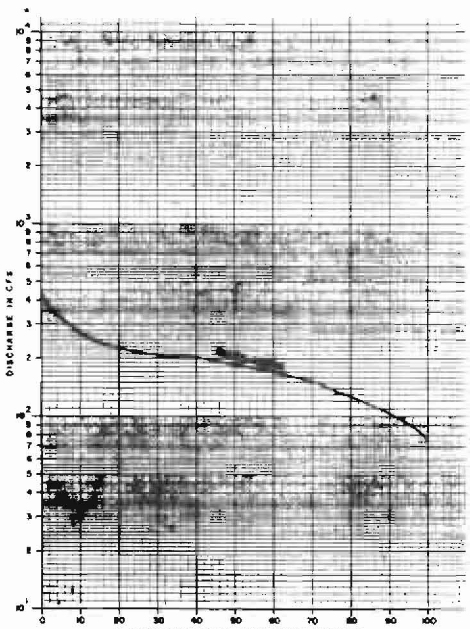


JULY



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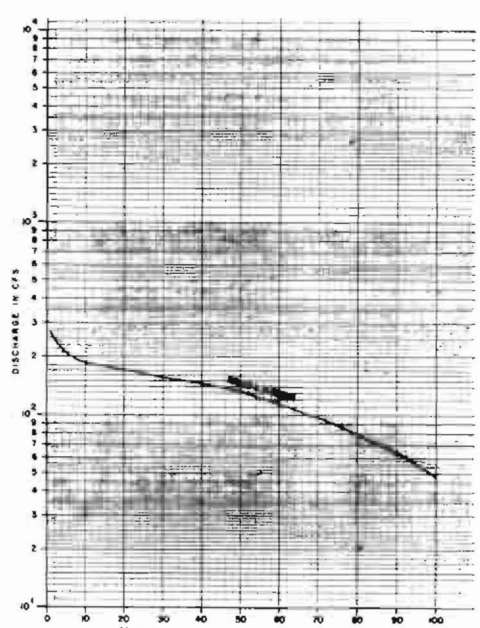

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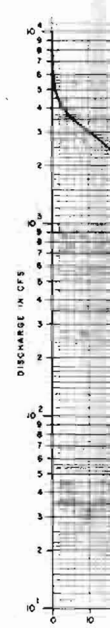

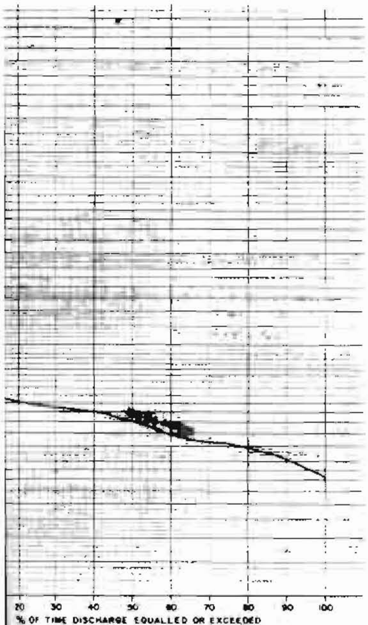

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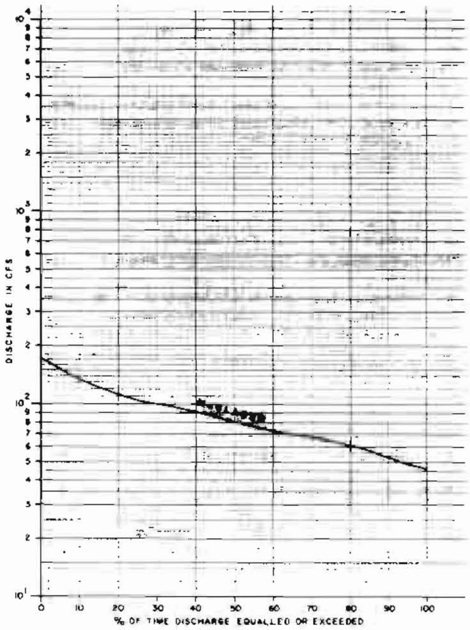

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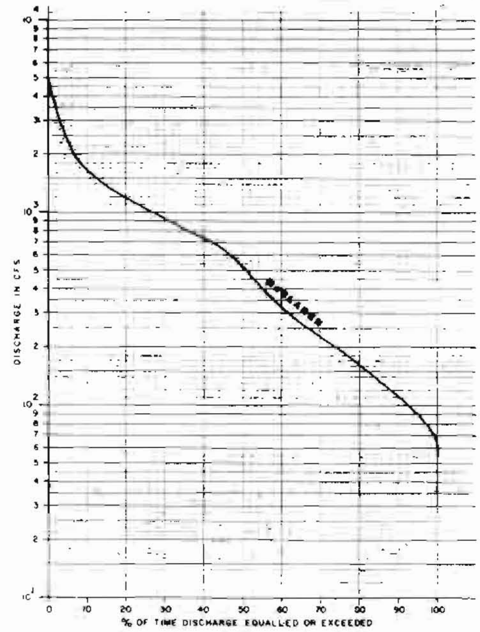
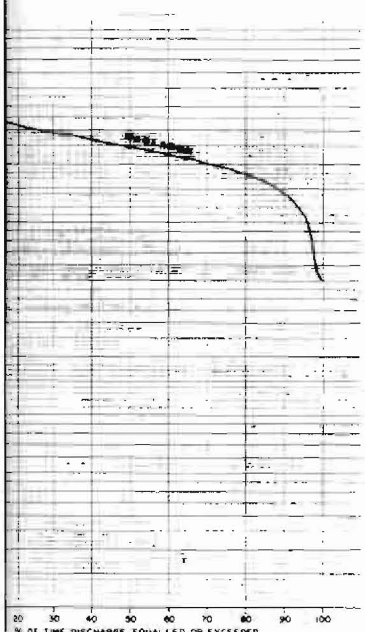


MAY



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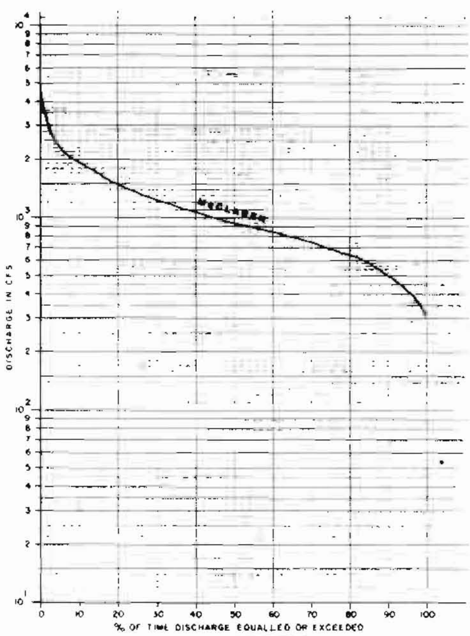

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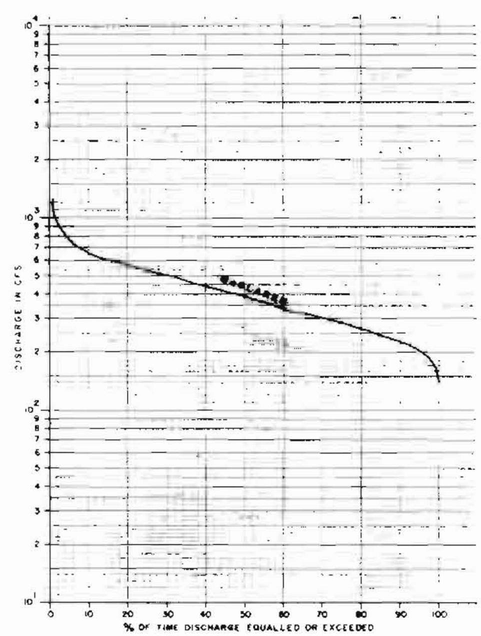

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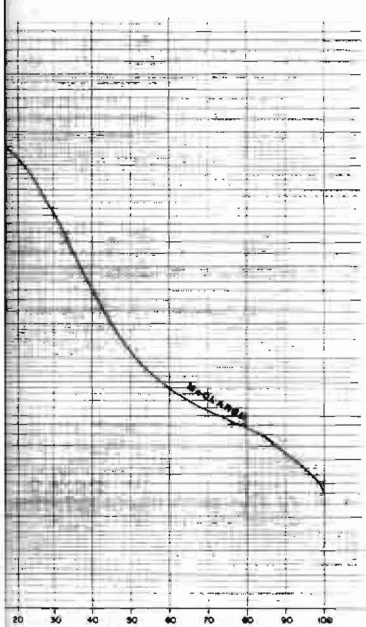
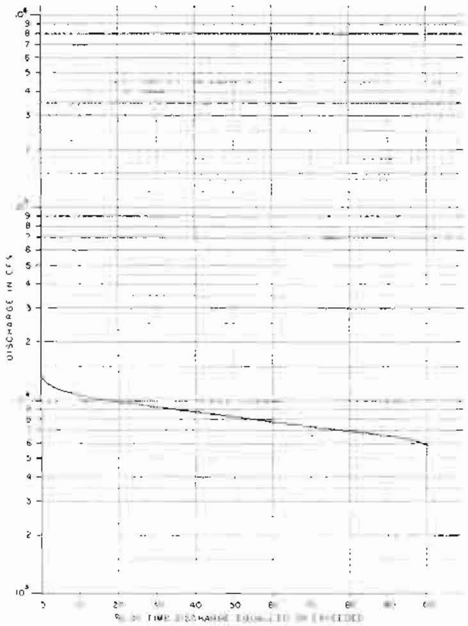


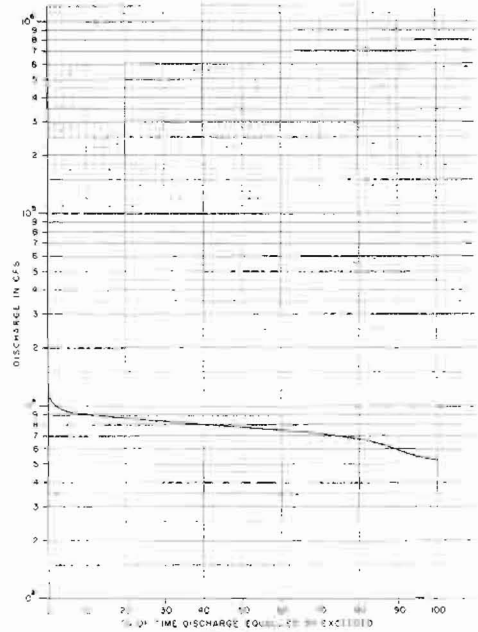
ANNUAL

MONTHLY AND ANNUAL
FLOW DURATION CURVES
MACLAREN RIVER AT PAXSON

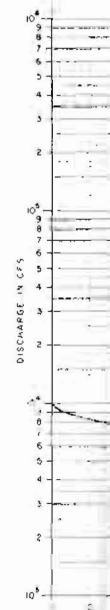
FIGURE E.2.15

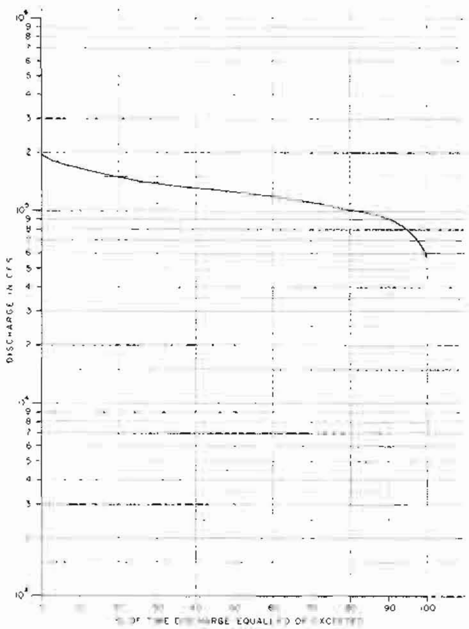


JANUARY



FEBRUARY





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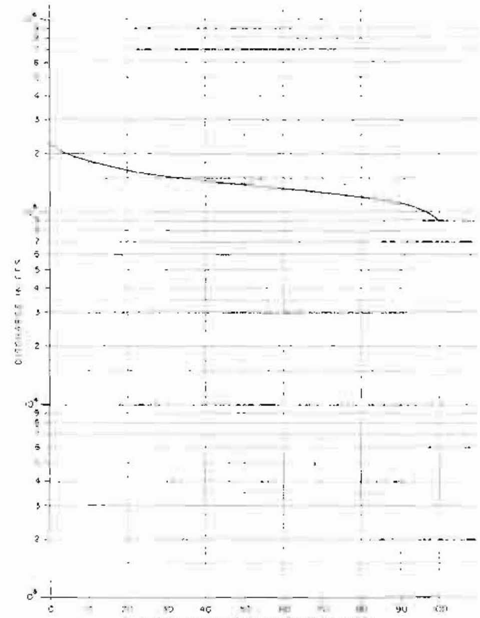

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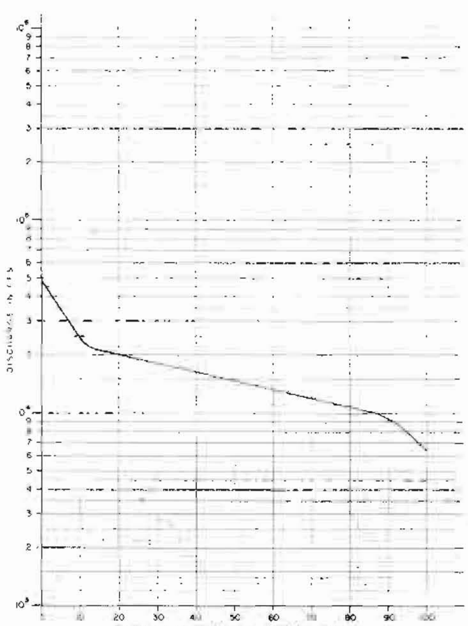

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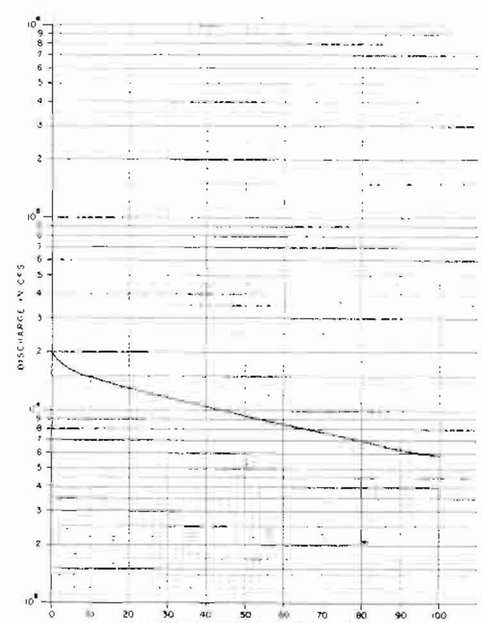

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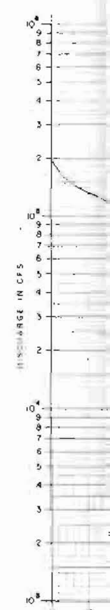
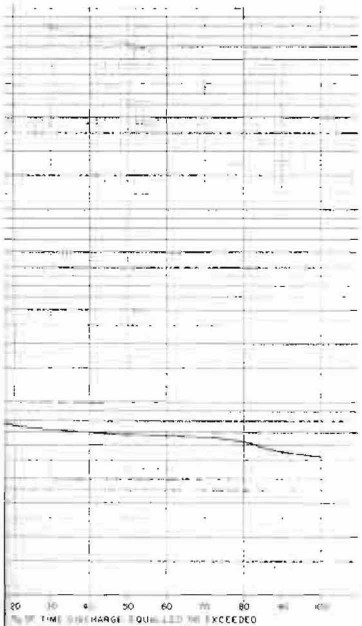
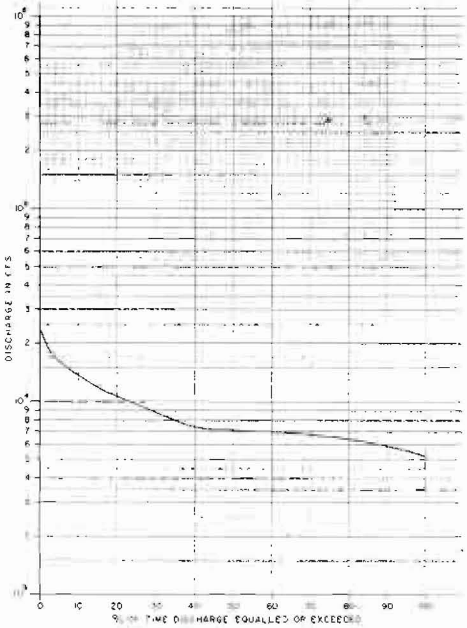




MARCH



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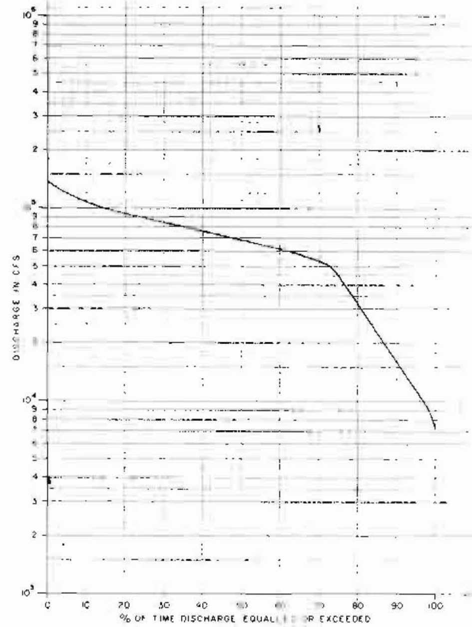
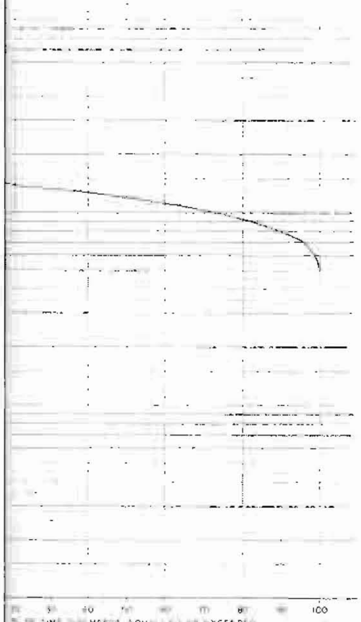
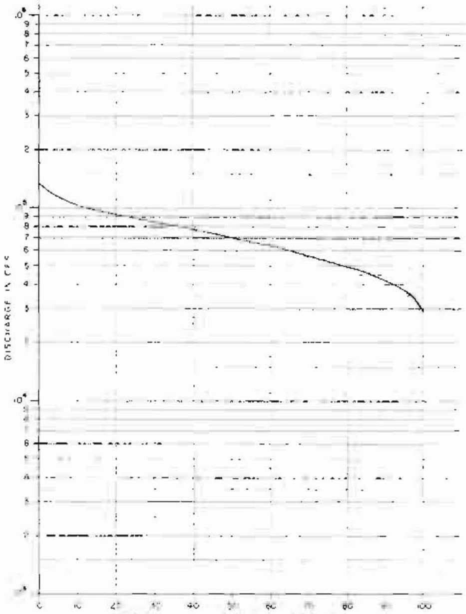


MAY



AUGUST



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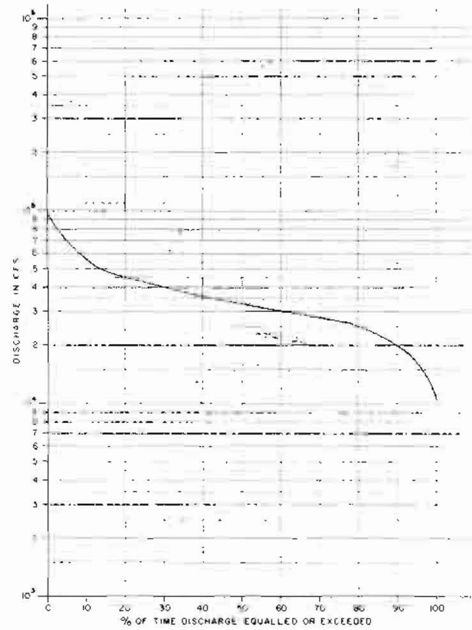
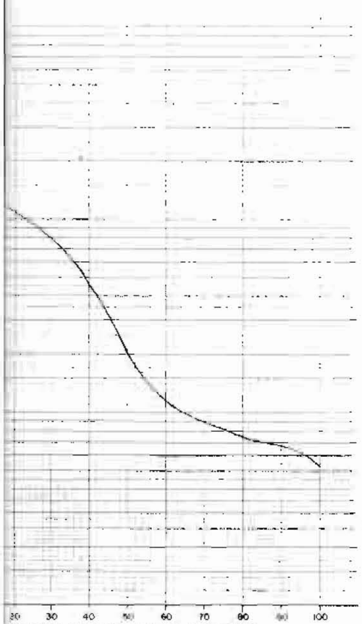


OCTOBER



ANNUAL

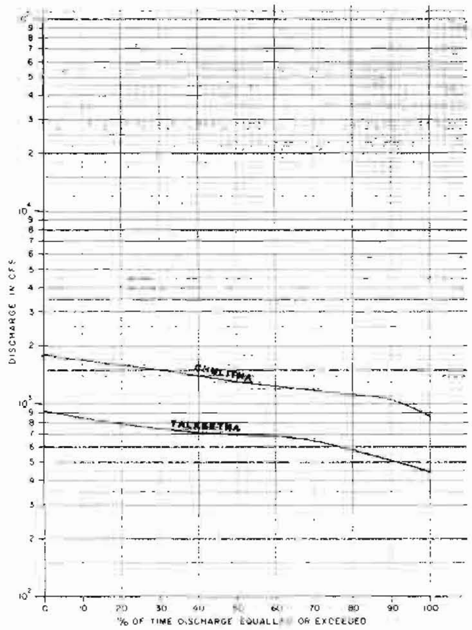
NOTES

1 FLOW DURATION CURVES BASED ON MEAN DAILY FLOWS

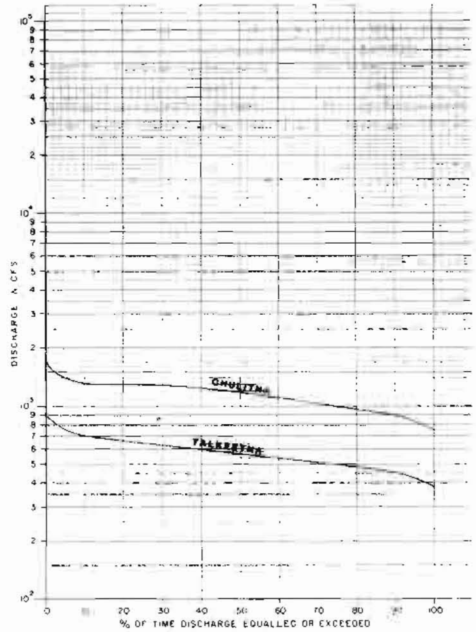
2 PERIOD OF RECORD, WY 75 - WY 81

MONTHLY AND ANNUAL FLOW DURATION CURVES SUSITNA RIVER AT SUSITNA STATION

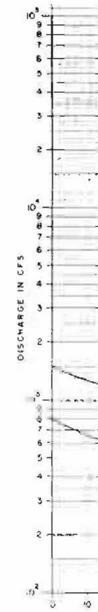
FIGURE E.2.16

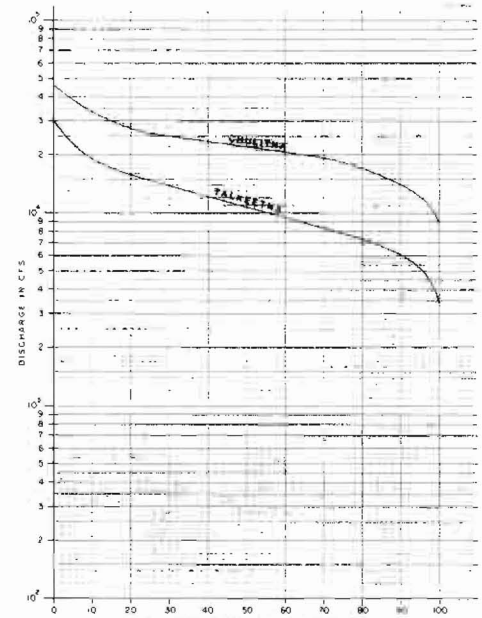


JANUARY



FEBRUARY





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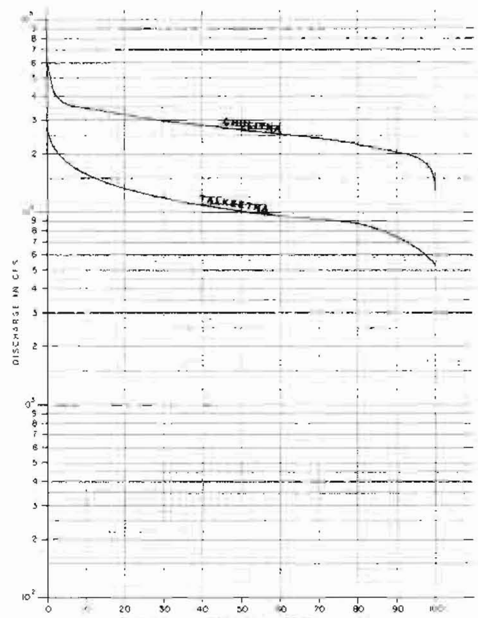

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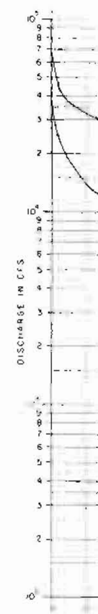

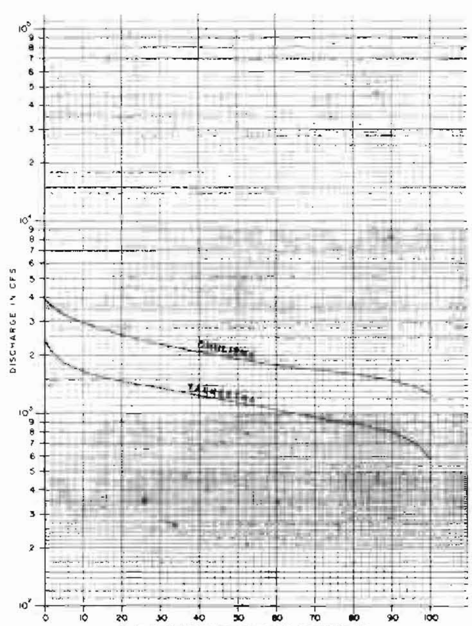

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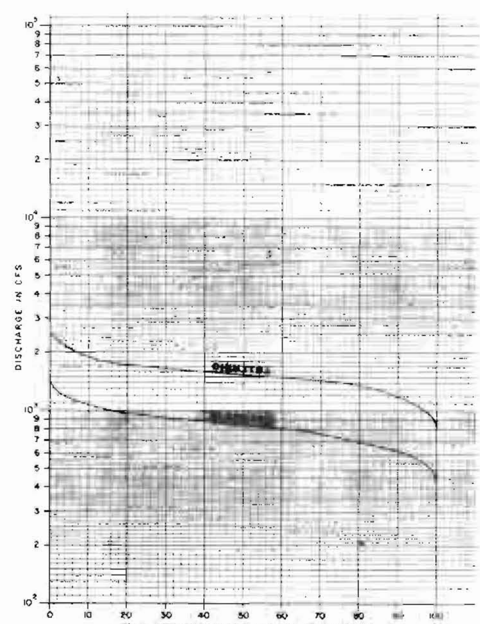

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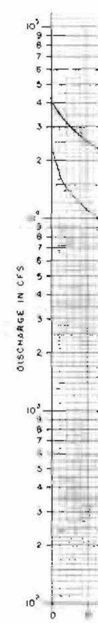

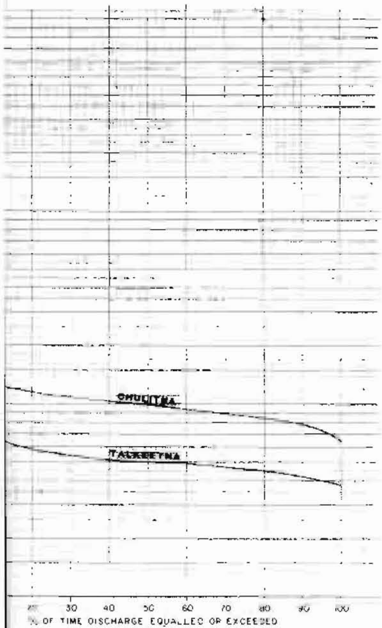

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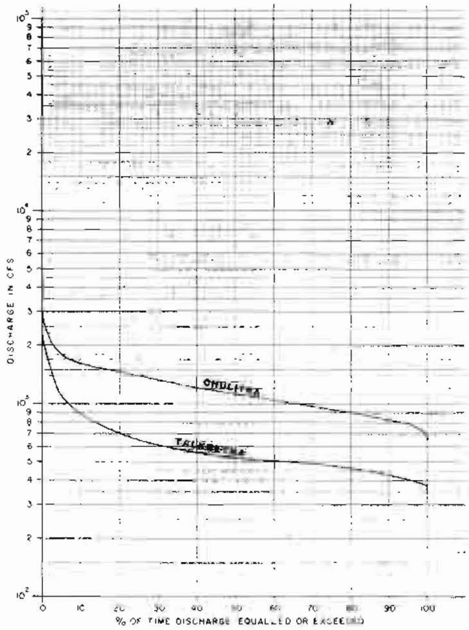

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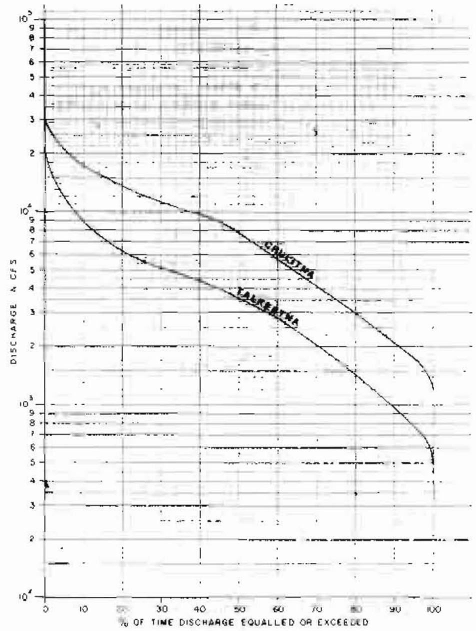
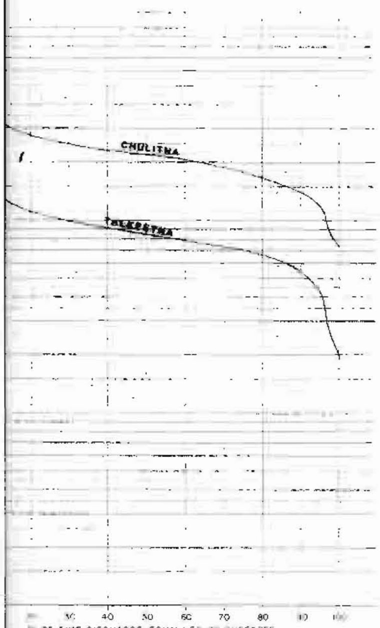
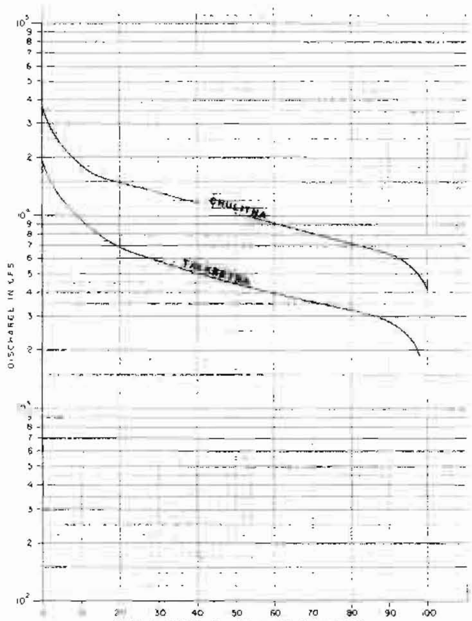


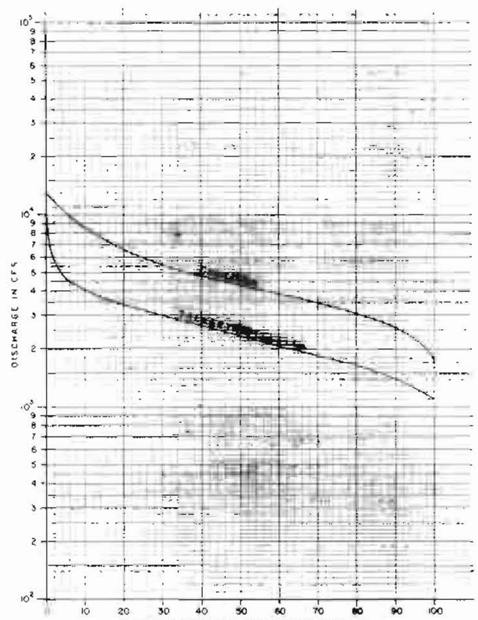
MAY



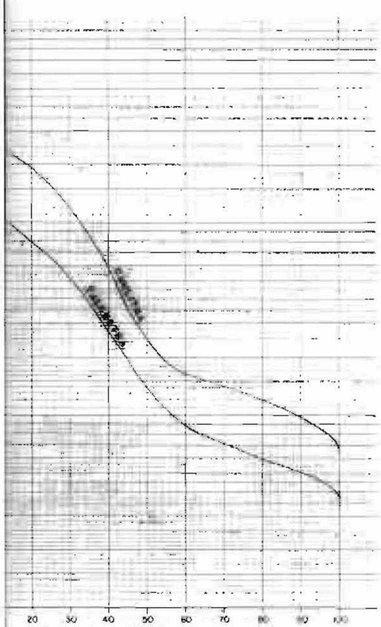
AUGUST



SEPTEMBER



OCTOBER



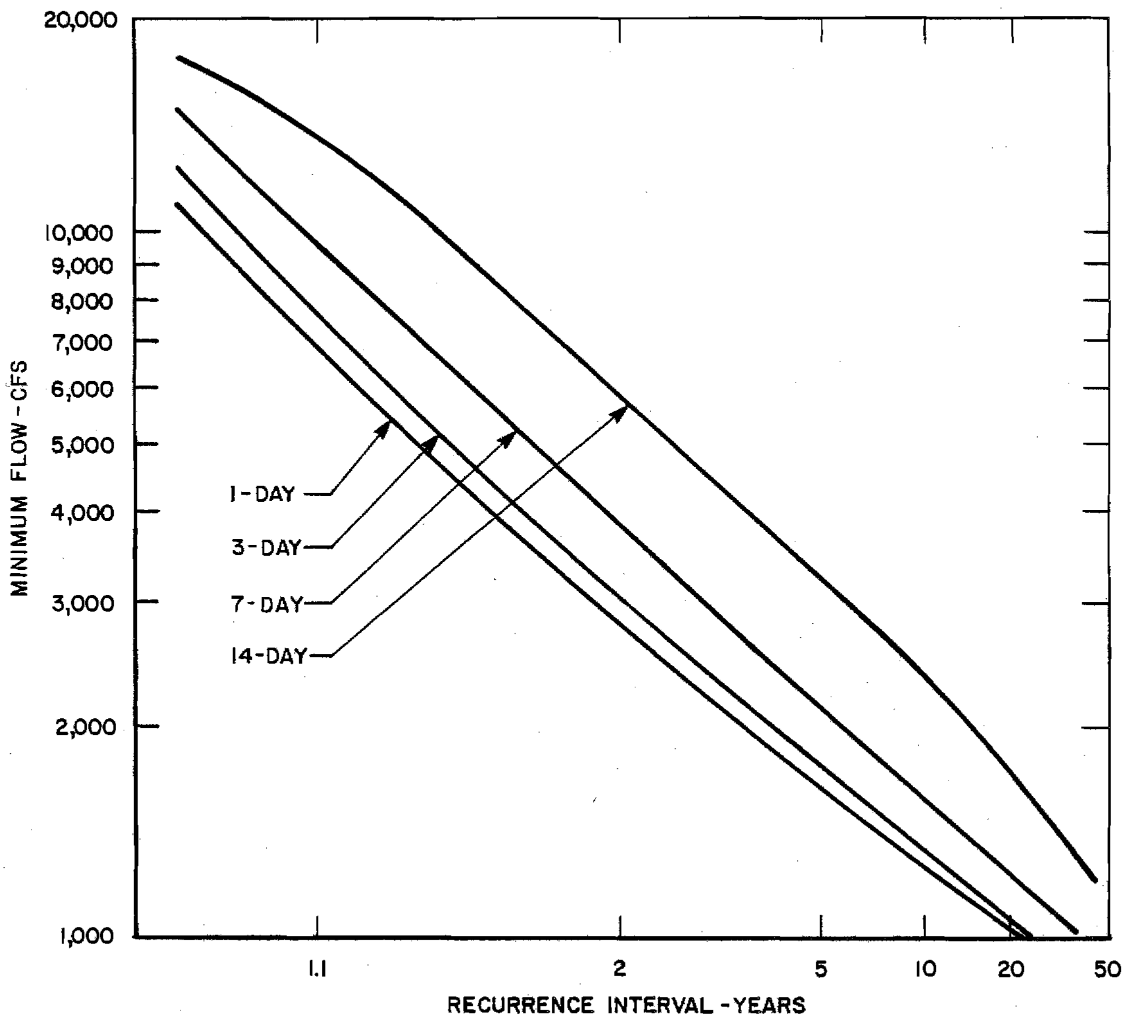
ANNUAL

NOTES

1. FLOW DURATION CURVES BASED ON MEAN DAILY FLOWS.
2. PERIOD OF RECORD CHULITNA RIVER WY59-WY72; WY81
   TALKEETNA RIVER WY65-WY81

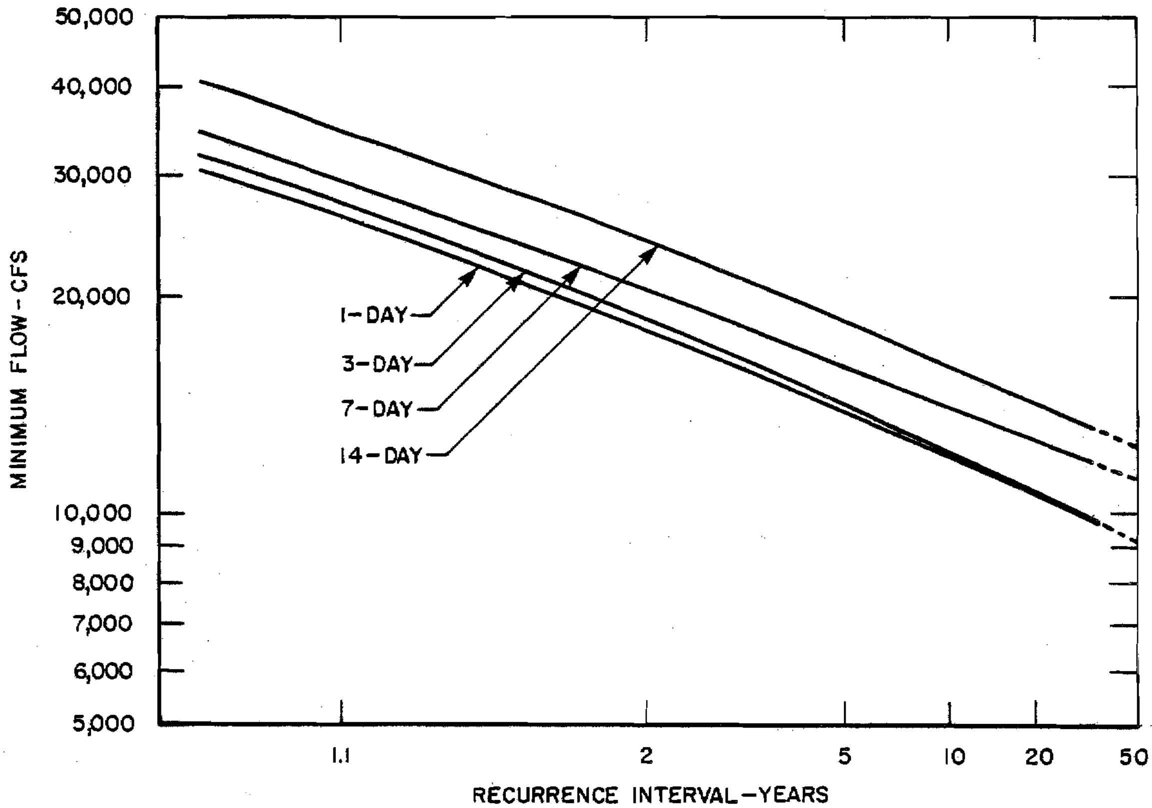
MONTHLY AND ANNUAL FLOW DURATION CURVES TALKEETNA RIVER NEAR TALKEETNA

FIGURE E.2.17



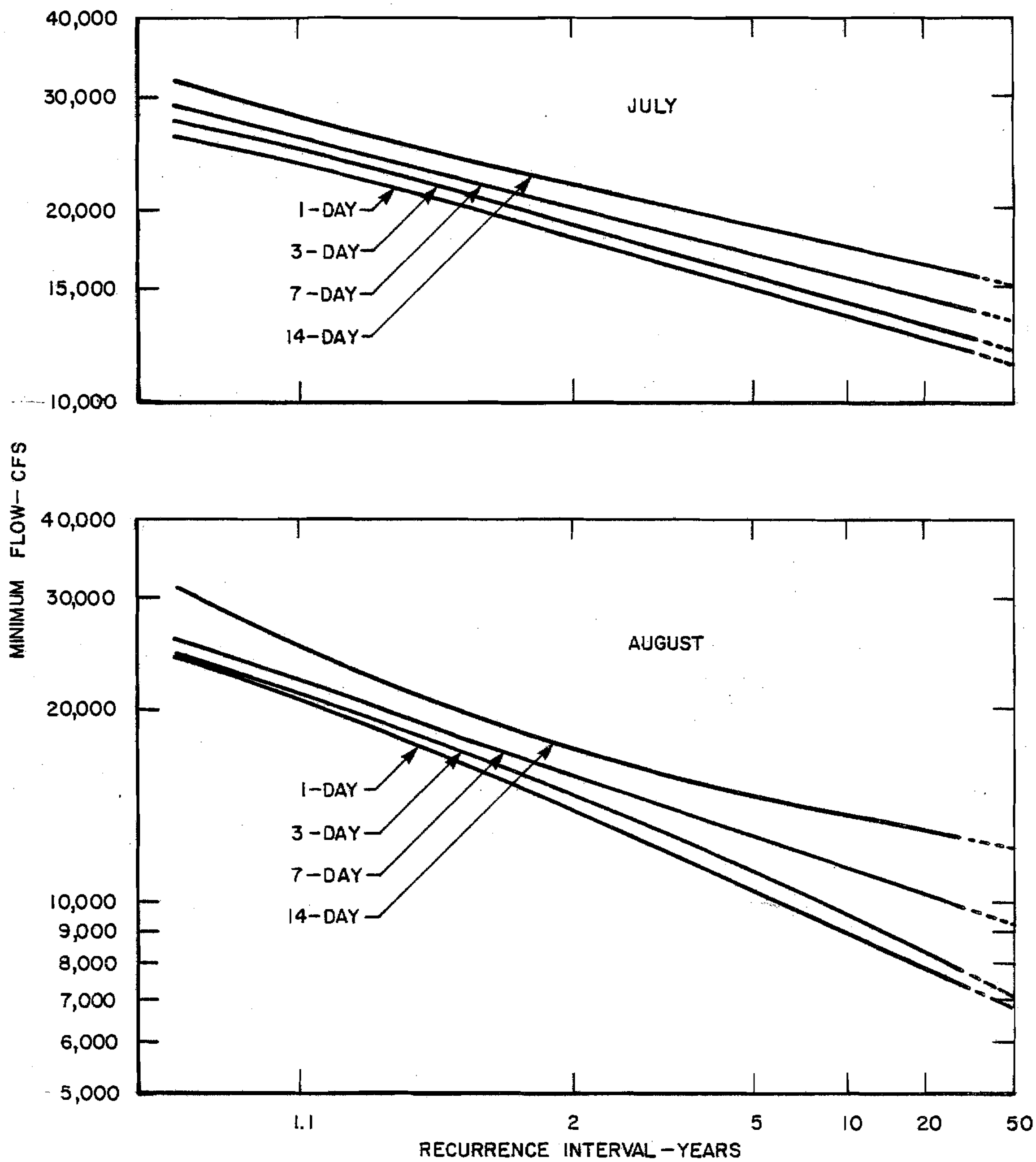
SUSITNA RIVER AT GOLD CREEK
LOW-FLOW FREQUENCY CURVES
MAY

FIGURE E.2.18



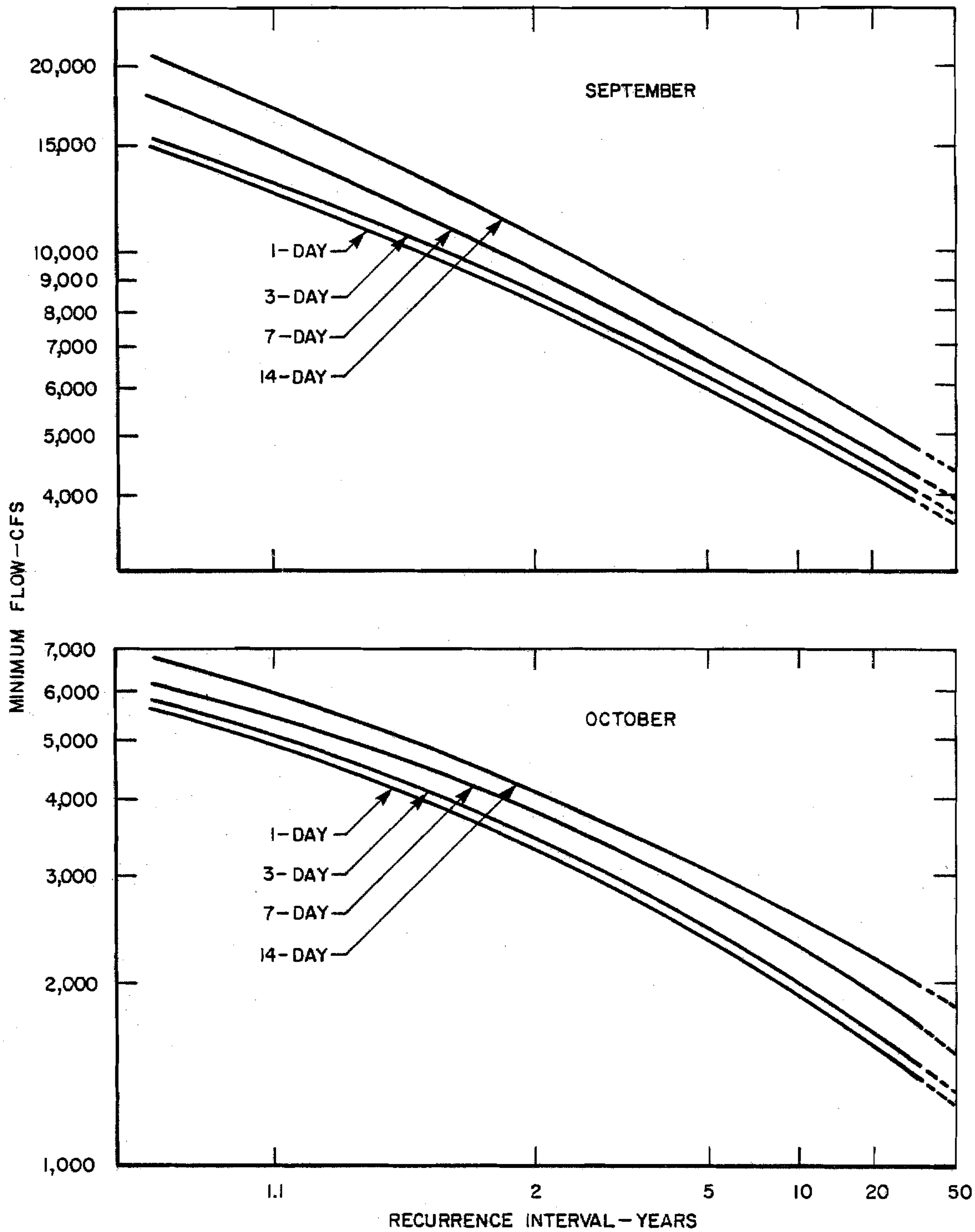
SUSITNA RIVER AT GOLD CREEK
LOW-FLOW FREQUENCY CURVES
JUNE

FIGURE E.2.19



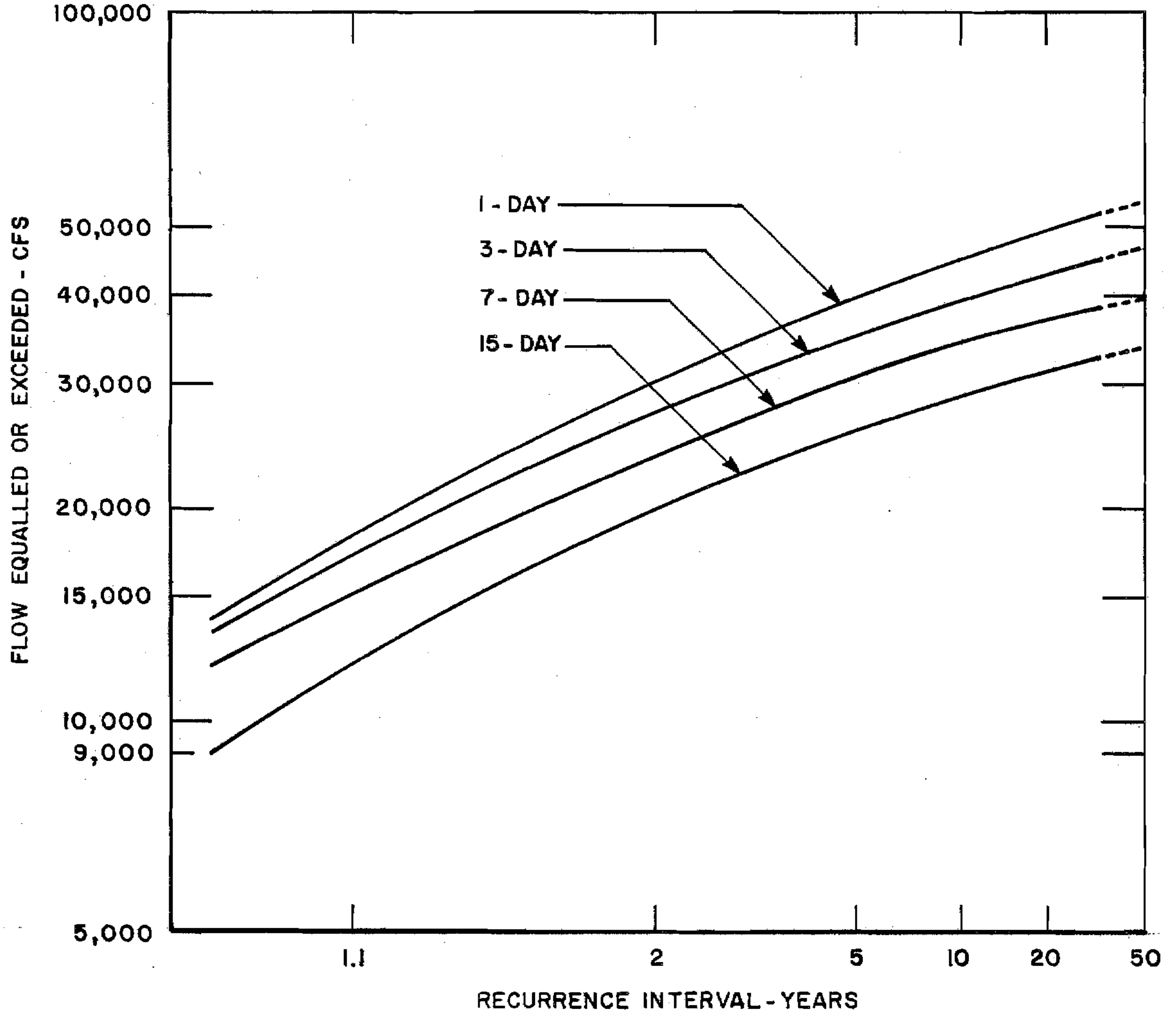
**SUSITNA RIVER AT GOLD CREEK
LOW-FLOW FREQUENCY CURVES
JULY AND AUGUST**

FIGURE E.2.20



SUSITNA RIVER AT GOLD CREEK
LOW-FLOW FREQUENCY CURVES
SEPTEMBER AND OCTOBER

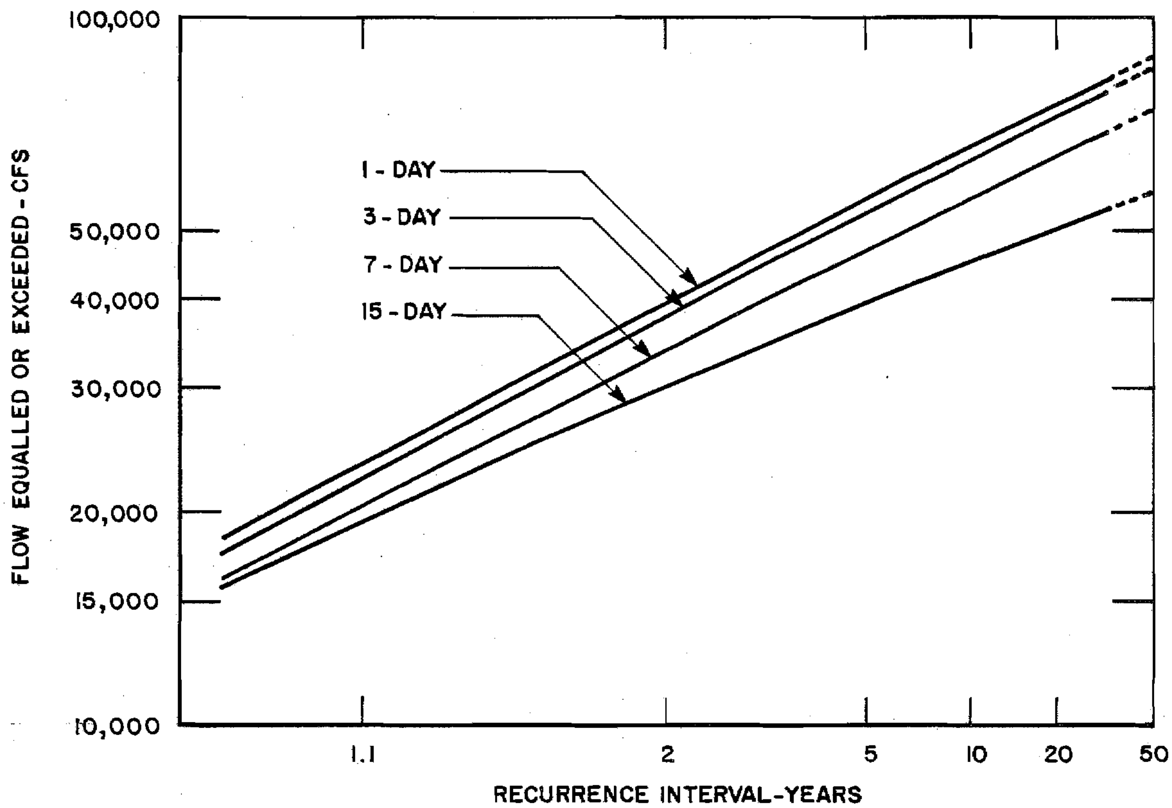
FIGURE E.2.21



NOTE: PERIOD OF RECORD IS 1950-1981.

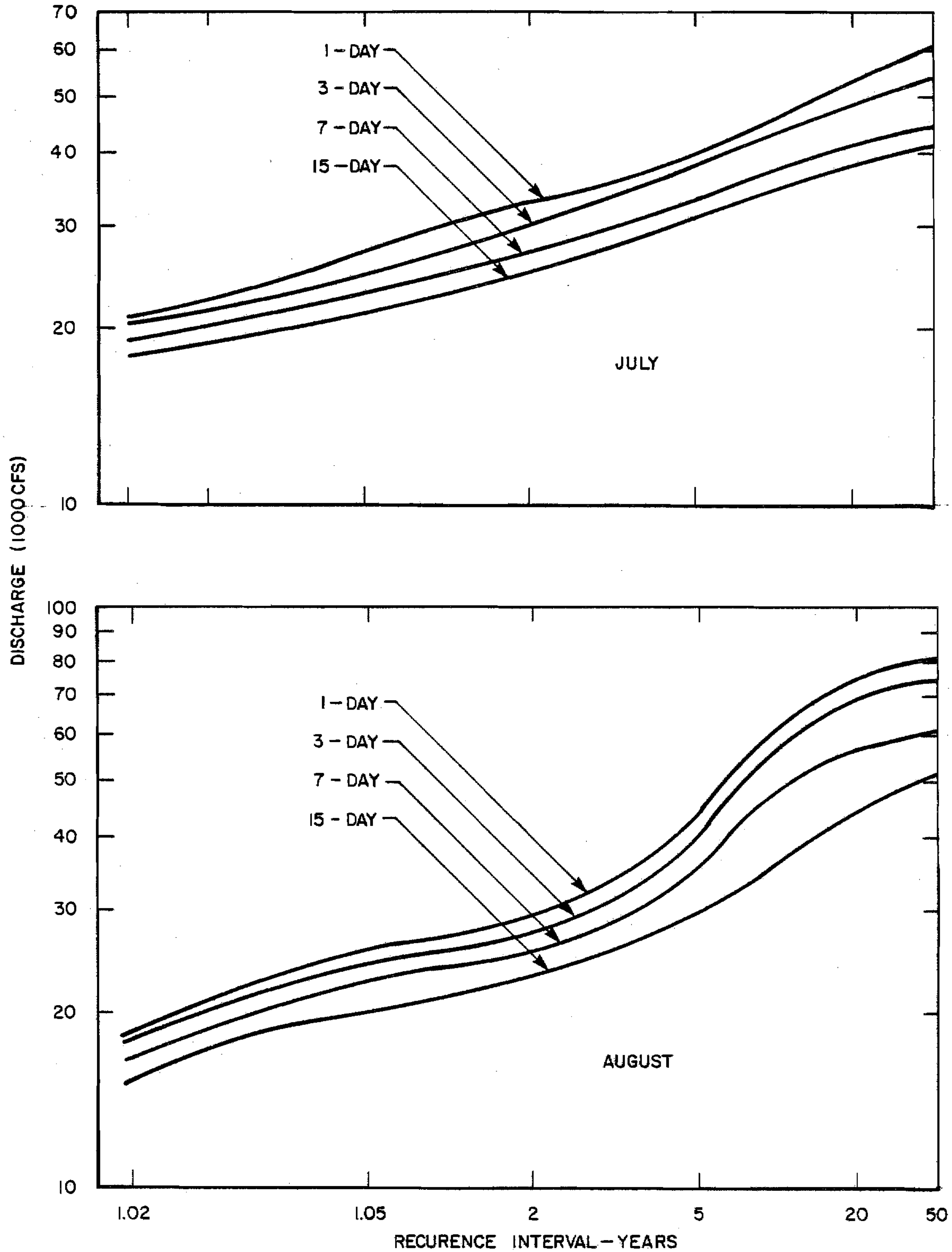
SUSITNA RIVER AT GOLD CREEK
HIGH-FLOW FREQUENCY CURVES
MAY

FIGURE E.2.22



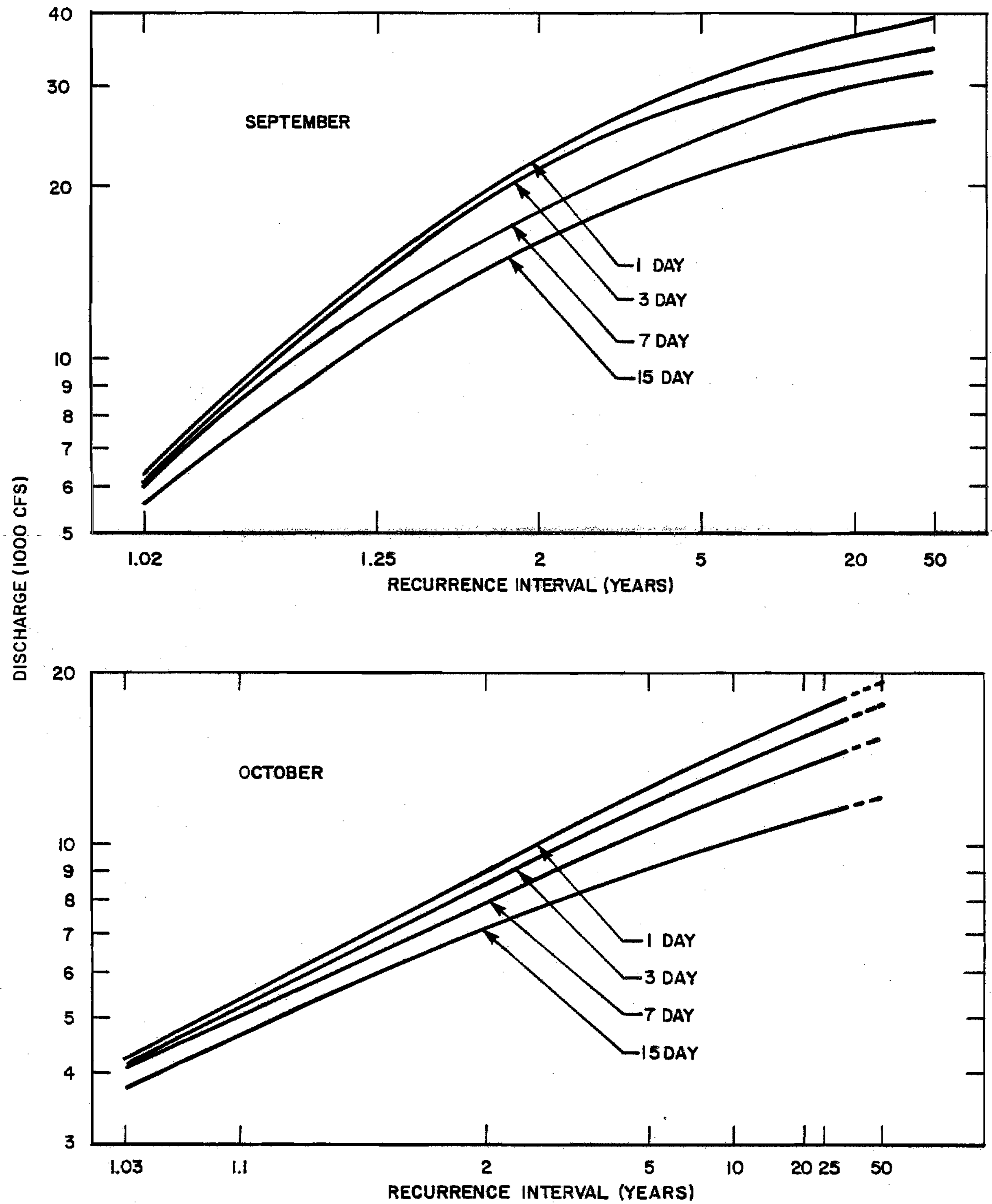
SUSITNA RIVER AT GOLD CREEK
HIGH-FLOW FREQUENCY CURVES
JUNE

FIGURE E.2.23



SUSITNA RIVER AT GOLD CREEK
HIGH-FLOW FREQUENCY CURVES
JULY AND AUGUST

FIGURE E.2.24



SUSITNA RIVER AT GOLD CREEK
HIGH-FLOW FREQUENCY CURVES
SEPTEMBER AND OCTOBER

FIGURE E.2.25

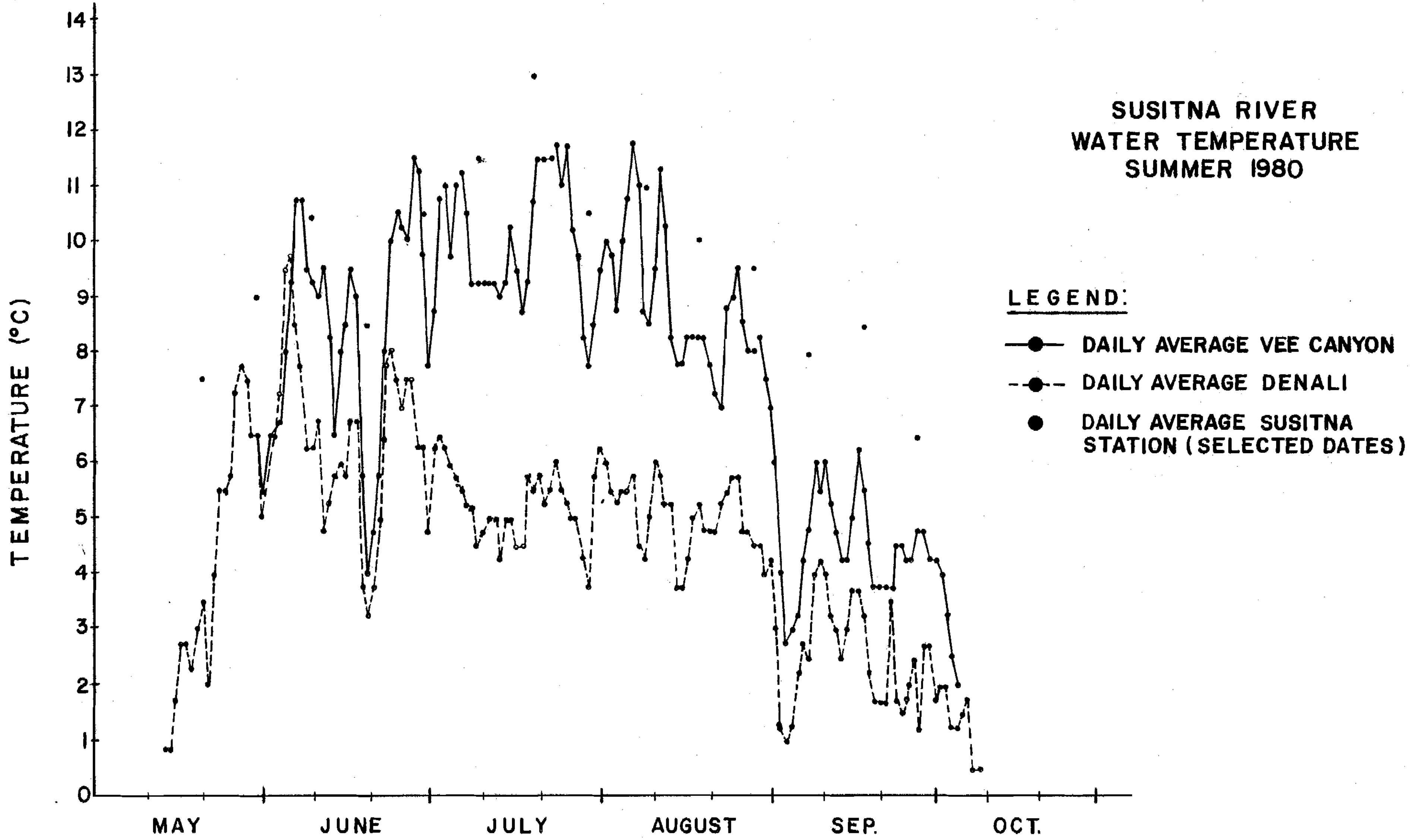

SUSITNA RIVER
WATER TEMPERATURE
SUMMER 1980
LEGEND:
DAILY AVERAGE VEE CANYON
DAILY AVERAGE DENALI
DAILY AVERAGE SUSITNA STATION (SELECTED DATES)
TEMPERATURE (°C)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
MAY
JUNE
JULY
AUGUST
SEP.
OCT.

FIGURE E.2.26

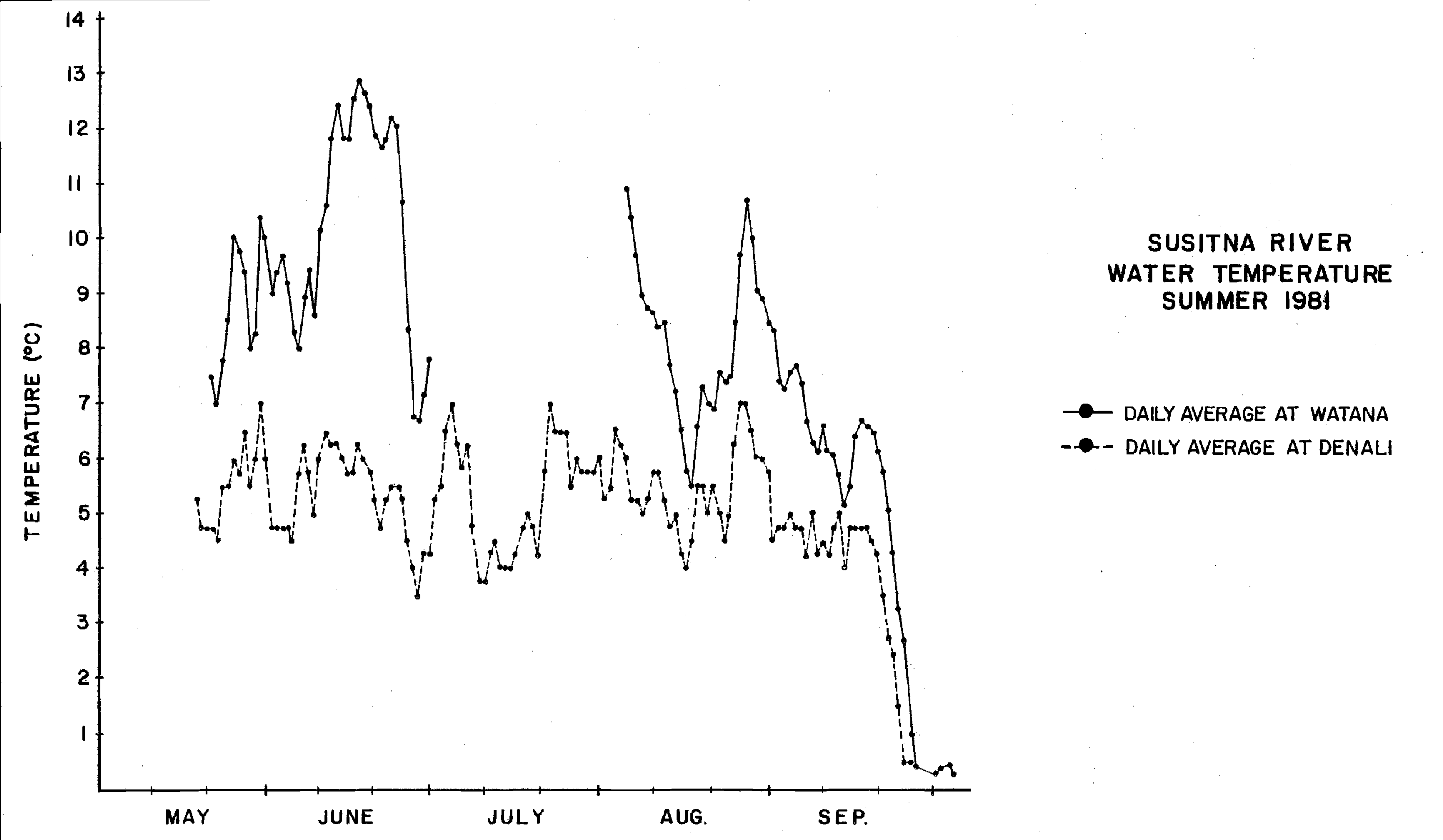

SUSITNA RIVER
WATER TEMPERATURE
SUMMER 1981
DAILY AVERAGE AT WATANA
DAILY AVERAGE AT DENALI
TEMPERATURE (°C)
14
13
12
11
10
9
8
7
6
5
4
3
2
1
MAY
JUNE
JULY
AUG.
SEP.

FIGURE E.2.27

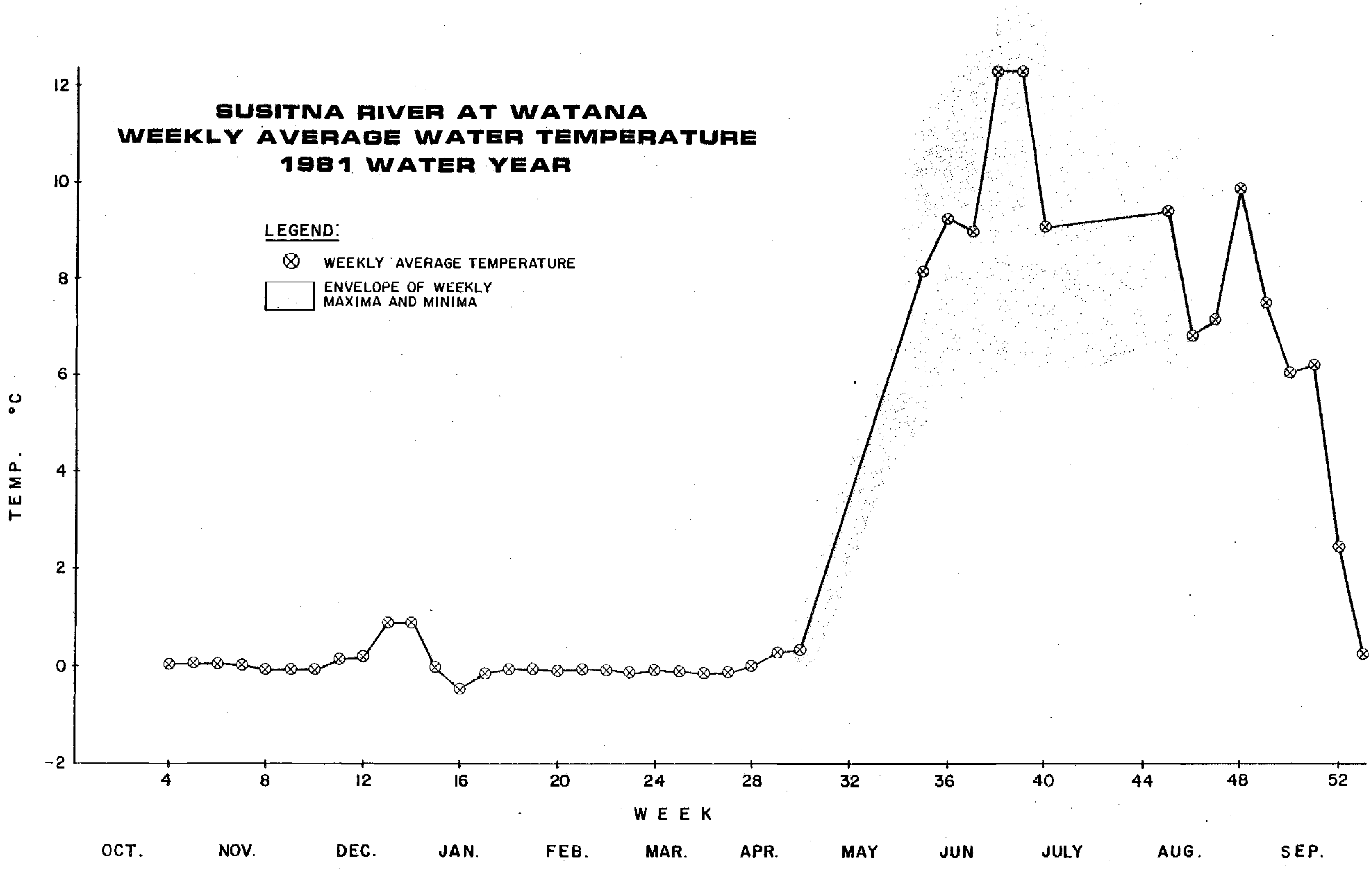
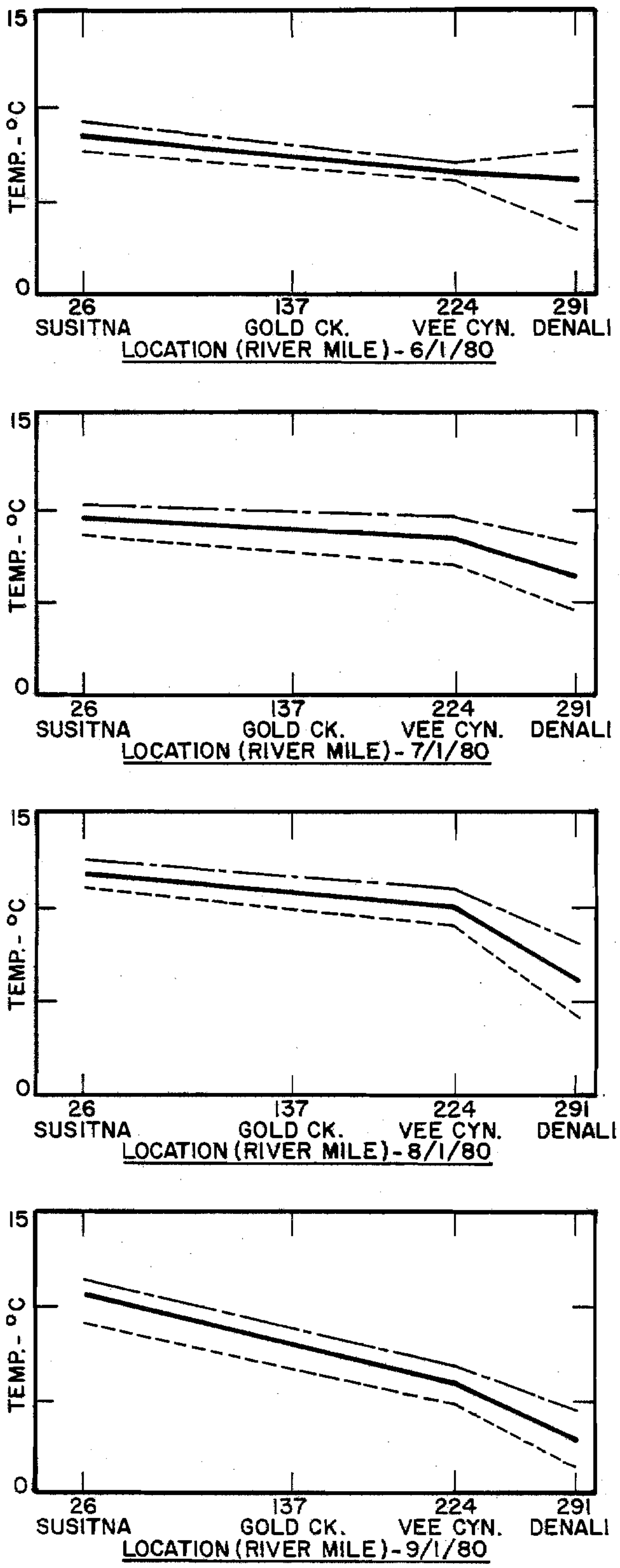

SUSITNA RIVER AT WATANA
WEEKLY AVERAGE WATER TEMPERATURE
1981 WATER YEAR
LEGEND:
WEEKLY AVERAGE TEMPERATURE
ENVELOPE OF WEEKLY MAXIMA AND MINIMA
TEMP. °C
12
10
8
6
4
2
0
-2
4
8
12
16
20
24
28
32
36
40
44
48
52
WEEK
OCT.
NOV.
DEC.
JAN.
FEB.
MAR.
APR.
MAY
JUN
JULY
AUG.
SEP.

FIGURE E.2.28



LEGEND

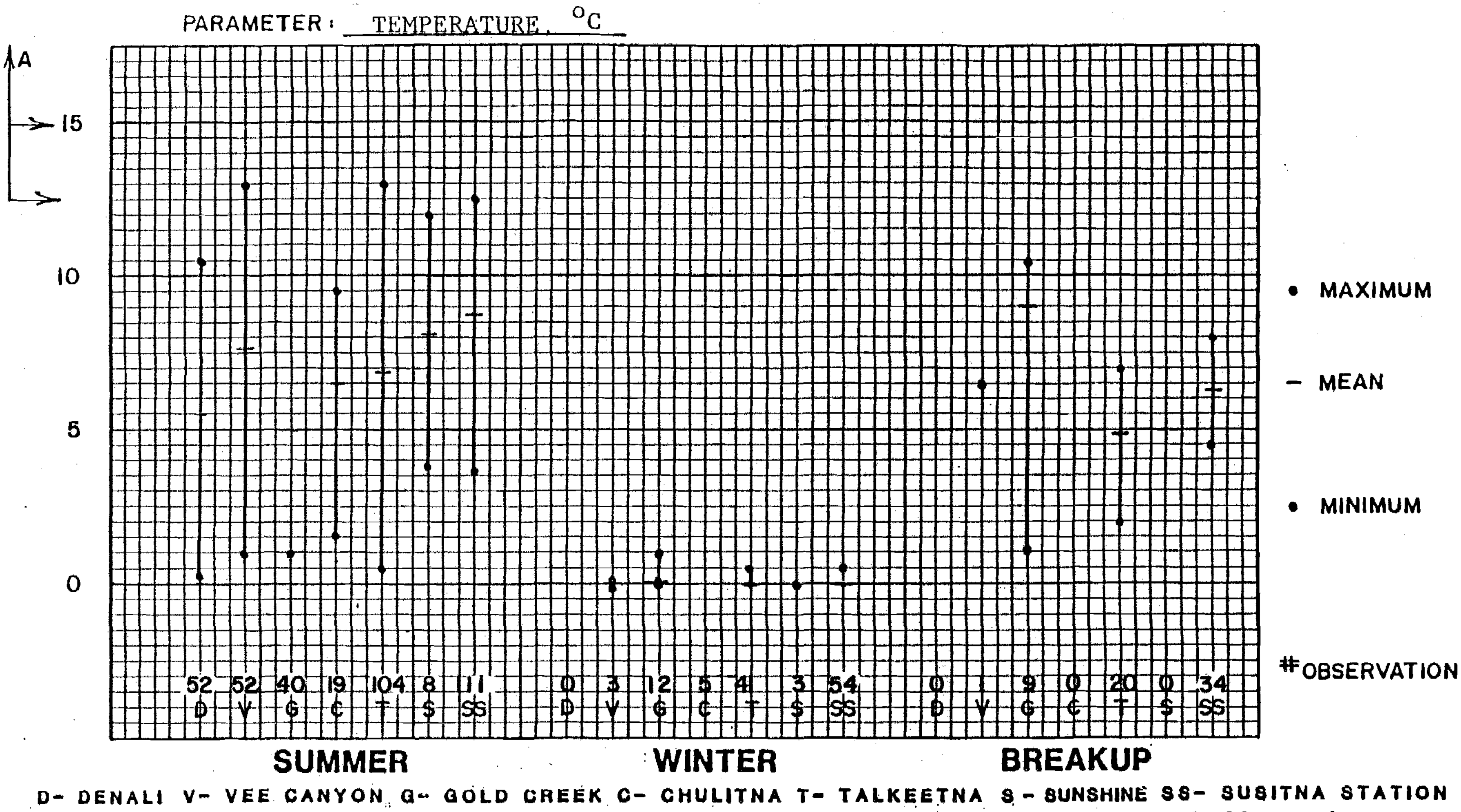
- MAXIMUM
- MEAN
- MINIMUM

NOTES

1.) ALL TEMPERATURES WERE RECORDED BY THE USGS WITH SINGLE THERMOGRAPHS AT EACH SITE.
2.) GOLD CREEK'S TEMPERATURES MAY BE INFLUENCED BY TRIBUTARY INFLOW AT THE SITE.
3.) DAILY MEAN TEMPERATURES COMPUTED AS AVERAGE OF MINIMUM AND MAXIMUM FOR THE DAY.

SUSITNA RIVER - WATER TEMPERATURE GRADIENT

FIGURE E.2.29

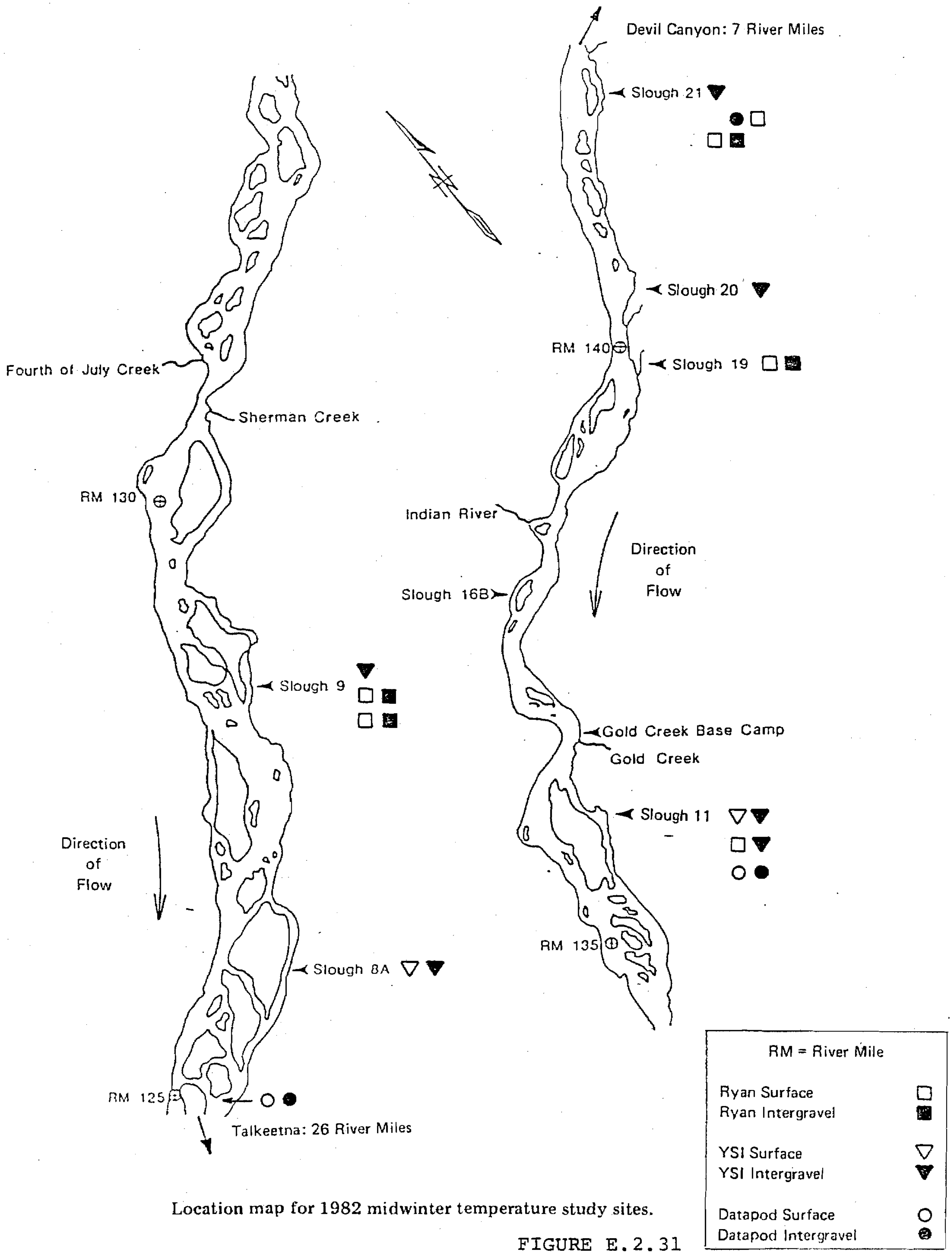


A. Shall not exceed 20°C at any time. The following maximum temperature shall not be exceeded where applicable: migration routes and rearing areas--15°C, spawning areas and egg and fry incubation--13°C (ADEC, 1979)

Established to protect sensitive important fish species, and for the successful migration, spawning, egg-incubation, fry-rearing, and other reproductive functions of important species.

DATA SUMMARY -TEMPERATURE

FIGURE E.2.30



Location map for 1982 midwinter temperature study sites.

FIGURE E.2.31

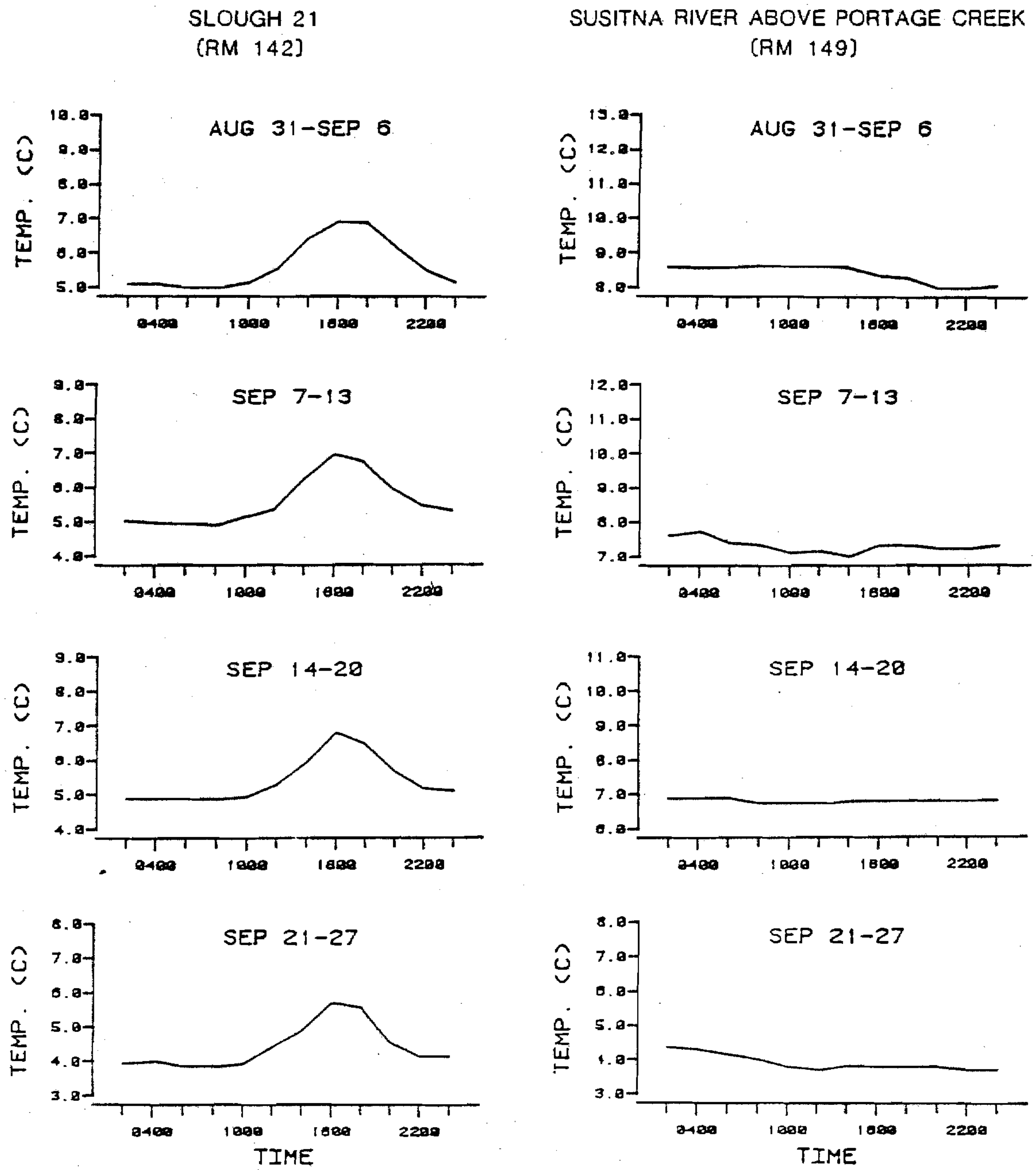
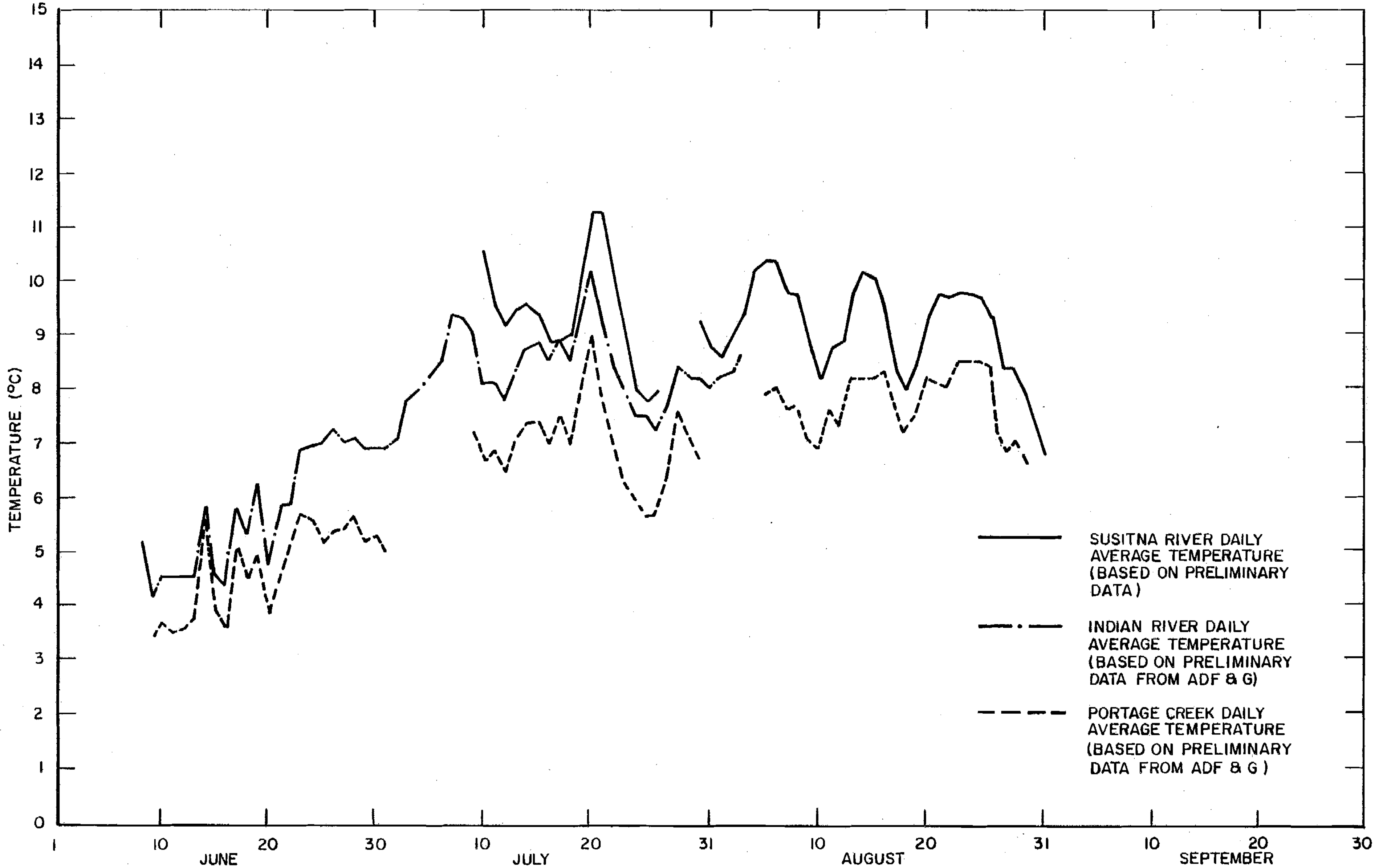


FIGURE E.2.32 Comparison of weekly diel surface water temperature variations in Slough 21 and the mainstem Susitna River at Portage Creek (adapted from ADF&G 1981).



SUSITNA RIVER, PORTAGE CREEK AND INDIAN RIVER WATER TEMPERATURES SUMMER 1982

FIGURE E.2.33

PARAMETER: TOTAL SUSPENDED SOLIDS, (mg./l.)

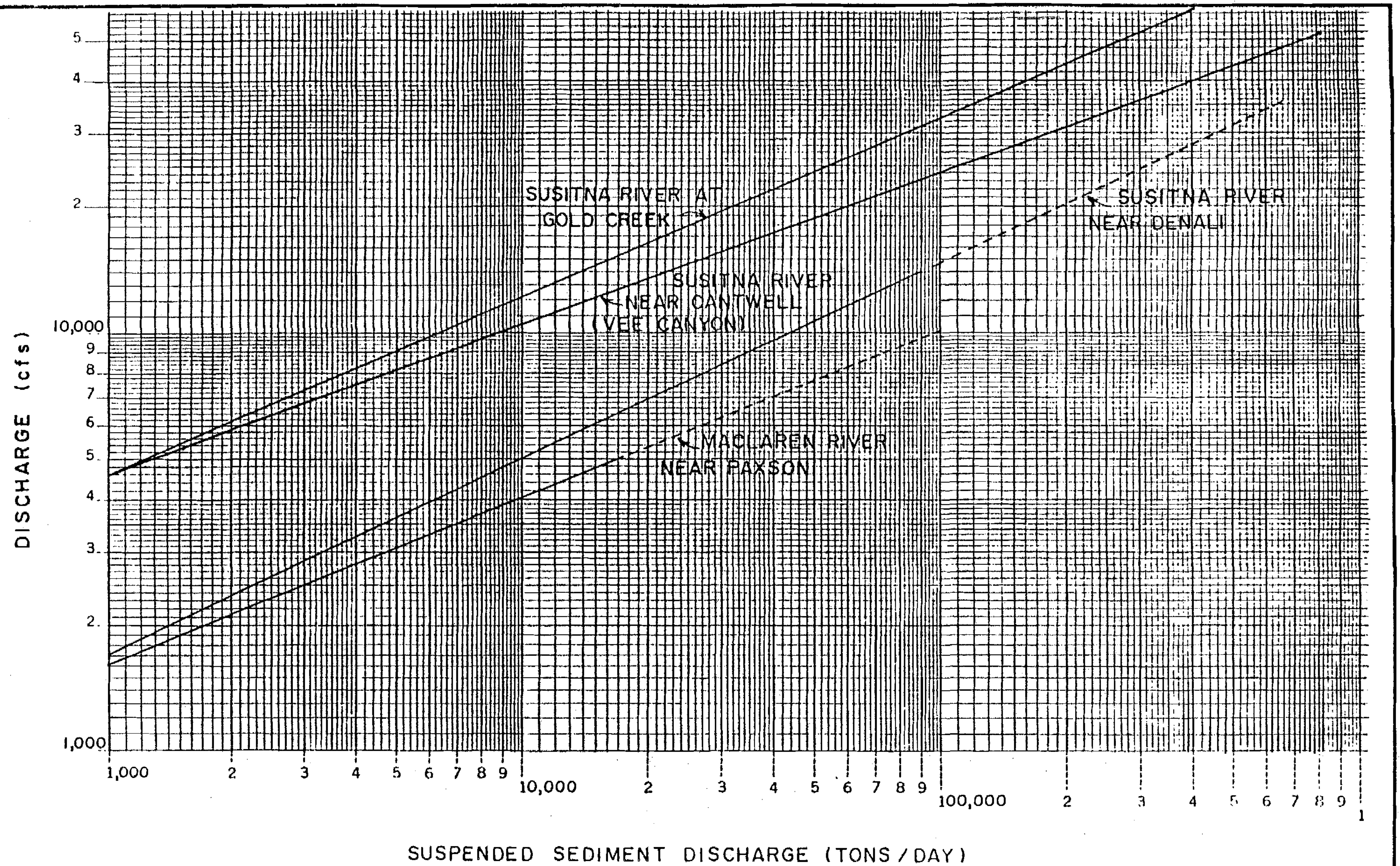
D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

No measurable increase above natural conditions (ADEC,1979).

Established to prevent deleterious effects on aquatic animal and plant life, their reproduction and habitat.

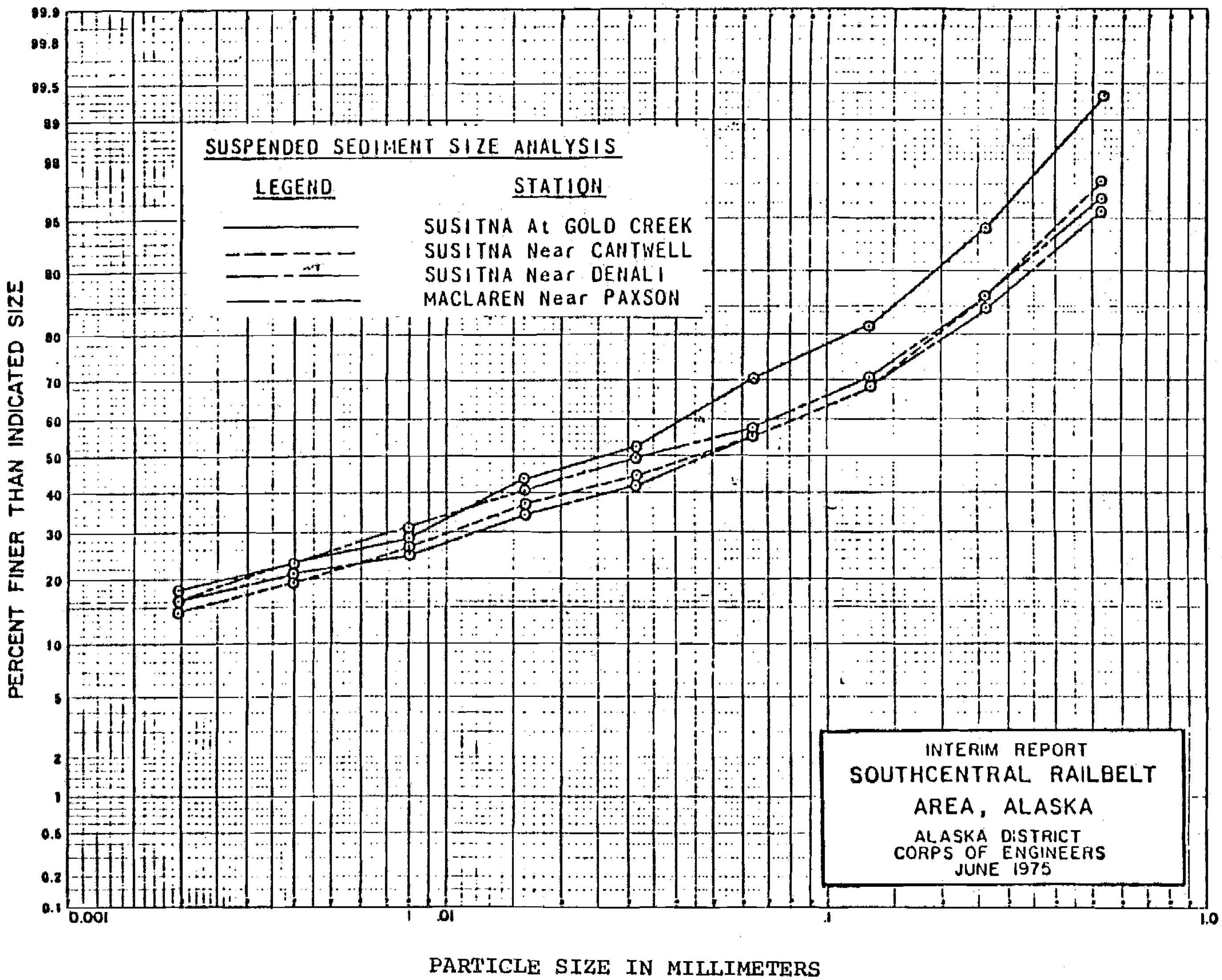
DATA SUMMARY - TOTAL SUSPENDED SEDIMENTS

FIGURE E.2.34



SUSPENDED SEDIMENT RATING CURVES
UPPER SUSITNA RIVER BASIN

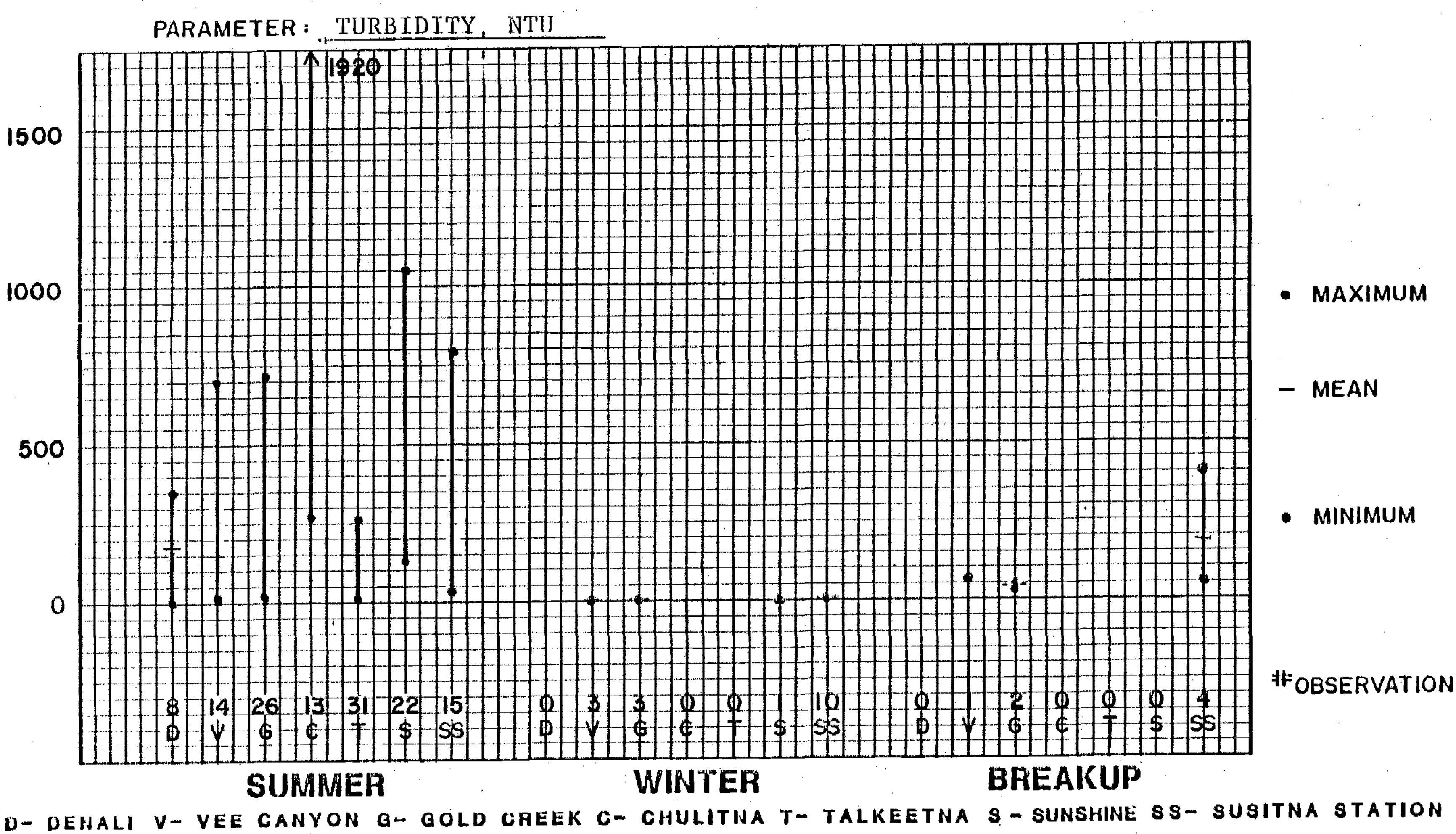
FIGURE E.2.35



SUSPENDED SEDIMENT SIZE ANALYSIS

SUSITNA RIVER

FIGURE E.2.36

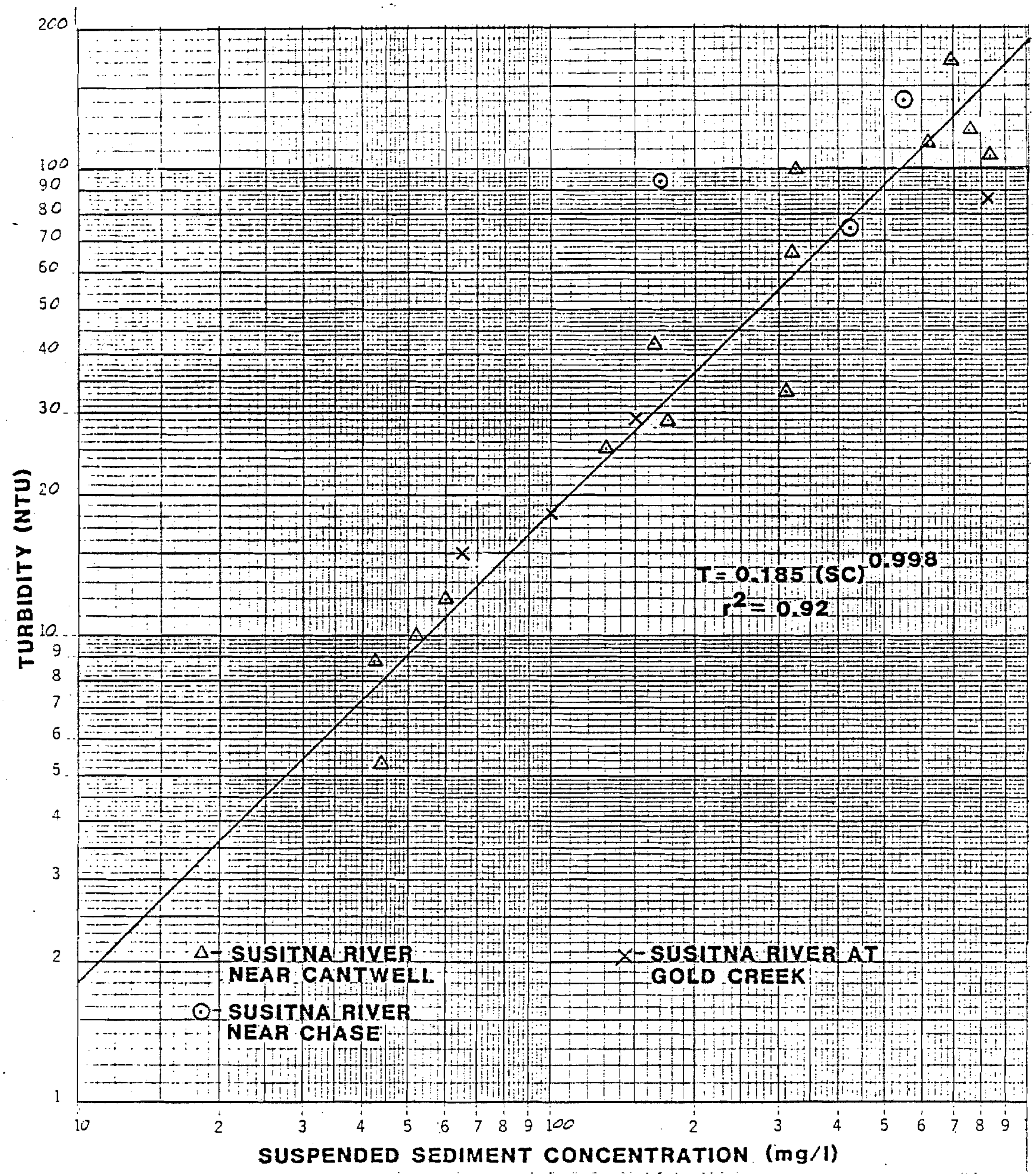


Shall not exceed 25 NTU above natural conditions (ADEC, 1979)

Established to prevent the reduction of the compensation point for photosynthetic activity, which may have adverse effects on aquatic life.

DATA SUMMARY - TURBIDITY

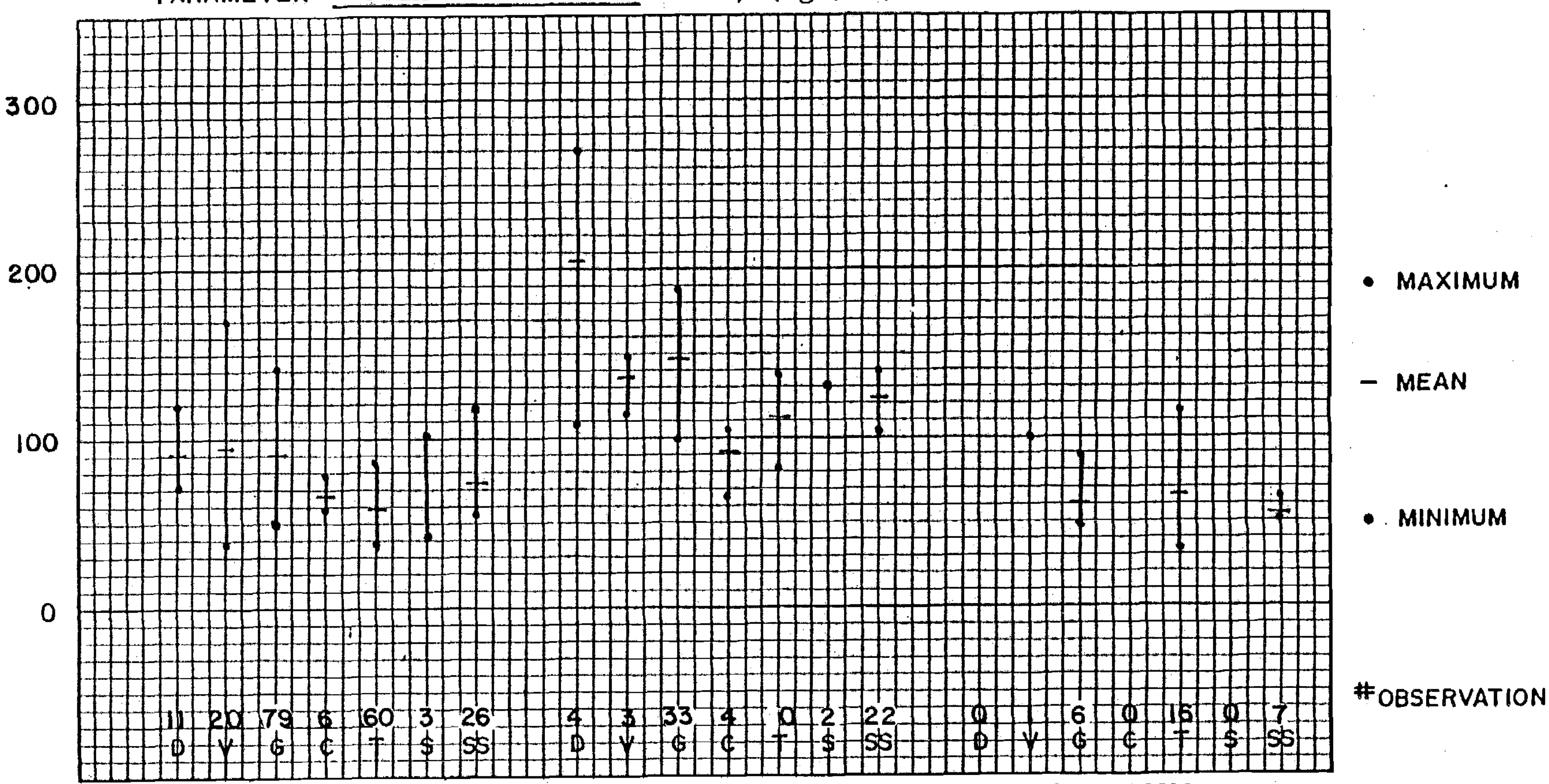
FIGURE E.2.37



TURBIDITY vs SUSPENDED SEDIMENT CONCENTRATION

FIGURE E.2.38

PARAMETER: TOTAL DISSOLVED SOLIDS, (mg./1.)



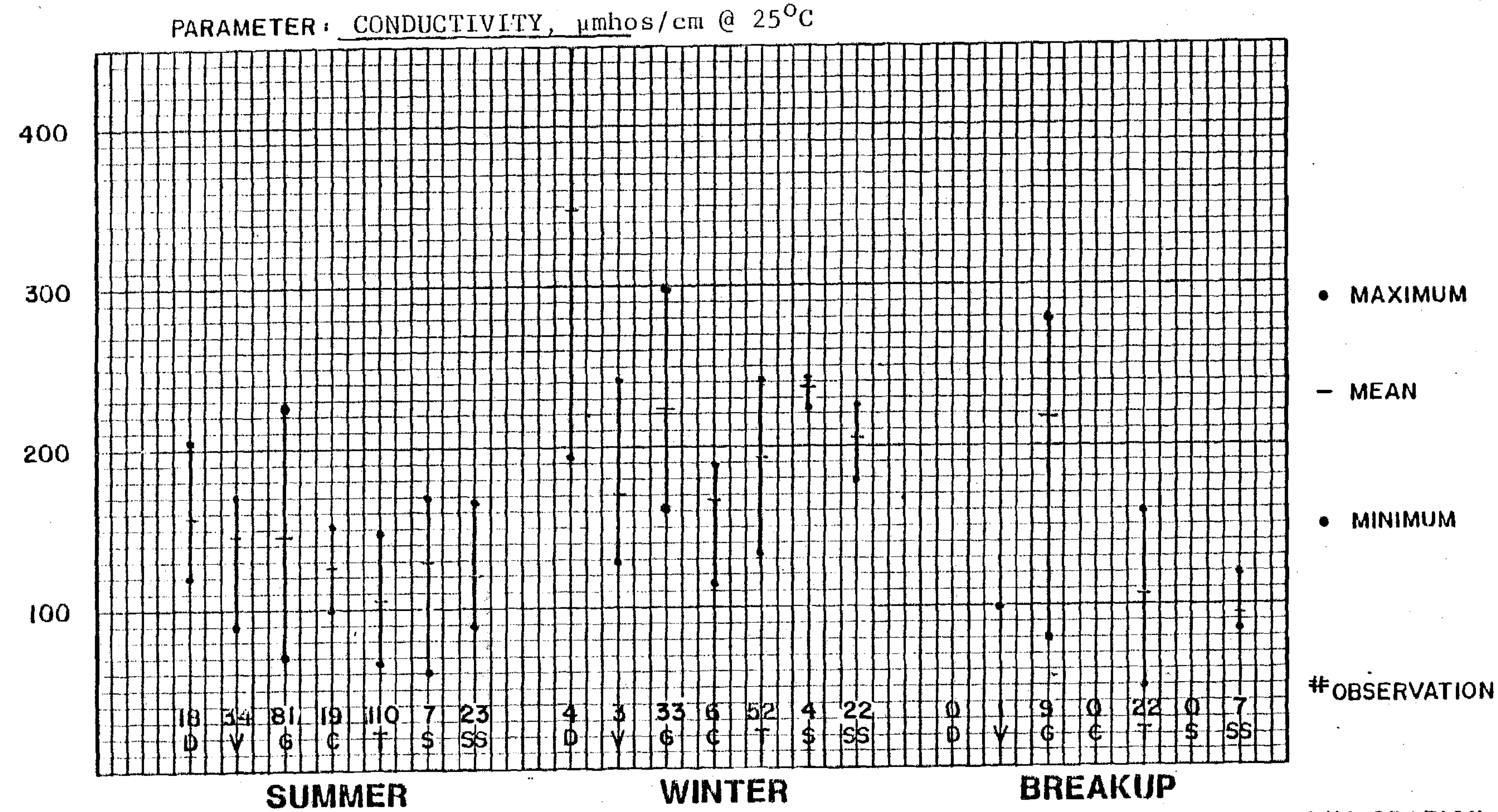
D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. 1,500 mg/1 (ADEC, 1979).

Established to protect natural condition of freshwater ecosystems (500 mg/1 is the criterion for water supplies).

DATA SUMMARY - TOTAL DISSOLVED SOLIDS

FIGURE E.2.39

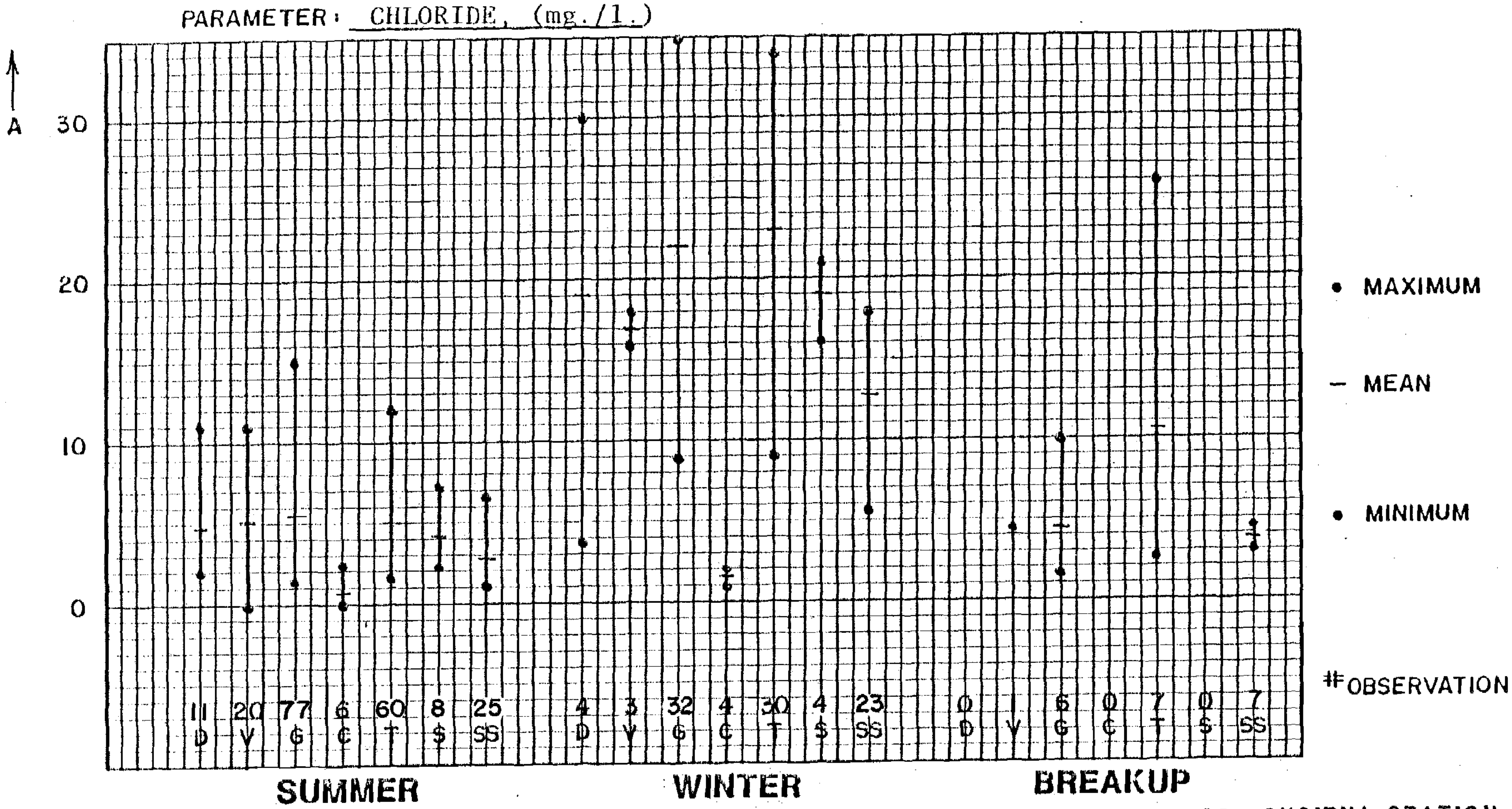


D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

No criterion established

DATA SUMMARY - CONDUCTIVITY

FIGURE E.2.40



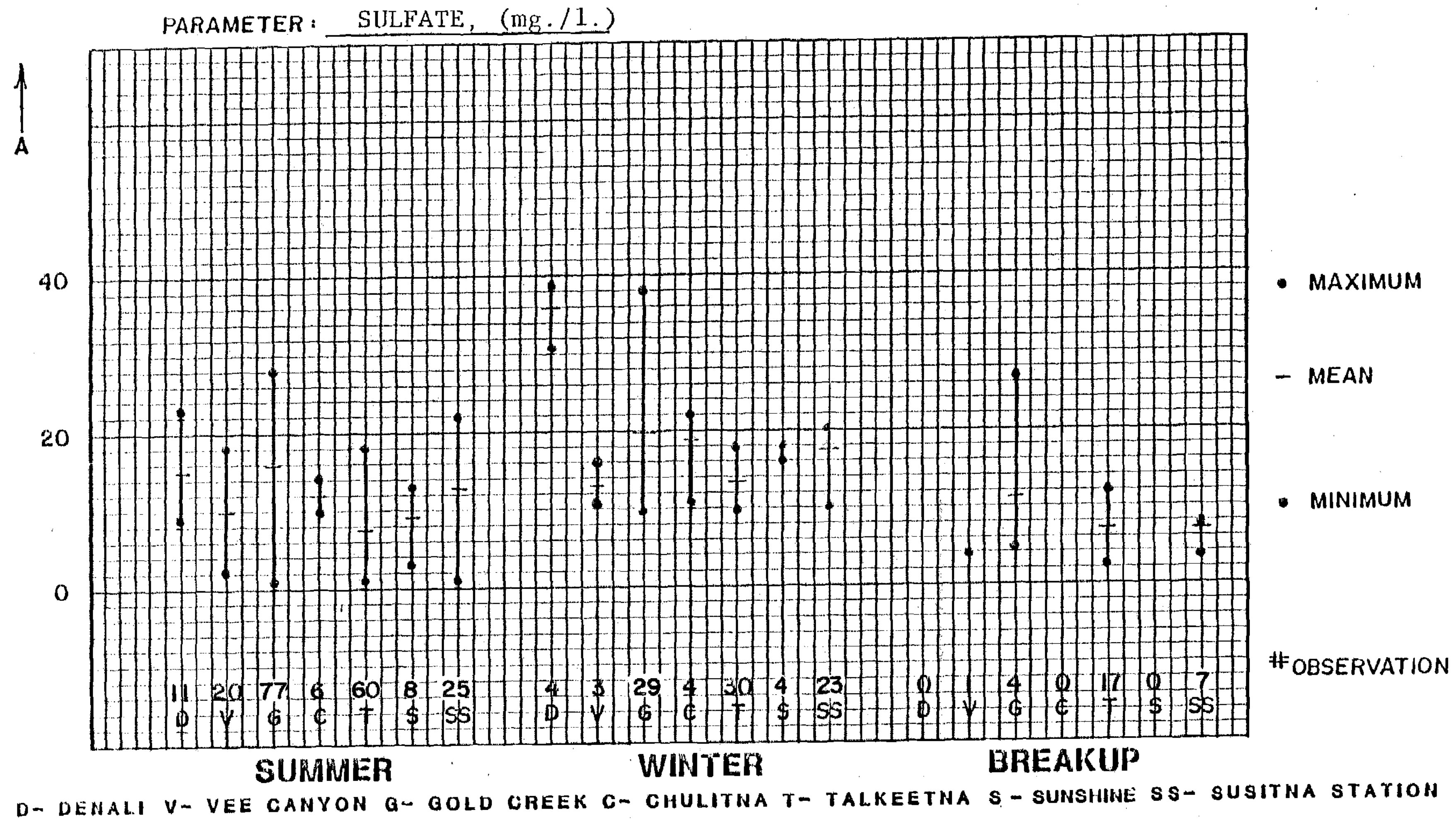
D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

Less than 200 mg/l$_x$ (ADEC, 1979)

Established to protect water supplies.

DATA SUMMARY - CHLORIDE

FIGURE E.2.41



A. Shall not exceed 200 mg/1. (ADEC, 1979).

Established to protect water supplies.

DATA SUMMARY - SULFATE

FIGURE E.2.42

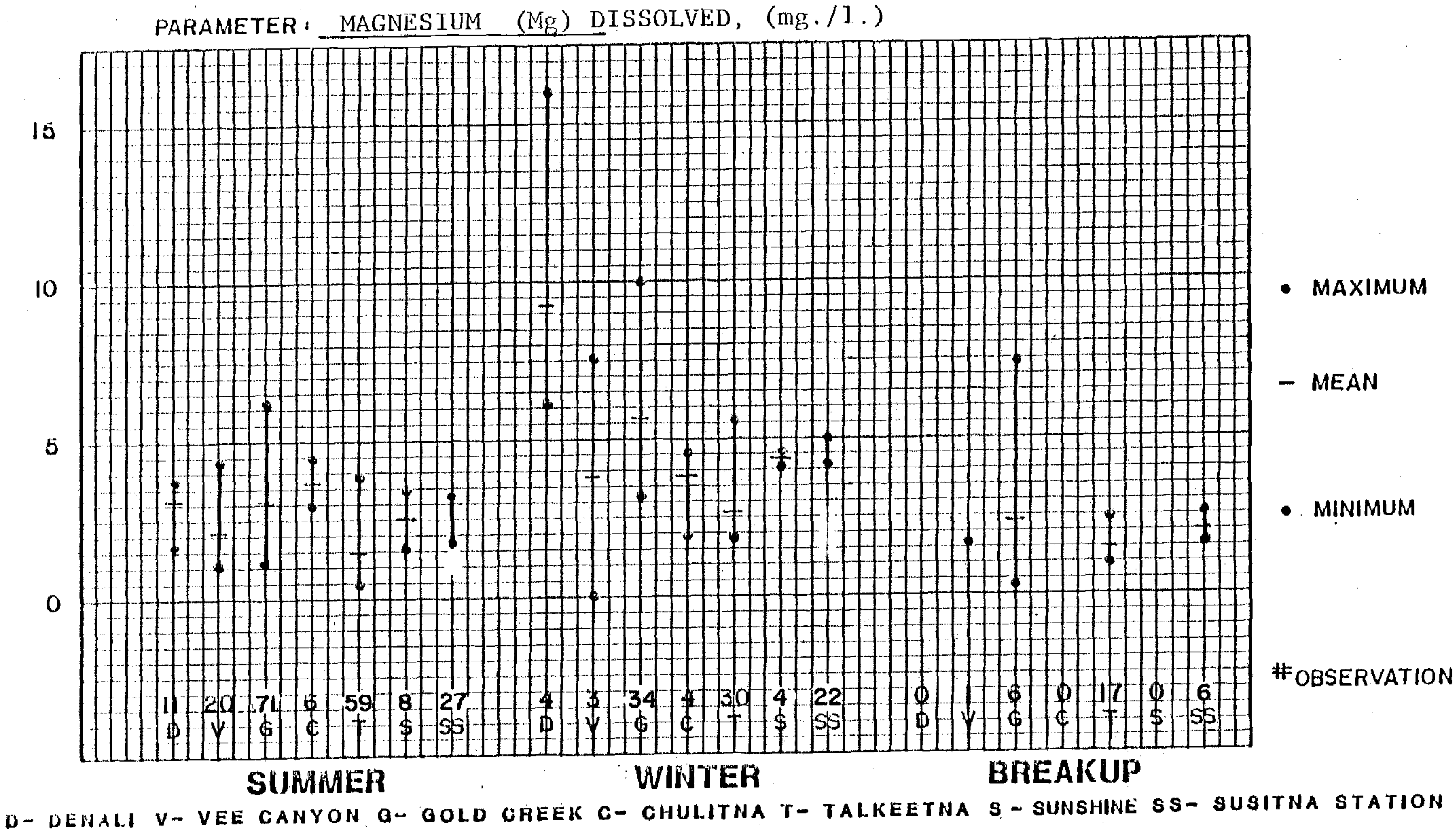
PARAMETER: CALCIUM (Ca) DISSOLVED, (mg./l.)

D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

No criterion established

DATA SUMMARY - CALCIUM (d)

FIGURE E.2.43



No criterion established.

DATA SUMMARY - MAGNESIUM (d)

FIGURE E.2.44

PARAMETER: SODIUM (Na) DISSOLVED, (mg./1.)

D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

No criterion established.

DATA SUMMARY - SODIUM (d)

FIGURE E.2.45

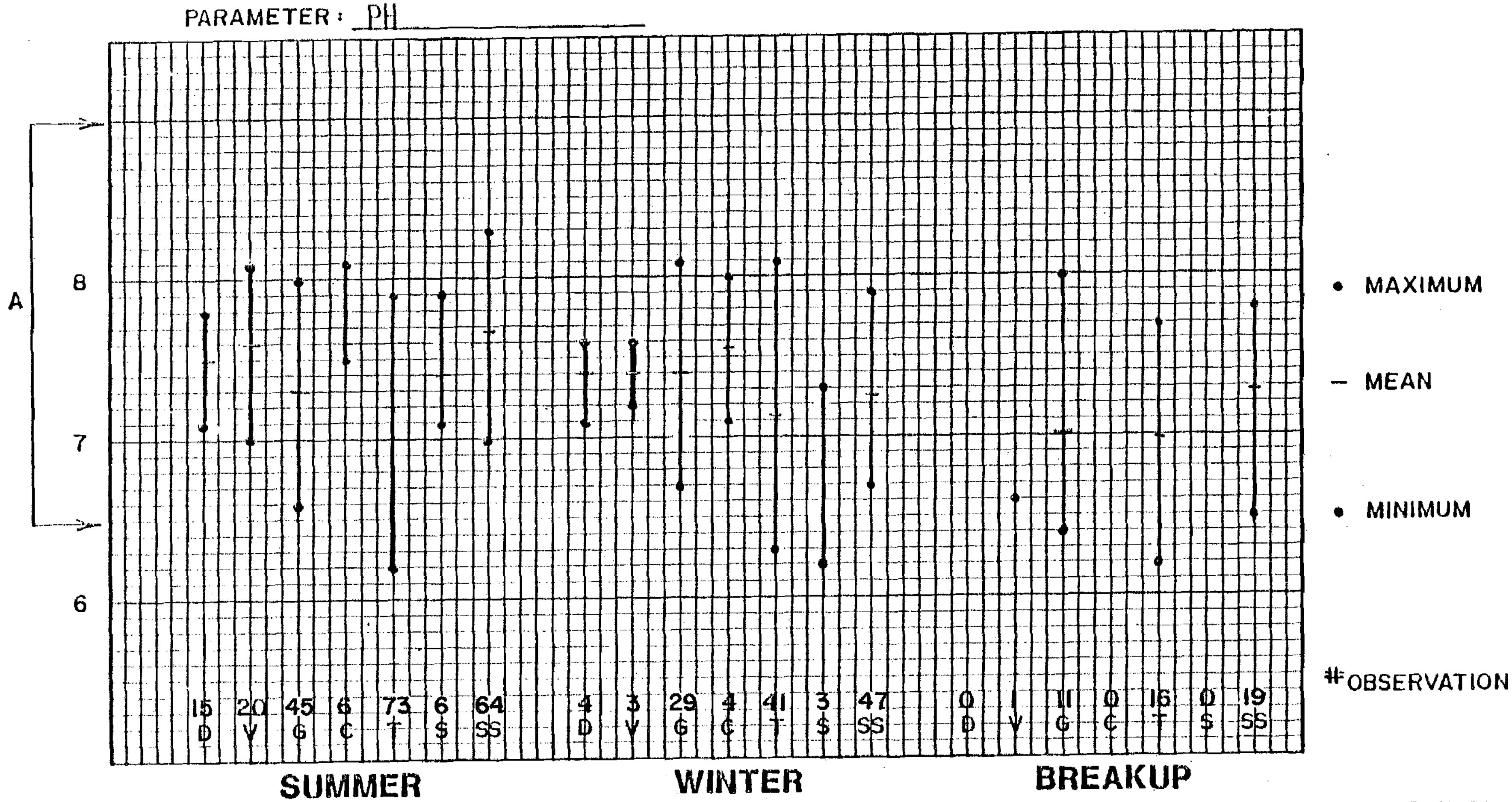
PARAMETER: POTASSIUM (K) DISSOLVED, (mg./l.)

D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

No criterion established.

DATA SUMMARY POTASSIUM (d)

FIGURE E.2.46



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. Not less than 6.5 or greater than 9.0. Shall not vary more than 0.5 pH unit from natural condition (ADEC, 1979).

Established to protect freshwater aquatic organisms.

DATA SUMMARY - PH

FIGURE E.2.47

PARAMETER: HARDNESS, as Ca CO_3, (mg./1.)

D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

No criterion established

Some metals have variable synergistic effects with hardness, dependent on the prevailing hardness in the water. The criteria for cadium, for example, is 0.0012 mg/l in hard water and 0.0004 mg/l in soft water.

DATA SUMMARY - HARDNESS

FIGURE E.2.48

PARAMETER: ALKALINITY, as $CACO_3$, (mg./1.)

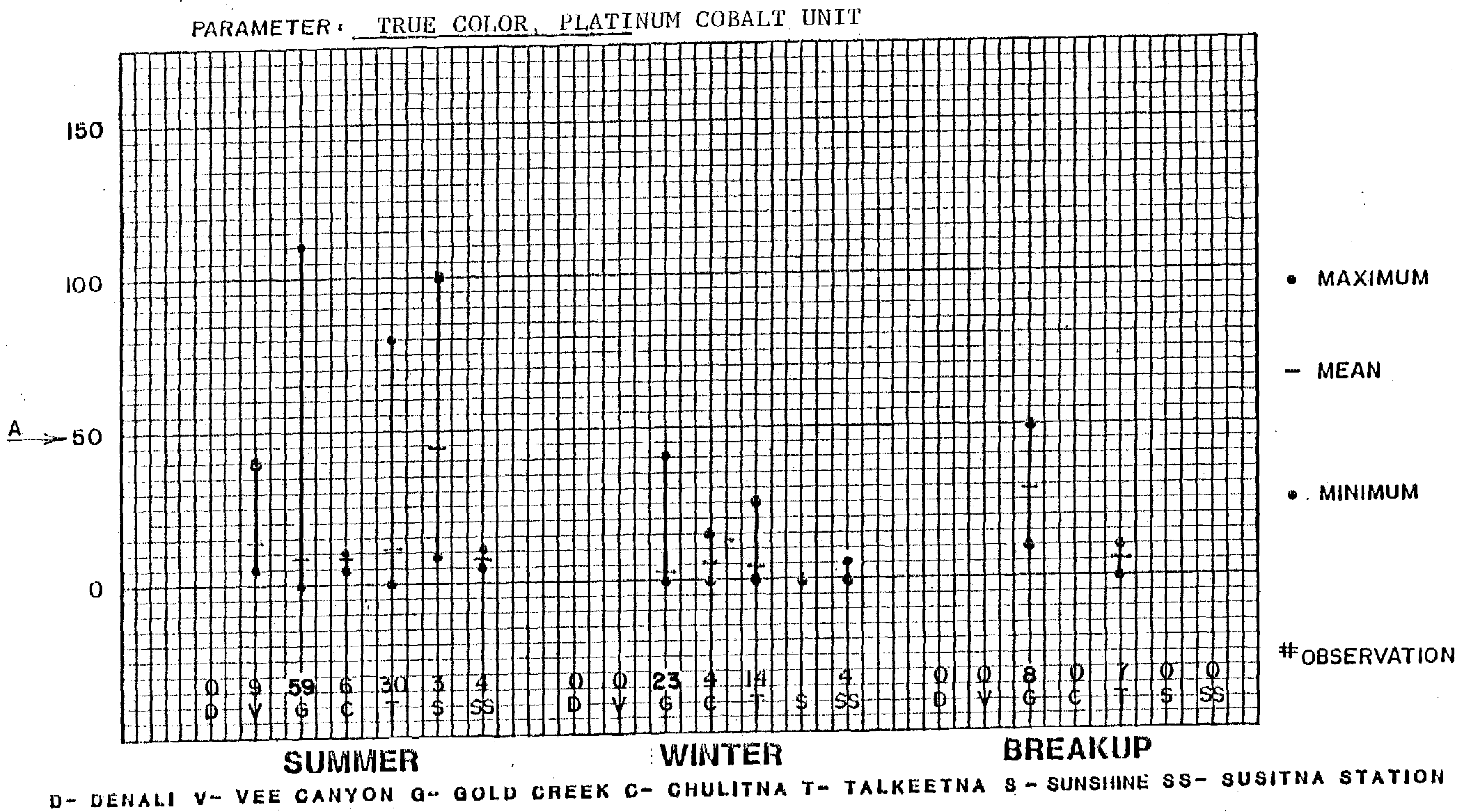
D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

20mg/1 or more except where natural conditions are less. (EPA, 1976).

Established to protect freshwater aquatic organisms.

DATA SUMMARY - ALKALINITY

FIGURE E.2.49



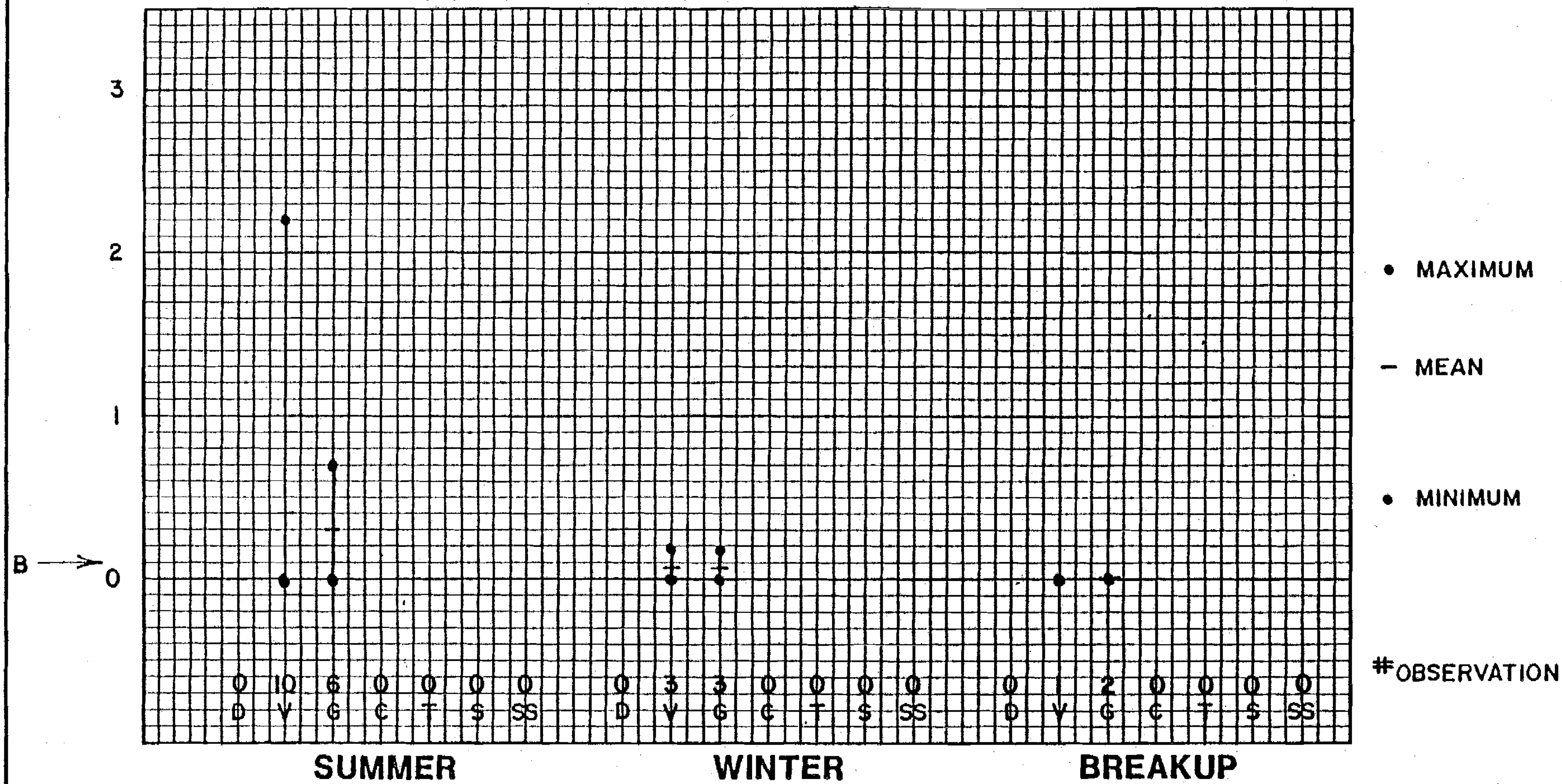
Shall not exceed 50 units (ADEC, 1979)

Established to prevent the reduction of photosynthetic activity which may have deleterious effects on aquatic life.

DATA SUMMARY - TRUE COLOR

FIGURE E.2.50

PARAMETER: ALUMINUM (Al) DISSOLVED, (mg./1.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. No criterion established

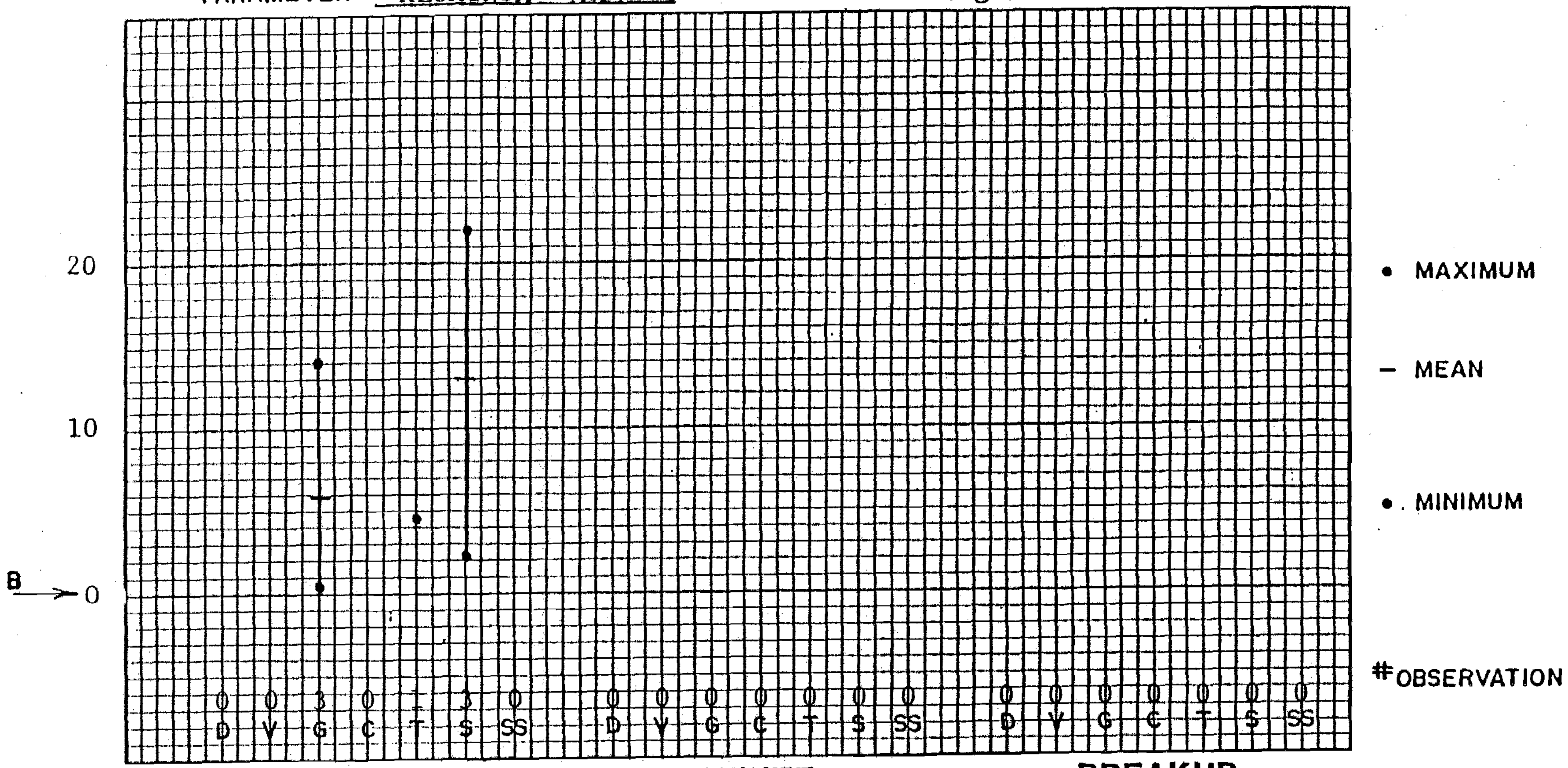
B. A limit of 0.073 mg/l has been suggested by EPA (Sittig, 1981).

This suggested limit is based on the effects of aluminum on human health.

DATA SUMMARY - ALUMINUM (d)

FIGURE E.2.51

PARAMETER: ALUMINUM (Al) Total Recoverable (mg./l.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

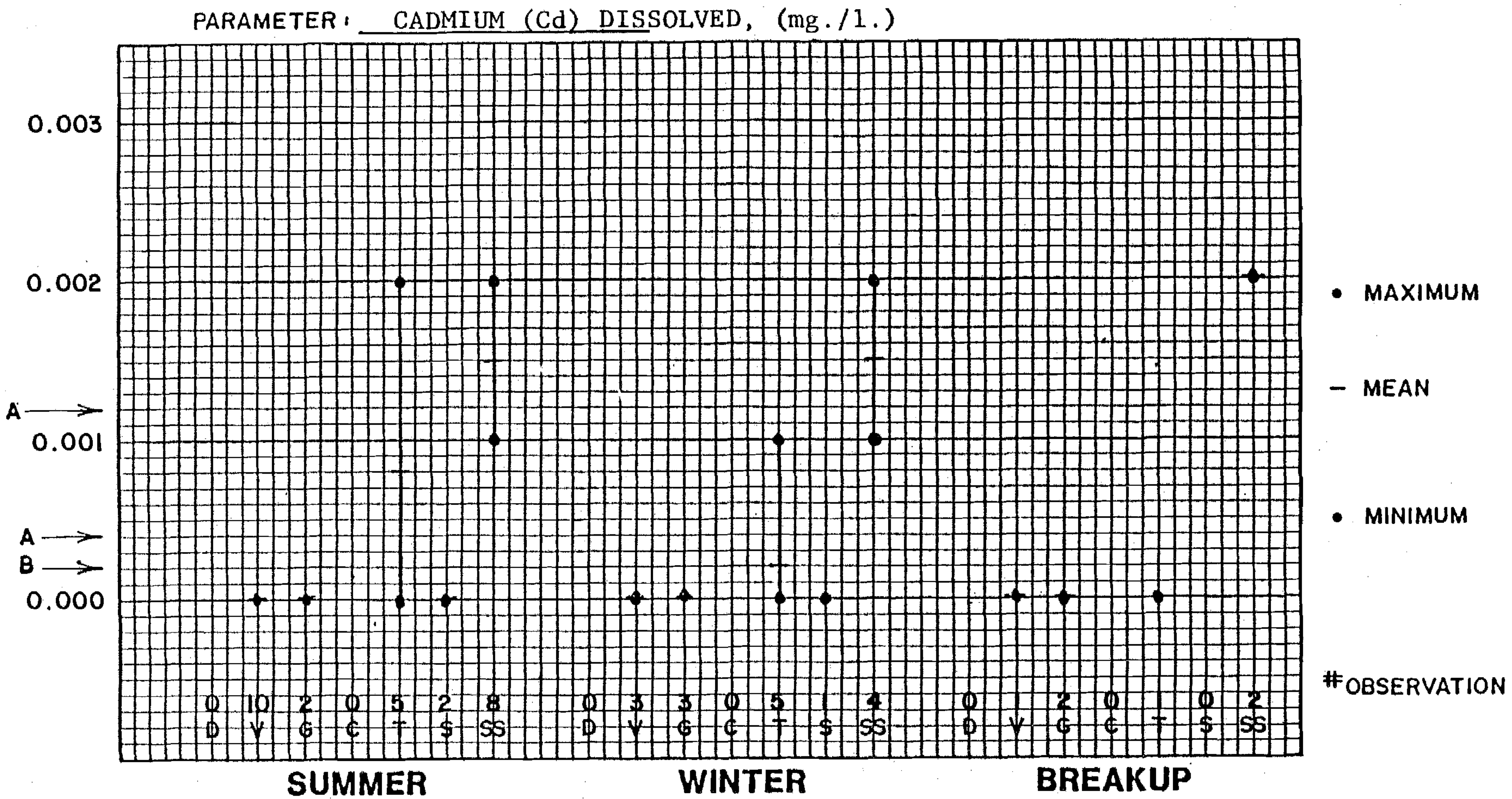
A. No criterion established

B. A limit of 0.073 mg/l has been suggested by EPA (Sittig, 1981)

This suggested limit is based on the effects of aluminum on human health.

DATA SUMMARY - ALUMINUM (t)

FIGURE E.2.52



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. 0.0012 mg/l in hard water and 0.0004 in soft water. (EPA, 1976)

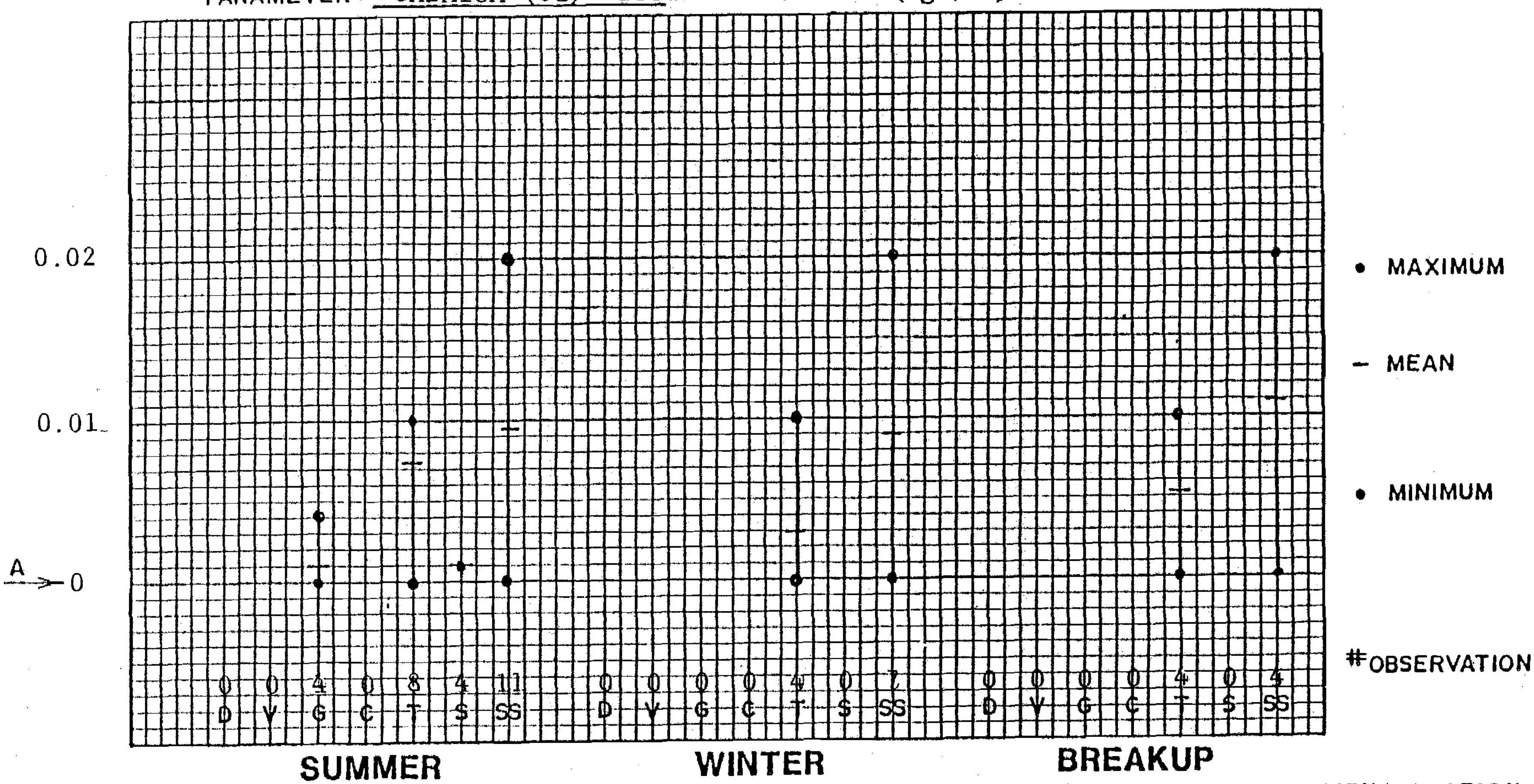
B. Less than 0.0002 mg/l. (McNeely, 1979)

Established to protect freshwater aquatic organisms.

DATA SUMMARY - CADMIUM (d)

FIGURE E.2.53

PARAMETER: CADMIUM (Cd) Total Recoverable (mg./l.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. 0.0012 in hard water and 0.0004 mg/l in soft water (EPA, 1976).

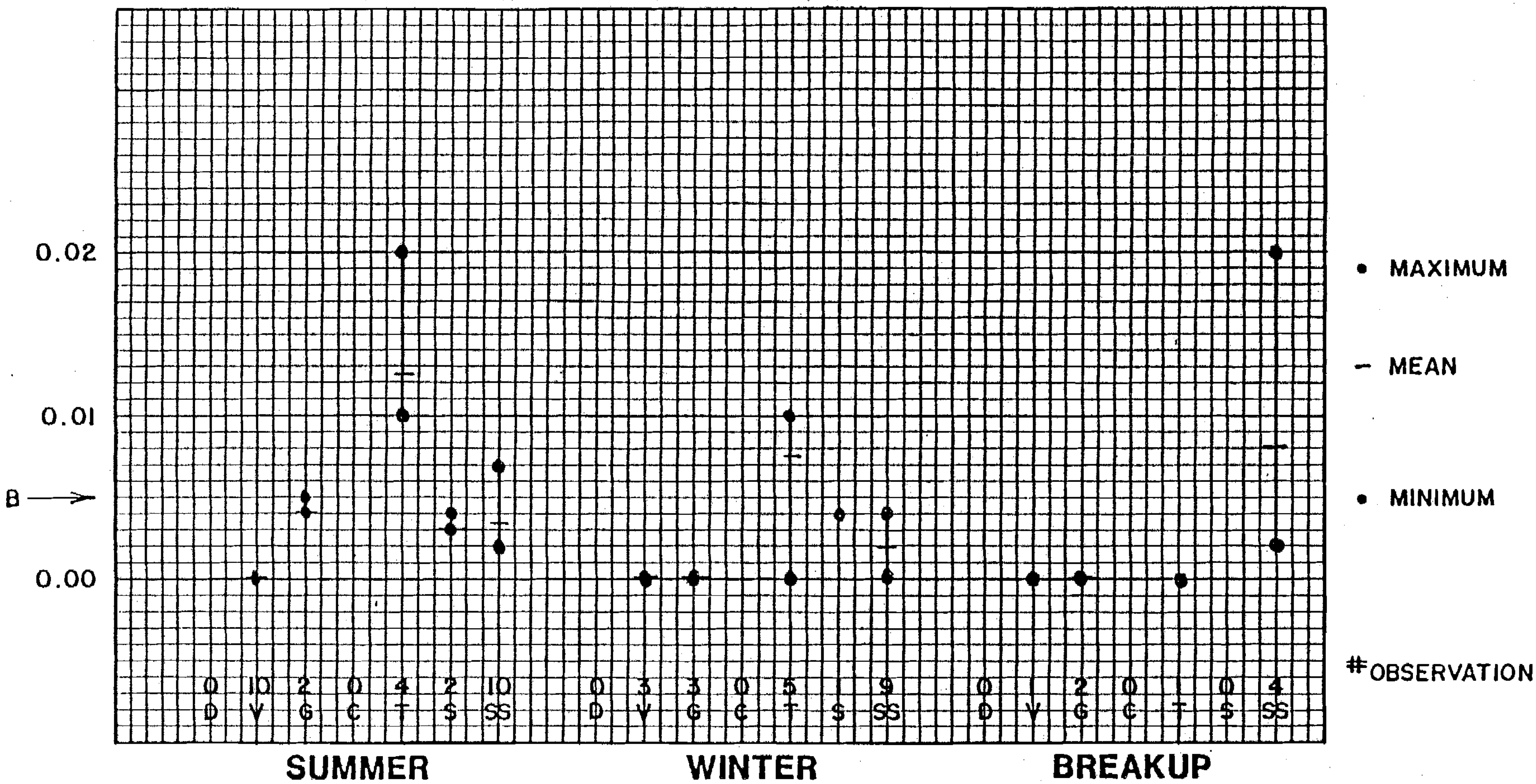
B. Less than 0.0002 mg/l (McNeely et al, 1979).

Established to protect freshwater aquatic organisms.

DATA SUMMARY - CADMIUM (t)

FIGURE E.2.54

PARAMETER: COPPER (Cu) DISSOLVED (mg./l.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. 0.01 of the 96-hour LC_{50} determined through bioassay (EPA, 1976).

B. 0.005 mg/l, (McNeely et al, 1979)

Established to protect freshwater aquatic organisms.

DATA SUMMARY - COPPER (d)

FIGURE E.2.55

PARAMETER: COPPER (Cu) (mg./1.) Total Recoverable

D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. 0.01 of the 96 - hour LC_{50} determined through bioassay (EPA, 1976).

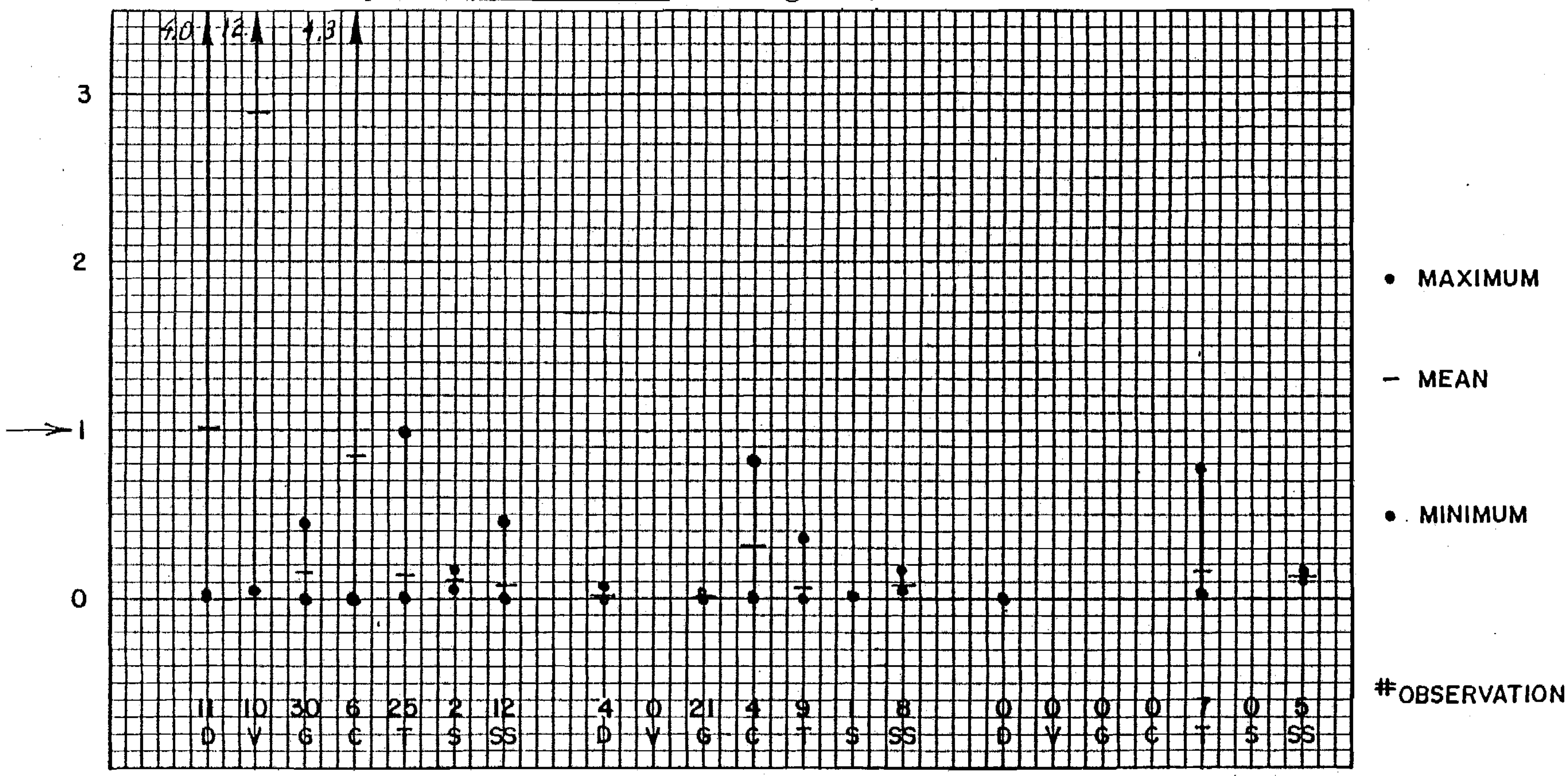
B. 0.005 mg/l (McNeely et al, 1979).

Established to protect freshwater aquatic organisms,

DATA SUMMARY - COPPER (t)

FIGURE E.2.56

PARAMETER: IRON (Fe) DISSOLVED, (mg./1.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

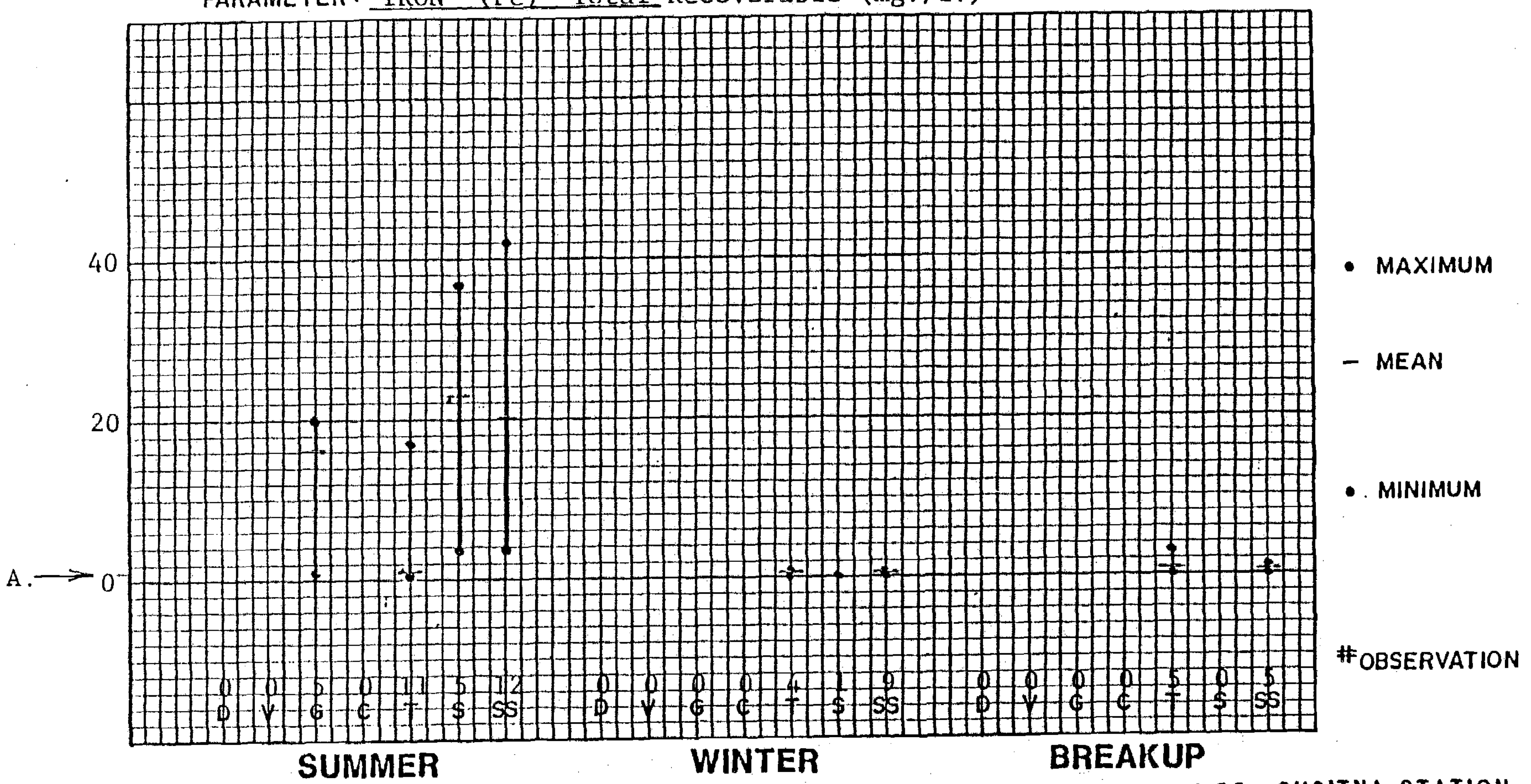
A. Less than 1.0 mg/1 (EPA, 1976; Sittig, 1981).

Established to protect freshwater aquatic organisms.

DATA SUMMARY - IRON (d)

FIGURE E.2.57

PARAMETER: IRON (Fe) Total Recoverable (mg./1.)



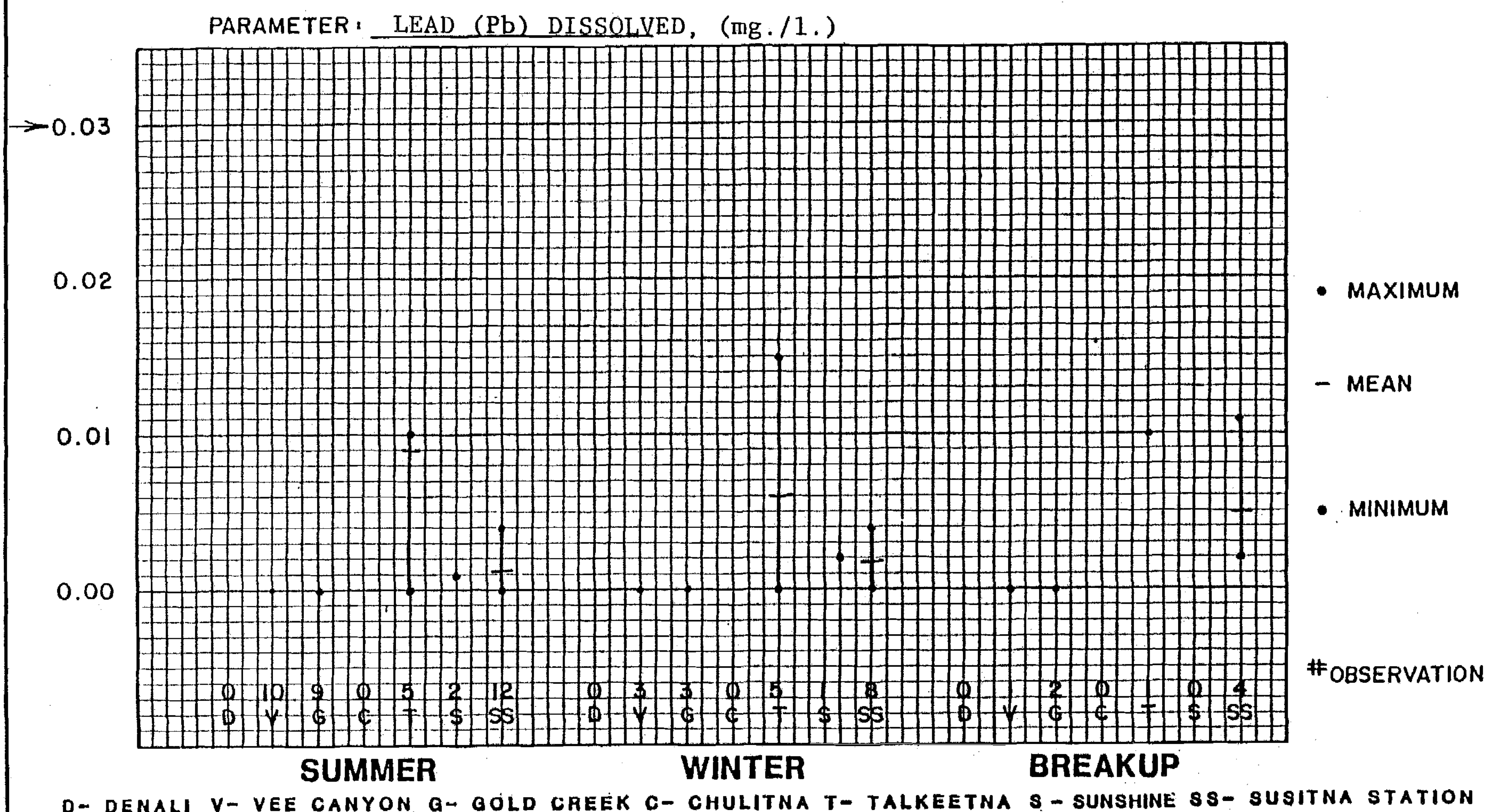
D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. Less than 1.0 mg/l (EPA, 1976; Sittig, 1981)

Established to protect freshwater aquatic organisms.

DATA SUMMARY - IRON (t)

FIGURE E.2.58



A. Less than 0.03 mg/1, (McNeely et al, 1979).

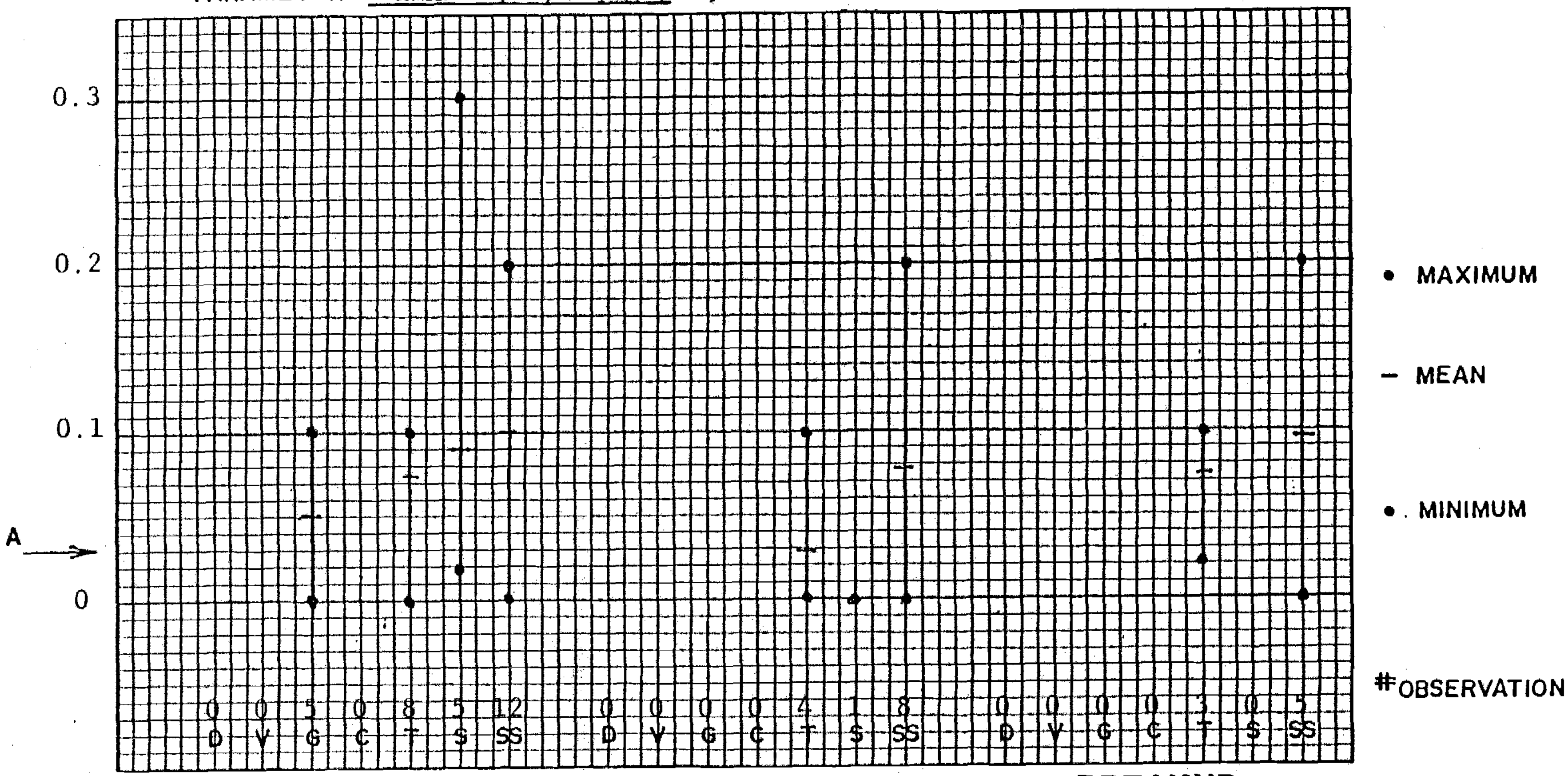
B. 0.01 of the 96-hour LC_{50} determined through bioassay. (EPA, 1976).

Established to protect freshwater aquatic orgqnisms.

DATA SUMMARY - LEAD (d)

FIGURE E.2.59

PARAMETER: LEAD (Pb) (mg./l.) Total Recoverable



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. Less than 0.03 mg/l (McNeely et al, 1979).

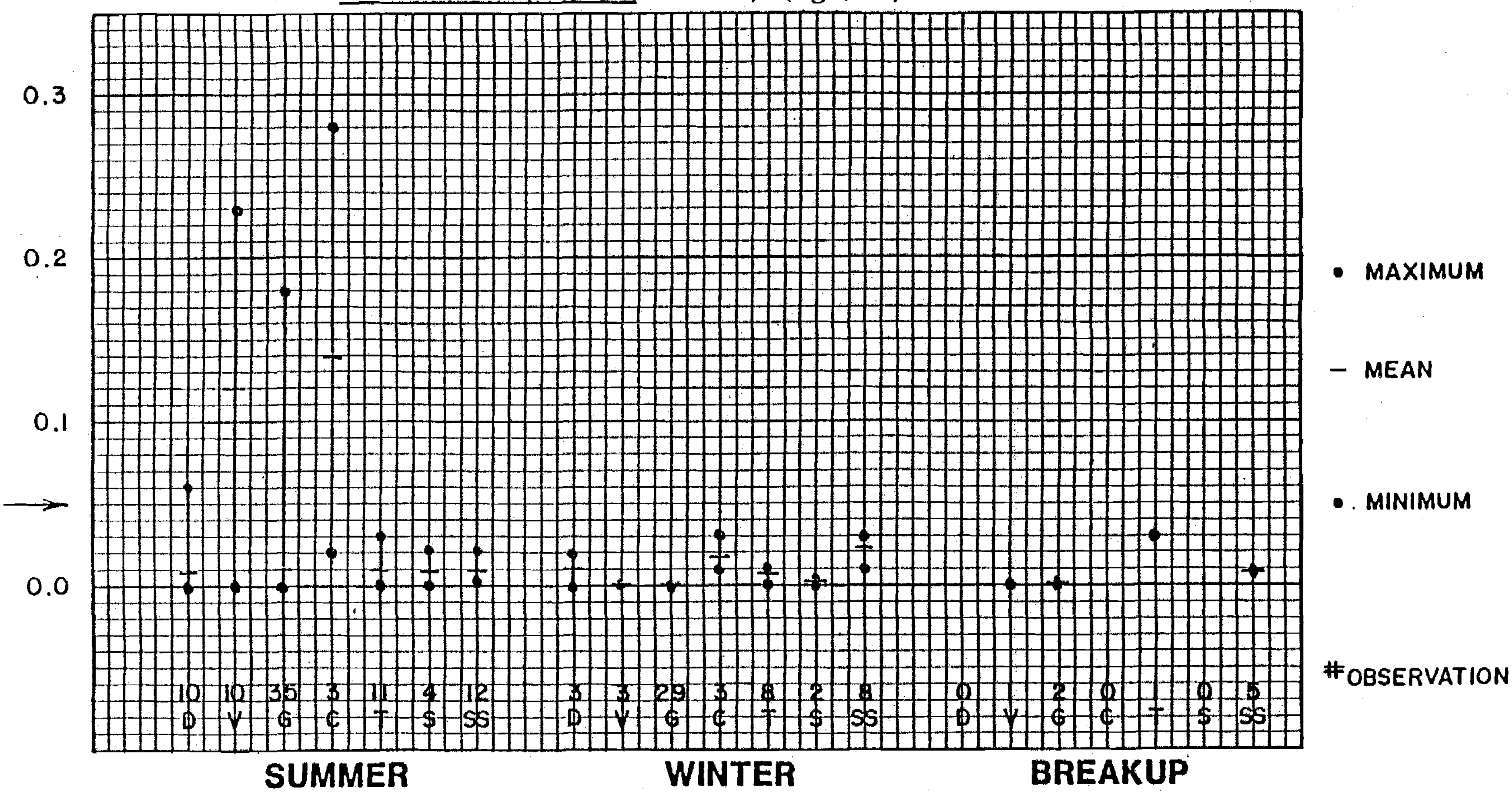
B. 0.01 of the 96 - hour LC_{50} determined through bioassay (EPA, 1976).

Established to protect freshwater aquatic organisms.

DATA SUMMARY - LEAD (t)

FIGURE E.2.60

PARAMETER: MANGANESE (Mn) DISSOLVED, (mg./1.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S- SUNSHINE SS- SUSITNA STATION

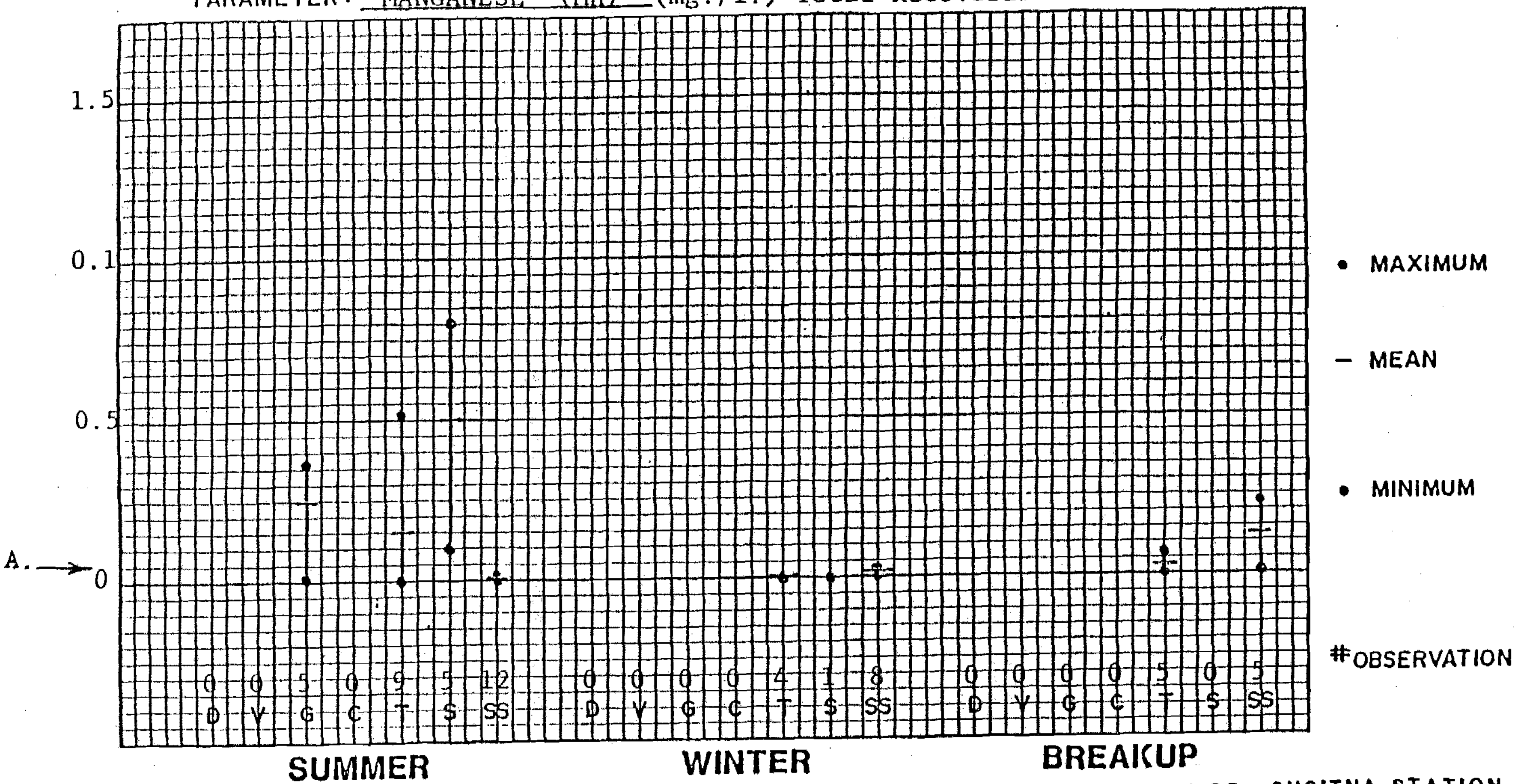
A. Less than 0.05 mg/1 for water supply.(EPA, 1976).

Established to protect water supplies.

DATA SUMMARY - MANGANESE (d)

FIGURE E.2.61

PARAMETER: MANGANESE (Mn) (mg./1.) Total Recoverable



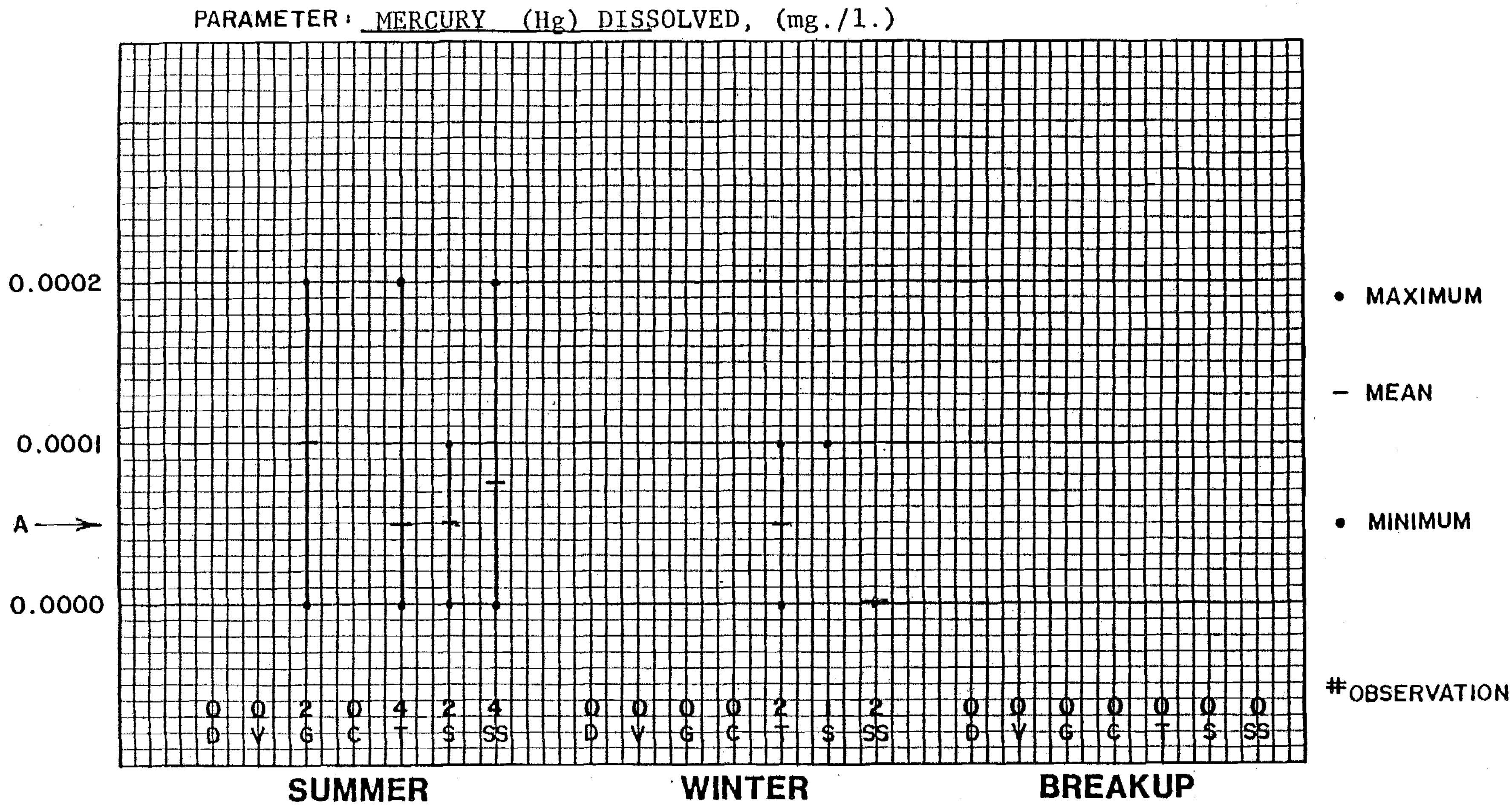
D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. Less than 0.05 mg/1 for water supply (EPA, 1976)

Established to protect water supplies.

DATA SUMMARY - MANGANESE (t)

FIGURE E.2.62



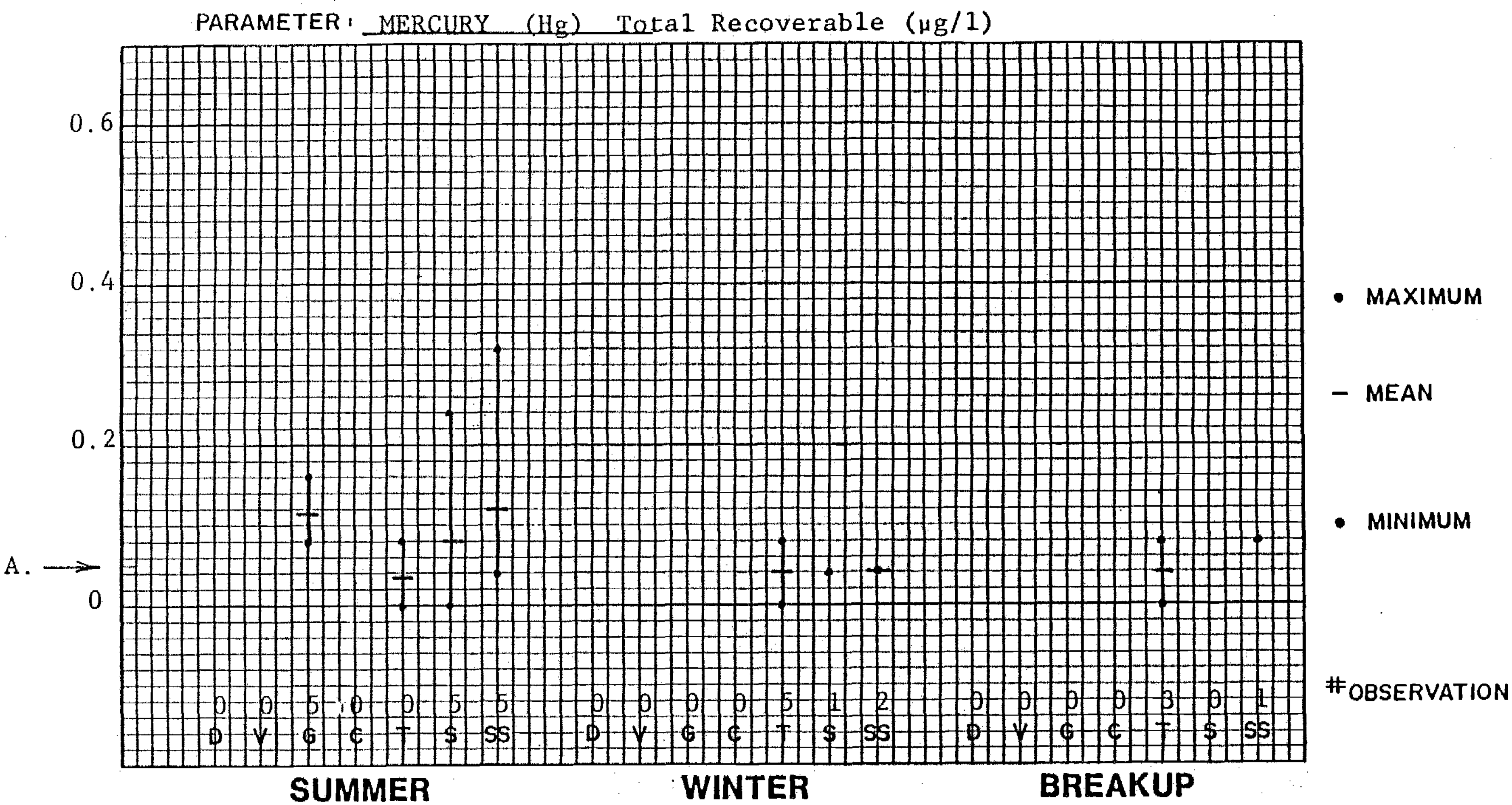
D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S- SUNSHINE SS- SUSITNA STATION

A. Less than 0.00005 mg/l. (EPA, 1976).

Established to protect freshwater aquatic organisms.

DATA SUMMARY - MERCURY (d)

FIGURE E.2.63



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHUL'TNA T- TALKEETNA S- SUNSHINE SS- SUSITNA STATION

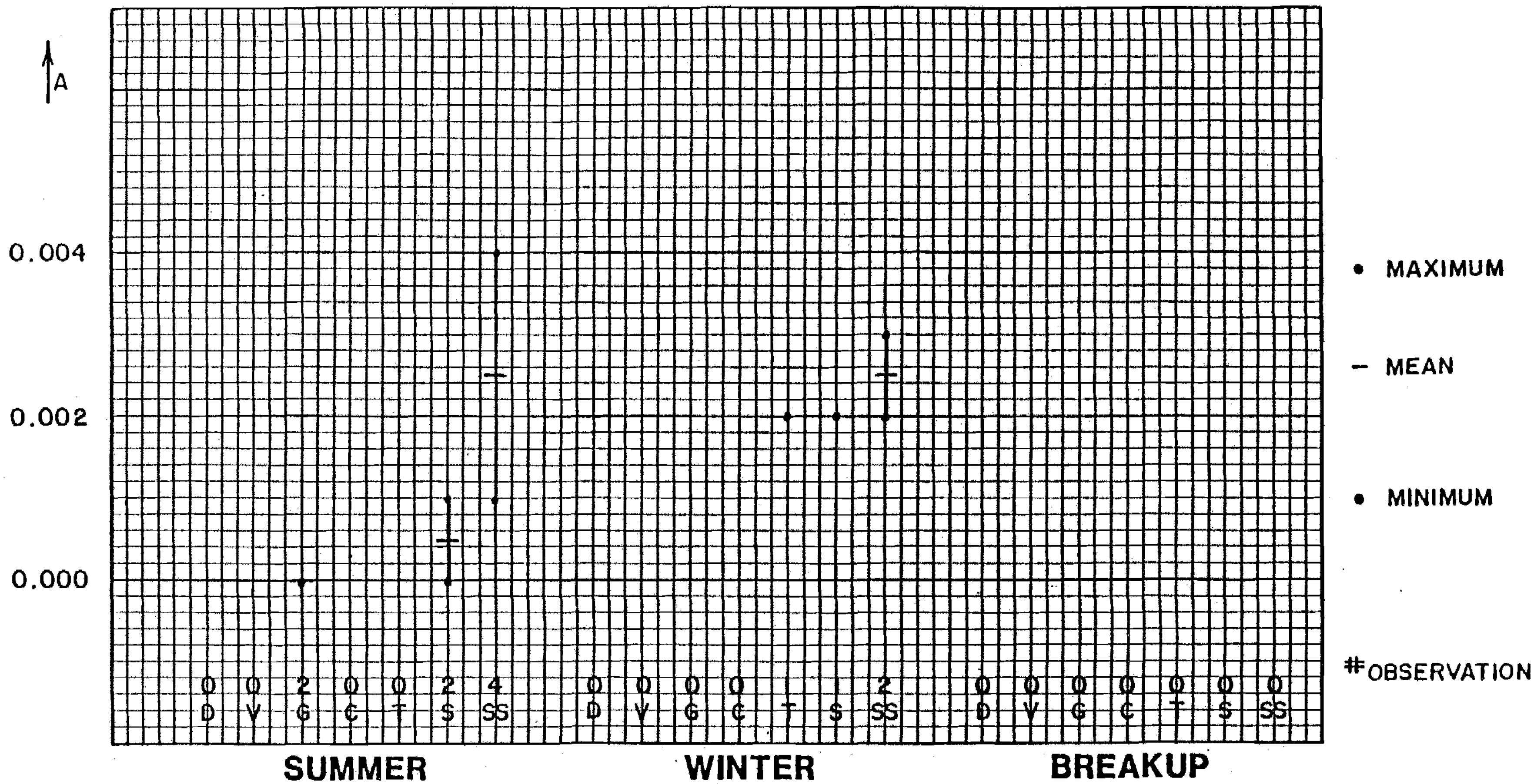
A. Less than 0.05 μg/1 (EPA, 1976)

Established to protect freshwater aquatic organisms.

DATA SUMMARY - MERCURY (t)

FIGURE E.2.64

PARAMETER: NICKEL (Ni) DISSOLVED, (mg./l.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S- SUNSHINE SS- SUSITNA STATION

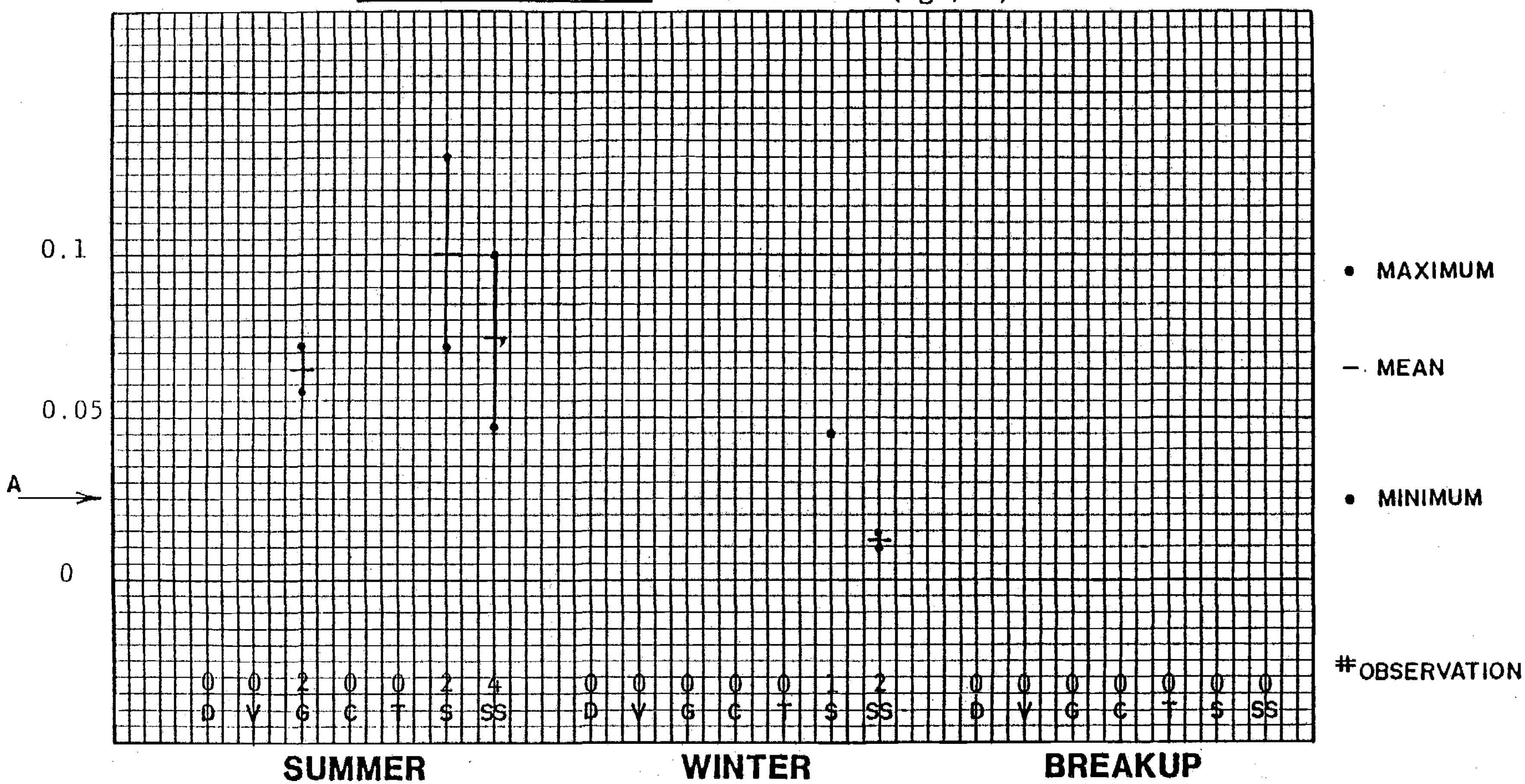
A. Less than 0.025 mg/l. (McNeely et al, 1979).

B. 0.01 of the 96-hour LC_{50} determined through bioassay. (EPA, 1976). Established to protect freshwater aquatic organisms.

DATA SUMMARY - NICKEL (d)

FIGURE E.2.65

PARAMETER: NICKEL (Ni) Total Recoverable (mg./l.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

A. Less than 0.025 mg/l (McNeely et al, 1979).

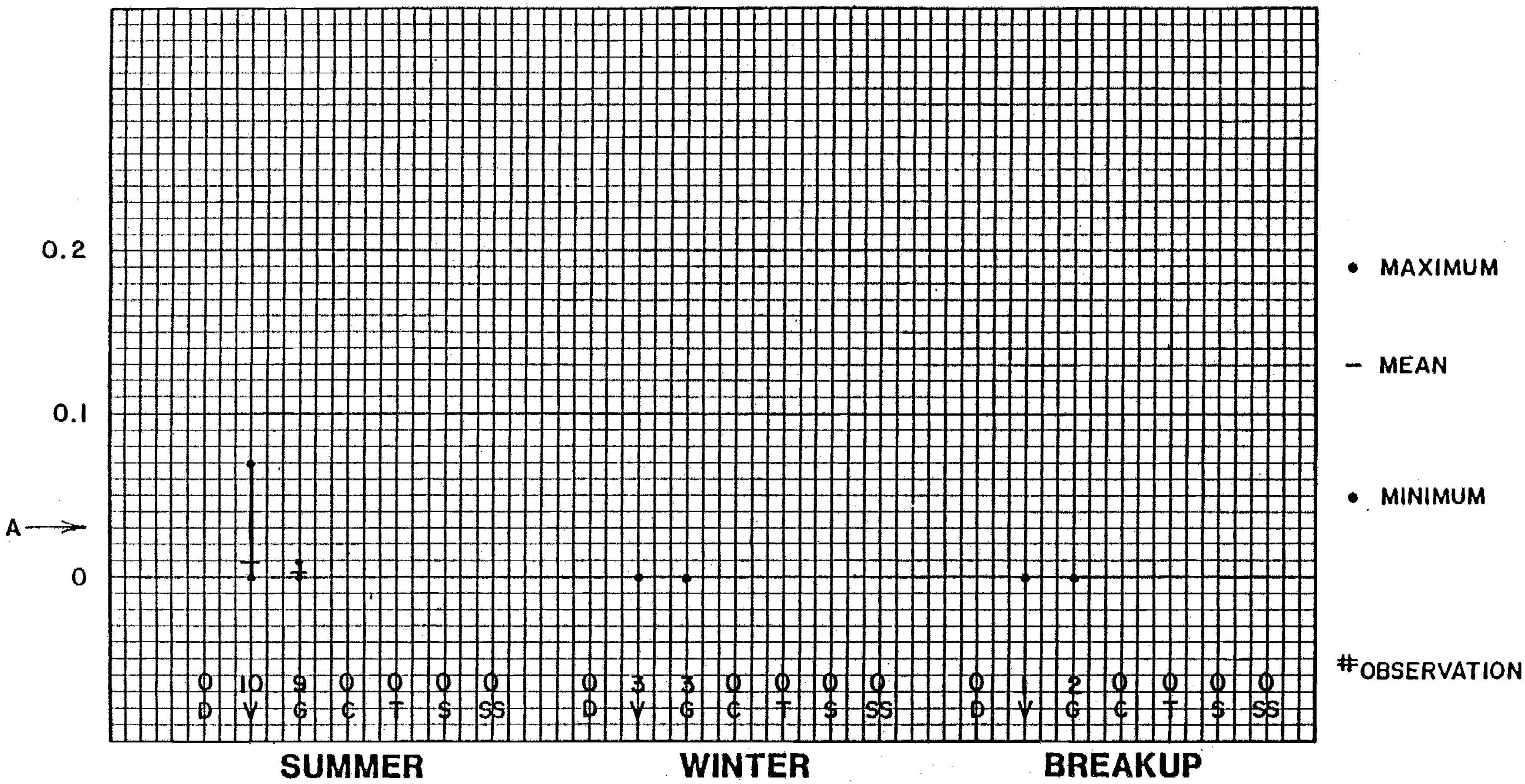
B. 0.01 of the 96 - hour LC_{50} determined through bioassay (EPA, 1976)

Established to protect freshwater aquatic organisms,

DATA SUMMARY - NICKEL (t)

FIGURE E.2.66

PARAMETER: ZINC (Zn) DISSOLVED, (mg./1.)



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

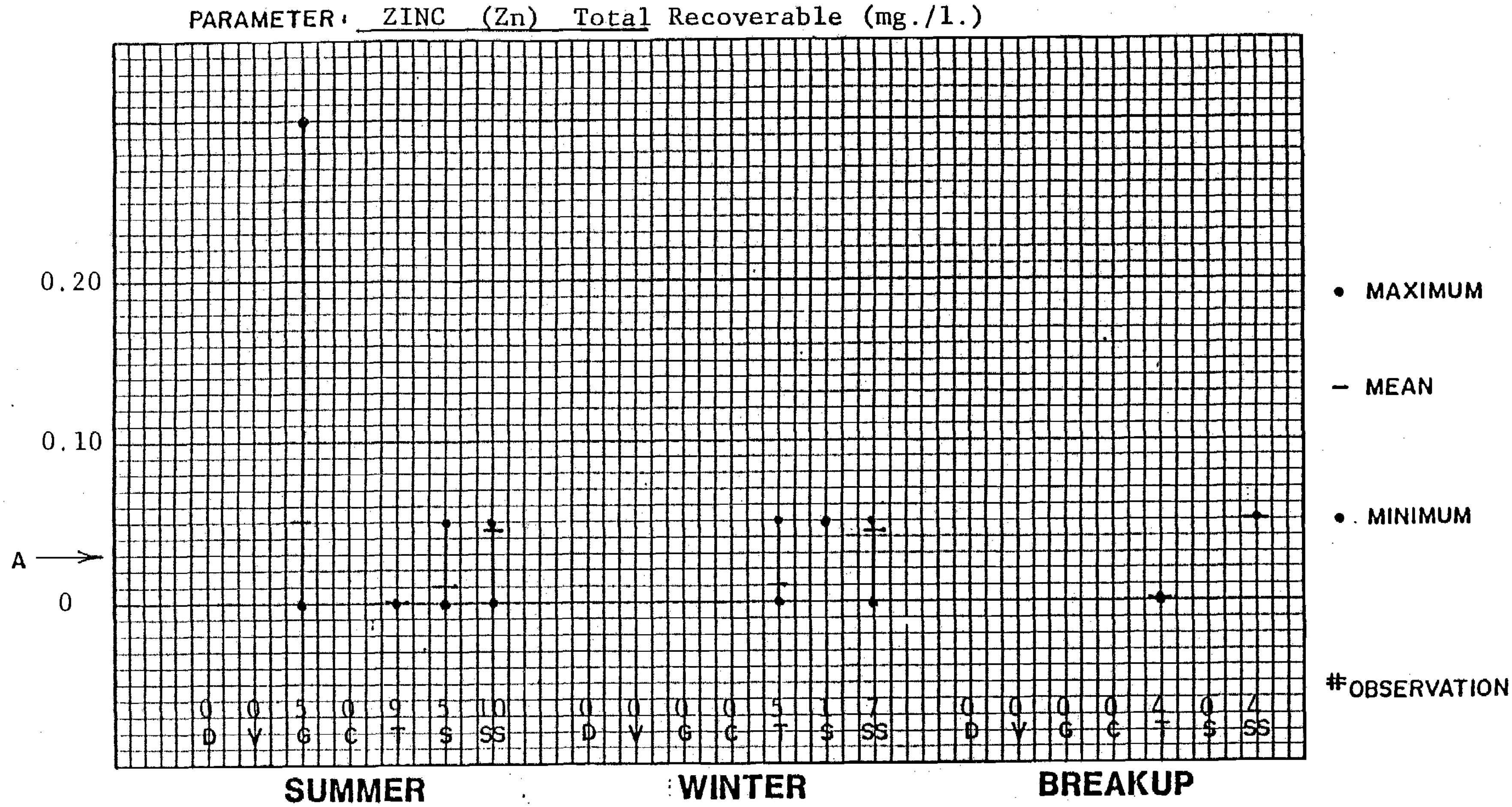
A. Less than 0.03 mg/l (McNeely, 1979)

B. 0.01 of the 96-hour LC_{50} determined through bioassay (EPA, 1976).

The suggested limit is based on human health effects.

DATA SUMMARY - ZINC (d)

FIGURE E.2.67



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

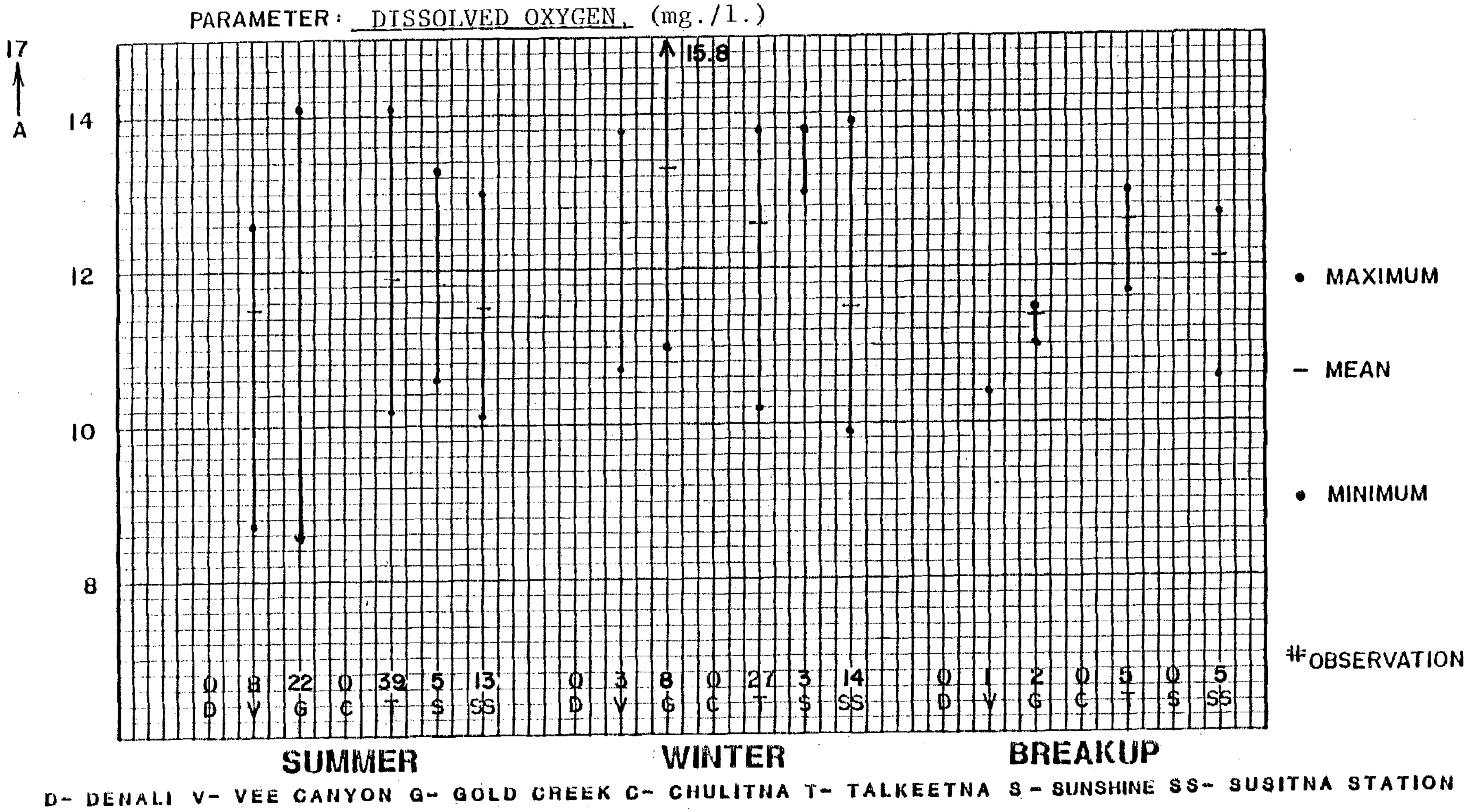
A. Less than 0.03 mg/l (McNeely, 1979).

B. 0.01 of the 96 - hour LC_{50} determined through bioassay (EPA, 1976).

Established to protect freshwater aquatic organisms.

DATA SUMMARY - ZINC (t)

FIGURE E.2.68

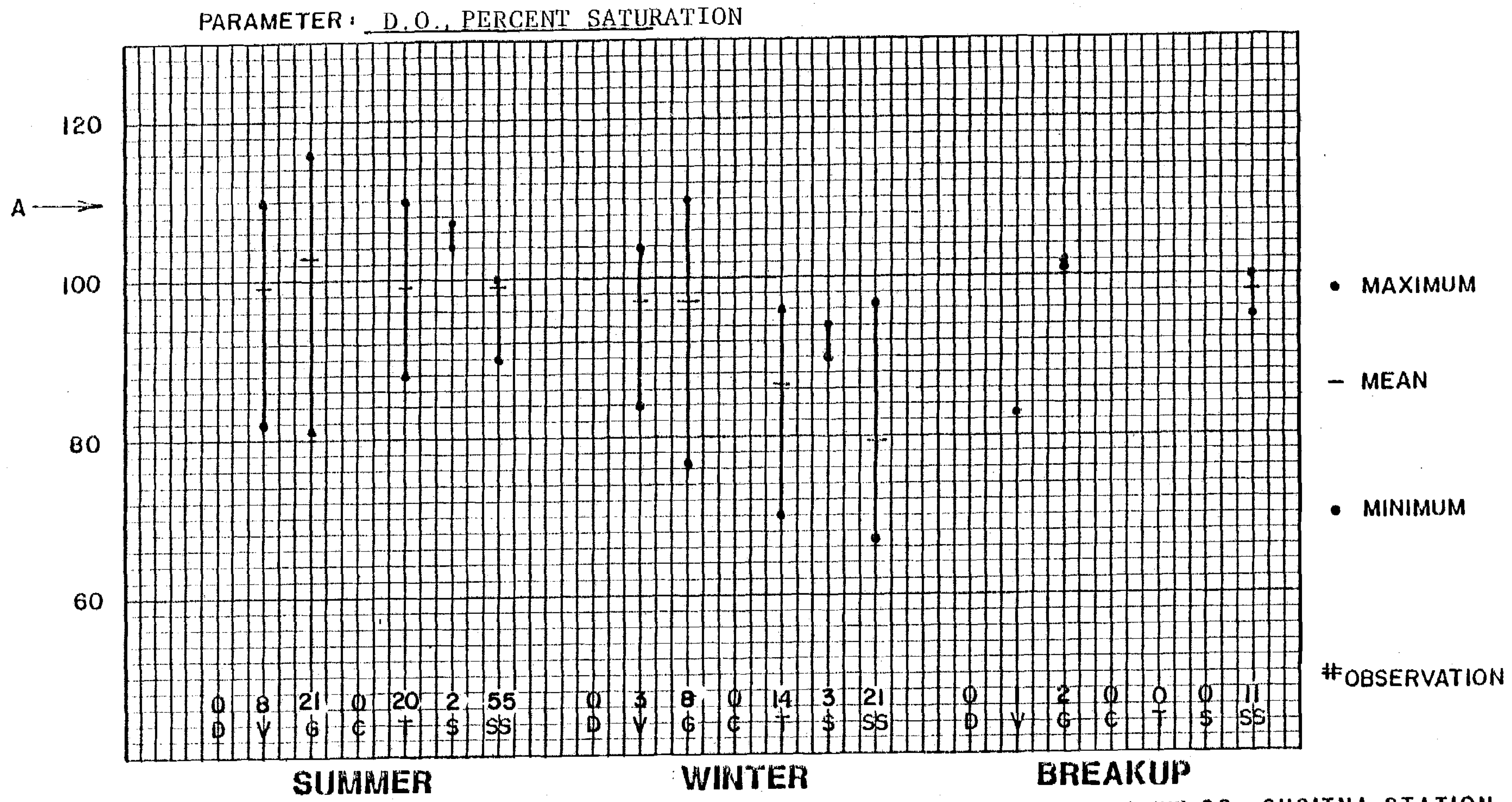


A. Greater than 7mg/l, but in no case shall D.O. exceed 17mg/l (ADEC, 1979).

Established for the protection of anadromous and resident fish.

DATA SUMMARY - OXYGEN, DISSOLVED

FIGURE E.2.69



D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S - SUNSHINE SS- SUSITNA STATION

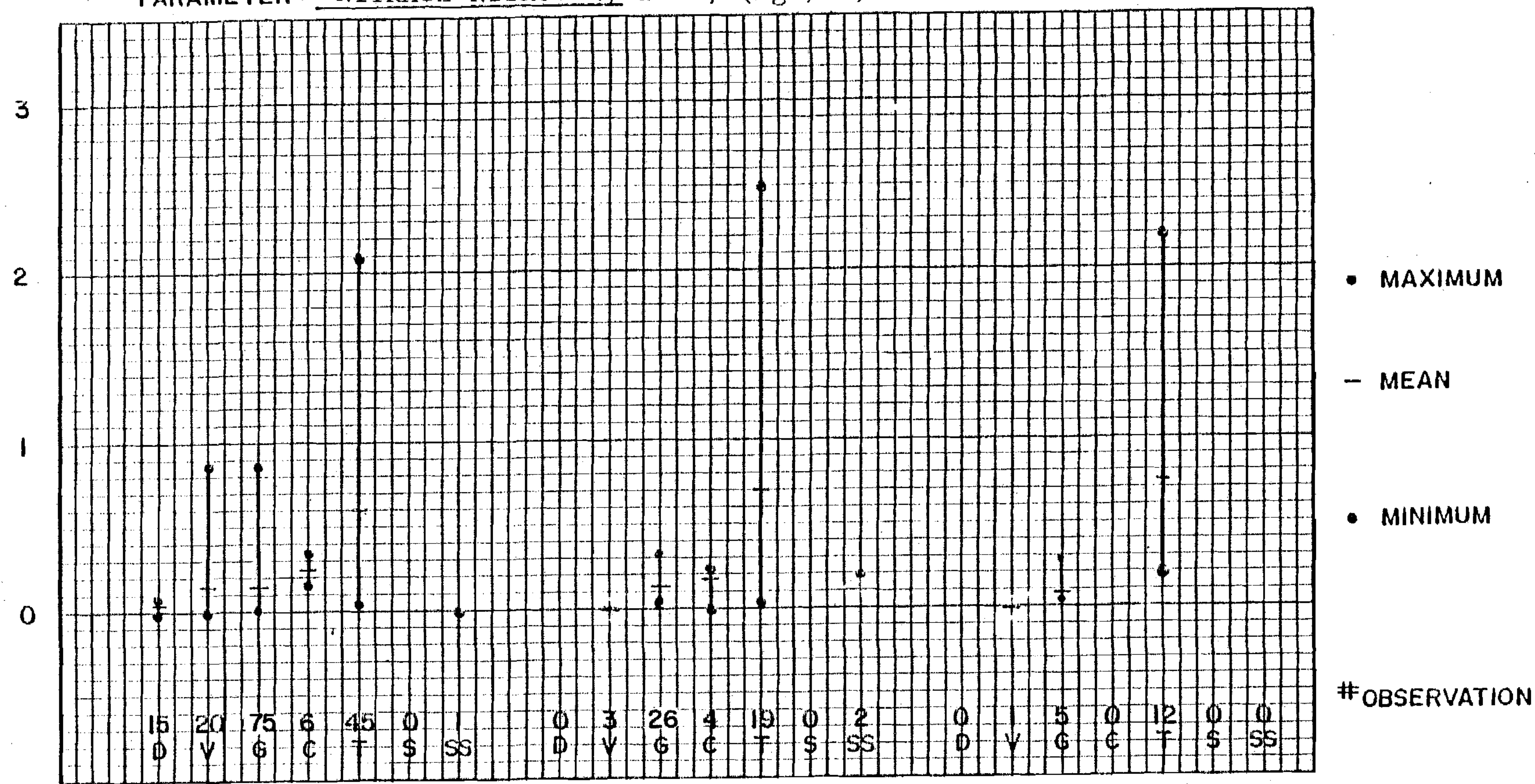
A. The concentration of total disolved gas shall not exceed 110% saturation at any point. (ADEC, 1979).

Established for the protection of anadromous and resident fish.

DATA SUMMARY - D.O., % SATURATION

FIGURE E.2.70

PARAMETER: NITRATE NITROGEN, as N, (mg./1.)



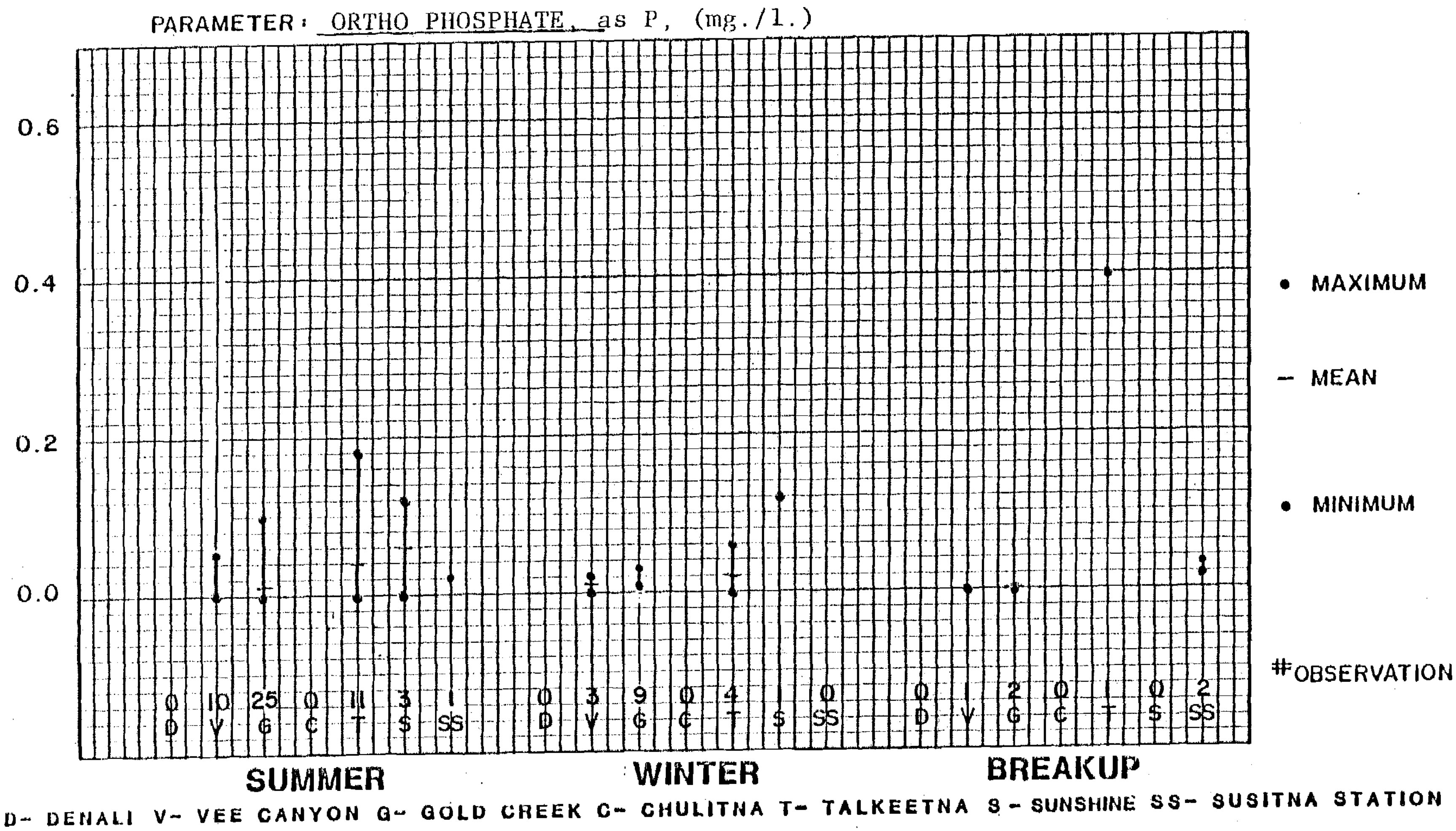
D- DENALI V- VEE CANYON G- GOLD CREEK C- CHULITNA T- TALKEETNA S- SUNSHINE SS- SUSITNA STATION

Less than 10 mg/l (water supply). (EPA, 1976).

Established to protect water supplies.

DATA SUMMARY - NITRATE NITROGEN

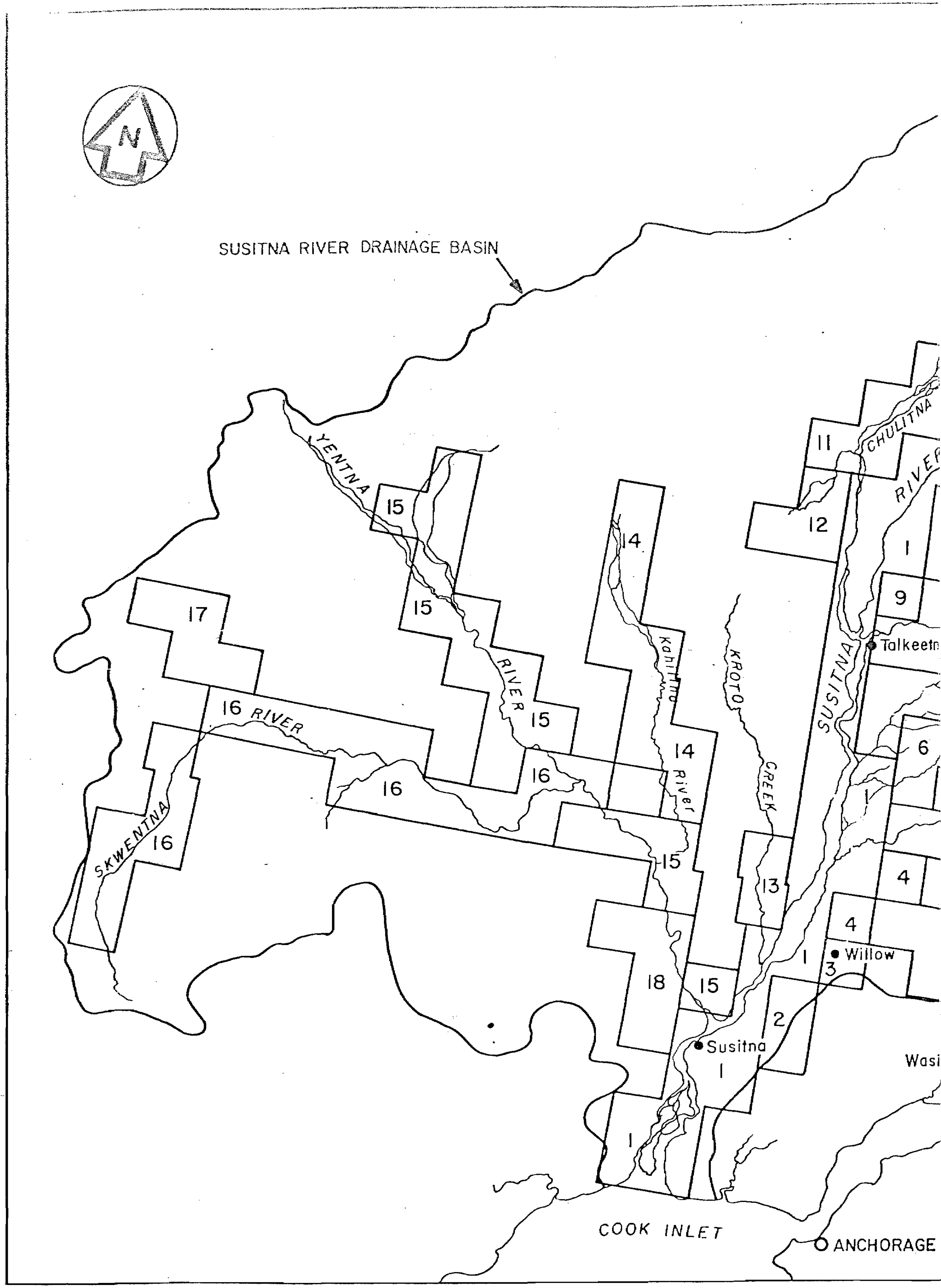
FIGURE E.2.71



No criterion established

DATA SUMMARY - ORTHO PHOSPHATE

FIGURE E.2.72


N
SUSITNA RIVER DRAINAGE BASIN
YENTNA
RIVER
CHULITNA
RIVER
SUSITNA
Kahiltna
River
KROTO
CREEK
SKWENTNA
16 RIVER
Talkeetna
Willow
Susitna
Wasi
COOK INLET
ANCHORAGE
11
12
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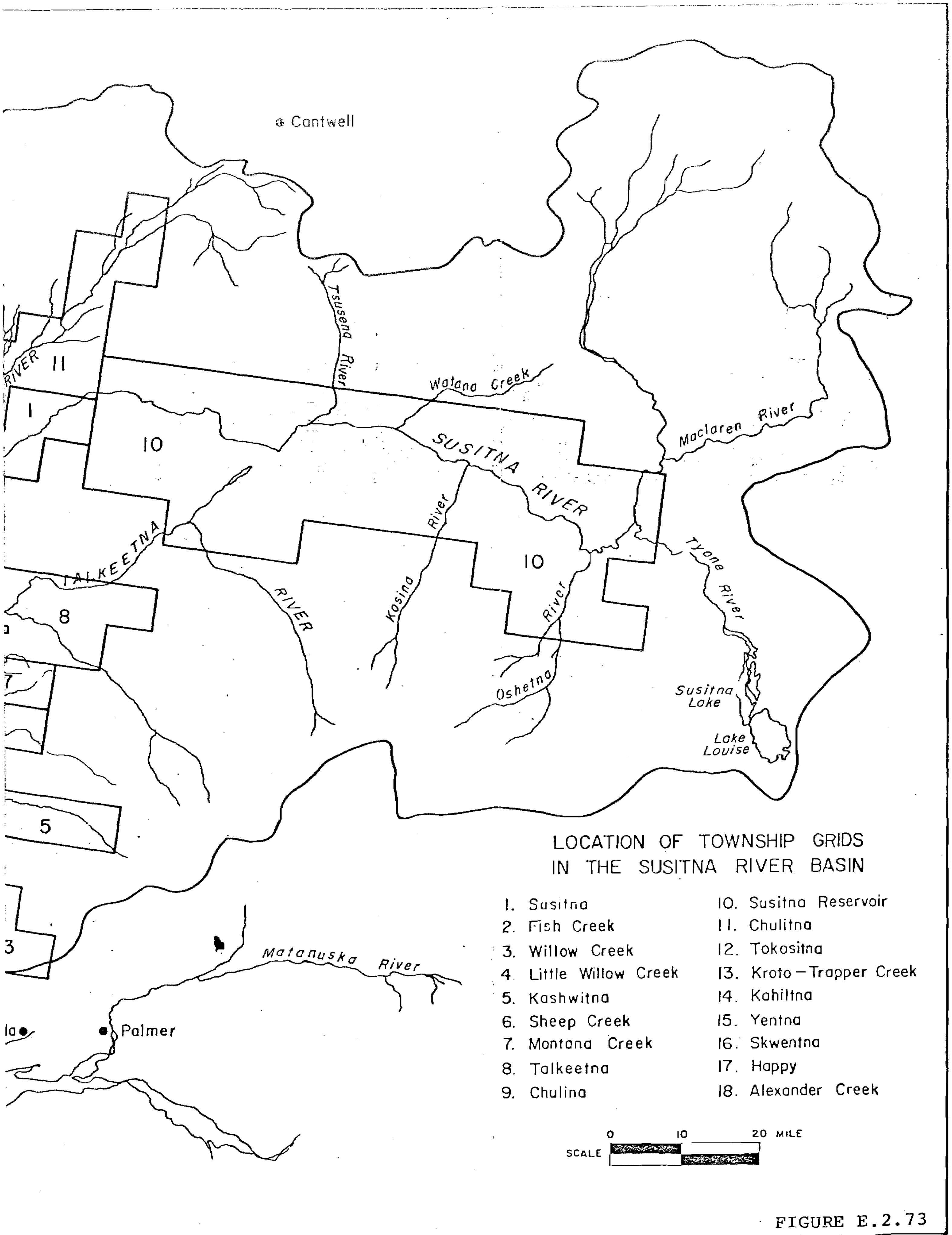
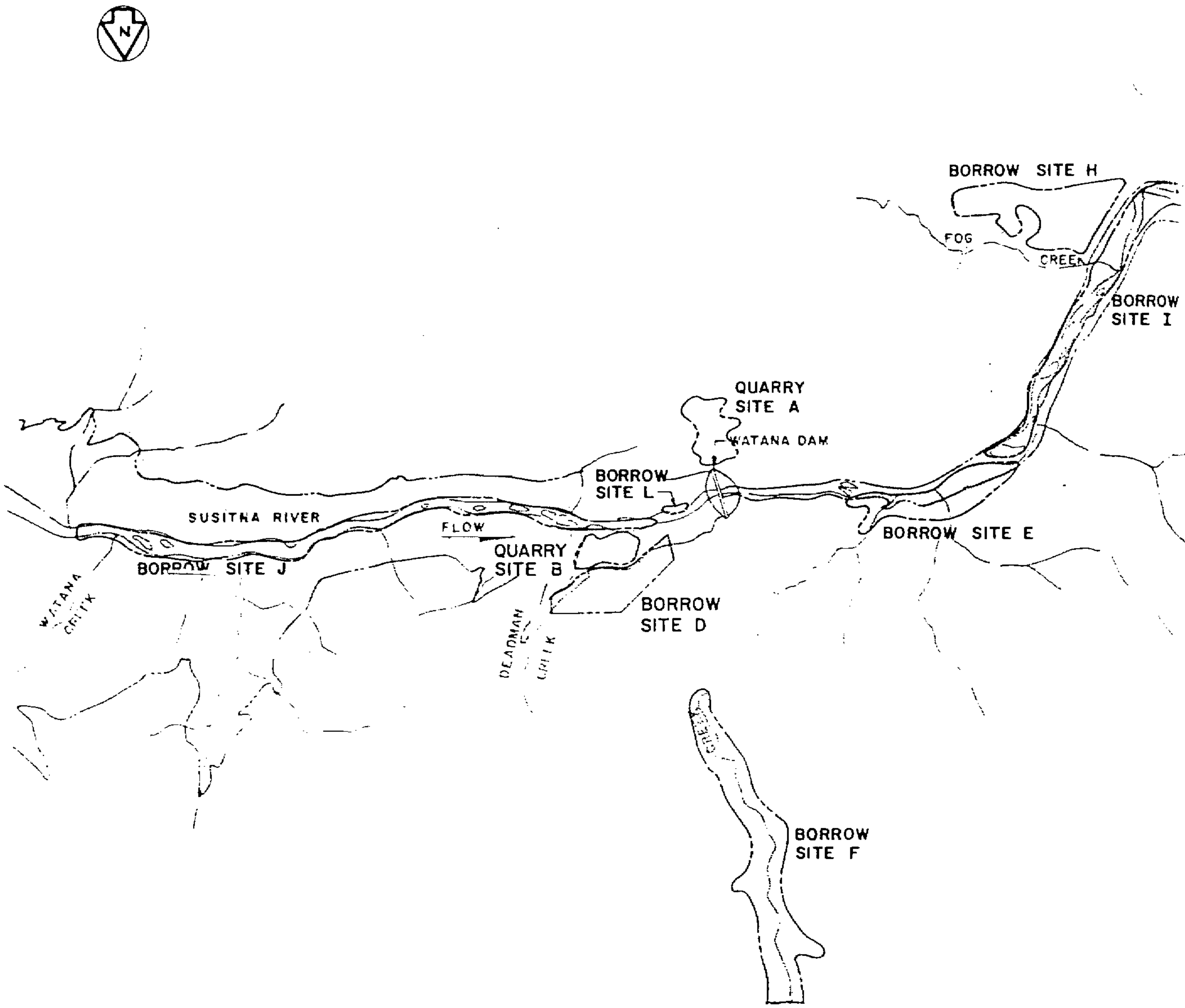


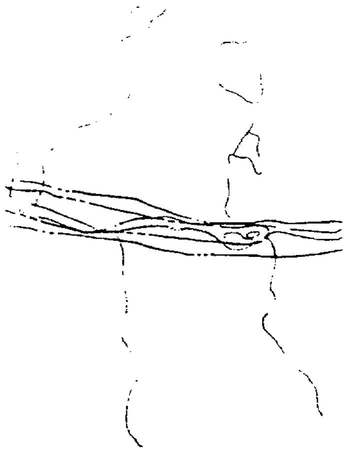
LOCATION OF TOWNSHIP GRIDS IN THE SUSITNA RIVER BASIN

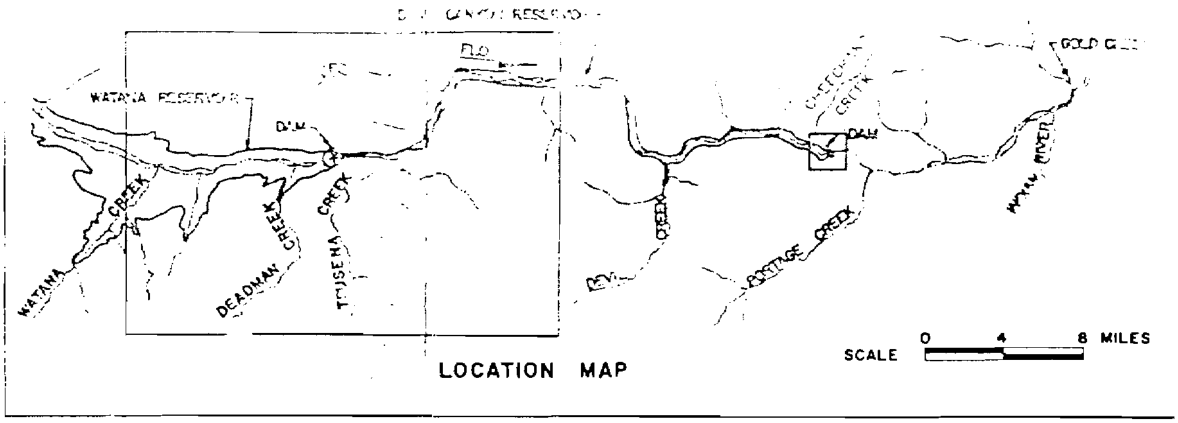
FIGURE E.2.73



N
BORROW SITE H
FOG CREEK
BORROW SITE I
QUARRY SITE A
WATANA DAM
BORROW SITE L
SUSITNA RIVER
FLOW
QUARRY SITE B
BORROW SITE E
BORROW SITE J
WATANA CREEK
DEADMAN CREEK
BORROW SITE D
CREEK
BORROW SITE F

BOR





LOCATION MAP

LEGEND

BORROW / QUARRY LIMITS

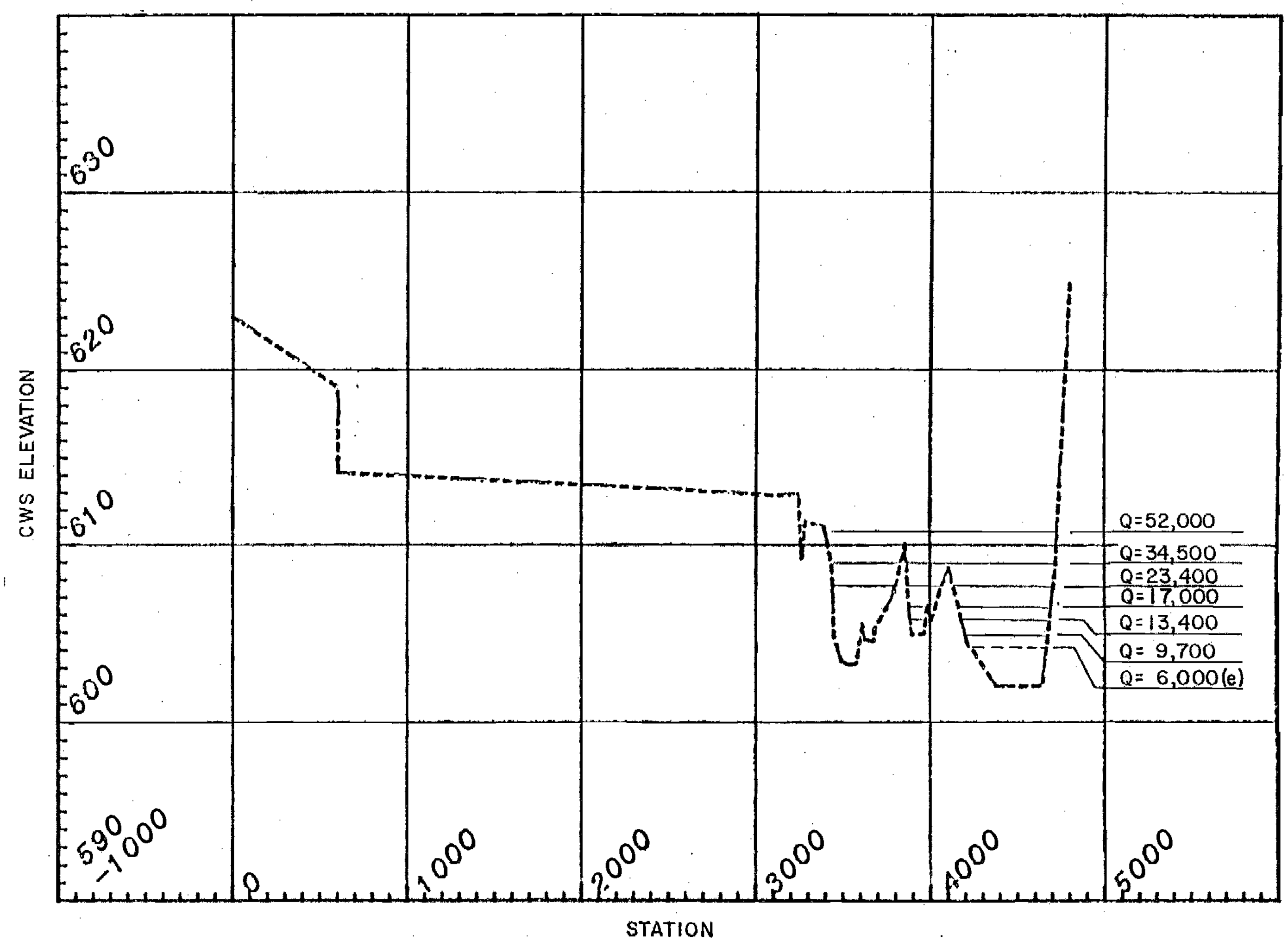
NOTE

1. MAP INDEX SHOWN ON FIGURE 6.1

SCALE 0 1 2 MILES

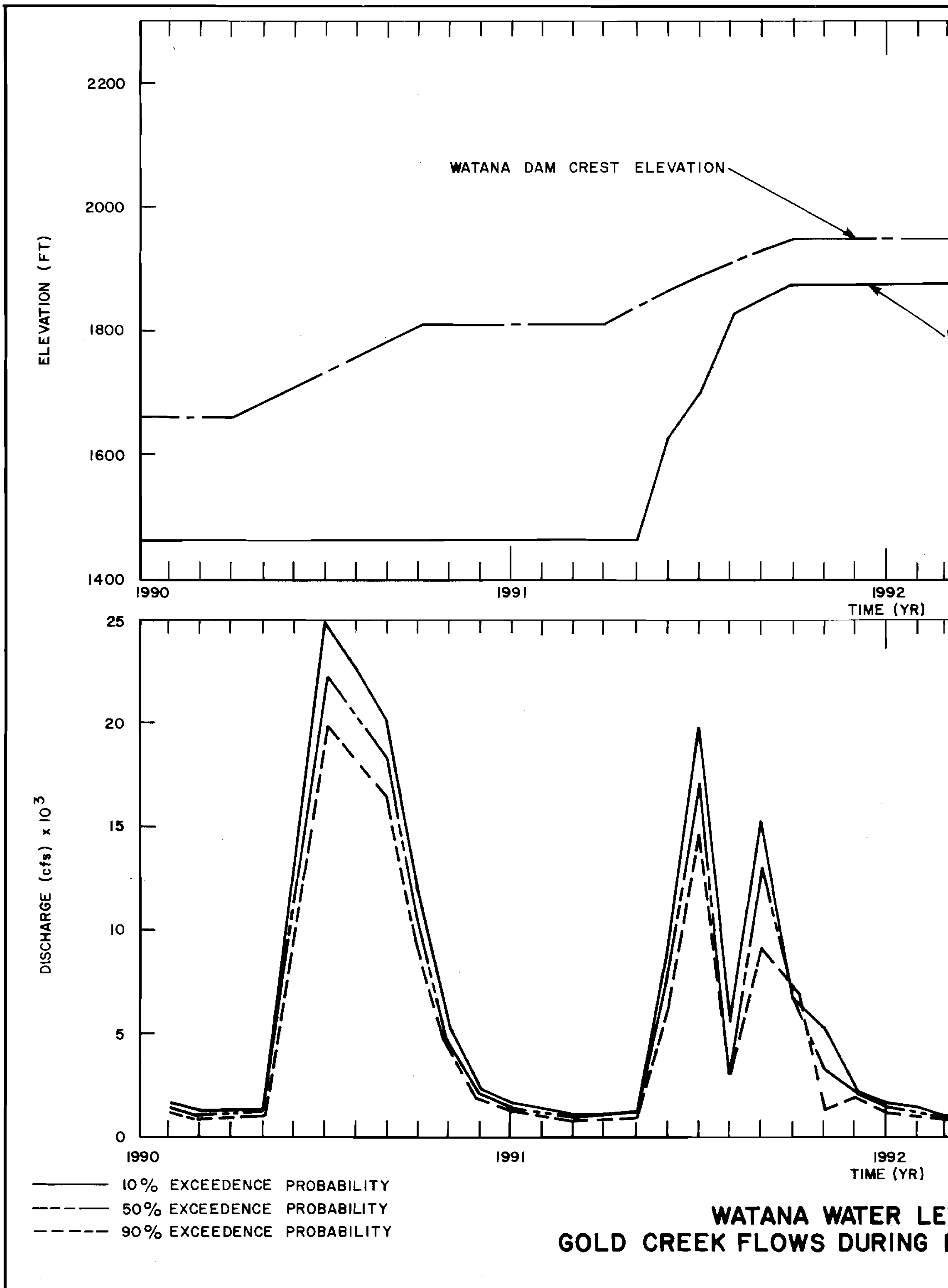
WATANA
RROW SITE MAP

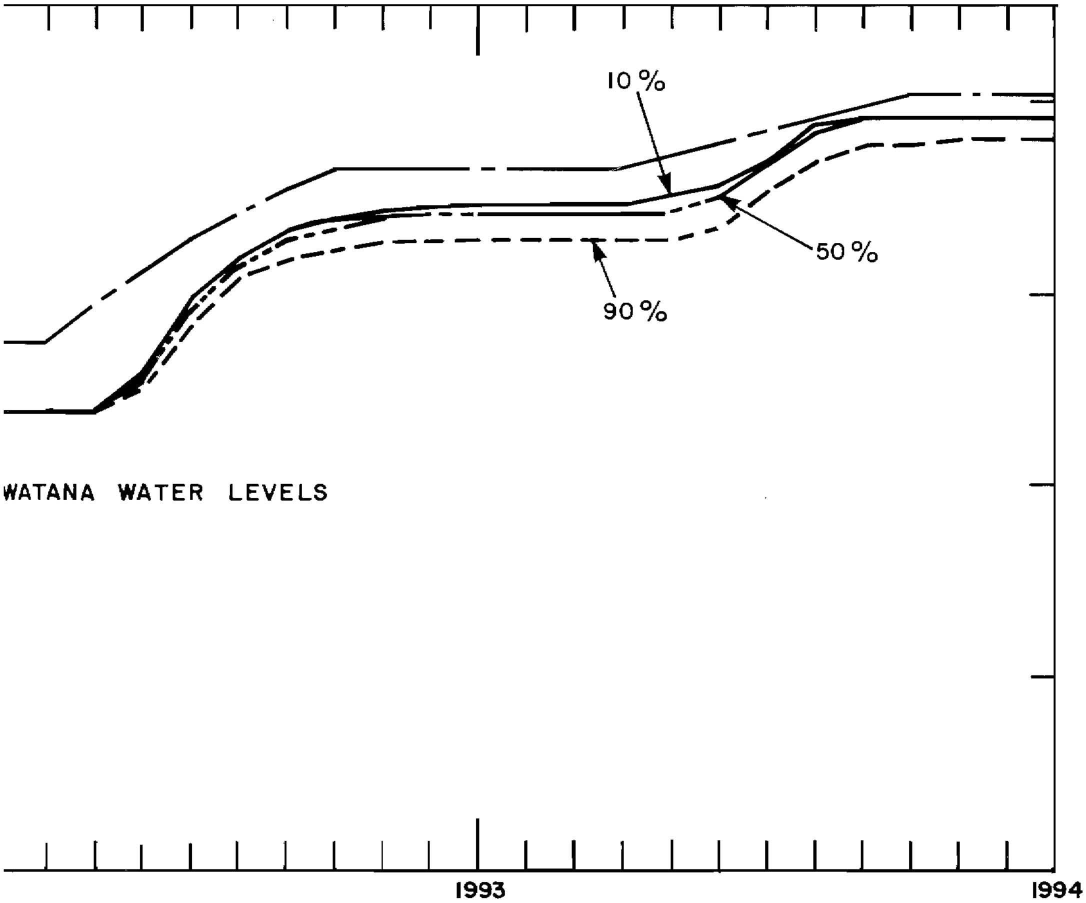
FIGURE E.2.74

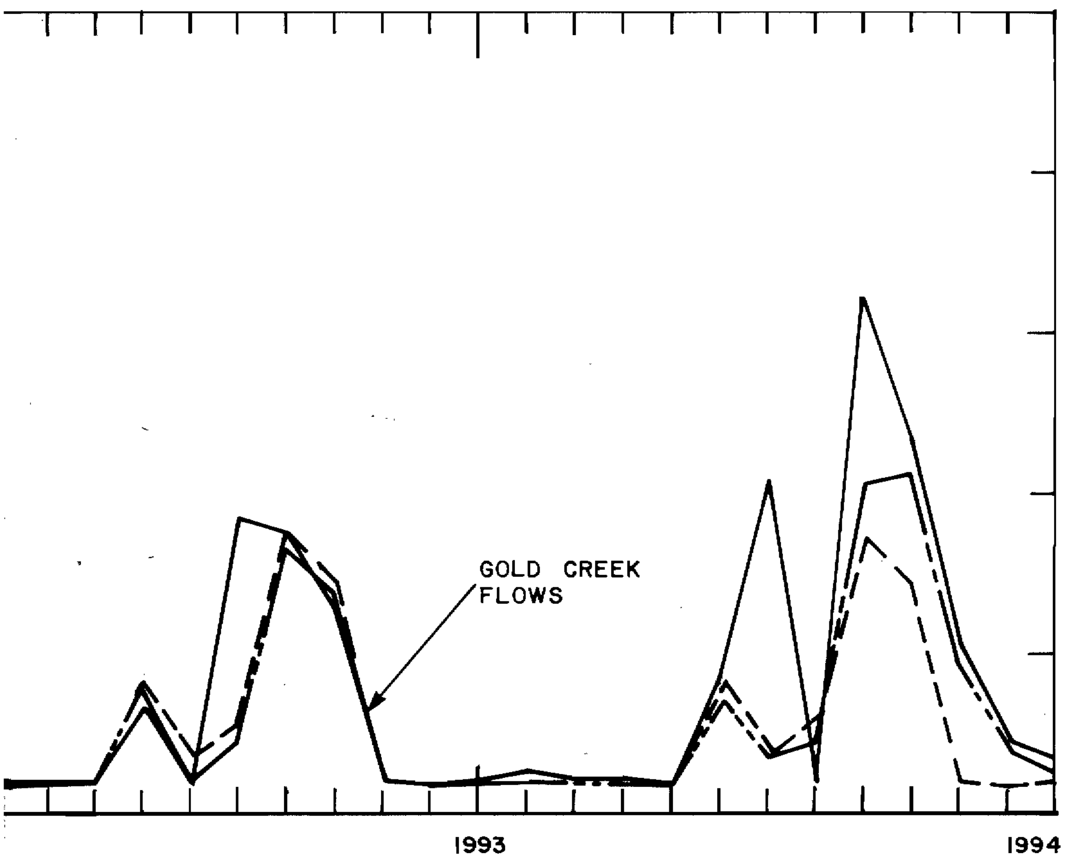


CROSS-SECTION NUMBER 32
RM 130

FIGURE E.2.75

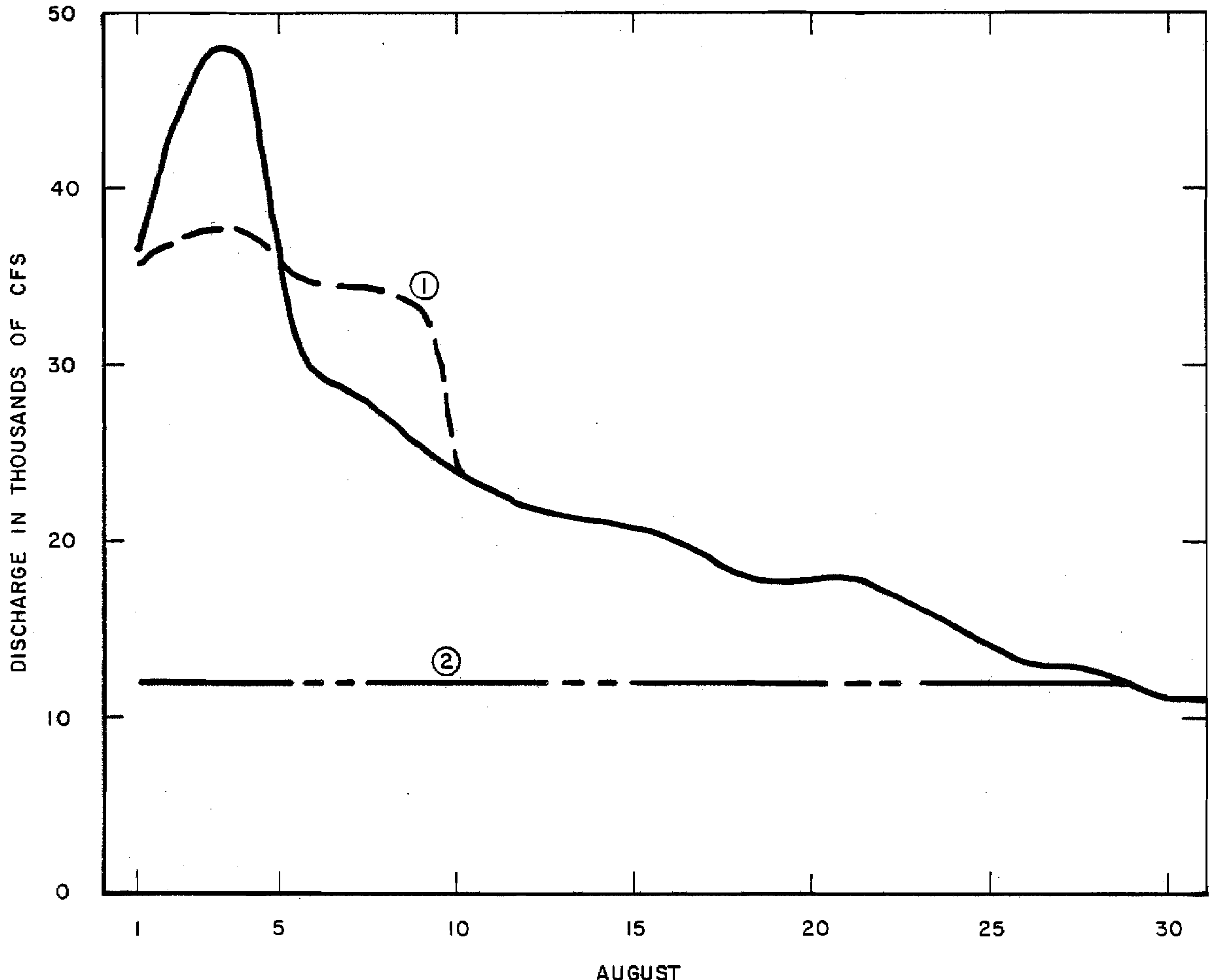

WATANA DAM CREST ELEVATION
ELEVATION (FT)
2200
2000
1800
1600
1400
1990
1991
1992
TIME (YR)
DISCHARGE (cfs) x 10³
25
20
15
10
5
0
1990
1991
1992
TIME (YR)
10% EXCEEDENCE PROBABILITY
50% EXCEEDENCE PROBABILITY
90% EXCEEDENCE PROBABILITY
WATANA WATER LE
GOLD CREEK FLOWS DURING I





VELS AND
RESERVOIR FILLING

FIGURE E.2.76



LEGEND:

AUGUST 1958 FLOWS

① FILLING SEQUENCE 1, AUGUST 1958 FLOWS – WATANA MINIMUM STORAGE CRITERIA VIOLATED

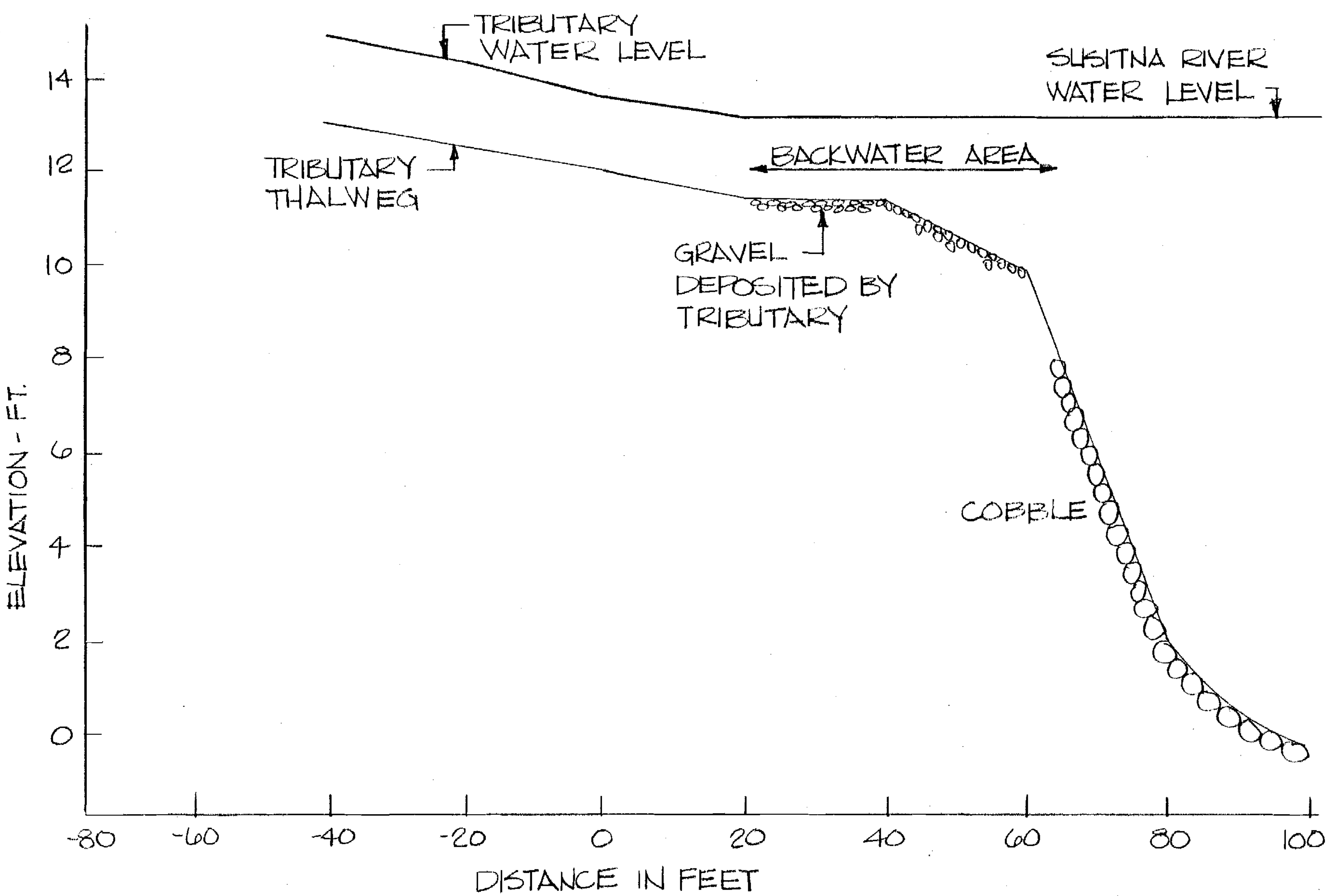
② FILLING SEQUENCE 2, AUGUST 1958 FLOWS – WATANA CAPABLE OF ABSORBING HYDROGRAPH

NOTES:

1. WATANA FLOW 84% OF GOLD CREEK FLOW
2. RESERVOIR FILLING CRITERIA EXCEEDED AUGUST WITH SEQUENCE ②
3. NEGLIGIBLE CHANGE IN DAM HEIGHT DURING FLOOD EVENT
4. MAXIMUM RELEASE AT WATANA 30,000 CFS

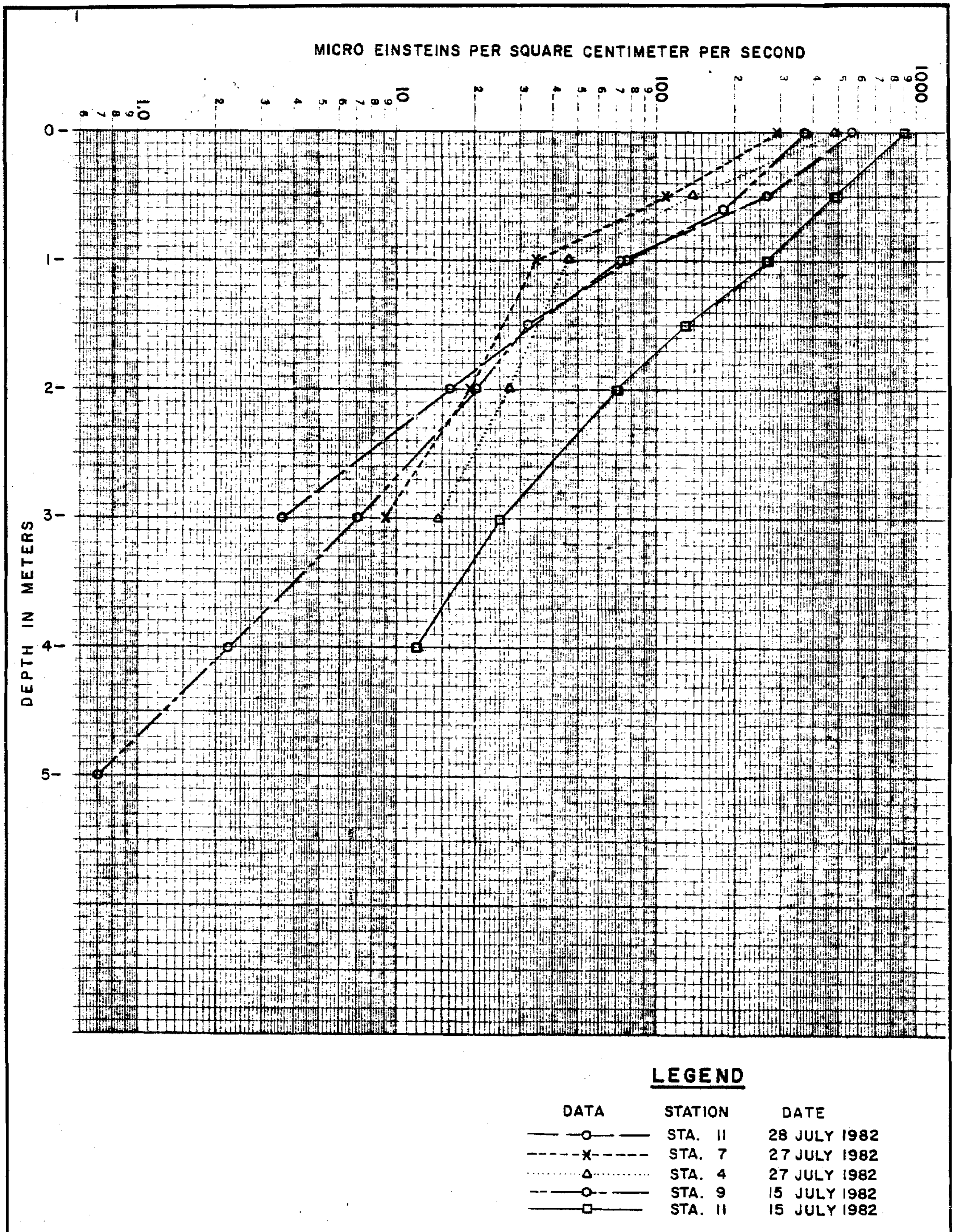
FLOW VARIABILITY
NATURAL AND FILLING CONDITIONS
DISCHARGE AT GOLD CREEK

FIGURE E.2.78



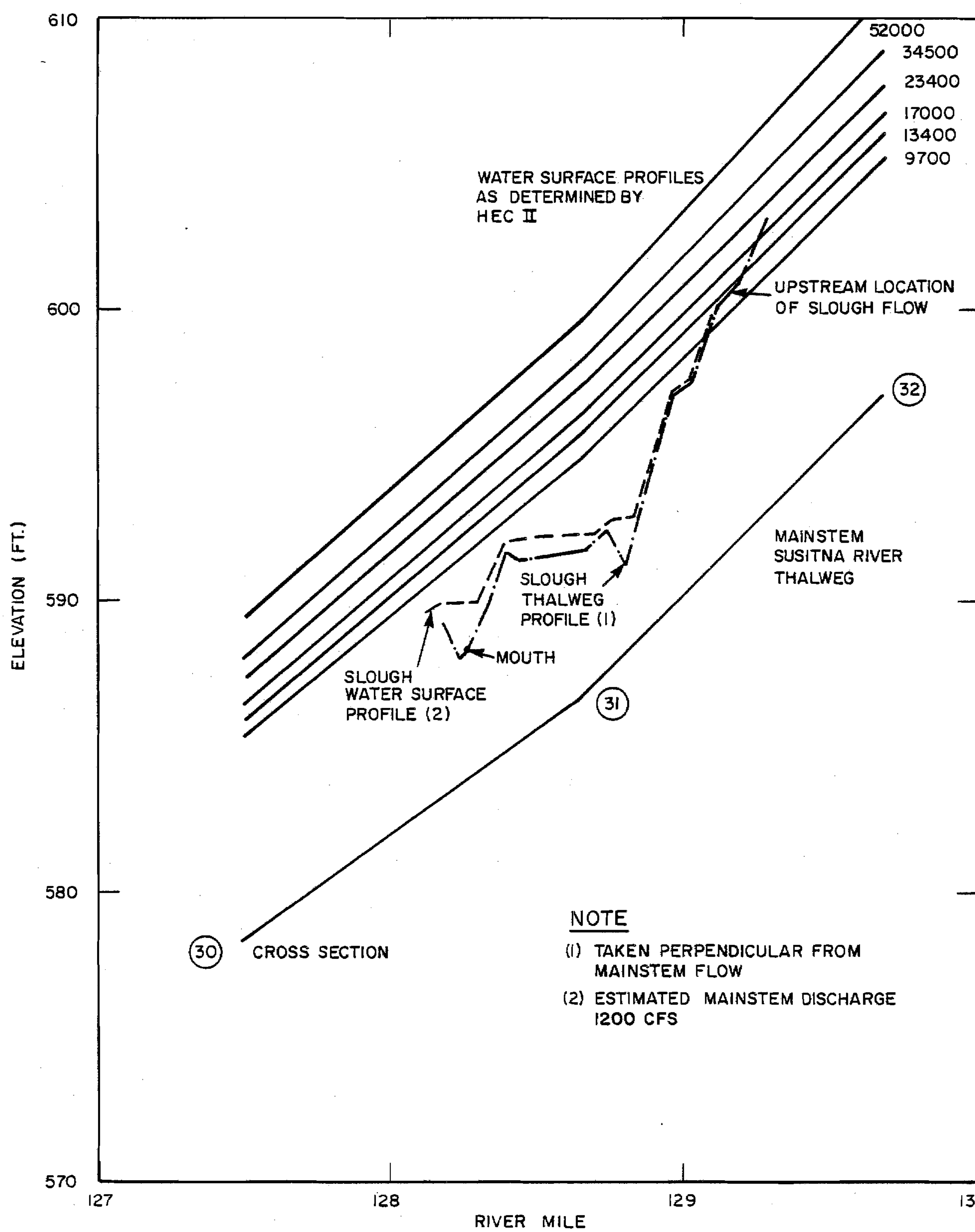
SCHEMATIC OF THE EFFECT OF THE SUSITNA RIVER ON A TYPICAL TRIBUTARY MOUTH

FIGURE E.2.79



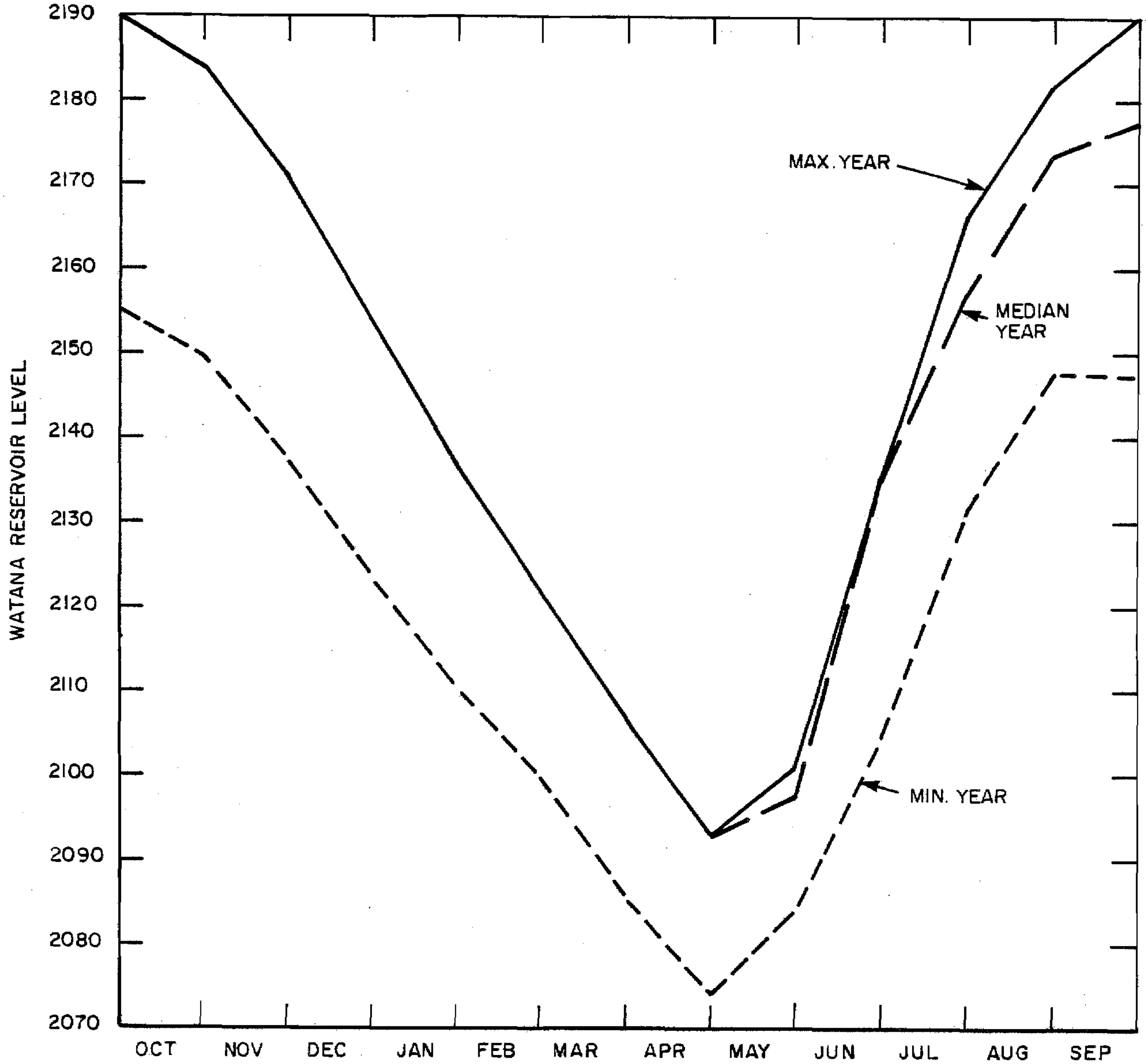
EKLUTNA LAKE
LIGHT EXTINCTION
IN SITU MEASUREMENTS

FIGURE E.2.80



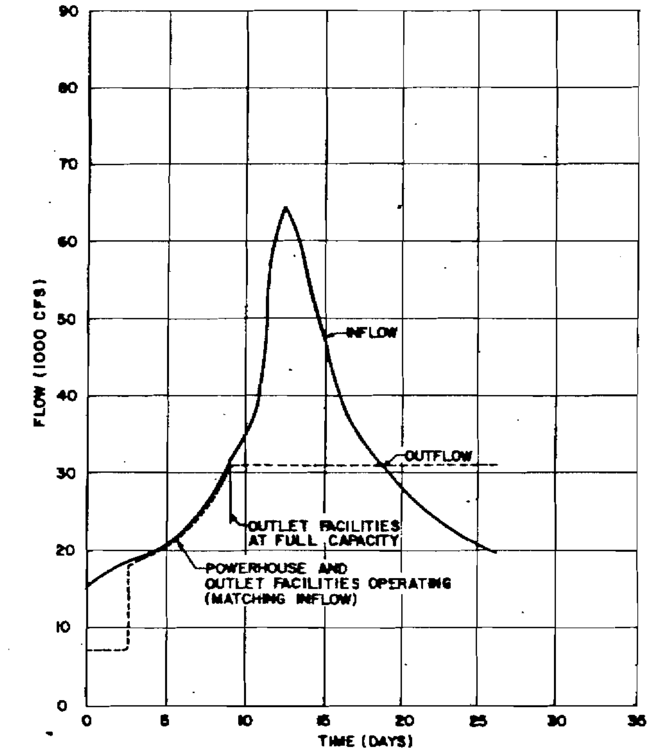
SLOUGH 9 THALWEG PROFILE AND SUSITNA RIVER MAINSTEM WATER SURFACE PROFILES

FIGURE E.2.81

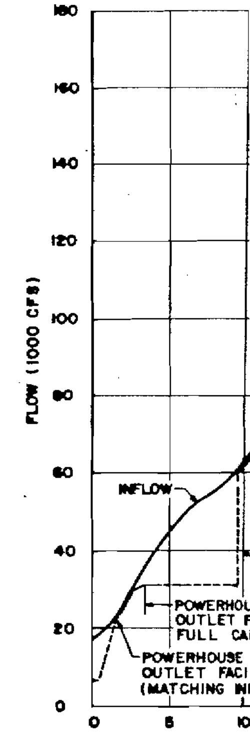


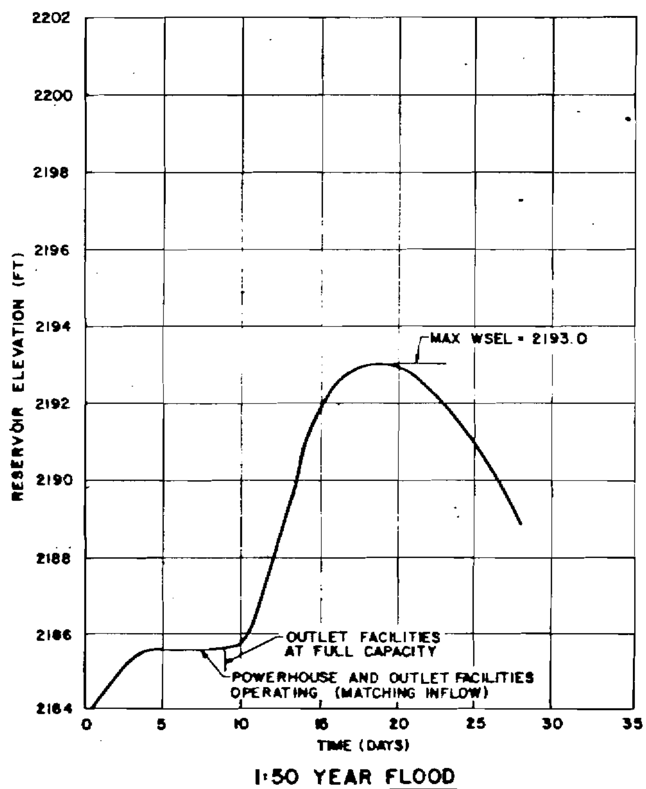
WATANA RESERVOIR WATER LEVELS
(WATANA ALONE)

FIGURE E.2.82

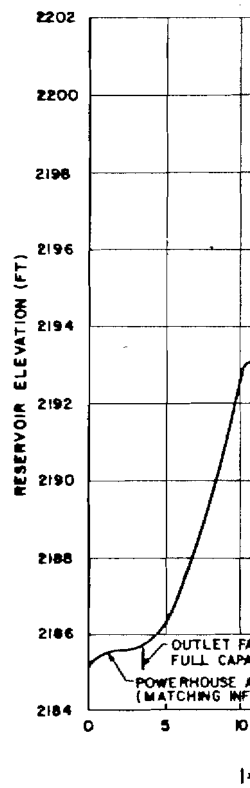


1:50 YEAR FLOOD
(SUMMER)

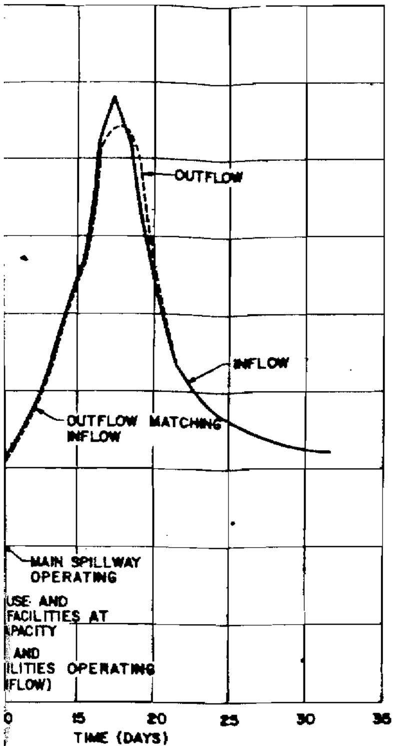




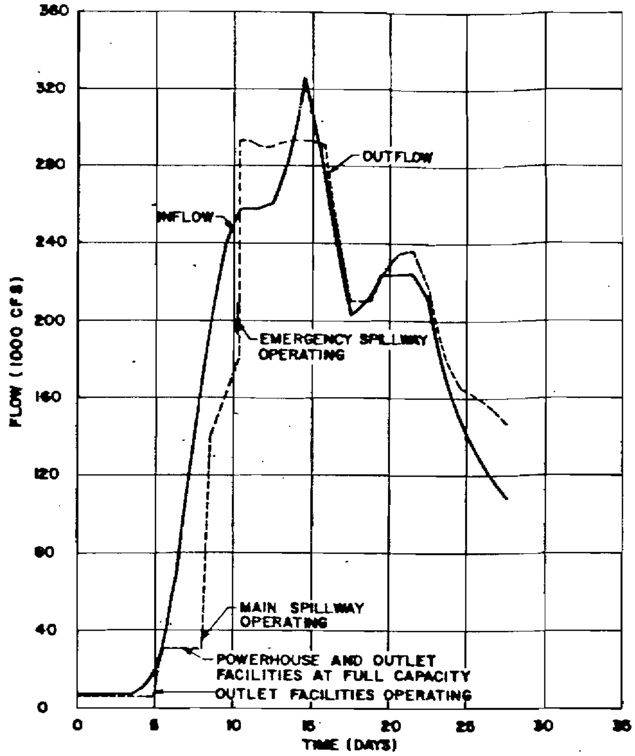
1:50 YEAR FLOOD
(SUMMER)



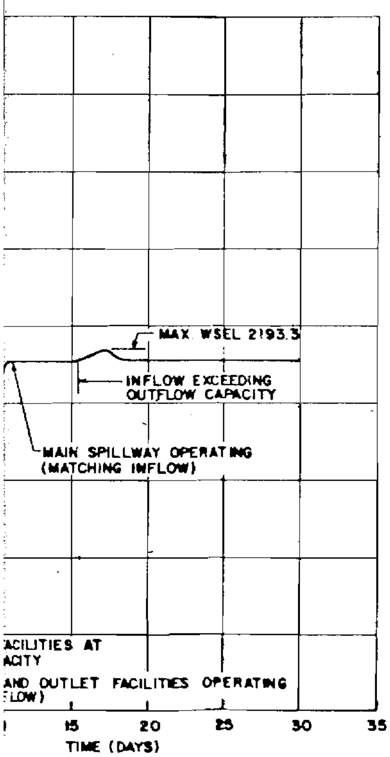
W
HYDROL
S



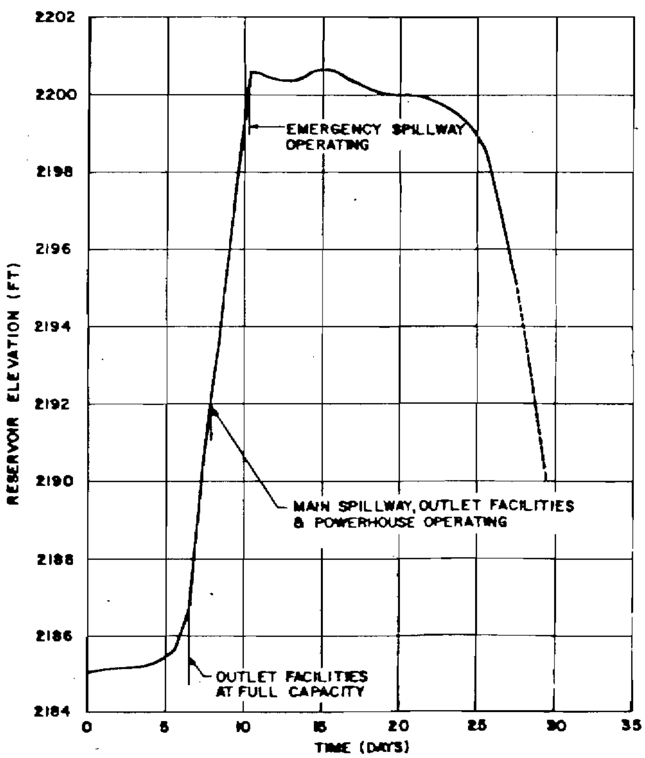
1:10,000 YEAR FLOOD



PROBABLE MAXIMUM FLOOD



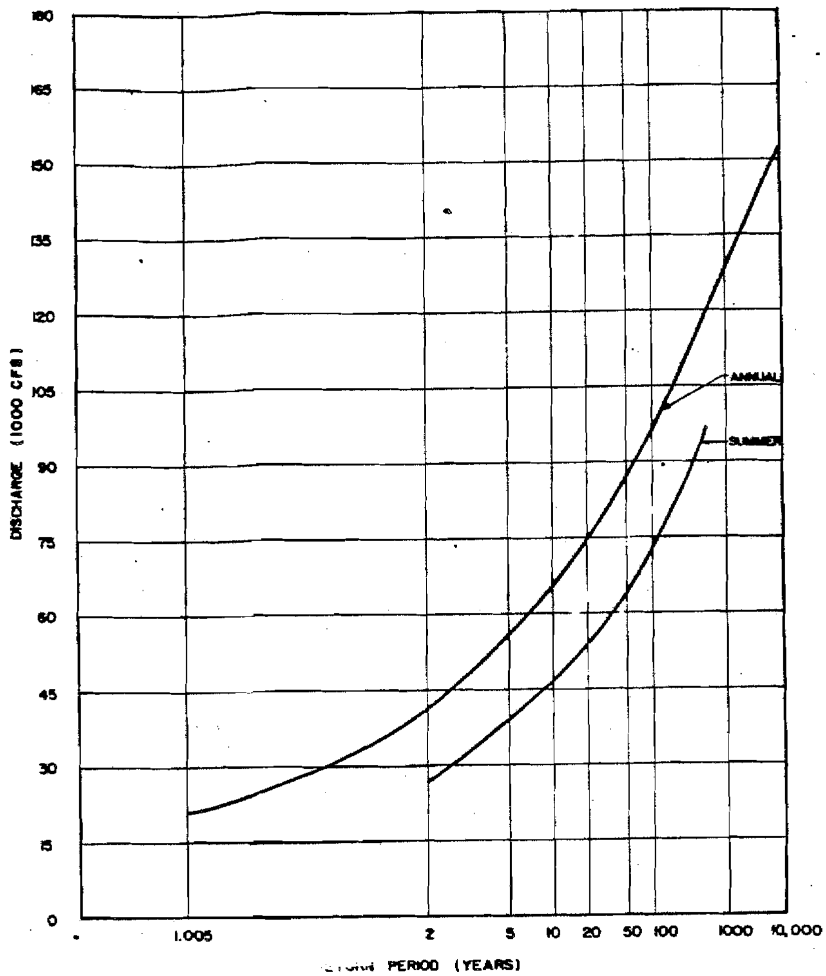
1:10,000 YEAR FLOOD



PROBABLE MAXIMUM FLOOD

WATANA
LOGICAL DATA
HEET 2

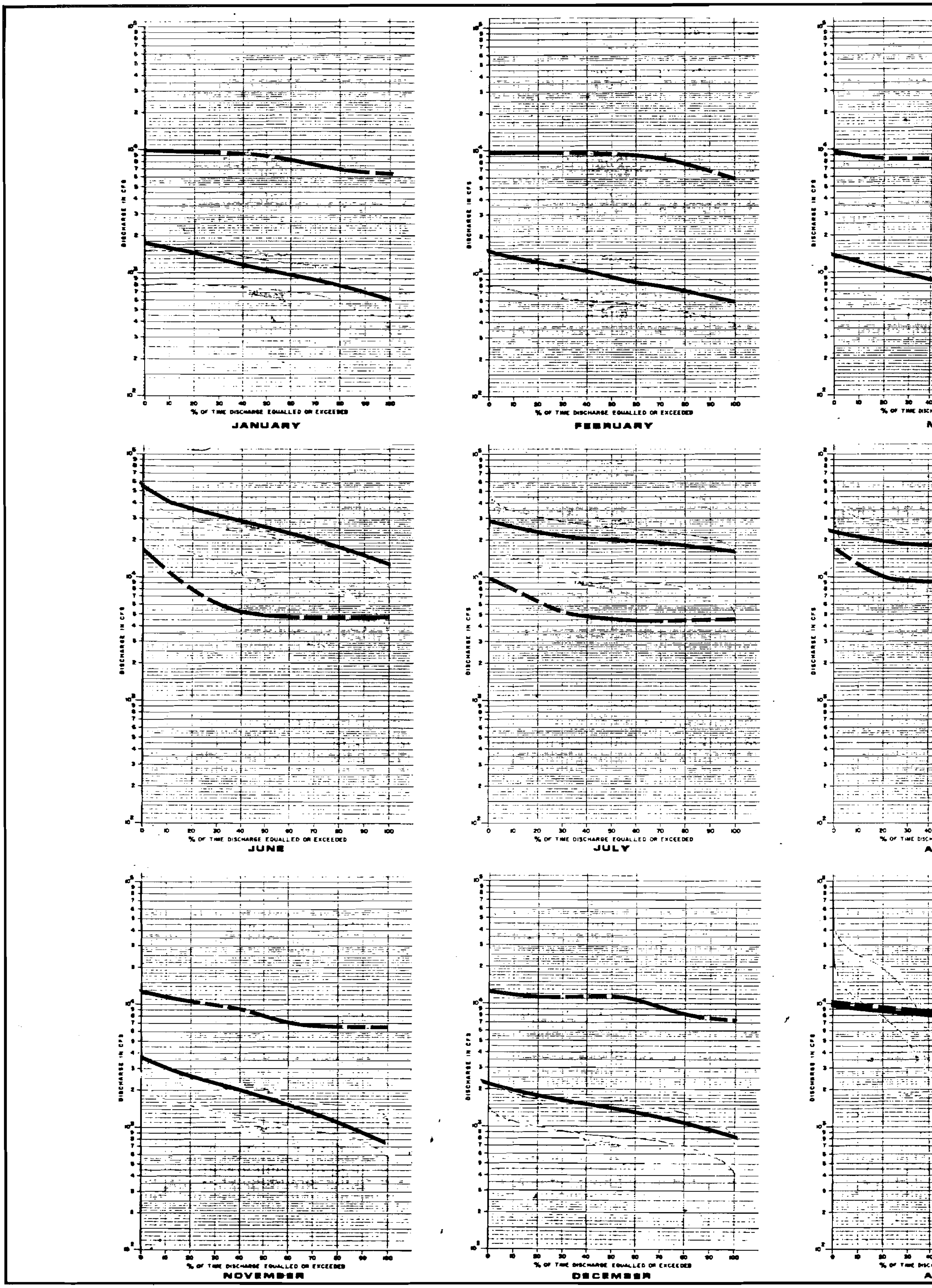
FIGURE E.2.83

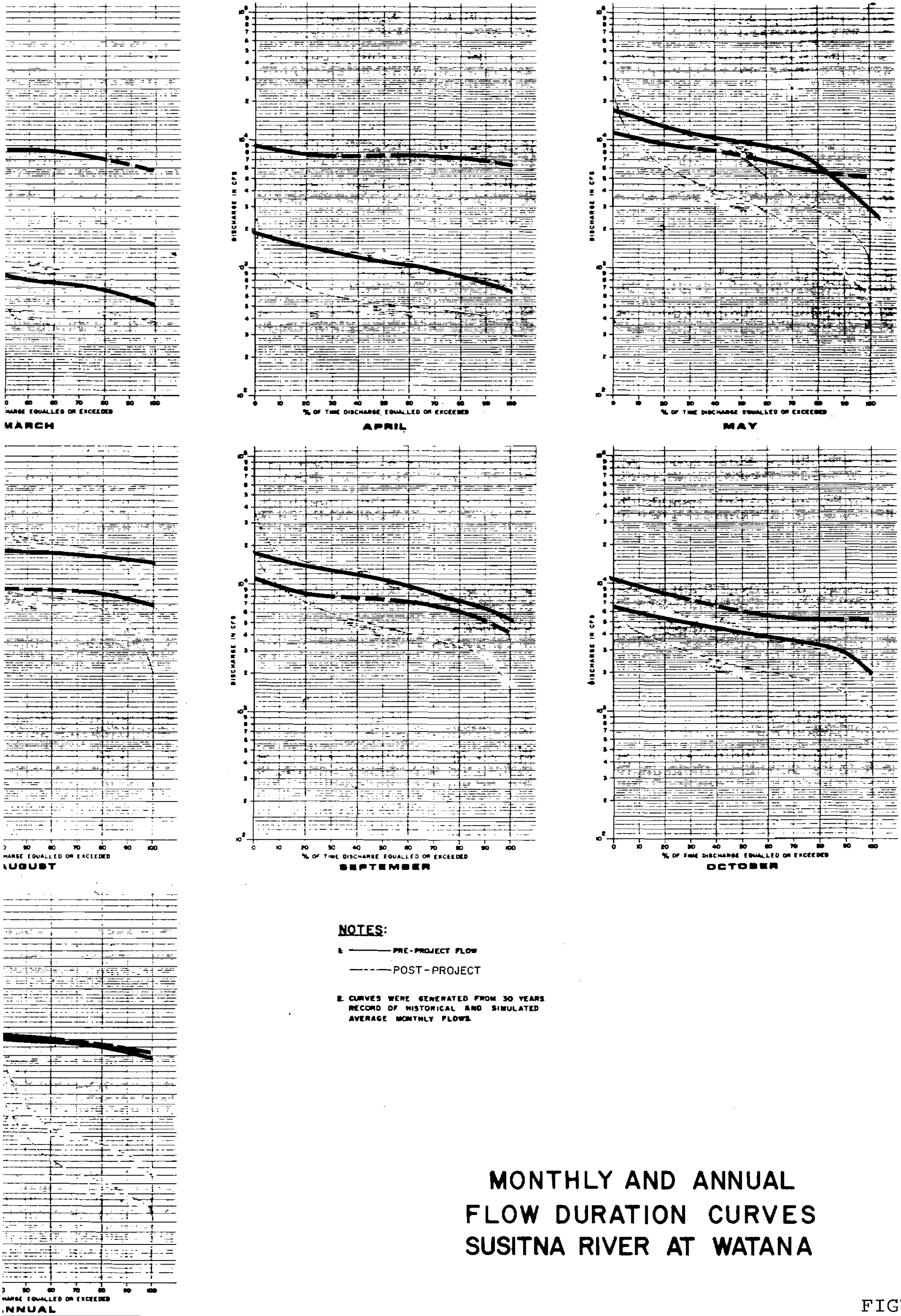


INFLOW FLOOD FREQUENCY

WATANA
INFLOW FLOOD FREQUENCY

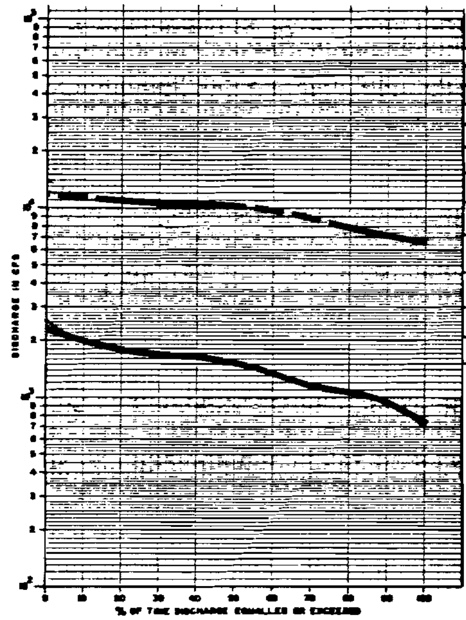
FIGURE E.2.84


DISCHARGE IN CFS
% OF TIME DISCHARGE EQUALLED OR EXCEEDED
JANUARY
FEBRUARY
JUNE
JULY
NOVEMBER
DECEMBER

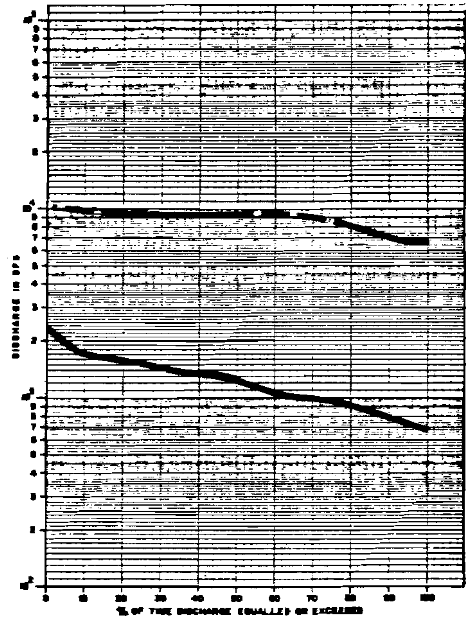


MONTHLY AND ANNUAL
FLOW DURATION CURVES
SUSITNA RIVER AT WATANA

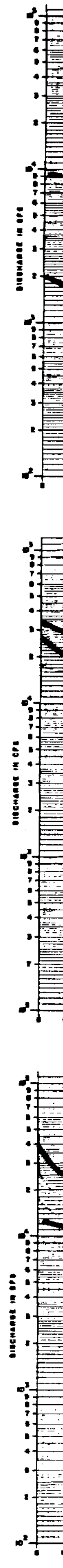
FIGURE E.2.85

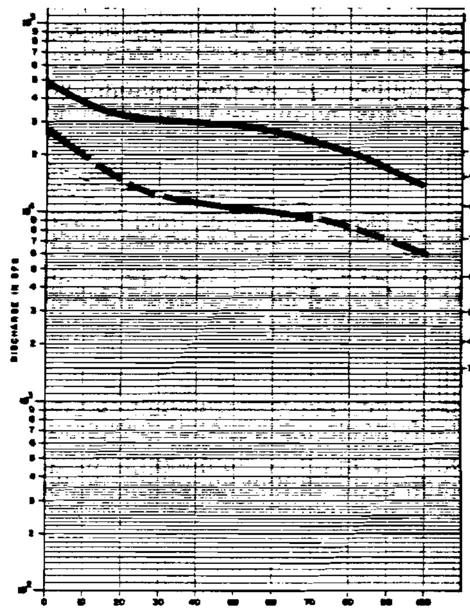


JANUARY



FEBRUARY





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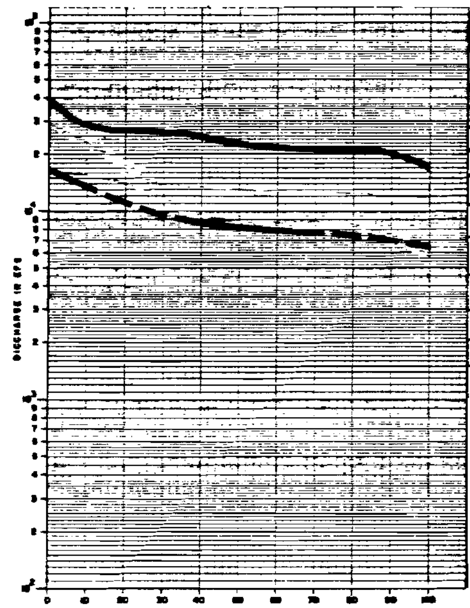
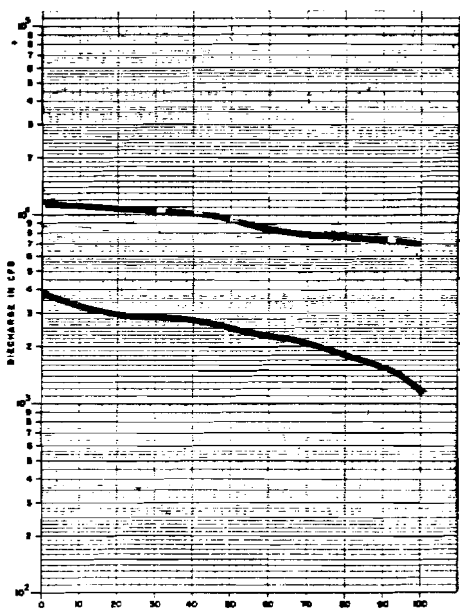


JULY



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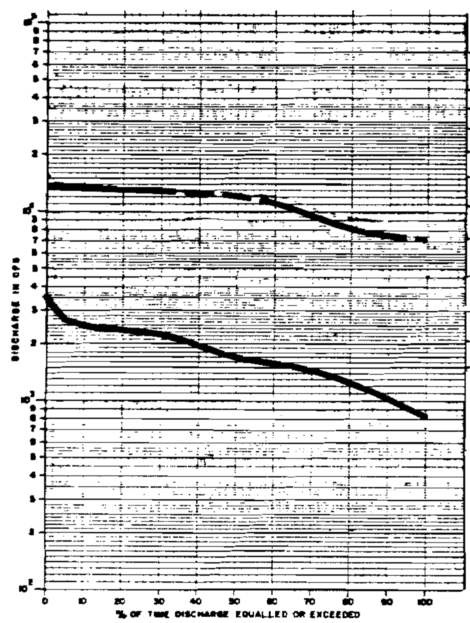
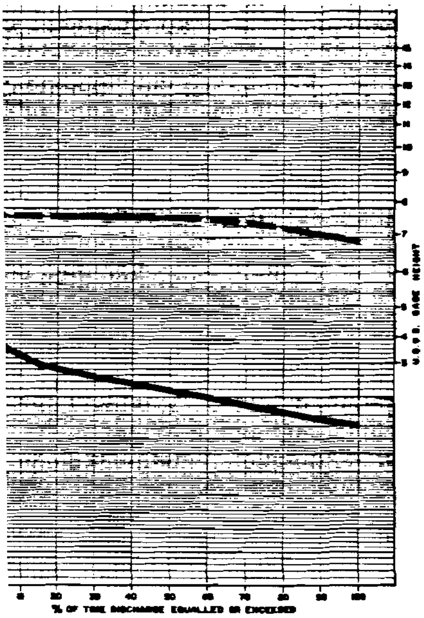
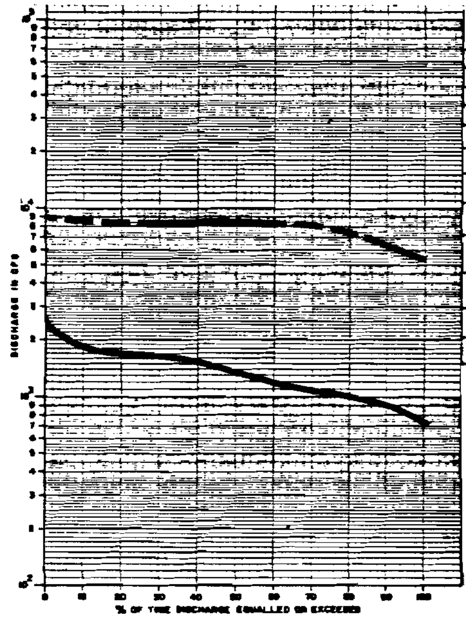


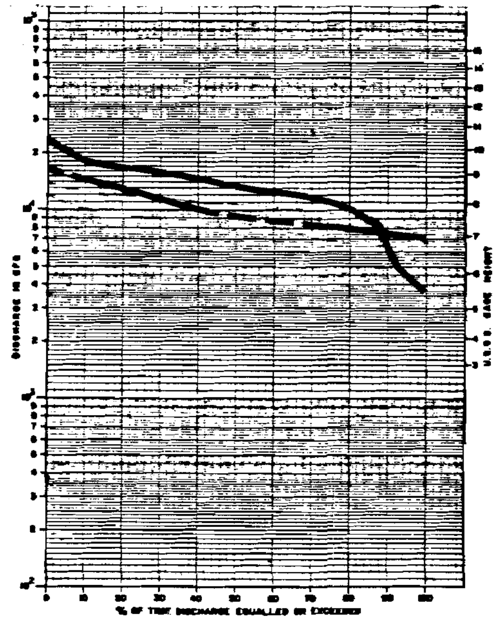
DECEMBER



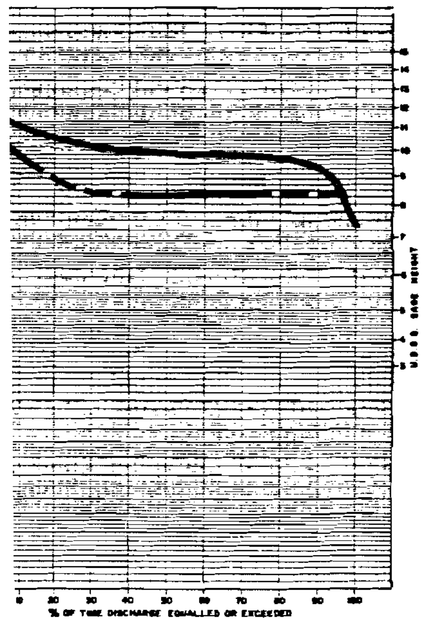
MARCH



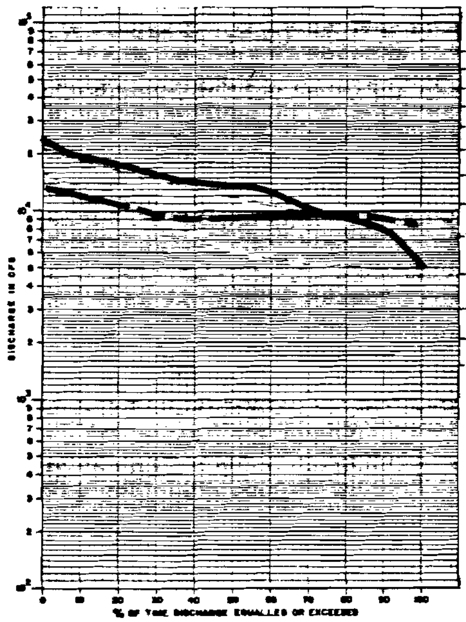
APRIL



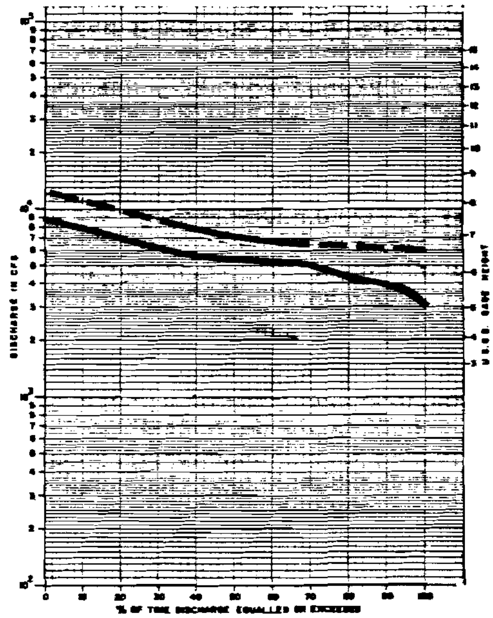
MAY



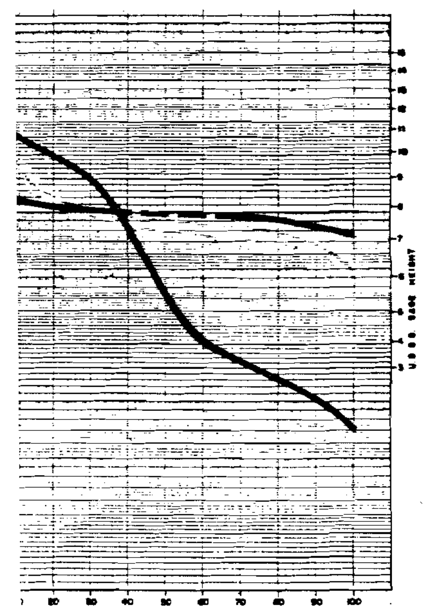
AUGUST



SEPTEMBER



OCTOBER



ANNUAL

NOTES:

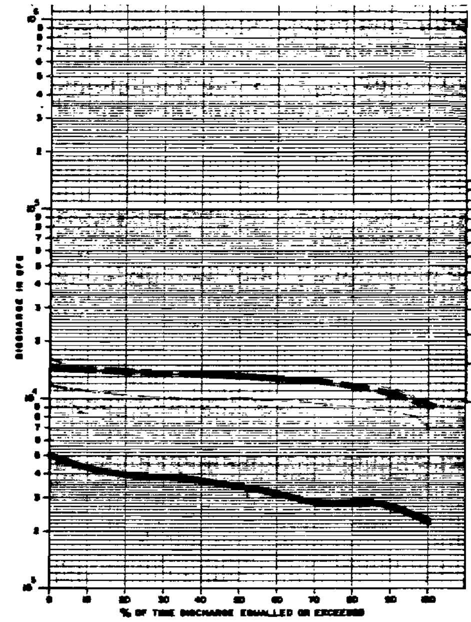
1. ——— PRE-PROJECT FLOW

   —·-·— CASE C

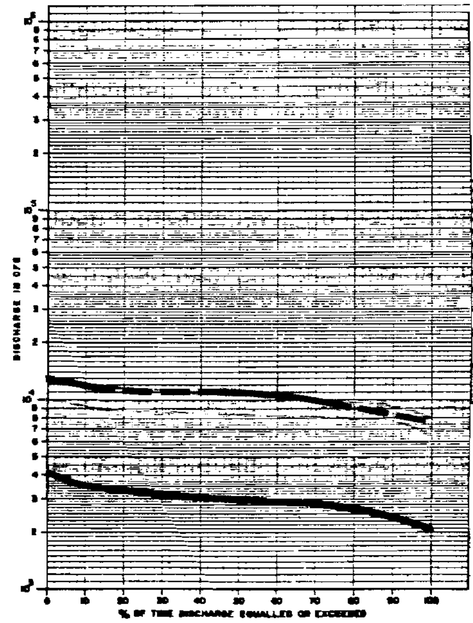
2. CURVES WERE GENERATED FROM 30 YEARS RECORD OF HISTORICAL AND SIMULATED AVERAGE MONTHLY FLOWS.

MONTHLY AND ANNUAL FLOW DURATION CURVES SUSITNA RIVER AT GOLD CREEK

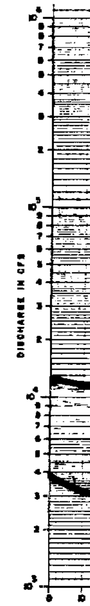
FIGURE E.2.86

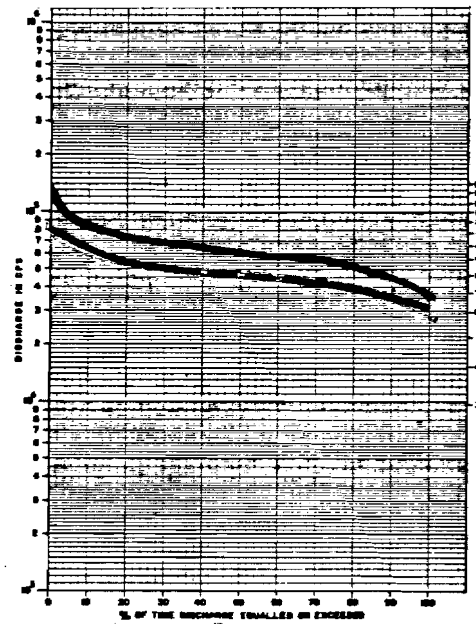


JANUARY



FEBRUARY





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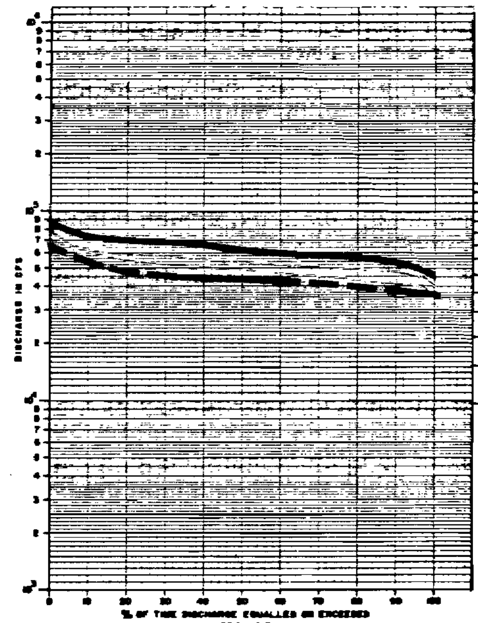
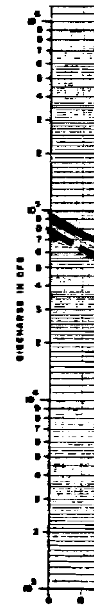
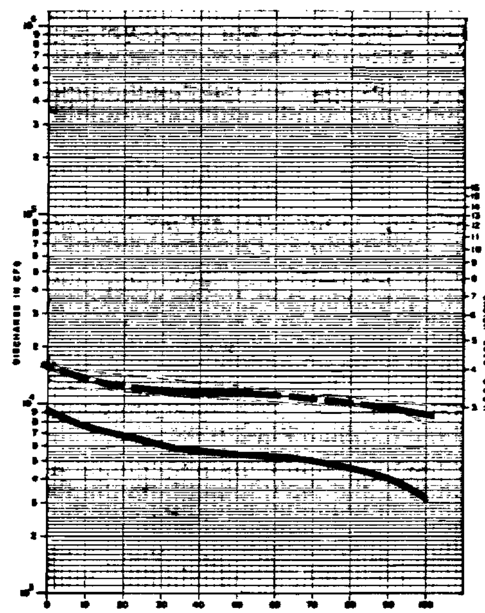
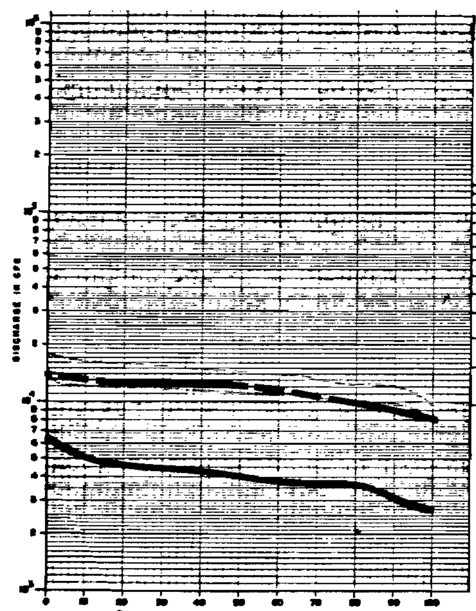


JULY

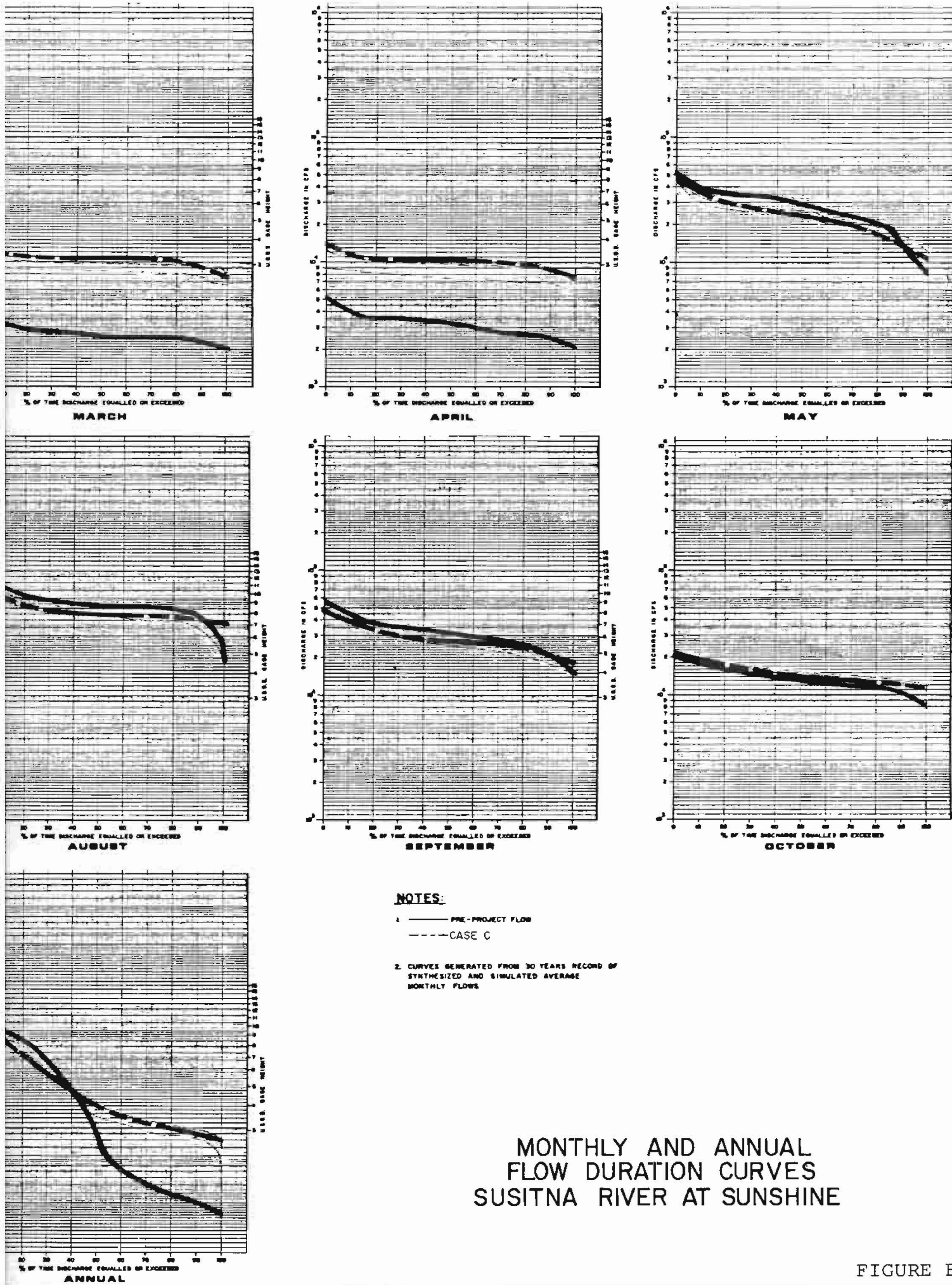




NOVEMBER

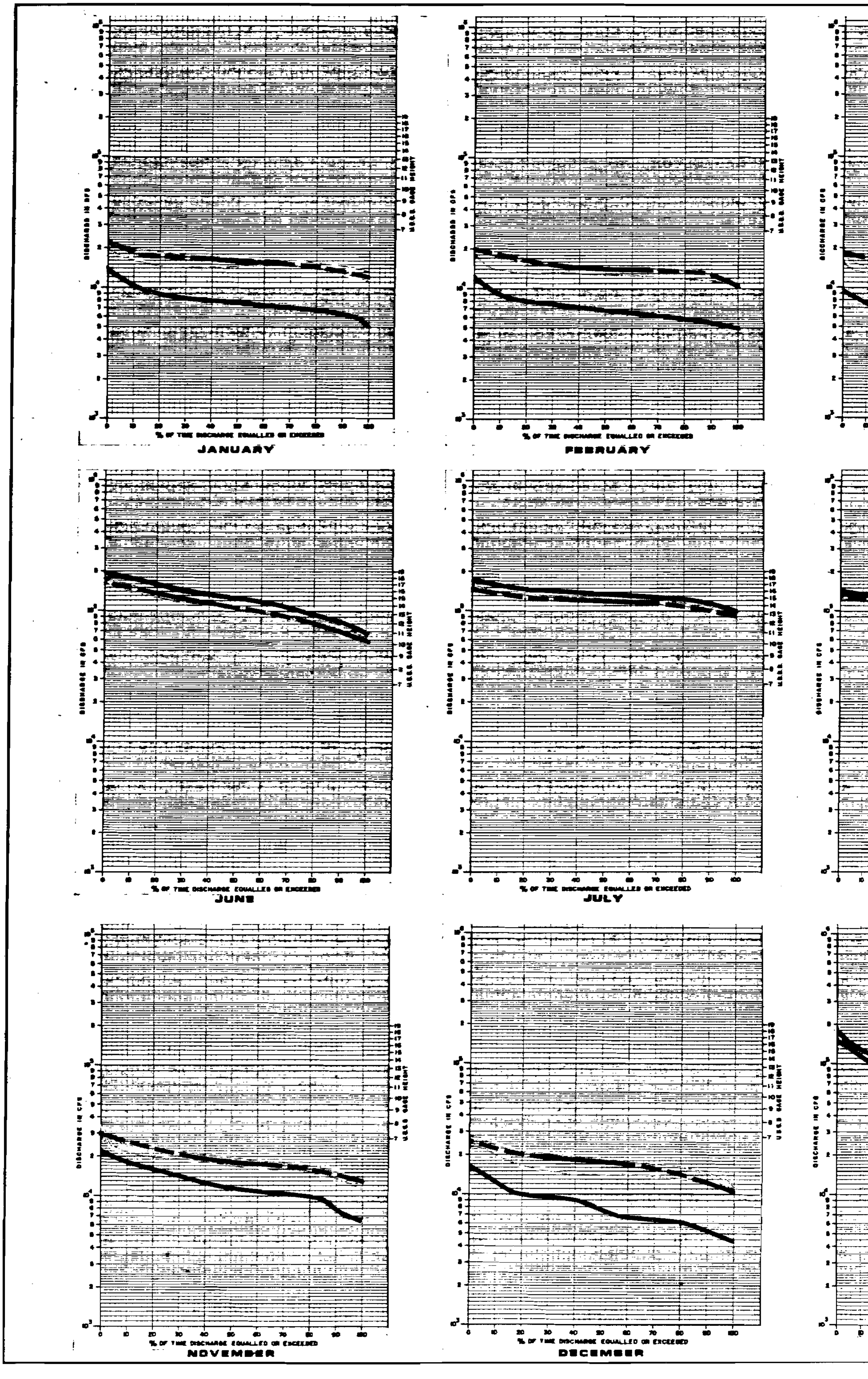


DECEMBER

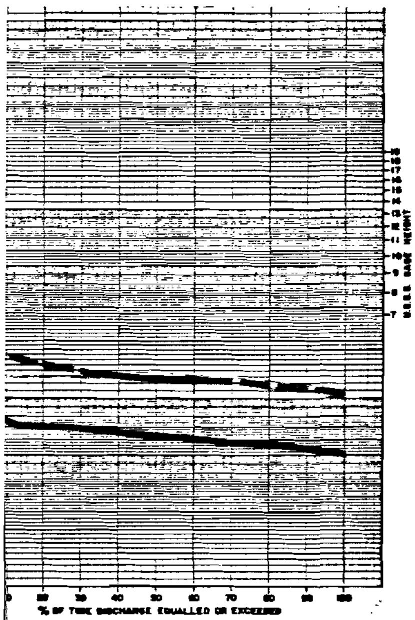


MONTHLY AND ANNUAL
FLOW DURATION CURVES
SUSITNA RIVER AT SUNSHINE

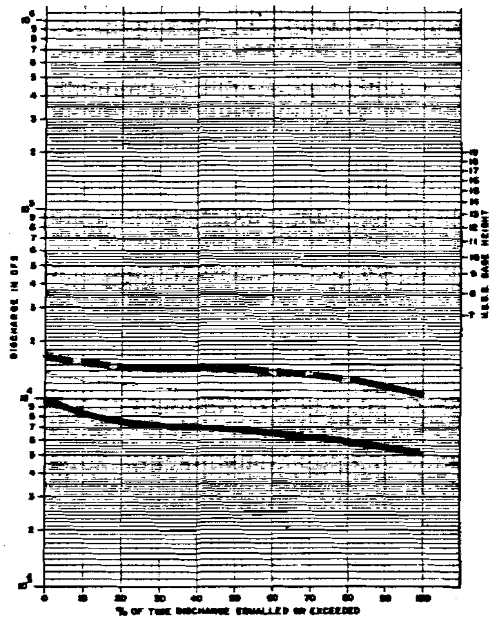
FIGURE E.2.87



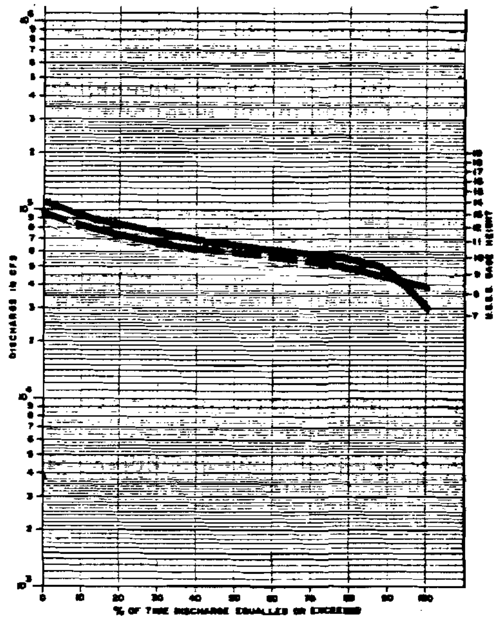
DISCHARGE IN CFS
U.S.G.S. GAGE HEIGHT
% OF TIME DISCHARGE EQUALLED OR EXCEEDED
JANUARY
FEBRUARY
JUNE
JULY
NOVEMBER
DECEMBER



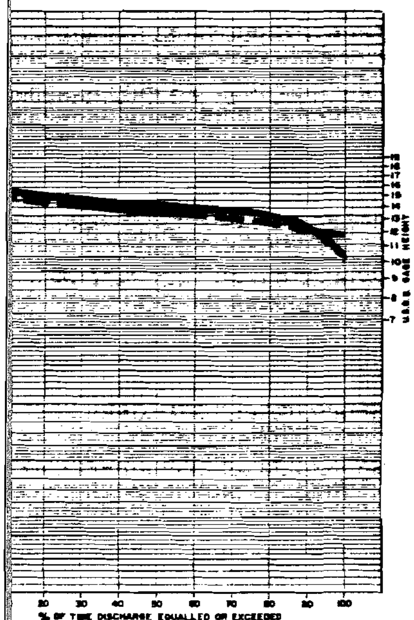
MARCH



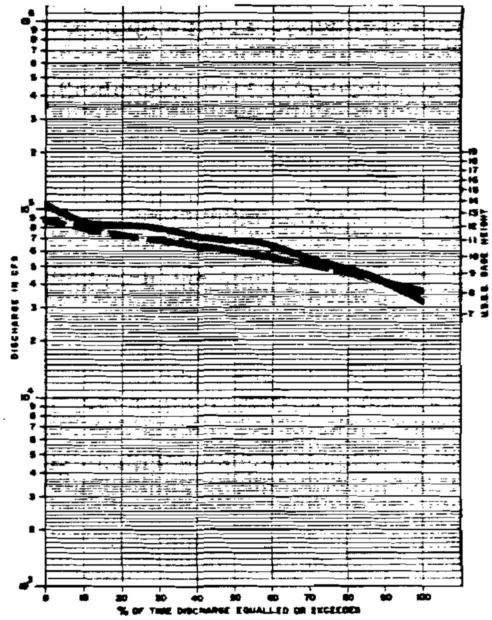
APRIL



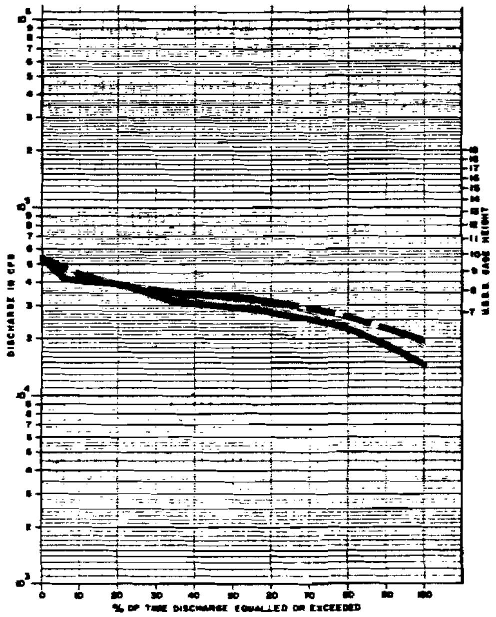
MAY



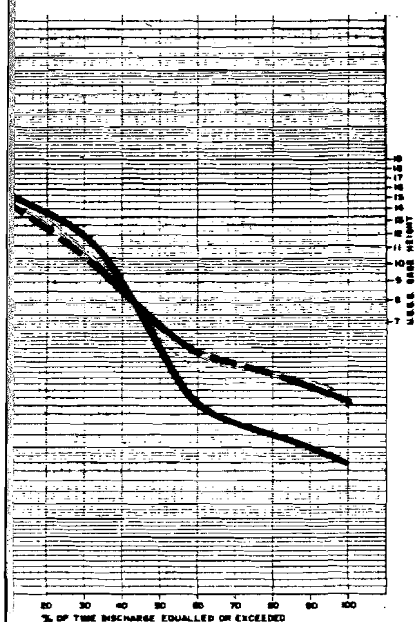
AUGUST



SEPTEMBER



OCTOBER



ANNUAL

NOTES:

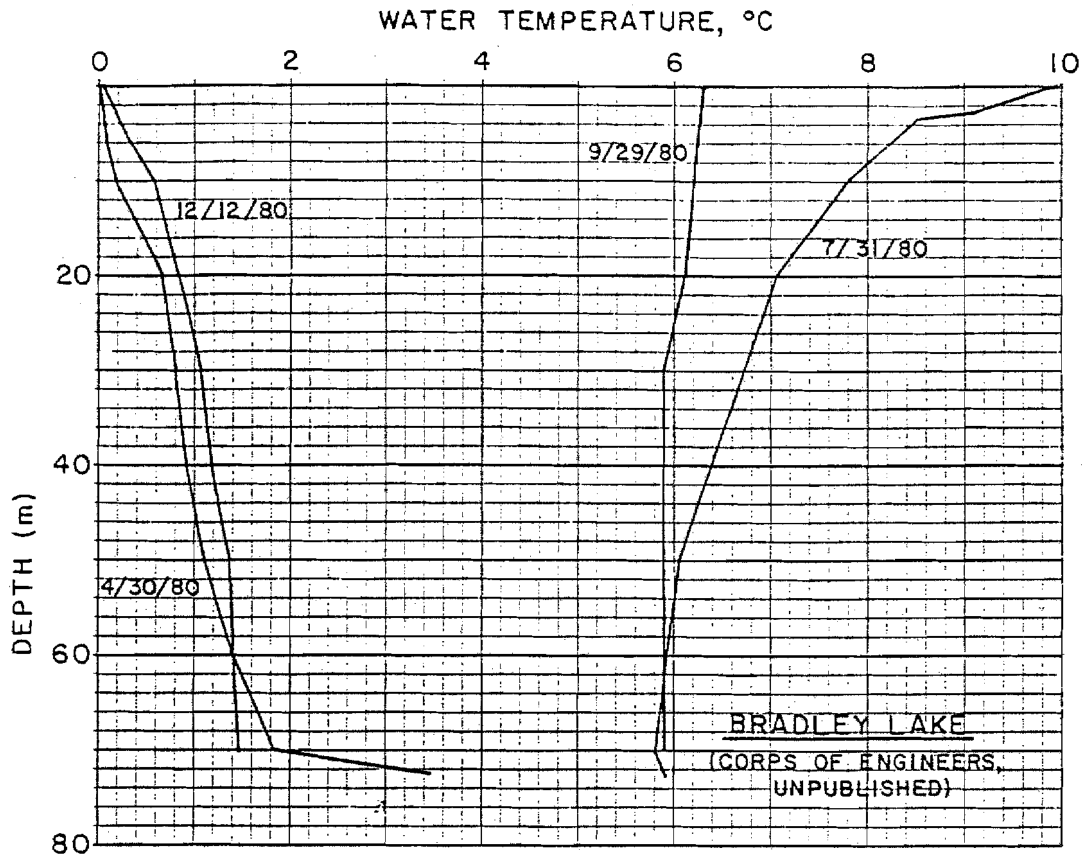
1. ——— PRE-PROJECT FLOW

   ----- CASE C

2. CURVES GENERATED FROM 30 YEARS RECORD OF HISTORICAL, SYNTHESIZED AND SIMULATED AVERAGE MONTHLY FLOWS

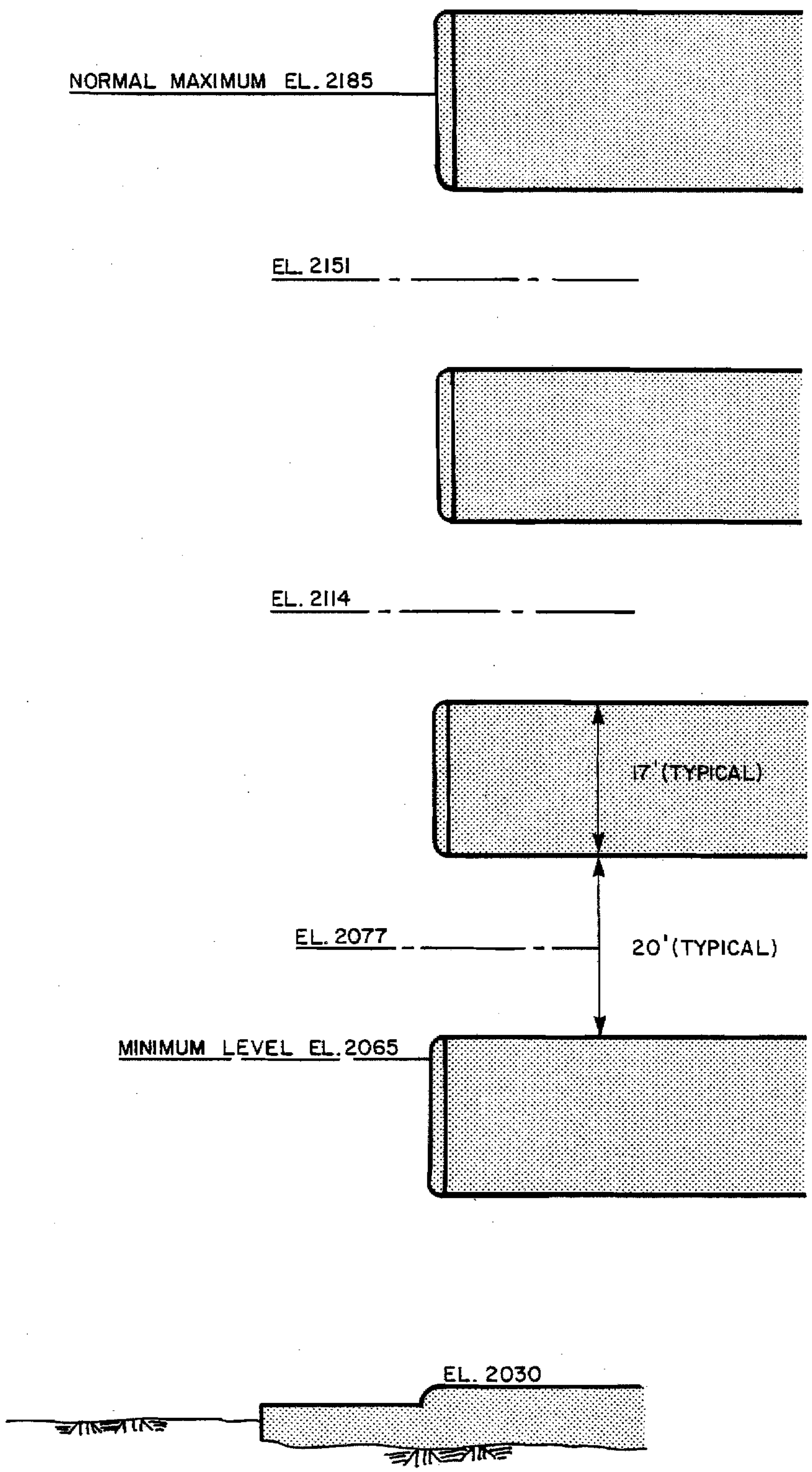
MONTHLY AND ANNUAL FLOW DURATION CURVES SUSITNA RIVER AT SUSITNA STATION

FIGURE E.2.88



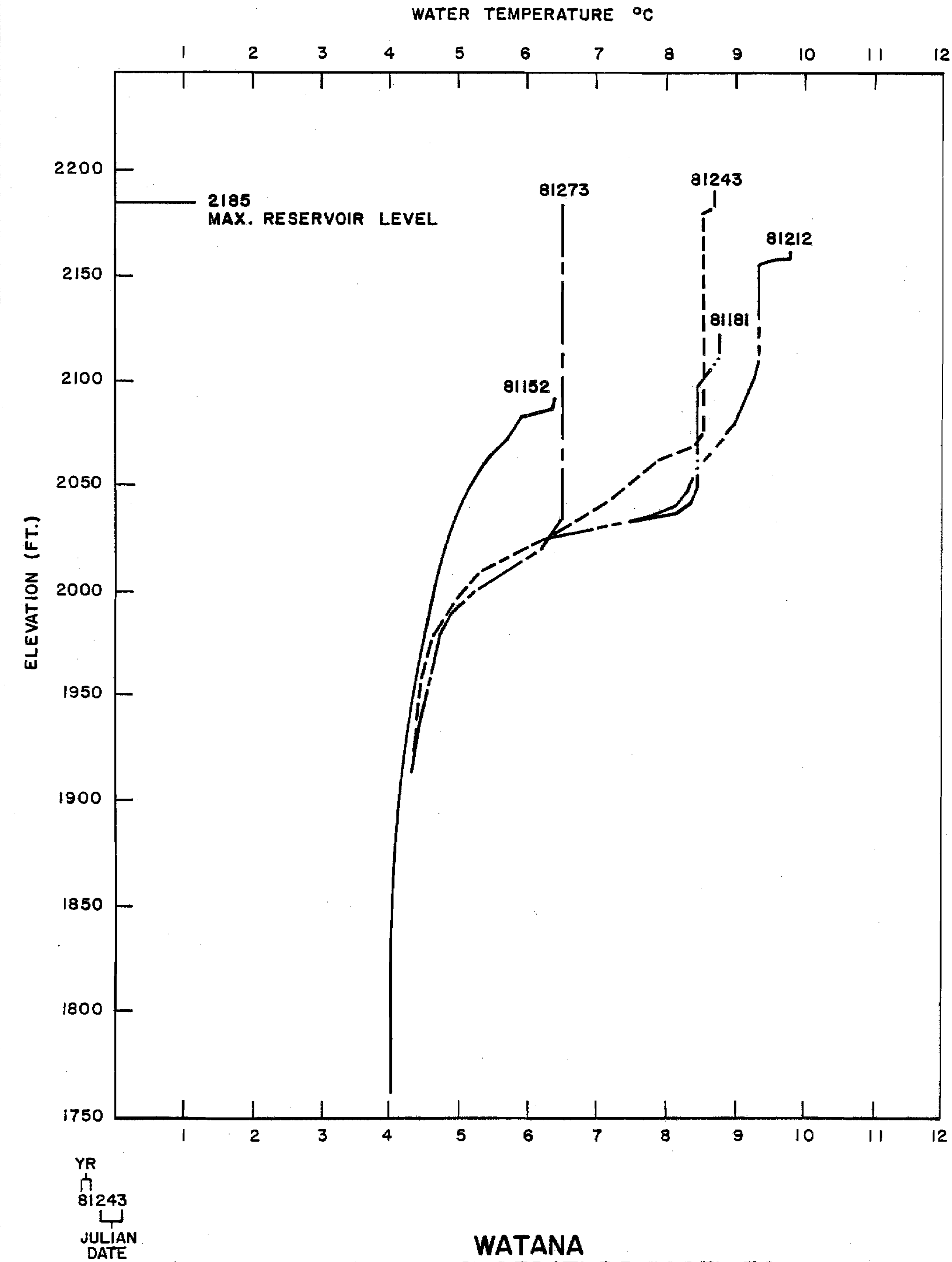
WATER TEMPERATURE PROFILES
BRADLEY LAKE, ALASKA

FIGURE E.2.89



MULTIPORT INTAKE LEVELS

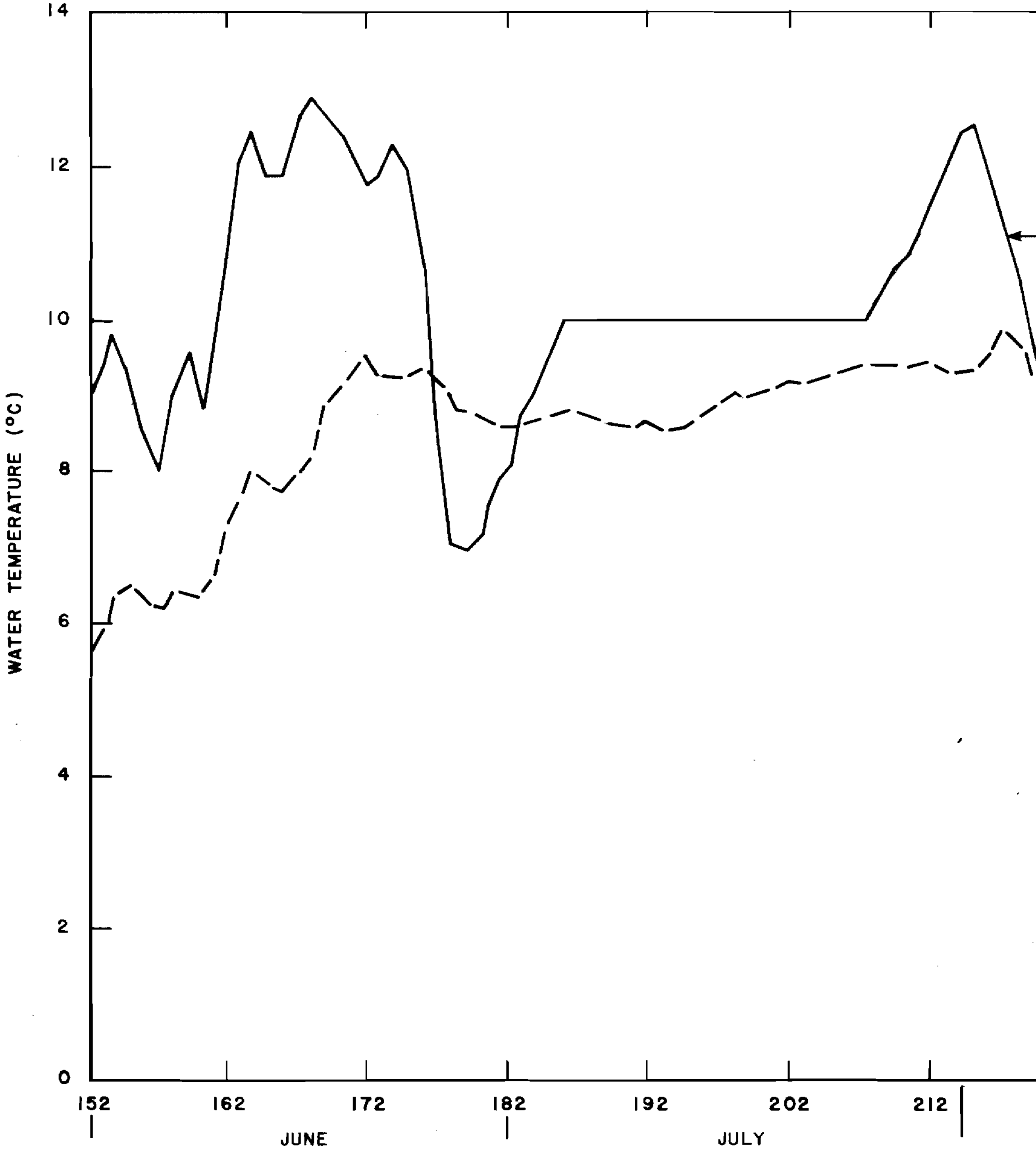
FIGURE E.2.90



WATANA
RESERVOIR TEMPERATURE PROFILES

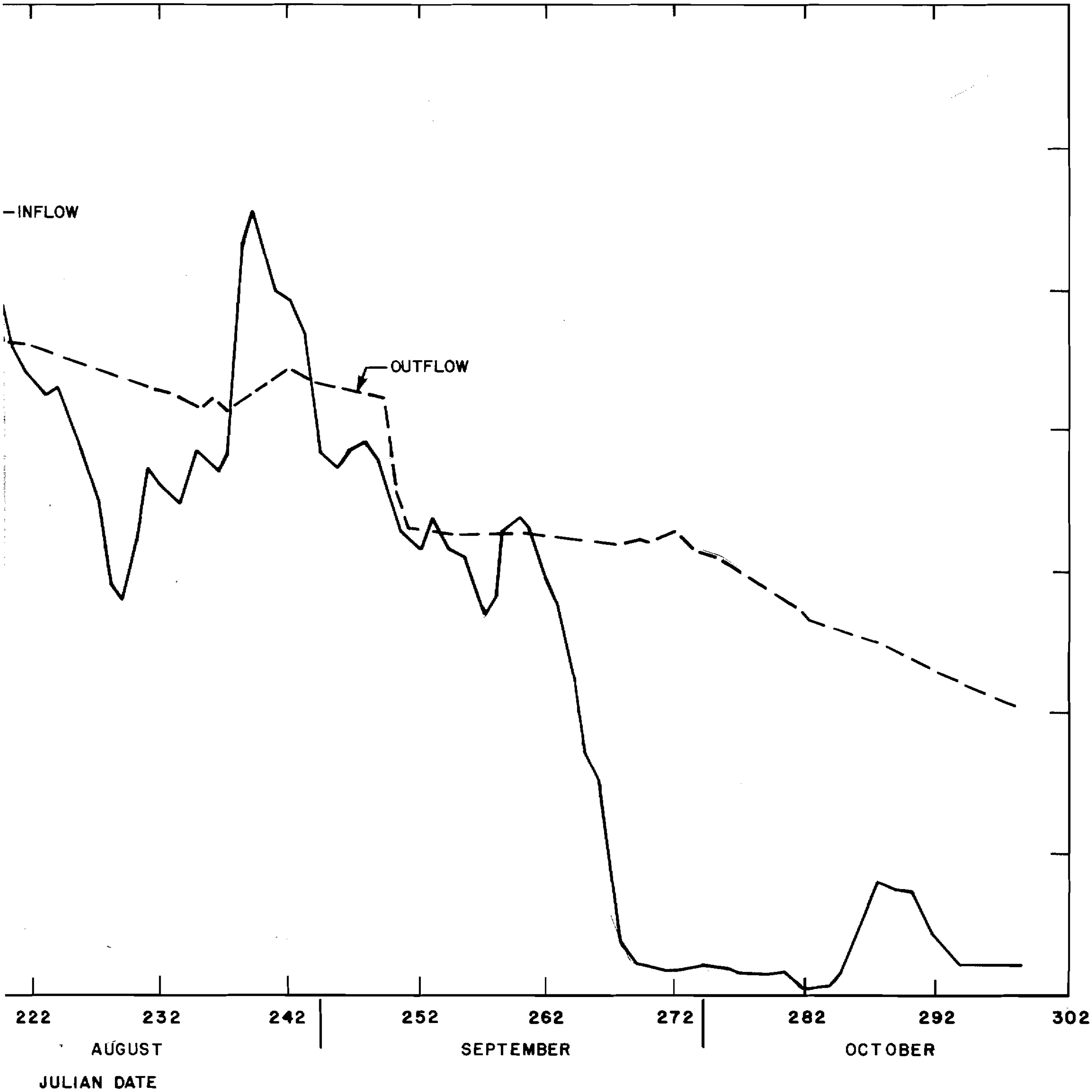
BASED ON 1981 DATA

FIGURE E.2.91



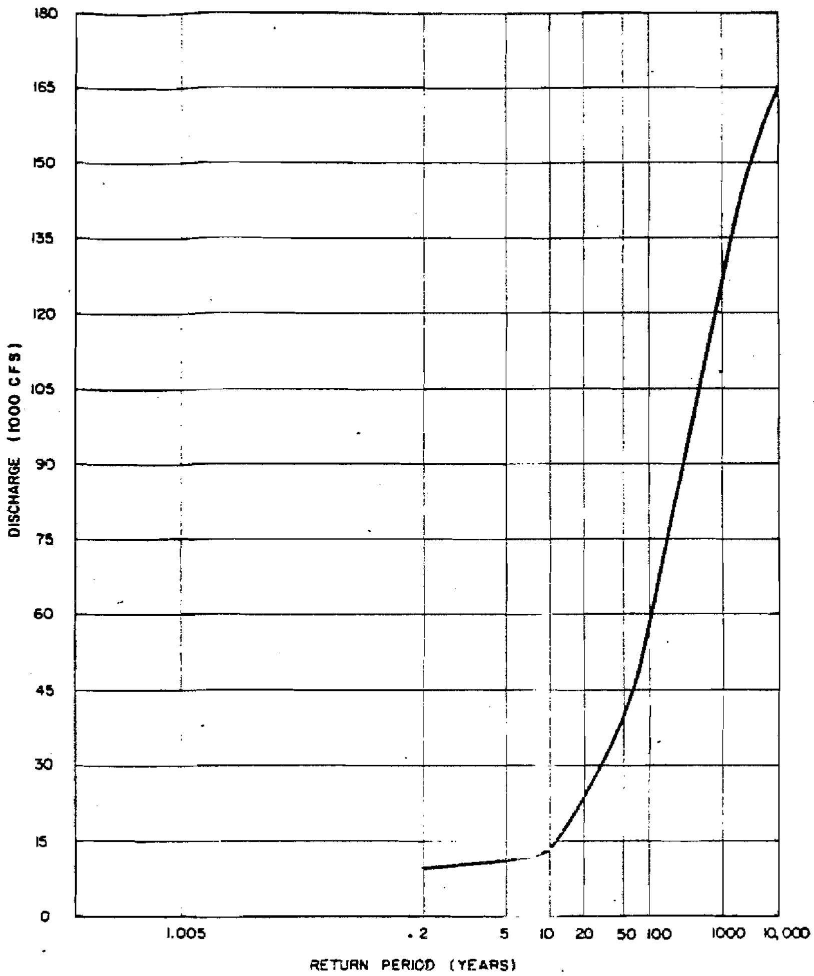
BASED ON 1981 DATA

RESERVOIR T
OUTFL



EMPERATURE MODELING
.OW TEMPERATURE

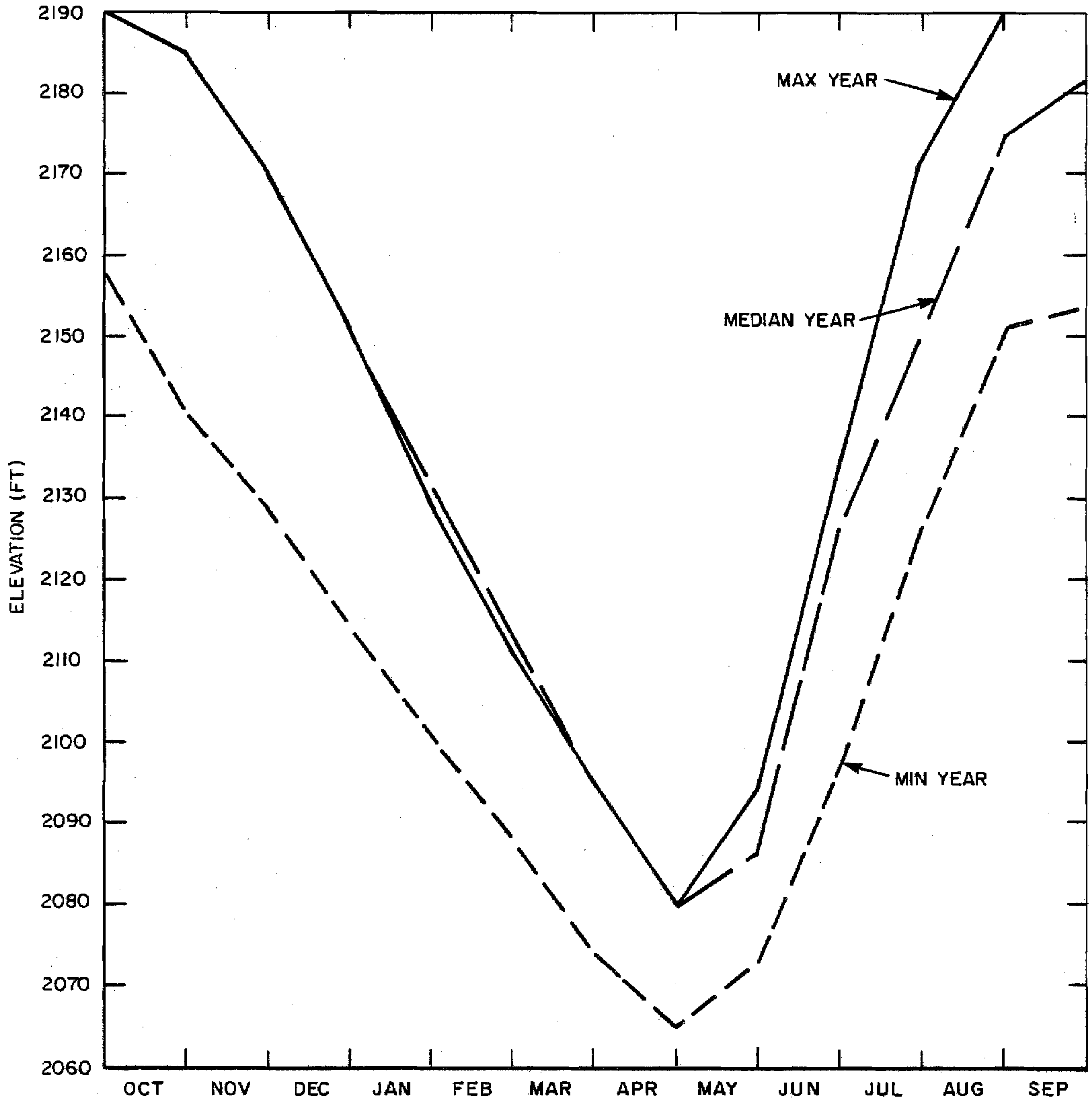
FIGURE E.2.92



FLOOD FREQUENCY CURVE
(INFLOW AFTER ROUTING THROUGH WATANA)

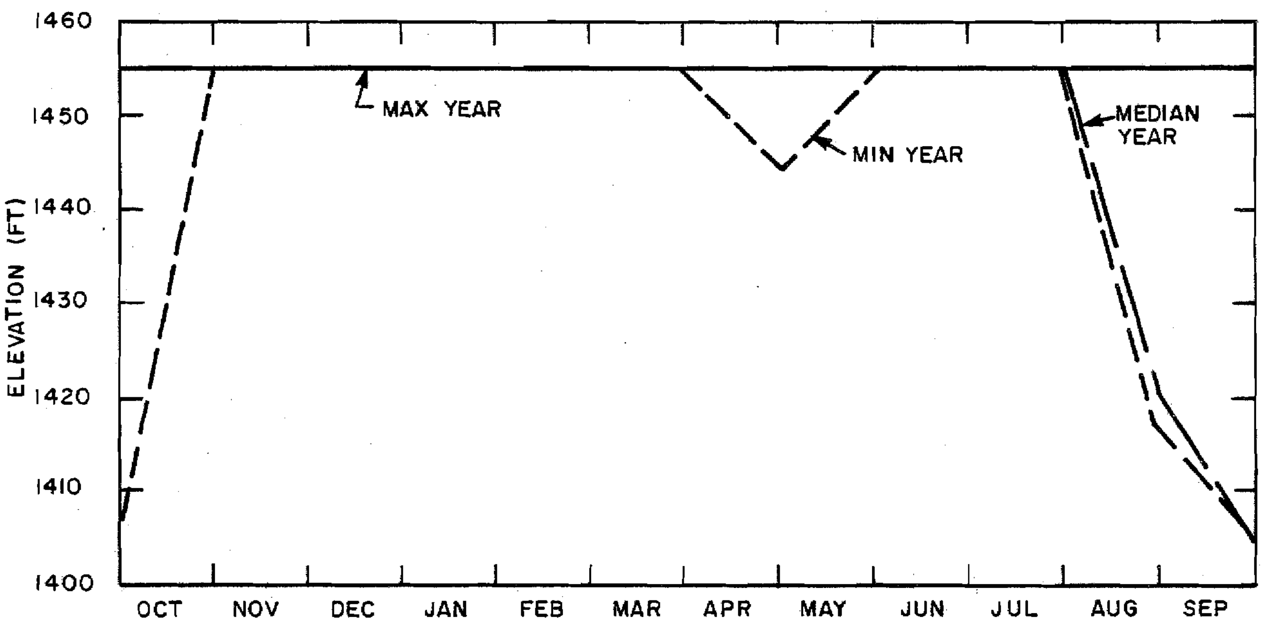
DEVIL CANYON
FLOOD FREQUENCY CURVE

FIGURE E.2.93



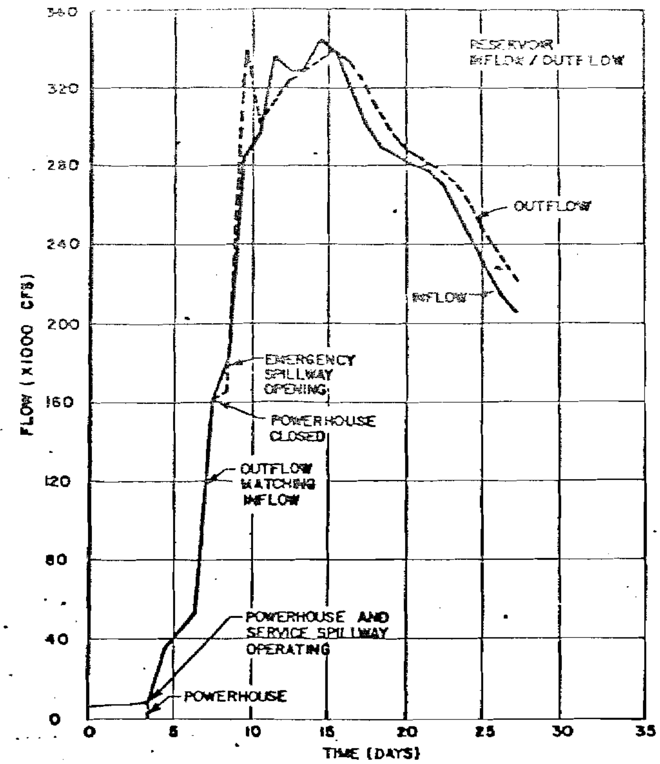
WATANA RESERVOIR WATER LEVELS
(WATANA AND DEVIL CANYON IN OPERATION)

FIGURE E.2.94

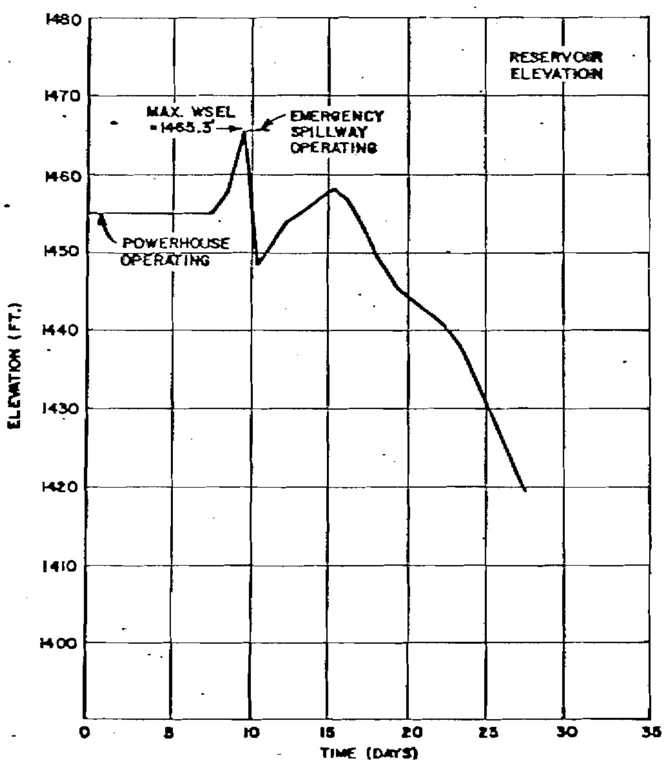


DEVIL CANYON RESERVOIR WATER LEVELS

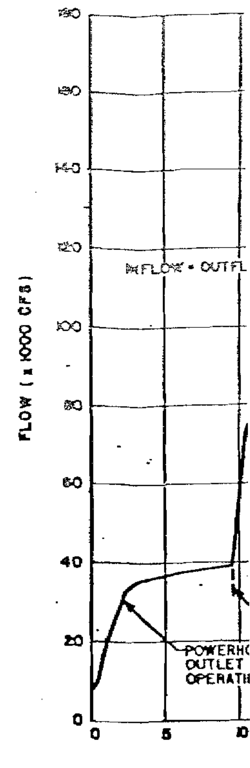
FIGURE E.2.95



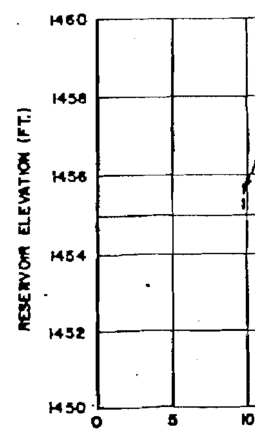
PROBABLE MAXIMUM FLOOD



PROBABLE MAXIMUM FLOOD

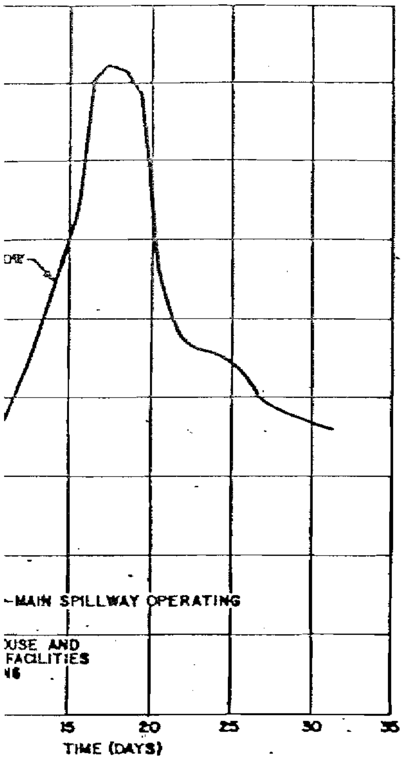


R



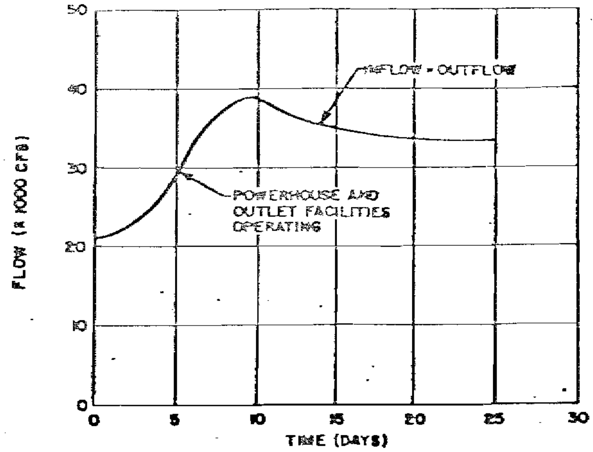
R

DEVI
HYDROL



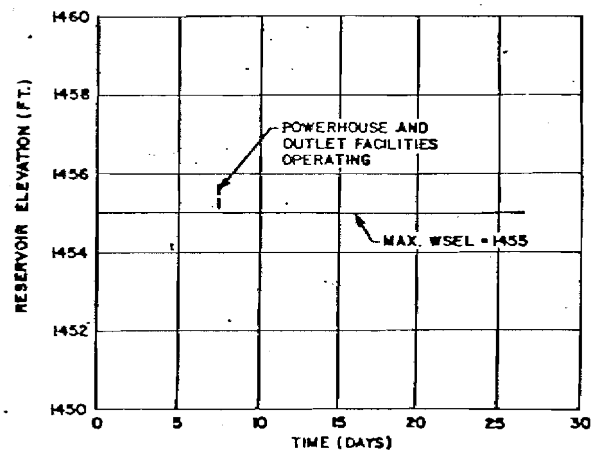
ESERVOIR ROUTING

1:10,000 YR. FLOOD



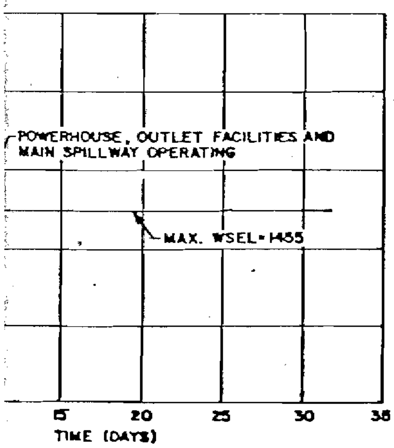
RESERVOIR ROUTING

1:50 YR. SUMMER FLOOD



RESERVOIR ROUTING

1:50 YR. SUMMER FLOOD



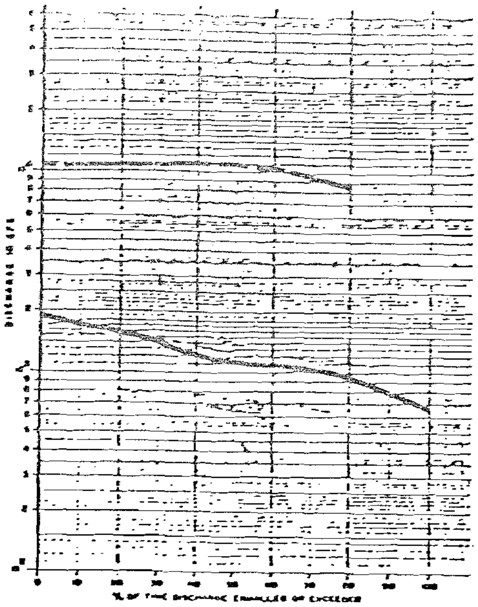
ESERVOIR ROUTING

1:10,000 YR. FLOOD

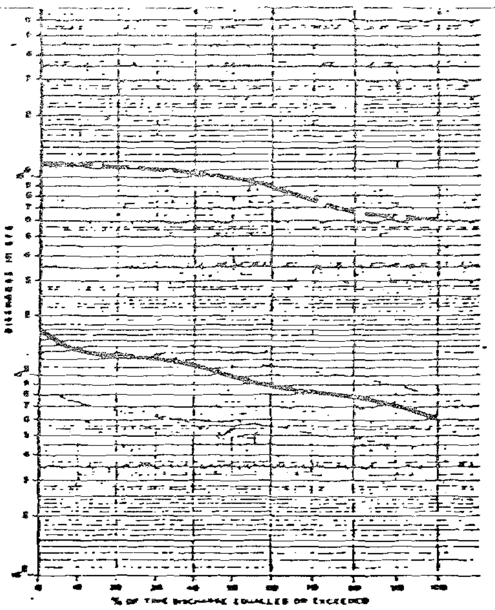
. CANYON

GICAL DATA

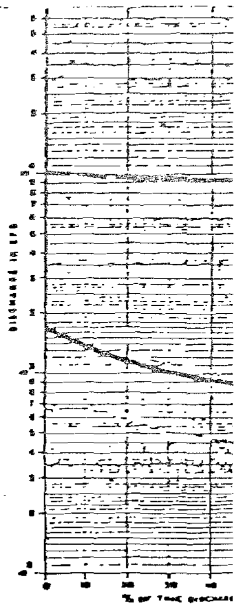
FIGURE E.2.96



JANUARY



FEBRUARY



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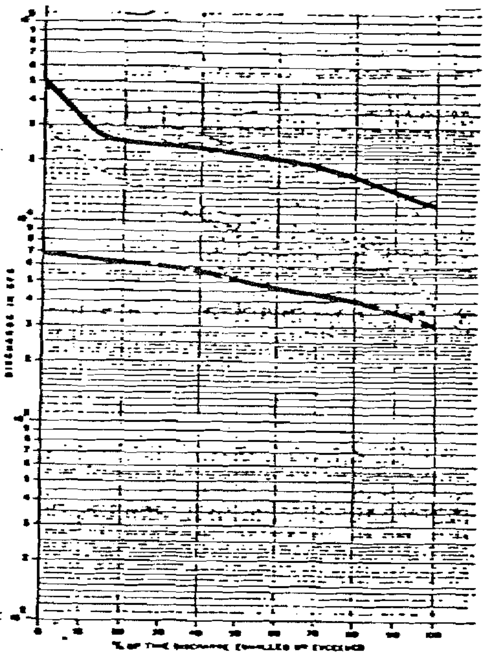
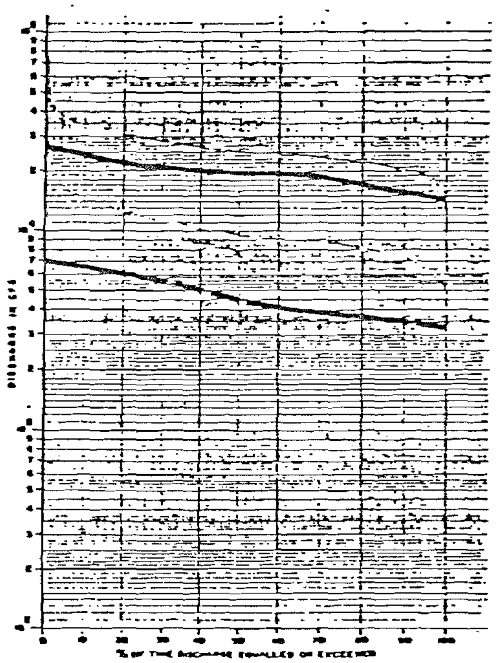
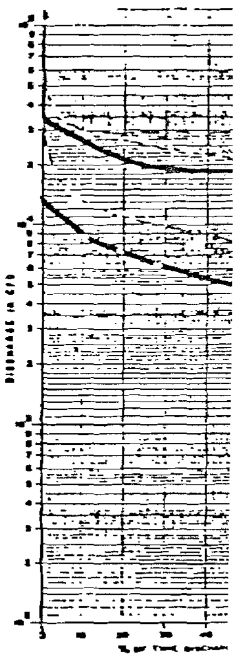


JUNE



JULY



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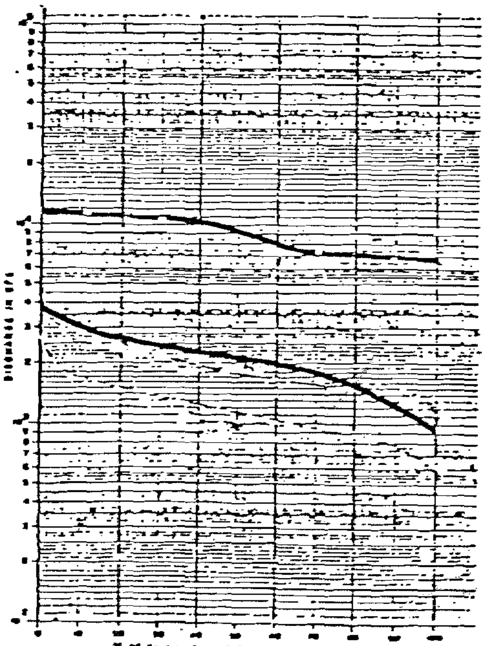

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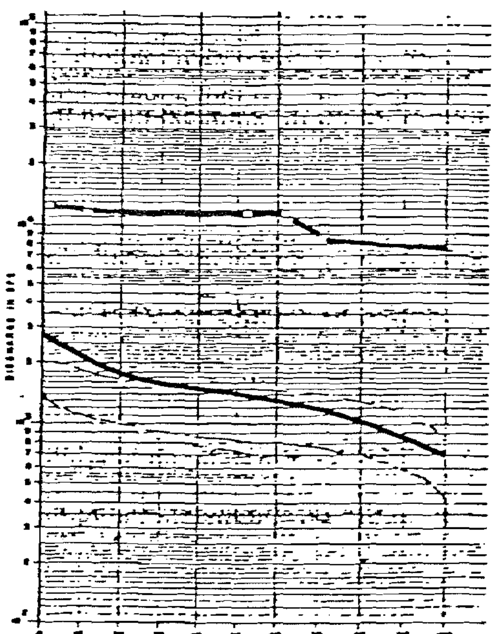
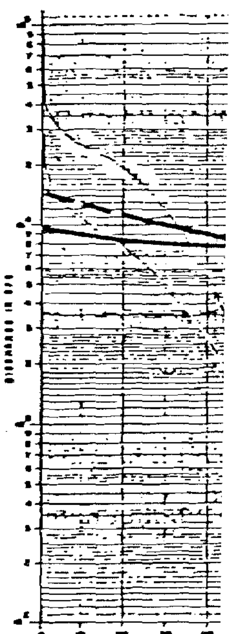


DECEMBER



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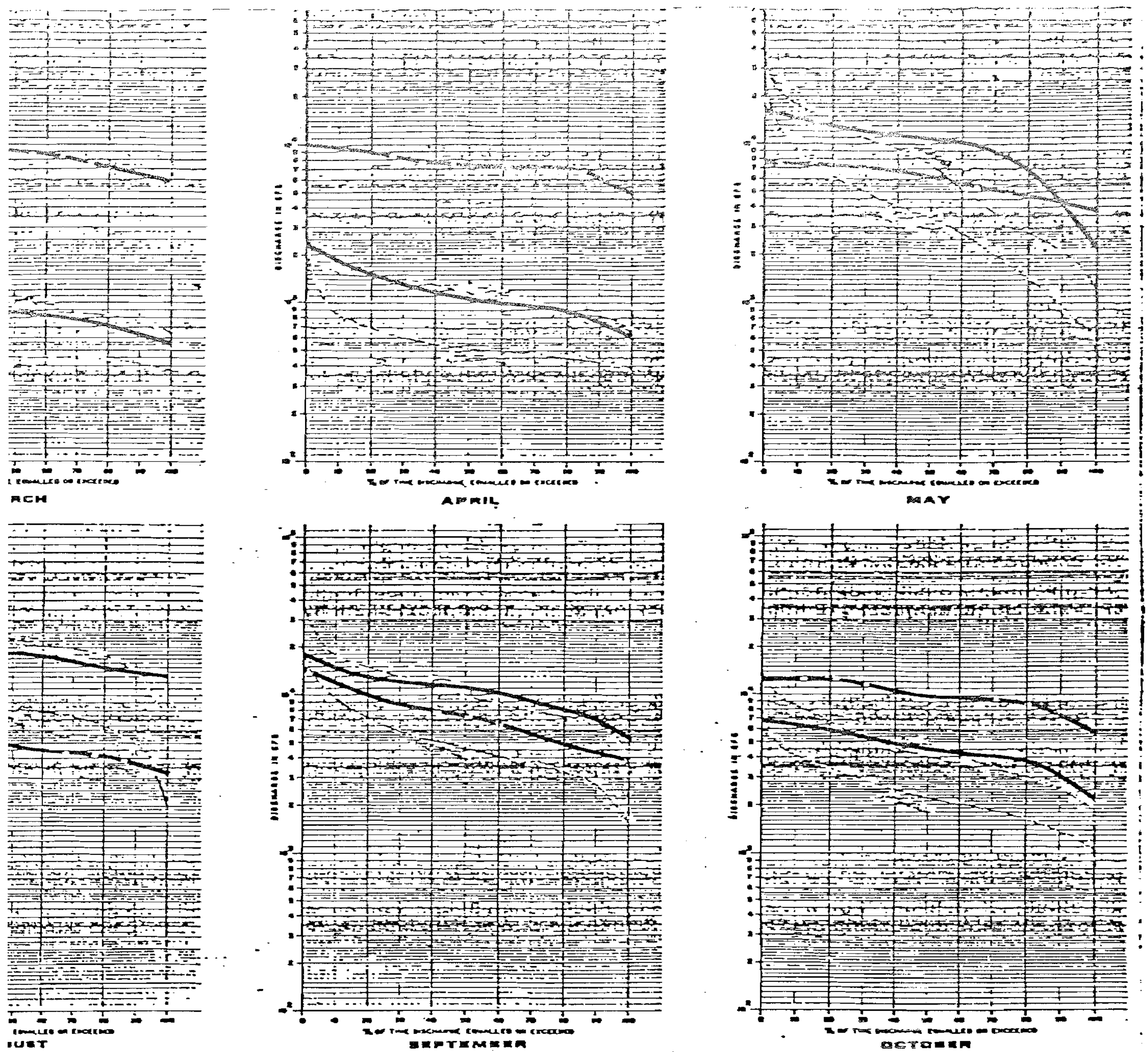
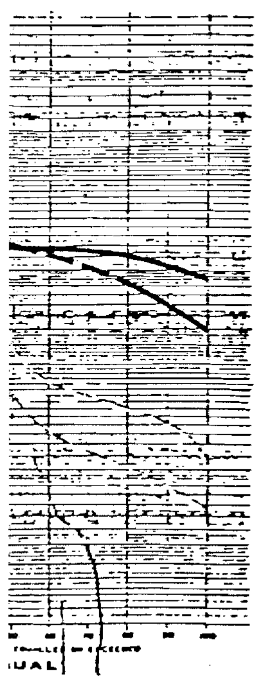




NOTES:

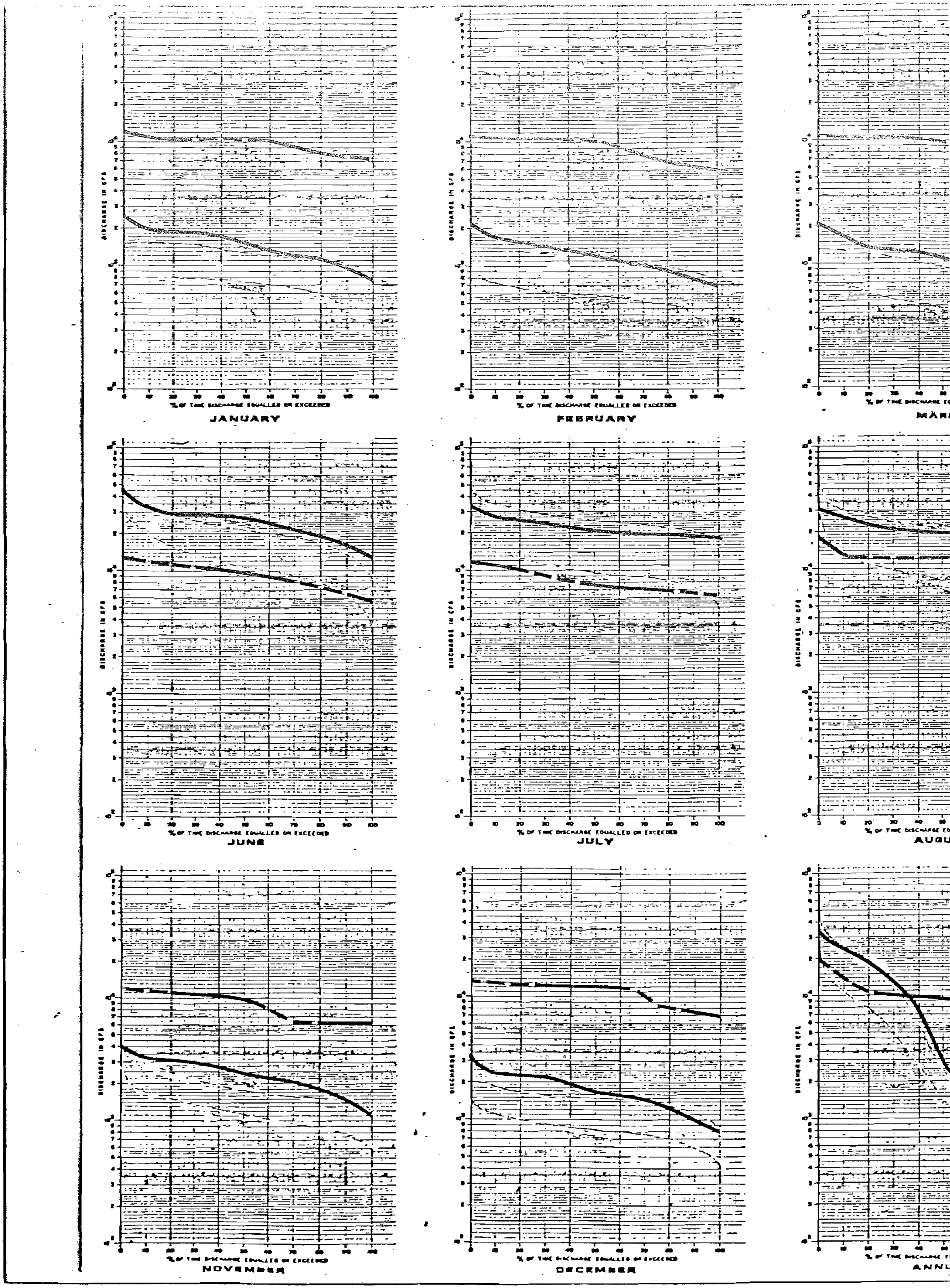
1. ——— PRE-PROJECT FLOW

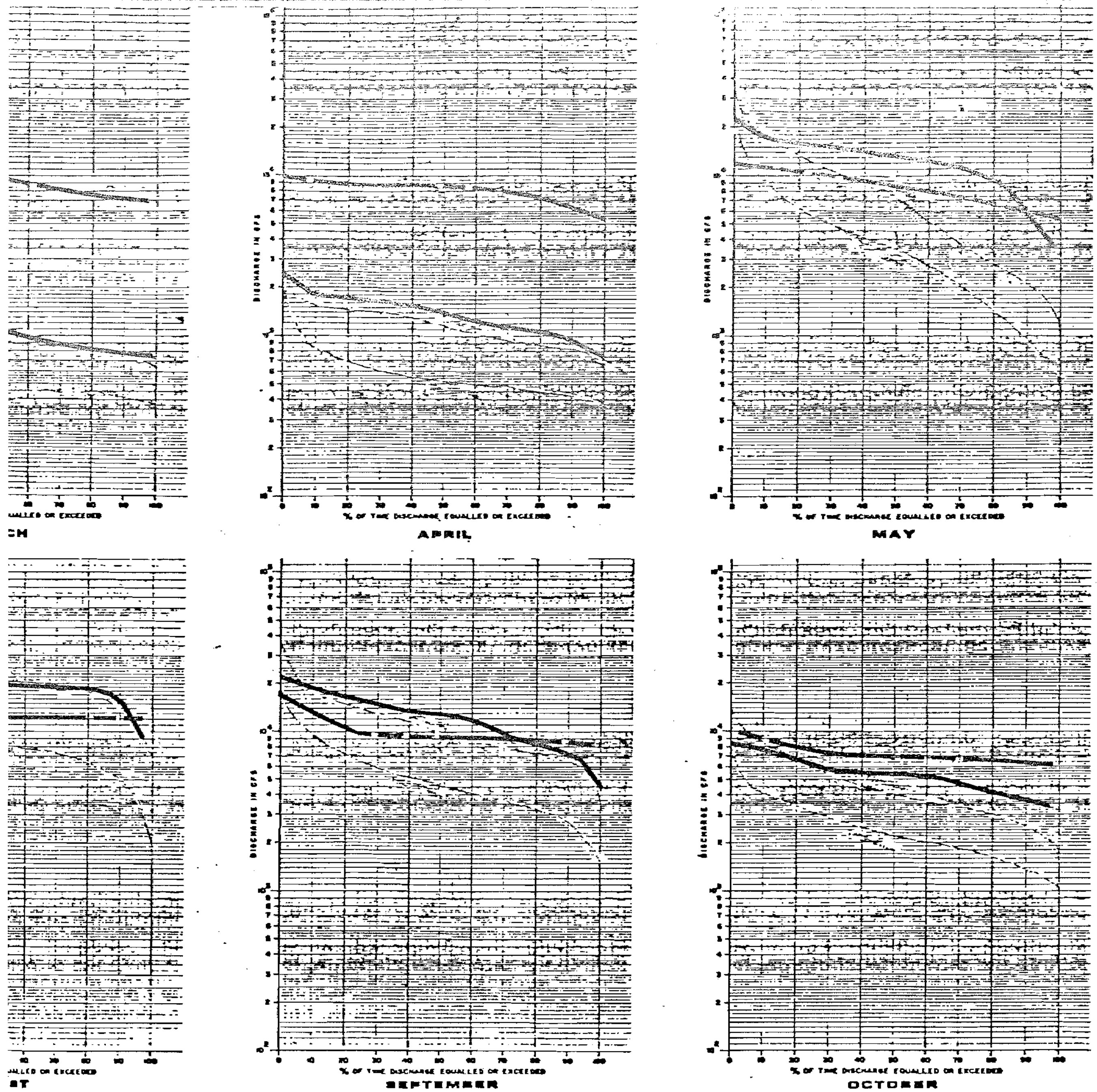
- - - - CASE C (WATANA/DEVIL CANYON)

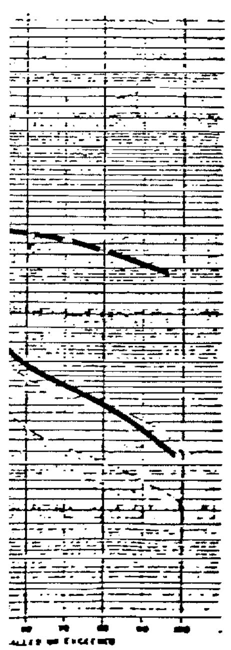
2. CURVES WERE GENERATED FROM 30 YEARS RECORD OF HISTORICAL AND SIMULATED AVERAGE MONTHLY FLOWS.

MONTHLY AND ANNUAL FLOW DURATION CURVES TALKEETNA RIVER NEAR TALKEETNA CHULITNA RIVER NEAR TALKEETNA

FIGURE E.2.97


DISCHARGE IN CFS
% OF TIME DISCHARGE EQUALLED OR EXCEEDED
JANUARY
FEBRUARY
JUNE
JULY
NOVEMBER
DECEMBER





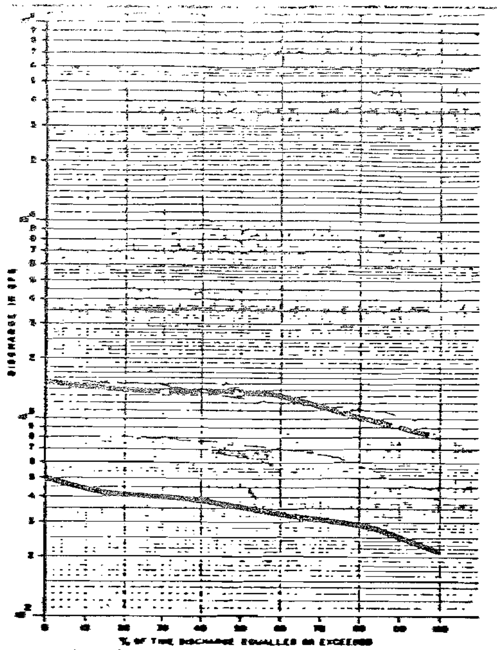
NOTES:

1. ——— PRE-PROJECT FLOW
- - - CASE C (WATANA / DEVIL CANYON)

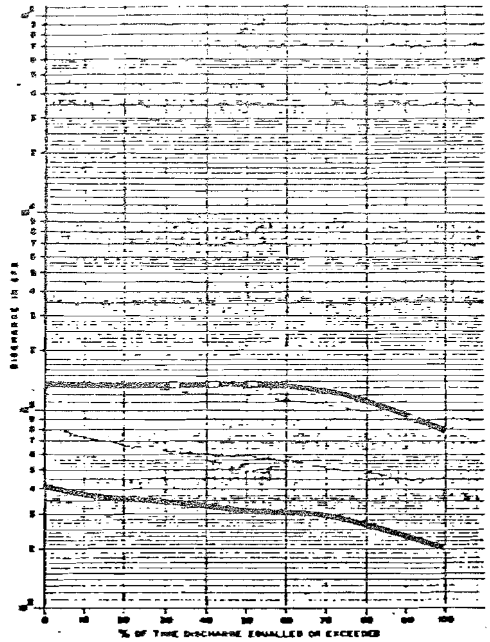
2. CURVES WERE GENERATED FROM 32 YEARS RECORD OF HISTORICAL AND SIMULATED AVERAGE MONTHLY FLOWS.

MONTHLY AND ANNUAL
FLOW DURATION CURVES
SUSITNA RIVER AT GOLD CREEK

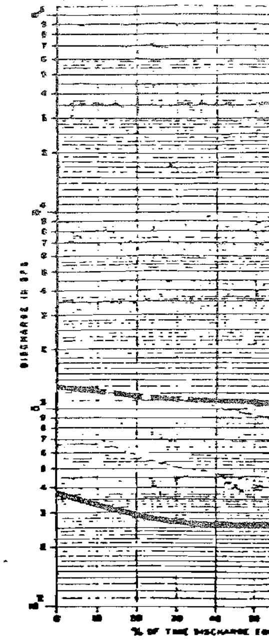
FIGURE E.2.98



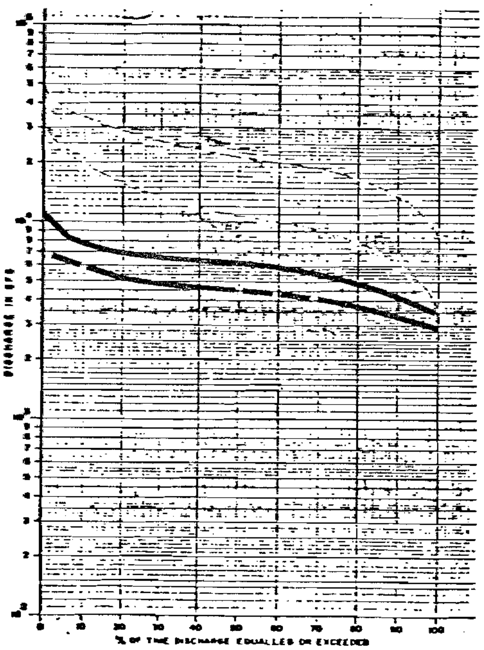
JANUARY



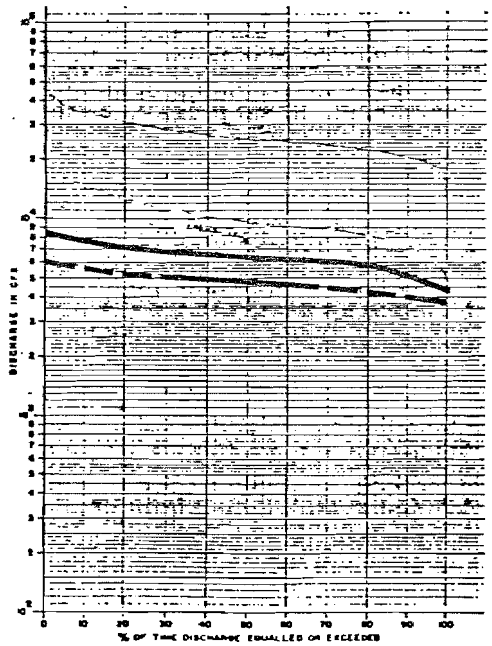
FEBRUARY



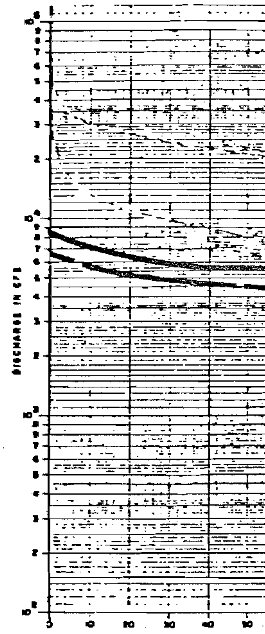
MARC



JUNE



JULY



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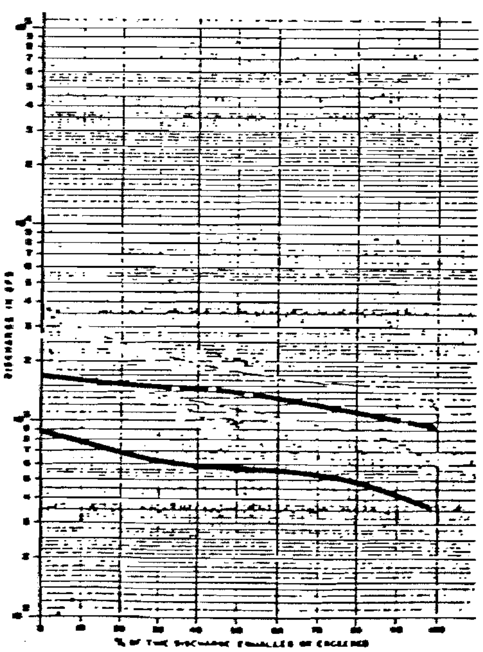

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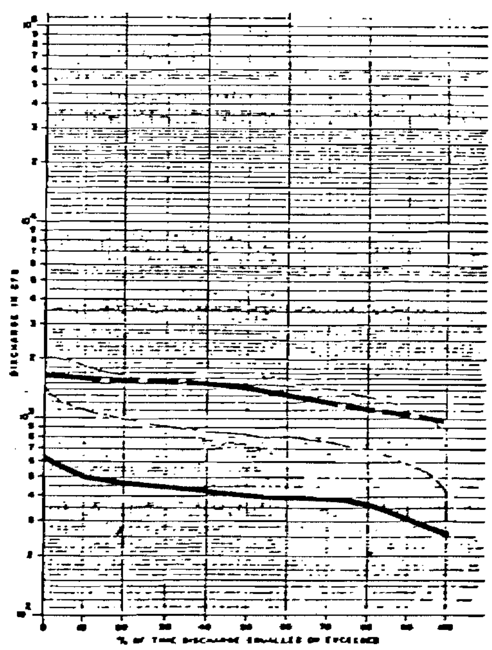
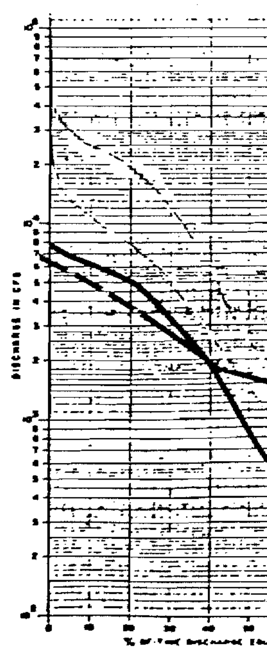
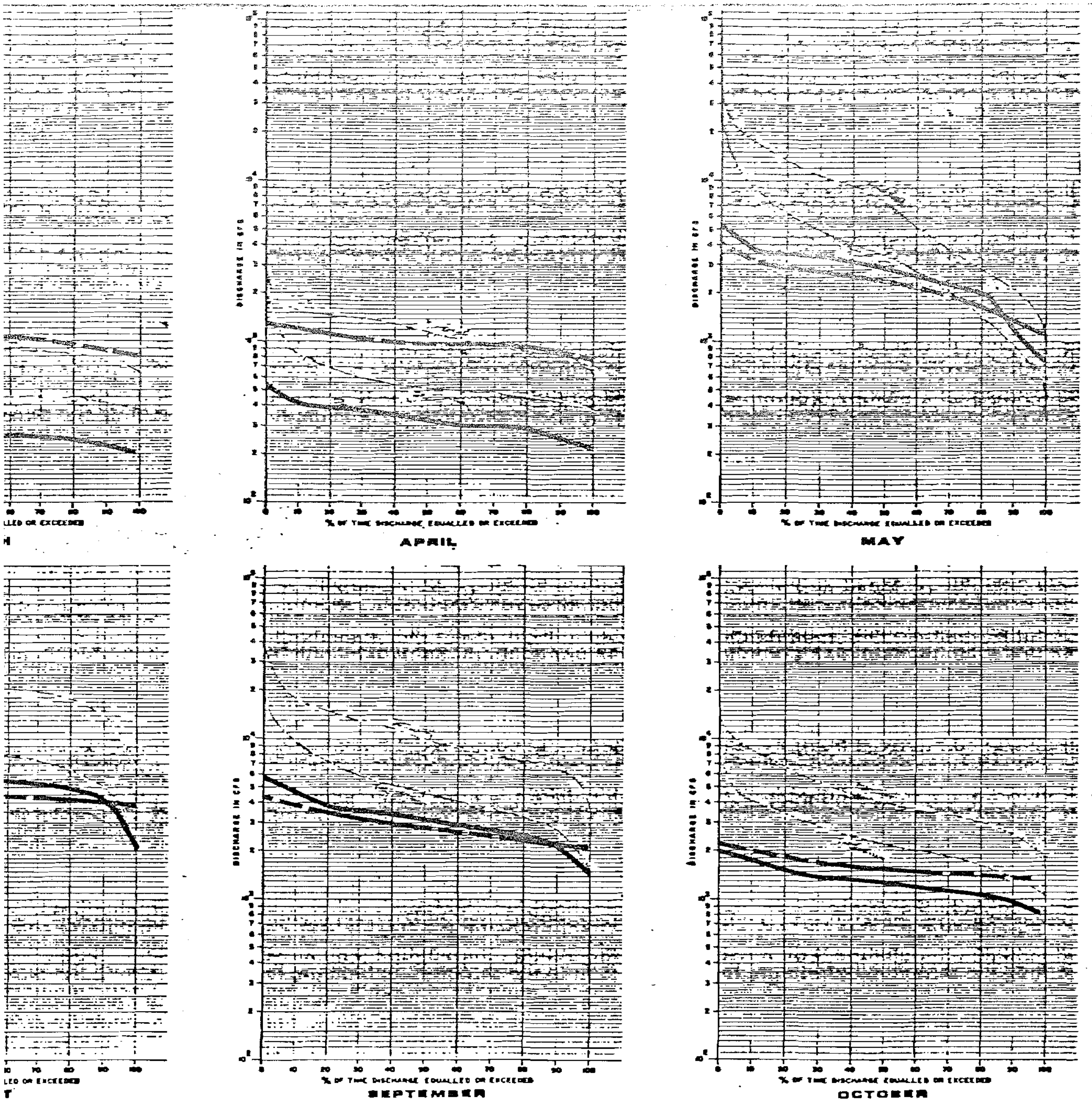
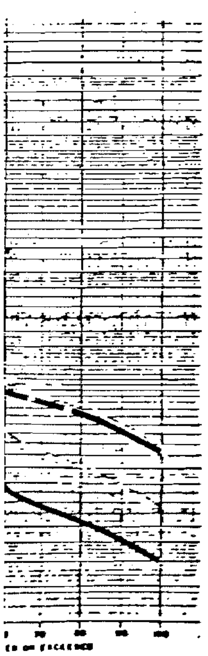


DECEMBER



ANNU





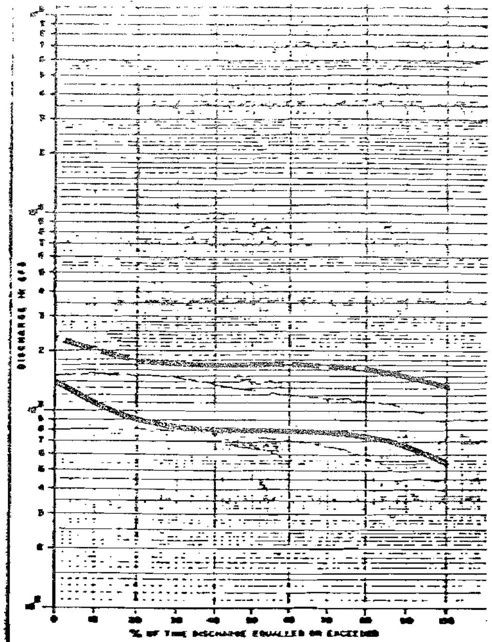
NOTES:

1. ——— PRE-PROJECT FLOW
   ---- CASE C (WATANA/DEVIL CANYON)

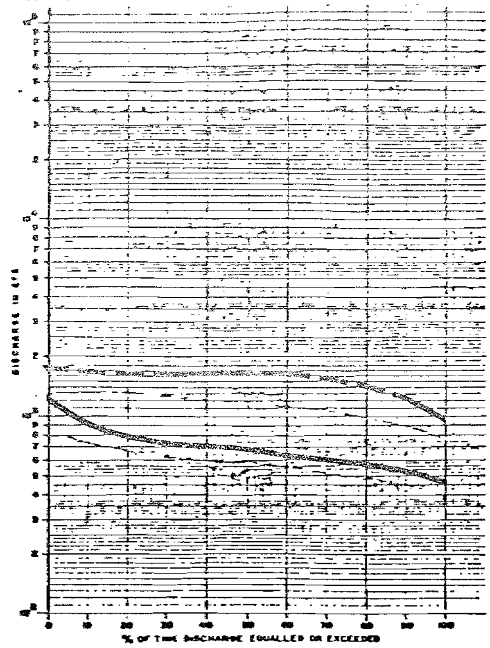
2. CURVES GENERATED FROM 30 YEARS RECORD OF SYNTHESIZED AND SIMULATED AVERAGE MONTHLY FLOWS.

MONTHLY AND ANNUAL FLOW DURATION CURVES SUSITNA RIVER AT SUNSHINE

FIGURE E.2.99



JANUARY



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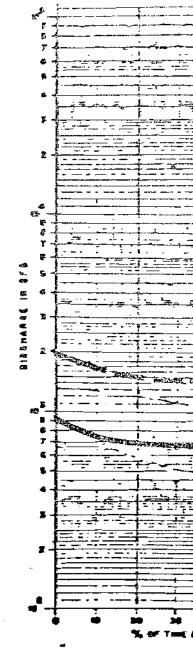

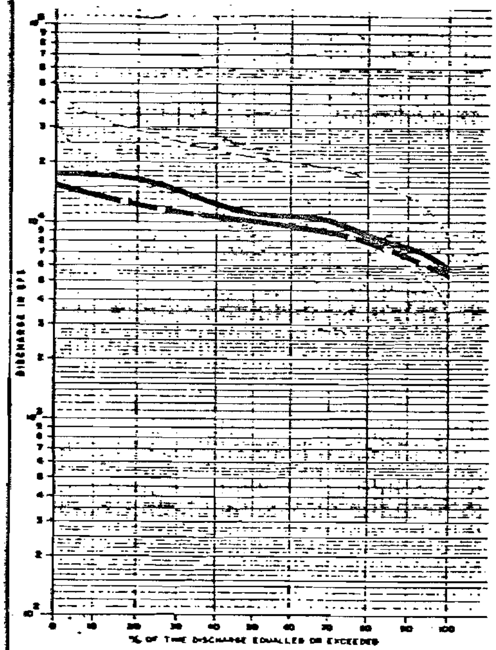

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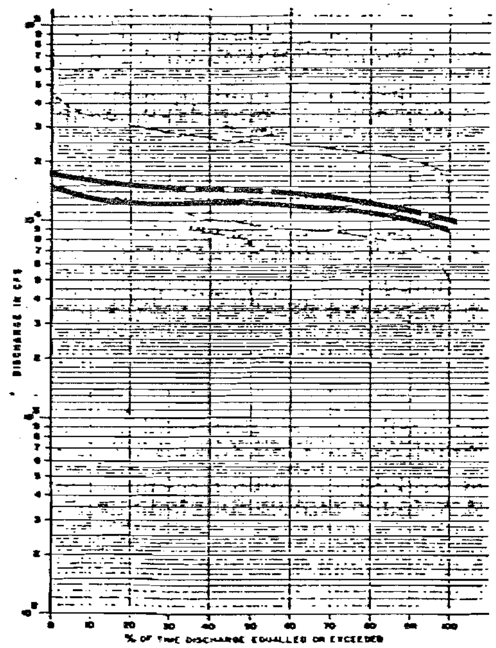

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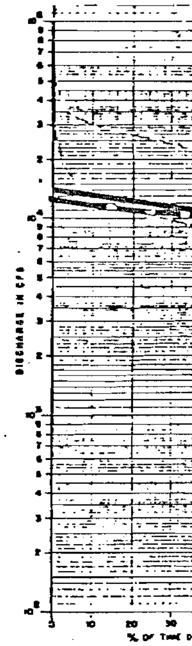

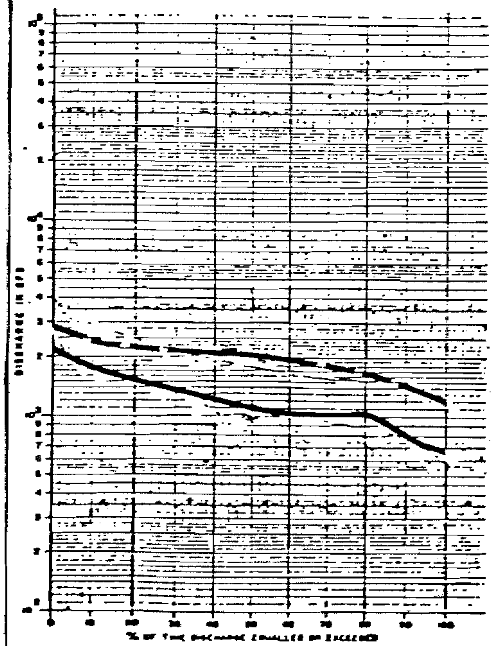

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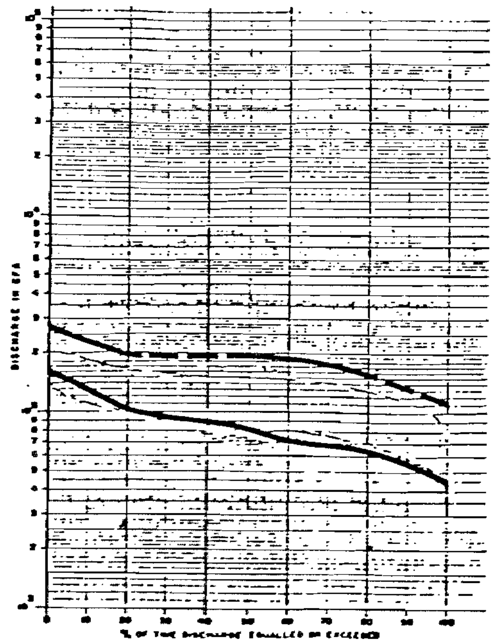
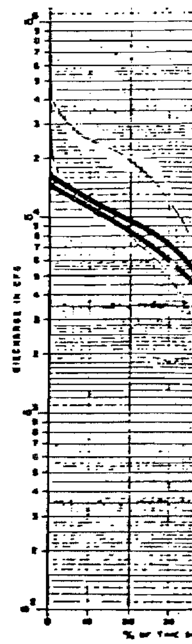
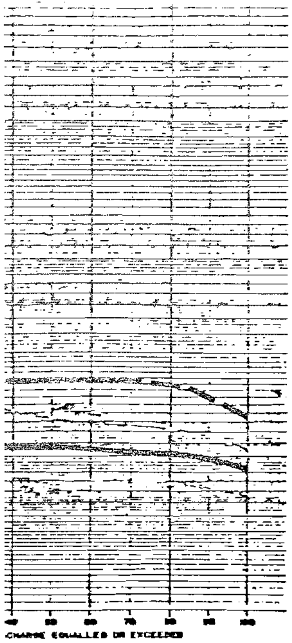


DECEMBER





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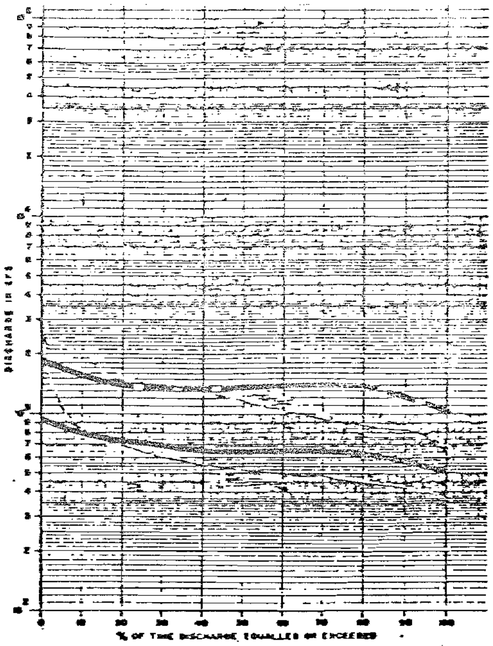
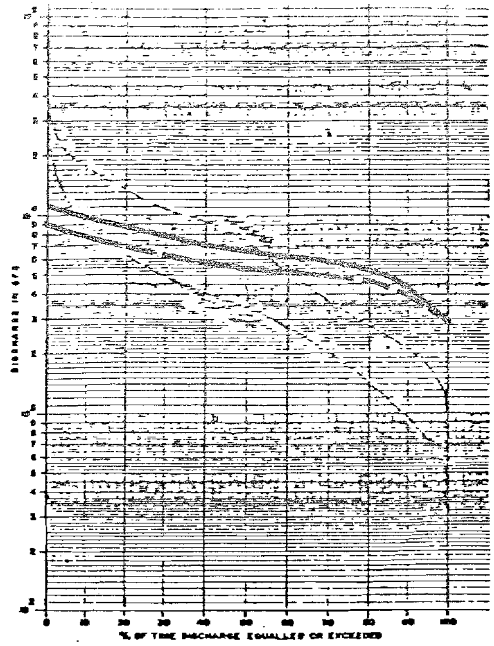
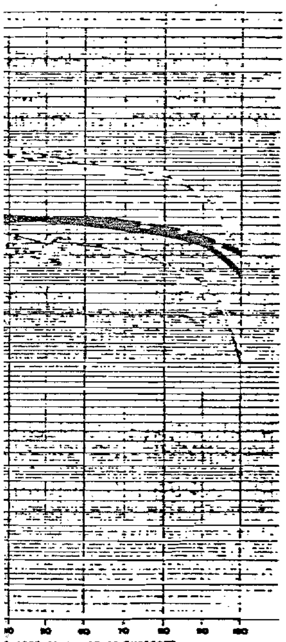


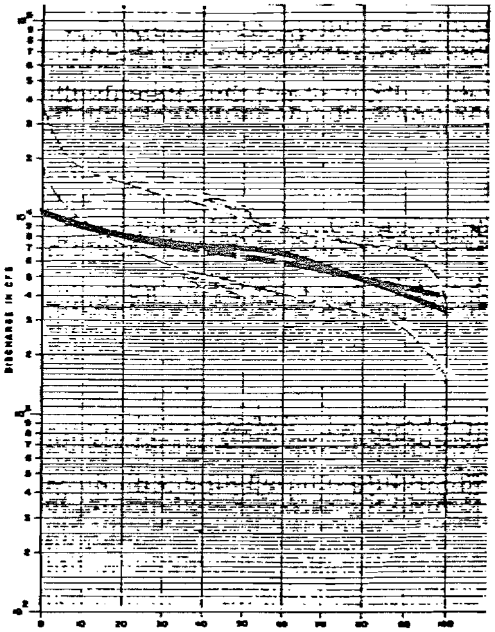
APRIL



MAY



AUGUST



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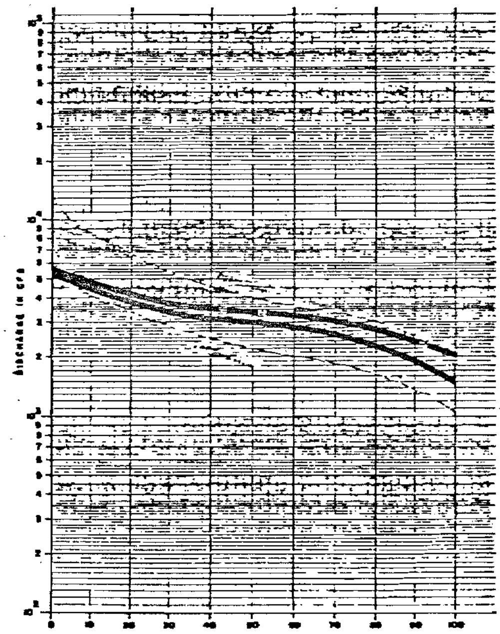
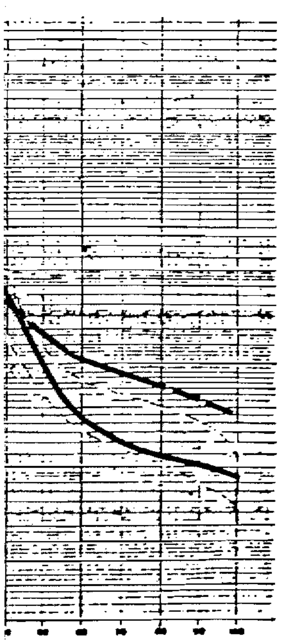


OCTOBER



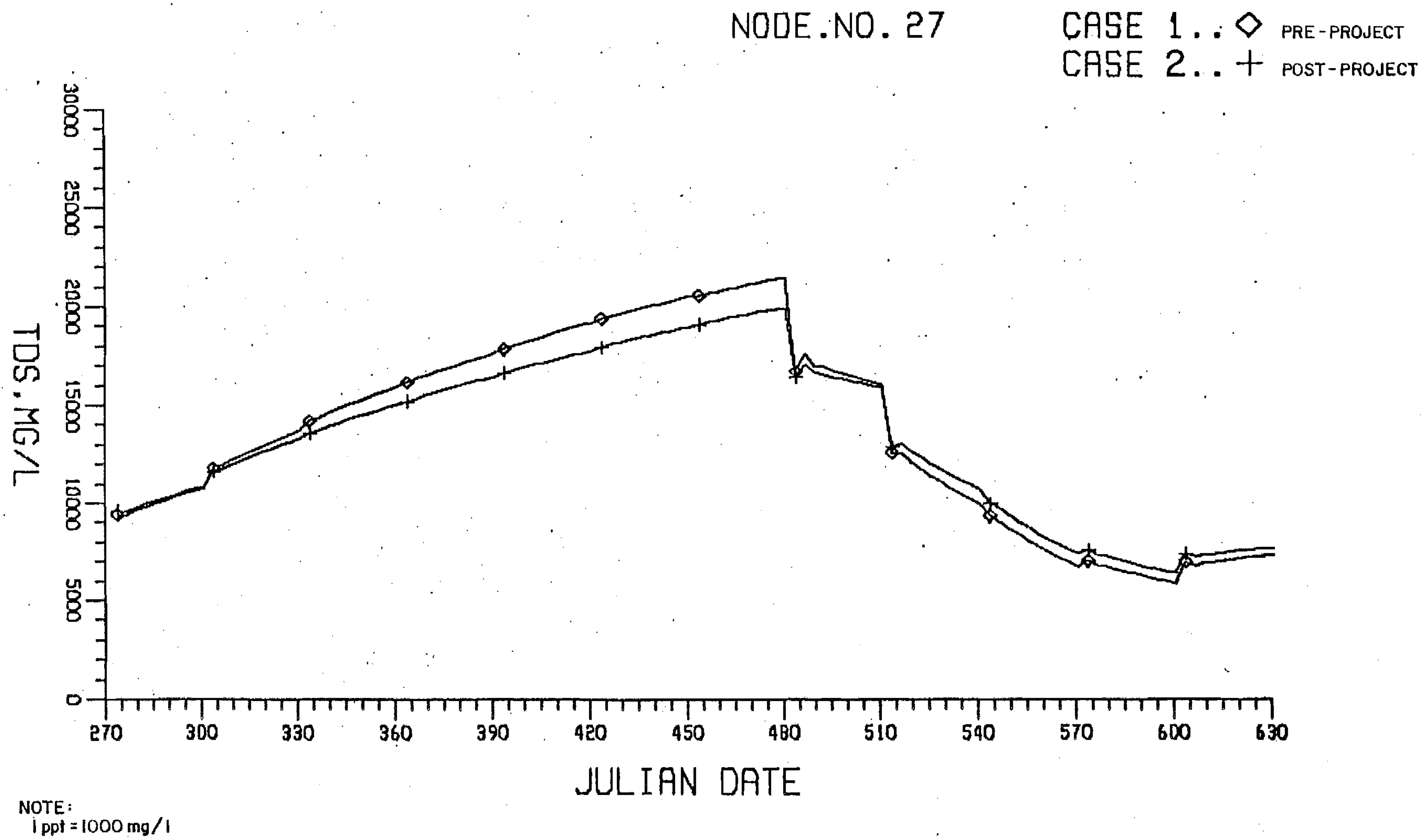
NNUAL

NOTES:

1. ——— PRE-PROJECT FLOW
   ---- CASE C (WATANA/DEVIL CANYON)
2. CURVES GENERATED FROM 30 YEARS RECORD OF HISTORICAL, SYNTHESIZED AND SIMULATED AVERAGE MONTHLY FLOWS.

MONTHLY AND ANNUAL FLOW DURATION CURVES SUSITNA RIVER AT SUSITNA STATION

FIGURE E.2.100



TEMPORAL VARIATION IN SALINITY WITHIN COOK INLET NEAR
THE SUSITNA RIVER UNDER PRE AND POST
SUSITNA HYDROELECTRIC PROJECT CONDITIONS

FIGURE E.2.101