SUSITNA
HYDROELECTRIC PROJECT

FEDERAL ENERGY REGULATORY COMMISSION
PROJECT No. 7114

EFFECTS OF THE PROPOSED PROJECT ON SUSPENDED SEDIMENT CONCENTRATION

FINAL REPORT

HARZA-EBASCO
SUSITNA JOINT VENTURE

DECEMBER 1985
DOCUMENT No. 2982

Alaska Power Authority

Document No. 2982
Susitna File No. 4.2.1

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Report by

Harza-Ebasco Susitna Joint Venture

Prepared for
Alaska Power Authority

Final Report
December 1985

NOTICE

ANY QUESTIONS OR COMMENTS CONCERNING
THIS REPORT SHOULD BE DIRECTED TO
THE ALASKA POWER AUTHORITY
SUSITNA PROJECT OFFICE

TABLE OF CONTENTS

LIST OF TABLES

LIST OF EXHIBITS

LIST OF EXHIBITS (continued)

1.0 SUMMARY

The concentrations and particle size distributions of suspended sediment were determined for natural and with-project conditions on the Susitna River at Gold Creek and Sunshine stations. The estimates for the natural conditions were based on data collected by the United States Geological Survey. Under with-project conditions, the concentrations were estimated using the concentrations in the Watana Reservoir releases and those from the area intervening between Watana and Gold Creek, and between Watana and Sunshine. The concentrations in the Watana Reservoir releases were determined using dynamic reservoir simulation model (DYRESM).

It is estimated that the average suspended sediment concentration of all flows entering Watana Reservoir will be about 830 milligrams per litre (mg/l). For Stage I, the summer suspended sediment concentrations would decrease from about 60-3000 mg/l to about 60-150 mg/l and the winter concentrations would increase from about 1-80 mg/l to about 20 - 100 mg/l. For Stage II operation, these concentrations will be about 10-20 percent smaller than those for Stage I operation.

The larger and deeper Stage III reservoir at Watana would further reduce the suspended sediment concentrations at Devil Canyon. The estimated concentrations in the releases from the Devil Canyon Reservoir would reach their lowest values of about 15 to 20 mg/l in April or May and approach a maximum of about 90 to 100 mg/l in July or August.

The estimated mean monthly suspended sediment concentrations at Gold Creek and Sunshine for Stage I and late Stage III are shown on Exhibits 12 and 13. Project operation would increase the concentration during winter and decrease that during summer. At Gold Creek, November through March concentrations approximately would increase from about 5 mg/l under natural conditions to between 40 and 100 mg/l for Stage I. The concentrations would decrease back to between 25 and 75 mg/l for Stage III. The increase at

Sunshine would be from about 5 mg/l under the natural conditions to between 35 and 75 mg/l for Stage I. For Stage III, the concentrations would be reduced back to between 25 and 60 mg/l. The concentrations in the months of April and October at Gold Creek also will increase compared to those under natural conditions. At Sunshine, the with-project May concentration would be nearly the same as under natural conditions while the October concentrations would be lower (Exhibits 12 and 13). The concentrations during May through September will decrease at both locations (Exhibits 12 and 13).

2.0 BACKGROUND

The first draft of this report was issued in June 1984, and was reviewed by various members of the Aquatic Study Team. Their comments were included in the second draft issued in November 1984. The analyses presented in those two drafts were made for a two-dam, two-stage development. Also the with-project suspended sediment concentrations at Watana were derived from a study made by Peratrovich, Nottingham and Drage, Inc.; (PND, 1982)[1/].

As of April 1985, a two-dam, three-stage development is being considered. Stage I would be a low Watana (normal pool elevation = 2,000 ft) development, Stage II would be a low Watana - Devil Canyon (normal pool elevation = 1,455 ft) development and Stage III would be high Watana (normal pool elevation = 2,185 ft) - Devil Canyon development. Stage III is further divided into early Stage III and late Stage III based on two energy demand scenarios.

This report presents the analyses made for the two-dam three-stage project. The with-project suspended sediment concentration estimates also have been revised based on new analyses.

1/ Indicates reference at the end of text.

3.0 SCOPE OF THE STUDY

The scope of this study includes the analysis of suspended sediment concentrations under natural conditions and changes in the estimated concentrations due to project operation. The analysis is made for the Susitna River at the Watana site, Gold Creek and Sunshine stream gaging stations (see Exhibit 1 for the locations). The major tasks are to:

1. define the characteristics of suspended sediment at selected locations upstream of the Sunshine stream gaging station (Sunshine gage);

2. define the characteristics of suspended sediment entering Watana Reservoir;

3. estimate probable suspended sediment concentrations of water released from the reservoir;

4. evaluate effects on suspended sediment concentrations in the mainstem due to major tributaries entering the Susitna River above Sunshine gage; and

5. provide a comparison of monthly suspended sediment concentrations at Gold Creek stream gaging station (Gold Creek gage) and at the Sunshine gage for natural and with-project conditions.

4.0 SETTING

The Susitna River drains an area of about 19,600 square miles (mi^2) in the south central region of Alaska. The major tributaries include the Chulitna, Talkeetna and Yentna rivers with drainage areas of about 2,650; 2,040 and 6,200 mi^2 respectively.

The Susitna River originates in the West Fork, Susitna, East Fork and Maclaren glaciers of the Alaska Range (Exhibit 1) and travels a distance of about 320 miles to its mouth at the Cook Inlet. The Chulitna River originates in the glaciers on the south slopes of Mount McKinley and joins the Susitna River from the west near Talkeetna at river mile (RM) 98 (river miles referenced from the Cook Inlet). The Talkeetna River originates in the Talkeetna Mountains and joins the Susitna River from the east near Talkeetna at RM 97. The Yentna River originates in the Alaska Range and enters the Susitna River from the west at RM 28.

The Susitna Hydroelectric Project will include two dams, Watana and Devil Canyon, located at RM 184 and 152, respectively. The drainage areas at the two sites are about 5,180 and 5,810 mi^2, respectively. The project will be developed in three stages.

Susitna streamflow is characterized by turbid high flows from May through September and clear low flows from October through April. High spring and summer flows are caused by snowmelt, glacial melt and storm rainfall.

5.0 SUSPENDED SEDIMENT

5.1 DATA SOURCES

Suspended sediment samples have been collected at a number of stream gaging stations in the Susitna River basin by the United States Geological Survey (USGS) (USGS Water Resources Data) and R&M Consultants (R&M, 1981). These samples have been analyzed for total suspended sediment concentration in mg/l. A number of samples also have been analyzed for particle size distribution. Exhibit 1 shows the sampling stations for which the suspended sediment data are available. The numbers of samples collected at selected stations by the USGS during the period of record are given in Table 1. R&M Consultants also collected about 10 samples at Cantwell and 8 samples at Gold Creek stream gaging stations during 1980 and 1981.

5.2 CHARACTERISTICS OF SUSPENDED SEDIMENT

Sediment is transported in suspension, as bed load rolling or sliding along the bed and interchangeably in suspension and as bed load. The nature of movement depends on the size, shape and specific gravity of the sediment particles and the associated flow velocity and turbulence. Under some conditions of high flow velocity and turbulence (such as those in steep-gradient mountain streams) cobbles (64 to 256 mm size) can be carried intermittently in suspension. Conversely, silt size particles (.004 to .062 mm) may move as bed load in low-gradient, low-velocity channels.

5.2.1 At Selected Locations

Suspended sediment is the sediment that is transported outside of the bed layer in suspension by the turbulent components of the flow. In the Susitna River, fine material (silt and clay finer than 0.062 mm) and fine to medium sand particles (sizes between 0.062 mm and up to 1.00 mm) have commonly been observed in suspension.

The fine material, also known as wash load, is derived from sheet erosion, glacier melt and bank erosion. The quantity of wash load being transported depends upon its availability because, for the observed range of flow, the Susitna River can transport much larger quantities of wash load than has been measured. The coarse material (sand particles) moving in suspension is derived either from river bed erosion or from glacier melt and other erosion processes. The maximum quantity of bed material being transported in suspension depends upon the magnitude of flow.

Suspended sediment samples at the USGS stream gaging stations generally have been collected during the months of May through October (Table 1). A few samples are available for some stations for the period from December through April but no sample has been collected in November at any station.

Since the suspended sediment consists of wash load and sand particles, its concentration varies both with the availability of wash load and the capacity of flow to transport sand particles. Available data for Gold Creek and Sunshine gages are plotted on Exhibits 2 and 3, respectively, to show the variation of sediment concentration with water discharge. The maximum, minimum and median concentrations measured at various stream gaging stations are listed in Table 2. The maximum and minimum concentrations are not provided for the months for which only one or two samples are available. The median values in such cases are also not given.

Knott and Lipscomb (1983, 1985) analyzed the periodically observed sediment concentrations and corresponding water discharges and estimated monthly suspended sediment transport rates for the Susitna, Chulitna and Talkeetna rivers (Table 3). Based on the few months of concurrent data, the suspended sediment transport rates in the Chulitna River are significantly higher than those in the Susitna River above its confluence with the Chulitna River. Therefore, the suspended sediment concentrations in the Susitna River below the confluence are controlled by the Chulitna River. The size distributions of suspended sediment at various stations are given in Table 4. The size distributions are available for the samples collected during the months of May through October. A few samples collected during the other months were not analysed by the USGS for size distribution probably because of insufficient sediment quantity. The smoothed size distribution curves based on Table 4 are shown on Exhibits 4 through 11. The percentages of fine material and sand particles at various locations taken from these exhibits are given below.

PERCENTAGES OF FINE MATERIAL AND SAND
IN SUSPENDED SEDIMENT

Station	Fine Material (< .062 mm)	Sand (> .062 mm)	Median Dia. (mm)
Susitna R. nr. Denali	52	48	.056
Susitna R. nr. Cantwell	54	46	.049
Susitna R. at Gold Creek	61	39	.038
Susitna R. nr. Talkeetna (above confluence)	70	30	.015
Chulitna R. nr. Talkeetna	62	38	.024
Talkeetna R. nr. Talkeetna	51	49	.060
Susitna R. at Sunshine	69	31	.014
Susitna R. at Susitna Station	61	39	.030

The above table indicates an increase in the percentages of fine material from Denali to above the confluence of the Susitna and Chulitna rivers. Downstream from the confluence, the trend is not clear primarily because of sediment contributions from the major tributaries and partly because of limited number of samples available for the Susitna River at Susitna station.

An insufficient number of samples are available at Sunshine and Gold Creek to precisely define the concentration for each month. However, by referring to data for various stations, some indicative values of monthly concentrations for the Susitna River at the two stations were estimated as shown on Exhibits 12 and 13, respectively. The values indicated on the exhibits are not related to specific discharges and approximately represent the median values from the range of observed concentrations under natural flow conditions.

5.2.2 Suspended Sediment Entering Watana Reservoir

The characteristics of the suspended sediment entering Watana Reservoir are best represented by those measured at the Cantwell station. This indicates that, on the average, the suspended sediment concentrations may vary approximately between 0 to 10 mg/l from November through April and between 80 to 3,000 mg/l from May through October. The average size distribution based on the samples collected from May through October is shown on Exhibit 5. This indicates that about 18 percent of the suspended sediment is less than .004 mm (clay sizes), about 36 percent is between .004 and .062 (silt sizes) and about 46 percent is larger than .062 mm (sand sizes). About 97 percent of the suspended sediment is finer than .500 mm. The average annual streamflow at Watana is about 8,000 cubic feet per second (cfs) (H-E, February 1985). The suspended sediment inflow is estimated to be about 6,530,000 tons per year (ton/yr) (H-E, April 1984). This gives an average concentration of about 830 mg/l for the flow entering the reservoir.

5.3 EFFECTS OF ICE COVER ON SEDIMENT TRANSPORT

A study made by W.W. Sayre and G.B. Song (Sayre, 1979) to evaluate the effects of ice-cover on alluvial channel flow and sediment transport processes indicates that ice causes a number of changes in alluvial channel flows by approximately doubling the wetted perimeter and thereby producing a redistribution of the boundary and internal shear stresses. The total depth of flow in the channel with a given unit discharge and slope is significantly increased (about 20 to 30 percent for a smooth cover and from 30 to 80 percent for rough cover, relative to the depth for a free surface condition). Due mainly to the lower velocities, sediment discharge is significantly reduced.

The above conclusions are applicable to the Susitna River for the period between early November and mid-May when an ice cover is generally present.

5.4 SEDIMENT TRANSPORT DURING FREEZE-UP

Field observations on the Susitna River show that freeze-up generally begins in October and generally continues until break-up in early to mid-May. The beginning of frazil ice (a spongy or slushy accumulation of ice crystals which form in supercooled water that is too turbulent to permit coagulation of the crystals into sheet ice) is marked by a rapid reduction in suspended sediment concentration. As the process continues, the river becomes clear within a day or two. The contributions of fine sediment from the erosion process and from glacial flour are stopped due to frozen ground and the elimination of glacier melt. The river remains practically clear until breakup.

The frazil crystals often flocculate into larger clusters. Since water can permeate through these clusters, they filter out sediment particles which remain entrapped in the ice. During breakup, a significant quantity of sediment, mostly silt and clay, is observed to be mixed with ice. The sediment is concentrated at places rather than distributed over the whole mass.

Anchor ice, similar to slush ice but adhering temporarily to the river bottom, also has been observed to be mixed with sediment. The anchor ice probably catches sediment moving as bed load as well as suspended load. The anchor ice is generally formed at night and released during the day and then drifts downstream.

5.5 PROJECT EFFECT

5.5.1 Suspended Sediments Concentrations at Watana Reservoir Outlet

Peratrovich, Nottingham and Drage, Inc.; (PND) made an analysis of turbidity levels in the Watana Reservoir using a computer model DEPOSITS (PND, 1982). The major conclusions made by PND that are pertinent to this study are given below.

1. Sediment particles of about .004 mm and less will remain in suspension;

2. Maximum sediment concentrations in the Watana releases would be between 200 and 400 mg/l; and

3. Minimum sediment concentrations in the Watana releases would be between 30 and 70 mg/l.

Harza-Ebasco studied the suspended sediment characteristics in the Watana Reservoir and in the outflow from the reservoir for the two-dam, three-stage project. The purpose of the study was to refine the analysis made by PND. The DYRESM model (Imberger and Patterson, 1981), used for the reservoir temperature and ice study, was enhanced to include a sub-routine to simulate, on a daily basis, the vertical distribution of suspended sediments in the reservoir and the suspended sediment concentration in the outflow. The model considers the sediment mixing due to meteorological forcing, turbulence, density currents and externally specified vertical settling velocities. The effect of the ice cover on the suspended sediment concentration also is considered. Compared to DYRESM, the DEPOSITS model used monthly inflow data and thus, was not responsive to rapidly changing sediment inflows during floods. The effects of stratification, density currents and ice cover also were not considered.

For the Stage I operation (Watana only, normal pool elevation = 2,000 ft), the suspended sediment concentrations in the reservoir and the outflow were simulated using the enhanced version of DYRESM model; 1970, 1981 and 1982 flow conditions with Case E-VI downstream flow requirements (H-E, November 1984) and daily suspended sediment inflow rates. The water years 1970, 1981 and 1982 were judged to represent near minimum, maximum and average suspended sediment inflow conditions, respectively. Daily sediment inflow rates were estimated for these years by transposing the corresponding data at Gold Creek. The transposition was made using the procedures discussed in a previous report (H-E, April 1984). The amount of suspended sediment corresponding to a given range of sediment particle sizes was estimated using the particle size distribution curve shown on Exhibit 5.

Results of the simulation indicated that all sizes above 10 microns would settle out in the reservoir. A large portion of particles with sizes between 3 and 10 microns also would settle out. The particle sizes up to 3 microns would remain in suspension for a long period due to low settling velocities and thus would constitute the major part of suspended sediment concentration during winter months. Exhibits 14, 15 and 16 show sediment concentrations in the outflows from the Watana Reservoir. The concentration is nearly constant from July through November and then decreases from December through early May when it reaches a minimum value. Table 5 gives the average and range of monthly concentrations under Stage I conditions.

Therefore, the downstream suspended sediment concentrations near the project site will be affected by the operation of the Watana Stage I Reservoir. The summer suspended sediment level would be decreased from about 60-3,000 mg/l to about 60-150 mg/l and in the winter, the level would be increased from about 1-80 mg/l to about 20 to 100 mg/l.

The enhanced DYRESM model was also applied to simulate the suspended sediment concentrations in the Watana and Devil Canyon reservoirs using Case E-VI downstream flow requirements, Stage II energy demand level and 1982 sediment inflow conditions (average year). The sediment inflows for maximum and minimum sediment conditions were not simulated because the analyses made for three scenarios for Stage I can be used to provide an indication of relative changes for minimum or maximum sediment inflows under Stage II. Table 6 summarizes the results of the analysis. Exhibits 17 and 18 show the estimated suspended sediment concentrations from the Watana and Devil Canyon reservoirs, respectively. These exhibits indicate that a small quantity of particles sizes below 10 microns also would settle out in the Devil Canyon Reservoir. The suspended sediment concentration in the Devil Canyon

Reservoir releases would be about 10-20 percent less than that from the Watana Reservoir under Stage I.

The enhanced DYRESM model also was applied to simulate the suspended sediment concentrations in the Watana and Devil Canyon reservoirs using late Stage III energy demand level, Case E-VI downstream flow requirements, and 1982 (average year) sediment inflow conditions. The results of this analysis are given in Table 7 and also shown on Exhibits 19 through 22. As under Stage II conditions, a small quantity of particles with sizes below 10 microns would settle out in the Devil Canyon Reservoir. The suspended sediment concentrations in the releases from the Devil Canyon Reservoir would be more uniform during summer compared to those under natural conditions. Under late Stage III conditions, the suspended sediment concentration in the Watana releases would be less than that under Stages I and II. During the months of July and August this reduction would be about 50 mg/l. This is due to the larger and deeper Watana Reservoir in Stage III. Correspondingly, the suspended sediment concentration in the releases from the Devil Canyon Reservoir would be less under Stage III than under Stages I and II.

For late Stage III, the suspended sediment concentration in the releases from the Devil Canyon Reservoir, would reach its lowest level of about 15 to 20 mg/l in April or May and approach a maximum of about 90 to 100 mg/l in July or August. These results are based on the simulation of average flow conditions during 1982. The corresponding values for a low or high sediment inflow year can be estimated by the relative decrease or increase for these years for the Stage I simulation.

5.5.2 River Water Temperatures

The extent of formation of ice cover on the Susitna River downstream from the reservoirs will depend upon the reservoir outflow temperatures and their effect on river water temperatures. Because the formation of ice cover affects the sediment transport as discussed under sub-section 5.3, an evaluation of with-project river water temperatures was made.

Harza-Ebasco has conducted a water temperature and ice study for the Watana and Devil Canyon reservoirs and a river ice study for the reach between the Devil Canyon Reservoir and the confluence with the Chulitna River. The study results are presented in the draft License Application Amendment Exhibit E, Chapter 2, Water Use and Quality (APA 1985), and in a report on ice simulations (HE November 1985) for the three-stage project. The study indicates that the outflow temperatures at Watana under Stage I can be controlled to approximate the natural instream temperatures using multi-level intakes. The outflow temperatures under Stage I, would range between 5°C and 12°C in the summer and between 0.5°C and 3°C in the winter depending upon the meteorological conditions. Under Stages II and III, the outflow temperatures from the Devil Canyon Reservoir would be between 1.5°C and 3°C in the winter and between 4°C and 10°C in the summer.

The Arctic Environmental Information and Data Center (AEIDC) has conducted river temperature studies (Exhibit E, Chapter 2, APA 1985) to investigate project effects on the river reach downstream from the dam(s) to Sunshine. For all three stages of the project, the river temperatures between the dam(s) and the end of the ice cover, were predicted to be between 0°C and 2° to 3°C in comparison to 0°C temperature in the same reach under natural conditions. Exhibits 23 to 25 show the positions of ice fronts for the three stages. Since the river temperatures during winter would be higher than those under natural conditions, frazil and anchor ice formation activities would be reduced. This would result in a decreased entrapment of suspended sediments by frazils.

5.5.3 Suspended Sediment Concentration between Watana and the Chulitna Confluence

The suspended sediment concentration in this reach will be controlled by the concentration in the reservoir releases (sub-section 5.5.1) and any sediment contribution from the reach.

The suspended sediment concentration in the reach above the ice front will be nearly the same as in the releases. Any reduction caused by frazil and anchor ice will be compensated by sand particles picked up from the river bed because of higher winter flow. The formation of ice in the reach between the ice front and the confluence will reduce the sediment transport capacity of the river and some sediment could be trapped by ice. However, the reduction in the concentration will be relatively small. Therefore, the with-project winter suspended sediment concentrations would be about the same as in the outflows from the Watana Reservoir under Stage I and from the Devil Canyon Reservoir under Stages II and III. During summer flood periods, the contribution from the intervening areas may increase concentrations in the mainstream but the concentration would be significantly less than those under natural conditions. Exhibit 12 shows approximate suspended sediment concentrations during various months at Gold Creek for an average flow year.

5.5.4 Suspended Sediment Concentration between the Chulitna Confluence and Sunshine

In this reach two major tributaries, the Chulitna and Talkeetna Rivers, join the Susitna River. These rivers carry little sediment during winter (Table 2). Under with-project conditions, the increased winter flow will pick up sand particles from the main channel of the Susitna River. However, some of the sediment will be trapped by ice, and the net increase in sediment concentrations will be insignificant. The concentration during winter will, therefore, be controlled by the concentration in the Susitna River above the confluence. During summer months, low concentrations in the Susitna River above the confluence will reduce the concentration at Sunshine compared to that under natural conditions. The monthly concentrations at Sunshine gage were estimated based on monthly suspended sediment concentrations and discharges observed in the Chulitna and Talkeetna rivers, with-project monthly discharges and concentrations in the Susitna River above the confluence and flow contributions from the intervening area. The with-project monthly discharges were those computed for various stages based on Case E-VI downstream requirements. Exhibit 13 shows approximate suspended sediment concentrations during various months at Sunshine for an average flow year. The minimum concentration is about 25 mg/l in March, with the maximum concentration of about 675 mg/l in August.

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TABLES

Table 1

SUSPENDED SEDIMENT SAMPLES
COLLECTED AT USGS STREAM GAGING STATIONS

Stream Gaging Stations	Period	J	F	M	A	M	J	J	A	S	O	N	D
		No. of Samples											
Susitna River nr. Denali	1961-62; 1964-66 1968; 1974-75; 1977; 1979-82	-	-	1	1	7	8	12	9	8	3	-	-
Susitna River nr. Cantwell	1962-72; 1980-82	1	-	1	-	3	11	14	9	12	3	-	-
Susitna River at Gold Creek	1962; 1974-82	3	1	4	-	9	7	9	9	8	5	-	-
Susitna River nr. Talkeetna	1982	-	-	-	-	-	5	4	5	1	-	-	-
Chulitna River nr. Talkeetna	1967-72, 1980-82	1	1	4	2	4	10	10	8	9	2	-	-
Talkeetna River nr. Talkeetna	1966-82	8	1	7	7	12	13	16	23	12	7	-	-
Susitna River at Sunshine	1971; 1977; 1981-82	-	-	2	-	1	7	7	8	3	1	-	-
Susitna River at Susitna Station	1975-81	2	-	3	2	3	4	6	4	1	2	-	2

Table 2

SUSPENDED SEDIMENT CONCENTRATIONS, MG/L
(Period 1962 to 1982)

Months

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Susitna R. nr. Denali												
Max.	-	-	-	-	1190	1600	2770	5690	3600	1400	-	-
Min.	-	-	-	-	102	302	886	350	124	85	-	-
Median	-	-	-	-	570	840	1350	890	293	104	-	-
Susitna R. nr. Cantwell												
Max.	-	-	-	-	726	1860	2790	1040	770	140	-	-
Min.	-	-	-	-	132	172	632	380	34	6	-	-
Median	-	-	-	-	661	417	1090	755	138	84	-	-
Susitna R. at Gold Creek 1/												
Max.	8	-	3	-	1110	1400	130	938	812	22	-	-
Min.	<1	-	1	-	65	151	100	158	23	7	-	-
Median	2	-	2	-	498	574	394	420	68	10	-	-
Susitna R. nr. Talkeetna												
Max.	-	-	-	-	-	769	768	341	-	-	-	-
Min.	-	-	-	-	-	181	145	219	-	-	-	-
Median	-	-	-	-	-	438	422	285	-	-	-	-
Chulitna R. nr. Talkeetna												
Max.	-	-	21	-	1040	1600	2200	1260	1680	-	-	-
Min.	-	-	4	-	500	90	717	694	129	-	-	-
Median	-	-	12	-	675	820	1165	817	396	-	-	-
Talkeetna R. nr. Talkeetna												
Max.	15	-	11	48	503	1340	1160	3530	310	29	-	-
Min.	2	-	1	2	21	171	90	38	13	8	-	-
Median	8	-	3	8	123	309	359	466	80	16	-	-
Susitna R. at Sunshine												
Max.	-	-	-	-	-	1630	1430	3510	-	-	-	-
Min.	-	-	-	-	-	360	503	424	-	-	-	-
Median	-	-	-	-	-	702	713	715	-	-	-	-
Susitna R. at Susitna Station												
Max.	-	-	5	-	572	918	1490	1490	-	-	-	-
Min.	-	-	3	-	378	326	561	483	-	-	-	-
Median	-	-	3	-	417	503	852	943	-	-	-	-

1/ U.S. Geological Survey, Water Supply Paper NO. 1500 gives estimated mean daily concentration of 2,730 on July 16, 1957.

Table 3

ESTIMATED MONTHLY SUSPENDED SEDIMENT TRANSPORT
AT THE SELECTED SITES ON THE SUSITNA RIVER

						Suspended Sediment Load (10^3 tons)							
Stream Gaging Station	Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Susitna R. nr. Talkeetna	1982					300	800	880	359	470	9.3	.78	.72
(above confluence)	1983	.79	.62	.34	.50	350	920	1080	980	121			
Chulitna R. nr. Talkeetna (above confluence)	1982					130	1280	2650	1400	1690			
Chulinta R. below Canyon	1982										37	5.1	2.6
nr. Talkeetna (below confluence)	1983	1.9	.63	.72	1.1	250	1660	2760	3200	630			
Talkeetna R. nr. Talkeetna	1982					60	400	510	138	242	10	.85	.63
(above confluence)	1983	3.8	.14	.15	.23	46	220	430	350	23.8			
Susitna R. at Sunshine	1982					600	2700	4200	2400	2270	110	4.5	3.2
	1983	2.7	1.7	.78	1.7	930	3400	3900	4700	690			

Table 4

PARTICLE SIZE DISTRIBUTION OF SUSPENDED SEDIMENT

Stream Gaging Station	No. of Sample [1]	.002	.004	.008	.016	.031	.062	.125	.250	.500	1.000
		Particle Size (mm) Percent Finer Than [2]									
Susitna River nr. Denali	34	12	16	23	31	41	53	64	81	96	100
Susitna River nr. Cantwell	27	12	18	25	33	43	54	67	86	97	100
Susitna River at Gold Creek	24	15	19	27	35	47	61	75	86	98	100
Susitna River nr. Talkeetna	13	29	35		53		72	79	90	100	
Chulitna River nr. Talkeetna	36	21	31	37	46	55	62	72	85	99	100
Talkeetna River nr. Talkeetna	16	9	16	22	31	41	53	65	85	99	100
Susitna River at Sunshine	17	22	33	43	53	62	67	79	90	100	
Susitna River at Susitna Station	9	16	23	33	43	52	60	82	94	100	

1/ Samples for which full range of size distributions were analyzed.

2/ The percentages given are the median values from a range of oberved percentages for various sizes.

Table 5

SUSPENDED SEDIMENT CONCENTRATIONS (MG/L)
WATANA OPERATION, STAGE I

Month	Range of Observed Concentration[1/]	Range of Estimated Concentration[2/]	Average Concentration in Reservoir Releases[3/] 1970 (Minimum)	1982 (Average)	1981 (Maximum)	Range of Concentration in Reservoir Releases[3/] 1970 (Minimum)	1982 (Average)	1981 (Maximum)
Jan	1-8	2-55	65	65	85	40-90	45-85	50-120
Feb	N/A[4/]	2-93	40	55	65	20-70	35-70	30-95
Mar	1-6	2-23	30	40	45	10-50	20-60	20-75
Apr	N/A	2-183	25	30	50	10-40	10-50	20-75
May	65-1,110	5-1,480	20	35	45	5-50	10-65	10-70
Jun	151-1,860	620-1,705	75	85	90	35-90	45-145	70-95
Jul	100-2,790	506-2,062	105	130	110	85-115	120-145	70-190
Aug	158-1,040	198-2,150	105	110	165	90-115	85-125	130-200
Sep	23-812	5-1,511	95	90	130	85-105	85-100	100-170
Oct	7-140	2-144	85	100	125	80-100	90-110	100-140
Nov	N/A	2-71	90	95	115	75-100	85-110	90-130
Dec	N/A	3-47	80	85	95	60-90	70-95	70-110

1/ From Table 2 using data from the Susitna River near Cantwell (period 1962-72, 1980-82) and at Gold Creek (period 1962, 1974-82).

2/ Estimated from daily sediment transport in tons per day and corresponding mean daily discharge in cfs at Watana, 1970, 81 and 82 flow conditions.

3/ Based on DYRESM simulation results.

4/ N/A = not available.

Table 6

SUSPENDED SEDIMENT CONCENTRATIONS (MG/L)
WATANA - DEVIL CANYON OPERATION, STAGE II

Month	Range of Observed Concentration[1/]	Range of Concentration[2/]	Average Concentration[3/] (Average Year)	Range of Concentration[3/] (Averge Year)
Jan	1-8	1-20	60	50-75
Feb	N/A[4/]	1-30	45	30-60
Mar	1-6	1-20	40	30-50
Apr	N/A	30-170	30	25-35
May	65-1,110	130-1,270	30	10-35
Jun	151-1,860	930-1,470	55	20-100
Jul	100-2,790	600-1,600	110	70-140
Aug	158-1,040	200-1,070	110	80-130
Sep	23-182	200-1,530	90	70-130
Oct	7-140	1-30	80	75-85
Nov	N/A	1-30	80	75-80
Dec	N/A	1-30	75	60-80

1/ From Table 2, using data for the Susitna River near Cantwell (period 1962-72, 1980-82) and at Gold Creek (period 1974-82).

2/ Estimated from daily sediment transport in tons per day and corresponding mean daily discharge in cfs at Watana, 1982 flow conditions (average year).

3/ Based on DYRESM simulation for 1982, releases from Devil Canyon Reservoir.

4/ N/A = not available.

Table 7

SUSPENDED SEDIMENT CONCENTRATIONS (MG/L)
WATANA - DEVIL CANYON OPERATION, LATE STAGE III

Month	Range of Observed Concentration[1/]	Range of Concentration[2/]	Average Concentration[3/] (Average Year)	Range of Concentration[3/] (Averge Year)
Jan	1-8	1-20	55	40-70
Feb	N/A[4/]	1-30	50	30-65
Mar	1-6	1-20	25	14-40
Apr	N/A	30-170	25	15-40
May	65-1,110	130-1,270	20	10-30
Jun	151-1,860	930-1,470	35	15-60
Jul	100-2,790	600-1,600	75	60-100
Aug	158-1,040	200-1,070	75	55-100
Sep	23-182	200-1,530	55	40-70
Oct	7-140	1-30	50	40-65
Nov	N/A	1-30	70	65-70
Dec	N/A	1-30	65	55-70

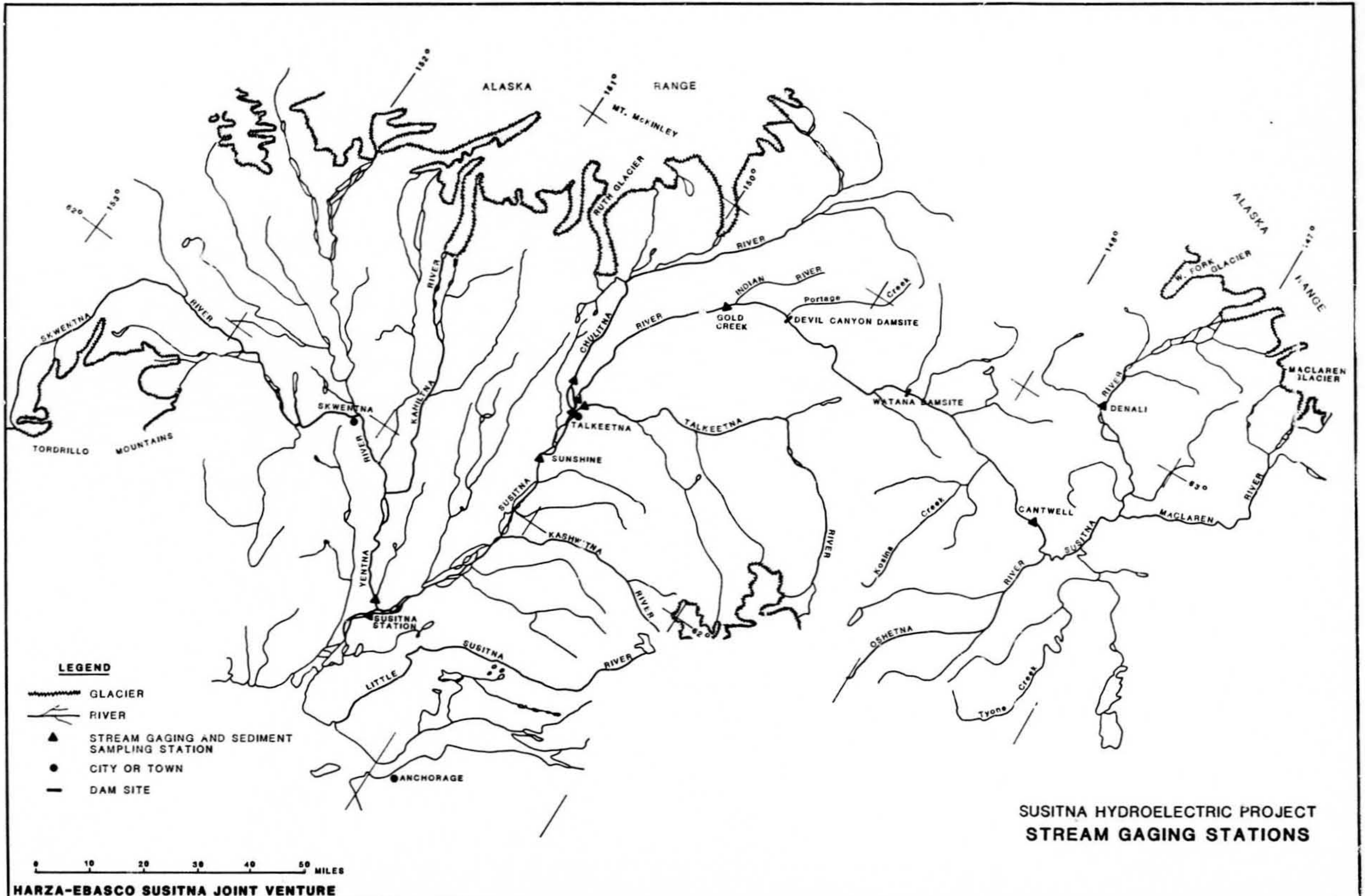
1/ From Table 2, using data for the Susitna River near Cantwell (period 1962-72, 1980-82) and at Gold Creek (period 1974-82).

2/ Estimated from daily sediment transport in tons per day and corresponding mean daily discharge in cfs at Watana, 1982 flow conditions (average year).

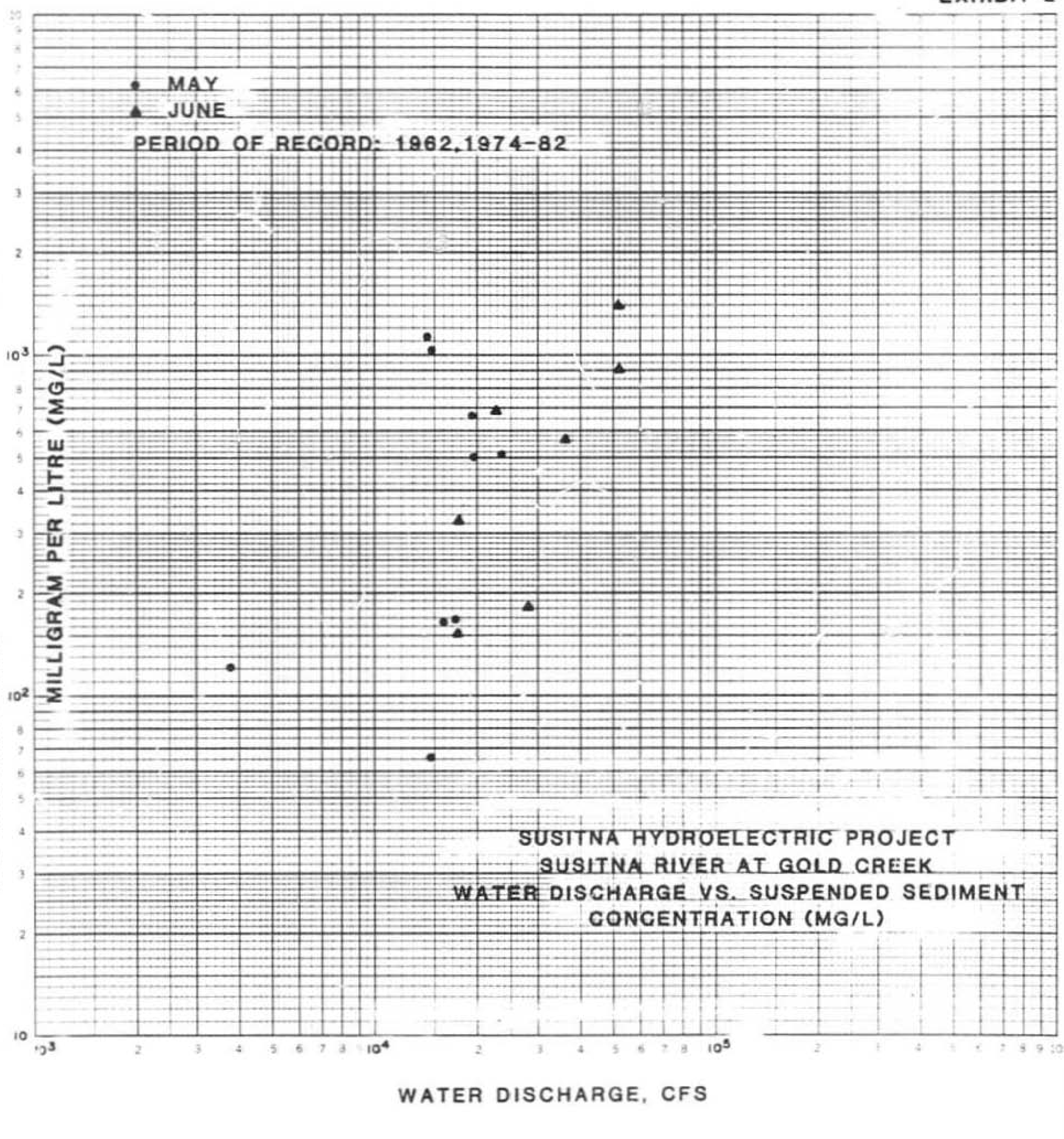
3/ Based on DYRESM simulation for 1982, releases from Devil Canyon Reservoir.

4/ N/A = not available.

EXHIBITS

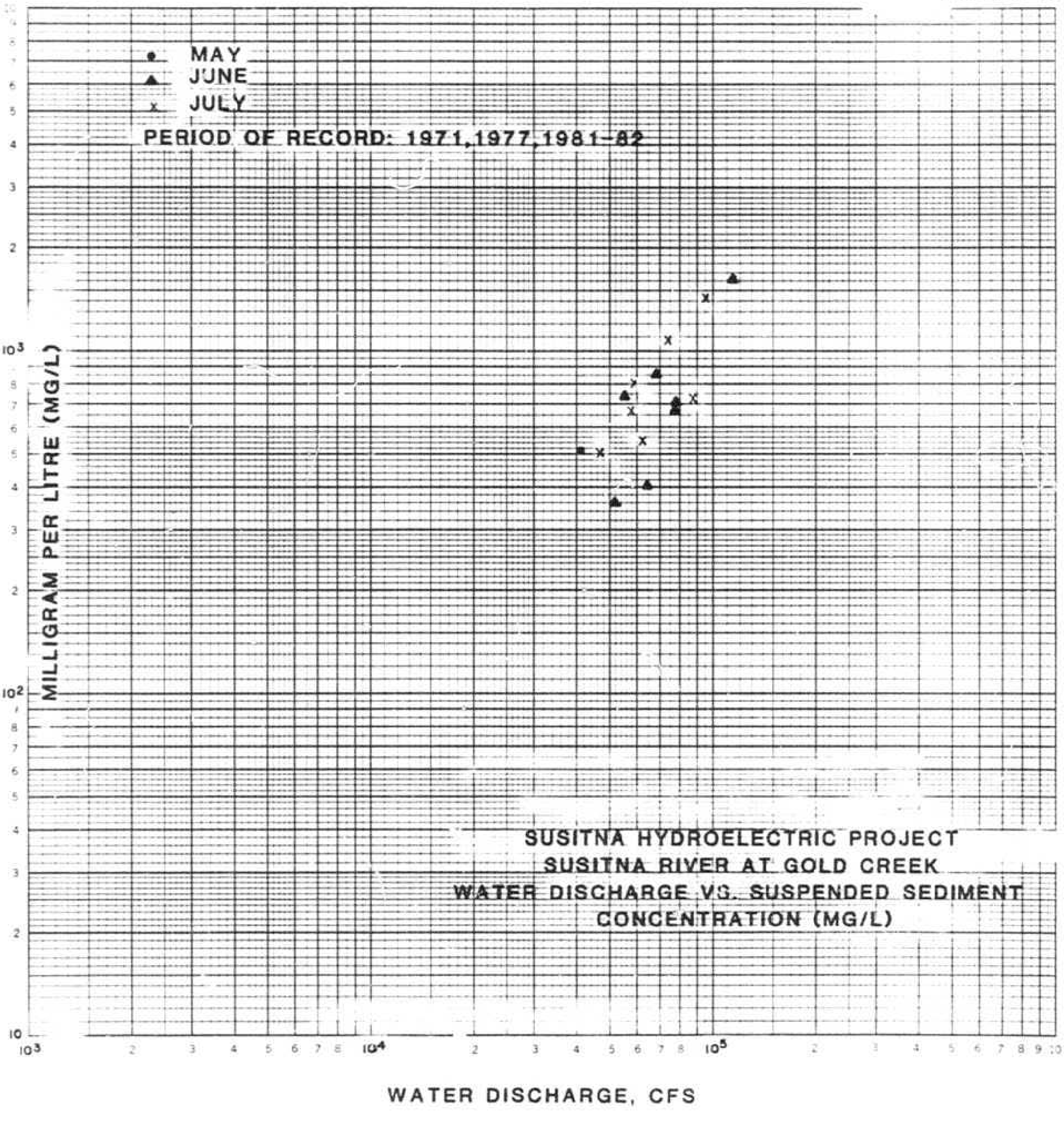


SUSITNA HYDROELECTRIC PROJECT
STREAM GAGING STATIONS



MAY
JUNE
PERIOD OF RECORD: 1962,1974-82
MILLIGRAM PER LITRE (MG/L)
WATER DISCHARGE, CFS
SUSITNA HYDROELECTRIC PROJECT
SUSITNA RIVER AT GOLD CREEK
WATER DISCHARGE VS. SUSPENDED SEDIMENT
CONCENTRATION (MG/L)

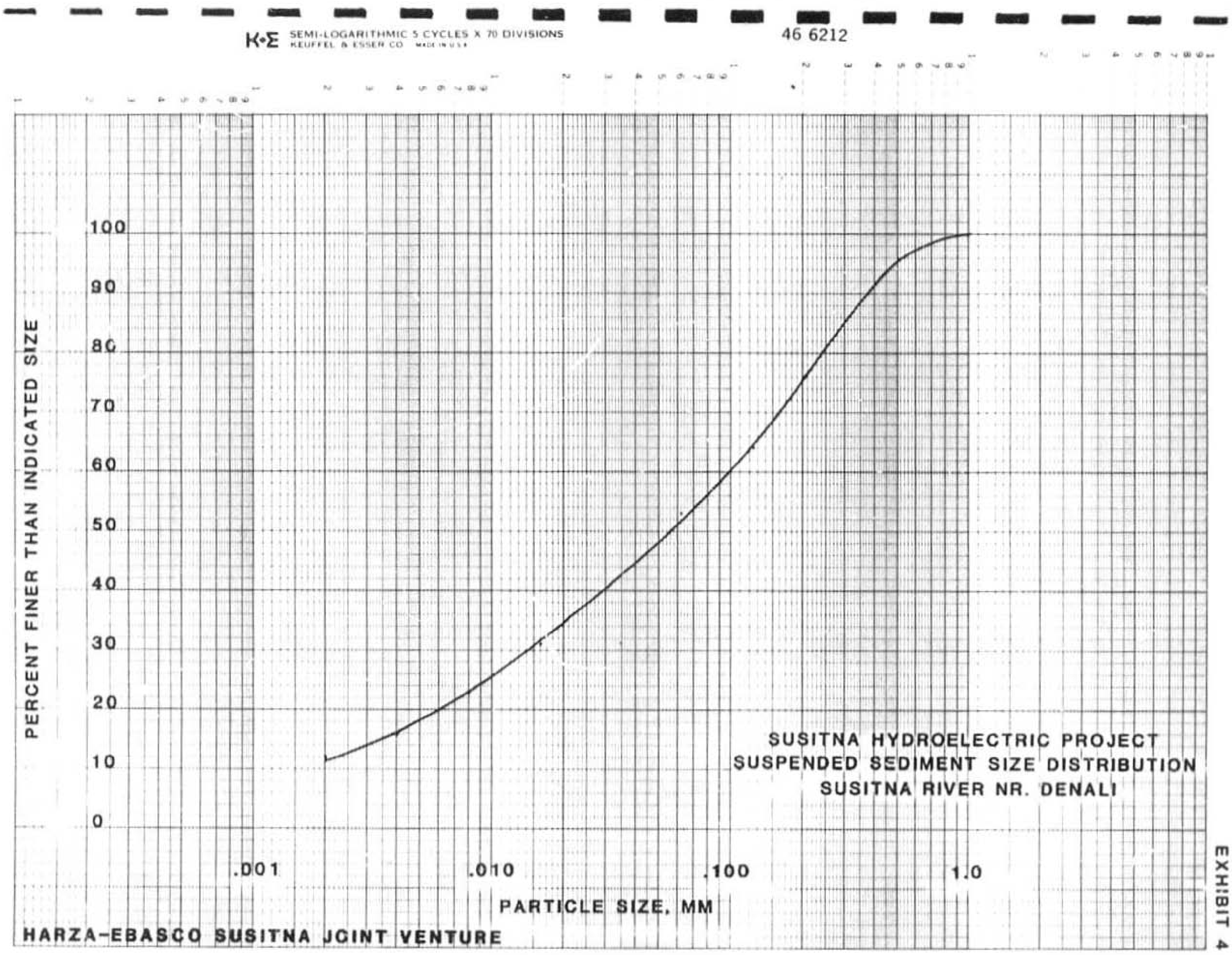
EXHIBIT 3



SUSITNA HYDROELECTRIC PROJECT
SUSITNA RIVER AT GOLD CREEK
WATER DISCHARGE VS. SUSPENDED SEDIMENT CONCENTRATION (MG/L)

HARZA-EBASCO SUSITNA JOINT VENTURE

EXHIBIT 4


K•Σ SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO.
46 6212
PERCENT FINER THAN INDICATED SIZE
100
90
80
70
60
50
40
30
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10
0
.001
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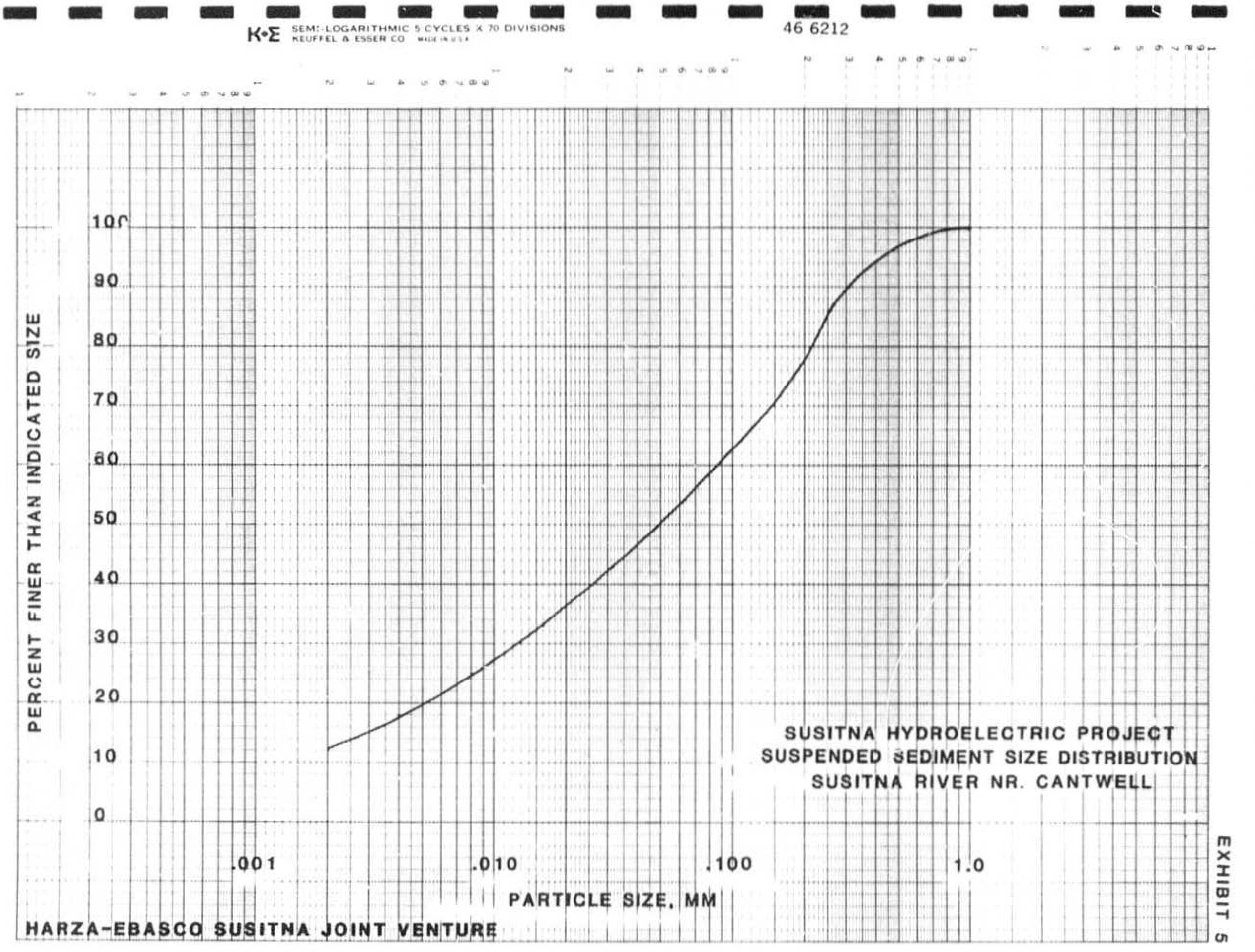
.100
1.0
PARTICLE SIZE, MM
SUSITNA HYDROELECTRIC PROJECT
SUSPENDED SEDIMENT SIZE DISTRIBUTION
SUSITNA RIVER NR. DENALI
HARZA-EBASCO SUSITNA JCINT VENTURE

EXHIBIT 5



K•E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO.
46 6212
PERCENT FINER THAN INDICATED SIZE
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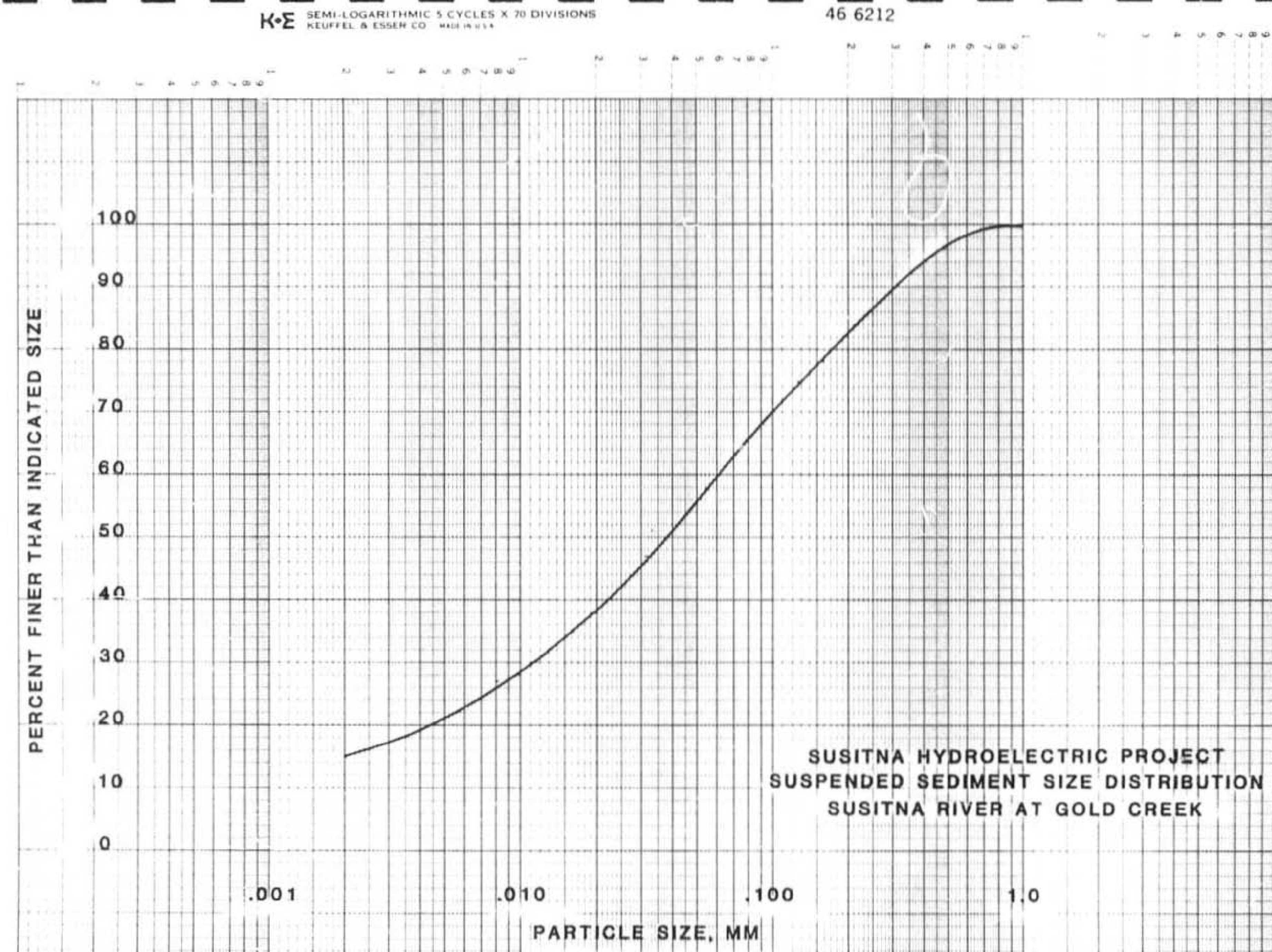
1.0
PARTICLE SIZE, MM
SUSITNA HYDROELECTRIC PROJECT
SUSPENDED SEDIMENT SIZE DISTRIBUTION
SUSITNA RIVER NR. CANTWELL
HARZA-EBASCO SUSITNA JOINT VENTURE

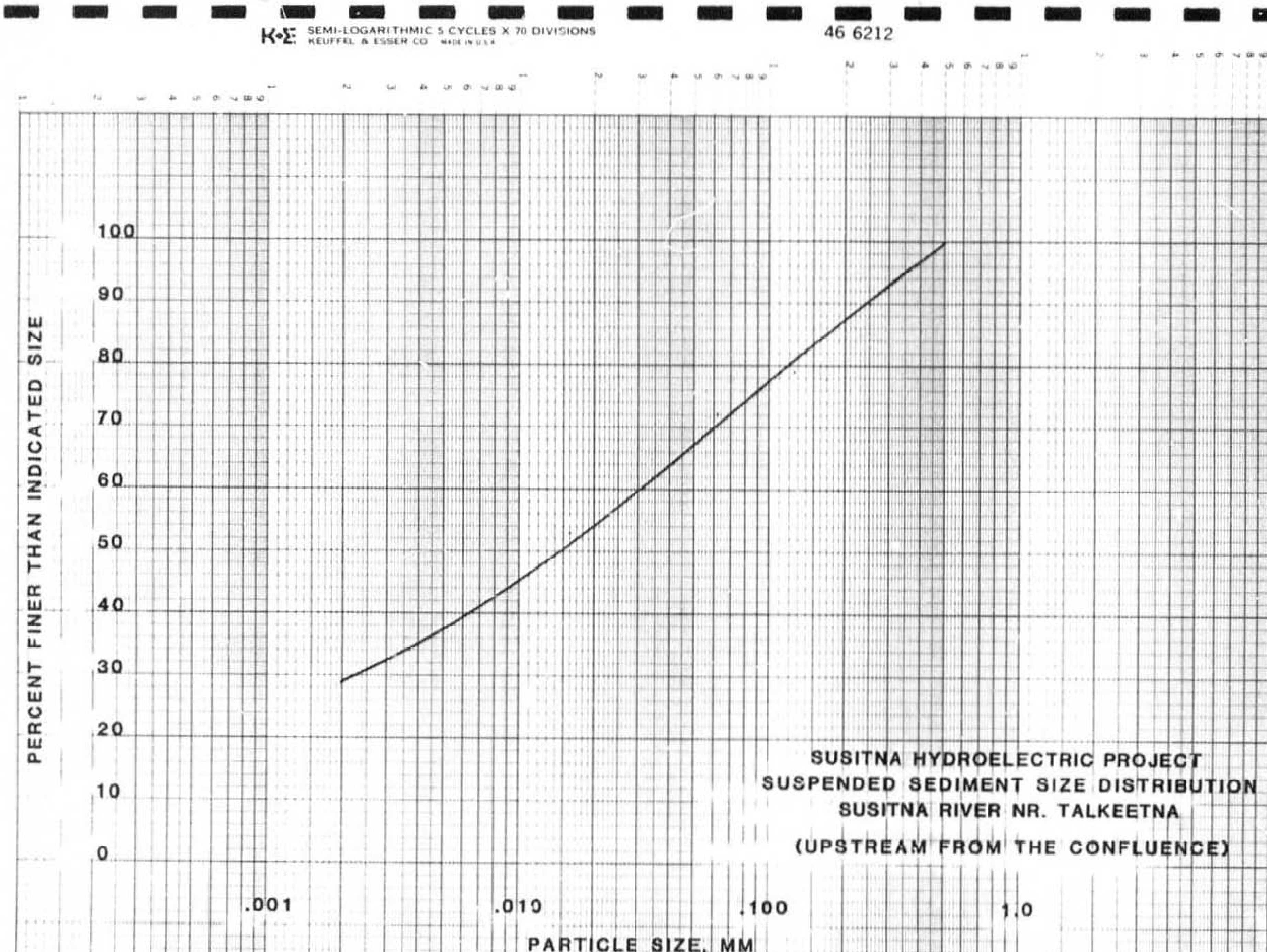
EXHIBIT 6



SUSITNA HYDROELECTRIC PROJECT
SUSPENDED SEDIMENT SIZE DISTRIBUTION
SUSITNA RIVER AT GOLD CREEK

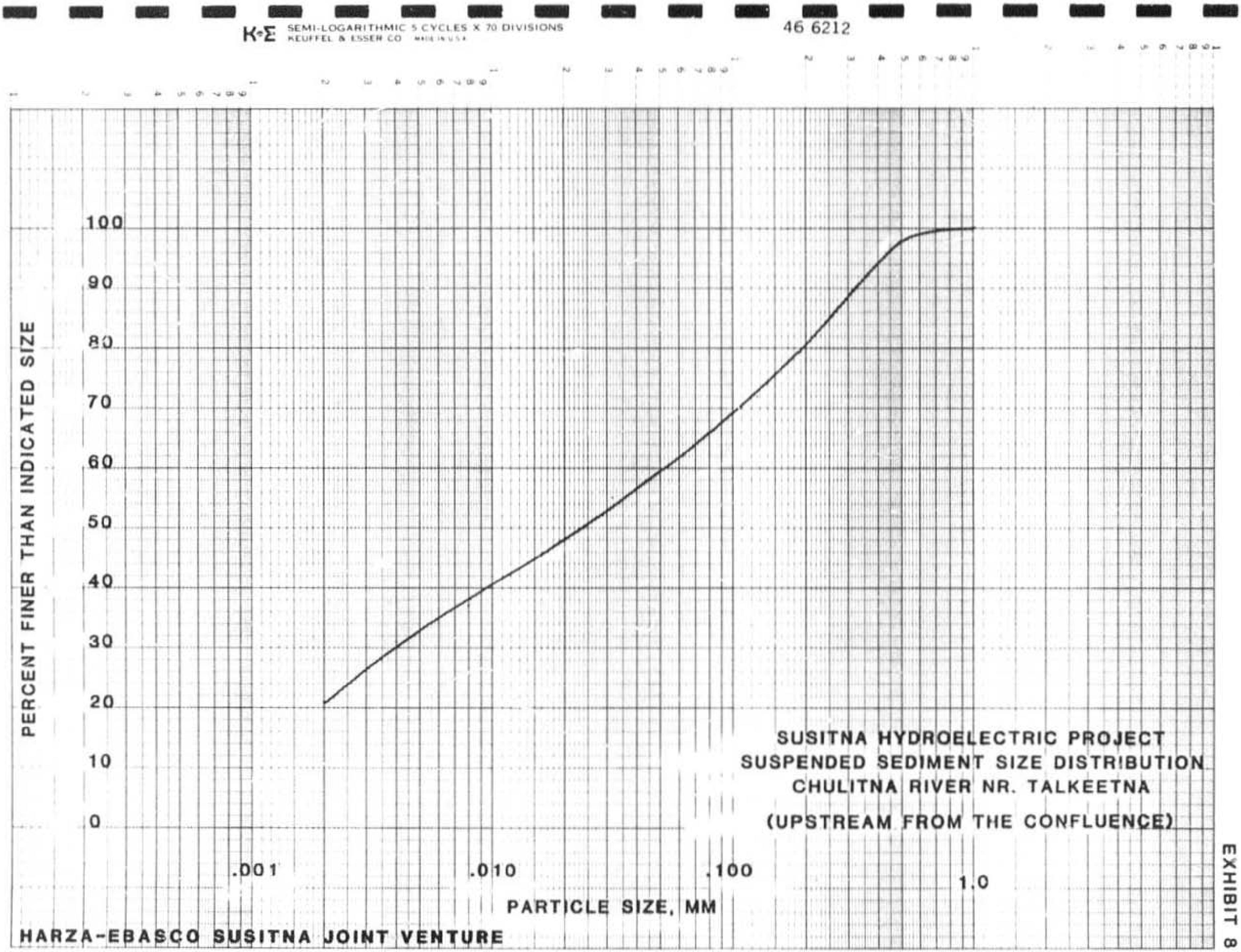
HARZA-EBASCO SUSITNA JOINT VENTURE

EXHIBIT 7



SUSITNA HYDROELECTRIC PROJECT
SUSPENDED SEDIMENT SIZE DISTRIBUTION
SUSITNA RIVER NR. TALKEETNA
(UPSTREAM FROM THE CONFLUENCE)

HARZA-EBASCO SUSITNA JOINT VENTURE


K+E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO.
46 6212
PERCENT FINER THAN INDICATED SIZE
100
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10
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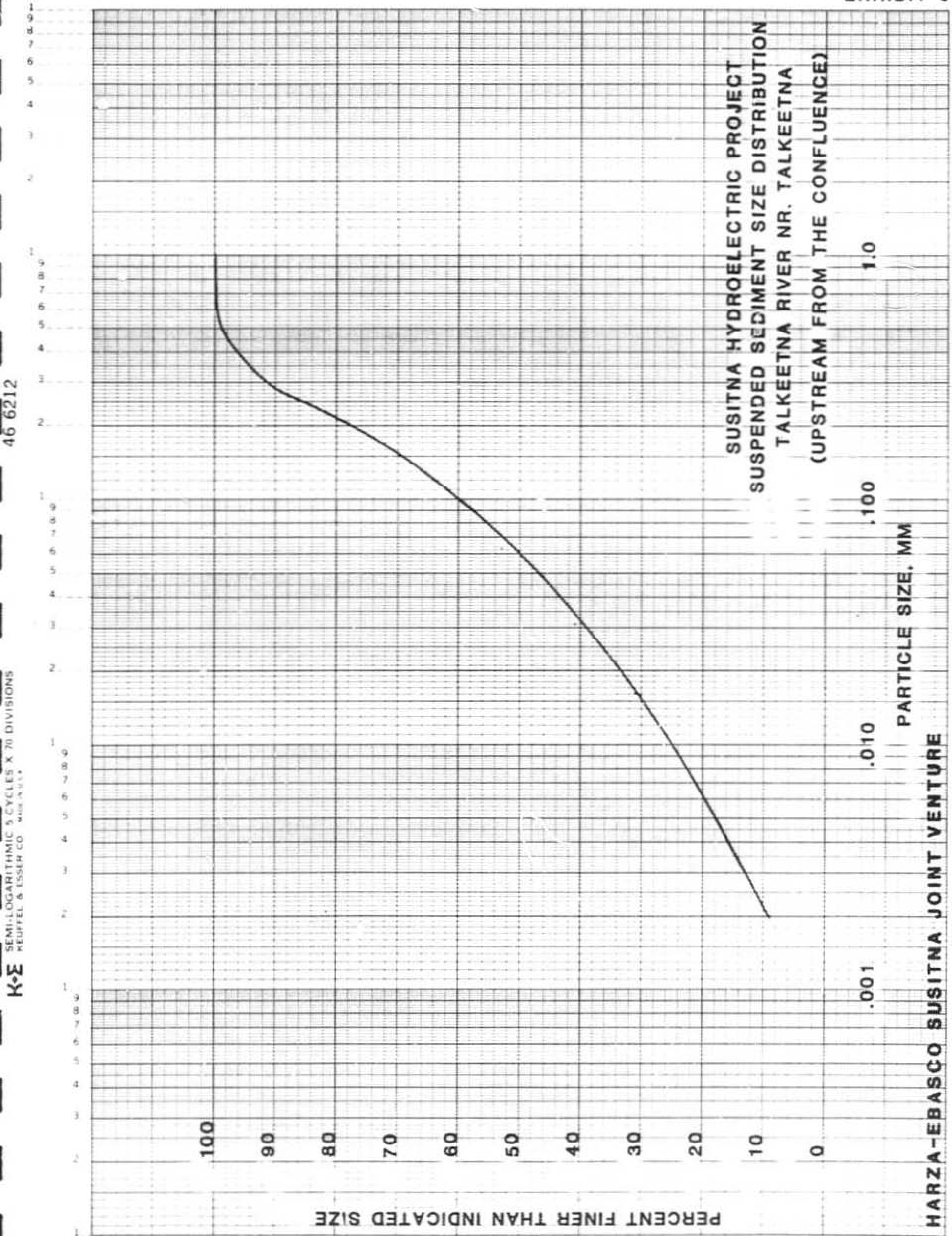
1.0
PARTICLE SIZE, MM
SUSITNA HYDROELECTRIC PROJECT
SUSPENDED SEDIMENT SIZE DISTRIBUTION
CHULITNA RIVER NR. TALKEETNA
(UPSTREAM FROM THE CONFLUENCE)
HARZA-EBASCO SUSITNA JOINT VENTURE

EXHIBIT 8

EXHIBIT 9


SUSITNA HYDROELECTRIC PROJECT
SUSPENDED SEDIMENT SIZE DISTRIBUTION
TALKEETNA RIVER NR. TALKEETNA
(UPSTREAM FROM THE CONFLUENCE)
PERCENT FINER THAN INDICATED SIZE
100
90
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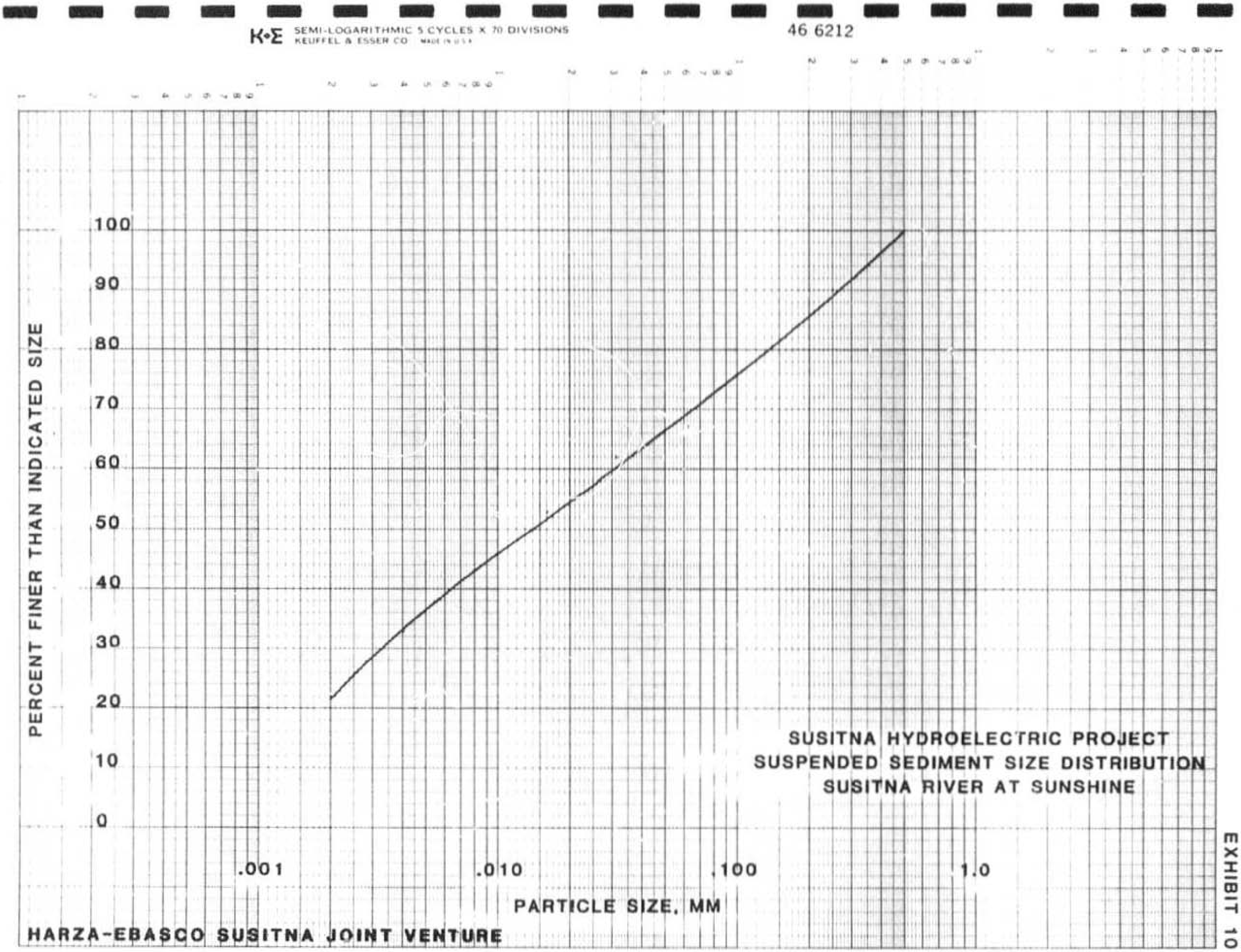
1.0
PARTICLE SIZE, MM
HARZA-EBASCO SUSITNA JOINT VENTURE
K•E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO.
46 6212

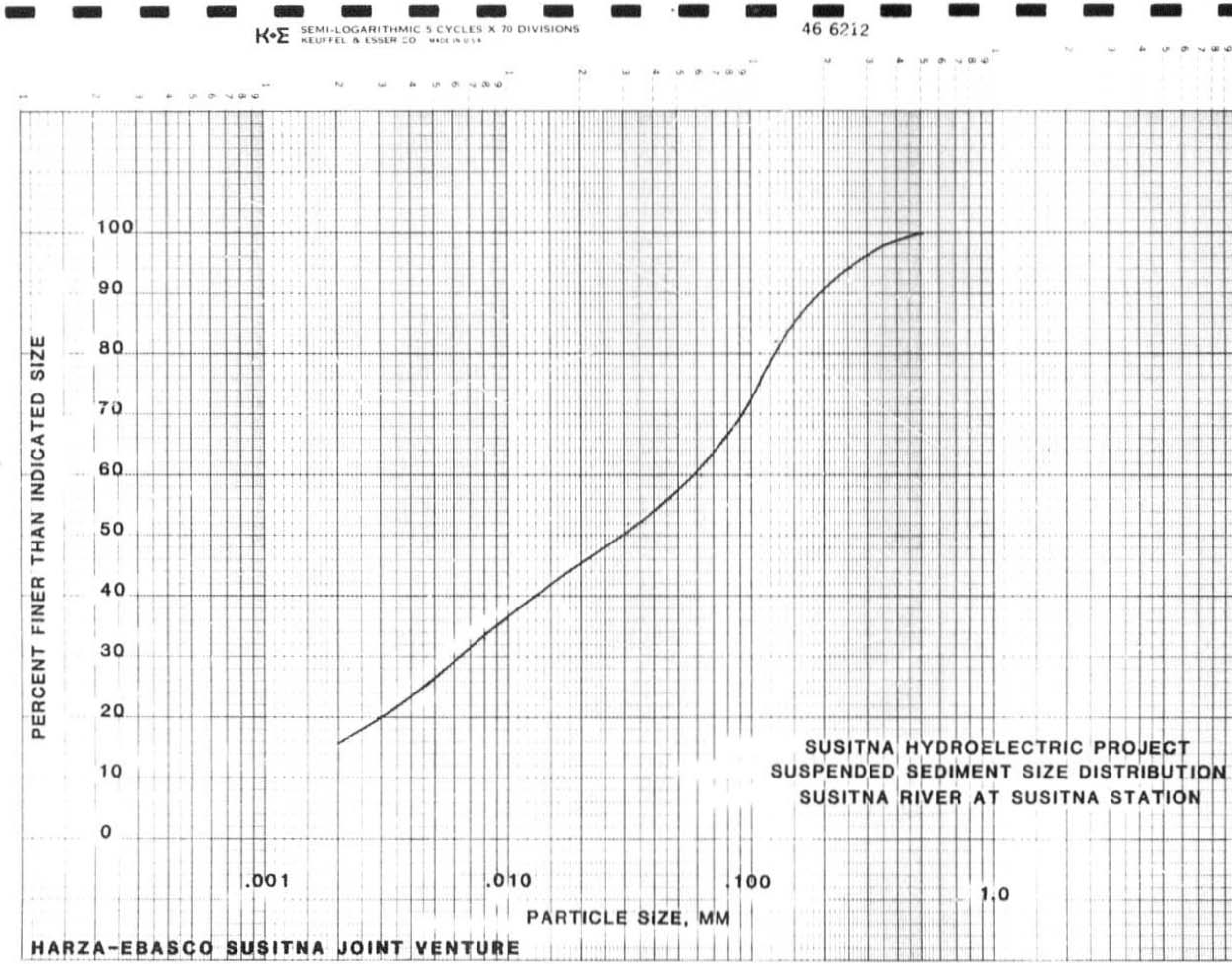
EXHIBIT 10



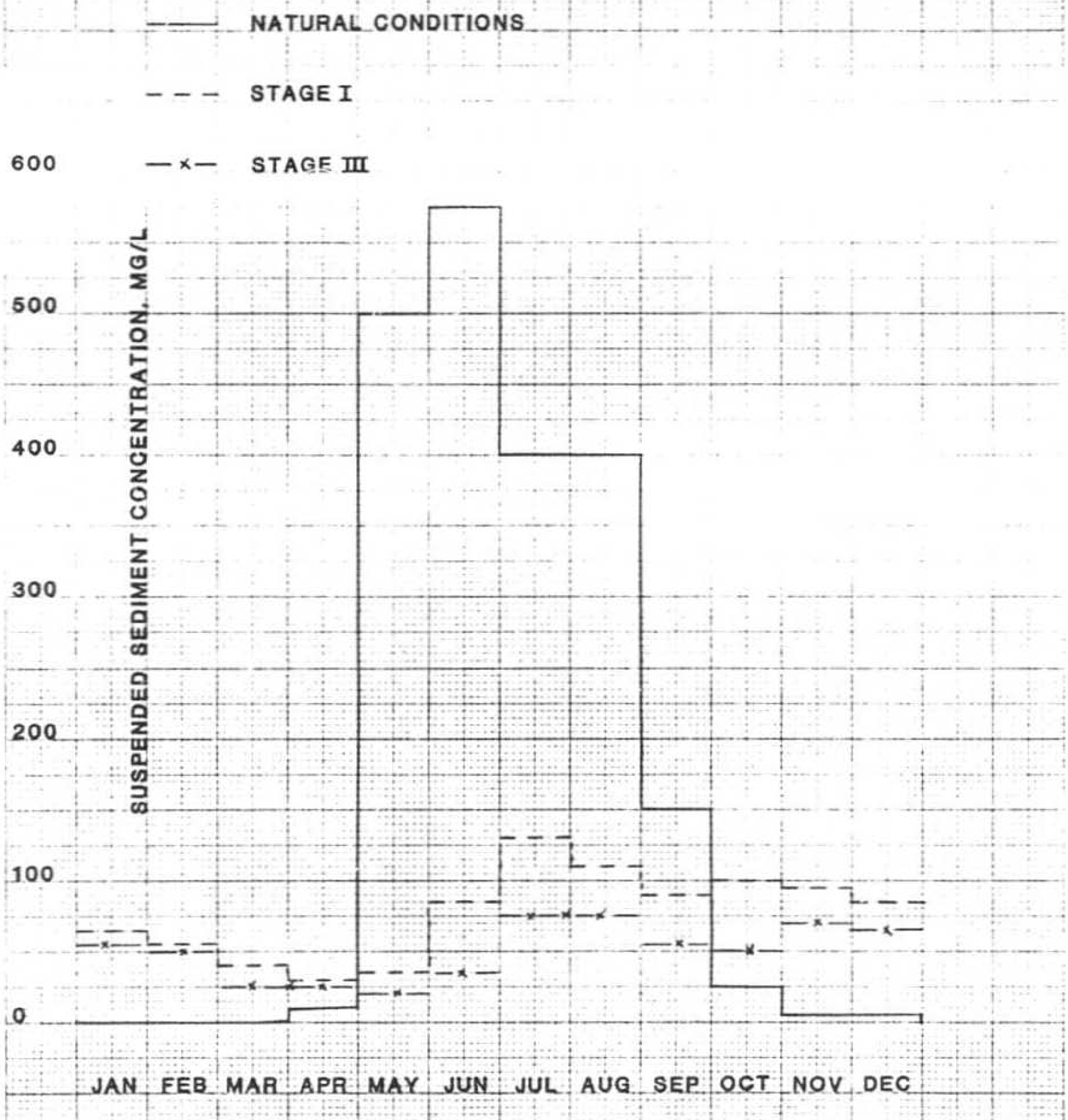
SUSITNA HYDROELECTRIC PROJECT
SUSPENDED SEDIMENT SIZE DISTRIBUTION
SUSITNA RIVER AT SUNSHINE

HARZA-EBASCO SUSITNA JOINT VENTURE

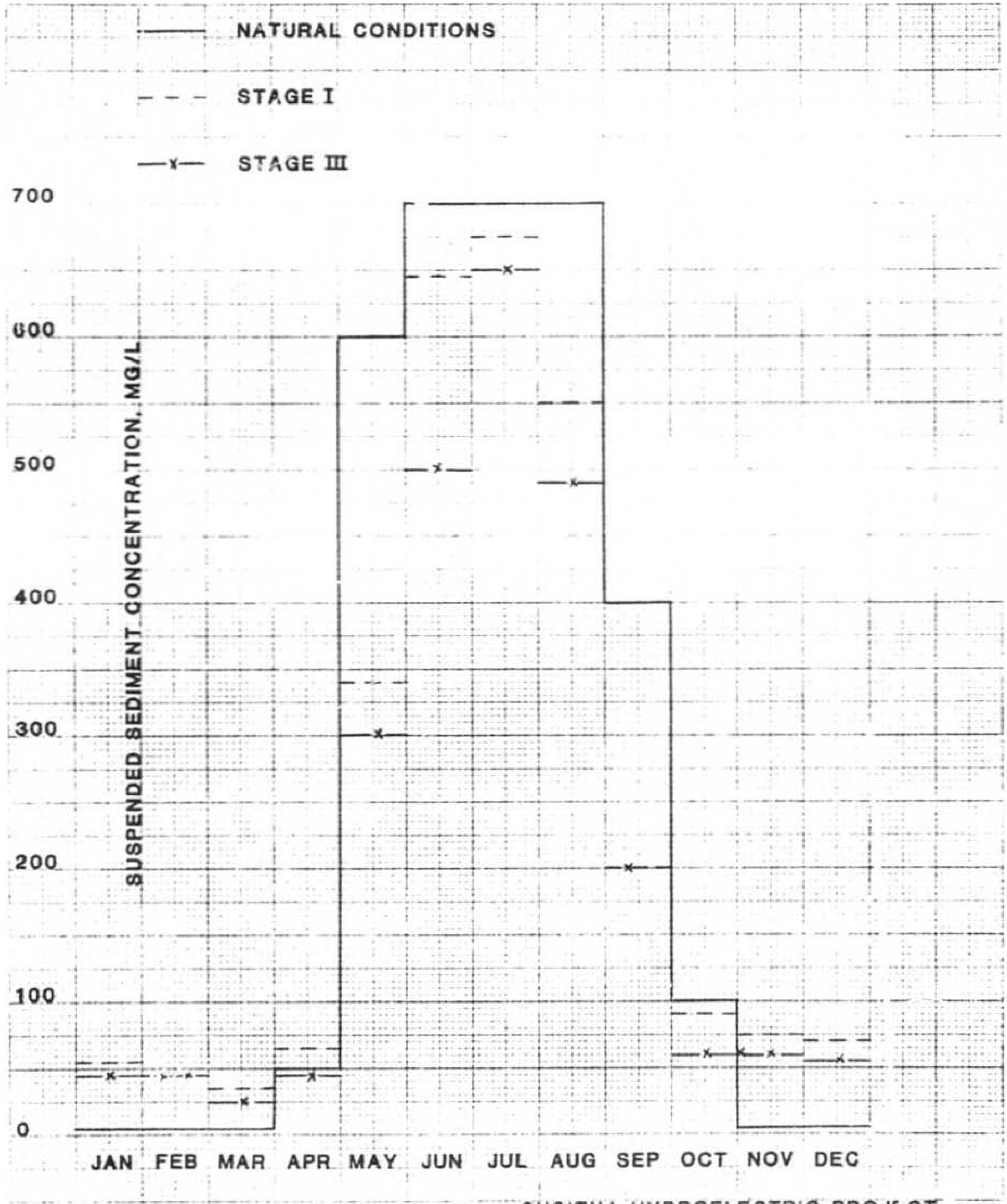
EXHIBIT 11



HARZA-EBASCO SUSITNA JOINT VENTURE

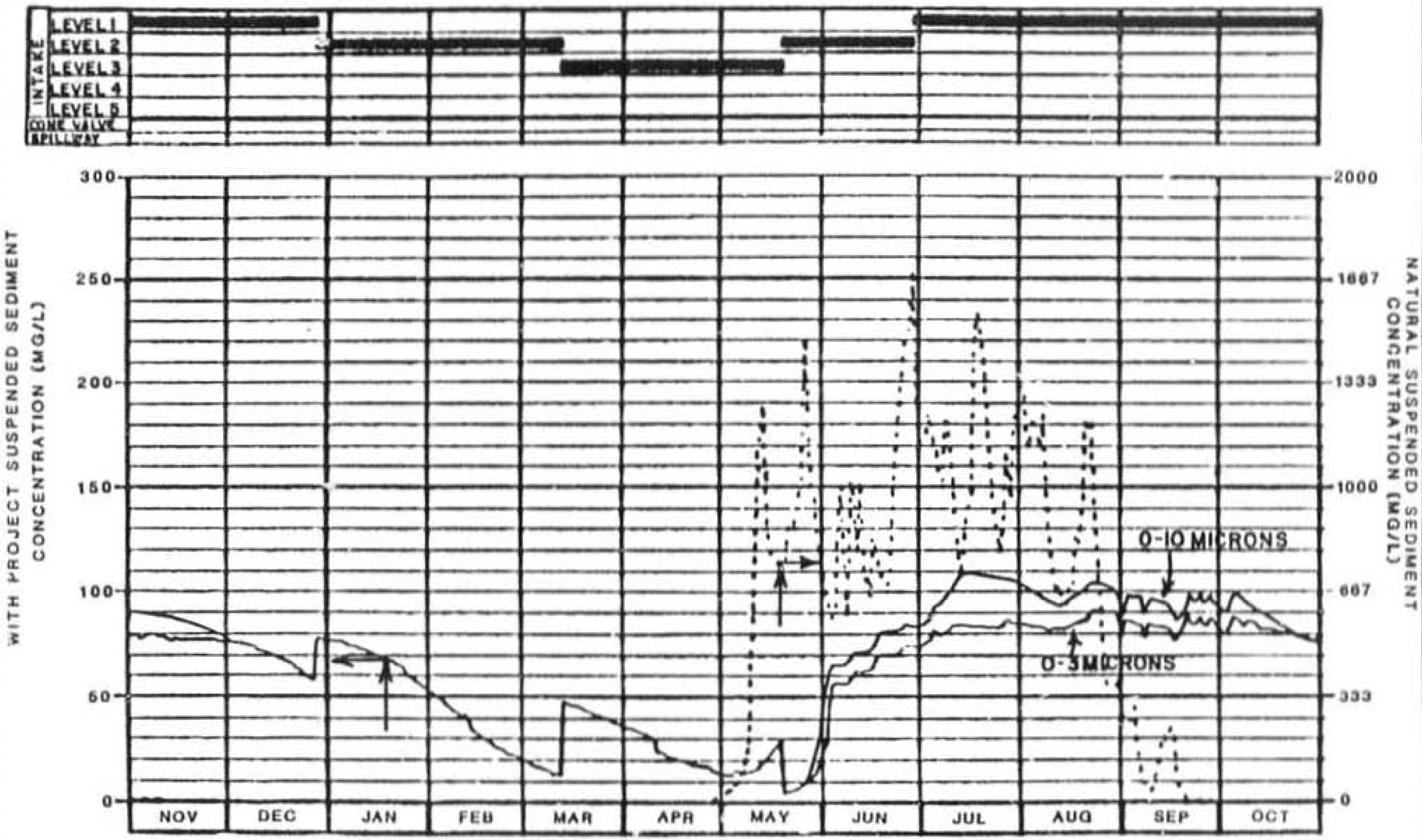


SUSITNA HYDROELECTRIC PROJECT
SUSITNA RIVER AT GOLD CREEK
MONTHLY SUSPENDED SEDIMENT
CONCENTRATIONS



SUSITNA HYDROELECTRIC PROJECT
SUSITNA RIVER AT SUNSHINE
MONTHLY SUSPENDED SEDIMENT
CONCENTRATIONS

HARZA-EBASCO SUSITNA JOINT VENTURE



LEGEND

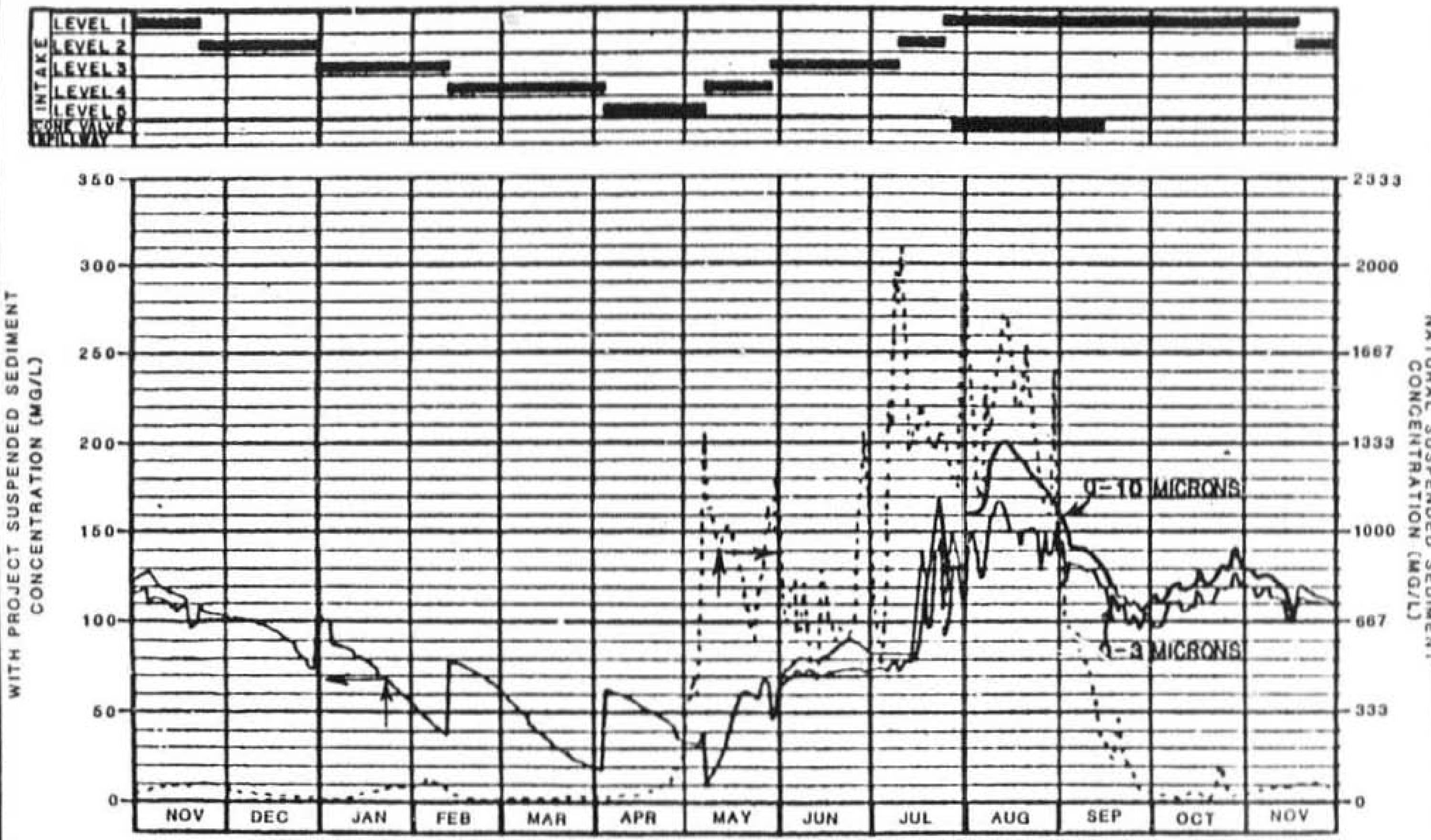
——— PREDICTED OUTFLOW SUSP. SED. CONCENTRATION (MG/L), STAGE I

······· INFLOW SUSP. SED. CONCENTRATION (MG/L)

HARZA-EBASCO SUSITNA JOINT VENTURE

WATANA RESERVOIR OUTFLOW SUSPENDED SOLIDS LOW INFLOW YEAR, STAGE I

EXHIBIT 14



LEGEND

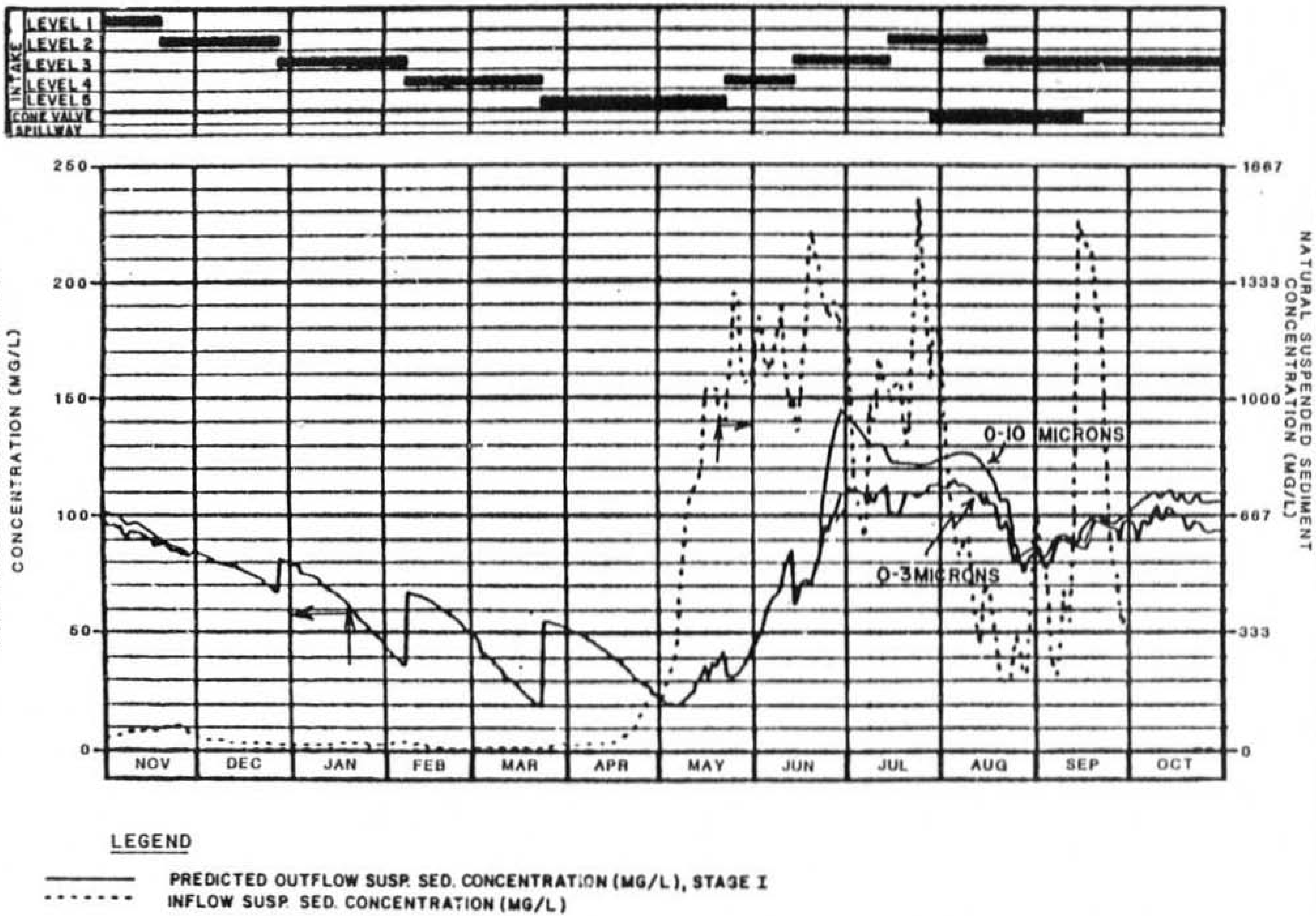
PREDICTED OUTFLOW SUSP. SED. CONCENTRATION (MG/L), STAGE I

INFLOW SUSP. SED. CONCENTRATION (MG/L)

WATANA RESERVOIR OUTFLOW SUSPENDED SOLIDS HIGH INFLOW YEAR, STAGE I

HARZA-EBASCO SUSITNA JOINT VENTURE

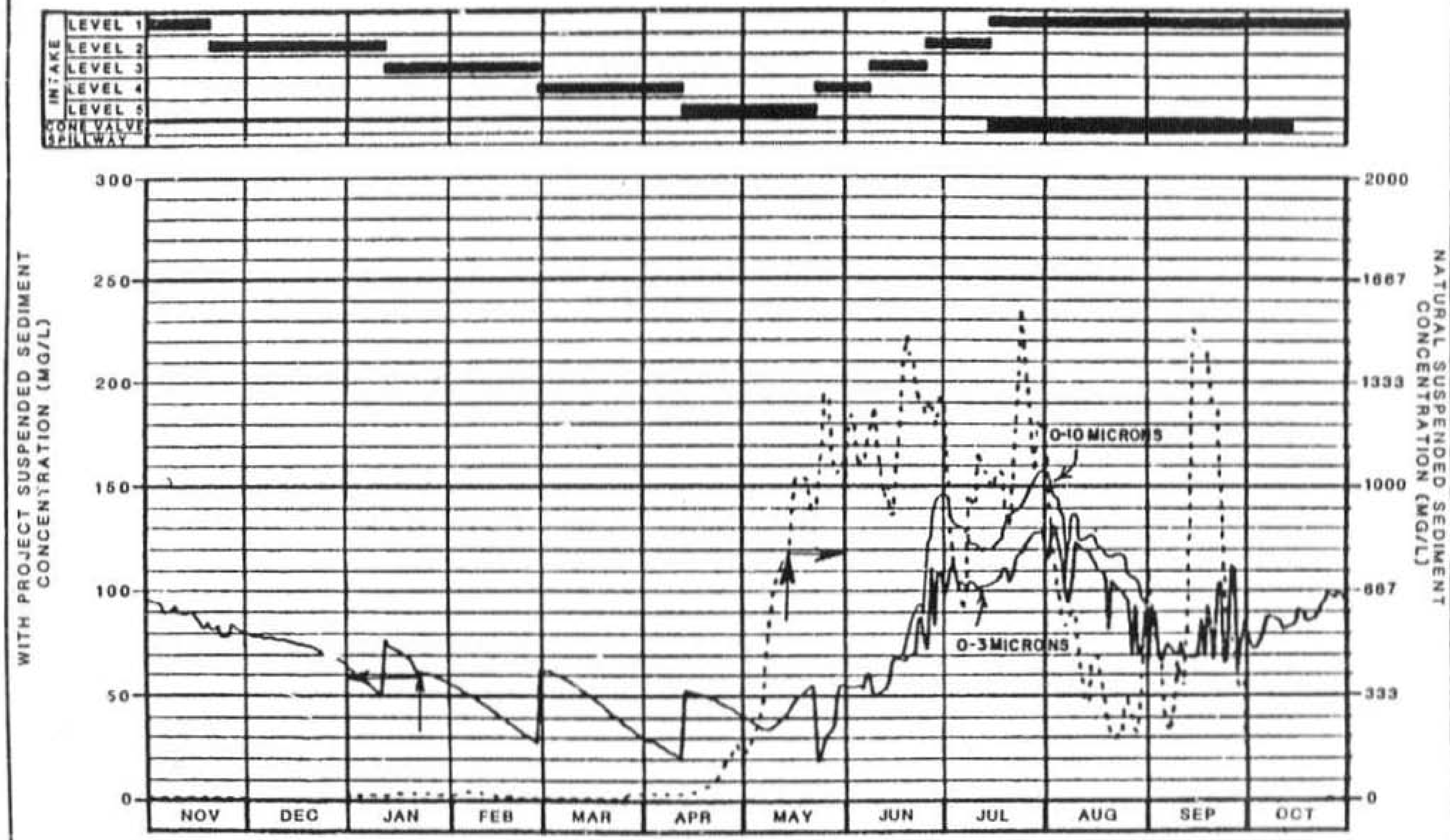
EXHIBIT 15



WATANA RESERVOIR OUTFLOW SUSPENDED SOLIDS AVERAGE INFLOW YEAR, STAGE I

HARZA-EBASCO SUSITNA JOINT VENTURE

EXHIBIT 16



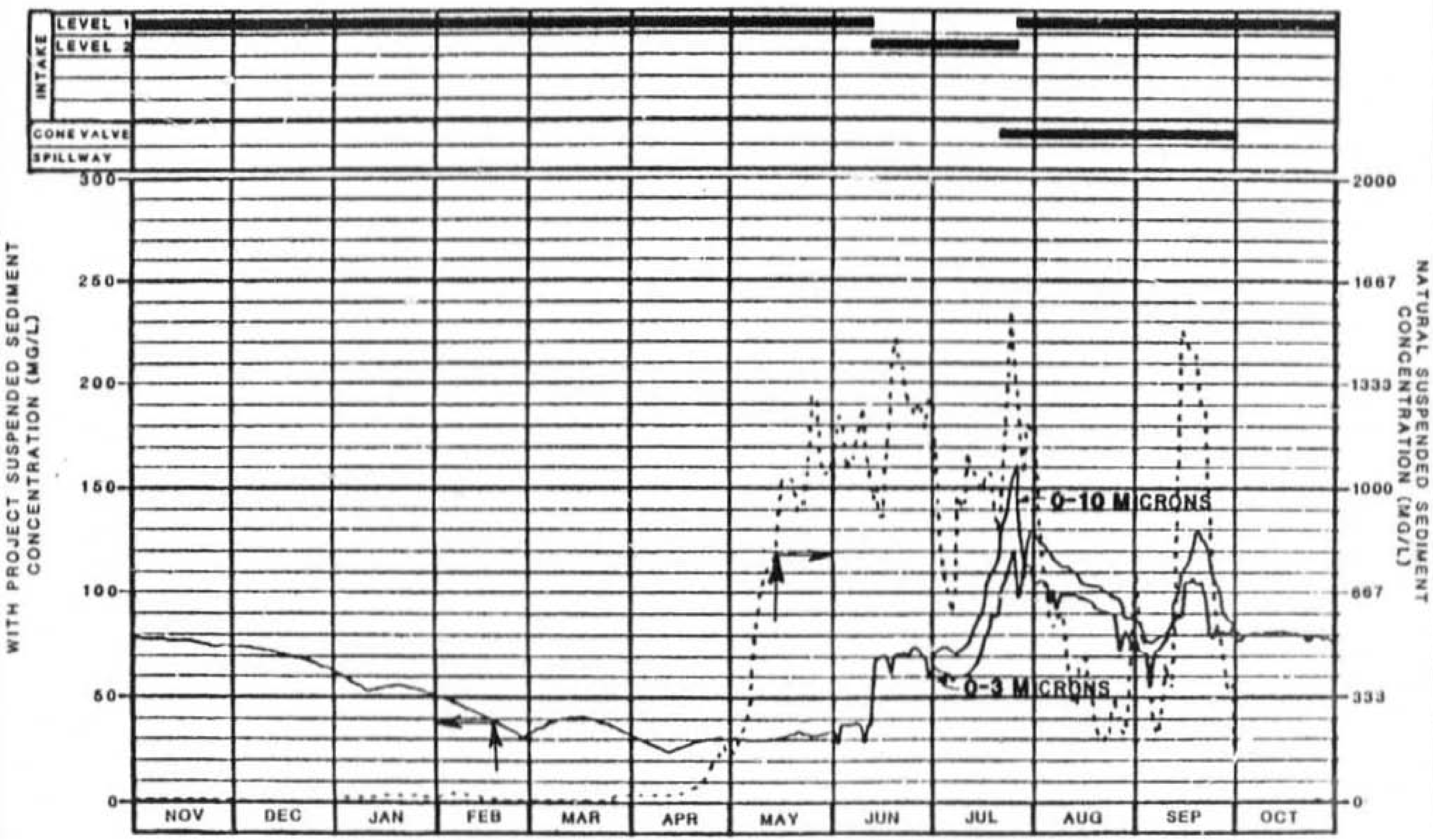
LEGEND

PREDICTED OUTFLOW SUSP. SED. CONCENTRATION (MG/L), STAGE II
INFLOW SUSP. SED. CONCENTRATION (MG/L)

HARZA-EBASCO SUSITNA JOINT VENTURE

WATANA RESERVOIR OUTFLOW
SUSPENDED SOLIDS STAGE II
AVERAGE YEAR

EXHIBIT 17



LEGEND

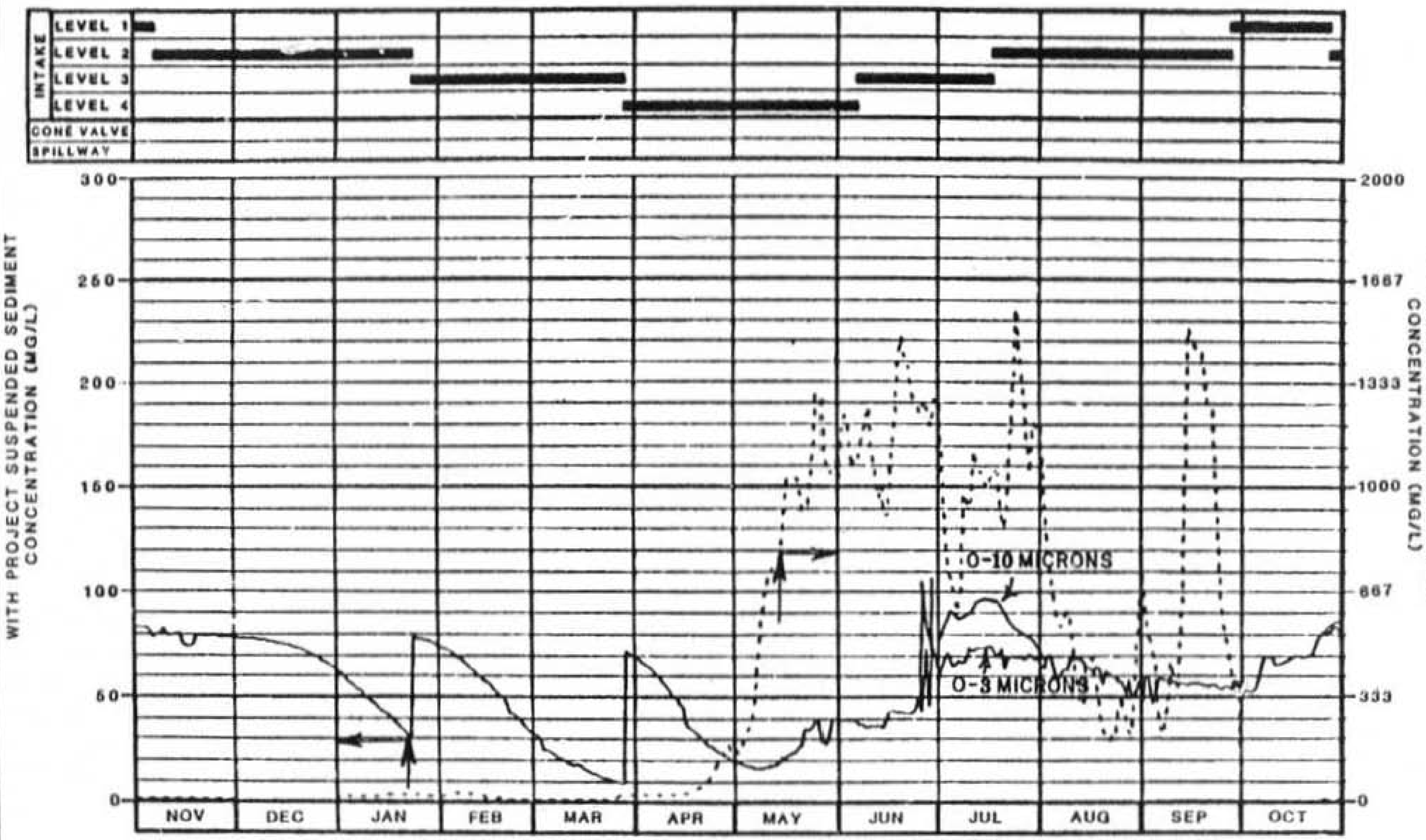
PREDICTED OUTFLOW SUSP. SED. CONCENTRATION (MG/L), STAGE II

INFLOW SUSP. SED. CONCENTRATION AT WATANA (MG/L)

DEVIL CANYON OUTFLOW
SUSPENDED SOLIDS STAGE II
AVERAGE YEAR

HARZA-EBASCO SUSITNA JOINT VENTURE

EXHIBIT 18



LEGEND

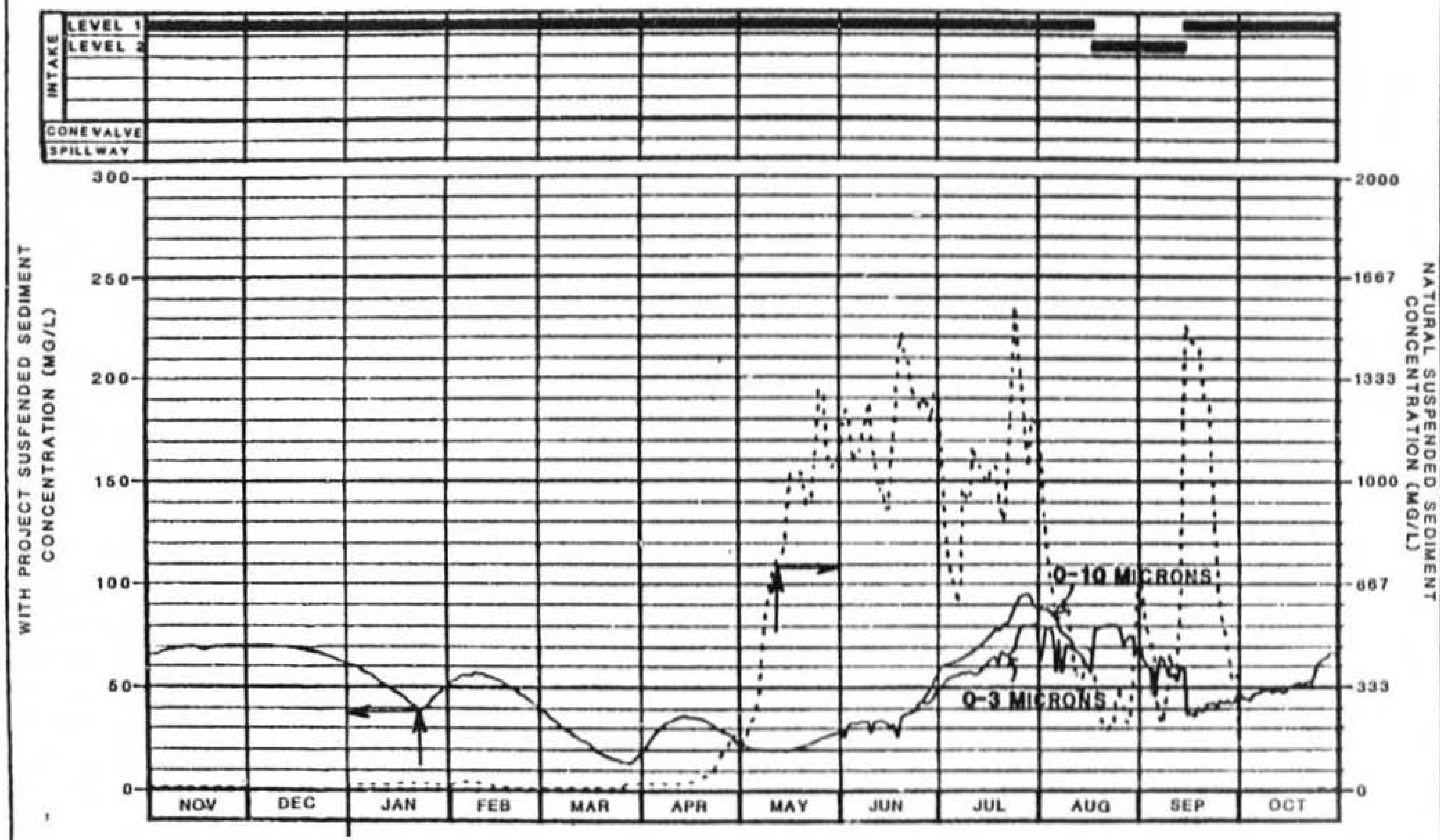
PREDICTED OUTFLOW SUSP. SED. CONCENTRATION (MG/L), STAGE III

INFLOW SUSP. SED. CONCENTRATION (MG/L)

STAGE III WATANA OUTFLOW
SUSPENDED SOLIDS
AVERAGE YEAR

HARZA-EBASCO SUSITNA JOINT VENTURE

EXHIBIT 19



LEGEND

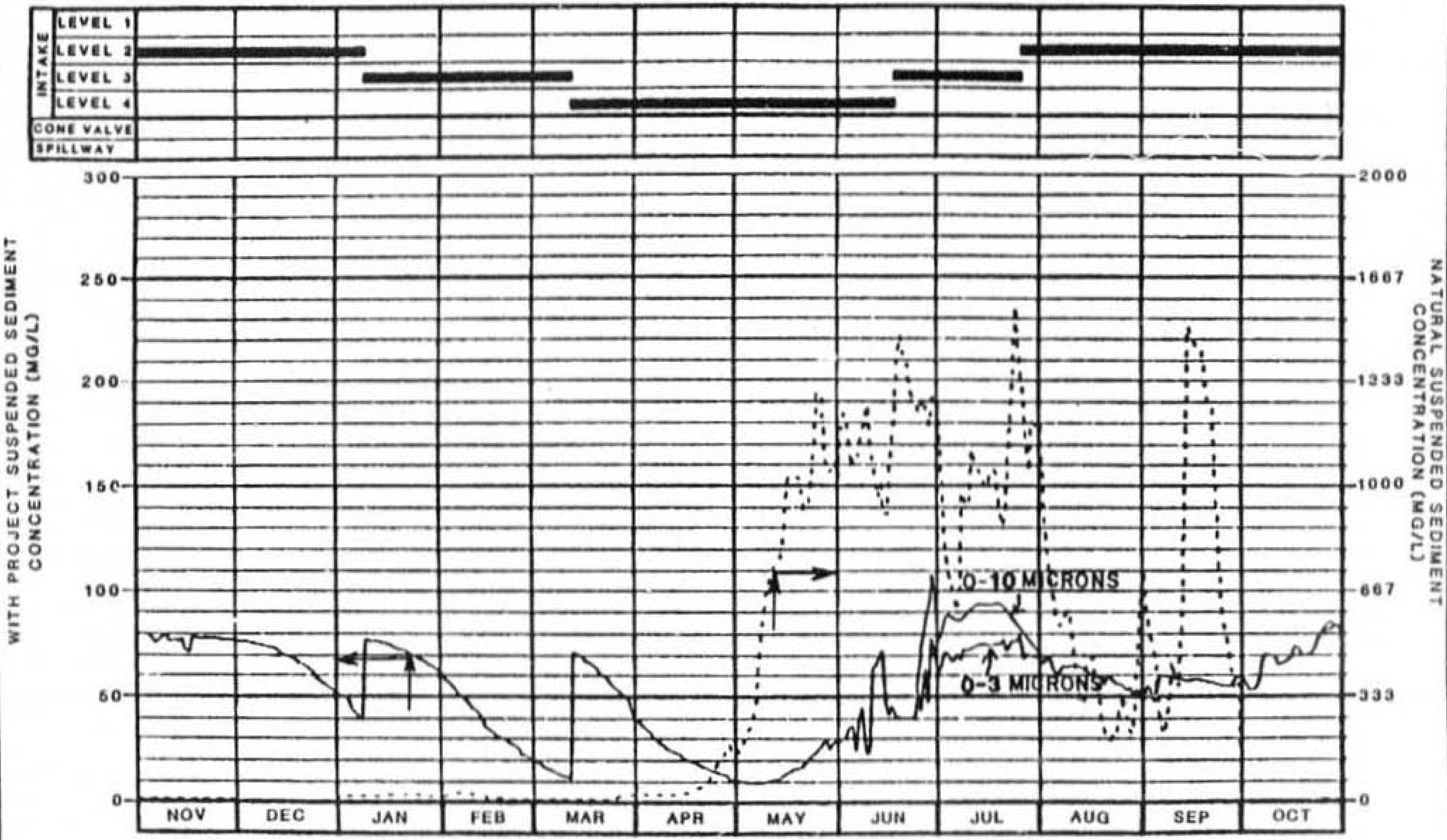
——— PREDICTED OUTFLOW SUSP. SED. CONCENTRATION (MG/L), STAGE III

- - - - - INFLOW SUSP. SED. CONCENTRATION AT WATANA (MG/L)

STAGE III DEVIL CANYON
OUTFLOW SUSPENDED SOLIDS
AVERAGE YEAR

HARZA-EBASCO SUSITNA JOINT VENTURE

EXHIBIT 20



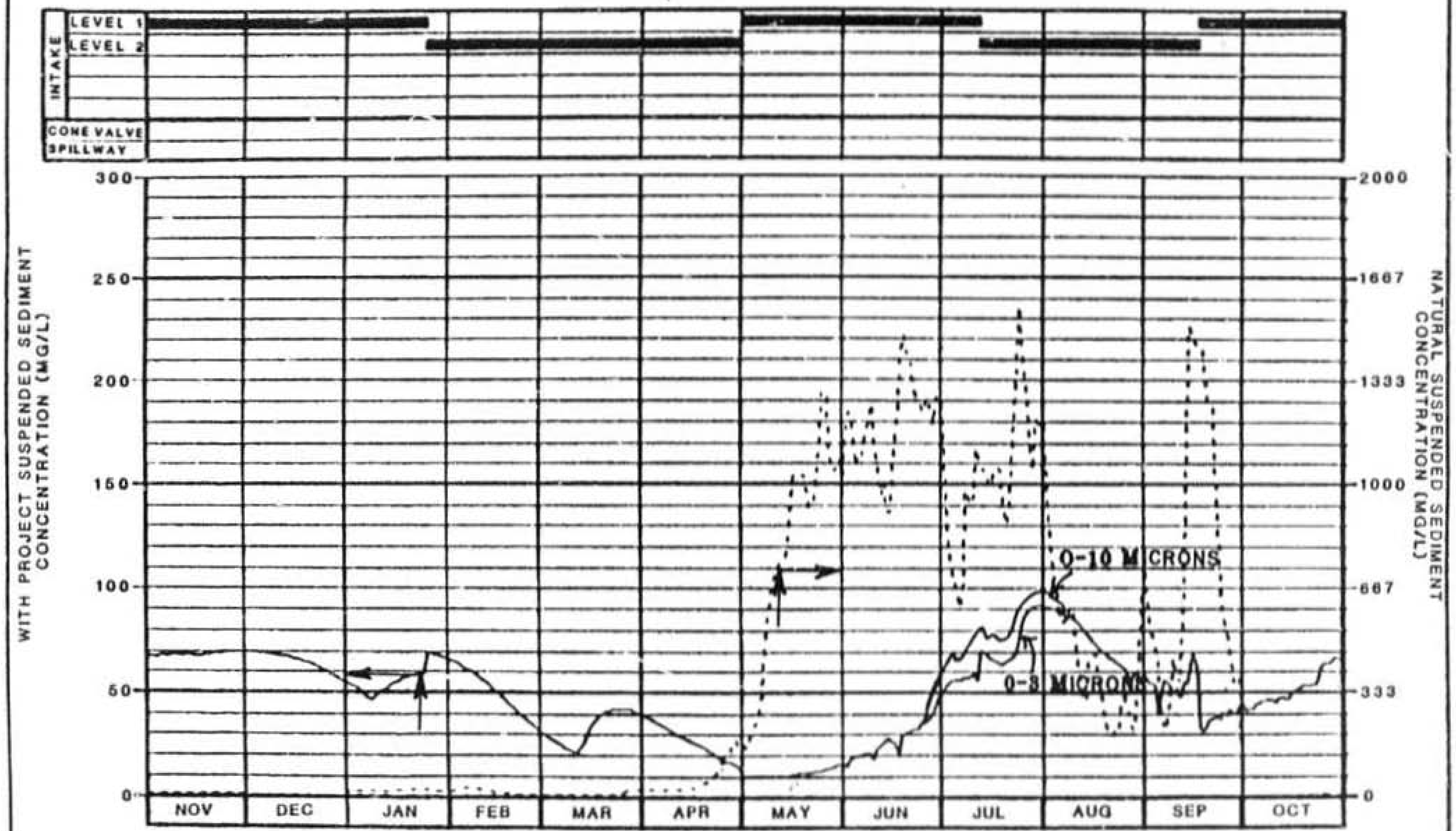
LEGEND

——— PREDICTED OUTFLOW SUSP. SED. CONCENTRATION (MG/L), STAGE III
······· INFLOW SUSP. SED. CONCENTRATION (MG/L)

STAGE III WATANA OUTFLOW
SUSPENDED SOLIDS
AVERAGE YEAR

HARZA-EBASCO SUSITNA JOINT VENTURE

EXHIBIT 21



LEGEND

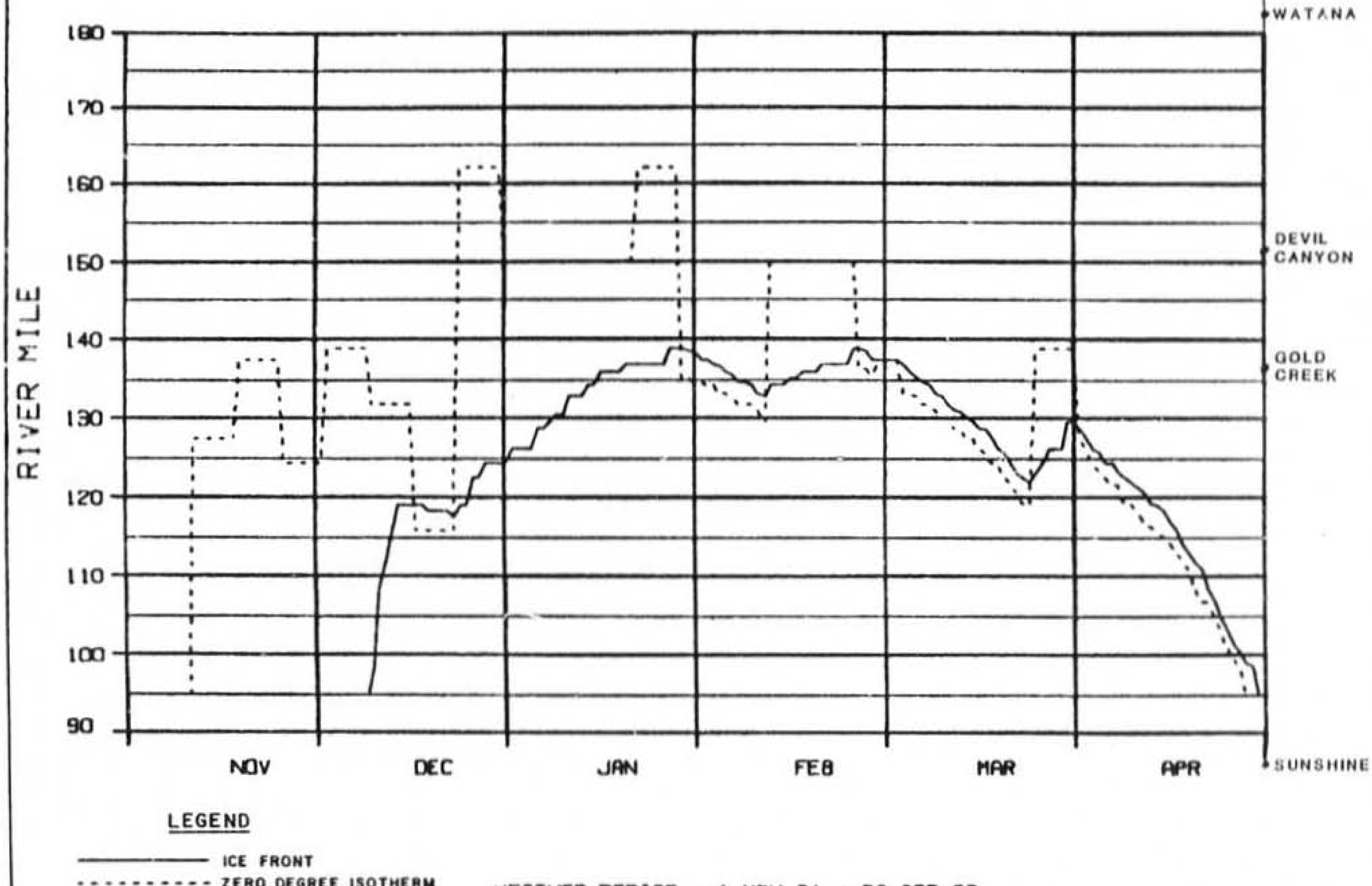
———— PREDICTED OUTFLOW SUSP. SED. CONCENTRATION (MG/L), STAGE III

- - - - - - INFLOW SUSP. SED. CONCENTRATION AT WATANA (MG/L)

HARZA-EBASCO SUSITNA JOINT VENTURE

STAGE III DEVIL CANYON
OUTFLOW SUSPENDED SOLIDS
AVERAGE YEAR

EXHIBIT 22



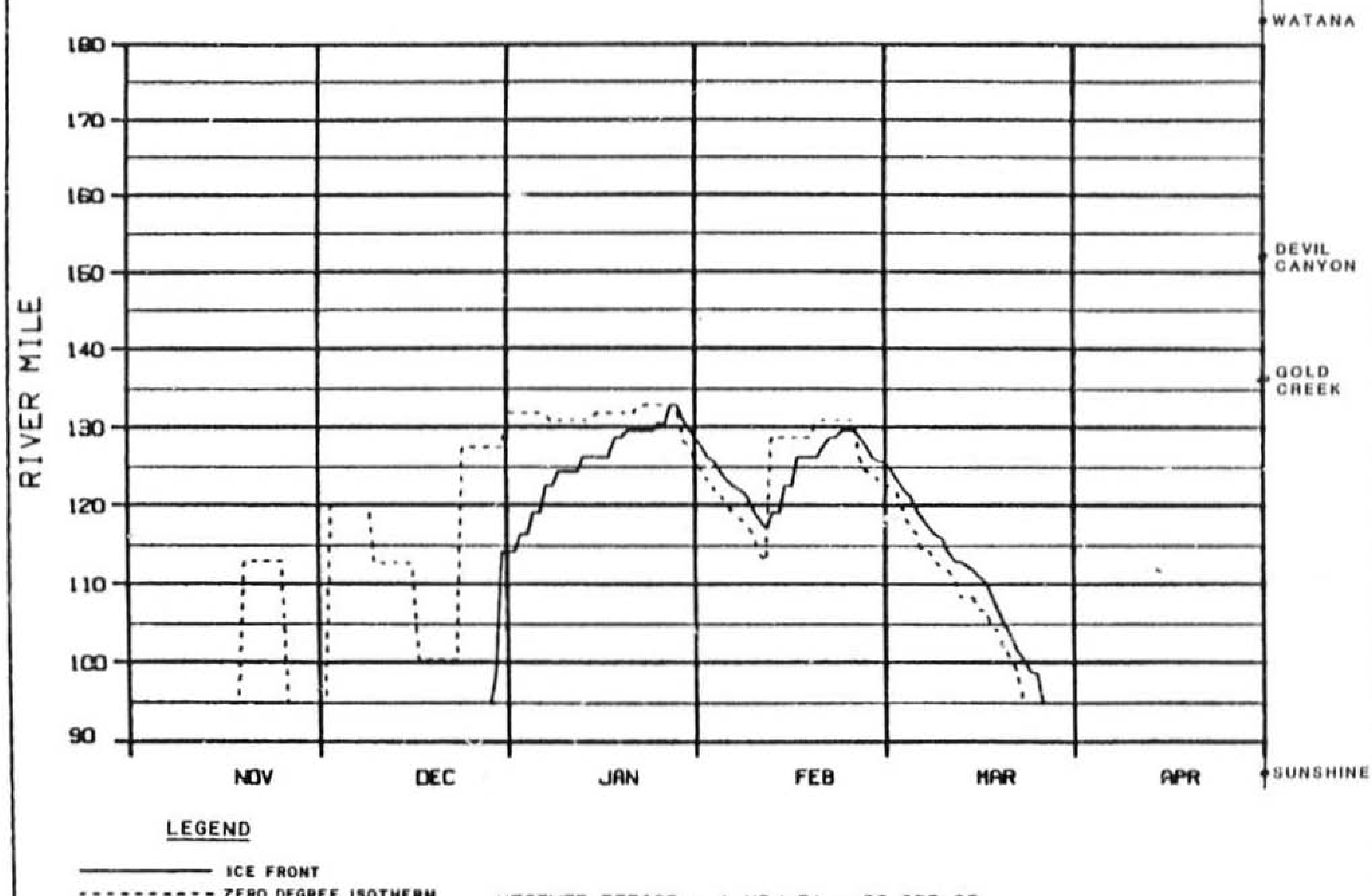
WEATHER PERIOD : 1 NOV 81 - 30 APR 82
STAGE I ENERGY DEMAND
FLOW CASE E-VI . INFLOW-MATCHING
REFERENCE RUN NO. : 8101ENX

SUSITNA RIVER PROGRESSION OF ICE FRONT & ZERO DEGREE ISOTHERM

EXHIBIT 23

OPTION?

HARZA-EBASCO SUSITNA JOINT VENTURE



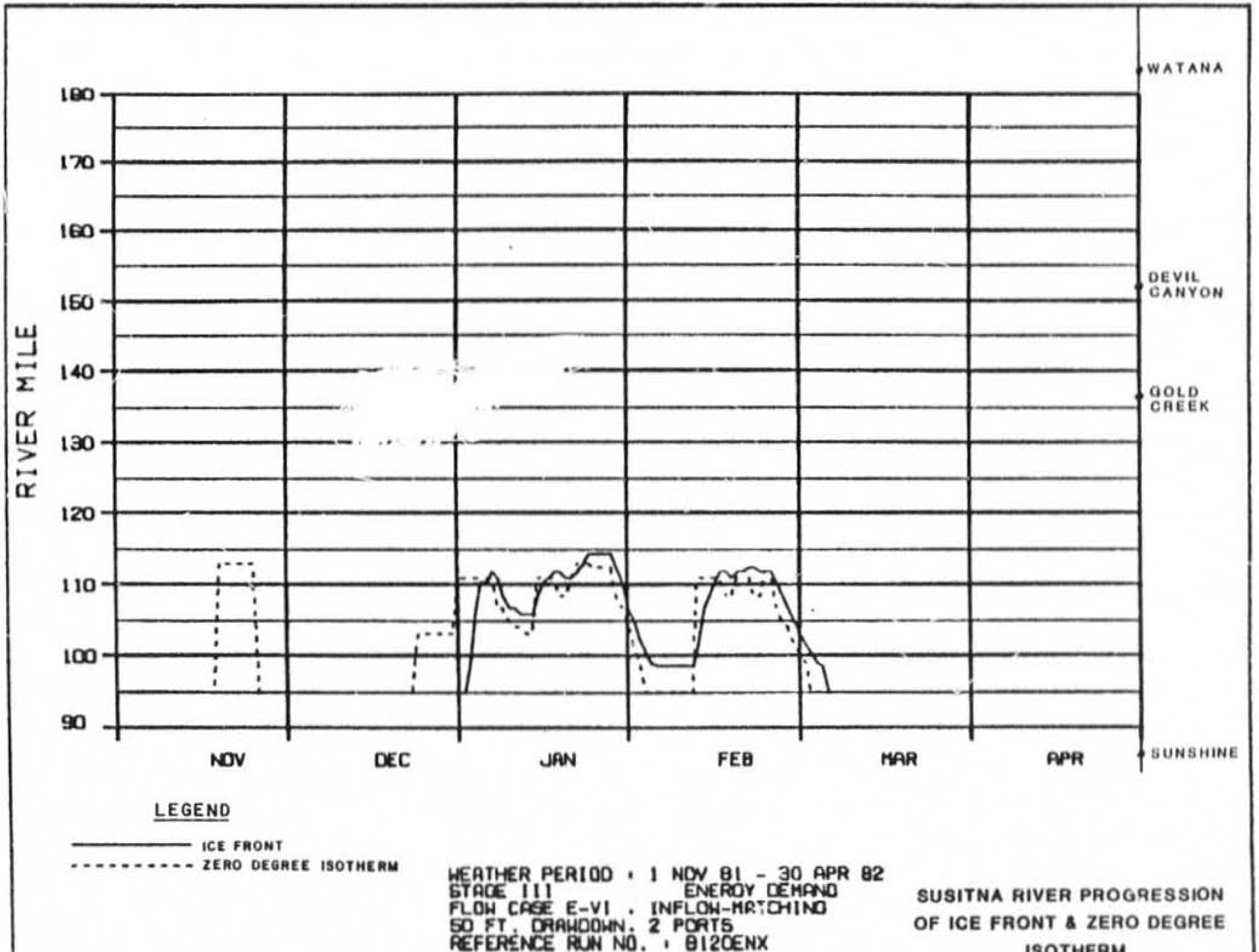
WEATHER PERIOD : 1 NOV 81 - 30 APR 82
STAGE II ENERGY DEMAND
FLOW CASE E-VI . INFLOW-MATCHING
50 FT. DRAWDOWN. 2 PORTS
REFERENCE RUN NO. : 8102ENX

SUSITNA RIVER PROGRESSION OF ICE FRONT & ZERO DEGREE ISOTHERM

EXHIBIT 24

OPTION?

HARZA-EBASCO SUSITNA JOINT VENTURE



SUSITNA RIVER PROGRESSION OF ICE FRONT & ZERO DEGREE ISOTHERM

OPTION?

HARZA-EBASCO SUSITNA JOINT VENTURE

EXHIBIT 25